Improving the Management of Patients with Meniscal Lesions of the Knee

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Doctor of Philosophy in Musculoskeletal Sciences

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ABSTRACT

Improving the Management of Patients with Meniscal Lesions of the Knee

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Meniscal lesions in the knee are common and keyhole surgery to excise a meniscal tear, arthroscopic partial meniscectomy (APM), is one of the most commonly performed orthopaedic surgical procedures worldwide. Despite the frequency with which the procedure is performed, the effectiveness of the procedure has been challenged by the publication of a series of clinical trials reporting similar outcomes following physiotherapy or placebo surgery. The broad aims of this thesis were (1) to determine trends and variation in the use of APM and consider if there is evidence for potential overuse of the procedure, (2) to systematically appraise the effectiveness of APM in different patient groups, (3) to determine the potential risks associated with undergoing APM, and (4) to deliver standardised descriptive terminology and treatment guidance informed by this new research.

APM was found to be performed increasingly frequently in England over a twenty-year period to 31 March 2017 and there was variation both in the intervention rate and the rate of patients subsequently undergoing a knee arthroplasty within one-year. This variation implied potential overuse of the procedure in some populations, especially those with advanced osteoarthritis, and suggested the need for new clinical treatment guidance to improve and standardise the care pathway for these patients.

The clinical effectiveness of APM was found to be limited in patients with osteoarthritis, improved in patients without osteoarthritis, but the interpretation of the evidence is limited by poor quality validation of outcome measures for use in patients with meniscal tears. No trial evidence was identified for patients meeting the strictest selection criteria, specifically a clinically and radiologically unstable meniscal tear, without osteoarthritis, for symptoms failing to resolve after physiotherapy.

The short-term risk (90-days) from undergoing APM was found to be low, with serious medical complications (myocardial infarction, stroke, death) occurring less frequently than in the general population. The risk of pulmonary embolism and septic arthritis was, however, elevated and for every 1500 fewer APMs performed, one pulmonary embolism and two knee infections could be prevented. In the long-term, patients with a history of APM were ten-times more likely to undergo arthroplasty annually in comparison to the general population without a history of APM. Women were at greater risk, with 22% undergoing arthroplasty within 15-years, in comparison to 10% of men.

A standardised terminology for the description and classification of the clinical and radiological features found in patients with meniscal lesions was developed through an expert consensus process. Using these definitions, a treatment appropriateness exercise was undertaken, informed by the new analysis of the latest clinical and epidemiological evidence, ultimately supporting the development of a new treatment guideline endorsed by the national knee society.

In conclusion, the findings reported in this thesis suggest there has been variation within the care pathway for patients with meniscal lesions which may be associated with undesirable outcomes and uncommon but serious adverse events. This thesis reports new standardised treatment guidance, with supporting evidence, and a corresponding change in clinical practice to improve the management of patients with meniscal lesions of the knee is recommended.

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ABBREVIATIONS

Term	Definition
AAOS	American Academy of Orthopaedic Surgeons
ACL	Anterior cruciate ligament
ACR	American College of Rheumatology
AJP	Andrew J. Price, Professor
AM	Andrew Paul Monk, Clinical Lecturer
APM	Arthroscopic partial meniscectomy
BASK	British Association for Surgery of the Knee
CI	Confidence interval
COSMIN	COnsensus-based Standards for the selection of health Measurement INstruments
DJB	David J. Beard, Professor
EH	Eli Harriss, Information Specialist, Bodleian Health Care Libraries
ESSKA	European Society of Sports Traumatology, Knee Surgery and Arthroscopy
GIRFT	NHS Getting It Right First Time
HES	Hospital Episode Statistics
HR	Hazard ratio
ICD-10	International Classification of Diseases, 10th Edition
ICRS	International Cartilage Repair Society
IKDC	International Knee Documentation Committee
ISAKOS	International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine
KOOS	Knee Injury and Osteoarthritis Outcome Score
LB	Lee Bayliss, Clinical Research Fellow
LCL	Lateral collateral ligament
MIC	Minimal important change
MCID	Minimum clinically important difference
MCL	Medial collateral ligament

MRI	Magnetic resonance imaging
NHS	National Health Service
NICE	The National Institute for Health and Care Excellence
NIHR	National Institute for Health Research
NNH	Number-needed to harm
OA	Osteoarthritis
ONS	Office for National Statistics
OPCS-4	Classification of Surgical Operations and Procedures, 4th Edition
OR	Odds ratio
PCL	Posterior cruciate ligament
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PROM	Patient-reported outcome measure
RAM	RAND/UCLA Appropriateness Method
RAND	Research And Development Corporation
RCT	Randomised controlled trial
RM	Rob Middleton, Clinical Research Fellow
RR	Risk ratio
SA	Simon Abram
SD	Standard deviation
SH	Sally Hopewell, Associate Professor
UCLA	University of California, Los Angeles
WOMAC	Western Ontario and McMaster Universities Osteoarthritis Index
WOMET	Western Ontario Meniscal Evaluation Tool

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1 BACKGROUND

This chapter introduces the subject of this thesis including a literature review that highlights areas of uncertainty.

1.1 Anatomical Terms of Location, Direction, Movement

The following conventional anatomical terms of location and direction are used throughout this thesis:

- Anterior: towards the front of the body; Posterior: towards the back.
- Medial: towards the midline of the body when viewed from the front or back; Lateral: away from the midline.
- Superior: above, relative to the long axis of the body when standing; Inferior: below.
- Proximal: near to a point or the middle of the body; Distal: away from a point or middle of the body.

Movements of the knee joint are described using the following terms:

- Flexion: articulation of the knee joint resulting in the posterior thigh and lower leg moving closer together. Extension: the articulating movement of the joint that results in the posterior thigh and lower leg moving farther apart: a ‘straightening’ of the leg by movement of the knee joint.
- Rotation of a long bone such as the tibia or femur is described about its long ‘axis’ (length). Medial rotation refers to rotation such that the anterior aspect of the bone turns inwards, towards the midline of the body. Lateral rotation refers to the opposite movement, whereby the anterior aspect of the bone turns outwards, away from the midline of the body.

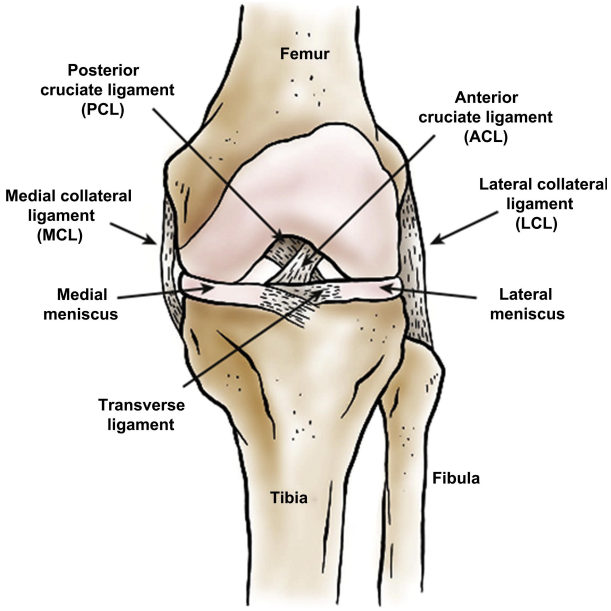
1.2 The Knee

The knee is a large, weight-bearing, synovial joint, formed primarily by the articulation in the leg between the distal thigh bone (the femur) and the proximal shin bone (the tibia): the tibiofemoral joint (Figure 1.1). At the front of the knee, there is also an articulation between the knee cap (the patella) and

the femur: the patellofemoral joint. The knee is the largest synovial joint in the body; the articulating surface of the bones is covered in hyaline cartilage and lubricated by synovial fluid.

The distal femur is separated into two articular condyles by a notch. The medial femoral condyle has an elongated curvature formed by the shape of two circles, anteriorly and posteriorly, with different radii and offset centre.[1] In comparison, the lateral facet has a circular posterior articular shape but a lesser degree of curvature anteriorly.[1] The medial tibia is relatively flat posteriorly but slopes upwards anteriorly at approximately 11 degrees and this region is in contact with the femur in extension.[1,2] The anterior portion of the horizontal surface is in contact with the femur between approximately 20 and 120 degrees of flexion.[1] The lateral tibia is convex but relatively flat centrally and this is the only portion of the articular surface that is normally (with normal menisci) in contact with the femur.[1] The congruity of the tibiofemoral articulation is enhanced both medial and laterally by the menisci (section 1.4.2) and both the most anterior and posterior surface of both the medial and lateral tibia slope down to accommodate the meniscal horns (section 1.4.2).[1,3] It must be noted, however, that there is individual variation in both the bony and soft tissue anatomy of the knee.[4–6]

Figure 1.1: Diagram of the knee (front view)



Note: Reproduced with kind permission from Professor Kyriacos Athanasiou.[3]

In addition to bony congruity, the knee is constrained by four large ligaments: the intra-articular anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL), and the extra-articular medial collateral ligament (MCL) and lateral collateral ligament (LCL) (Figure 1.1). The two menisci (medial and lateral) also play an important role in joint stability and movement (see section 1.4).

Mechanically, the knee is a partially constrained, complex, 'hinge' joint, moving through flexion and extension, slightly offset from the sagittal plane, in association with some internal and external rotation.[7] See section 1.4.4 for a detailed description of the kinematics of the knee.

1.3 Osteoarthritis

1.3.1 Definition and diagnosis

Osteoarthritis is a progressive disease of multi-factorial aetiology affecting a musculoskeletal joint characterised by cartilage (chondral) degradation. Structural, mechanical, genetic and inflammatory factors may play a role in the pathophysiology of osteoarthritis.[8] The predominance of these respective factors and influences is associated with different 'phenotypes' of osteoarthritis that have been identified in clinical and research practice.[8–10] Diagnosis of osteoarthritis is classically clinical, based upon the American College of Rheumatology (ACR) criteria of knee pain and any three of the following:[11] (1) Age > 50 years; (2) Less than 30 minutes of morning stiffness, (3) Crepitus on active movement; (4) Bony tenderness, (5) Bony enlargement, (6) No palpable warmth. Alternatively, using history, examination and the radiographic finding of osteophytes with knee pain and one of the following:[11] (1) Age > 50 years, (2) Less than 30 minutes of morning stiffness, (3) Crepitus on active movement.

1.3.2 Structural classification of osteoarthritis

A number of classification systems have been developed based upon the chondral and bony structure of the joint as visualised using either radiological or arthroscopic ('key-hole surgery') techniques.

1.3.2.1 Radiographic classification

Perhaps the most universally accepted classification of structural osteoarthritis was published in 1957 and has become known as the Kellgren-Lawrence Classification.[12] Based upon appearances visualised on an x-ray radiograph of any joint, the classification is divided into five grades: (0) None, (1) Doubtful narrowing of joint space, possible osteophyte formation, (2) Possible joint space narrowing and definite osteophyte formation, (3) Definite joint space narrowing and moderate osteophyte formation, some sclerosis and possible bone end deformity, and (4) Severe narrowing of joint space, sclerosis, large osteophytes, and definite bone end deformity.[12,13] According to the authors, grade zero represents a definite absence of visible changes associated with osteoarthritis and grade two represents definite osteoarthritis but of minimal severity.[12] Although interrater reliably is reported to be "good" or "very good" for use of the Kellgren-Lawrence classification, some inter- and intra-rater variation is expected for all such classification systems and should be appropriately considered when reviewing such data.[13]

After Kellgren-Lawrence, the most widely radiographic classification system is perhaps that of Ahlbäck.[14] In this classification: (0) is a normal radiograph, (1) definite joint space narrowing, (2) obliteration of the joint space, (3) minor bony attrition, (4) moderate bony attrition, (5) severe bony deformity.[14] Ahlbäck grade zero therefore may be considered to represent no osteoarthritis, and Ahlbäck grade one or greater to be osteoarthritis, analogous to Kellgren-Lawrence two or greater.

The International Knee Documentation Committee (IKDC) Radiographic Grading System classifies the medial, lateral, patellofemoral, anterior and posterior joint spaces of the knee as normal, nearly normal, abnormal, or severely abnormal.[15] There are some other classification systems that have been developed such as the OARSI atlas, but these are less commonly used in clinical practice.[16]

1.3.2.2 MRI classification

Magnetic resonance imaging (MRI) has advantages over plain radiography, being non-ionising and multi-planar. MRI is also considered more sensitive than plain radiographs at detecting the early

structural changes associated with osteoarthritis.[17] Although these findings are generally asymptomatic, they may precede the onset of knee symptoms.[17] There is no universally accepted MRI classification of osteoarthritis however those that have been developed grade structural severity according to either thickness of cartilage loss (partial or full thickness), the surface area of the joint compartment affected, or both.[18,19]

The Whole Organ Magnetic Resonance Imaging Score (WORMS) aims to "semi-quantitively" rate the severity of knee osteoarthritis.[18] The system includes scoring of cartilage abnormalities, marrow abnormalities, bone cysts, bone attrition and osteoarthritis, along with a rating for meniscal pathology, ligamentous pathology, and synovitis.[18] Cartilage lesions are scores as follows: (0) Normal thickness and signal, (1) Normal thickness but increased signal on T2-weighted images, (2.0) Partial-thickness defect <1 cm in width, (2.5) Full-thickness focal defect <1 cm in greatest width, (3) Multiple areas of partial-thickness (grade 2.0) defects or a grade 2.0 defect wider than 1 cm but <75% of the region, (4) Diffuse (≥75% of the region) partial-thickness loss, (5) Multiple areas of full- thickness loss (grade 2.5) or a grade 2.5 lesion wider than 1 cm but <75% of the region, (6) Diffuse (≥75% of the region) full-thickness loss. Meniscal pathology is graded as follows according to WORMS: (0) Intact, (1) Minor radial tear or parrot-beak tear (2) Non-displaced tear or prior surgical repair, (3) Displaced tear or partial resection, (4) Complete maceration/destruction or complete resection. Each meniscus is scored separately and a maximum score of six is obtained by adding according to the combination of grades and combination of regions (anterior horn, mid-portion, posterior horn) of the meniscus involved.[18]

The Boston Leeds Osteoarthritis Knee Score (BLOKS) grades the extent and depth of cartilage loss, bone marrow lesions, osteophytes, synovitis, effusions, meniscal pathology, ligamentous pathology, and other features.[19] BLOKS scores the extent of partial thickness loss and the extent of full thickness loss in specific regions of the knee.[19] Similar to WORMS, BLOKS scores the presence or absence of intra-meniscal high-signal or tear in each region of each meniscus, and also derives a score for the presence of a meniscal cyst and presence and extent of meniscal extrusion.[19] The MRI Osteoarthritis Knee Score (MOAKS) is a later evolution of the BLOKS classification, aimed at refining the grading

of bone marrow lesions, cartilage, and meniscal pathology features (adding hypertrophy and maceration).[20]

The Knee Osteoarthritis Scoring System (KOSS) scores cartilage defects according to depth: (0) Normal signal intensity and morphology, (1) less than 50% reduction of cartilage thickness, (2) 50% or greater reduction of cartilage thickness, (3) full-thickness or near-full-thickness cartilage defect.[21] Other aspects scored included bone marrow lesions, subchondral cysts, meniscal intrasubstance degeneration, presence and shape of meniscal tear, and meniscal subluxation.[21] A meniscal tear was defined for this classification as "a region of intermediate signal intensity on proton density-weighted images within the meniscus, communicating with its superior or inferior surface or inner margin."[21] Meniscal tears were classified by shape as: (1) horizontal, (2) vertical, (3) radial, (4) complex, (5) bucket-handle.[21]

1.3.2.3 Arthroscopic classification

The most commonly used classification systems for the severity of chondral defects, based upon direct visualisation at the time of a knee arthroscopy, are Outerbridge and ICRS (International Cartilage Repair Society).[22]

The Outerbridge classification was first used to classify the severity of cartilage damage associated with chondromalacia patellae as follows: (0) normal, (1) softening and swelling, (2) partial-thickness fissuring in an area less than 1.5 cm (half an inch) in diameter, (3) partial-thickness fissuring in an area greater than 1.5 cm (half an inch) in diameter, (4) erosion to subchondral bone.[23]

The ICRS classification of cartilage defects was first described in 1998 as follows: (0) normal, (1A) soft indentation (1B) superficial fissures and cracks, (2) lesions extending < 50% of cartilage depth, (3A) lesions extending > 50% of cartilage depth, (3B) down to subchondral bone, (4) penetrating subchondral bone.[24]

1.4 The Meniscus

Each knee contains two menisci (pleural). The term meniscus (singular) is derived from the Greek word minískos (μηνίσκος), meaning 'crescent' or 'crescent moon'.[25] In anatomy, "menisci" were first described in English in 1830, translated from the description of fibro-cartilaginous tissue originally written by French anatomist Professor P.A. Béclard (1785-1825).[26] The meniscus may also be referred to as a 'semilunar cartilage', again alluding to the C-shaped, crescent moon, appearance. The development, structure and function of the meniscus is described below.

1.4.1 Development

The lower limb buds of the embryo begin to form at approximately 4 weeks after fertilization and the skeleton begins to form first as cartilage from five weeks.[27] The menisci are formed early in foetal development and may be visible macroscopically as early as week seven.[27] Early in development the menisci are highly vascular but this vascularity declines as development progresses and the menisci become increasingly cellular.[28] By the end of the first post-natal year, vascularity is limited to approximately the outer two-thirds of the meniscus and later, by adulthood, only the outer one-quarter to one-third.[28,29] The medial meniscus and lateral meniscus cover approximately 60% and 80% of the medial and lateral plateau respectively and there is little change in this proportion from early development to adulthood.[28,30]

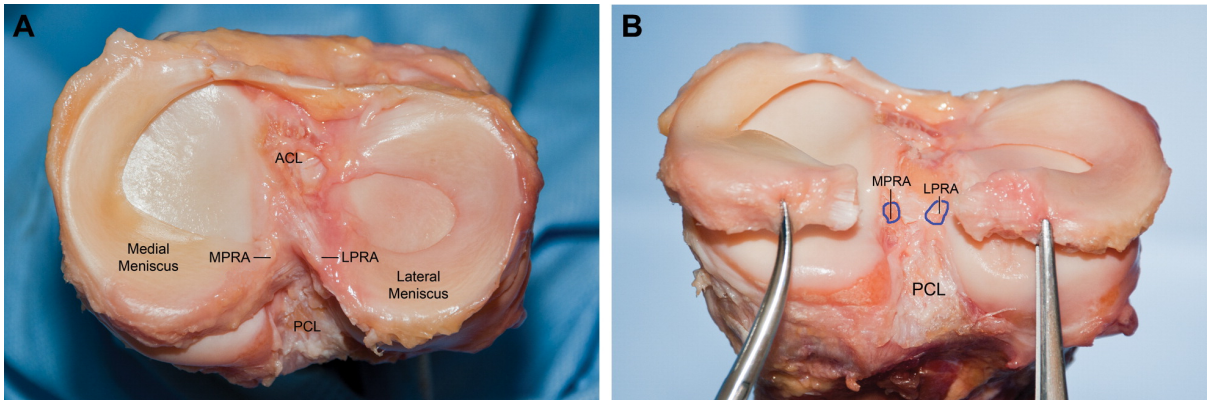
1.4.2 Structure of the Meniscus

1.4.2.1 Macroscopic

Macroscopically, the menisci are crescent shaped joint structures that are thick and convex peripherally where they are attached to the knee joint capsule.[3,31,32] Internally, they are thin and concave and, in cross-section, the menisci appear triangular with a flat inferior surface and relatively concave superior surface. This shape serves to increase the articular congruity of the tibiofemoral joint, deepening and widening the upper tibial surface (tibial plateau) to accommodate the convex femoral condyles.[33]

The medial meniscus is continuous with the medial joint capsule and medial collateral ligament.[3] The lateral meniscus is also attached to the joint capsule except at the level of the popliteus tendon, posterolaterally, but does not have attachments to the lateral collateral ligament. Both menisci are anchored to the bony tibial plateau at their respective anterior and posterior "horn" regions and the medial meniscus is broader posteriorly than anteriorly (Figure 1.2). The posterior horn of the lateral meniscus is variably anchored to the lateral part of the medial femoral condyle by the ligament of Humphrey's (anterior meniscofemoral ligament) in front of the PCL and the ligament of Wrisberg's (posterior meniscofemoral ligament), behind the PCL.[34]

Figure 1.2: Photographs of cadaveric right knee specimen (proximal tibia)



Note: A = superior view, B = postero-superior view. ACL = anterior cruciate ligament attachment footprint, PCL = posterior cruciate ligament attachment footprint; MPRA = medial meniscus posterior root attachment; LPRA = lateral meniscus posterior root attachment. Reproduced with kind permission from Professor Robert LaPrade.[35]

1.4.2.2 Microscopic

Microscopically, the meniscus contains collagen fibres arranged in three configurations: (1) A superficial mesh layer of randomly oriented thin fibres on the upper and lower surface, (2) A "lamellar" layer of thicker, primarily radial fibres peripherally and randomly oriented fibres centrally, immediately below the superficial layer on the tibial and femoral surface, and (3) An internal lattice of circumferentially oriented fibril bundles.[36] The lamellar layer is continuous with the joint capsule and the internal circumferential bundles are also penetrated by a portion of the joint capsule.[36]

Both menisci are formed of fibrocartilage and it is the fibrous element that predominates. The largest constituent of the meniscus, however, is water, which makes up 70-75% of the meniscus by weight.[37] The remaining meniscus is composed primarily of type I and also type II, III, V, VI collagen (~20%), elastin, proteoglycans and glycoproteins.[38,39] The cells of the meniscus have features of both chondrocytes and fibroblasts and are termed fibrochondrocytes; these cells can replenish or repair the meniscal matrix, especially in the well vascularised peripheral regions of the meniscus.[39–41] Proteoglycans make up less than 1% of the dry weight of the meniscus and although they do not appear to contribute to tensile strength, they may have an important role in resisting compression.[38] The collagen content of the meniscus has been shown to increase from birth until approximately 30 years age and then stabilise until approximately 70 years before declining.[42] In contrast, the non-collagenous proteins of the meniscus have been found to decrease from birth to age 30, stabilise, and then increase from age 70.[42] In macroscopically "degenerate" regions of the meniscus, the collagen content has been found to be lower than normal tissue, whereas non-collagenous protein content was elevated.[42] The water content and water binding proteoglycan content of "degenerating" meniscal tissue has been found to be greater than that of "normal" age-matched controls.[37]

The peripheral meniscus receives vascular supply from capillary loops of the fibrous capsule and synovial membrane.[29] Bloods vessels form a circumferential plexus originating from the superior and inferior geniculate vessels.[43] The peripheral 10-30% of the meniscus is vascularised and, in addition, the anterior and posterior meniscal horns are well vascularised.[29,44] The inner meniscus, however, is relatively avascular in adults (see also section 1.4.1) and cells in these regions may be vulnerable to biochemical or traumatic insults, being less able to regenerate.[29,38]

The meniscus is innervated most densely in the outer third circumferentially and the anterior and posterior horns, and these regions also contain mechanoreceptors providing pressure and proprioceptive feedback to the central nervous system.[45–47]

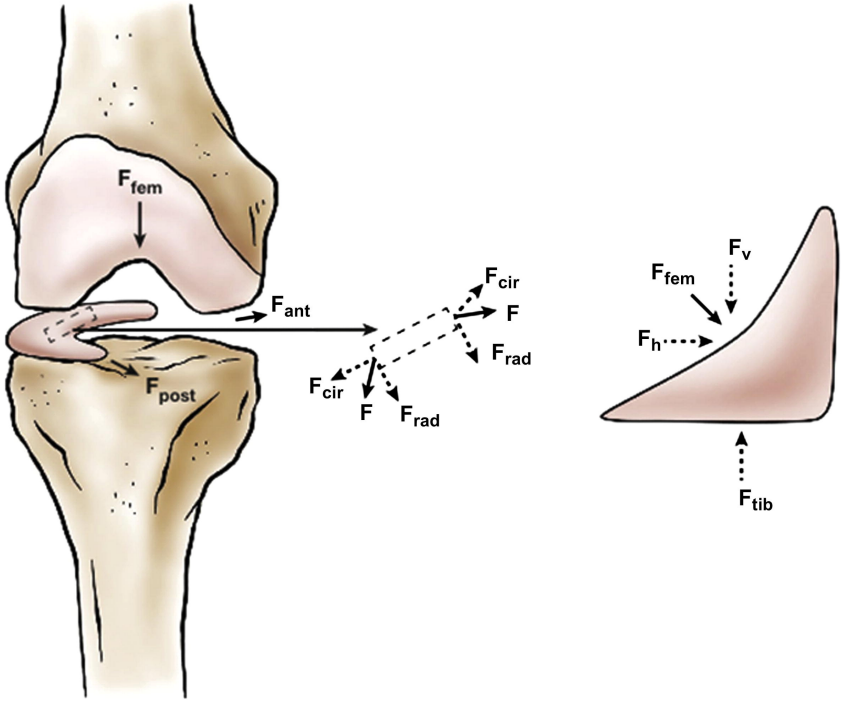
1.4.3 Function of the meniscus

The structure and function of the meniscus are intimately related. Firstly, as for menisci present in several other joints of the musculoskeletal system, the knee menisci improve congruity between the articulating surfaces of the joint.[1] Figure 1.3 represents the forces acting upon the meniscus in weightbearing stance. The meniscus resists tension, shear, and compressive forces. As the menisci are anchored at the anterior and posterior horns, the circumferential fibres must resist "hoop stress" from compressive load between these two fixed points (Figure 1.3).[48,49] Disruption of these fibres by physical disruption, or general structural degradation, may result in the loss of the ability to resist displacement and meniscal 'extrusion' from the joint may occur.[49–51] Radial shear is resisted by radial collagen fibres (see section 1.4.2). Inferiorly, the meniscus converts a compressive femoral shear force vector over a small surface area to a perpendicular force spread over a large surface area of the tibia (Figure 1.3).

Studies have demonstrated that around 50% of knee joint load is transmitted through the meniscus when the knee is in extension and up to 90% when the knee is at 90 degrees of flexion.[30] Due to the important role of the meniscus in joint congruity, complete resection of a meniscus decreases the contact area by 50-75% and may increase joint contact pressures by 235%.[30,52] Partial meniscectomy resulting in a reduction in joint surface contact area of approximately 10% may be associated with increased joint contact pressure of 65%.[52] A 40-50% reduction in joint contact after excision of a horizontal cleavage tear (see section 1.6.2) may be associated with a 75-80% increase in peak contact pressures.[53] Even resection of only the inferior leaf of a horizontal cleavage tear lesion has been shown to increase joint contact pressures by 36-43%.[53]

The function of the meniscus in the knee extends beyond joint congruity and it also plays a role in maintaining the stability of the knee and this role has been shown to be particularly important if the anterior cruciate ligament is deficient.[54,55] The meniscus may also play a role in joint lubrication and synovial nutrition.[56] As described above, in section 1.4.2.2, the meniscus also plays a role in joint feedback and proprioception.[45–47]

Figure 1.3: Free body diagram of forces acting upon meniscus during weight-bearing



Note: F_{fem}=compressing femoral force; F_{tib}=tibial reaction force; F_v=vertical force; F_h=horizontal force; F_{cir}=circumferential force; F_{rad}=radial forces; F_{ant}=anterior horn force; F_{post}=posterior horn force. Reproduced with kind permission from Professor Kyriacos Athanasiou.[3]

1.4.4 Kinematics and knee movement

Understanding of knee kinematics has improved greatly over time.[7] Studies initially focussed on the bony anatomy of the joint, especially a model of kinematics based around the elongated curvature of the femoral condyles in relation to the tibia.[7] A limitation of this model, described as the "instant centre" model, was only the sagittal plane of movement was considered, however it was useful in explaining a large proportion of knee movement in this plane.[7] Later, the model was amended based upon observations that the plane of movement appeared to be offset from the direct sagittal plane, and a new "fixed axis" flexion model became accepted.[7] With the development of MRI based techniques, more accurate analysis of three-dimensional motion of the knee has been possible over the last thirty years.[7] Knee movement is now accepted to be the composite of movements relative to three axes: (1) posterior condylar axis (offset 7 degrees from the posterior condylar line and parallel to the epicondylar line), (2) distal condylar axis, and (3) the longitudinal axis of the femur.[7]

Movement in flexion is primarily determined by the posterior condylar axis and in extension by the distal condylar axis.[7] With increasing flexion, the knee "rolls back" from the posterior tibia and the joint contact area decreases.[57] Much more rollback is experienced in deep flexion and squatting, however, in comparison to normal walking.[58] There is variability in the degree of rollback and range of movement experienced in the knee between populations.[57]

Rotation on the longitudinal axis is determined primarily by the ligaments and the position and loading of the tibia.[2,7] Through the range of movement, the femur tends to internally rotate on the tibia but this movement may be resisted or prevented in certain loading patterns of the knee.[2,7,59] A so-called "screw-home" mechanism was previously thought to occur passively as the knee extended due to the bony anatomy of the joint, bringing stability to the knee in full extension, however it is now established that this movement may also be actively overcome.[2,7,59] The lateral meniscus is more mobile than the medial and, combined with differences in the bony anatomy of the medial and lateral tibia (see section 1.2), this centres the axis of rotation on the medial side of tibia.[1,60] MRI studies confirm that on flexion there is less excursion of medial meniscus in comparison to the lateral meniscus.[60]

Knee flexion is accomplished with a combination of tibiofemoral "roll" and "glide" and the stability of the knee throughout range of movement is heavily influenced not just by the bony anatomy but also by ligamentous tension.[2,7,61] The MCL and the various ligamentous 'bundles' of the ACL and PCL are relatively isotonic through the range of movement.[7,61] All the ligaments and especially the LCL are more taught in extension than flexion, largely due to the increased radius of curvature of the femur (see also section 1.2).[7,61] The posterior capsule of the knee joint is also tensioned in extension, providing some additional restraint and stability at full extension.[7,61]

1.5 Clinical Care Pathways

1.5.1 Definition and description

The European Pathway Association (EPA) established the following definition for a care pathway in 2005:[62]

> *"A care pathway is a complex intervention for the mutual decision making and organisation of care processes for a well-defined group of patients during a well-defined period."*

The care pathway starts when a patient first starts considering treatment for a condition until the point of treatment. This period of treatment consideration may be days, weeks, months or even years and there may be many points of contact with healthcare over this time. The first point of contact for most patients with a new musculoskeletal condition will be with primary care (community general practitioners) but for some patients, particularly if an injury has occurred, this may be with secondary (hospital) care, for example attending an emergency department.

After first contact with primary care, a general practitioner will decide on initial treatment recommendations and whether to recommend onwards referral based upon their own knowledge and condition specific guidelines. This is a shared-decision, with the patient ultimately deciding whether to accept onwards referral after an informed discussion with their general practitioner. If onwards referral is agreed, the next contact with healthcare depends on the regional service arrangements. The next point of contact may either be a review in a specialist clinic in secondary care or, often, assessment in a general musculoskeletal clinic (for example, a musculoskeletal "hub"). If the patient is reviewed in a general hub, the shared-decision about onwards referral to a secondary care specialist is again made based upon the reviewing clinical professional's recommendations: discussions with the patient informed by the clinician's knowledge and any condition specific clinical guidance.

As a patient progresses through a care pathway, more information may become available about the patient's condition and the anticipated benefits or risks from any proposed treatment. By the point of review in secondary care, a patient will frequently have undergone serial clinical examination and investigations such as blood tests and radiological imaging. Similar to referral recommendations, clinical professionals will request and interpret investigations on the basis of their own knowledge and experience and condition specific guidelines. In a well-designed care pathway, the clinical professionals reviewing the patient at each stage will have the knowledge and experience to be able to help the patient make an informed decision about proceeding to the next step in the pathway.

The goal of the review in secondary care is diagnosis and a recommendation on definitive treatment. In some cases, to achieve this, a 'tertiary referral' (to a sub-specialist clinical professional within a hospital unit) may be the outcome of the initial secondary care review. Clinical diagnosis is a dynamic process representing the 'best' judgement of the reviewing clinician based upon a perceived balance of probabilities that is informed by their knowledge, experience, the history of preceding events (such as an injury) associated with onset of the symptoms and signs of the condition, and supported by the findings from the clinical examination and investigations.

The role of the specialist clinicians is to not only convey to the patient the level of certainty regarding their condition diagnosis, but also to discuss the treatment options and treatment recommendations. The discussion of the treatment options should clearly inform the patient of the anticipated benefits and potential risk associated with the treatment options in their individual circumstances.[63] See also section 1.5.5 below.

1.5.2 Assessment of care pathways

The goal of a successful care pathway is high quality, consistent care, but even established care pathways must be kept under review through regular local, regional and national clinical audits and evaluation of new evidence. When appraising a care pathway, factors that should be considering include

treatment intervention rates (especially changes over time and in response to new evidence or guidance), variation in intervention rates, and patient outcomes. Patient outcomes include not only an assessment of benefits such as improvement in symptoms, function, quality of life, but also undesirable outcomes including short- and long-term adverse events such as infection, medical complications, and need for further treatments. A summary of some of these considerations follows in sections 1.5.3, 1.5.4, and 1.5.5.

1.5.3 Variation in the care pathway and regional intervention rates

One of the key drivers of variation in surgical treatment is surgeon "belief" that there is benefit associated with undergoing the procedure for certain indications (the "enthusiasm hypothesis"), which may be reinforced by a degree of "confirmation bias" even when challenged by new evidence.[64–67] Where there is a lack of good quality evidence or standardised treatment guidelines for a condition, variation in treatment recommendations is to be expected.[66] Clinicians may be less able to reach a diagnosis with a high level of certainty and be less able to inform patients of the potential benefits and harms of a treatment in their particular circumstances. Such variation in care is seen across healthcare as documented, for example, in the "Atlas of Variation" publications by Public Health England.[68] In contrast, in circumstances where there is very clear evidence-based guidance on diagnosis and treatment, dramatically less variation and improved care outcomes may be observed – as has been shown in the treatment of hip fractures in the UK.[66,69]

At a patient level, there are many other factors that can ultimately determine whether a decision is made to undergo an intervention. Care seeking attitudes may be influenced by factors including sex, culture, socioeconomic status and occupation.[70–72] Communication and cultural differences may also play a role in access to healthcare.[73] Some patients may prefer to undergo the most minor intervention available, even if the anticipated benefit is low, if the perceived risk is much lower than an alternative, more effective, procedure. Patients may prefer to undergo such an intervention in an attempt to delay or avoid

undergoing the more major procedure – for example, a young patient delaying arthroplasty for advanced osteoarthritis due to the probability of later revision surgery.[74]

Procedures where there is a high degree of regional variation in treatment intervention rate (after standardising for patient factors such as age and sex) may, therefore, be indicative of clinician or provider level variation in care recommendations and a need for more evidence, or guidelines, to improve and standardise the care pathway.[66]

1.5.4 Patient reported outcome measures

Patient reported outcome measures (PROMs) are collected in a range of settings and are increasingly important in care pathways. In orthopaedics, PROMs are important for auditing treatment outcomes and increasingly to demonstrate the cost-effectiveness of treatment.[75] With the rapid increase in usage, it is important to ensure that PROMs have formally validated measurement properties. Although generic PROMs enable the comparison of patients with different conditions, these PROMs may fail to capture important items in specific populations.[76] Ideally, a PROM should either be developed with condition-specific patient involvement or subsequently studied for validity in the population of interest.[77] Fundamentally, a PROM should comprehensively and consistently reflect the intended 'construct' to be measured in the population with the condition of interest – for example, health-related quality of life in patients with meniscal tears.[78] There have also been calls for selection of standardised 'core' PROMs for consistent use in clinical trials and the clinical evaluation of patients with specific conditions.[79] A systematic review of the evidence is an important step in the selection of such a 'core outcome set' and may determine the need for further validation studies or even the development of a new PROM.[79]

1.5.5 Benefits, harms, and developing clinical guidelines

The ability of a clinician to make a clinical diagnosis with a high level of certainty is greatly facilitated when there are established diagnostic criteria: the specific combination of history, examination and investigation findings present in patients with a certain condition and not present in patients with other

conditions. The importance of clear, standardised terminology in health care research and clinical practice is well established.[80,81] A lack of standardised terminology limits the aggregation, interpretation, and communication of clinical knowledge which can have a direct impact on the quality of clinical care and ability to develop guidelines for well-defined groups of patients.

The clarity with which a clinician can inform a patient of their individual expected benefit and potential risks from possible treatment options also depends on evidence. In surgery, the best evidence regarding benefits comes from well-designed randomised controlled trials and, ultimately, systematic reviews of these trials that clearly state the evidence that is applicable to particular conditions and patients. As described above (section 1.5.4), the primary outcome of surgical trials is usually a PROM, which should be well validated for the particular population.

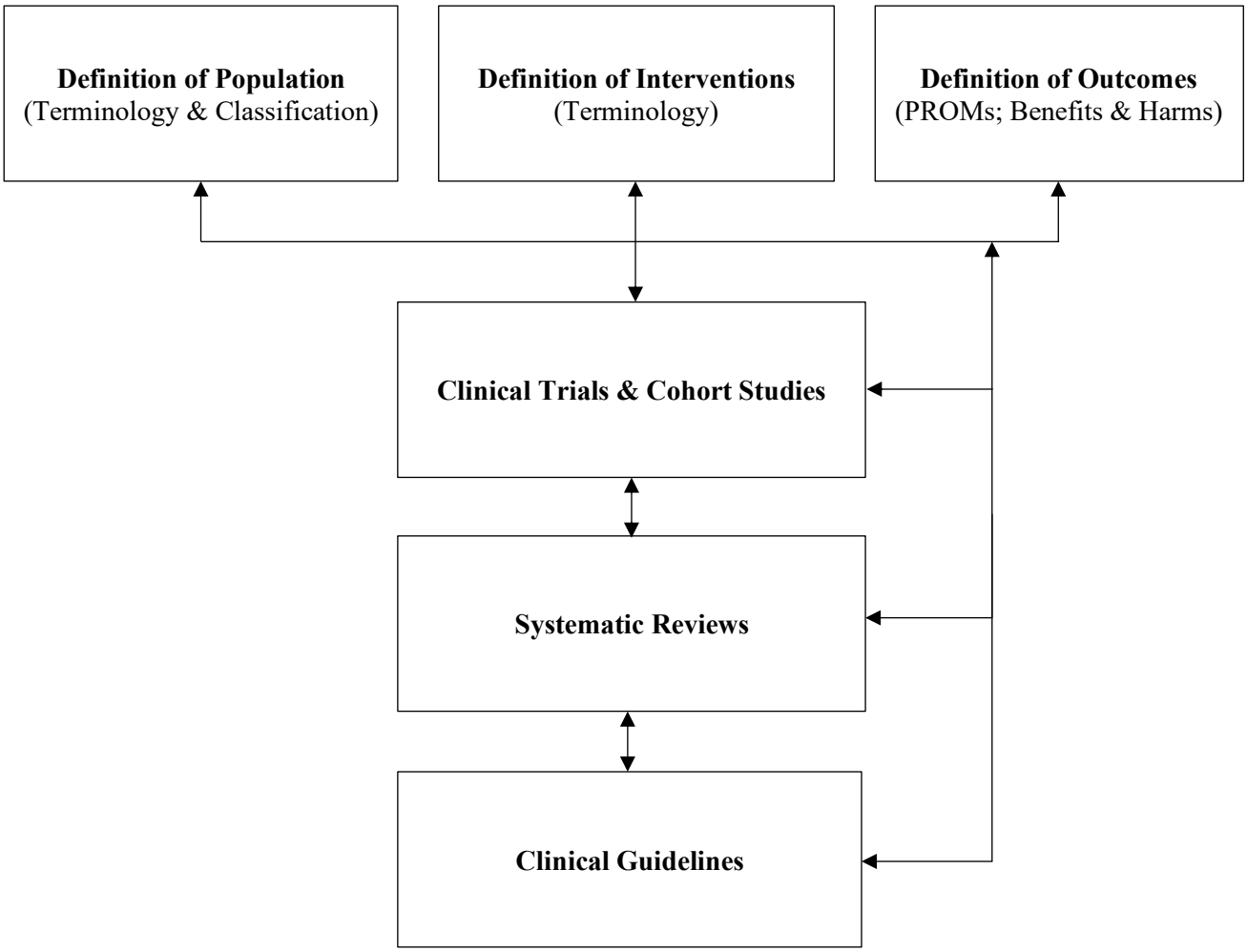
Defining the potential harms of a treatment intervention is also important and can be challenging, especially where adverse outcomes are rare or difficult to attribute to the intervention itself (see later, section 1.8.4). These data often come from large patient cohorts, reported in health provider databases and clinical registries such as the National Joint Registry in the UK.[82]

Informed by clinical trials and systematic review, summary clinical guidelines may be issued by national and international societies, with the aim of producing a clear summary of 'best-practice' in diagnosis and treatment for a particular condition. A simplified diagram of the evidence required in the development and review of clinical guidelines is shown in Figure 1.4. Many groups may be involved in generating treatment guidelines at a local, regional, or national level. At a national level, specialist societies are often well placed to develop and issue guidelines to improve and standardise practice. In the UK, the National Institute for Health and Care Excellence (NICE) has a public health remit to produce evidence-based guidance on the management of conditions across all medical specialties.[83] These recommendations consider all the evidence regarding benefits and harms but also the cost of different treatment interventions. NICE guidance is particularly impactful in the UK as NICE has the

power to determine whether certain treatments are to be supported and, crucially, funded (or "commissioned") within the National Health Service (NHS).[83]

There is evidence that the issuance of guidelines can improve practice, especially when financial or other incentives are in place to encourage provider compliance.[66,84–86] In musculoskeletal care, this is evidenced by the improvement in the care and outcomes of hip fracture patients, which was supported by the issuance of clear guidance from NICE and other bodies, alongside financial incentives to health providers for delivering compliant care.[69]

Figure 1.4: Evidence synthesis and the development and review cycle for clinical guidelines



1.5.6 Consensus methods and treatment appropriateness

As introduced above (1.5.5), clinical guidelines may be developed by many different groups or committees. In order to reach agreement on the topics under discussion, most national and international groups use a form of structured and controlled interaction between group participants. The most commonly used formal approaches are the Delphi method, nominal group techniques, or a combination of these.[87,88]

1.5.6.1 Delphi method

The Delphi method is a technique of controlled interaction, classically without meetings or face-to-face discussion, aiming to facilitate group communication leading to agreement on a topic or solutions to a problem.[87,89,90] First, the problem or topic for consideration is set by the organisers of the process and participants are invited to take part. Most commonly, a series of questionnaires are then sent to participants of the group, who are invited to respond with their ideas on this topic. This first round might be to refine the topic, problem, and questions, or to collect initial answers. A series of questionnaire rounds are undertaken to refine and rank items within the participant group. Between the questionnaire rounds, or 'iterations', a summary of all the previous round responses is provided to each participant by the organisers with proposed amendments to any statements.[89,90] Participants may then re-rate and rank items and propose further amendments. The process continues until responses reach an agreed threshold for 'agreement' or until no further changes in responses occur. The primary goal of the Delphi method is controlled communication within a group to address a complex topic, usually without direct contact between group members and some degree of anonymity.[90] There are, however, many possible modifications to this approach and it is commonly also used as a supplement to group meetings to validate and refine group output. In this modified approach, the process includes some of the features of the nominal group technique (below) and there is often some overlap between these techniques.

1.5.6.2 Nominal group techniques

The nominal group technique was first developed in 1971 as a formal method of structuring face-to-face meetings and communication.[87,91] The goal is to overcome potential limitations to informal groups, where individuals may be inhibited from sharing their own thoughts and ideas, hindering the performance of the group as a whole. The technique aims to counter risks such as the "Asch Effect" or "Groupthink": such as the blind acceptance of group norms, illusion of unanimity, or dominant members.[92,93]. Generally, only two meetings are organised and prior to the first meeting participants may be invited to consider their own thoughts and ideas on a topic or problem, before meeting and discussing these within the group.[88] The structured interactions between members are controlled by a chair or facilitator. The output from the first meeting is then considered by each individual member again and there may be a ranking exercise, or the level of agreement measured by voting. The next meeting is then arranged, and members are provided with a summary of the group's rankings and votes for further discussion, ranking, and voting (generally on the same day as the second or final meeting). The output of the second meeting is generally considered the final output of the group.[88]

1.5.6.3 Treatment appropriateness exercises

Treatment appropriateness exercises are well established and have been used previously to deliver treatment recommendations for a wide range of medical and surgical treatments.[94–98] The dominant technique is the RAND/UCLA Appropriateness Method (RAM), which was first developed in the 1980s and designed to be a tool for the estimation of the over- or under-use of medical or surgical interventions by applying a consensus based method.[99] The process is based on the findings of a military defence study performed with RAND in the 1950s.[100] The initial study was concerned with estimating bombing requirements with a technique of controlled interaction between experts in the field that aimed to deliver a considered 'consensus' opinion by supporting independent thought with controlled group feedback.[100] Following declassification, the technique was refined and modified by RAND and UCLA statisticians and psychologists.

RAM provides the opportunity to use controlled interaction between experts to derive knowledge and treatment recommendations. The process is informed by the existing evidence but not reliant on data where no data is available. At the start of the process, a structured list of clinical presentations for the condition of interest is created and the process is limited to measuring the level of agreement on the appropriateness (and sometimes 'necessity') of an intervention for each of the presentations.[99] In common with other consensus techniques, the RAM anonymous rating process aims to limit the impact from experts otherwise showing "unwillingness to abandon publicly held beliefs" or the pressure to conform.[100] A key stated benefit of the military application was that original data collection and modelling would, at the time, have been time and cost-prohibitive. For clinical applications, this remains a key benefit as definitive information might require multiple large clinical trials to be performed with different treatment protocols: an approach which could be prohibitively costly, time consuming, and in the case of some treatments also unethical.

1.5.6.4 Group composition

There is a lack of agreement on the ideal size and composition of a consensus group. One of the main criteria for selection of participants is that they are considered 'expert': one definition being individuals that are "highly trained and competent within the specialized area of knowledge related to the target issue" under evaluation.[88,89] The decision whether to include individuals with a mixture of backgrounds or clinical specialisms depends on the intended purpose of the output.[88] Patient and non-clinical participants may be invited to participate in some groups or to provide feedback on the output of clinical groups, especially where patient information is the intended output.[101]

A greater number of participants may attract more diverse opinions but fewer participants may respond to questionnaires or attend meetings when part of a larger group, seeing their own contribution as less important or impactful in these circumstances, and the group coordination and data analysis process may also become unnecessarily cumbersome. For the nominal group and RAM techniques, the number of participants should be chosen to ensure some diversity in opinion without the group becoming so large that all participants become unable to meaningfully contribute. Most Delphi studies involve

around 15-20 participants and for nominal group and RAM techniques, numbers of 9-15 participants have been suggested.[89,99] The number of recruited participants must also account for group attrition and incomplete participation.

1.5.7 The care pathway for meniscal lesions

The care pathway for patients developing symptoms that may be associated with a meniscal lesion follows the model described above in section 1.5.1. For most patients, symptoms may begin without an injury or an apparently trivial incident such as a slip or twist whilst crouched or turning – most of these patients are likely to present first to their general practitioner in primary care. For some, there may be an injury from a fall, impact, or similar, and these patients may present instead to an emergency department where they may either be discharged back to primary care or referred on directly to a specialist clinic in secondary care. In the UK, it is possible for patients to be referred for additional investigations and imaging from either primary or secondary care, and the findings of this imaging may help guide the patient through the care pathway.

The following sections document the evidence available, prior to this thesis, to inform the management of patients on the care pathway for meniscal lesions: the diagnosis, treatment selection options, and potential benefits and harms associated with meniscal surgery. The limitations of the current evidence and previous attempts at evidence synthesis and treatment guidance are discussed.

1.6 Meniscal Lesions

1.6.1 Incidence and prevalence

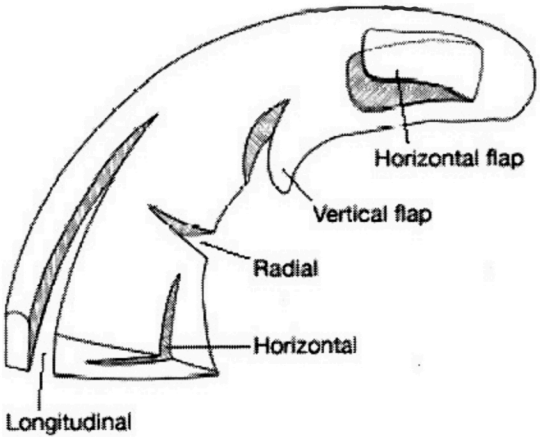
The annual incidence of meniscal tears has been estimated to be between 60 and 70 per 100,000 population.[102] The prevalence of meniscal tears in a young, asymptomatic population (mean age 28 years; range 19-39) has been estimated to be approximately 5.6%.[103] Over the age of 50 years, however, meniscal pathology is more common and detectable in around 50% of people without radiographic evidence of osteoarthritis, rising to over 60% in those with radiographic osteoarthritis.[104] In one series

of patients with a mean age of 65, up to 90% of patients with symptomatic osteoarthritis had an associated medial meniscus tear.[105]

1.6.2 Patterns of meniscal tear

Meniscal tears may be classified based on symptoms, signs, or structural appearances (MRI or at the time of arthroscopic examination). Classical terms that orthopaedic surgeons have used to describe meniscal tears are based upon structural appearance and include: bucket handle, flap, radial, longitudinal, horizontal, or complex.[106] Complex tears are generally defined as lesions with more than one structural plane of tear; in most cases this includes a horizontal component.[107] In 2010, the International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine (ISAKOS) published a diagram to illustrate the common patterns of meniscal tear, but without accompanying descriptive terminology (Figure 1.5).[108]

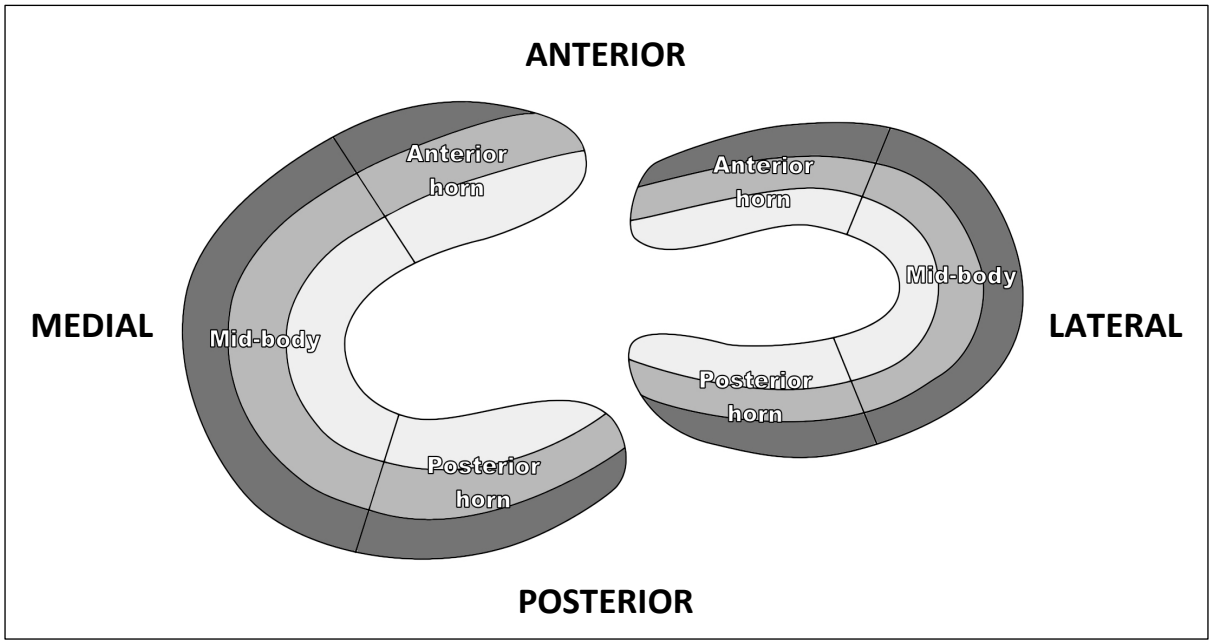
Figure 1.5: Diagrammatic representation of patterns of meniscal tear according to ISAKOS[108]



Meniscal tears may also be classified according to the location in the meniscus in which they occur. These regions may be anterior, mid-body, posterior, or alternatively peripheral versus central, as shown in Figure 1.6. Peripheral tears have been defined as those in the outer (circumferential) third of the meniscus.[106] Meniscal tears may also be classified radiographically and arthroscopically as stable or

unstable according to their location, size, and any associated displacement.[109–111] Stable tears, in some circumstances, may heal spontaneously.[112]

Figure 1.6: Diagram depicting regions of medial and lateral meniscus (modified from description by Cooper et. al.[113])



Note: The shaded regions depict the circumferential "thirds" of the menisci: central third (light shading), middle third, and peripheral (outer) third (dark shading), respectively.

The frequency of these patterns of tears varies with age and gender and this likely reflects differences in activity levels, injury patterns, and meniscal degeneration.[106] A summary of age and gender differences in meniscal tear patterns identified by arthroscopy in a series of 1485 tears (1370 patients with stable knees) is shown in Table 1.1 and Table 1.2 respectively.[106] Bucket handle, radial and longitudinal tears in this series were more common in patients under the age of 40, whereas horizontal and complex tear patterns were more common in patients over the age of 40 years (Table 1.1).[106] In this series of stable knees, only 39% were peripheral, whereas in a series by the same authors in unstable knees (anterior cruciate ligamentous deficiency), 61% of 575 tears were in the peripheral zone, and the population was younger (mean age 25 years versus 46 years).[106,114]

Table 1.1 – Age differences in tear patterns (adapted from Metcalf and Barrett 2004)[106]

	Age ≤ 40 years		**Age > 40 years**	
	Number	Percentage	Number	Percentage
Bucket handle	91	21.0 %	37	3.5 %
Flap	74	17.0 %	158	15.0 %
Radial	44	10.0 %	34	3.2 %
Horizontal	96	22.0 %	379	36.0 %
Longitudinal	74	17.0 %	74	7.0 %
Complex	57	13.0 %	368	35.0 %

Table 1.2 - Gender differences in tear region and pattern (adapted from Metcalf & Barrett 2004)[106]

	Male	**Female**
Tear location		
Anterior	5.1 %	12.0 %
Mid-body	38.0 %	33.0 %
Posterior	88.0 %	82.0 %
Tear pattern		
Bucket handle	11.0 %	3.8 %
Flap	16.0 %	13.0 %
Radial	4.7 %	6.9 %
Horizontal	30.0 %	37.0 %
Longitudinal	11.0 %	8.2 %
Complex	27.0 %	31.0 %

Overall, there were differences between the region of the medial and lateral meniscus involved in tears: on the medial side, for example, 98% of the tears involved the posterior horn in comparison to 55% on

the lateral side.[106] On the medial side, 28% involved the mid-body and 1% anterior horn, in comparison to 59% and 24% respectively on the lateral side.[106]

The differing patterns of meniscal tears in younger age groups in comparison to older was first described in 1967.[115] Professor Smillie noted that longitudinal tears occurred in young patients with normal fibrocartilage whereas horizontal tears occurred in middle age in abnormal fibrocartilage.[115] This observation regarding the age-distribution of tear patterns, especially horizontal tears, was confirmed in subsequent series.[106,116] It was also noted by Smillie that in older patients, degeneration appears to lead to strain within the substance of the meniscus and failure of the fibrocartilage and a tear even after trivial injury or without any provoking episode.[115] Certain patterns of meniscal tears, particularly horizontal cleavage and complex tears are associated with cartilage damage and osteoarthritis.[107] Meniscal extrusion or maceration is also strongly associated with osteoarthritis severity and progression.[117] It has also been demonstrated that meniscal pathology is responsible for a large proportion of the joint space narrowing detected on weight-bearing radiographs of the knee.[118]

1.6.3 Meniscal pathology and osteoarthritis

Meniscal pathology may be detected on MRI imaging in patients without radiographic osteoarthritis and may be an early event in the osteoarthritic disease process.[119,120] In patients without baseline osteoarthritis, the development of a meniscal tear has been shown to be associated with progression to radiographic osteoarthritis, even in patients not undergoing surgery.[121] Overall, the prevalence of meniscal pathology in the population is correlated with the severity of radiographic knee osteoarthritis.[104]

"Degeneration" of the meniscus is associated with macroscopic, histological and chemical changes.[37] Chemically, the water content of the meniscus, by weight, increases from around 70% to 85% and there is also an increased glycosaminoglycan concentration suggesting increased water binding proteoglycan.[37] Degenerative changes in the meniscus may be detected as intra-meniscal 'high-signal'

on MRI imaging and longitudinal evidence suggests these changes pre-dispose to the development of a meniscal 'tear'.[122]

Although it appears that the meniscus may degrade with age and develop structural lesions in association with a failing osteoarthritic joint, there is evidence that the presence of a meniscal tear may independently be associated with progressive osteoarthritis.[123] This may be because, as described earlier, the meniscus plays an important role in load transmission, joint stability, and tibiofemoral joint congruity (section 1.4.3). Complete excision of the meniscus after a meniscal injury has been found to be associated with accelerated osteoarthritic progression.[124–127] Indeed, the gold standard experimental murine model of osteoarthritis is considered to be the surgical destabilisation of the medial meniscus by surgical menisco-tibial detachment.[128]

T.J. Fairbank is credited with first highlighting, in 1948, the important chondroprotective function of the meniscus.[124] In a cohort of clinical cases, Fairbank described specific radiographic changes that were observed after total meniscectomy: ridging, flattening, and narrowing of the medial or lateral joint space corresponding to the side of meniscectomy.[124] A higher rate of progressive osteoarthritis in the operated knee of patients undergoing meniscectomy, in comparison to their non-operated knee, was subsequently also reported in an influential paper by J.P. Jackson published in 1968.[129] This led to subsequent focus on meniscal preservation with minimal resection of meniscus (partial meniscectomy).[125,130] Although it had been postulated that a meniscal tear may cause direct mechanical damage to the chondral surfaces of the femur in particular, Jackson observed no association between the duration of pre-operative symptoms ranging from less than 6 months to over 5 years, with the proportion of these patients developing radiographic signs of osteoarthritis.[129] Interestingly, a recent systematic review noted a strong association between arthroscopic partial meniscectomy and subsequent progressive radiographic osteoarthritis in a series of studies, but noted that the associated clinical symptoms that were present in these patients were generally "not significant".[131] In contrast, however, another recent study reported a fifteen-times greater odds of knee replacement in patients with history of a "meniscal injury" in comparison to the general population.[132] The relative significance of

the meniscal lesion itself and previous knee trauma, in comparison to any deleterious effect from partial meniscectomy, in determining the clinical and radiological outcome remains uncertain.

Another meniscal finding that is strongly associated with osteoarthritis is meniscal "extrusion". Meniscal extrusion may be defined as protrusion of the meniscus more than 3mm from the edge of the tibial plateau or by greater than 30% of meniscal width.[133] Meniscus extrusion is associated with meniscal tears, knee malalignment and cartilage damage.[134] Meniscus extrusion may be caused by a meniscal root tear and may precede the development of osteoarthritis.[51] Meniscal extrusion may also occur in the absence of a meniscal tear and may be asymptomatic.[135] Meniscus extrusion is a highly complex process and the underlying pathophysiology is not yet fully understood.[136]

1.6.4 Diagnosis of meniscal tears

Of all musculoskeletal symptoms, knee pain is second only to back pain in terms of prevalence.[137] One quarter of all people over the age of 55 experience persistent episodes of knee pain and around one sixth of these people with knee pain consult their general practitioner each year.[138] The prevalence of painful disabling knee osteoarthritis in people aged over 55 years is 10%.[138] Meniscal pathology is also extremely common, with an overall prevalence of approximately 45% in patients over the age of 50 reporting knee pain, aching or stiffness.[104]

The following is a description by Mr Hey of Leeds in the late 19th century, of a clinical pattern of symptoms that may be brought on by "some slight derangement of the semi-lunar cartilages":[139]

> *"This joint is not unfrequently affected with an internal derangement of its component parts, and that sometimes in consequence of trifling accidents. The disease is, indeed, now and then removed, as suddenly as it is produced, by the natural motions of the joint without surgical assistance but it may remain for weeks*

or months, and will then become a serious misfortune, as it causes a considerable degree of lameness."

Some patterns of meniscal tear are strongly, although not exclusively, associated with certain patterns of symptoms. For example, the displaced 'bucket handle' meniscal tear is frequently associated with a 'locked' or 'blocked' knee, with the individual being unable to fully extend or flex the knee due to the meniscal tissue becoming entrapped within the joint articulation. Nevertheless, no single symptom or sign is pathognomonic for the presence of a meniscal tear and the sensitivity and specificity of clinical assessment is reliant on an integrated interpretation of both the history and clinical examination.[106,140–142]

Not all meniscal tears are symptomatic and may be incidental findings on MRI.[104,105] One series reported a prevalence of 76% in asymptomatic individuals with an average age of 67 years, rising to 91% in similarly aged patients with clinical symptomatic osteoarthritis.[105] Another series reported a prevalence of 60% in patients over the age of 50 years without knee pain.[104] When a meniscal tear is suspected, radiological imaging is generally performed to confirm a diagnosis and MRI has become the imaging modality of choice.[143,144] Diagnostic arthroscopy is considered the "gold standard" for diagnosis of a meniscal lesion and MRI has a reported sensitivity and specificity for meniscal lesions of approximately 88% and 94% respectively in comparison to arthroscopic findings.[145] Modern sequences may further enhance the diagnostic accuracy of MRI and specialist interpretation of imaging has also been shown to be important.[146–149]

1.7 Treatment Options for a Meniscal Tear

1.7.1 Non-Surgical

Non-surgical (non-operative; conservative) treatments include exercise therapy (physiotherapy or exercise therapy, which may be augmented by joint bracing or taping); pharmacological interventions such as intra-articular corticosteroid injection or nonsteroidal anti-inflammatory drugs (for example,

hydrocortisone with or without local anaesthetic, and ibuprofen, respectively); or no treatment (observation).

Physiotherapy (exercise therapy) aims to address limitations with an appropriately prescribed combination of range of movement, neuromuscular function, strength, flexibility, and proprioceptive (balance), or weight loss focussed activities. These interventions may be effective by directly improving cartilage turnover and nutrition or, indirectly, by improving mechanical loading patterns and stability of the joint and related joints.[8,150] Knee braces may reduce pain, improve joint stability, or reduce the risk of falling by applying external forces to the knee in a static or dynamic design. Bracing has been recommended for carefully selected patients with osteoarthritis in many treatment guidelines.[151]

Intra-articular corticosteroid injection may be effective in reducing inflammation that can develop as a result of a meniscal tear, and there is some evidence of a short term benefit to residual symptoms after APM has been performed.[152] Nonsteroidal anti-inflammatory drugs are generally administered systemically but may similarly work to reduce inflammation and associated symptoms.

No treatment (observation) may be effective where the natural history of a condition results in the resolution of symptoms over time. For example, healing of stable meniscal tears has been demonstrated without surgical intervention.[112] Some evidence suggests that for a considerable proportion of individuals with a meniscal tear, symptoms may resolve with a non-surgical treatment strategy.[153]

1.7.2 Surgical

Arthroscopic ('key-hole' surgery) partial meniscectomy (APM) is the most commonly performed surgical procedure for the treatment of meniscal tears and one of the most commonly performed surgical procedures worldwide.[154,155] This procedure involves the use of a camera probe that delivers sterile irrigation fluid to provide clear vision in the joint and specialised instruments within the knee joint to excise unstable meniscal tear tissue, preserving as much remaining, stable, meniscus as possible.[156,157]

APM is performed with the intention of removing an unstable portion of 'torn' meniscal tissue when this is thought to be the origin of the pain and other symptoms. A large 'bucket handle' tear of the meniscus, for example, may cause a 'locked knee' as a result of a direct, mechanical block to normal tibio-femoral articulation.[158] In these patients, a benefit from meniscal surgery (excision or repair) is strongly anticipated but in other patients with meniscal lesions, the decision on whether to surgically intervene is more challenging. As described earlier, some meniscal tears are more "unstable" and, indeed, patients undergoing APM for the treatment of certain patterns of meniscal tears may have less satisfactory outcomes.[159] Lateral meniscectomy may be associated with worse outcomes than medial, perhaps due to the greater surface area of the lateral plateau covered by the lateral meniscus (section 1.4.2).[160,161]

One alternative to APM is meniscal repair. Meniscal repair was first described by Annandale in 1885, performed open for a 30 year old miner with a displaced tear of the medial meniscus.[162] It was only in the 1980s, however, that there was renewed interest and rapid development of the technique.[52,113,163] Still, today, only a minority of meniscal lesions are managed with meniscal repair.[164] Another evolving treatment is that of meniscal transplant, most commonly of an allograft meniscus after a patient has undergone a total or sub-total meniscectomy. The first description of meniscal transplantation was published in 1989.[165] The technique has been researched over the last 10-20 years and is performed in increasing numbers in specialist centres, in carefully selected patients, with the intention to reduce the risk of progressive osteoarthritis.[31,166,167]

1.8 Arthroscopy of the Knee

1.8.1 History of development

Orthopaedic arthroscopy including knee arthroscopy was preceded by developments in urology. The first device designed to use light to visualise internal body cavities was developed by Phillip Bozzini in Germany and first described as a Lichtleiter or "light-conductor" in 1806.[168] The first device was

primitive, consisting of a simple candle, speculum, mirror and viewing aperture, however reports suggest it was used successfully to visualise inside the bladder before Bozzini's death in 1809.[168]

In 1867, a dentist, Julius Bruck, began to experiment with visualising internal organs using an incandescent platinum filament for illumination, attempting to overcome the heat generated by this using the circulation of cold water.[169] This device proved too large for use in cystoscopy and Bruck instead attempted to illuminate the bladder by placing the device in the vagina or rectum.[169]

Further developments in endoscopy were led by Max Nitze in Dresden and, later, Vienna.[169] Nitze worked with opticians to combine a 21Fr diameter metal catheter with lenses and a water-cooled platinum filament inside the bladder.[169] This was first demonstrated on a cadaver in 1877 and later, following refinement, in a living patient in 1879.[169] The device was still large and cumbersome owing to the need for the irrigation system to compensate for the heat emitted from the wire filament. The solution to this problem followed the invention of the incandescent light bulb by Thomas Edison and Joseph Swan in 1878. In 1883, David Newman in Glasgow was first to place an incandescent bulb on the end of cystoscope and in 1886 Nitze also produced a prototype cystoscope with an Edison bulb, that did not require water cooling, and further developed this into an operating cystoscope between 1891 and 1894.[169,170]

The first published description of diagnostic visualisation of the knee joint using a very basic, trochar like, device was by Severin Nordentoft from Denmark in 1912.[171,172] This device had many limitations and was apparently not developed further with Nordentoft instead turning his attention to research in radiotherapy.[171] The further development of the "arthroscope", began in 1918 with Kenji Takagi in Japan attempting, unsuccessfully, to use a cystoscope to visualise joints in a cadaver.[173] In 1920, Takagi developed a basic arthroscope but found it was still too large for routine use.[173] In 1921, Eugen Bircher, in Switzerland, reported on the use of diagnostic knee arthroscopy in a series of 60 patients, although his use of a laparo-thoracoscope had many limitations and he abandoned the procedure in favour of arthrography.[172] Soon after, in 1925, Philip Kreuscher, from Chicago, described the arthroscopic

visualisation of meniscal tears in the knee using a similar device, and advocated the use of diagnostic arthroscopy to detect the presence of meniscal tears in patients with non-specific symptoms of the knee.[174] Soon after, however, like his contemporaries, he abandoned the procedure in favour of arthrography.[172]

In 1931, it was Takagi who designed a new arthroscopic device, with a 3.5mm diameter and he began using this routinely in patients with knee and hip disease, filling the joint with either fluid or gas.[173] He presented his findings at several orthopaedic meetings in 1932.[173] At the same time, Michael Burman in New York had a 4mm arthroscopy designed for him and published his findings using the device in cadaveric knee, hip, shoulder, wrist, ankle, and elbow joints.[172,175] In 1937, an arthroscope with adjustable optical focus was developed.[173]

Following the second world war, Masaki Watanabe in Japan continued the work of his former professor, Kenji Takagi.[172] From 1954 he developed several new arthroscope designs and was the first to present colour images of the inside of the knee joint using his "number 14" arthroscope in 1957.[172,176] In 1958, he developed the Watanabe number 21 arthroscope, which had a diameter of 6mm with a wide field of vision and adjustable focus – this became the first arthroscope to enter wider production and use worldwide, including the United States, Canada, England and France.[172,176] In 1962, Watanabe performed the first arthroscopic partial meniscectomy in a seventeen year old patient, reporting that the boy returned to playing basketball six weeks after surgery.[172,176] The number 21 was the last arthroscope design to use an incandescent light source and Watanabe's number 22 arthroscope, introduced in 1967, used a fibre-optic style light source which is the basis of modern arthroscopic illumination with the worldwide adoption of orthopaedic arthroscopy beginning in the 1970s.[172,176]

1.8.2 Rates of arthroscopic knee surgery

Historically, both osteoarthritis and meniscal pathology have been treated arthroscopically.[177] Knee arthroscopy is reportedly the most commonly performed orthopaedic surgical procedure worldwide and

approximately two million cases are performed each year, with combined estimated healthcare costs of several billion US dollars.[157,178] Between 1997 and 2008, multiple clinical trials were published reporting that joint washout for the treatment of advanced osteoarthritis was ineffective.[179–181] Subsequent epidemiological data suggested that rates of knee washout declined in response to the publication of this evidence.[182,183] For other types of knee arthroscopy, including arthroscopic partial meniscectomy, simple procedure count data in England suggested a rapid rise in the rate of intervention until at least 2012.[184,185]

Variation in knee arthroscopy intervention rates has been reported internationally. For example, in 2012, rates of arthroscopic meniscal surgery in Finland were approximately 125 per 100,000, yet the same study found the rate in Sweden was less than 50 per 100,000.[186] In the United States, in 2006, a knee arthroscopy intervention rate of approximately 400 per 100,000 population was reported.[187] In 2012, the rate of knee arthroscopy in Scotland was around 120 per 100,000 in patients over the age of 60 and this rate remained relatively stable between 2000 and 2013.[188] In Canada, a rate of approximately 180 per 100,000 was reported in 2004.[189] In Australia, a relatively stable rate of knee arthroscopy was reported from 2001 to 2008 at just under 350 per 100,000.[190] Comparison of data reported by studies from other countries is, however, limited by differing reporting years, variation in the procedures included, and the inclusion or exclusion of patients treated in private hospitals. Within country regional variation has also been reported previously for a number of procedures such as shoulder arthroscopy.[186–191]

1.8.3 Clinical effectiveness of arthroscopic partial meniscectomy

Although the rate of arthroscopic knee washout being performed for osteoarthritis has decreased over the last twenty-years, there has been an overall increase in the rate of APM being performed in patients (with or without osteoarthritis) over the same period until at least 2012.[164,182,192–195] A number of trials were published between 2007 and 2016 evaluating the effectiveness of arthroscopic partial meniscectomy (APM) in the treatment of meniscal tears.[196–203] Subsequent systematic reviews of the

trial evidence have been published but have had a number of limitations with respect to evaluating the effectiveness of APM specifically. For example, reviews have evaluated 'undifferentiated' arthroscopy (combining lavage, debridement, and APM trials) for the degenerative knee.[204–207] The findings of these reviews support the view that this 'undifferentiated' approach to treatment is outdated and not recommended.[208,209] Two reviews have been performed including only APM trials, but these reviews did not stratify patients by their clinical or radiological findings and also combined trials of APM versus a surgical comparator (placebo or sham surgery) with trials versus non-surgical comparators (physiotherapy or pharmacological), limiting their interpretability in clinical practice.[205,210]

Another limitation has been uncertain validity of PROMs in this population (see also section 1.5.4). No systematic review has been published evaluating the the quality of evidence for the PROMs that are available for patients with meniscal tears.[79,211] This is a barrier to the interpretation of previous research and to the design of future studies in these patients. The validity of the currently available PROMs has been unclear for this population.

The correct interpretation of the clinical effectiveness evidence for APM has, therefore, remained controversial.[177,178,220–223,212–219] Some groups have recommended against arthroscopy in "nearly all patients" with "degenerative knee disease" and suggest that further research is not required.[185] Given the heterogeneity of the population, however, others have highlighted the importance of patient selection criteria to achieve treatment success with APM, given that symptoms may be explained by an underlying degenerative process and not the meniscal tear.[104,208,223]

1.8.4 Risk of complications from undergoing arthroscopic partial meniscectomy

Estimates of the rate of complications that occur following arthroscopic knee surgery vary widely and previous studies have had a number of limitations.[207] Many studies analysed harms in a cohort of patients that included major procedures with combined open techniques, such as ligament reconstruction, alongside less invasive and purely arthroscopic procedures, such as APM. Studies have

also frequently been limited by small patient numbers or relied upon regional or insurance company databases which may underrepresent the true rate of complications. Several studies have focused only on venous thromboembolic complications or infection, and comparisons between studies is challenging due to population, age group, health system, insurance provider, database, data collection, coding, and methodological variation.

A meta-analysis of studies of adverse events following knee arthroscopy, published in 2015, reported summary estimates of the following complications: deep vein thrombosis in 0.413% (95% CI 0.178 to 0.960; 5 studies; 432,663 patients/procedures), pulmonary embolism in 0.145% (95% CI 0.059 to 0.354; 6 studies; 736,823 patients/procedures), venous thromboembolism (deep vein thrombosis or pulmonary embolism [PE]) in 0.568% (0.296 to 1.09; 6 studies; 571,793 patients/procedures), infection in 0.211% (0.080 to 0.556; 4 studies, 946,230 patients/procedures), and death in 0.096% (0.004 to 2.39; 2 studies; 106,967 patients/procedures).[207] Heterogeneity (I-square) in all these estimates exceeded 90% and the included studies had a number of limitations. As introduced above, studies had inconsistent inclusion criteria, often including complex arthroscopic procedures (such as ligament reconstruction) and reported for different outcomes, endpoints, and units of analysis (patient or procedure). There were also concerns about the completeness of insurance company database case capture (where applicable). Consequently, confidence intervals were wide, the range of complications reported incomplete, and the generalisability of the findings to patients undergoing the most commonly performed procedure, arthroscopic partial meniscectomy, in isolation, unknown. Performing an updated search of MEDLINE, Embase, CENTRAL and CINAHL on 08/02/18, following the published search strategy from this previous meta-analysis of harms, four subsequent studies of venous thromboembolism and one study of infection reported comparable rates to those of the previous meta-analysis.[224–228] One small cohort study reported myocardial infarction in 0.05% of patients within 30-days of knee arthroscopy.[229]

Recently, there has been increased scrutiny on the requirement for individualised patient consent.[63] Estimation of an individual's 'attributable' risk from undergoing a procedure, rather than the unadjusted

absolute risk, is crucial and previous studies have been unable to report this important information due to a lack of comparison to general population data.

1.8.5 Arthroscopic meniscal surgery guidelines

Meniscal treatment guidelines have been issued by surgical expert groups including the American Orthopaedic Society for Sports Medicine (AOSSM) and Arthroscopy Association of North America (AANA),[230] the European Society of Sports Traumatology, Knee Surgery and Arthroscopy (ESSKA),[209] and International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine (ISAKOS).[208] The guidelines have had limited impact in the UK for a number of reasons including a lack of standardised terminology to describe meniscal lesions, lack of clarity and rigour in development methods, and evidence synthesis limitations with the systematic review evidence often including heterogeneous patient populations. Similarly, one non-specialist group recently issued guidance for the management of all patients "with or without meniscal tears", "mechanical symptoms", or "mild to severe osteoarthritis" as a single population.[185]

In the UK, the National Institute for Health and Care Excellence (NICE) release guidelines on the treatment of a range of conditions. In the past, guidelines have been released that address the use of knee arthroscopy for osteoarthritis, but no guidelines currently exist for the management of meniscal lesions.[231]

Specifically for APM, there has been some apparent conflict when considering published treatment guidelines: on one side, the view that APM in the right patient is effective, and on the other, the view that APM in all patients with degenerative meniscal tears is ineffective.[185,208] Several specialist knee societies have highlighted that there are important patient factors to consider before a patient should undergo APM and that these were not reflected in the selection criteria of the randomised clinical trials.[208,209] The relevant terminology and classification of meniscal lesions has not, however, been agreed and, further, there has been no systematic review of the clinical effectiveness evidence with

stratification by these factors, meaning the level of evidence underpinning such recommendations has been unknown.

In light of the differing views, new emerging evidence and the impact of this clinical condition on such a large number of patients, there is a need to appraise the evidence for APM in the management of meniscal tears with specific emphasis on areas of uncertainty.[211]

2 SCOPE OF THESIS

2.1 Summary of Background

The meniscus is a fibrocartilaginous structure within the knee with a role in joint load distribution, stability, proprioception, lubrication and synovial nutrition.[1,45–47,54–56] Knee pain is common and amongst musculoskeletal symptoms it is second only to back pain in terms of prevalence.[137] The prevalence of meniscal lesions is strongly correlated with the presence of radiographic osteoarthritis and for this reason it can be challenging to distinguish patient symptoms that are attributable to a meniscal lesion. More than one third of people over the age of 50 without any radiographic evidence of osteoarthritis have meniscal pathology detectable on MRI imaging, rising to over 60% for individuals with osteoarthritis.[104]

Meniscal tears may be stable or unstable mechanically and may be symptomatic or asymptomatic.[104,109–111] When a meniscal lesion is considered to be the cause of symptoms, the treatment of choice has been arthroscopic partial meniscectomy (APM): keyhole surgery to excise the unstable meniscal tissue. APM has become one of the most commonly performed orthopaedic surgical procedures worldwide.[154,155] Heterogeneity in the clinical presentation of patients with meniscal lesions has, however, led to diagnostic difficulties when clinicians assess patients with knee pain that may or may not be associated with a meniscal lesion.[106,140–142] It is unclear whether certain types of meniscal lesion truly cause pain and symptoms. There is also uncertainty about whether excising meniscal tissue could increase the risk of progressive osteoarthritis by detrimentally affecting load distribution and contact pressures across the joint.[30,52,53]

Although there has been an increase in the rate of arthroscopic knee surgery being performed in England until at least 2012, more recent data has not been reported and there has been only limited stratification by procedure type, patient age, gender, and region of treatment.[184,185] Some recent clinical trial data has challenged routine use of knee arthroscopy for the treatment of meniscal lesions and it is unclear what

impact this has had on clinical practice. Contemporary data is required to understand current practice, any impact from the publication of new trial evidence, and the potential need for standardised treatment guidance to address any variation and inconsistency in the care pathway for this population.

Knee washout or debridement has previously been shown to be an ineffective treatment for patients with painful osteoarthritis and, more recently, some evidence suggests that arthroscopic partial meniscectomy in patients with osteoarthritis may also be ineffective in some patients.[179–181,204–207] One suggested marker of overuse of arthroscopy in patients with osteoarthritis is the rate that these patients subsequently undergo knee arthroplasty within one year.[189] This may suggest an individual underwent arthroscopic surgery on the background of already advanced osteoarthritis. The number of affected patients and regional variation in this undesirable outcome over time for patients undergoing arthroscopic partial meniscectomy is currently unknown and may be a key indicator of the need to improve and standardise treatment selection decisions for patients with meniscal lesions.

Although a number of clinical trials have investigated the clinical effectiveness of arthroscopic partial meniscectomy, the correct interpretation of the outcomes reported have been limited by: (1) uncertain validity of the patient-reported outcome measures collected for use in this population and (2) uncertain generalisability of the evidence (to different groups of patients with meniscal lesions).[204–207,221,223] There is a need for a systematic appraisal of the measurement properties and quality of the evidence supporting the validity of the available outcome measures. Then, there is a need to investigate the clinical evidence for benefit from APM in subgroups of patients with meniscal lesions: especially patients without coexistent osteoarthritis and those with other, specific, clinical and radiological findings that may be indicative of a symptomatic, unstable, meniscal lesion.

Any evaluation of the appropriateness of an intervention must consider not only the potential benefits but also the risks. Previous studies have attempted to investigate the short-term risk associated with undergoing knee arthroscopy but have had a number of limitations, such as small patient numbers, combining major and minor arthroscopic procedures in a single cohort, a narrow range of complications

evaluated, and inconsistent or limited data sources.[207] Furthermore, the true, attributable, risk from undergoing the procedure in comparison to patients in the general population is unknown and may be especially important for procedures where adverse events occur rarely. The balance of benefit and risk must be carefully considered in the context of shared-decision making. This information is crucial to the correct interpretation of the clinical effectiveness evidence by clinicians, patients, and health-policy officials, and to the development of new clinical guidance.

As part of the shared treatment decision making process, it is also important that patients understand their anticipated long-term outcome. Reoperation rates and rates of progressive osteoarthritis, especially requirement for subsequent knee arthroplasty, are examples of undesirable outcomes that may occur in the long-term after a meniscal injury and APM. Meniscal pathology and meniscal surgery are known to be associated with a change in joint contact pressures and the development of osteoarthritic changes.[30,52,53,195,207,209,213,232,233] The long-term risk of an individual undergoing knee arthroplasty in a knee after undergoing APM is, however, uncertain and how this risk may compare to the individual's other knee, or to risk in the general population without a history of APM, is not well understood.

To standardise treatment selection decisions, it is important that consistent terminology is used when describing the clinical and radiological features present in different patients.[80,81] This has not been possible for patients with meniscal lesions as there has been no agreement on the terminology to be used, nor the important symptoms, signs, and radiological findings in this population. As a result, the generalisability of the clinical trial evidence to different populations of patients with meniscal lesions has been challenged. There is a need for consensus in this area in order for the clinical evidence to be interpreted correctly and for treatment guidance to be applied consistently.

Considering all the evidence, there is a need for clear guidance on the appropriateness of arthroscopic partial meniscectomy in patients with meniscal lesions, stratified according to important associated clinical and radiological findings. No treatment appropriateness exercise has been performed for patients in this population, in part because this would require use of standardised terminology that has

not been available previously. An appropriateness exercise should also be informed by an understanding of the anticipated benefits and harms that may be associated with undergoing the intervention. With this new information, an evidence-based clinical treatment guideline could be developed utilising established consensus methods to improve treatment decisions and facilitate more consistent clinical practice. This process would also highlight areas of remaining uncertainty to ensure optimal future allocation of clinical and academic resources to further improve the management of these patients.

2.2 Thesis Scope

The scope of this thesis is the investigation of the role of arthroscopic partial meniscectomy in the management of patients with meniscal lesions of the knee, including which patient factors may have an impact on anticipated treatment outcomes. Broadly, this thesis aims to improve the management of this patient population, by: (1) assessing whether there is evidence of variation in the care pathway for patients with meniscal lesions in terms of the arthroscopic partial meniscectomy intervention rate and outcomes; (2) determining what evidence is available on the benefits of the procedure and how these benefits vary in association with patient factors such as type of meniscal lesion and osteoarthritis; (3) investigating the risk of adverse events and long-term rates of knee arthroplasty following arthroscopic partial meniscectomy; and (4) delivering new standardised terminology and evidence-based treatment guidance.

2.3 Thesis Aims

In summary, there are a number of uncertainties that must be addressed to improve the management of patients with meniscal lesions. The aim of this thesis is to explore and answer the following questions:

1. What is the APM intervention rate in England and how has this changed over time? To what extent is there regional and age-group variation in the intervention rate? With comparison to other types of arthroscopic knee surgery, how may the publication of clinical trial evidence and national guidelines have influenced practice?

2. Is there any evidence for overuse of APM in patients with osteoarthritis?

3. How reliable are patient-reported outcome measures in the population of patients with meniscal lesions?

4. According to current clinical trial evidence, how effective is APM for the treatment of meniscal lesions in patients stratified using clinical and radiological criteria?

5. What is the short-term risk of adverse events associated with undergoing APM?

6. In the longer-term, what is the risk of requiring a knee arthroplasty after APM in comparison to individuals in the general population without a history of APM, and the patient's other knee (with and without a history of APM)?

7. How should we describe and stratify patients with meniscal lesions? What clinical and radiological features may be important in determining candidacy for APM versus alternative treatments?

8. Considering the benefits, risks, and areas of remaining uncertainty, when may APM be considered "appropriate" in patients with meniscal lesions? When should APM be avoided?

2.4 Thesis Structure

Chapter 1 is a literature review summarising the background to the condition and treatment options. This chapter contains a summary of the development and anatomy of the meniscus and the existing definitions and classification of osteoarthritis and meniscal pathology. The role of care pathways in clinical care is introduced in general terms and specifically for meniscal surgery. The available treatment options for meniscal lesions are reviewed including the development of knee arthroscopy and

emergence of arthroscopic partial meniscectomy as the treatment of choice. Existing data on the effectiveness of arthroscopic partial meniscectomy and the risks associated with knee arthroscopy are reviewed. The steps involved in developing new clinical guidelines are discussed and the evidence required to inform this process described.

Chapter 3 reports the rate of arthroscopic knee surgery being performed in England including trends in practice over twenty-years. Underlying age-group and regional variation is reported. Current practice in arthroscopic partial meniscectomy is considered in the context of the changes in practice of other types of arthroscopic knee surgery and the publication of clinical trial evidence, systematic reviews, and national guidelines over the same period of time.

Chapter 4 reports the proportion of patients undergoing knee arthroplasty within one-year or two-years of arthroscopic partial meniscectomy and considers how this many reflect suboptimal treatment selection and overuse, especially in the context of regional variation in this undesirable outcome.

Chapter 5 documents a systematic review of patient-reported outcome measures that have been tested in a population of patients with meniscal lesions. The measurement properties of each outcome measure are presented, and the quality of the supporting evidence evaluated.

Chapter 6 reports findings of a systematic review of the benefits and harms of arthroscopic partial meniscectomy in comparison to alternative treatments as reported in randomised controlled trials. Previously unpublished sub-group data provided by several trial authors is analysed for three patient groups: (1) all patients (including those with osteoarthritis), (2) patients without osteoarthritis, and (3) patients without osteoarthritis and with a symptomatic unstable meniscal lesion.

Chapter 7 presents the findings of an analysis of adverse events occurring within 90 days of arthroscopic partial meniscectomy, using data from a national cohort of almost 700,000 procedures. The risk of complications is stratified by patient factors including age, gender, comorbidity and, where possible,

compared with general population risk data (for myocardial infarction, stroke, pulmonary embolism, infection, death).

Chapter 8 reports the long-term rate of knee arthroplasty following arthroscopic partial meniscectomy, stratified by patient demographic factors and compared to the patient's other knee (with and without a history of APM) and the risk in the general population (without a history of APM).

Chapter 9 describes work to deliver standardised terminology using consensus methods for the description and classification of clinical and radiological findings that may be present in patients with meniscal lesions.

Chapter 10 reports the findings of a surgical treatment appropriateness exercise that integrated all the evidence presented in the preceding chapters regarding the potential benefits, risks, and remaining uncertainties surrounding the treatment of patients with meniscal lesions, stratified using the standardised terminology reported in Chapter 9. The output of collaborative work with the British Association for Surgery of the Knee (BASK) in developing new national treatment guidance for use in clinical practice is reported.

Chapter 11, the concluding chapter, summarises the contribution of this thesis to the whole body of evidence that informs management decisions for patients with meniscal lesions. The potential clinical impact of the work is considered and further work that is ongoing, planned or recommended is discussed in this chapter.

3 TRENDS AND VARIATION IN KNEE ARTHROSCOPY INTERVENTION RATES IN ENGLAND*

3.1 Introduction

As introduced in Chapter 1 (section 1.8.2), rates of knee arthroscopy were previously reported to be broadly increasing in England until at least 2012. These data have been limited, however, by a lack of stratification by patient factors (including age) and procedure type. The extent of regional variation in the rate of APM has not been reported, and the impact of the publication of clinical trials and other evidence on practice was unknown. More recent intervention rate data is required to understand current practice and direct future practice. Should there be an increasing number of patients undergoing APM annually and/or any regional or age-group variation in practice this may indicate issues with the standardisation of the care pathway for patients with meniscal lesions of the knee.

3.2 Aims

The purpose of the work reported in this chapter was to determine the trends in arthroscopic knee surgery intervention rates over twenty-years until 31st March 2017 with particular focus on APM. Age and sex variation in the rate of surgery was determined and interpreted in the context of the publication of relevant clinical trial evidence.

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* *The content of this chapter has been published, in part, as: Abram SGF, Judge A, Beard DJ, Wilson HA, Price AJ. Temporal trends and regional variation in the rate of arthroscopic knee surgery in England: analysis of over 1.7 million procedures between 1997 and 2017. Has practice changed in response to new evidence? Br J Sports Med 2018; DOI:10.1136/bjsports-2018-099414.*

3.3 Methods

3.3.1 Data Source

National Hospital Episode Statistics (HES) data, which contains a record of all patient attendances at NHS hospitals in England, was obtained from NHS Digital (application DARS-NIC-68703).[234] HES includes episodes of care delivered in treatment centres (including those in the independent sectors) funded by the NHS, episodes of care in England where patients are resident outside of England, and privately funded patients treated within NHS England hospitals. The data is submitted by hospital trusts for financial remuneration for treatment delivered, including surgical procedures. HES includes codes for each hospital treatment episode including patient demographics, region of patient residence and hospital treatment, diagnoses (including comorbid conditions), procedures, area deprivation, rurality, and patient ethnicity.

3.3.2 Procedures

All HES records between 1 April 1997 and 31 March 2017 were extracted for patients undergoing: (1) arthroscopic partial meniscectomy, (2) diagnostic arthroscopy, (3) arthroscopic washout, and (4) arthroscopic chondroplasty. Episodes were identified from the Classification of Surgical Operations and Procedures (OPCS-4) codes in the procedure fields within the HES data (see Appendix A for OPCS-4 code list).[235] Simultaneous procedures (ipsilateral or contralateral) were included.

To investigate geographic variation in practice, the Clinical Commissioning Group (CCG) responsible for the episode of treatment was identified. In England, CCGs were created as part of the Health and Social Care Act 2012 and replaced Primary Care Trusts in April 2013.[236] CCG regions were selected for this analysis as they are the statutory bodies responsible for the planning and commissioning of all health care services for their local area. Each CCG may include one or more hospitals delivering care for the regional population and, as of April 2017, there were 207 CCGs in England with each being responsible for an average population of approximately 250,000 (range 70,000 to 900,000).[236,237] Evaluating intervention rates by CCG is therefore a useful reflection of the care pathway and service

configuration in comparison to larger geographic regions or individual hospitals or clinician level data. Population data by age, gender and year within each CCG was obtained from the Office for National Statistics (ONS) and linked with the HES data for analysis.

Statistical analysis

Stata v15.1 (StataCorp, College Station, Texas, USA) was used to perform all analysis. Descriptive statistics were used to summarise the age and sex of patients undergoing each type of procedure. Population data from the ONS was used to calculate age and sex standardised rates of intervention by year of treatment, following the methodology of the Association of Public Health Observatories (APHO).[238] Annual trends were reported at procedure level (not mutually exclusive: including simultaneous ipsilateral or contralateral procedures). Overall trends in the number of hospital care episodes (patient admissions) were determined. In accordance with ONS and NHS Digital guidance, rates where the number of events was less than six were suppressed.[239] The Geographic Information System, QGIS v2.99 (qgis.org), was used to graphically summarise age and sex standardised rates for each CCG, per year. Standardised CCG level data was determined for all episodes and mapped using the April 2017 boundaries for consistency over time.[240]

3.4 Results

Between 1 April 1997 and 31 March 2017, a total of 1,088,872 arthroscopic partial meniscectomies, 326,600 diagnostic knee arthroscopies, 308,618 washout procedures, and 252,885 chondroplasties were performed. This was a total of 1,976,975 procedures (1,759,467 hospital admissions) in 1,447,142 patients. A summary of the patient demographics for each procedure is shown in Table 3.1.

Table 3.1: Demographics of patients by procedure type

	Number of procedures	**Number of patients**	**Females**	**Mean age (SD)**
APM	1,088,872	938,612	425,126 (45.3%)	48.7 (15.1)
Diagnostic	326,600	305,823	138,210 (45.2%)	43.1 (17.1)
Washout	308,618	286,127	122,516 (42.8%)	50.4 (17.5)
Chondroplasty	252,885	233,594	107,456 (46.0%)	49.9 (14.1)

National trends

Figure 3.1 summarises the trends in the age-sex standardised rate of surgery per 100,000 population for each type of arthroscopic procedure. Overall, the number of procedures increased 22% over this time period from 151/100,000 (95% confidence interval [CI] 150 to 152) in 1997-98 to 184/100,000 (95% CI 183 to 185) in 2016/17, and the number of hospital admissions for knee arthroscopy increased 9.2% over this period from 137/100,000 (95% CI 135 to 138) to 149/100,000 (95% CI 148 to 150).

Arthroscopic partial meniscectomy (APM)

The rate of APM increased from a low of 51/100,000 population (95% CI 51 to 52) in 1997-98 to 92/100,000 (95% CI 91 to 93) in 2006-7, before increasing rapidly then plateauing between 2010 and 2015, with a peak at 149/100,000 (95% CI 148 to 150) in 2013-14 (Figure 3.1). Rates then declined to 120/100,000 (95% CI 119 to 121) in 2016-17. Figure 3.2 summarises the trend in the rate of APM surgery over time by age group. The greatest increase in the rate of surgery was seen in the 40-59 and 60-79 age groups between 1997-98 and 2013-14. This trend reversed after 2013-14 and a decline in the rate of APM in these age groups has been observed to 2016-17.

Arthroscopic knee washout, diagnostic arthroscopy

Rates of arthroscopic knee washout and diagnostic arthroscopy declined from 50/100,000 (95% CI 49 to 50) and 47/100,000 (95% CI 46 to 47) respectively in 1997-98, to 4.8/100,000 (95% CI 4.6 to 5.0)

and 8.1/100,000 (95% CI 7.9 to 8.3) respectively in 2016-17 (Figure 3.1). Age-group trends are available in the supplementary appendix (Appendix B).

Arthroscopic chondroplasty

Rates of chondroplasty increased steadily from a low of 3.2/100,000 (95% CI 3.0 to 3.3) in 1997-98 to 51/100,000 (95% CI 51 to 52) in 2016-17 (Figure 3.1). Age-group trends are available in the supplementary appendix (Appendix B).

Variation by clinical commissioning group (CCG)

Geographic variation by CCG in the age-sex standardised rate of APM over time is summarised in Figure 3.3. There was a striking, near 10-fold, variation in the rate of surgery between CCGs for APM and all the other procedures evaluated (Figure 3.4; see also Appendix B). In contrast to the overall declining national trend in APM, many CCGs performed surgery at an increasing rate or unchanged rate in recent years. Between 2015-16 and 2016-17, the rate of APM performed increased by at least 5% in twenty-five percent (52/207) of CCGs (Table 3.2).

Table 3.2: Variability in the rate of change in APM per 100,000 population (CCG) by year

Years	National % change in intervention rate	Variability in intervention rate changes (Number of CCGs)					
		Increase > 5%		+/- 5%		Decrease > 5%	
		n CCGs	%	n CCGs	%	n CCGs	%
2002-03 to 2003-04	6.3	118	57%	30	14%	59	29%
2003-04 to 2004-05	5.1	109	53%	29	14%	69	33%
2004-05 to 2005-06	2.2	100	48%	30	14%	77	37%
2005-06 to 2006-07	7.2	111	54%	29	14%	67	32%
2006-07 to 2007-08	21.1	153	74%	21	10%	33	16%
2007-08 to 2008-09	12.8	129	62%	31	15%	47	23%
2008-09 to 2009-10	7.4	124	60%	25	12%	58	28%
2009-10 to 2010-11	14.6	137	66%	33	16%	37	18%
2010-11 to 2011-12	- 0.9	77	37%	46	22%	84	41%
2011-12 to 2012-13	- 1.5	79	38%	44	21%	84	41%
2012-13 to 2013-14	3.2	94	45%	50	24%	63	30%
2013-14 to 2014-15	- 4.6	71	34%	54	26%	82	40%
2014-15 to 2015-16	- 10.1	59	29%	37	18%	111	54%
2015-16 to 2016-17	- 14.2	52	25%	35	17%	120	58%

Note: This table shows the number and proportion of Clinical Commissioning Groups (CCGs) increasing or decreasing their population standardised APM intervention rate between years, with comparison to the percentage change in intervention rate nationally.

In 2016-17, twenty-two CCGs (10.6%) performed more than double the national average rate of APM, whilst in the same year, fifteen CCGs (7.2%) performed less than 10% of the national average rate (Figure 3.4). For chondroplasty, twelve CCGs (5.8%) performed less than 10% of the national average, whereas thirty CCGs (14.5%) performed at least double the national average rate. For washout/lavage sixty-two CCGs (30.0%) performed less than 10% of the national average, whereas thirty-two CCGs (15.5%) performed at least double the national average rate. For diagnostic arthroscopy, forty-two CCGs (20.3%) performed less than 10% of the national average, whereas thirty-four CCGs (16.4%) performed at least double the national average rate.

Figure 3.1: Age-gender standardised rates of arthroscopic procedures per 100,000 population

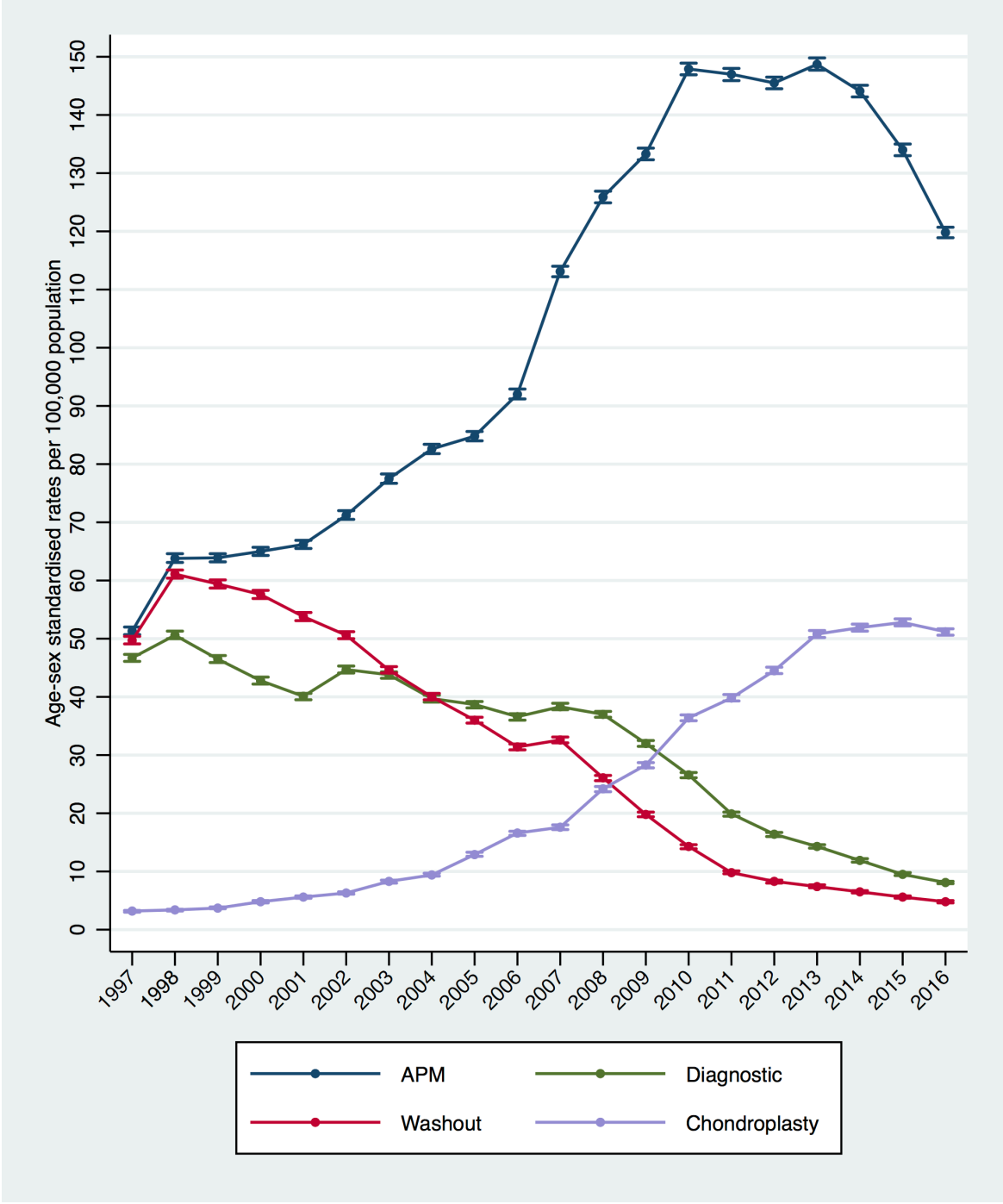


Figure 3.2: Gender standardised rate of APM per 100,000 population by age group and year

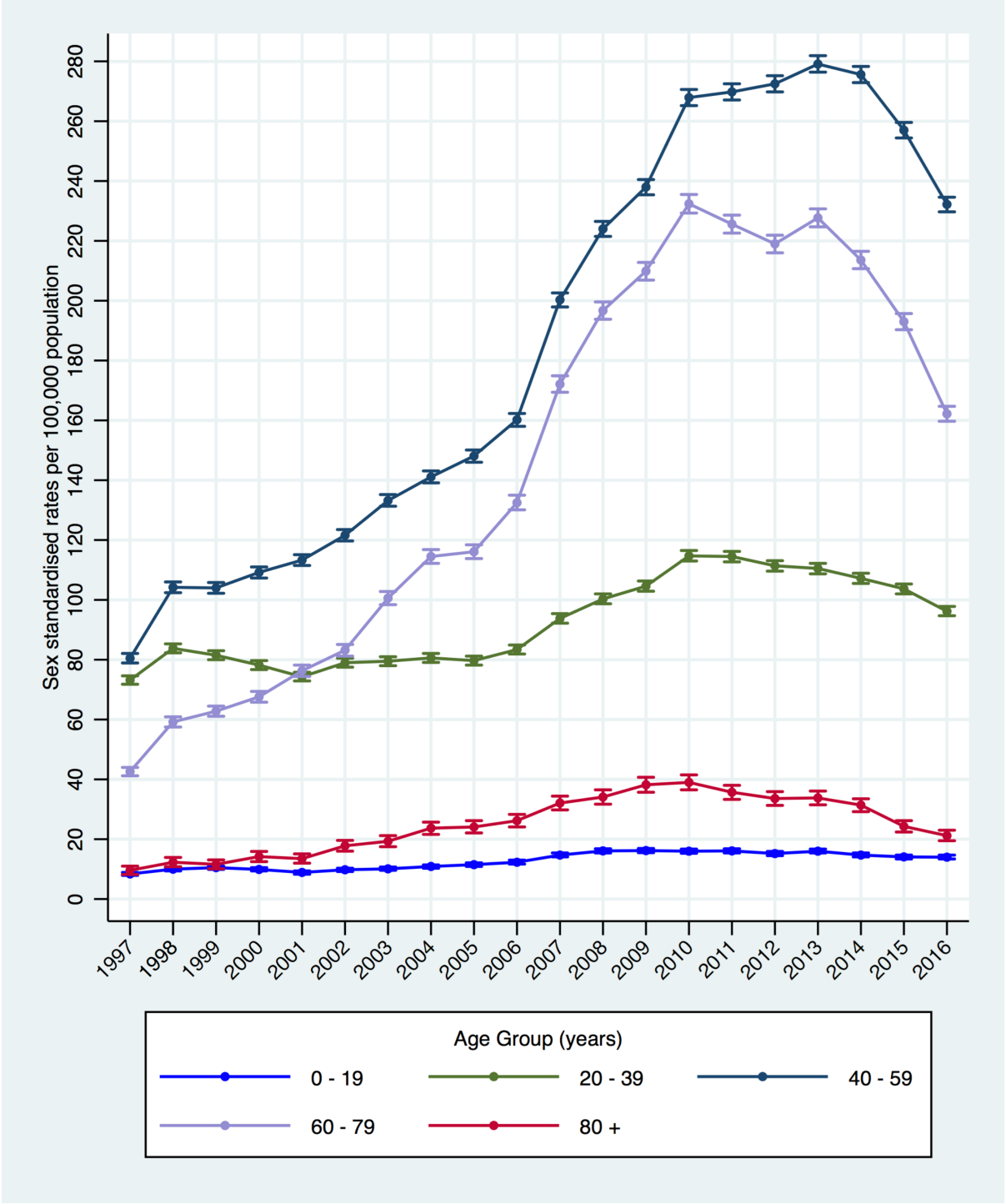


Figure 3.3: Regional variation in age-gender standardised rate of arthroscopic partial meniscectomy per 100,000 population by NHS Clinical Commissioning Group

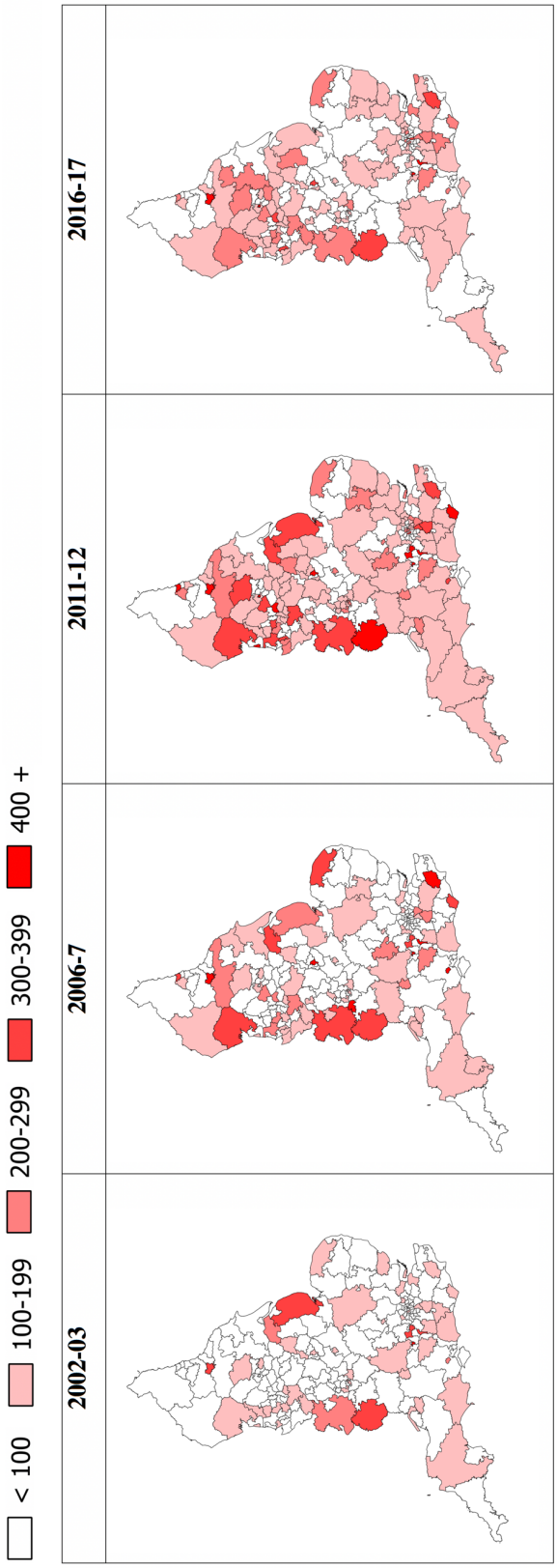
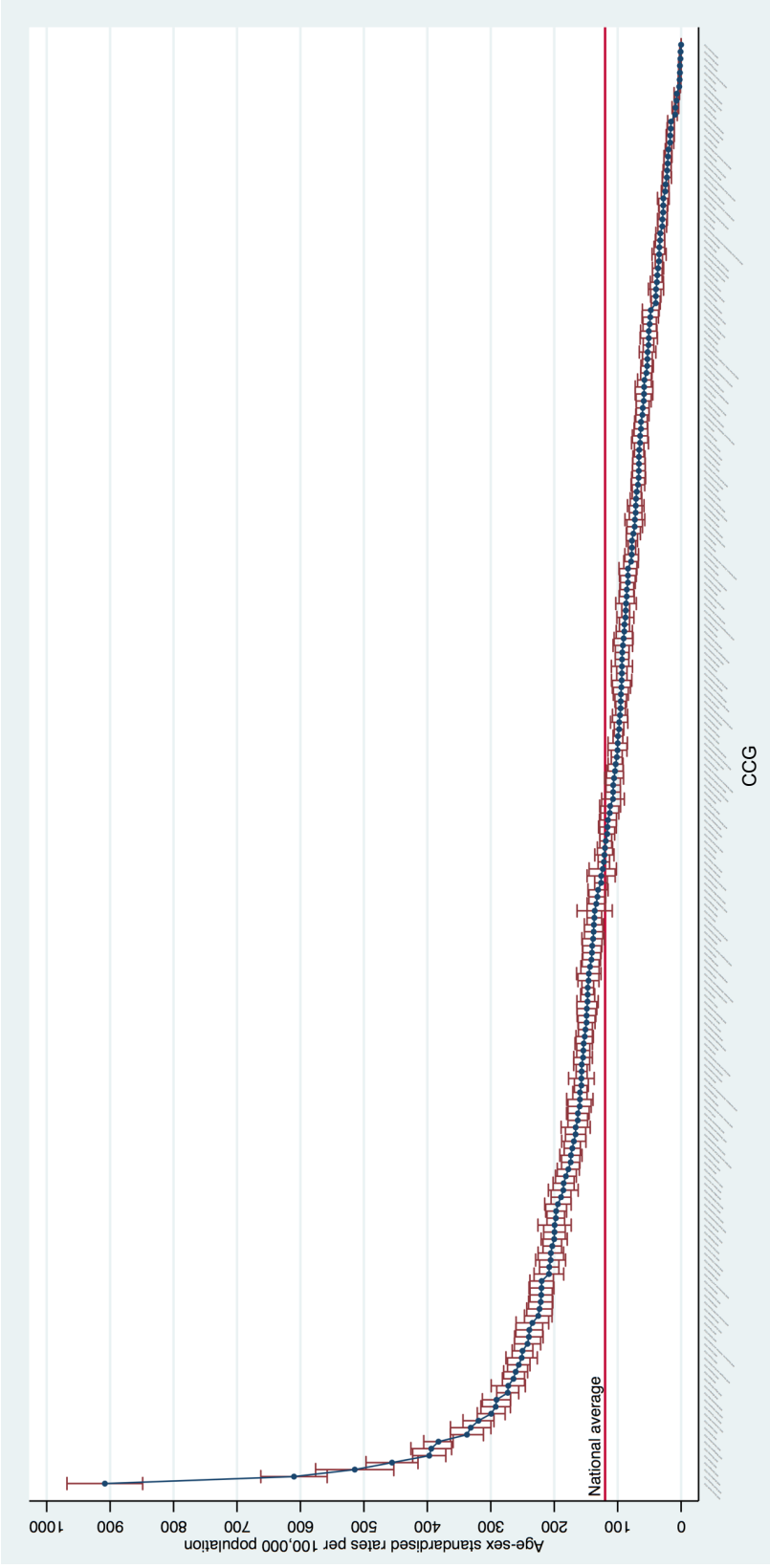


Figure 3.4: Plot summarising the variation in the rate of APM/100,000 population by NHS Clinical Commissioning Group in 2016-17



Note: x-axis CCG labels are not intended to be readable: for illustration of data points only.

3.5 Discussion

3.5.1 Principal findings

Over the last 20 years, and likely in response to new evidence, rates of arthroscopic knee washout and diagnostic arthroscopy have declined by up to 90%. APM rates increased about 130% overall but there was some decline in the APM intervention rate in the most recent years between 2014 and 2017. Substantial regional and age–group variation in practice was detected. In 2016/2017, between 11% (22/207) and 16% (34/207) of CCGs performed at least double the national average rate of each procedure. The appropriate population intervention rate for these procedures remains unknown and therefore it is unclear whether the differences in intervention rate observed between regions reflect regional care under- or over-provision. Nevertheless, these findings suggest there is a need for evidence-based guidance at a national level, with the aim of standardising treatment selection.

3.5.2 Comparison with other studies

3.5.2.1 National trends

The rate of APM surgery increased by 190% from 51 per 100,000 in 1997-98 to 149 per 100,000 in 2013-14, before declining to 120 per 100,000 in 2016-17. In contrast, a consistent decline in the rate of arthroscopic washout procedures was observed – in line with published clinical trial evidence challenging the efficacy of arthroscopic washout and debridement for osteoarthritis between 1993 and 2008, and National Institute for Health and Care Excellence (NICE) guidance published in 2007 (Table 3.3).[179,180,231,241] A similar decline in the rate of diagnostic knee arthroscopy was noted over the twenty-year study period. This may reflect increased adoption of magnetic resonance imaging (MRI) as the diagnostic modality of choice for the knee.[143,144] Trends in meniscal repair were not reported in this chapter but are reported elsewhere using this same dataset and twenty-year study period.[242] In 2016-17, in England, the age-sex standardised rate of meniscal repair had risen to just 7.3/100,000 population and therefore increased use of meniscal repair cannot fully explain the recent fall in APM intervention rate.[242]

Rates of chondroplasty procedures including abrasion and radiofrequency chondroplasty have increased steadily by a total of 1500% from 3 per 100,000 in 1997-98 to 51 per 100,000 in 2016-17. NICE guidance issued in May 2014 was cautiously supportive of radiofrequency chondroplasty for discrete chondral defects of the knee, based on clinical trials comparing radiofrequency chondroplasty with mechanical debridement (Table 3.3).[243–246] The increase in the rate of chondroplasty has, however, occurred in the absence of high-quality controlled trials comparing the intervention to either a non-operative or placebo surgical comparator. Patient selection criteria are unclear, and the procedure has not been evaluated for treatment of patients with non-discrete lesions. More evidence is required to determine the efficacy of this procedure and should be a priority for further research.

For APM, a large increase in the rate of surgery was noted in older age groups, 40-59 and 60-79, followed by a partial decline. Eight randomised controlled clinical trials of APM were published between 2007 and 2016.[196–203] The decline was particularly evident since the publication of five of the eight trials in 2012-2013. These trials challenged the efficacy of the procedure, predominantly in older patients with degenerative knee disease; this study demonstrates some change in practice coincident with this evidence.

Table 3.3: Evidence and guidelines by arthroscopic procedure type

	1997/98	1999/00	2001/02	2003/04	2005/06	2007/08	2009/10	2011/12	2013/14	2015/16
Lavage/Washout		2 RCT	2 RCT	2 RCT		1 RCT 1 NG	2 SR		1 NG	1 SR
APM						1 RCT		1 RCT	5 RCT 1 SR	1 RCT 2 SR
Chondroplasty			2 RCT		1 RCT	1 RCT	1 RCT		1 NG	1 SR

Note: See Appendix C for table reference list. RCT = randomized controlled clinical trial; SR = systematic review; NG = NICE guideline (National Institute for Health and Care Excellence)

3.5.2.2 Variation by clinical commissioning group (CCG)

Although, there has been an overall decrease in the number of knee arthroscopy procedures performed in England in recent years, these findings show that there is considerable variation in this trend across CCGs. On average, 14% of CCGs were performing at least double the national average rate of these procedures in 2016-17. Factors that may underlie such regional variation have previously been discussed (see section 1.5.3).[67] CCGs with considerably higher rates of APM may have a greater number of specialist surgeons with greater belief in the efficacy of the procedure, greater availability of hospital resources such as appropriate day case theatre time, or the variation may reflect patient treatment choices – both regarding surgery versus alternative treatment options and also the ability of patients to choose their treating hospital.

Perhaps the greatest challenge to the interpretation of these findings is that the 'appropriate' intervention rate for the population is unknown. The number of patients presenting annually meeting the clinical and radiological criteria representing surgical 'candidacy' is unknown. Further work is required in this area, considering the indications applied, patient preferences, an evaluation of risks, and an assessment of the associated rates of undesirable outcomes such as subsequent knee arthroplasty (see Chapter 4).

3.5.3 Strengths and limitations

This study was performed using the most comprehensive and complete hospital episode dataset for England. All hospital episodes of NHS patients (including those treated in the independent sector) over a twenty-year period were included. The population intervention rates reported in this study will, however, be an underestimate of the true population rate as private patient data are not available unless these patients were treated in NHS hospitals. Although the proportion of arthroscopic procedures performed in the private sector over time is unknown, national data does indicate that private healthcare expenditure as a proportion of total healthcare expenditure has remained relatively stable.[247] For example, between 2005 and 2015, private expenditure increased just 1% from 17% of total expenditure to 18%.[247]

A further potential limitation is the reliance on accurate data coding. No direct validation of the codes used in this study (Appendix A) was possible, however these are commonly performed procedures that are familiar to NHS coding departments. Surgical procedure codes such as those analysed are directly linked to hospital remuneration and this provides a strong incentive for hospitals to accurately record this information. It remains possible, however, that some of the apparent change in the number of procedures being performed may reflect a change in coding rather than a real change in practice. For example, hospital coding may incorrectly interpret health record data at the point of coding, or surgical record keeping, and procedure terminology, could change over time. This is a potential limitation of all large health database studies as direct validation of such a large number of procedures at a national level is not possible. Regional validation is also generally not feasible for many reasons: care may be delivered on several sites per CCG with different health records and coding departments, the process of identifying a sample for testing may often rely again on local coding, difficulties in the selection of the appropriate 'gold standard' for comparison (treatment documentation versus procedure performed), and assessor bias, especially where the assessor may have a clinical rather than procedural coding background. Nevertheless, the findings are important, in the context of the number of patients affected and the direct linkage between the coding records and financial costs of reimbursement to the health service.

Geographic variation data was available from 2002 and configured to the CCG boundaries as on 1st April 2017 for consistency over time. In interpreting these data, it should be noted that CCGs only replaced the previous Primary Care Trusts in April 2013 and not all CCG regions include a hospital that performs arthroscopic surgery. The regional rates of surgery are adjusted by the age and sex of the regional population, but patient migration and other geographic factors may underlie the reported variation. The purpose of this study was not, however, to determine the cause of variation but simply to report and discuss this variation and the associated trends in practice over time.

3.5.4 Conclusion

The change in surgical practice reported in this chapter may represent a response, in part, to the publication of clinical trial evidence and guidelines, particularly applicable to the practice of knee washout and APM. There remains wide geographic variation in practice and, for all types of arthroscopic knee surgery, the 'appropriate' population intervention rate that maximises the clinical and cost-effectiveness of these procedures is still unknown. The findings do suggest, however, that there is a need for standardised treatment guidance, informed by the latest applicable evidence. The aim of such work would be to support consistent treatment selection, reduce regional variation, and to enable feedback and comparison of outcomes over time to improve the care pathway.

4 EARLY CONVERSION TO KNEE ARTHROPLASTY FOLLOWING ARTHROSCOPIC PARTIAL MENISCECTOMY[†]

4.1 Introduction

Chapter 3 indicates that although there has been some decline in the rate of APM since 2013, the rate of surgery is still considerably higher than in prior years. APM is one of the most commonly performed types of orthopaedic surgery, worldwide.[157,178,195] As stated, however, the appropriate rate of intervention is currently unknown. Signals for surgical treatment overuse in retrospective data sets are not straightforward or clear. One potential marker of overuse of arthroscopy is the proportion of patients undergoing knee arthroplasty within one year of undergoing arthroscopy. This would suggest that the arthroscopy may have been performed in a patient with already advanced osteoarthritis.[189]

As discussed in the Background (section 1.8.3), knee arthroscopy is rarely appropriate in patients with advanced osteoarthritis (historically, these patients were treated with knee washout and debridement) and the identification of such patients who have undergone arthroscopy with advanced osteoarthritis could indicate overuse. One explanation in the past was that diagnostic arthroscopy was relatively common (Chapter 3), perhaps in circumstances where radiographic imaging findings were equivocal, and some of these patients will have been found to have advanced osteoarthritis and then undergo arthroplasty. With increased use of MRI, however, diagnostic arthroscopy is now rare (Chapter 3). In younger patients, arthroscopy, including APM, could rarely be performed to treat mechanical symptoms despite osteoarthritis, as an agreed approach to delay undergoing arthroplasty – given the lifetime risk of revision surgery in younger patients.[74] An investigation of early arthroplasty rates that focuses on

[†] *The content of this chapter has been published, in part, as: Abram SGF, Judge A, Beard DJ, Price AJ. Rates of knee arthroplasty within one-year of undergoing arthroscopic partial meniscectomy in England: temporal trends, regional and age-group variation in conversion rates. Osteoarthritis and Cartilage. 2019; DOI:10.1016/j.joca.2019.03.009.*

older patients and a therapeutic procedure such as APM, however, is most likely to identify possible overuse (or inappropriate treatment) in the care pathway of this population. This line of investigation has not been conducted previously for APM or using the latest national data for England.

4.2 Aims

The purpose of the work reported in this chapter was to investigate the proportion of patients undergoing knee arthroplasty within one-year or two-years of APM in England between 1997/98 and 2016/17. Specific focus is given to patients undergoing APM over the age of sixty-years who may be at greater risk of osteoarthritis and subsequent knee arthroplasty and, as introduced above (section 4.1), are much less likely to have an appropriate indication for arthroscopy in the presence of advanced osteoarthritis. Patient-specific prognostic factors associated with this undesirable outcome are investigated and trends and regional variation in practice analysed and discussed.

4.3 Methods

4.3.1 Data source

National Hospital Episode Statistics (HES) data, which contains a record of all patient attendances at NHS hospitals in England, was obtained from NHS Digital (application DARS-NIC-68703). See section 3.3.1 for further information on this data source.

4.3.2 Participants

All patients undergoing APM between 1 April 1997 and 31 March 2017 were identified. Patients undergoing concurrent intra-articular ligament reconstruction were excluded. Diagnostic arthroscopies were also excluded (see section 4.1), as were patients documented as undergoing knee arthroplasty on the same day (or before) an APM as probable cases of miscoding. For patients undergoing multiple APMs, the 'index' APM procedure for analysis was defined as the latest APM. Episodes were identified from the Classification of Surgical Operations and Procedures (OPCS-4) codes in the procedure fields within the HES data (see Appendix A for OPCS code list).[235] All prior and subsequent hospital episodes

were identified for each of these patients and any subsequent knee arthroplasty (total or partial) in the same knee (using the OPCS-4 laterality codes) was identified.

4.3.3 Outcomes

The primary outcome analysed was arthroplasty (partial or total, in the same knee) within 1 year or 2 years of the index APM. Secondary outcomes investigated were variation in the proportion of APM patients undergoing subsequent knee arthroplasty over time, by age-group and other patient factors, and NHS Clinical Commissioning Group (CCG) region where the APM was performed.

4.3.4 Statistical analysis

Stata v15.1 (StataCorp, College Station, Texas, USA) was used to perform all statistical analysis. In accordance with ONS and NHS Digital guidance, rates where the number of events was less than six were suppressed.[239] Cases with date errors or missing the side of intervention were excluded. The percentage of the total number of APMs in each group undergoing arthroplasty was analysed and reported with descriptive statistics (proportion and corresponding 95% confidence interval). Trends in this outcome were analysed over time. Sensitivity analysis was performed analysing the 1-year outcome by age group for first APM by patient excluding prior procedures, in comparison to the primary results for the most recent APM per patient (no material difference in results).

Logistic regression modelling was used to first determine the unadjusted odds of undergoing knee arthroplasty (within 1-year or 2-years) following APM by age, sex, year of treatment, modified Charlson comorbidity index (Summary Hospital-level Mortality Indicator Specification; derived with maximum 5-year diagnosis code lookback period),[248–250] index of multiple deprivation (quintile derived from regional factors in England including average income, employment, education, housing, and crime; 1=least deprived area, 5=most deprived), rurality, and ethnicity. These variables were then included together in the model to calculate adjusted odds ratios.

The CCG of treatment (for the index APM) recorded in HES was used to determine the overall rate of arthroplasty following APM by the CCG delivering the APM. A Geographic Information System, QGIS v3.0 (qgis.org), was used to graphically summarise these rates on a map of England, using the April 2017 CCG boundaries.[240]

4.4 Results

Between 1 April 1997 and 31 March 2017, a total of 938,612 patients underwent at least one APM, of which 883,930 patients were eligible for inclusion (Figure 4.1). Of these, 806,195 patients had at least one-year of follow up (APM cases to 31 March 2016) in the cohort and 746,630 with at least two-years (APM cases to 31 March 2015) (Figure 4.1). The demographics of the cohort are summarised in Table 4.1; APM was most frequently performed in patients aged 40-59 years (47.81%) and male patients (63.33%).

The rate of arthroplasty by age-group, sex, Charlson comorbidity index, deprivation, rurality and ethnicity is summarised in Table 4.1 and Table 4.2. For all patients (aged 20 years or older), 4.17% (33,637/806,195; 95% confidence interval [CI] 4.13 to 4.22) underwent arthroplasty within 1 year of their APM (1997-2016) and 7.05% (52,604/746,630; 95% CI 6.99 to 7.10) within 2 years of their APM (1997-2015) (Table 4.1 and Table 4.2). For patients aged 60 years or greater in 2015-16, 9.91% (1689/17043; 95% CI 9.47-10.37) underwent arthroplasty within 1-year of APM. In 2014-15, 16.55% (3100/18734; 95% CI 16.02-17.09) of patients aged 60 years or greater underwent arthroplasty within 2-years of APM. Sensitivity analysis (first APM by patient, excluding prior procedures) confirmed no material difference in outcomes: 1-year rates all less than 0.6% lower than primary results for each age group.

Figure 4.2 summarises the trend in the proportion of patients undergoing subsequent arthroplasty over time. By year of treatment, the proportion of patients subsequently undergoing knee arthroplasty increased from 1.74% (95% CI 1.50 to 1.98) in 1997-98 to a peak of 4.97% (95% CI 4.80 to 5.13) in

2009-10, before declining to 4.19% (95% CI 4.04 to 4.34) in 2015-16. The 2-year proportion increased from 4.70% (95% CI 4.32 to 5.07) in 1997-98 to a peak of 7.84% (95% CI 7.63 to 8.04) in 2009-10, before declining to 7.27% (95% CI 7.08 to 7.46) in 2014-15.

The unadjusted and adjusted odds of arthroplasty by age, sex, Charlson comorbidity index, deprivation, rurality and ethnicity are summarised in Table 4.3. Adjustment for age attenuated the odds associated with female sex, Charlson comorbidity index, and year of treatment although these remained significant. Adjustment for age also resulted in changes to the odds of arthroplasty associated with social deprivation: from negative odds with greater social deprivation, to positive odds. In the fully adjusted model, the odds of patients undergoing subsequent arthroplasty within 1-year increased by year of APM over the study period (adjusted odds ratio [OR] 3.10 in 2014 versus 2000; 95% CI 2.75 to 3.50). Increasing age was associated with increased odds of arthroplasty at 1-year (adjusted OR 1.48 per five years; 95% CI 1.47 to 1.49) and 2-years (adjusted OR 1.47 per five years; 95% CI 1.47 to 1.48). Female patients were more likely to undergo arthroplasty at both 1-year (adjusted OR 1.48; 95% CI 1.45 to 1.52) and 2-years (adjusted OR 1.55; 95% CI 1.52 to 1.58). In the fully adjusted model, patients from the most deprived regions were more likely to undergo subsequent arthroplasty in comparison to the least deprived regions at both 1-year and 2-years (Table 4.3). Patients with a greater Charlson comorbidity index and patients of white ethnicity were also more likely to undergo subsequent arthroplasty at both 1-year and 2-years (Table 4.3).

Regional variation in the age-sex standardised rate of subsequent arthroplasty within 1-year of APM in 2015-16 is shown in Figure 4.3. In 2015-16, there was ten-fold variation in arthroplasty conversion rates and 16/207 CCGs (7.7%) had a rate at least 50% greater than the national average. The regional variation in 1-year and 2-year conversions rates is also summarised in the maps shown in Figure 4.4.

Figure 4.1: Flow diagram illustrating cohort extraction

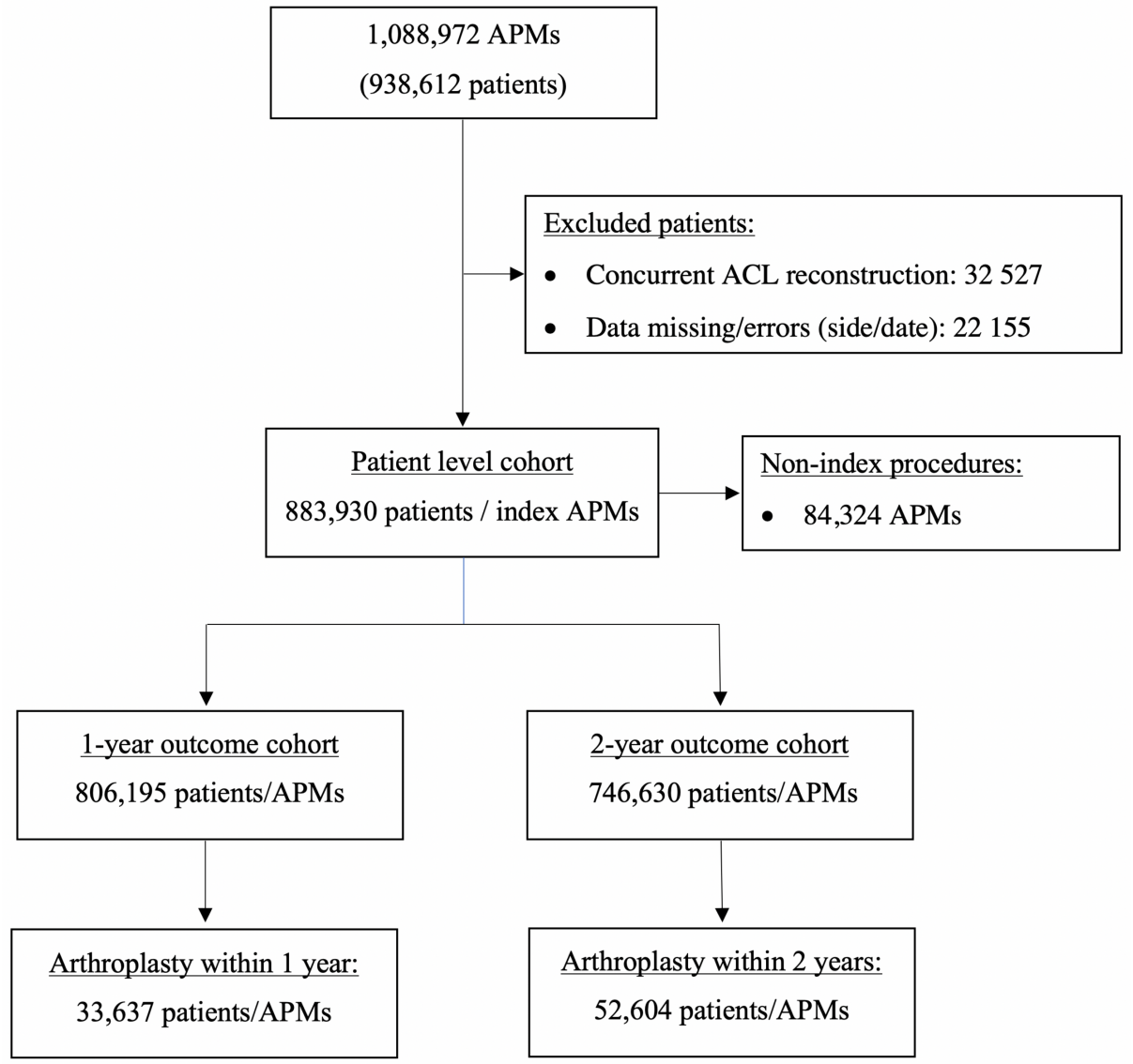


Table 4.1: Demographics and descriptive statistics: all procedures and 1-year outcome cohort

	All index procedures *		**1-year outcome cohort †**		
	n	**%**	**n**	**n TKA**	**% (95% CI)**
Total					
Overall	883,930	100%	806,195	33,637	4.2% (4.1, 4.2)
Sex					
Male	559,791	63.3	509,617	14,427	2.8% (2.8, 2.9)
Female	324,139	36.7	296,578	19,210	6.5% (6.4, 6.6)
Age group (years)					
< 20	23,643	2.67	-	-	-
20 - 39	196,847	22.3	186,270	136	0.1% (0.1, 0.1)
40 - 59	422,621	47.8	393,809	10,184	2.6% (2.5, 2.6)
60 - 79	230,248	26.1	216,067	21,793	10.1% (10.0, 10.2)
80 +	10,571	1.20	10,049	1,524	15.2% (14.5, 15.9)
Charlson comorbidity index					
0	736,832	83.4	673,865	23,787	3.5% (3.5, 3.6)
1 - 15	141,275	16.0	127,063	9,265	7.3% (7.2, 7.4)
16 - 30	5,434	0.61	4,919	549	11.2% (10.3, 12.1)
31 - 50	389	0.04	348	36	10.3% (7.4, 14.0)
Index of multiple deprivation (quintiles)					
1 = least deprived	196,587	22.2	180,097	7,633	4.2% (4.2, 4.3)
2	193,030	21.8	176,639	7,772	4.4% (4.3, 4.5)
3	185,527	21.0	169,880	7,283	4.3% (4.2, 4.4)
4	161,628	18.3	146,916	5,826	4.0% (3.9, 4.1)
5 = most deprived	138,247	15.6	125,010	4,854	3.9% (3.8, 4.0)
Missing	8,911				
Rurality					
Urban	676,253	76.5	616,524	25,069	4.1% (4.0, 4.1)
Rural	203,131	23.0	186,041	8,461	4.6% (4.5, 4.6)
Missing	4,546				
Ethnicity					
White	780,685	88.3	714,522	32,299	4.5% (4.5, 4.6)
Asian	24,010	2.72	21,262	587	2.8% (2.5, 3.0)
Black	12,837	1.45	11,328	150	1.3% (1.1, 1.6)
Mixed	5,137	0.58	4,372	90	2.1% (1.7, 2.5)
Other	5,664	0.64	4,964	50	1.0% (0.8, 1.3)
Missing	55,597	6.29			

*Note: * 1-April-1997 to 31-March-2017; † 1-April-1997 to 31-March-2016; - = suppressed due to small numbers; CI = confidence interval.*

Table 4.2: Descriptive statistics: 2-year outcome cohort

	2-year outcome cohort ‡		
	n	**n TKA**	**% (95% CI)**
Total			
Overall	746,630	52,604	7.1% (7.0, 7.1)
Sex			
Male	473,490	22,666	4.8% (4.7, 4.9)
Female	273,140	29,938	11.0% (10.8, 11.1)
Age group (years)			
< 20	-	-	-
20 - 39	175,050	267	0.2% (0.1, 0.2)
40 - 59	362,507	17,315	4.8% (4.7, 4.9)
60 - 79	199,602	32,962	16.5% (16.4, 16.7)
80 +	9,471	2,060	21.8% (20.9, 22.6)
Charlson comorbidity index			
0	628,098	38,147	6.1% (6.0, 6.1)
1 - 15	113,875	13,648	12.0% (11.8, 12.2)
16 - 30	4,349	759	17.5% (16.3, 18.6)
31 - 50	308	50	16.2% (12.3, 20.8)
Index of multiple deprivation (quintiles)			
1 = least deprived	167,375	11,756	7.0% (6.9, 7.2)
2	163,871	12,004	7.3% (7.2, 7.5)
3	157,485	11,425	7.3% (7.1, 7.4)
4	135,920	9,394	6.9% (6.8, 7.1)
5 = most deprived	114,940	7,596	6.6% (6.5, 6.8)
Missing			
Rurality			
Urban	570,250	39,360	6.9% (6.8, 7.0)
Rural	173,113	13,106	7.6% (7.5, 7.7)
Missing			
Ethnicity			
White	662,430	50,455	7.6% (7.6, 7.7)
Asian	19,135	996	5.2% (4.9, 5.5)
Black	10,254	273	2.7% (2.4, 3.0)
Mixed	3,929	140	3.6% (3.0, 4.2)
Other	4,498	77	1.7% (1.4, 2.1)
Missing			

Note: ‡ 1-April-1997 to 31-March-2015; - = suppressed due to small numbers; CI = confidence interval.

Table 4.3: Unadjusted and adjusted odds of undergoing subsequent knee arthroplasty after APM by sex, age group, and year of APM treatment*

	Odds of undergoing arthroplasty within 1 year				**Odds of undergoing arthroplasty within 2 years**			
	Unadjusted		**Adjusted**		**Unadjusted**		**Adjusted**	
	OR	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Sex								
Male	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Female	2.38	2.33, 2.43	1.48	1.45, 1.52	2.45	2.40, 2.49	1.55	1.52, 1.58
Age undergoing APM (per 5 years) ‡								
Age	1.52	1.52, 1.52	1.48	1.47, 1.49	1.52	1.51, 1.52	1.47	1.47, 1.48
Year of treatment (APM) †								
2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2007	4.16	3.69, 4.69	3.24	2.87, 3.67	2.19	2.03, 2.36	1.67	1.55, 1.81
2014	3.94	3.50, 4.43	3.10	2.75, 3.50	2.17	2.02, 2.33	1.68	1.55, 1.81
Charlson comorbidity index (per 5 units)								
Charlson index	1.48	1.47, 1.50	1.04	1.02, 1.05	1.49	1.47, 1.51	1.04	1.03, 1.06
Index of multiple deprivation (quintile)								
1 = least deprived	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	1.04	1.01, 1.07	1.08	1.05, 1.12	1.05	1.02, 1.07	1.09	1.06, 1.12
3	1.01	0.98, 1.05	1.13	1.09, 1.16	1.04	1.01, 1.06	1.15	1.12, 1.18
4	0.93	0.90, 0.97	1.17	1.13, 1.21	0.98	0.96, 1.01	1.23	1.19, 1.27
5 = most deprived	0.91	0.88, 0.95	1.30	1.25, 1.35	0.94	0.91, 0.97	1.33	1.28, 1.37
Rurality								
Urban	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Rural	1.12	1.10, 1.15	1.02	0.99, 1.05	1.10	1.08, 1.13	1.01	0.98, 1.03
Ethnicity								
White	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Asian	0.60	0.55, 0.65	0.73	0.67, 0.79	0.67	0.62, 0.71	0.81	0.76, 0.87
Mixed	0.44	0.36, 0.55	0.66	0.53, 0.82	0.45	0.38, 0.53	0.66	0.56, 0.79
Black	0.28	0.24, 0.33	0.37	0.31, 0.44	0.33	0.29, 0.37	0.43	0.38, 0.49
Other	0.21	0.16, 0.28	0.38	0.29, 0.51	0.21	0.17, 0.26	0.37	0.29, 0.46

*Note: * adjusted logistic regression model including all variables in the table; ‡ age < 20 years suppressed due to small numbers; OR = odds ratio; CI = confidence interval; APM = arthroscopic partial meniscectomy.*

Figure 4.2: The proportion of patients undergoing knee arthroplasty within 1-year or 2-years of APM over time

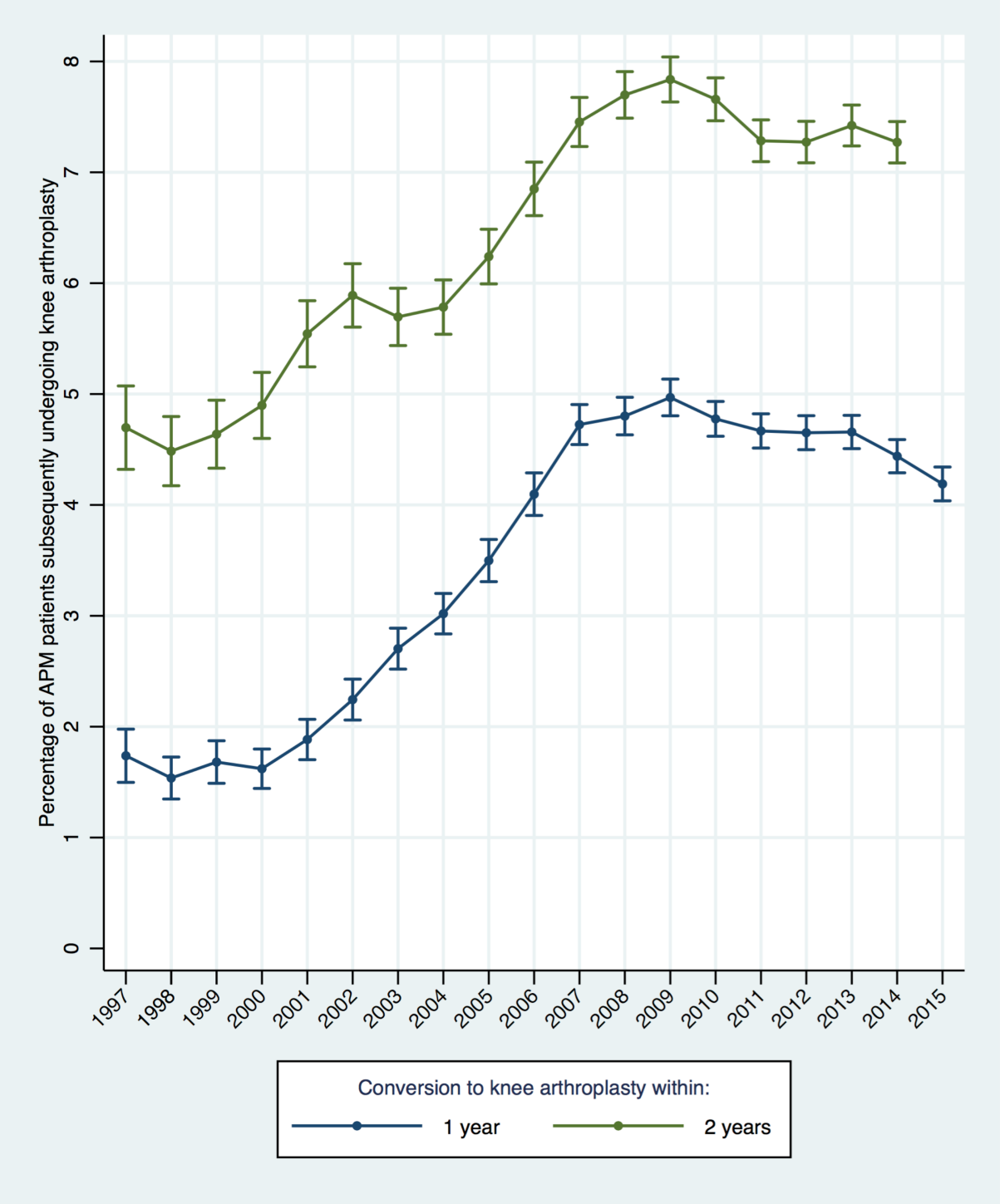
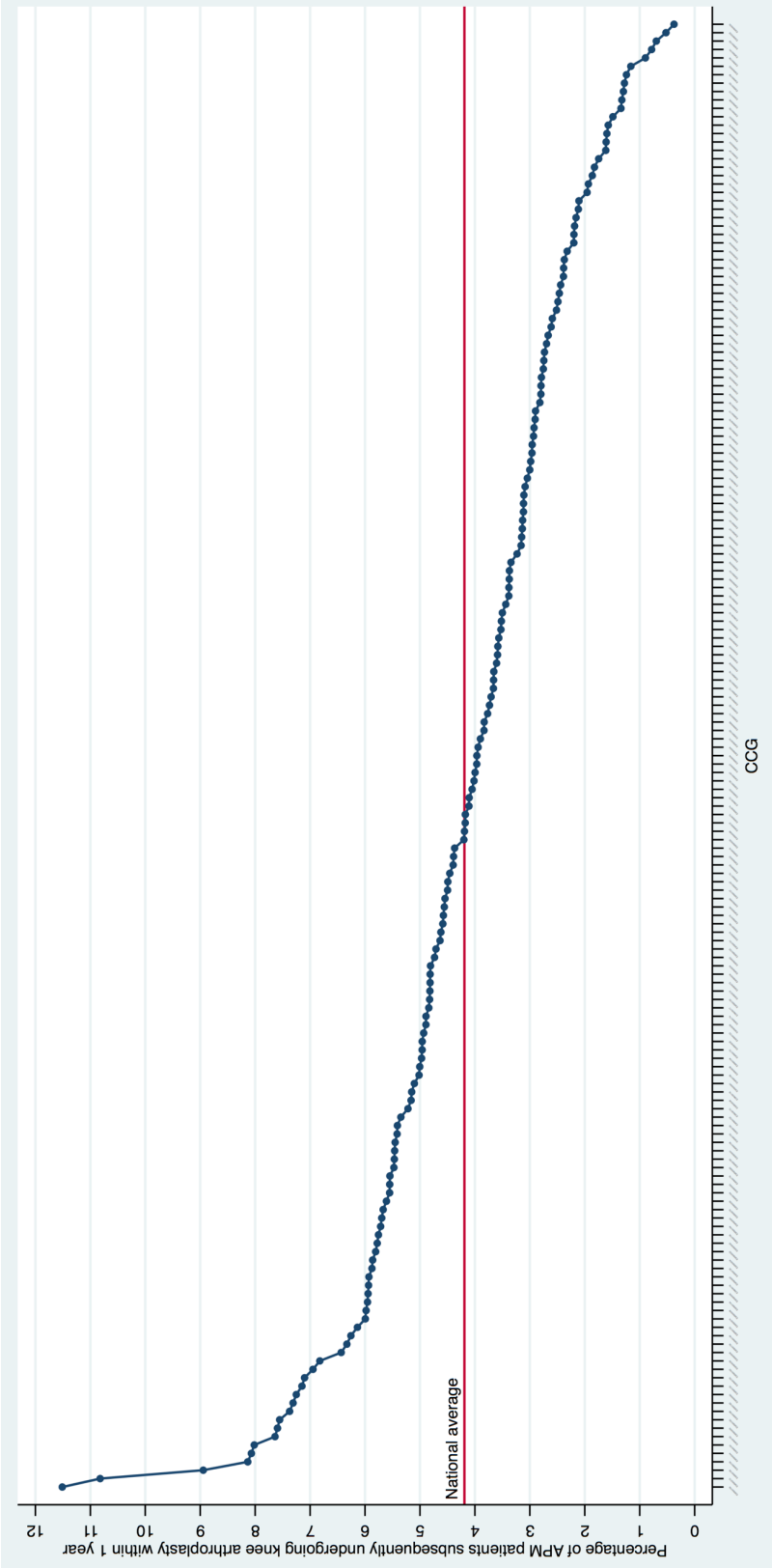
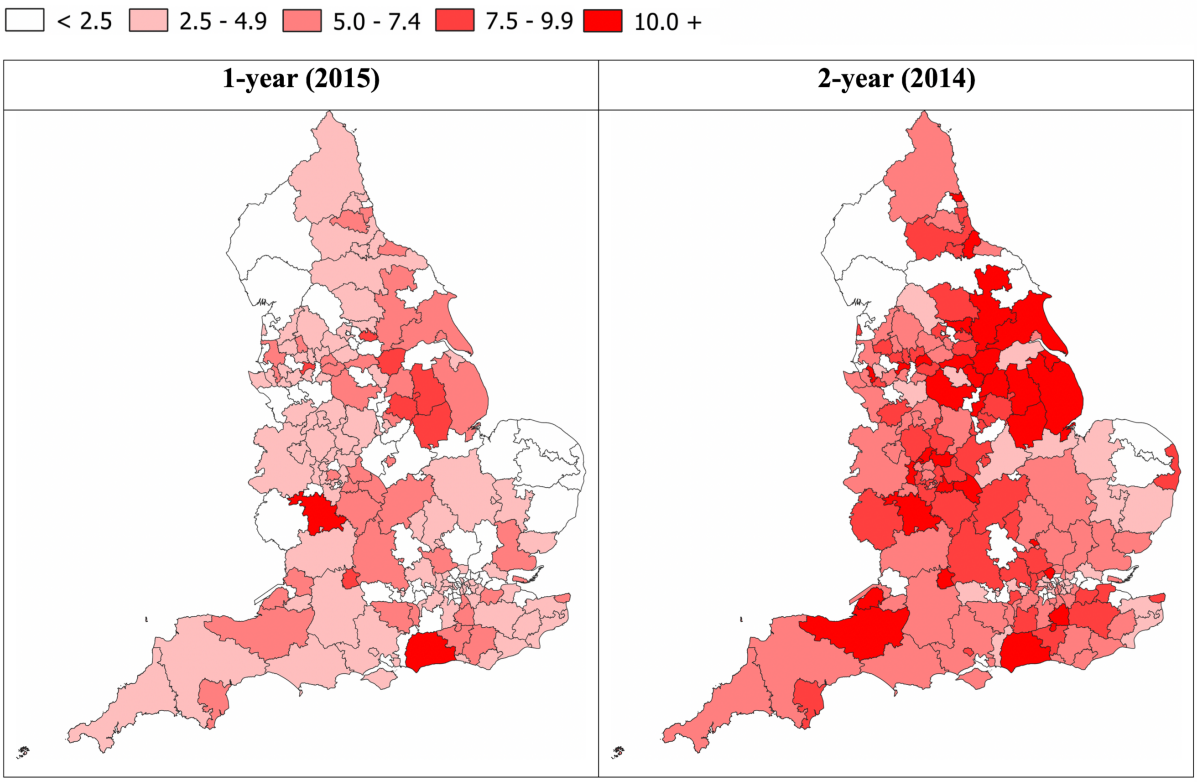


Figure 4.3: Variation in the proportion of patients undergoing arthroplasty within 1-year of APM by treating CCG in 2015-16



Note: x-axis CCG labels are not intended to be readable: for illustration of data points only.

Figure 4.4: Regional variation in the percentage of patients undergoing arthroplasty within 1-year or 2-years of index APM



Note: Charts show the latest data, by Clinical Commissioning Group of original treatment (APM)

4.5 Discussion

4.5.1 Principal findings

The proportion of patients undergoing knee arthroplasty within 1-year or 2-years of APM increased over the 20-year study period and there were particularly high rates of arthroplasty conversion in patients over the age of sixty years. Overall, the proportion of patients undergoing arthroplasty within 1-year of APM increased by 141% between 1997/98 and 2015/16 and there was ten-fold variation in the conversion rate between healthcare regions delivering the primary APM. For patients over the age of sixty years, the rate of arthroplasty conversion was 10% at one-year from 2015-16, and 17% at two-years from 2014-15. There was considerable regional variation in practice, with ten-fold differences in the 1-year arthroplasty rate by CCG. Factors underlying variation have been previously investigated and, to some extent, trends and regional variation can be explained by population and service delivery differences, surgeon beliefs and patient preference influences.[66,67] The regional variation in outcomes

suggests that there is a need for more standardised treatment at a national level. As described in section 1.5.3, variation in outcome suggests a need for more evidence to improve the delivery of the care pathway for this population. This is an undesirable outcome, and with clearer guidelines more consistency in outcome would be anticipated. A fall in the APM intervention rate in patients over the age of sixty years would also be the anticipated result of such guidance but would need to await data: routine monitoring and healthcare provider feedback based upon this undesirable outcome may improve care over time. Routine monitoring of arthroplasty conversion rate after knee arthroscopy may be one possible future marker of ineffective commissioning of care.

4.5.2 Comparison with other studies

One previous study investigated the association between general knee arthroscopy (including washout for osteoarthritis) and subsequent arthroplasty in England.[189] This study reported that 4.8% of patients (aged 20 years or older) that underwent any type of knee arthroscopy for the treatment of osteoarthritis in 1997 subsequently received knee arthroplasty within 1 year.[189] The equivalent 1-year arthroplasty rate following APM in this study, without restriction by age or to patients with a diagnosis of osteoarthritis, was 4.2% in 2015/16. This similarity is surprising given changing trends in practice that have resulted in a dramatic decline in knee washout for osteoarthritis since 1997 but an overall increase in the rate of APM.[195] A partial decline in the rate of APM being performed has been observed since 2013 and this was seemingly broadly correlated with a slight decline in the rate of subsequent arthroplasty.[195] The proportion of arthroplasty conversions remains considerably higher, however, than prior to the rapid increase in the rate of APM observed since 2001.[195]

In the study cohort, 16.5% of patients aged 60-79 years underwent knee arthroplasty within 2-years. This rate is less than a rate of 21.5% reported for patients aged over 65 in an Australian knee arthroscopy cohort in 2006 but greater than a rate of 13.7% for knee arthroscopy patients over the age of 50 years in the United States.[190,251] The proportion of APM patients undergoing subsequent arthroplasty was greater in older age groups as might be expected due to higher rates of degenerative knee disease in this

population, however APM is not considered appropriate in patients with advanced osteoarthritis and early conversion to arthroplasty after APM is concerning in this context.[185,252,253]

Previously, it has been suggested that rising rates of obesity in the population may contribute to an increased incidence of osteoarthritis and associated interventions.[254] Other studies, however, have indicated that although reports of knee pain and clinical cases of suspected osteoarthritis have risen in recent years, the rate of diagnosed and advanced radiographic osteoarthritis has remained relatively unchanged.[255,256] Nevertheless, it is possible that an increased burden of knee pain could have resulted in a greater rate of interventions such as knee arthroscopy, perhaps in an attempt to delay or avoid subsequent arthroplasty, especially in younger patients. Additionally, the temporal trend in conversion rate could be explained by lower thresholds for knee arthroplasty over time, but the findings would still be suggestive of overuse of APM in patients with advanced osteoarthritis.

This study demonstrated a higher rate of subsequent arthroplasty in female patients, patients from more deprived regions of England, and patients of white ethnicity. The reason for these observations is likely to be multi-factorial. For example, individual patients may or may not choose to seek care, influenced by factors including culture, social and economic status, occupation, and relative perceptions of symptom severity or disability.[71,72] Access to care may also play a part, perhaps in relation to communication challenges and unconscious bias in the interaction with healthcare professionals.[73]

4.5.3 Strengths and limitations

The large sample size of prospectively recorded data enhanced the precision of the findings of this study and the ability to analyse trends over time as well as investigate associations with patient-specific factors and regional variation. This study is also strengthened by the exclusion of patients undergoing ligament reconstruction, as ligament injury may independently increase the risk of osteoarthritis.[132] Despite the exclusions, this is the largest cohort of APM patients analysed for this purpose and a number of potential confounding factors were controlled for. Nevertheless, there are potential sources of

unmeasured confounding such as body mass index and severity of osteoarthritis which may partly explain the slightly increased rate of subsequent arthroplasty in patients with a higher Charlson comorbidity index. Except for ligament reconstruction, patients undergoing other concurrent procedures were not excluded as secondary procedure coding could be inconsistent and inclusion of these cases ensured the cohort remained representative of clinical practice and patient selection over time.

Observational HES data is recorded by hospitals in England for the purposes of reimbursement for treatment, clinical audit and research.[234] Whilst some coding errors are inevitable, as hospitals rely on the coding of procedures for financial reimbursement, as stated in the previous chapter (section 3.5.3), this is a strong incentive for coding accuracy, and the APM OPCS-4 code has not changed over time. Although the coding of arthroscopic and arthroplasty procedures has not been specifically validated, studies of the Charlson comorbidity index as calculated from HES diagnosis fields and records of serious vascular complications have been shown to correlate strongly with primary care records.[257,258] HES covers all NHS hospitals in England, reducing the chances of regional migration impacting upon these results, but patients undergoing APM in an NHS hospital but subsequently undergoing knee arthroplasty in a private healthcare setting would not be captured. This is an important consideration that could have led to some underestimation of the proportion of subsequent arthroplasty procedures, but the number of these patients moving from the NHS to the private sector over a two-year period is likely to be small. The generalisability of the reported findings to other healthcare settings, including private practice, is also unknown, and the specific factors underlying the variation in arthroplasty rates warrant further investigation.

In this observational cohort it was not possible to determine an individual patient's relative risk of undergoing knee arthroplasty had they not received an APM, and in some cases the APM itself might have altered the natural history of progression of osteoarthritis.[233] This interesting area is explored and discussed further in Chapter 8, but unlikely to have significantly impacted upon the early rate of arthroplasty at one-year. Even without alteration of the natural history, it is also possible that some

patients received APM for appropriate indications with pre-existent osteoarthritis, as discussed in the introduction (section 4.1). For example, patients with a "locked knee" due to a displaced "bucket-handle" meniscal tear, and then later progressed to end-stage osteoarthritis within 1-2 years.[209,259] Finally, patients might have undergone an otherwise "diagnostic" arthroscopy for decision making regarding suitability for either a partial or total knee arthroplasty, or arthroscopy for other reasons such a removal of intra-articular implants or loose bodies.[260] Diagnostic arthroscopy is, however, becoming less common (as reported in Chapter 3) with increased utilisation of magnetic resonance imaging (MRI) and radiographic decision aids.[143,144,195,259,261] Also, to minimise the impact from these potential cases, purely diagnostic arthroscopies were excluded from this study and patients documented as undergoing knee arthroplasty on the same day (or before) an APM were excluded as probable cases of miscoding (see Methods 4.3.2).

For regional analysis over time, CCG boundaries were standardised to those in April 2017. Index APM cases were linked to the CCG delivering this initial arthroscopy whereas subsequent arthroplasty procedures were identified at a national level, irrespective of the CCG performing the arthroplasty, to maximise data capture. A number of unmeasured factors may underlie regional variation such as surgeon beliefs and patient choice – these factors may influence both the decision to undergo the index APM procedure and also the threshold at which patients choose to undergo a subsequent arthroplasty, which may be especially applicable to younger age groups.[66,67,74] Patients with functional disability and pain but either unwilling to undergo joint arthroplasty or assessed to be clinically ineligible for arthroplasty, may agree to undergo APM as a perceived more minor intervention.[255,256] Based upon the latest evidence, however, there is agreement that APM in the presence of advanced structural osteoarthritis is ineffective.[185,208,209] Whilst this study could not determine the true reason for regional variation, given there are concerns about potential overuse, the findings do support a case for standardising patient selection, where possible at a national level, and for routine monitoring and feedback of outcomes to improve practice and the care pathway over time.

4.5.4 Conclusion

Over the period of this study, the proportion of patients undergoing arthroplasty within one or two years of APM increased and there was up to ten-fold regional variation in this outcome. Nationally, 10% of patients over the age of sixty underwent arthroplasty within one year and 17% within two years. These rates suggest possible overuse of APM in this population and the regional variation suggests inconsistent treatment selection in the care pathway for this population of patients in the UK. There are many factors than can explain such variation in intervention rates, including surgeon beliefs and patient preferences.[67] Specifically for APM, no UK guidelines exist (section 1.8.5) and surgeons may continue to perform APM in some patients with osteoarthritis due to belief in potential benefits (the "enthusiasm hypothesis" and "confirmation bias") or in responses to patients requesting APM as a perceived more minor intervention than arthroplasty due to an incorrect treatment recommendation or lack of knowledge about anticipated benefit versus risk.[64–66] As discussed in section 1.5.3 and 1.5.5, these issues may be effectively addressed with clear evidence on the benefits and risks for both surgeons and patients, clear national treatment guidelines, and financial (commissioning) incentives (and disincentives) to practice accordingly.[66] The following chapters of this thesis aim to deliver new evidence in these areas to inform practice and to develop standardised treatment guidance.

5 EVALUATING THE POPULATION-SPECIFIC VALIDITY OF PATIENT REPORTED OUTCOME MEASURES[‡]

5.1 Introduction

Chapter 4 reports the early rate of knee arthroplasty following APM in England. Whilst knee arthroplasty is an objective end-stage outcome, it is binary and may not fully reflect the spectrum of outcomes and overall health burden of symptoms and disease in this population due to the high threshold for intervention, especially in younger patients. To overcome the limitation of such an end-stage measure of outcome, the success of treatment and severity of symptoms may alternatively be assessed from patient-reported outcome data. Patient-reported outcome measures (PROMs) are frequently selected as the primary outcome measure of surgical randomised controlled trials and the evaluation of care pathway outcomes (see section 1.5.4). As introduced in the Background chapter (section 1.8.3), the best PROMs for use in the population of patients with meniscal tears is unknown.[79,211] This is an important area that must be considered before the clinical trial evidence for this population can be correctly interpreted.

5.2 Aims

The purpose of the work reported in this chapter was to investigate the measurement properties and evidence for the validity of all PROMs which have been evaluated in patients with meniscal tears. This work will inform the interpretation of existing clinical trial evidence and also support the design of future clinical trials and outcome evaluation in the care pathway for this population. It will also highlight where there may be a need for further validation and development work.

[‡] *The content of this chapter has been published, in part, as: Abram SG, Middleton R, Beard DJ, Price AJ, Hopewell S. Patient-reported outcome measures for patients with meniscal tears: a systematic review of measurement properties and evaluation with the COSMIN checklist. BMJ Open 2017; 7: e017247.*

5.3 Methods

The systemic review reported in this chapter is based upon the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) guidelines.[262] The protocol for the review was submitted to PROSPERO (CRD42017056847) on 20/02/2017.

5.3.1 Study selection criteria

Studies of adults with meniscal tears of the knee were included. Those studies with less than 50% of patients having a meniscal tear as the primary diagnosis (i.e. without other significant knee pathology e.g. concomitant anterior cruciate ligament (ACL) rupture) were excluded unless the meniscal tear group was reported separately.

Studies administrating PROMs for the purpose of assessing measurement properties were included. PROMs using standard scoring methods, without clinician completed elements, measuring health related quality of life, health status, symptoms including pain, or functional status were included. Some studies included patients undergoing surgery (e.g. arthroscopic partial meniscectomy, meniscal repair) as part of this assessment process, but the purpose of this review was not to assess the effectiveness of such interventions.

5.3.2 Measurement properties

All PROM measurement properties reported by the included studies were evaluated. The primary measurement properties assessed were those within the reliability, validity, and responsiveness domains. The secondary domains assessed were interpretability and generalisability. The Consensus-based Standards for the selection of health Measurement Instruments (COSMIN) definition of the domains and measurement properties follows below.[263]

5.3.2.1 Reliability

The reliability domain is a measure of how free a PROM is from measurement error.[263] The measurement properties within this domain are assessed by repeated collection of the PROM in a defined period when there has been no change in the patient's condition. Ideally, rather than assume the patient's condition is unchanged, a methodologically strong study will assess for change, for example by administering a knee-specific global transition question on symptoms.

- Internal consistency: is the degree of inter-relatedness among the PROM items.[263]
- Reliability: is the proportion of total variance in the measurement which is because of true differences among patients.[263]
- Measurement error: is the systematic and random error of a patient's score that is not attributed to true changes in the construct to be measured.[263]

5.3.2.2 Validity

The validity domain is the extent to which the PROM measures the 'construct' it purports to measure.[263]

- Content validity: is the degree to which the content of a PROM is an adequate reflection of the construct to be measured.[263] The items should be comprehensive and relevant.
- Construct validity: is the degree to which the scores of a PROM are consistent with hypotheses (e.g. relationship of the score to that of other PROMs collected in the same group) based on the assumption the PROM validly measures the intended construct.[263]
    - Structural validity: is the degree to which the scores of a PROM are an adequate reflection of the dimensionality of the construct to be measured.[263]
    - Hypothesis testing: assumes that the PROM validly measures the construct of interest. Hypotheses are prepared *a priori* with regards to the correlation of the PROM with other relevant PROMs or domains of other PROMs. The magnitude and direction of the correlation should be stated in advance of testing.

- Cross-cultural validity: is the degree to which the performance of the items on a translated or culturally adapted PROM are comparable to the performance of the original version of the PROM.[263]

5.3.2.3 Responsiveness

Responsiveness is defined by COSMIN as the ability of a PROM to measure change over time in the construct to be measured.[263] It is important to note that in studies assessing the measurement properties of a PROM, responsiveness should be assessed against another valid PROM as for the assessment of construct validity. Measurement of effect size alone is not appropriate as this is a measure of the magnitude of the change and not the quality of the measurement.[264]

5.3.2.4 Interpretability

Interpretability is defined as the degree to which it is possible to assign qualitative meaning to a PROM's quantitative score.[263] It is not considered a measurement property but is important when interpreting the findings from administration of a PROM in the context of a clinical condition. Interpretability includes an assessment of minimal important change (MIC), floor and ceiling effects. In general, floor and ceiling effects <15% are considered acceptable although some authors have argued the threshold should be set at <30%.[265,266] A high floor or ceiling effect suggests that items at the lower or upper end are missing from a question item, domain, or the PROM overall.

5.3.2.5 Generalisability

Generalisability is an assessment of external validity: the extent to which the findings on the measurement properties of a PROM may be considered relevant to a population or construct of interest. For example, a study of the measurement properties of a PROM in a population with advanced knee osteoarthritis cannot be generalised to athletes with knee ligament injury without further study in the target population. In this review, the population of patients involved in the original development of each PROM is determined and the inclusion and exclusion criteria of all studies reporting measurement

properties of the included PROMs is reported to highlight any heterogeneity. The generalisability of findings to the population of patients with meniscal tears is considered.

5.3.3 Search Strategy

A search of MEDLINE, Embase, AMED and PsycINFO, unlimited by language or publication date was performed. The search was based upon a validated search filter designed to be highly sensitive in identifying all studies of measurement properties.[267] Full details of the search are available in Appendix D. The final search was performed on 20/02/2017, following submission of the protocol to PROSPERO. A review of study citations was performed to further increase the sensitivity of the search strategy.

5.3.4 Selection of studies

The title and abstract of all records retrieved by the search was independently reviewed by two reviewers against the inclusion and exclusion criteria (SA and RM). Any disagreement was resolved with review of the full text publication and discussion. Referral to a third reviewer (SH) was not required for agreement. The original PROM development article was retrieved for all PROMs identified: for example, where a PROM was developed for a condition other than meniscal pathology and subsequently tested in a population with meniscal tears.

5.3.5 Data extraction: Measurement properties and assessing the quality of studies

Data extraction was performed by two reviewers (SA and RM) and any disagreement resolved in consultation with a third reviewer (SH). The following was extracted from each publication: the PROM, the intended construct for measurement, measurement properties, administration method, study population and diagnosis, number of patients, patient demographics, country, language and setting and method of administration (e.g. postal, online).

The quality of each included study was assessed by two reviewers (SA and RM) using the Consensus-based Standards for the selection of health Measurement Instruments (COSMIN) appraisal checklist.[268]

When reviewing a study of a PROM, it is necessary to consider a combination of the reported measurement properties, the patient population, and the quality of the study methodology. To help overcome some of the difficulties in evaluating the quality of PROMs, COSMIN was published in 2010.[264,269] COSMIN contains rules for grading overall methodological quality of studies performed into the measurement properties of PROMs. These consensus standards are regularly reviewed and revised based on the latest evidence and research. COSMIN initially separated standards into boxes including a series of binary methodological ratings. The scoring methodology was subsequently revised to a four level (excellent/good/fair/poor) rating system in 2012.[268] Each measurement property is assessed by a box containing 5-18 questions scored on this scale according to defined COSMIN criteria. A system of 'worst score counts' applies for each box – that is, if one question in the box is scored as poor, the overall quality of the evidence for that measurement property is determined to be poor.

5.3.6 Data synthesis

Data synthesis was performed by SA and checked by RM. For each included PROM, a summary of the features of the PROM is presented including details of the original development process, the development population and target construct to be measured.

For each PROM, a rating (positive, negative or indeterminate) for the measurement properties reported in the study was first determined based upon consensus standards described in Appendix E.[266] This assessment was then combined with an overall quality of evidence assessment which was adapted for COSMIN from the work of the Cochrane Back Review Group (Table 5.1).[270,271] For example, one good quality study reporting positive measurement properties (e.g. internally consistent with Cronbach's alpha ≥ 0.70) results in an overall rating of 'moderate' (++). Where the quality of study methodology on a measurement property is rated 'poor' the overall rating of the measurement property is always rated 'indeterminate', irrespective of the number of such studies and whether the reported measurement property itself would otherwise be considered positively. These standards are designed to ensure reported measurement properties are interpreted in the context of study quality and overall reliability.

Table 5.1: Overall levels of evidence for the quality of the measurement property[270,271]

Level of Evidence	Rating	Quality Criteria
Strong	+++ or - - -	Consistent findings (positive or negative) in multiple studies of good methodological quality OR in one study of excellent methodological quality
Moderate	++ or - -	Consistent findings (positive or negative) in multiple studies of fair methodological quality OR in one study of good methodological quality
Limited	+ or -	One study of fair methodological quality (positive or negative)
Conflicting	+/-	Conflicting results
Unknown	?	Only studies of poor methodological quality

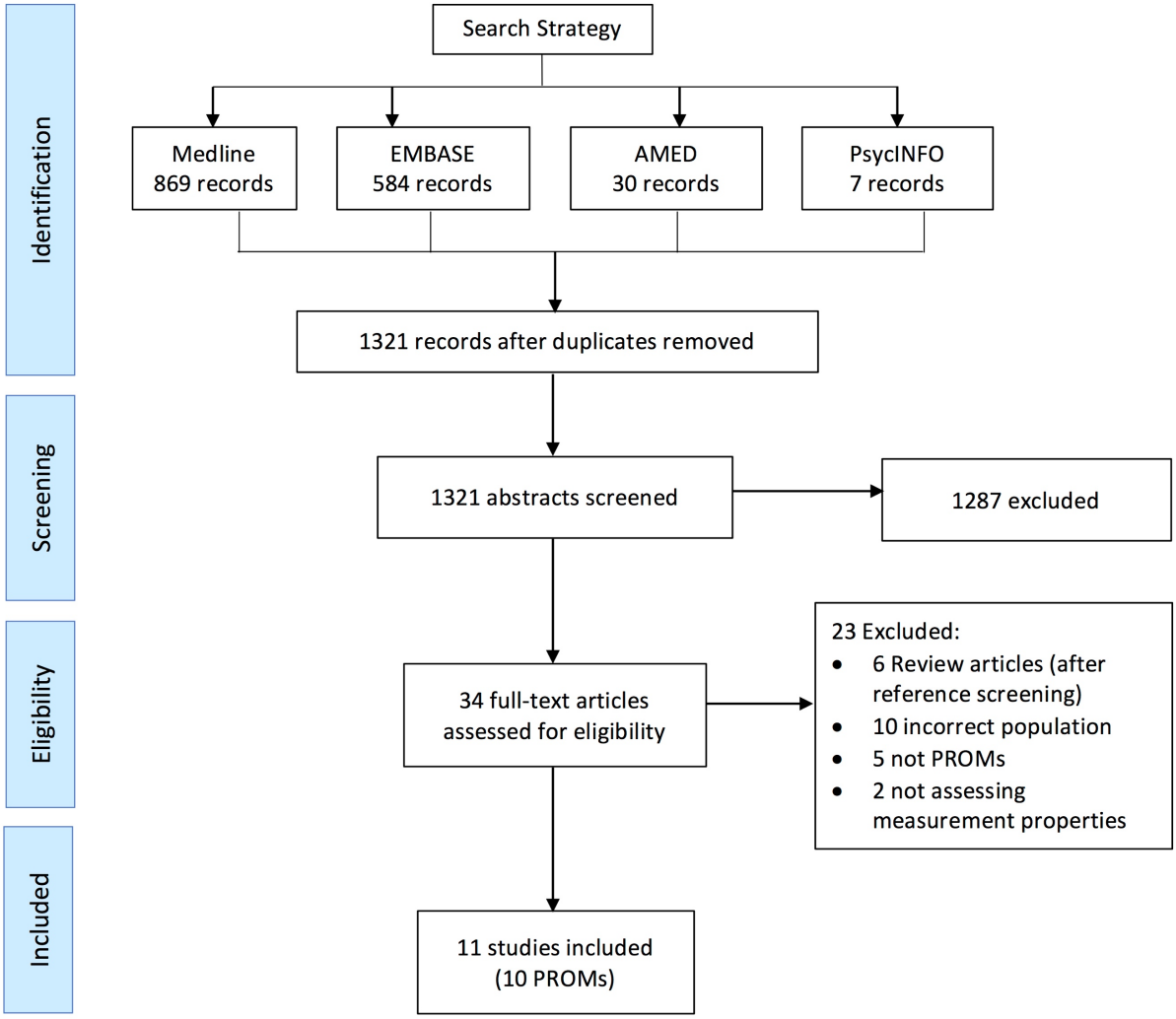
Note: The quality of the evidence for the measurement property for each PROM, considering the quality criteria for each measurement property (Appendix E), the methodology of each study reporting the measurement property (Table 5.4) and the number of studies reporting the measurement property including consistency of findings. + = positive rating, ? = indeterminate rating, - = negative rating

5.4 Results

5.4.1 Selection of studies

The search strategy identified 1321 unique articles for screening. After screening, 34 full text articles were retrieved of which 11 met the inclusion criteria for this review. Figure 5.1 summarises the study selection process. The 11 studies reported measurement properties for 10 PROMs.

Figure 5.1: PRISMA flow diagram



Note: Full search strategy may be found in Appendix D.

5.4.2 Study characteristics

The characteristics of the included studies are shown in Table 5.2. The mean age of patients included in the studies ranged from 38-53 years. The proportion of female patients included ranged from 14-64%. Inclusion and exclusion criteria were inconsistent with regards to age, symptoms, investigations and treatment (Table 5.2).

Table 5.2: Characteristics of the included studies (continued overleaf)

Study (year)	**Instrument(s)**	**Country (language)**	**Population (inclusion and exclusion criteria)**	***N***	**Mean age (SD, range)**	**Female : Male**
Goodwin (2011)[272]	**Hughston EQ-5D SF-6D**	**UK (English)**	**Inclusion:** Patients previously undergoing arthroscopic partial meniscectomy.	84	38 (SD 8, 21-58)	14 : 86 %
Crawford (2007)[273]	**IKDC**	**USA (English)**	**Inclusion:** Patient with "meniscal pathology requiring treatment" and completed IKDC questionnaire **Exclusion:** Patients with ligament pathology or a chondral defect greater than Outerbridge grade 2	Groups: A: 31 B: 264 C: 50 D: 50	48 (18-81)	29 : 71 %
Van de Graaf (2014)[274]	**IKDC KOOS WOMAC**	**Netherlands (Dutch)**	**Inclusion:** Age >18, knowledge of Dutch language, either on waiting list for meniscal surgery or between 6 weeks and 6 months after meniscal surgery. **Exclusion:** Received arthroplasty in either knee or previous ACL surgery on the knee of interest.	75	48.8 (35-62)	50 : 50 %
Roos (1998)[275]	**KOOS**	**Sweden (Swedish)**	**Inclusion:** Patient waiting for knee arthroscopy for either meniscal lesion, ACL injury or tibio-femoral cartilage damage. (54% meniscal tear, 20% ACL+meniscal tear, 13% ACL, 13% isolated chondral damage) **Exclusion:** Multiple joint involvement, other diagnosis.	142	39.7 (14-75)	22 : 78 %
Garratt (2008)[276]	**KQoL-26**	**UK (English)**	**Inclusion:** Patients aged 18-55, referred to hospital clinic with suspected meniscus or knee ligament pathology. (67% meniscal tear, 30% ACL, 3% other) **Exclusion:** Requiring urgent referral, non-traumatic arthropathy, chronic knee instability, previous same knee surgery (except diagnostic arthroscopy)	323	47 (14.3)	44 : 56 %
Briggs (2006)[265]	**Lysholm Tegner**	**USA (English)**	**Inclusion:** Patient previously undergoing surgery for meniscal lesion or waiting list for meniscal surgery.	Groups: A: 122 B: 191 C: 477	40 (13-81)	32 : 68 %
Kirkley (2007)[277]	**WOMET**	**Canada (English)**	**Inclusion:** Patients with "meniscal symptoms (swelling, catching, locking)" and magnetic resonance imaging suggestive of meniscal pathology.	Groups: A: 31 B: 36 C: 34 D: 69	Not reported	Not reported
Sihvonen (2012)[278]	**WOMET**	**Finland (Finnish)**	**Inclusion:** Patients with arthroscopically verified degenerative meniscal tear and no	Groups: A: 485	53 (18-81)	45 : 55 %

			previous knee trauma. **Exclusion:** Trauma, bilateral arthroscopy, re-operation within 6 months	B: 385 C: 100 D: 40		
Celik (2013)[279]	**WOMET**	**Turkey (Turkish)**	**Inclusion:** Age >16, presence of meniscal tear or previous meniscal repair or resection, complete questionnaires. **Exclusion:** Ligament injury, "articular cartilage damage causing instability", inability to complete the form due to cognitive impairment.	96	43.6 (23-71)	64 : 36 %
Tong (2016)[280]	**WOMET**	**China (Chinese)**	**Inclusion:** Patients with meniscal pathology who underwent arthroscopic surgery for meniscal repair or resection. Age >18, able to read and speak Chinese. **Exclusion:** Ligament injuries, history of leg surgery, infection, tumours, rheumatologic disease, neurological or musculoskeletal disorders.	121	41.2 (14.3)	57 : 43 %
Van der Wal (2016)[281]	**WOMET**	**Netherlands (Dutch)**	**Inclusion:** Patients with MRI confirmed, symptomatic, meniscal tear. Age 18-70, understanding of Dutch language. **Exclusion:** Concomitant ligament injury, previous ligament injury with instability, previous knee surgery, chondral defect greater than Outerbridge grade 2 on MRI or during surgery, inability to participate due to cognitive impairment.	86	Median 52 (IQr 43-60)	41 : 59 %

Note: IQr = interquartile range.

5.4.3 Quality of the included studies

In total, the 11 studies reported 93 measurement properties for the 10 PROMs. The COSMIN methodology rating for 49 of these (53%) was poor. Many measurement properties were not reported and there was inconsistent reporting between studies (Table 5.4).

5.4.4 Quality of PROMs

Interpretability factors including floor and ceiling effects are summarised in Table 5.5. The overall level of evidence for the measurement properties of each PROM is summarised in Table 5.6. This combines the rating of the reported measurement property using the consensus criteria available in Appendix E with the COSMIN scoring and the number of studies per PROM (as described in Table 5.1).

Of the 10 PROMs identified, five intended to measure symptoms and functional status, four health-related quality of life and one activity level. The development and features of the included PROMs are summarised below and in Table 5.3.

5.4.4.1 Symptoms & Functional Status

Hughston: The Hughston Clinic Questionnaire was developed in 1991 as a knee-specific rather than disease-specific outcome measure.[282] It includes questions on symptoms, functional status and sports activity and patients were not involved in the development of the questions. Only one study has evaluated use of the Hughston questionnaire in patients with meniscal tears.[272] Content validity was rated poor as patients were not involved in the original development and content validity has not been subsequently assessed in patients with meniscal tears. In patients with meniscal tears, there was moderate negative evidence against construct validity based on hypothesis testing and all other measurement properties were either not reported or indeterminate due to poor study design or reporting (Table 5.6).

IKDC: The International Knee Documentation Committee (IKDC) Subjective Knee Form was developed in 2001 as a knee-specific rather than disease-specific outcome measure.[283] It includes question domains on symptoms, functional status and sports activity and patients were not involved in the development of the questions. Two studies have evaluated use of the IKDC score in patients with meniscal tears.[273,274] In English, there is limited positive evidence for reliability and construct validity based on hypothesis testing.[273] In Dutch, there is moderate positive evidence for reliability and construct validity based on hypothesis testing but limited negative evidence against structural validity.[274] In both studies, all other measurement properties were either not reported or indeterminate (Table 5.6). For the English-version, although no floor or ceiling effect was detected for the overall score, unacceptable floor effects were reported for 9 items and unacceptable ceiling effects in 5 items (Table 5.5).

KOOS: The Knee injury and Outcome Osteoarthritis Score (KOOS) was developed in 1998 as a knee-injury specific outcome measure for patients at risk of developing osteoarthritis.[284] It includes question domains on symptoms, functional status, sports activity and quality of life. Patients with anterior cruciate ligament (ACL) or meniscal injuries were included in the development process. The KOOS includes the WOMAC osteoarthritis score in full and the WOMAC may therefore be calculated from the KOOS. The KOOS has been studied in Dutch and Swedish for patients with meniscal tears; no study has evaluated the English-version of KOOS in this population.[274,275] There is moderate positive evidence for reliability and construct validity from hypothesis testing of the Dutch-version.[274] For the Swedish-version, there is limited positive evidence for reliability and construct validity based on hypothesis testing.[275] For both the Dutch and Swedish versions, content validity and all other measurement properties were either rated indeterminate or were not reported (Table 5.6).

Lysholm: The Lysholm knee score was developed in 1982 and modified in 1985 as a disease-specific outcome measure for patients with knee ligament injury.[285,286] The Lysholm knee score was originally designed to be completed by clinicians and developed without patient involvement. One study has evaluated the use of Lysholm in English speaking patients with meniscal tears.[265] There is limited positive evidence for reliability and construct validity based on hypothesis testing. Content validity and all other measurement properties are either indeterminate or were not reported (Table 5.6). There was no floor or ceiling effect for the Lysholm score overall however an unacceptable floor effect was detected for 2 items and unacceptable ceiling effects for 5 items (Table 5.5).

WOMAC: The Western Ontario McMaster Osteoarthritis Index (WOMAC) was developed in 1982 as a disease-specific outcome measure for patients with osteoarthritis of the hip or knee.[287] The WOMAC includes question domains for pain, stiffness and functional status and patients with osteoarthritis were involved in the development of the questions. The WOMAC is incorporated in its entirety in the KOOS (see above). One study has evaluated the Dutch version of WOMAC in patients with meniscal tears.[274] In these patients, there is moderate positive evidence for reliability and construct validity (hypothesis

testing). No floor or ceiling effects were detected. Content validity and all other measurement properties are either indeterminate or were not reported (Table 5.6).

5.4.4.2 Health-related quality of life

EQ-5D: EQ-5D is a generic measure of health-related quality of life developed in 1990.[288] It was developed with patient involvement and includes question domains on mobility, self-care, usual activities, pain, and anxiety or depression. One study has evaluated the English EQ-5D in patients with meniscal tears.[272] In this population, there is moderate positive evidence for construct validity based on hypothesis testing. All other measurement properties are either indeterminate or were not reported.

KQoL-26: The Knee Quality of Life (KQoL-26) 26-item questionnaire was developed in 2008, in English, as a disease-specific health-related quality of life measure for patients with suspected ligamentous or meniscal injury of the knee.[276] In the study population, 67% of patients had a meniscal tear and there is limited positive evidence for internal consistency, reliability, content validity, and construct validity (hypothesis testing and structural validity). Administered by post, an overall response rate of 59% was reported with 14.9% missing items.[276] Floor and ceiling effects were poorly reported with at least one question having an unacceptable floor effect and one an unacceptable ceiling effect (Table 5.5).

SF-6D: The short form-6 dimensions (SF-6D) generic health-related quality of life measure is derived from the SF-36 or SF-12 and was developed in 2004.[289] It was developed with patient involvement and contains 6 domains: physical functioning, role limitation, social functioning, pain, mental health and vitality. One study has evaluated the English version of SF-6D in patients with meniscal tears.[272] There is moderate positive evidence for construct validity based on hypothesis testing but all other measurement properties are indeterminate or were not reported.

WOMET: The Western Ontario Meniscal Evaluation Tool (WOMET) is a meniscal tear disease-specific, quality of life measure developed in 2007.[277] Patients with meniscal tears were involved

throughout the development process although the authors reported that the same patients were "admittedly heterogeneous with respect to the incidence of coexisting knee pathology such as chondral damage or ligament injury".[277] The WOMET has been evaluated in English, Chinese, Dutch, Finnish and Turkish. There is strong positive evidence for content validity in the English version and moderate positive evidence in the Dutch version. There is limited positive evidence for reliability, construct validity (hypothesis testing) and responsiveness of the English-version.[277] Measurement error was only reported for the Dutch-version of WOMET and in this case it was concerning that the minimal important change (MIC) for the PROM was found to be less than the smallest detectable change (SDC). A summary of the level of evidence for the measurement properties in all languages is shown in Table 5.6. Although the overall score does not exhibit floor or ceiling effects, unacceptable levels were reported for several items (Table 5.5).

5.4.4.3 Activity Level

Tegner: The Tegner Activity Scale was developed in 1985 for patients with ACL injury.[286] Patients were not involved in the development of the scale. One study has evaluated use of the scale in patients with meniscal tears.[265] In this population, there is limited positive evidence for reliability and construct validity based on hypothesis testing. All other measurement properties were either not reported or indeterminate.

Table 5.3: Characteristics of the included PROMs (continued overleaf)

Instrument	Year of development	Original language	Intended Construct & Domains	Number of questions	Target or Development Population	Patients involved in development?
Symptoms & Functional Status						
Hughston	1991[272]	English	**Knee-specific symptoms, functional status, sports activity.** No sub-domains	28 questions	"Patients who had undergone knee surgery that varied from arthroscopy to total arthroplasty."[282]	No
IKDC	2001[283]	English	**Knee-specific symptoms, functional status, sports activity.** 1. Symptoms 2. Sports activities 3. Function	18 questions	"A knee-specific, rather than a disease-specific, measure of symptoms, function, and sports activity."[283]	No
KOOS	1998[284]	English	**Knee injury-specific symptoms, functional status, sports activity, quality of life.** 1. Symptoms & Stiffness 2. Pain 3. Activities of daily living (ADL) 4. Function in sports and recreation 5. Knee-related quality of life (QoL)	42 questions	Patients with knee injury (ACL or meniscus injury) at risk of developing osteoarthritis.	Yes
Lysholm	1982[285] / 1985[286]	English	**Disease-specific (knee ligament) symptoms, functional status** No sub-domains	8 questions	"A scoring scale for knee ligament surgery follow-up emphasizing evaluation of symptoms of instability."[285]	No
WOMAC	1982[287]	English	**Disease-specific (osteoarthritis of hip or knee) symptoms, functional status** 1. Pain 2. Stiffness 3. Function & Daily activities	24 questions	"Outcomes of anti-rheumatic drug therapy in patients with osteoarthritis of the hip or knee."[290]	Yes
Health-related quality of life						
EQ-5D	1990[288]	English, Dutch, Finnish, Norweigan,	**General population health-related quality of life** 1. Mobility 2. Self-care	6 questions	General tool for describing and valuing health related quality	Yes

		Swedish	3. Usual activities 4. Pain/Discomfort 5. Anxiety/Depression		of life – items developed and valued after questioning large samples of randomly selected adults.	
KQoL-26	2008[276]	English	**Disease-specific (knee ligament or meniscus) health-related quality of life** 1. Physical functioning 2. Activity limitations 3. Emotional functioning	26 questions	"Patients with a suspected ligamentous or meniscal injury of the knee."[276]	Yes
SF-6D	2004[289]	English	**General population health-related quality of life** 1. Physical functioning 2. Role limitation 3. Social functioning 4. Pain 5. Mental health 6. Vitality	6 questions	Derived from SF-36 or SF-12. A general, preference based classification for describing health-related quality of life.	Yes
WOMET	2007[277]	English	**Disease-specific (meniscus) health-related quality of life** 1. Physical symptoms 2. Sports/Recreation/Work/Lifestyle 3. Emotions	16 questions	"Patients with meniscal symptomology (swelling, catching, locking) and in whom magnetic resonance imaging had suggested meniscal pathology."[277]	Yes
Activity level						
Tegner	1985[286]	English	**Disease-specific (knee ligament) symptoms, functional status** No sub-domains	1 question	Patients with ACL injury diagnosed by clinical examination under anaesthesia and confirmed by arthroscopy or arthrotomy.	No

Note: ACL = anterior cruciate ligament

Table 5.4: Quality of each study per PROM and measurement property (COSMIN rating)

Instrument and Study	Internal consistency	Reliability	Measurement error	Content validity	Structural validity	Hypothesis testing	Cross-cultural validity	Responsiveness
Symptoms & Functional Status								
Hughston								
Goodwin (2011)[272]	Poor	na	na	Poor	na	Good	na	Poor
IKDC								
Crawford (2007)[273]	Poor	Fair	Fair	Poor	na	Fair	na	Poor
Van de Graaf (2014)[274]	Poor	Good	Good	Poor	Fair	Good	Poor	na
KOOS								
Roos (1998)[275]	Poor	Fair	na	Poor	Poor	Fair	Poor	Poor
Van de Graaf (2014)[274]	Poor	Good	Good	Poor	Poor	Good	Poor	na
Lysholm								
Briggs (2006)[265]	Poor	Fair	Fair	Poor	na	Fair	na	Poor
WOMAC								
Van de Graaf (2014)[274]	Poor	Good	Good	Poor	Poor	Good	Poor	na
Health-related quality of life								
EQ-5D								
Goodwin (2011)[272]	Poor	na	na	Poor	na	Good	na	Poor
KQoL-26								
Garratt (2008)[276]	Fair	Fair	na	Fair	Fair	Fair	na	Poor
SF-6D								
Goodwin (2011)[272]	Poor	na	na	Poor	na	Good	na	Poor
WOMET								
Kirkley (2007)[277]	Poor	Fair	na	Excellent	na	Fair	na	Fair
Sihvonen (2012)[278]	Poor	Poor	na	Poor	na	Fair	Poor	Poor
Celik (2013)[279]	Poor	Good	Good	Poor	na	Good	Poor	na
Tong (2016)[280]	Poor	Good	na	Poor	na	Good	Poor	Poor
Van der Wal (2016)[281]	Poor	Good	Good	Good	na	Good	Poor	Good
Activity level								
Tegner								
Briggs (2006)[265]	na	Fair	Fair	Poor	na	Fair	na	Poor

Table 5.5: Interpretability including missing items, response rate, floor and ceiling effects (continued overleaf)

Instrument and Study	Administration	Missing responses	Missing items	Overall % lowest possible total score (floor)	Overall % highest possible score (ceiling)	Items or Domains with >15% responses with lowest score (floor)	Items or Domains >15% highest possible score (ceiling)	MIC
Symptoms & Functional Status								
Hughston								
Goodwin (2011)	Clinic	Not reported	Not reported	0%	0%	Not reported	Not reported	Not reported
IKDC								
Crawford (2007)	Clinic / Postal	Not reported	Not reported	0%	0%	• Activity pain • Pain last 4 weeks • Pain severity • Catching • Kneeling • Sitting • Running • Jumping • Stopping	• Swelling • Catching • Climb stairs • Sitting • Rising	Not reported
Van de Graaf (2014)	Online / Postal	Unclear	0%	0%	0%	Nil	Nil	Not reported
KOOS								
Roos (1998)	Postal	7.2%	0.8%	Not reported	Not reported	Nil	Nil	Not reported
Van de Graaf (2014)	Online / Postal	Unclear	0%	0%	3%	Nil	Nil	Not reported
Lysholm								
Briggs (2006)	Clinic	Not reported	Not reported	0%	0.5%	• Squatting • Pain	• Swelling • Instability • Support • Limp • Locking	Not reported
WOMAC								
Van de Graaf (2014)	Online / Postal	Unclear	0%	0%	6%	Nil	Nil	Not reported
Health-related quality of life								
EQ-5D								
Goodwin (2011)	Clinic	Not reported	Not reported	4%	1%	Not reported	Not reported	Not reported
KQoL-26								
Garratt (2008)	Postal	41%	14.9%	Not reported	Not reported	• Avoiding turning, twisting, or sideways movements • *	• Staying seated for 15 minutes • *	Not reported

SF-6D								
Goodwin (2011)	Clinic	Not reported	Not reported	0%	0%	Not reported	Not reported	Not reported
WOMET								
Kirkley (2007)	Clinic	Not reported	Not reported	5.7%	1.7%	Not reported	Not reported	Not reported
Sihvonen (2012)	Unclear	16%	7.5%	0%	0%	• Numbness	Nil	Not reported
Celik (2013)	Unclear	Not reported	Not reported	0%	0%	• Numbness • Swelling	• Consciousness • Activities • Specific skills • Squatting • Fear injury • Concern about future of knee • Frustration	Not reported
Tong (2016)	Unclear	Not reported	0%	0%	0%	Nil	Nil	Not reported
Van der Wal (2016)	Clinic	0%	<1%	0%	0%	• Numbness • Swelling	Nil	14.7
Activity level								
Tegner								
Briggs (2006)	Clinic	Not reported	Not reported	2.5%	2.5%	na	na	Not reported

*Note: MIC = minimal important change; * = other domains not reported*

Table 5.6: Overall rating of measurement properties and level of evidence for each PROM

Instrument	Internal consistency	Reliability	Measurement error	Content validity	Structural validity	Hypothesis testing	Cross-cultural validity	Responsiveness
Symptoms & Functional Status								
Hughston								
English[272]	**?**	**na**	**na**	**?**	**na**	**- -**	**na**	**?**
IKDC								
English[273]	**?**	+	**?**	**?**	**na**	+	**na**	**?**
Dutch[274]	**?**	++	**?**	**?**	-	++	**?**	**na**
KOOS								
Dutch[274]	**?**	++	**?**	**?**	**?**	++	**?**	**na**
Swedish[275]	**?**	+	**na**	**?**	**?**	+	**?**	**?**
Lysholm								
English[265]	**?**	+	**?**	**?**	**na**	+	**na**	**?**
WOMAC								
Dutch[274]	**?**	++	**?**	**?**	**?**	++	**?**	**na**
Health-related quality of life								
EQ-5D								
English[272]	**?**	**na**	**na**	**?**	**na**	++	**na**	**?**
KQoL-26								
English[276]	+	+	**na**	+	+	+	**na**	**?**
SF-6D								
English[272]	**?**	**na**	**na**	**?**	**na**	++	**na**	**?**
WOMET								
English[277]	**?**	+	**na**	+++	**na**	+	**na**	+
Chinese[280]	**?**	++	**na**	**?**	**na**	++	**?**	**?**
Dutch[281]	**?**	++	**- -**	++	**na**	++	**?**	++
Finnish[278]	**?**	**?**	**na**	**?**	**na**	+	**?**	**?**
Turkish[279]	**?**	++	**?**	**?**	**na**	++	**?**	**na**
Activity level								
Tegner								
English[265]	**na**	+	**?**	**?**	**na**	+	**na**	**?**

Note: See Table 5.1 for a summary of the rating methodology.

5.5 Discussion

5.5.1 Principal findings

The review reported in this chapter identified 11 studies evaluating 10 PROMs in patients with meniscal tears: five PROMS measuring symptoms and functional status, four PROMs measuring health-related quality of life and one for activity level. Unfortunately, the findings of the studies were limited by poor methodology and all PROMs that have been tested in patients with meniscal tears lack data on many measurement properties. The limited evidence weakly supports the use of the Lysholm knee scale, IKDC, KOOS, and WOMET in this population

5.5.2 Comparison with other studies

One previous review has been published summarising the reported measurement properties of a range of PROMs in studies of patients with any knee condition.[291] In this previous review, WOMET was broadly recommended for use in patients with meniscal injuries without distinguishing the intended health-related quality of life construct from others or assessing the quality of the studies.[291] The present study is the first systematic review of PROMs for patients with meniscal tears and the first to evaluate and report the quality of study methodology. In orthopaedics and sports medicine, systematic reviews of PROMs applying the COSMIN appraisal checklist are established and have been published for patient populations including those with hip and knee osteoarthritis, hip and groin disability, patellofemoral pain, distal radius fractures, shoulder pain, and undergoing hip arthroscopy.[292–299]

For studies included in this review, the COSMIN methodology rating was poor for just over half (53%) of reported measurement properties. Internal consistency was rated poor in all but one of the 11 studies. A key reason for this was the failure of most studies to perform factor analysis to assess the structural validity of PROMs. Internal consistency is an assessment of the inter-relatedness of the items measuring the same underlying construct i.e. the PROM or sub-domain should be ‘unidimensional’ for the construct to be measured. Factor analysis is a technique that may be used to determine whether a PROM

or sub-domain is 'unidimensional'. Without this assessment of structural validity, there can be no clear interpretation of internal consistency statistics.[264]

Cross-cultural validity and responsiveness were also particularly poorly evaluated. Regarding responsiveness, frequently studies reported only an effect size for the studied PROM. Effect size alone is a measure of the magnitude of a change score and not the quality of the measurement and is therefore insufficient to assess this measurement property.[264] Responsiveness refers to the validity of a change score and should be assessed with, for example, hypothesis testing against the change score of another related PROM, analogous to the assessment of construct validity.

Measurement error was poorly reported in the included studies and the minimal important change (MIC) was calculated for only one of the PROMS – the Dutch-version of WOMET.[281] It was concerning that in this case the MIC was found to be less than the smallest detectable change (SDC) due to measurement error. Failure to determine and report this information affects the ability of researchers to design high-quality prospective studies and limits interpretation of previous work. Other important measurement properties, for group comparisons, include the minimal clinical important difference (MCID) and patient acceptable symptom state (PASS).[300,301] MCID is a measure that is related to MIC but applicable to differences between groups rather than within group or individual change.[300,301] PASS is the level of symptoms for a specific condition that patients will tolerate and still consider themselves "well".[301] Although these measurement properties are not specifically evaluated by COSMIN, the findings reported in this chapter confirm previous reports that the MCID and PASS are unknown for PROMs in patients with meniscal tears.[302] This is a major limitation of the current evidence in the context of clinical trial design and interpretation.

Evidence for the content validity of the available PROMs was limited. Only the KQoL-26 and WOMET were developed with involvement from patients with meniscal tears. Overall, there was heterogeneity in the population of patients recruited to the included studies as shown in Table 5.2. Although most patients in the included studies had meniscal tears as their primary diagnosis, many also had a diagnosis

of ligament injury or chondral damage. This reflects the heterogeneity of patients with meniscal tears in general, ranging from the isolated traumatic tear in a young athlete without osteoarthritis to atraumatic tears in older patients with osteoarthritis. Meniscal tears are not always symptomatic, and given the association with osteoarthritis, the distinction between the onset of meniscal pain and osteoarthritic pain is often unclear.[104,119] No single patient factor is sufficient in isolation.[208] For example, the degenerative meniscus will be more susceptible to tearing following knee trauma than a normal meniscus and no difference in symptom profile or treatment response has been demonstrated based on the mechanism of symptom onset.[303,304]

For studies in this review, there was significant variation in the methods used to identify patients. Several studies included only patients with meniscal tears verified by previous arthroscopic surgery whereas others verified meniscal tears were visible on MRI imaging. For all the included studies, it was unclear how patients were identified to have symptoms correlating with a meniscal tear rather than other pathology such as osteoarthritis. Identifying patients with symptoms that definitely originate from the meniscus is challenging for both clinicians and researchers (see section 1.6.4).

The mean age range of patients included in the studies was 38-53 years and therefore the generalisability of the findings to other age groups is unclear. It is highly likely that the symptom profile and expectations of younger, active patients sustaining a tear to a normal meniscus in an otherwise normal knee will be different to the patients with predominantly "degenerative" meniscal tears and underlying osteoarthritis. This has not yet been evaluated.

5.5.3 Strengths and limitations

One strength of this review is the use of a validated, highly-sensitive search strategy to identify relevant studies.[267] The rigorous COSMIN methodology was followed and only studies specifically designed to appraise the measurement properties of PROMs were included. Trials and other clinical studies of patients with meniscal tears were therefore not included as these studies are not designed to assess

measurement properties and the reporting of these properties would be highly unusual. For the same reason, clinical trial registries were not searched for ongoing studies.

This is the first review of PROMs for patients with meniscal tears and the first to apply the COSMIN checklist, which is a validated and accepted tool for the appraisal of study quality. Although it has been shown to have acceptable inter-rater and intra-rater properties, the scoring of some items is reliant on reviewer judgement.[305] Pre-testing was performed to ensure scoring consistency and reviewers scored studies independently with any disagreement being settled by consensus or discussion with a third reviewer. Nevertheless, it is feasible that another review team might score some items differently.

Currently, although a wide range of PROMs are available for patients with knee conditions, the PROMs that have been tested in patients with meniscal tears all lack data on a large proportion of measurement properties. This is disappointing given moves to select condition-specific, standardised, 'core' outcome sets for use in clinical trials and general clinical evaluation.[79] Considerable further work is required before this will be possible for patients with meniscal tears.

For the assessment of symptoms and functional status in patients with meniscal tears, there is currently only very limited evidence supporting the selection of the English-version of Lysholm or IKDC, or Dutch-version of KOOS. Although the total score of these three PROMs does not exhibit floor or ceiling effects, a considerable number of sub-domain items from both IKDC and Lysholm were reported to have unacceptable floor or ceiling effects. For health-related quality of life, only limited evidence supports the selection of WOMET. One study suggests that measurement error may limit the ability of the WOMET to detect the minimal important change in score for meniscal patients.[281] Several WOMET sub-domain items, but not the total score, have been reported to exhibit unacceptable floor or ceiling effects. For assessment of activity level, only the Tegner activity scale has been evaluated and only very limited evidence is available.

Of all the PROMs evaluated, WOMET has the strongest evidence for content validity. In common with many of the validation studies in this population, however, the included patients frequently had other diagnoses in the same knee such as ligament injuries or chondral defects. This impacts upon the interpretation of clinical evidence in sub-groups of patients that were poorly represented within the development or validation study population. The findings of these validation studies may not be generalisable to such sub-groups and a PROM may fail to detect important clinical differences. Further validation studies may be required in sub-groups or the development of a more specific outcome measure may be necessary.[306] Further work is required, targeting the deficiencies highlighted by this systematic review, to ensure these PROMs truly reflect the symptoms, function, and quality of life of patients with meniscal lesions.

5.5.4 Conclusion

Many PROMs have been used in clinical studies of patients with meniscal lesions but the overall quality of evidence supporting the validity of these PROMs is limited. For measurement of symptoms and functional status, there is only very limited evidence supporting the selection of either the Lysholm Knee Scale, International Knee Documentation Committee Subjective Knee Form or the Knee injury and Osteoarthritis Outcome Score. For measuring health-related quality of life, only limited evidence supports the selection of the Western Ontario Meniscal Evaluation Tool (WOMET). Of all the PROMs evaluated, WOMET has the strongest evidence for content validity. The findings reported in this chapter inform the interpretation of clinical studies of arthroscopic partial meniscectomy in patients with meniscal tears, including the summary findings of the systematic review reported in the next chapter.

6 A SYSTEMATIC REVIEW OF THE BENEFITS OF ARTHROSCOPIC PARTIAL MENISCECTOMY[§]

6.1 Introduction

Chapters 3 and 4 report a high-level of temporal, geographic, and patient age-group variation in both the APM intervention rate in England and rate of subsequent knee arthroplasty within one-year. These findings may be indicative of some degree of overuse of APM in the population and undesirable outcomes in some patients. The findings in these chapters suggest a need to standardise treatment selection to improve the care pathway for this population. In order to inform the development of treatment guidance, however, it is crucial to first understand the evidence regarding the effectiveness of APM in different patient groups.

For measuring the benefit associated with undergoing treatment for a meniscal lesion, Chapter 5 reports that limited evidence supports the use of the Lysholm knee scale, IKDC, KOOS, or WOMET patient-reported outcome measures. This information was not previously available to inform the interpretation of outcomes reported in this population. Furthermore, no review has been performed including the most recently reported trials and, in some cases, reviews have included trials of interventions other than APM, such as arthroscopic washout for osteoarthritis, in their evidence synthesis.[204–207] Importantly, previous reviews have also not stratified the clinical trial evidence according to patient factors such as the severity of any associated osteoarthritis or stability of the meniscal tear (see section 1.6). To inform management decisions, and for the development of treatment guidance, there is a need to consider the impact of these patient factors on outcomes.

[§] *The content of this chapter has been published, in part, as: Abram SGF, Hopewell S, Monk AP, Bayliss LE, Beard DJ, Price AJ. Arthroscopic partial meniscectomy for meniscal tears of the knee: a systematic review and meta-analysis. Br J Sports Med. 2019;bjsports-2018-100223.*

6.2 Aims

The aim of the systematic review reported in this chapter was to appraise the clinical trial evidence informing on the benefit and risk from undergoing APM, with stratification by comparator intervention and clinical and radiological criteria.

6.3 Methods

This systemic review was conducted following the methods of the Cochrane Handbook for Systematic Reviews and reported in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) statement.[262,307] The protocol for this review was published on PROSPERO (CRD42017056844) on 22/02/2017.

Study eligibility criteria

Participants

Studies of adults (18 years of age and older) with meniscal tears of the knee were included. Studies of individuals with other injuries to the knee (e.g. ACL ligament injury, fracture), previous surgery to the knee (e.g. ligament reconstruction, arthroscopy) or anatomical variants (e.g. discoid meniscus) were excluded.

Three population groups with knee pain and a meniscal tear were considered based on the presence or absence of structural osteoarthritis and types of meniscal tear (the importance of these factors is introduction in section 1.6). This stratification was performed as it has been postulated that if the population selection criteria are defined more specifically, then the effectiveness of the intervention may be different.[208,219–221,223] As introduced above, this has not been considered by previous systematic reviewers (see section 6.1). The groups considered were: (A) all patients (any type of meniscal tear with or without radiographic osteoarthritis); (B) patients with any type of meniscal tear in a non-osteoarthritic knee; (C) patients without osteoarthritis and with an unstable meniscal tear as defined by symptoms (meniscal or ‘mechanical’ symptoms – author definition) and the pattern of the meniscal tear

on MRI imaging (author definition). Group (A) is the most mixed group representing relatively non-specific selection criteria for APM, where effectiveness may be inconsistent between patients and limited overall at a population level, and group (B) restricts selection further to patients without osteoarthritis but still any, non-specific, pattern of meniscal tear lesion. Group (C) represents a patient population that may be 'ideal candidates' for APM based on these clinical and radiological criteria.[208] Table 6.1 summarises the characteristics of the three population groups considered.

Severity of osteoarthritis is recognised as a key selection factor and, in accordance with previously published consensus, osteoarthritis was defined radiographically as Kellgren-Lawrence grade 2 or greater changes on a plain x-ray radiograph of the knee (or equivalent).[12,207,208] As described earlier (section 1.8.3), although mechanical symptoms and unstable meniscal tears have been defined and investigated by several groups, there is a lack of agreement in published definitions.[110,208,308–311] Therefore, for the purposes of the review in this chapter, study author definitions of these terms were accepted for inclusion in group (C) (Table 6.1).

Table 6.1: Characteristics of population groups evaluated

Group	Severity of radiographic osteoarthritis (OA)	Type of meniscal tear	Corresponding symptoms
(A)	Any (K-L 0-4)	Any	Pain
(B)	Without OA (K-L 0-1)	Any	Pain
(C)	Without OA (K-L 0-1)	Unstable (author definition)	Meniscal (author definition)

Note: K-L=Kellgren-Lawrence grade

Intervention

Studies of APM as the primary intervention were included. Studies of open or 'total' meniscectomy were excluded.

Comparators

The following comparators were included and analysed separately: (1) Non-surgical (e.g. physiotherapy, exercise therapy); (2) Pharmacological (e.g. NSAIDS, intra-articular steroid injection);

(3) Surgical (e.g. arthroscopic lavage, diagnostic arthroscopy, sham surgery, placebo surgery); (4) No intervention (e.g. waiting list, active monitoring). Studies with other surgical intervention comparators (e.g. open meniscectomy, meniscal repair, allograft or implant transplantation, chondroplasty) were excluded. Placebo surgery was defined as diagnostic arthroscopy with omission of partial meniscectomy as the 'critical element'.[312] Sham surgery was defined as a procedure requiring an anaesthetic and surgical skin incision but without any knee arthroscopy procedure (diagnostic, washout, other) being performed.

6.3.1 Outcomes

The primary outcomes assessed were knee function and knee pain, as measured using a patient-reported outcome measure (PROM) (e.g. Lysholm knee scale, Knee injury and Osteoarthritis Outcome Score [KOOS] pain scale, respectively) (see also Chapter 5).[313] As the minimum clinically important difference (MCID) is unknown in this population, an estimated MCID, based on results in patients with osteoarthritis, was used to interpret clinical effectiveness (as described, where applicable, in the Results sections below and discussed further in section 6.5.3).[302,314–316] Secondary outcomes assessed, where reported, were knee-specific quality of life (e.g. KOOS quality of life, Western Ontario Meniscal Evaluation Tool [WOMET]) and generic health-related quality of life (e.g. EuroQol five dimensions questionnaire [EQ-5D]), presence of knee 'mechanical symptoms' (e.g. sub-domain Lysholm or Meniscal Symptom Index); and activity level (e.g. Tegner); and number of individuals requiring repeat surgery (e.g. further arthroscopy, knee replacement); number of individuals developing complications (e.g. venous thromboembolism, infection, mortality). Outcomes were assessed at 6 to 12 months (mid-term) follow up. If both 6- and 12-month data were reported, the 12-month data was included in the meta-analysis. In addition, analysis of early (under 6 months) and long term (over 12 months) outcome was performed where data were available.

6.3.2 Information sources and search strategy

A search of MEDLINE, Embase, CENTRAL, Scopus and Web of Science was performed (24/03/2017; updated 12/04/2018 and 18/10/2018), unlimited by language or publication date. The search was designed and performed in collaboration with an independent information specialist (SA and EH); full details are available in Appendix F. Clinical trial registries (clinicaltrials.gov and ISRCTN) were also searched (SA) to identify ongoing and recently completed studies. Randomised controlled trials (RCTs; including quasi-randomised) were eligible for inclusion. When no trial was identified which included patients with the previously described characteristics (group C), the cohort evidence was reviewed in this context to provide narrative results, where applicable, for this group.

6.3.3 Study selection and data extraction

The title and abstract of the search results was screened by two reviewers (SA and AM/LB). The full text articles were retrieved for all studies meeting the inclusion criteria. Where there was disagreement on inclusion of a study based on the title and abstract, the full text article was retrieved, and inclusion decided by consensus.

Data was extracted using a previously piloted data extraction form. Data items extracted included study design, study centres and location, length of follow up, funding source and conflicts of interest, inclusion and exclusion criteria, number of randomised participants, number lost to follow up, number analysed, baseline demographics including age and gender, details of the intervention and comparator delivered. Final value outcome data was extracted for the primary and secondary outcomes.

6.3.4 Risk of bias

Studies meeting the inclusion criteria were formally evaluated for risk of bias using the Cochrane 'risk-of-bias tool', assessing for selection bias, performance bias, detection bias, attrition bias, reporting bias, other bias (including baseline imbalance and cross-over).[317] Two reviewers (SA and SH) assessed each

of the included studies and each potential source of bias was graded as high, low or unclear risk of bias; any disagreements were resolved by consensus.[317]

6.3.5 Data synthesis

Meta-analyses were undertaken where studies were considered sufficiently similar (clinically and methodologically) and reported for the relevant population group. Where studies met criteria for inclusion, but published data was inadequate for meta-analysis, study authors were contacted to request appropriate summary or raw data for inclusion. In addition, unpublished sub-group data was requested from the authors of included studies.

Data were analysed separately to compare the effects of APM versus each of the main comparator interventions: (1) Non-surgical (e.g. physiotherapy, exercise therapy); (2) Pharmacological (e.g. NSAIDS, intra-articular steroid injection); (3) Surgical (e.g. arthroscopic lavage, diagnostic arthroscopy, sham surgery, placebo surgery); (4) No intervention (e.g. waiting list, active monitoring).

The standardised mean difference (SMD) with 95% confidence intervals (CIs) was used to pool the results of individual trials for continuous outcomes measured using different scales. The mean difference (MD) and 95% CIs were used for pooling continuous outcomes measured using the same scale. When considered appropriate, a random effects model was used to pool results of comparable groups of trials in a meta-analysis. Scales were transformed if required to ensure that a higher score indicated a better outcome. If the standard deviation (SD) or mean was not reported in the original article, where possible, it was calculated from the reported data, obtained directly from the study authors, or estimated using established methods.[307,318]

6.3.5.1 Summary of findings tables

A Summary of Findings table was constructed for the two comparisons with more than one trial: APM versus Non-surgical intervention (physiotherapy), and versus Surgical intervention (placebo surgery,

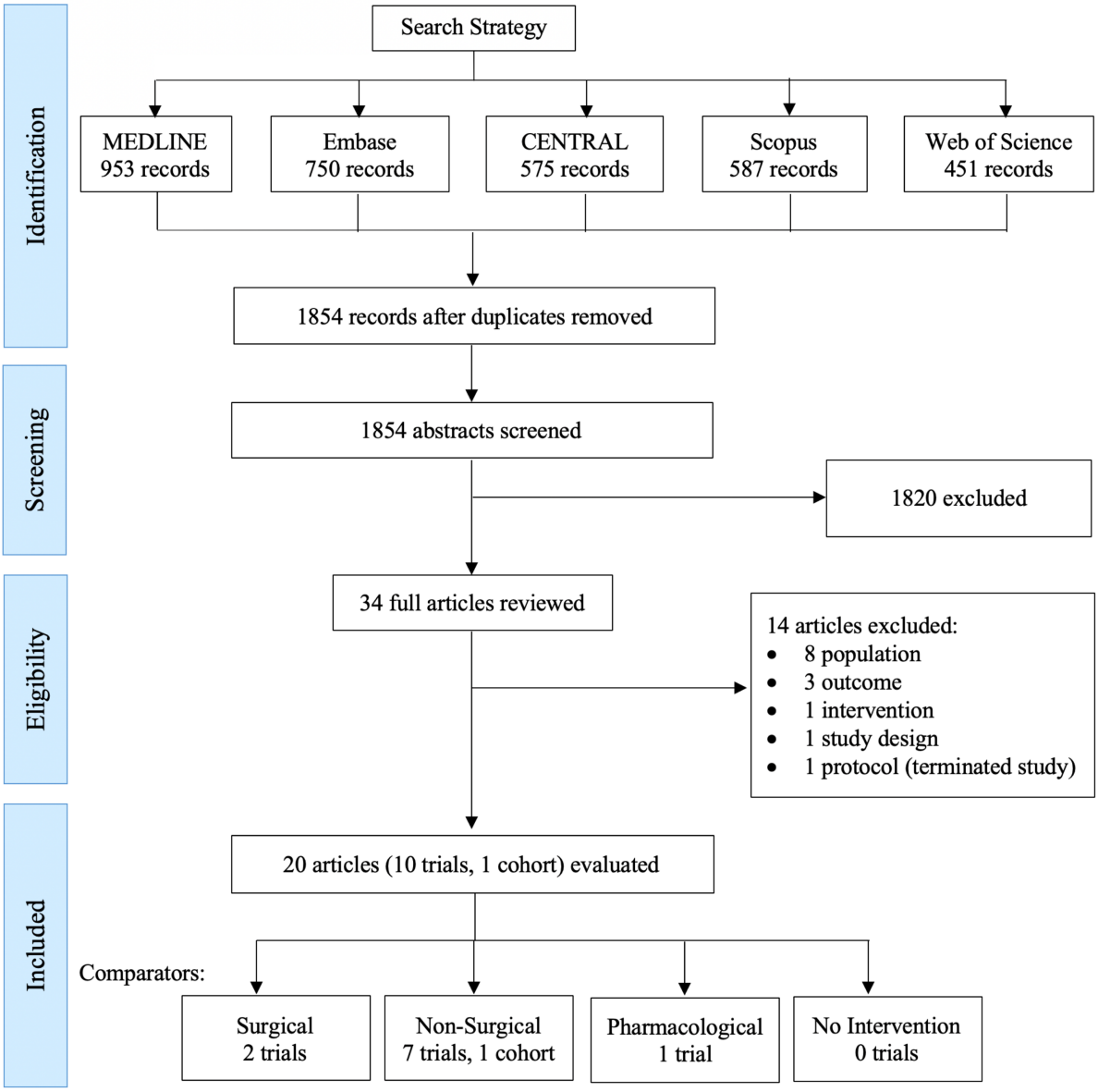
sham surgery). The outcomes included were: knee function, knee pain, knee-specific quality of life, and generic quality of life. GRADE (Grading of Recommendations Assessment, Development and Evaluation) considerations (risk of bias, consistency of effect, imprecision, indirectness, publication bias) were assessed and used to summarise the quality of the study evidence that contributed data to each outcome.[319]

6.4 Results

The search strategy identified 1854 unique articles for screening. After screening, 34 full text articles were retrieved of which 20 articles (reporting 11 studies) were eligible for evaluation. Ten studies were RCTs (published in 19 articles) and one was a cohort study (1 article). The study selection process is summarised in the PRISMA flow diagram (Figure 6.1). Excluded studies are listed in Appendix G. Unpublished data were requested from the authors of all included studies, with data subsequently provided for four studies (Gauffin 2014; Kise 2016; Roos 2018; Van de Graaf 2018).[198,199,320,321] The search of clinical trial registries identified three ongoing studies (Appendix H).[322–326]

Seven RCTs (Herrlin 2007; Katz 2013; Osteras 2012; Yim 2013; Gauffin 2014; Kise 2016; Van de Graaf 2018) compared the effects of APM versus non-surgical interventions.[196,198–200,202,321,327] One RCT (Vermesan 2013) compared the effects of APM versus pharmacological interventions.[201] Two RCTs (Sihvonen 2013; Roos 2018) compared the effects of APM versus surgical interventions.[198,320] No studies were identified comparing the effects of APM versus no intervention. The characteristics of the included studies are summarised in Table 6.2. Full details of the inclusion, exclusion criteria, delivery of the intervention and comparator interventions, location and funding are included in Appendix I.

Figure 6.1: PRISMA flow diagram



Note: Full search strategy is available in Appendix F.

6.4.1 (1) Arthroscopic partial meniscectomy versus non-surgical interventions

6.4.1.1 Study characteristics

Eight studies (7 RCTs and one cohort study) were identified, including a total of 1186 participants randomised with a mean age of ranging from 47 to 58 years.[196,198–200,202,321,327] All RCTs included a physiotherapy comparator (intervention delivered for between 6 weeks and 3 months) with follow-up ranging from 3 months to 60 months (Table 6.2). All the RCTs included at least one outcome measure

with some supporting validation evidence for patients with meniscal tears (Chapter 5), however, as explained above (6.3.1), because the minimum clinically important difference (MCID) is unknown in this population, an estimated MCID, based on results in patients with osteoarthritis, was used to interpret the findings (as described, where applicable, below).[302,314–316] All seven RCTs were eligible for analysis in group A; data from four RCTs (after receipt of unpublished data) excluding patients with osteoarthritis were eligible for analysis in group B.

6.4.1.2 Risk of bias

All seven RCTs were rated at high risk of performance and detection bias due to a lack of blinding. The method of random sequence generation was unclear in four RCTs and allocation concealment was unclear in four (Table 6.2). One RCT was rated at high risk of attrition bias due to greater than 10% loss to follow up. Five were rated at high risk of bias due to cross-over rates exceeding 10% of non-surgical participants (other bias) (Table 6.2).

6.4.1.3 Knee Pain

(A) All patients (any type of meniscal tear with or without radiographic osteoarthritis)

There was some improvement in knee pain following APM compared to physiotherapy at 6-12 months (SMD 0.22 [95% CI 0.03 to 0.40]; 5 trials, 943 patients; I^2 48%; GRADE: Low) (Figure 6.2A). This is the equivalent of a mean difference (MD) of 4.10 KOOS [0.74 to 7.46], measured using the KOOS pain scale, where the MCID is estimated to be around 8-10.[314,315] There was no difference at under 6 months (SMD 0.18 [95% CI -0.00 to 0.37]; 2 trials, 434 patients; I^2 0%; GRADE: Very low) but some improvement at over 12 months (SMD 0.22 [95% CI 0.04 to 0.40]; 3 trials, 484 patients; I^2 0%; GRADE: Very low) (Table 6.3; Appendix J).

(B) Patients with any type of meniscal tear in a non-osteoarthritic knee

There was some improvement in knee pain following APM compared to physiotherapy at 6-12 months (SMD 0.35 [95% CI 0.04 to 0.66]; 3 trials, 402 patients; I^2 58%; GRADE: Very low) (Figure 6.2B). This is the equivalent of a mean difference (MD) of 6.91 [95% CI 2.87 to 10.94]; measured using the

KOOS pain scale, where the MCID is estimated to be around 8-10.[314,315] There was also no difference at under 6 months (SMD 0.16 [95% CI -0.25 to 0.57]; 2 trials, 306 patients; I^2 68%; GRADE: Very low) or over 12 months (SMD 0.21 [95% CI 0.00 to 0.42]; 3 trials, 368 patients; I^2 0%; GRADE: Very low) (Table 6.3; Appendix J).

(C) Patients with an unstable meniscal tear in a non-osteoarthritic knee

One cohort study was identified in patients undergoing physiotherapy, with patients still complaining or unsatisfied on completion of treatment being offered APM.[328] This cohort reported failure of physical therapy in all 50 included patients after a period of 8 weeks due to no significant change in visual analogue pain scores (VAS). All 50 patients subsequently opted to undergo APM and a significant improvement in patient-reported pain was reported at average 12.5 months follow-up.

6.4.1.4 Knee Function

(A) All patients (any type of meniscal tear with or without radiographic osteoarthritis)

There was some improvement in knee function following APM versus non-surgical treatment at 6-12 months (SMD 0.18 [95% CI 0.04 to 0.33]; 6 trials, 1050 patients; I^2 27%; GRADE: Low) (Figure 6.3A), equivalent to a MD 3.36 [95% CI 0.55 to 6.16], measured using the Lysholm scale, where the MCID is estimated to be around 8-10 as measurement properties are similar to KOOS.[302,314,315] There was no difference at under 6 months (SMD 0.08 [95% CI -0.08 to 0.25]; 4 trials, 561 patients; I^2 0%; GRADE: Low) but some improvement at over 12 months (SMD 0.18 [95% CI 0.04 to 0.33]; 5 trials, 730 patients; I^2 0%; GRADE: Low) (Table 6.3; Appendix J).

(B) Patients with any type of meniscal tear in a non-osteoarthritic knee

There was some improvement in knee function following APM versus non-surgical treatment at 6-12 months (SMD 0.30 [95% CI 0.06 to 0.53]; 4 trials, 507 patients; I^2 44%; GRADE: Very low) (Figure 6.3B), equivalent to a MD of 5.31 [95% CI 1.12 to 9.51], measured using the Lysholm scale, where the MCID is estimated to be around 8-10 as measurement properties are similar to KOOS.[302,314,315] There was also no difference at under 6 months (SMD 0.11 [95% CI -0.13 to 0.35]; 3 trials, 411 patients; I^2

33%; GRADE: Low) but some improvement at over 12 months (SMD 0.19 [95% CI 0.01 to 0.36]; 4 trials, 501 patients; I^2 0%; GRADE: Low) (Table 6.3; Appendix J).

(C) Patients with an unstable meniscal tear in a non-osteoarthritic knee

One cohort study was identified with patients undergoing a physiotherapy programme, with patients still complaining or unsatisfied after completion of this treatment being offered APM.[328] In this study, the authors defined an unstable meniscal tear using previously published MRI based radiological criteria and also corresponding positive "McMurray test" on clinical examination.[110,328] This cohort reported failure of physical therapy in all 50 included patients after a period of 8 weeks due to no significant change in function (Lysholm knee scale). All 50 patients subsequently opted to undergo APM and a significant improvement in patient-reported function was reported at average 12.5 months follow-up.

6.4.1.5 Knee specific and generic quality of life

(A) All patients (any type of meniscal tear with or without radiographic osteoarthritis)

There was improvement in knee-specific quality of life following APM compared to non-surgical treatment at 6-12 months (SMD 0.43 [95% CI 0.10 to 0.75]; 3 trials, 350 patients; I^2 44%; GRADE: Low) (Figure 6.4A). This is the equivalent of a mean difference (MD) of 10.36 [95% CI 3.58 to 17.14], measured using the KOOS quality of life scale, where the MCID is estimated to be around 8-10.[314,315] There was also improvement at under 6 months (SMD 0.45 [95% CI 0.10 to 0.80]; 1 trial, 129 patients; GRADE: Low), and over 12 months (SMD 0.30 [95% CI 0.05 to 0.56]; 2 trials, 245 patients; I^2 0%; GRADE: Very low) (Table 6.3 ; Appendix J). There was no difference in generic quality of life following APM versus non-surgical treatment at 6-12 months (SMD 0.01 [95% CI -0.34 to 0.35]; MD 0.00 EQ-5D [95% CI -0.06 to 0.06]; 1 trial, 130 patients; GRADE: Low) but a difference was reported at over 12 months (SMD 0.47 [95% CI 0.10 to 0.85]; MD 0.10 EQ-5D [95% CI 0.02 to 0.18]; 1 trial, 113 patients; GRADE: Very low) (Table 6.3). For EQ-5D, a MCID of 0.15 is proposed.[316]

(B) Patients with any type of meniscal tear in a non-osteoarthritic knee

There was improvement in knee-specific quality of life following APM compared to non-surgical treatment at 6-12 months (SMD 0.59 [95% CI 0.11 to 1.07]; 2 trials, 244 patients; I^2 65%; GRADE: Low) (Figure 6.4B). This is the equivalent of a mean difference (MD) of 12.89 [95% CI 3.60 to 22.18], measured using the KOOS quality of life scale, where the MCID is estimated to be around 8-10.[314,315] There was also improvement at under 6 months (SMD 0.52 [95% CI 0.16 to 0.87]; 1 trial, 124 patients; GRADE: Low), and over 12 months (SMD 0.39 [95% CI 0.13 to 0.65]; 2 trials, 231 patients; I^2 0%; GRADE: Low) (Table 6.3; Appendix J). There was no improvement in generic quality of life at 6-12 months (SMD 0.06 [95% CI -0.30 to 0.42]; MD 0.01 ED-5D [95% CI -0.05 to 0.08]; 1 trial; 119 patients; GRADE: Low) but a significant difference was reported at over 12 months (SMD 0.63 [95% CI 0.23 to 1.02]; MD 0.13 EQ-5D [95% CI 0.05 to 0.21]; 1 trial, 105 patients; GRADE: Very low) (Table 6.3). For EQ-5D, a MCID of 0.15 is proposed.[316]

(C) Patients with an unstable meniscal tear in a non-osteoarthritic knee

No studies were identified.

6.4.1.6 Other outcomes

(A) All patients (any type of meniscal tear with or without radiographic osteoarthritis)

Herrlin 2007 reported activity level at 6-12 months. After 8 weeks 18 of 47 patients (42%) in the APM group and 22 of 43 patients (51%) in the physiotherapy group had reached their pre-injury activity level.[200] This was the same after 6 months for the APM group, but not for the physiotherapy group, where 17 of 43 patients (40%) had reached their pre-injury activity level.[200] Thirteen patients (28.2%; 13/46) that were treated with physiotherapy "did not feel better after the treatment but were improved after arthroscopic surgery" performed at average 6.5 months.[329] Van de Graaf 2018 reported activity level data using the Tegner scale. At 12 months, there was no significant difference in the activity level for participants in group A (MD 0.048; 95% CI -0.36 to 0.46) or group B (MD -0.07; 95% CI -0.63 to 0.49).[321]

Katz 2013 reported that by 6 months, 30.2% (51/169) of patients randomised to physiotherapy had undergone APM. In this study, over the 12-month period of follow-up, serious adverse events occurred in 1.7% (3/174) patients randomised to APM and 1.1% (2/177) randomised to physiotherapy (including one death in each group); adverse events rated as mild or moderate in severity occurred in 8.6% (15/174) participants in the APM group and 7.3% (13/177) participants in the physiotherapy group.[196] Total knee replacement was performed in 2.9% (5/174) participants assigned to arthroscopic partial meniscectomy and 1.7% (3/177) participants assigned to physical therapy.[196] Yim 2013 reported cross-over of 1.9% (1/54) of participants randomised to physiotherapy undergoing APM.[202] Gauffin 2014 reported 21.3% (16/75) of patients crossed-over from the non-surgery group to undergo arthroscopy.[199] Kise 2016 reported that 18.6% (13/70) in the physiotherapy group crossed-over to undergo APM at mean 7.7 months and achieved a similar outcome to patients responding to physiotherapy without cross-over.[202] Two participants (3%) in the APM group were subsequently re-operated on and one participant who had crossed over underwent another operation six months after the primary operation.[202] One participant in the APM group and one participant who crossed over from the exercise to APM group underwent osteotomy.[202] Van de Graaf 2018 reported cross-over of 29% (47/162) of participants randomised to physiotherapy undergoing APM.[321] Van de Graaf 2018 reported "serious" adverse events (including repeat surgery, cardiovascular, neurological, general medical conditions, venous thromboembolism) in 5.66% (9/159) APM patients and 4.94% (8/162) physiotherapy patients.[321] Two patients (1.26%; 2/159) in the APM group underwent knee arthroplasty within 2 years.[321]

6.4.2 (2) Arthroscopic partial meniscectomy versus pharmacological comparators

6.4.2.1 Study characteristics

One RCT comparing APM to intra-articular steroid injection was identified, including 114 randomised patients with a mean age of 58 (Table 6.2; Appendix J).[201] Patients were followed up at 1 month and 12 months and only the Oxford Knee Score (pain and function) and repeat operation data was reported. Although the Oxford Knee Score has been extensively validated for patients with osteoarthritis, no supporting validation evidence is available for the meniscal tear population (Chapter 5).[300,330] A MCID

of 5 points is proposed for the Oxford Knee Score for patients with osteoarthritis and was used to aid the interpretation of the clinical effectiveness findings below.[300] This RCT included patients with osteoarthritis and was therefore only eligible for analysis in group A.

6.4.2.2 Risk of bias

A summary of the risk of bias assessment is shown in Table 6.2. This study was rated at high risk of performance and detection bias due to a lack of blinding. The method of random sequence generation and allocation concealment was unclear. The rate of loss to follow up was 14.0% (n=16/114) and therefore the trial was rated at high risk of attrition bias. The trial was also rated at high risk of bias due to a cross-over rate exceeding 10% of non-surgical participants (20.8%; other bias).

6.4.2.3 Knee pain and function

(A) All patients (any type of meniscal tear with or without radiographic osteoarthritis)

There was no improvement following APM versus intra-articular steroid injection at 6-12 months (SMD 0.38 [95% CI -0.02 to 0.78]; 1 trial; 98 patients; GRADE: Low). This corresponds to a mean difference (MD) of 1.40 [95% CI -0.07 to 2.87], using the Oxford Knee Score from 0 (severe symptoms) to 48 (no symptoms), where a MCID of 5 points is proposed for patients with osteoarthritis.[300] There was some improvement at under 6 months (SMD 0.82 [95% CI 0.41 to 1.23]; MD 2.90 Oxford Knee Score [95% CI 1.50 to 4.30]; 1 trial; 98 patients; GRADE: Low).

(B) Patients with any type of meniscal tear in a non-osteoarthritic knee AND

(C) Patients with an unstable meniscal tear in a non-osteoarthritic knee

No studies were identified.

6.4.2.4 Other outcomes

(A) All patients (any type of meniscal tear with or without radiographic osteoarthritis)

The RCT reported that by 1 year, 4.2% (5/120) had undergone total knee replacement. At 1 month, 25% (12/48) patients in the steroid group and 14% (7/50) had persisting symptoms and received an additional steroid injection. By one year, 20.8% (10/48) steroid group patients crossed-over and underwent knee arthroscopy which "amended the symptoms" in 7/10 (70%). No adverse event or activity level data was reported.

(B) Patients with any type of meniscal tear in a non-osteoarthritic knee AND

(C) Patients with an unstable meniscal tear in a non-osteoarthritic knee

No studies were identified.

6.4.3 (3) Arthroscopic partial meniscectomy versus surgical interventions

6.4.3.1 Study characteristics

Two RCTs (Sihvonen 2013; Roos 2018) were identified, including a total of 190 participants' randomised with a mean age of 46 and 52 years respectively.[198,320] One RCT (Sihvonen 2013) compared the effect of APM versus placebo surgery (diagnostic arthroscopy).[197] The other RCT (Roos 2018) compared the effect of APM versus sham surgery (skin incisions only) (Table 2).[320] Both RCTs included at least one outcome measure with some supporting validation evidence for patients with meniscal tears (Chapter 5), however, as explained earlier and in section 6.3.1, because the MCID is unknown in this population, an estimated MCID, based on results in patients with osteoarthritis, was again used to interpret the findings (as described, where applicable, below).[302,314–316] Available study data for both RCTs excluded patients with osteoarthritis and were eligible for analysis in group A and group B.

6.4.3.2 Risk of bias

A summary of the risk of bias assessment for the included studies is shown in Table 6.2. One study (Roos 2018) was rated at high risk of bias due to a high proportion (36%) of patients randomised to the comparator intervention 'crossing-over' to undergo APM before final follow up (other bias).

6.4.3.3 Knee Pain

(A) All patients (any type of meniscal tear with or without radiographic osteoarthritis) AND

(B) Patients with any type of meniscal tear in a non-osteoarthritic knee

There was no improvement in knee pain in those patients who received APM compared to those who received placebo surgery at 6-12 months (SMD 0.08 [95% CI -0.24 to 0.41]; 1 trial, 146 patients; GRADE: Low). This is the equivalent of a mean difference (MD) of 2.00 [95% CI -5.69 to 9.69] measured using the KOOS pain scale from 0 (worse) to 100 (better) where a MCID is estimated to be around 8-10.[314,315] There was also no improvement in knee pain in comparison to sham surgery at under 6 months (SMD 0.26 [95% CI -0.41 to 0.93]; 1 trial; 35 patients; GRADE: Low). At over 12 months, there was improvement in patients receiving APM in comparison to sham surgery (SMD 0.72 [95% CI 0.02 to 1.42]; 1 trial, 34 patients; GRADE: Low) equivalent to a mean difference of 17.50 [95% CI 1.16 to 33.84] measured using the KOOS pain scale. There was no improvement in comparison to placebo surgery (SMD 0.00 [95% CI -0.33 to 0.33]; MD 0.00 KOOS pain [95% CI -8.35 to 8.35]; 1 trial; 144 patients; GRADE: Low) or combining the placebo and sham surgery trials (SMD 0.29 [95% CI -0.40 to 0.99]; 2 trials, 178 patients; I^2 71%; GRADE: Very low) (Table 6.4; Appendix J).

(C) Patients with an unstable meniscal tear in a non-osteoarthritic knee

No studies were identified.

6.4.3.4 Knee Function

(A) All patients (any type of meniscal tear with or without radiographic osteoarthritis) AND

(B) Patients with any type of meniscal tear in a non-osteoarthritic knee

There was no improvement in knee function following APM compared to placebo surgery at 6-12 months (SMD -0.08 [95% CI -0.41 to 0.24]; 1 trial, 146 patients; GRADE: High); equivalent of a MD of -1.55 [95% CI -7.95 to 4.66] measured using the Lysholm scale from 0 (worse) to 100 (better), where the MCID is estimated to be around 8-10 as measurement properties are similar to KOOS.[302,314,315] There was also no improvement versus sham surgery at under 6 months (SMD 0.07 [95% CI -0.60 to 0.73]; 1

trial; 35 patients; GRADE: Low). At over 12 months, there was no improvement in participants receiving APM in comparison to sham surgery (SMD 0.63 [95% CI -0.06 to 1.32]; MD 12.2 Lysholm [95% CI -1.16 to 25.6]; 1 trial, 34 patients; GRADE: Low) or placebo surgery (SMD -0.18 [95% CI -0.51 to 0.14]; MD -3.49 Lysholm [95% CI -9.89 to 2.72]; 1 trial; 144 patients; GRADE: Low). Combining placebo and sham surgery trials, there was no difference at over 12 months (SMD 0.16 [95% CI to -0.62 to 0.95]; 2 trials, 178 patients; I^2 77%; GRADE: Very low) (Table 6.4; Appendix J).

(C) Patients with an unstable meniscal tear in a non-osteoarthritic knee

No studies were identified.

6.4.3.5 Knee-specific and generic quality of life

(A) All patients (any type of meniscal tear with or without radiographic osteoarthritis) AND

(B) Patients with any type of meniscal tear in a non-osteoarthritic knee

There was no improvement in knee-specific quality of life following APM compared to placebo surgery at 6-12 months (SMD 0.05 [95% CI -0.27 to 0.38]; 1 trial, 146 patients; GRADE: High). This is the equivalent of a mean difference (MD) of 1.10 [95% CI -5.64 to 7.84] measured using the KOOS quality of life scale from 0 (worse) to 100 (better), where the MCID is estimated to be around 8-10.[314,315] There was also no difference at under 6 months in comparison to sham surgery (SMD 0.25 [95% CI -0.42 to 0.91]; 1 trial; 35 patients; GRADE: Low). At over 12 months, there was no improvement in participants receiving APM in comparison to sham surgery (SMD 0.65 [95% CI -0.04 to 1.35]; MD 16.50 KOOS quality of life [95% CI -0.27 to 33.27]; 1 trial, 34 patients; GRADE: Low) or placebo surgery (SMD -0.01 [95% CI -0.34 to 0.32]; MD -0.20 KOOS quality of life [95% CI -6.27 to 5.87]; 1 trial; 144 patients; GRADE: Low). Combining placebo and sham surgery trials, there was no difference at over 12 months (SMD 0.25 [95% CI -0.39 to 0.88]; 2 trials, 178 patients; I^2 70%; GRADE: Very low) (Table 6.4; Appendix J). There was no improvement in generic health-related quality of life following APM versus placebo surgery at 6-12 months (SMD 0.23 [95% CI -0.09 to 0.56]; 1 trial, 146 patients; GRADE: High), equivalent to a mean difference (MD) of 0.02 [95% CI -0.01 to 0.05], measured using EQ-5D, where the MCID is estimated to be around 0.15.[316] There was no improvement versus sham surgery at

under 6 months (SMD 0.37 [95% CI -0.30 to 1.04]; 1 trial; 35 patients; GRADE: Low) or over 12 months (SMD 0.69 [95% CI -0.01 to 1.38]; 1 trial; 34 patients; GRADE: Low).

(C) Patients with an unstable meniscal tear in a non-osteoarthritic knee

No studies were identified.

6.4.3.6 Other outcomes

(A) All patients (any type of meniscal tear with or without radiographic osteoarthritis) AND

(B) Patients with any type of meniscal tear in a non-osteoarthritic knee

One RCT (Sihvonen 2013) reported on the presence of "mechanical symptoms", using a modified version of the 'locking domain' of the Lysholm knee scale.[311] There was no difference between APM and sham surgery in the number of patients reporting catching or locking" during the 12-month follow-up period (risk difference (RD) 0.03 (95% CI -0.06 to 0.12). In this study, two patients (2.9%; 2/70) in the APM group underwent additional surgery after unblinding: total knee replacement and repeat APM. Five patients (6.6%; 5/76) in the placebo surgery group were unblinded and underwent additional surgery: (four APM; one high tibial osteotomy). There was one reported adverse event in the APM group (deep infection). Roos 2018 reported a cross-over rate of 36% (8/22) of the skin-incisions group undergoing APM.[320] Four knee-related adverse events were recorded (two re-arthroscopies, one cutaneous nerve lesion, one mild knee swelling) in the APM group. Further adverse events were reported in two APM group patients and three in the skin-incisions group (chest pain, finger injury, nausea, dizziness and kidney stone) including two regarded as serious (abdominal surgery and malignant melanoma). Activity level was not reported in either study.

(C) Patients with an unstable meniscal tear in a non-osteoarthritic knee

No studies were identified.

6.4.4 (4) Arthroscopic partial meniscectomy versus no intervention.

No studies were identified for inclusion in this group.

Table 6.2: Study characteristics and risk of bias assessment (continued overleaf)

Comparator group:	**(1) Non-surgical**						
	Herrlin 2007[200,329]	Katz 2013[196,331,332]	Østeras 2012[203,333]	Yim 2013[202]	Gauffin 2014[199,334]	Kise 2016[198]	Van de Graaf 2018[321]
Comparator (control)	Physiotherapy	Physiotherapy	Physiotherapy	Physiotherapy	Physiotherapy	Physiotherapy	Physiotherapy
Sample (randomised)	99	351	17	108	150‡	140‡	321
Sample (analysed)	90	320	17	102	130‡	129‡	289
Lost to follow up (%)	9 (9.1%)	31 (8.8%)	0 (0%)	6 (5.6%)	20 (13.3%)	11 (7.9%)	13 (4.0%)
Number of centres	Single	Multiple	Multiple	Single	Single	Multiple	Multiple
Age mean (SD) (controls)	55 (5.5)	58 (6.8)	47 (10.4)	58 (11)	54 (6)	50 (6.2)	57.3 (6.8)
Female % (controls)	37%	57%	11%	77%	25%	39%	50.3%
Minimum symptom duration	2 months	4 weeks	3 months	6 weeks	3 months	2 months	NR
Osteoarthritis grade	Ahlbäck 0-1	K-L 0-3	K-L 0-2	K-L 0-1	K-L 0-2‡	K-L 0-3‡	K-L 0-2‡
Intervention	APM	APM	APM	APM	APM	APM	APM
Outcome measures (PROMs)	KOOS Lysholm VAS Pain Tegner	WOMAC (physical) SF-36 (physical) KOOS Pain	KOOS VAS Pain	Lysholm VAS Pain	KOOS EQ-5D	KOOS-4 SF-36 (physical) SF-36 (mental)	IKDC VAS Pain SF-36 (physical) EQ-5D (NR) Tegner
Endpoints (months)	6, 24, 60	6, 12	3	3, 6, 12, 24	12, 36	3, 12, 24	3, 6, 12, 24
Cross-over* %	28.2%	30.2%	NR	1.9%	21.3%	18.6%	29.0%
Risk of Bias (Cochrane Collaboration risk-of-bias tool)[317]							
Random sequence generation (selection bias)	Unclear	Low	Unclear	Unclear	Unclear	Low	Low
Allocation concealment (selection bias)	Unclear	Low	Unclear	Unclear	Low	Low	Unclear
Blinding of participants and researchers (performance bias)	High	High	High	High	High	High	High
Blinding of outcome assessment (detection bias)	High	High	High	High	High	High	High
Incomplete outcome data (attrition bias)	Unclear	Low	Low	Low	High	Low	Low
Selective reporting (reporting bias)	Unclear	High	Unclear	Unclear	Unclear	High	Unclear
Other bias (cross-over*, baseline imbalance)	High	High	Unclear	Low	High	High	High

*Note: K-L=Kellgren-Lawrence grade; OKS=Oxford Knee Score; IKDC=International Knee Documentation Committee *****= Underwent APM intervention after randomisation to control treatment; ‡ = Previously unpublished sub-group data (K-L 0-1) received; NR = Not reported.*

Cont.

Comparator group:	**(2) Pharmacological**	**(3) Surgical**	
	Vermesan 2013[201]	Sihvonen 2013[197,311,335–337]	Roos 2018[320]
Comparator (control)	Steroid injection	Placebo APM	Sham APM
Sample (randomised)	114	146	44‡
Sample (analysed)	98	146	42‡
Lost to follow up (%)	16 (14.0%)	0 (0%)	2 (4.5%)
Number of centres	Single	Multiple	Multiple
Age mean (SD) (controls)	58 (7.8)	52 (7)	46 (5.7)
Female % (controls)	46%	38%	61%
Minimum symptom duration	NR	3 months	2 months
Osteoarthritis grade	NR	K-L 0-1	K-L 0-2‡
Intervention	APM	APM	APM
Outcome measures (PROMs)	OKS	Lysholm WOMET 15D VAS Pain	KOOS EQ-5D SF-36 (physical) SF-36 (mental)
Endpoints (months)	1, 12	6, 12, 24	3, 24
Cross-over* %	20.8%	6.6%	36.0%
Risk of Bias (Cochrane Collaboration risk-of-bias tool)[317]			
Random sequence generation (selection bias)	Unclear	Low	Low
Allocation concealment (selection bias)	Unclear	Low	Low
Blinding of participants and researchers (performance bias)	High	Low	Low
Blinding of outcome assessment (detection bias)	High	Low	Low
Incomplete outcome data (attrition bias)	High	Low	Low
Selective reporting (reporting bias)	Unclear	Low	Low
Other bias (cross-over*, baseline imbalance)	High	Low	High

Note: K-L=Kellgren-Lawrence grade; OKS=Oxford Knee Score; IKDC=International Knee Documentation Committee ***= Underwent APM intervention after randomisation to control treatment; ‡ = Previously unpublished sub-group data (K-L 0-1) received; NR = Not reported.*

Figure 6.2: Pain following arthroscopic partial meniscectomy versus non-surgical intervention (6-12 months)

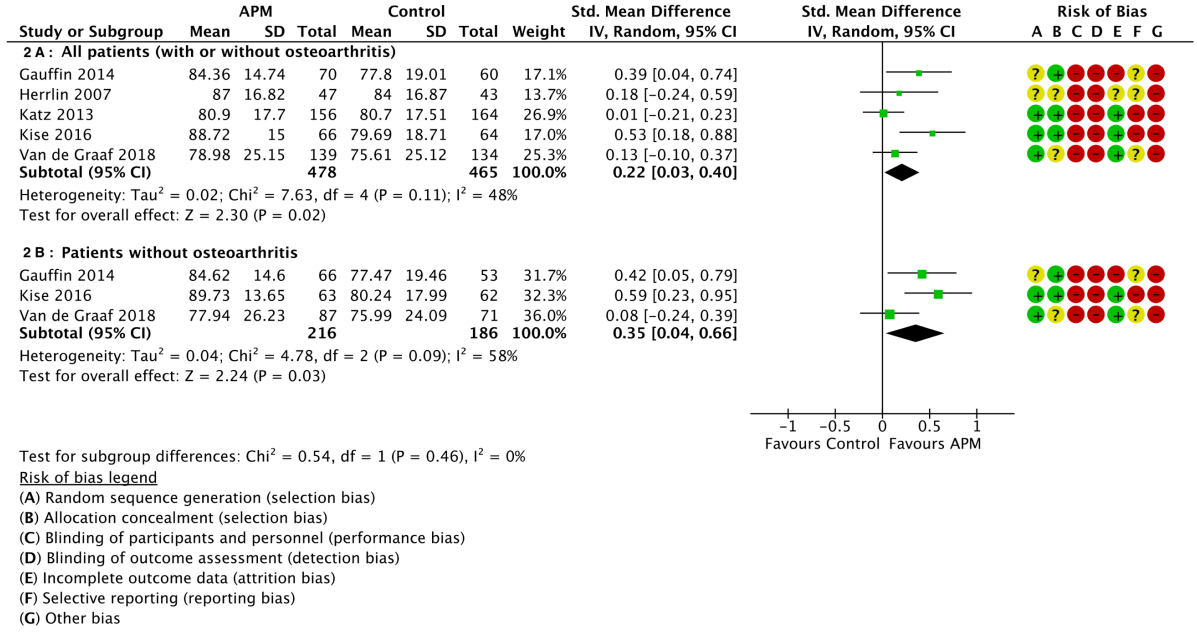


Figure 6.3: Function following arthroscopic partial meniscectomy versus non-surgical intervention (6-12 months)

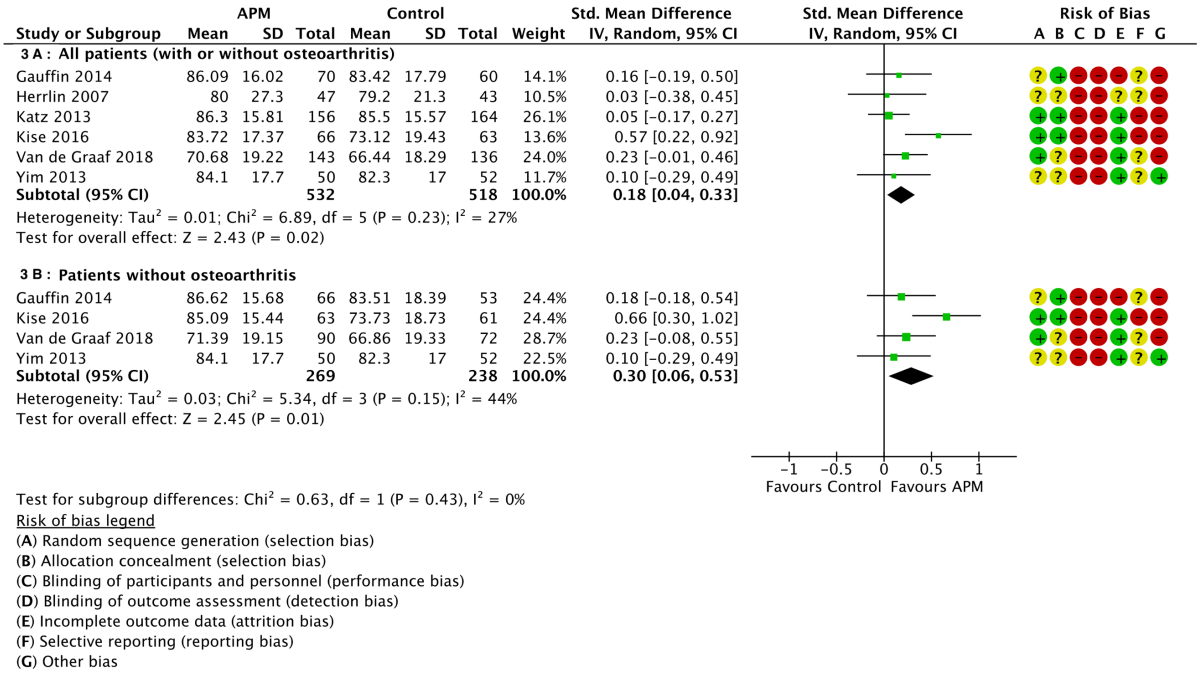


Figure 6.4: Knee-specific health-related quality of life following arthroscopic partial meniscectomy versus non-surgical intervention (6-12 months)

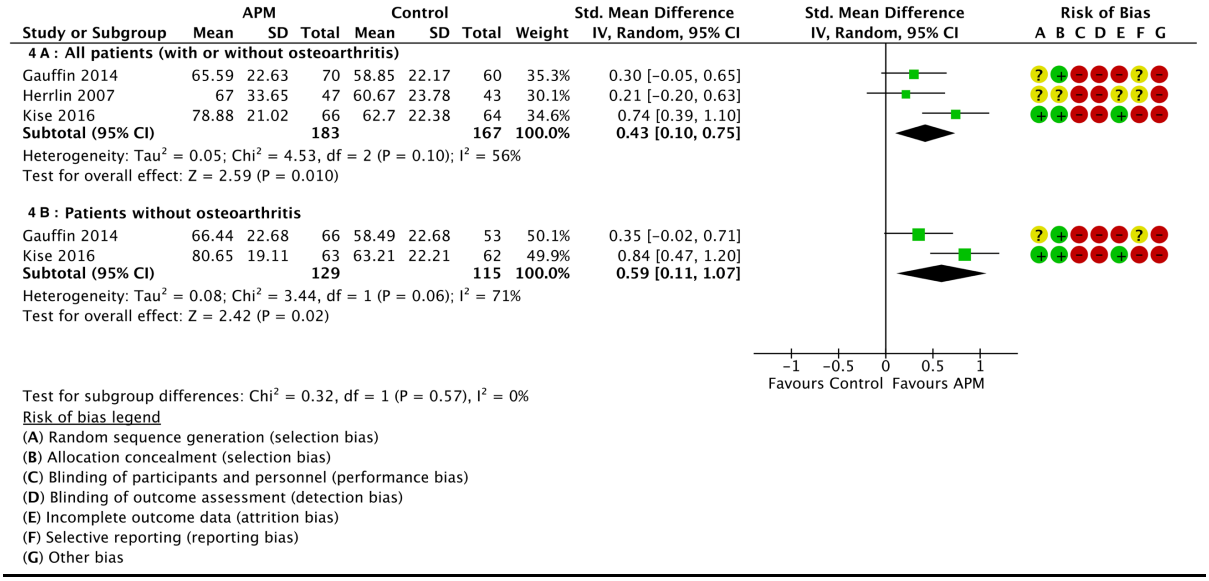


Table 6.3: Summary of Findings: APM versus non-surgical comparators (continued overleaf)

Outcome	**Endpoint**	**Participants (RCTs)**	**Standardised MD (95% CI)**	**MD (95% CI)**	**I^2**	**GRADE Quality***
(A) All patients (any type of meniscal tear with or without radiographic osteoarthritis)						
Pain	Under 6 months	434 (2 RCTs)	0.18 [-0.00, 0.37]	(KOOS pain) 4.46 better [0.22, 8.71]	0%	⊕◯◯◯ VERY LOW [c,d]
	6 - 12 months	943 (5 RCTs)	0.22 [0.03, 0.40]	4.10 better [0.74, 7.46]	48%	⊕⊕◯◯ LOW [c]
	Over 12 months	484 (3 RCTs)	0.22 [0.04, 0.40]	4.43 better [0.72, 8.14]	0%	⊕◯◯◯ VERY LOW [c,d]
Function	Under 6 months	561 (4 RCTs)	0.08 [-0.08, 0.25]	(Lysholm scale) 1.38 better [-1.54, 4.31]	0%	⊕⊕◯◯ LOW [c]
	6 - 12 months	1050 (6 RCTs)	0.18 [0.04, 0.33]	3.36 better [0.55, 6.16]	27%	⊕⊕◯◯ LOW [c]
	Over 12 months	730 (5 RCTs)	0.18 [0.04, 0.33]	2.59 better [0.29, 4.89]	0%	⊕⊕◯◯ LOW [c]
Knee-specific QoL	Under 6 months	129 (1 RCT)	0.45 [0.10, 0.80]	(KOOS QoL) 9.59 better [2.34, 16.84]	NA	⊕⊕◯◯ LOW [c]
	6 - 12 months	350 (3 RCTs)	0.43 [0.10, 0.75]	10.36 better [3.58, 17.14]	44%	⊕⊕◯◯ LOW [c]
	Over 12 months	245 (2 RCTs)	0.30 [0.05, 0.56]	6.92 better [1.33, 12.52]	0%	⊕◯◯◯ VERY LOW [c,d]
Generic QoL	Under 6 months	None	NA	(EQ-5D VAS) NA	NA	NA
	6 - 12 months	130 (1 RCT)	0.01 [-0.34, 0.35]	0.00 better [-0.06, 0.06]	NA	⊕⊕◯◯ LOW [c]
	Over 12 months	113 (1 RCT)	0.47 [0.10, 0.85]	0.10 better [0.02, 0.18]	NA	⊕◯◯◯ VERY LOW [c,d]

Note: MD: mean difference; Qol: quality of life; CI: confidence interval; I2: heterogeneity. SMD in function was translated and re-expressed as a MD in the Lysholm knee scale, using the standard deviation of 19.4 reported for patients with isolated meniscal tears.[265] ***GRADE rating explanations***[319]*: a. Imprecision (very serious): Wide confidence interval including no benefit and potential MCID (benefit); b. Inconsistency (very serious): High level of heterogeneity (>50%) between studies; c. Risk of bias (very serious): No blinding of participants; d. Imprecision (serious): Wide confidence interval including potential MCID (benefit) with MD less than MCID.*

Cont.

(B) Patients with any type of meniscal tear in a non-osteoarthritic knee						
Pain	Under 6 months	306 (2 RCTs)	0.16 [-0.25, 0.57]	(KOOS pain) 3.28 better [-4.33, 10.90]	68%	⊕◯◯◯ VERY LOW [b,c,d]
	6 - 12 months	402 (3 RCTs)	0.35 [0.04, 0.66]	6.91 better [2.87, 10.94]	58%	⊕◯◯◯ VERY LOW [a,b,c]
	Over 12 months	368 (3 RCTs)	0.21 [0.00, 0.42]	4.15 better [0.14, 8.16]	0%	⊕◯◯◯ VERY LOW [c,d]
Function	Under 6 months	411 (3 RCTs)	0.11 [-0.13, 0.35]	(Lysholm scale) 1.93 better [-2.40, 6.26]	33%	⊕⊕◯◯ LOW [c]
	6 - 12 months	507 (4 RCTs)	0.30 [0.06, 0.53]	5.31 better [1.12, 9.51]	44%	⊕◯◯◯ VERY LOW [c,d]
	Over 12 months	501 (4 RCTs)	0.19 [0.01, 0.36]	2.69 better [-0.65, 6.03]	0%	⊕⊕◯◯ LOW [c]
Knee-specific QoL	Under 6 months	124 (1 RCT)	0.52 [0.16, 0.87]	(KOOS QoL) 10.42 better [3.36, 17.48]	NA	⊕⊕◯◯ LOW [c]
	6 - 12 months	244 (2 RCTs)	0.59 [0.11, 1.07]	12.89 better [3.60, 22.18]	65%	⊕⊕◯◯ LOW [c]
	Over 12 months	231 (2 RCTs)	0.39 [0.13, 0.65]	8.40 better [2.86, 13.95]	0%	⊕⊕◯◯ LOW [c]
Generic QoL	Under 6 months	None	NA	(EQ-5D VAS) NA	NA	NA
	6 - 12 months	119 (1 RCT)	0.06 [-0.30, 0.42]	0.01 better [-0.05, 0.08]	NA	⊕⊕◯◯ LOW [c]
	Over 12 months	105 (1 RCT)	0.63 [0.23, 1.02]	0.13 better [0.05, 0.21]	NA	⊕◯◯◯ VERY LOW [c,d]

Note: MD: mean difference; Qol: quality of life; CI: confidence interval; I2: heterogeneity. SMD in function was translated and re-expressed as a MD in the Lysholm knee scale, using the standard deviation of 19.4 reported for patients with isolated meniscal tears.[265] ***GRADE rating explanations**[319]*: a. Imprecision (very serious): Wide confidence interval including no benefit and potential MCID (benefit); b. Inconsistency (very serious): High level of heterogeneity (>50%) between studies; c. Risk of bias (very serious): No blinding of participants; d. Imprecision (serious): Wide confidence interval including potential MCID (benefit) with MD less than MCID.*

Table 6.4: Summary of Findings: APM versus surgical comparators

Outcome	Endpoint	Participants (RCTs)	Standardised MD (95% CI)	MD (95% CI)	I^2	GRADE Quality*
(A) All patients (any type of meniscal tear with or without radiographic osteoarthritis) & (B) Patients with any type of meniscal tear in a non-osteoarthritic knee						
Pain	Under 6 months	35 (1 RCT)	0.26 [-0.41, 0.93]	(KOOS pain) 5.30 better [-7.89, 18.49]	NA	⊕⊕◯◯ LOW [a]
	6 - 12 months	146 (1 RCT)	0.08 [-0.24, 0.41]	2.00 better [-5.69, 9.69]	NA	⊕⊕◯◯ LOW [a]
	Over 12 months	178 (2 RCTs)	0.29 [-0.40, 0.99]	7.28 better [-9.62, 24.19]	71%	⊕◯◯◯ VERY LOW [a,b]
Function	Under 6 months	35 (1 RCT)	0.07 [-0.60, 0.73]	(Lysholm scale) 1.36 better [-11.64, 14.16]	NA	⊕⊕◯◯ LOW [a]
	6 - 12 months	146 (1 RCT)	-0.08 [-0.41, 0.24]	-1.55 worse [-7.95, 4.66]	NA	⊕⊕⊕⊕ HIGH
	Over 12 months	178 (2 RCTs)	0.16 [-0.62, 0.95]	3.10 better [-12.03, 18.43]	77%	⊕◯◯◯ VERY LOW [a,b]
Knee-specific QoL	Under 6 months	35 (1 RCT)	0.25 [-0.42, 0.91]	(KOOS QoL) 4.50 better [-7.37, 16.37]	NA	⊕⊕◯◯ LOW [a]
	6 - 12 months	146 (1 RCT)	0.05 [-0.27, 0.38]	1.10 better [-5.64, 7.84]	NA	⊕⊕⊕⊕ HIGH
	Over 12 months	178 (2 RCTs)	0.25 [-0.39, 0.88]	6.25 better [-9.69, 22.18]	70%	⊕◯◯◯ VERY LOW [a,b]
Generic QoL	Under 6 months	35 (1 RCT)	0.37 [-0.30, 1.04]	(EQ-5D VAS) 0.04 better [-0.03, 0.12]	NA	⊕⊕◯◯ LOW [a]
	6 - 12 months	146 (1 RCT)	0.23 [-0.09, 0.56]	0.02 better [-0.01, 0.05]	NA	⊕⊕⊕⊕ HIGH
	Over 12 months	34 (1 RCT)	0.69 [-0.01, 1.38]	0.11 better [0.00, 0.22]	NA	⊕⊕◯◯ LOW [a]

Note: MD: mean difference; Qol: quality of life; CI: confidence interval; I2: heterogeneity. SMD in function was translated and re-expressed as a MD in the Lysholm knee scale, using the standard deviation of 19.4 reported for patients with isolated meniscal tears.[265] *GRADE Explanations*[319]*:a. Imprecision (very serious): Wide confidence interval including no benefit and potential MCID (benefit). b. Inconsistency (very serious): High level of heterogeneity (>50%) between studies.*

6.5 Discussion

6.5.1 Principal findings

The systematic review reported in this chapter examined the effectiveness of APM with a methodology that stratified trials by comparator intervention and patients by important clinical and radiological findings. Considering trials with a non-surgical comparator, the findings indicate that non-surgical treatment (physiotherapy) may be an effective first-line treatment. For patients that do not respond to non-surgical treatment and "cross-over" from physiotherapy to undergo APM, these studies report that APM may be effective in improving pain, function and quality of life to the level of

responders.[196,198,199,201,202,321,329] One trial with a pharmacological comparator (intra-articular steroid injection) detected no difference in pain and function. No trial has compared APM to no intervention and in trials of APM versus surgical comparators (placebo or sham surgery), results were mixed. In the one trial with a placebo surgery comparator, both groups improved, and the mean difference did not exceed a threshold for clinical importance. In the one trial with a sham surgery comparator, confidence intervals were wide but the absolute mean differences in favour of APM exceeded the threshold for clinical importance in pain, function, and knee-specific quality of life at 24 months. Data on harms was inconsistently reported by the included studies. No trial was designed to detect a difference in complication rate as a primary outcome, and these data were therefore limited by the relatively uncommon event rate and small numbers of patients.

6.5.2 Comparison with other studies

Prior reviews have included trials of interventions such as knee lavage or debridement for advanced osteoarthritis alongside trials of APM for meniscal tears.[204–207] For example, the aim of the recent review by Thorlund *et. al.* was to determine the "benefits and harms of arthroscopic knee surgery for middle aged or older patients with knee pain and degenerative knee disease".[207] The systematic review reported in this chapter is more specific, including only trials of APM performed for meniscal tears. The analysis confirms, however, that outcomes after APM surgery are inferior in patients with osteoarthritis and that APM should not be considered a first-line treatment option, especially in those with non-specific "knee pain". The greatest improvement in pain and quality of life was seen in patients with knee pain and a meniscal tear but without osteoarthritis (group B). In this group, APM is associated with improvement in pain and knee-specific quality of life in comparison to non-surgical treatment, at a level that, as discussed later, may exceed the minimal clinical important difference (MCID). Effect estimates were limited, however, by small study numbers, large numbers of patients 'crossing over' to undergo APM after being randomised to comparator interventions, a lack of blinding in those studies without a surgical comparator, and wide confidence intervals. Little data on harms has been contributed by these studies as they were not designed for these outcomes. Previous evidence on the risk of harms from APM is

discussed in section 1.8.4, and this area of uncertainty is addressed further by the work reported in Chapter 7 and also Chapter 8.

No trial has been performed, or been registered, with inclusion criteria limited to patients meeting strict clinical and radiological criteria – that is, an unstable pattern of tear with symptoms that are considered likely to be "meniscal" in origin rather than non-specific knee pain (group C).[208,259] Previous trials have not used or recorded these specific criteria in individual patients and therefore no meaningful sub-group data was available for analysis.

As postulated by other groups, this review does suggest that APM performed in a population with more focussed indications (excluding patients with osteoarthritis) may be beneficial to pain and quality of life, especially in patients that fail to respond to non-surgical treatment.[338,339] Other reviews have not identified this trend but were not designed to answer this question. In previous reviews limited to trials of APM, the important patient selection criteria were not applied to study eligibility or analysis.[204,205,210] Furthermore, the authors of the four most recent trials provided supplementary sub-group data for inclusion in this review (Gauffin 2014; Kise 2016; Roos 2018, Van de Graaf 2018).[198,199,320,321]

Up to 30% of patients randomised to non-surgical treatment 'crossed over' to undergo APM before final follow up and this is a serious limitation of the current trial evidence.[196,198,199,201,202,321,329] These patients chose to proceed to APM because they failed to improve with non-surgical treatment, and reportedly improved significantly, to the level of responders, after APM.[196,198,199,201,202,321,329] This issue was not limited to studies with a non-surgical comparator, and also observed in up to 36% of comparator patients in studies with a surgical comparator and 21% with a pharmacological comparator.[201,320] The outcome of these individuals had they not undergone APM is unknown but the high cross-over rate confounds the non-surgical intention-to-treat analysis, particularly at longer term follow up.[340] For many years now, there have been calls for all patients with meniscal tears to be treated non-surgically in the first instance, with APM being reserved for those patients failing to improve with this treatment strategy.[208,213,338,339,341] None of the included trials restricted inclusion to patients that had failed a

specific non-surgical treatment programme but, nevertheless, the evidence does broadly support a treatment strategy of only performing APM in selected patients with specific persisting symptoms despite physiotherapy. It should be noted, however, that the physiotherapy delivered by the included trials was intensive, generally including a progressive combination of muscle strength, endurance, flexibility and balance exercises with gym sessions 2-3 times per week for 3-12 weeks. The associated outcomes may not be generalizable to clinical practice with, for example, a less costly unsupervised home exercise programme.

Two RCTs have been performed of APM versus a surgical comparator and interpretation of these studies requires careful consideration.[197,320] In the larger study (Sihvonen 2013), with a placebo surgery comparator, although no difference was reported between the APM and placebo surgery (arthroscopic lavage) groups, a considerable improvement was noted from baseline to follow up in both groups.[197] As the trial lacked a non-surgical control arm, and patients had not undergone structured physiotherapy before randomisation, it is not clear what underlies this improvement.[339] In contrast, the other study (Roos 2018) had a true sham surgery comparator, with patients receiving an anaesthetic but skin incisions only.[320] Thirty-six percent of patients in the sham group crossed-over to undergo APM yet the mean difference between groups in the intention-to-treat analysis was still suggestive of a better outcome in the APM group at 24 months.[320] Confidence intervals were wide in this small study but the authors concluded that "a clinically relevant difference could not be excluded".[320] These conflicting results lead to uncertainty regarding the efficacy of APM and the 'critical surgical element' in the recruited patients.[312] Meniscal tears may be asymptomatic and pain and mechanical symptoms may be caused by other knee pathology.[104,179,342] Therefore, it is essential that clinical and radiological features correspond before arthroscopy is recommended over alternative non-surgical treatments.[208] In the majority of RCTs, patients were eligible for inclusion if they had knee pain localised to a joint line and any pattern of meniscal tear. In the one study (Sihvonen 2013) where knee arthroscopy was performed in all patients, 27% had full thickness cartilage loss and 47% had partial thickness cartilage degeneration, despite minimal radiographic evidence of osteoarthritis prior to surgery.[343] For these individuals, partial resection of the meniscus is unlikely to be the critical surgical element needed to

induce a treatment effect; treatment effects could be attained by placebo effect or any other effect, for example, from the joint lavage performed in both the intervention and control groups of this particular study.[312]

No trials have been performed with inclusion criteria limited to patients with meniscal symptoms corresponding with an unstable meniscal lesion visible on MRI as the treatment target.[208] Although authors have attempted to report outcomes in underpowered sub-samples of patients with either unstable meniscal tears or with mechanical symptoms, no attempt has, so far, been made to relate the symptoms with the pathology.[336] As a result, the efficacy of APM in this group is unknown, despite some cohort data supporting the usefulness of the treatment after failure of physiotherapy.[328] No other systematic review has attempted to address this question and clearly more evidence is required to define the efficacy of APM in these patients.

6.5.3 Strengths and limitations

This review is the first to specifically focus on the effectiveness of APM in patients with meniscal tears, stratified according to clinical and radiological patient selection criteria.[208] The analysis was bolstered by the provision of unpublished data by the authors of four trials. Only randomised controlled trials were included in the pooled analysis due to the risk of selection bias in cohort studies. The review search strategy was, however, highly sensitive and designed to also identify cohort studies and on-going studies, to provide context and narrative when no completed trial evidence was available.

To ease interpretation, all outcomes were converted to familiar PROM instruments in the Summary of Findings tables. When considering the magnitude of the effect from APM reported, it must be noted that the minimum clinically important difference (MCID) and patient acceptable symptom state (PASS) in PROM scores for patients with meniscal tears is unknown.[302,313] Although generally not designed for use in patients with meniscal tears, attempts have been made to validate a number of PROMs for use in this population (see Chapter 5). Although this validation evidence broadly supports use of the KOOS,

Lysholm knee scale, IKDC, and WOMET as primary outcome measures in this population (Chapter 5), the evidence is still poor quality and incomplete. All but one trial (Vermesan 2013) included at least one of these outcome measures. Nevertheless, the MCID for the outcome measures in patients with meniscal tears is uncertain and therefore, to ease interpretation, a MCID threshold of 8-10 was used to attribute potential clinical relevance for outcomes measured on the 0-100 KOOS scale, as proposed by the developers of the tool.[314,315] As the Lysholm Knee Scale is measured on the same scale (0-100) and has otherwise comparable measurement properties in similar patient groups, the same tentative threshold was applied to interpreting functional differences measured on the Lysholm Scale.[302] For the Oxford Knee Score, no validation evidence supports use in the patients with meniscal tears, however a MCID of 5 has been proposed in patients with osteoarthritis and was used to aid interpretation of the clinical effectiveness results reported by one study (Vermesan 2013).[300] For generic quality of life, one estimate of a MCID of 0.15 on the EQ-5D has been suggested for patients with osteoarthritis.[316] Even for osteoarthritis of the knee, however, MCID estimates vary widely from 4 to 20 for KOOS pain and 3 to 9 for KOOS-ADL.[316] The thresholds for interpretation are therefore intended as a tentative guide only, as the true MCID and PASS for the population of patients with meniscal tears remains unknown.[302,313]

Another important limitation to the interpretation of the current evidence is that the treatment preferences of patients with meniscal tears are currently unknown. In general, any benefit from APM seen in the early (under 6 months) and mid-term (6-12 months) was not detected in the longer term (over 12 months). The relative patient preference for a potentially more rapid improvement in pain and quality of life following APM, in comparison to avoiding surgery but a slower rate of improvement with non-surgical treatment, has not been evaluated. This is a limitation for the interpretation of the current evidence and an important consideration for the design of future trials. Whilst a primary outcome endpoint at 12-months is perhaps most appropriate for this population, it is important that earlier and later outcomes are also reported and considered in this context. Only one trial has evaluated outcomes at greater than two years and therefore the longer-term outcomes of APM, including rates of progressive osteoarthritis, in comparison to alternative treatments remains relatively uncertain. The high

rate of cross-over of non-surgically treated patients to APM may reflect patient treatment preferences and information regarding the rate of cross-over may also influence future patient treatment decisions.

6.5.4 Conclusions

This chapter highlights the importance of stratifying the trial evidence to specific populations of patients with meniscal lesions. The findings suggest that the benefit from APM is dependent on the treated population (patient selection factors), however clinical trials to date have had relatively non-specific selection criteria and little data on potential harms is available. Outcomes can be improved by selecting out patients with certain characteristics (those with osteoarthritis), and better outcomes are anticipated in those with unstable patterns of meniscal tear, but there is currently no clinical trial evidence applicable to this group.

Perhaps the most important conclusion of this work is that the current trial evidence should be interpreted with care due to limitations from non-specific selection of patients (without stratification), overall small numbers of included patients, and although some evidence supports the outcome measures reported in these studies (see Chapter 5), the minimum clinically important difference in this population remains uncertain. Patients undergoing APM without radiological osteoarthritis were found to have a greater mean effect size (in absolute terms) in comparison to patients without osteoarthritis, but the apparent difference, although consistently observed for pain, function, and quality of life, was not statistically significant with wide confidence intervals.

The available evidence suggests that structured physiotherapy may be an effective first-line treatment, with many patients treated with physiotherapy improving to the same level as patients undergoing APM. However, up to 30% of patients failed to respond to physiotherapy and subsequently underwent APM with trial authors reporting subsequent improvement in these patients to the level of responders. No trial has been limited to individuals failing to respond to non-surgical treatment, and patients meeting the strictest clinical and radiological indications for APM are not represented by the current evidence.

7 ATTRIBUTABLE RISKS FROM UNDERGOING ARTHROSCOPIC PARTIAL MENISCECTOMY**

7.1 Introduction

Given the large number of APM procedures performed each year (Chapter 3) and the possibility of some degree of overuse (Chapter 4), it is important to also consider the potential occurrence of rare but serious complications following APM.[207] Chapter 6 reports the clinical trial evidence regarding the potential benefit from undergoing APM in different populations: highlighting how this benefit varies in association with patient specific selection factors. In comparison, previous evidence to help inform patients and clinicians of the potential risks associated with undergoing knee arthroscopy has had a number of limitations that prevent useful interpretation specifically for APM (as described in the background chapter: section 1.8.4). In clinical trials of APM, although small numbers of adverse events have been reported (Chapter 6), risk estimates are associated with wide confidence intervals due to the small corresponding sample sizes. Clinical trials are therefore not usually, by design, the best type of study to investigate the rate of uncommon adverse events associated with a treatment and no clinical trial has included adverse events as a primary outcome.

The association between patient factors such as age and sex with the risk of adverse events has also been unclear, and it is not known whether rare adverse events that might occur following APM are "attributable" to undergoing APM or occur comparably frequently in the general population. In order to improve the management of patients with meniscal tears, patients must be able to make a treatment choice informed by an understanding of both the anticipated benefits and potential risk of harms, defined as clearly as possible in relation to their own individual circumstances.

** *The content of this chapter has been published, in part, as: Abram SGF, Judge A, Beard DJ, Price AJ. Adverse outcomes after arthroscopic partial meniscectomy: a study of 700 000 procedures in the national Hospital Episode Statistics database for England. Lancet 2018; 392: 2194–202.*

7.2 Aims

The aim of the work reported in this chapter was to analyse the 90-day risk of complications associated with undergoing isolated APM, using the national HES database for England. Risks are stratified by a range of patient factors and, where appropriate data was available, comparison was made to the risk of adverse events such as mortality, pulmonary embolism, myocardial infarction, and stroke in the general population to estimate the 'attributable risk' from undergoing APM for the first time.

7.3 Methods

7.3.1 Data source

National Hospital Episode Statistics (HES) data, which contains a record of all patient attendances at NHS hospitals in England, was obtained from NHS Digital (application DARS-NIC-68703). See section 3.3.1 for further information on this data source.

7.3.2 Procedures

All HES records between 1 April 1997 and 31 March 2017 were extracted for patients undergoing APM. Episodes were identified from the Classification of Surgical Operations and Procedures (OPCS-4) codes in the procedure fields within the HES data (W82.2).[235] Only isolated APM cases were included and simultaneous or staged (within 6 months) bilateral cases were excluded. Per patient, per side, only the first (primary) APM procedure was included as an index procedure. Subsequent revision procedures in the same patient were not eligible for analysis as index procedures but were counted as a 'reoperation' complication if performed within 90-days of the index APM in the same knee (see Outcomes section 7.3.3, below). For each patient identified as undergoing an index APM, all the patient's prior and subsequent hospital episodes were identified for the entire data extraction period. Cases missing essential data (age, sex, procedure date, procedure laterality) were excluded from the study. Cases missing non-essential data (index of multiple deprivation, ethnicity, rurality) were included except for analyses adjusting for these specific variables.

7.3.3 Outcomes

Complications were identified for the 90-day period following the index procedure to be sensitive in the detection of both acute and subacute adverse events.[344–346] Complications were identified by a review of a combination of the twenty International Statistical Classification of Diseases and Related Health Problems (ICD-10) diagnosis fields per hospital episode and twenty-four OPCS operation fields per episode.[235,347] Complications identified from the ICD-10 diagnosis fields were as follows: pulmonary embolism (PE), myocardial infarction, stroke, lower respiratory tract infection, acute kidney injury, urinary tract infection, and neurovascular injury (Appendix K). Complications identified from the OPCS operation codes were confirmed to match with the laterality (left versus right) of the index procedure using the OPCS laterality codes. The procedure-based complications were as follows: joint infection, fasciotomy, and reoperation (any surgical procedure performed in the same knee within 90 days). Mortality data was extracted from the linked ONS mortality fields. The primary outcome evaluated was the occurrence of at least one serious complication within 90-days of an index APM. A serious complication was defined as either myocardial infarction, stroke, PE, infection requiring surgery, fasciotomy, neurovascular injury, or death. The rate of each individual complication was then evaluated secondarily, with each complication counted whether in isolation or in combination with other adverse outcomes.

7.3.4 Statistical analysis

Stata v15.1 (StataCorp, College Station, Texas, USA) was used to perform all analysis. Descriptive statistics were used to report demographic data. Complication rates were reported with confidence intervals corresponding to the proportion of the study sample. In accordance with ONS and NHS Digital guidance, rates where the number of events was less than six were suppressed.[239]

Logistic regression methods were used to first calculate the unadjusted odds of each complication occurring by age group, sex, index of multiple deprivation (quintile derived from regional factors in

England including average income, employment, education, housing, and crime; 1=least deprived area, 5=most deprived), ethnicity, modified Charlson comorbidity index (Appendix L; derived with maximum 5-year diagnosis code lookback period), year of treatment, ethnicity, and rurality.[248–250,348] The odds ratios were then adjusted including all these variables in the same statistical model.

In order to guide patients and clinicians regarding the relative risk of undergoing the procedure, general population study data was reviewed. Population and adverse event numbers were extracted from the ONS national mortality report, and from publications reporting population rates of myocardial infarction, PE, stroke, and septic arthritis respectively.[349–353] Annualised rates were adjusted directly to estimate 90-day complication rates. The relative risk (risk ratio) of each adverse event occurring following APM was calculated by comparing the adverse event rates in an age-sex matched sample of the APM study data to the extracted general population data. The number needed to harm (NNH) was calculated as the reciprocal of the risk difference between the study cohort and the general population data (attributable risk).

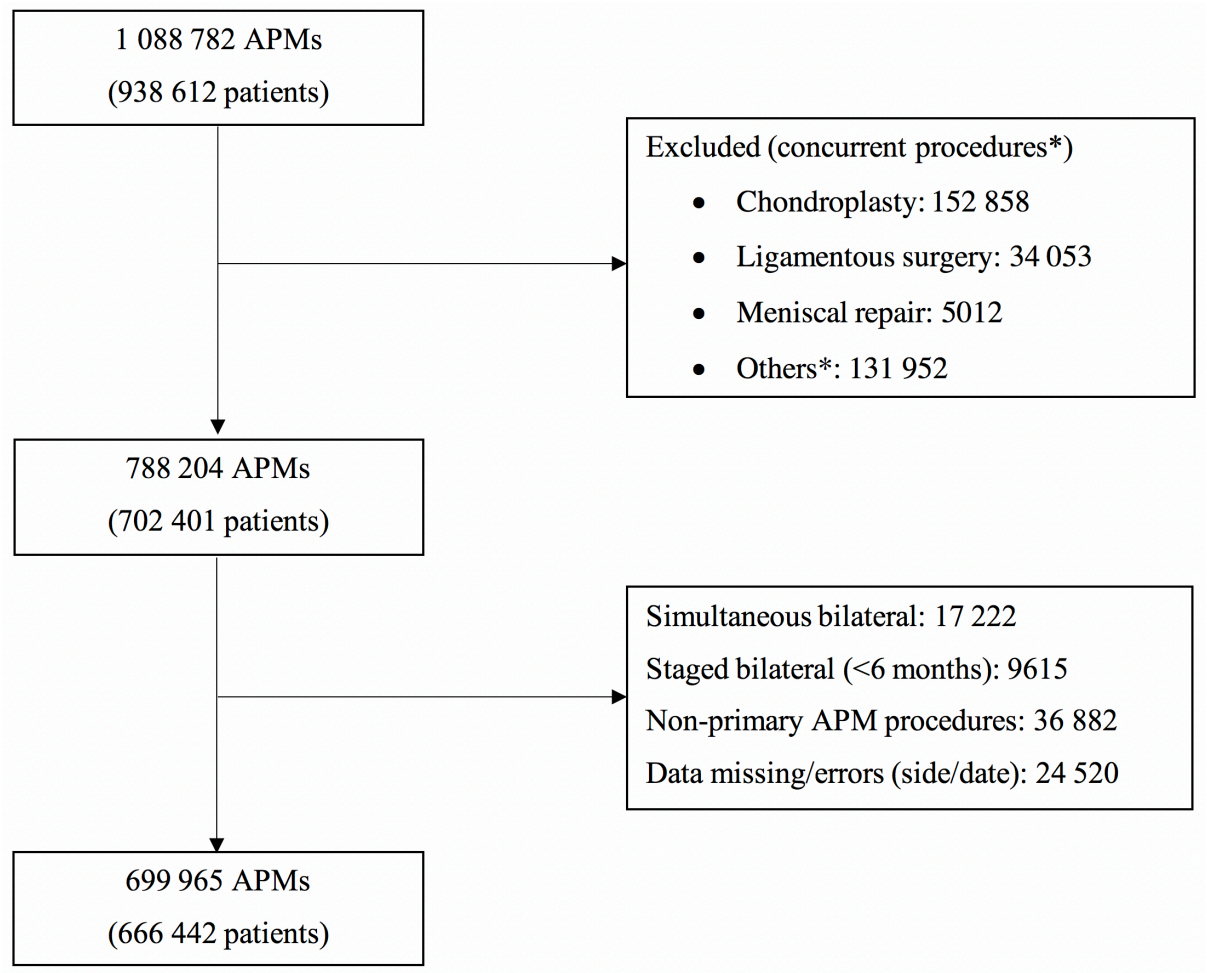
7.4 Results

Between 1 April 1997 and 31 March 2017, a total of 1,088,782 arthroscopic partial meniscectomy procedures were performed, of which 699,965 isolated procedures (666,442 patients) were eligible for inclusion as index procedures in this study (Figure 7.1).

Table 7.1 summarises the characteristics of the patient cohort and those patients developing serious complications (defined as pulmonary embolism, myocardial infarction, stroke, infection requiring further surgery, fasciotomy, neurovascular injury, or death) within 90 days. Surgery was performed more frequently in male patients (453,726 cases; 65%) and the most common age group was 40-59 (330,752 cases; 47%).

Table 7.2 summarises the overall risk of all complications evaluated. Patients underwent re-operation (planned or unplanned) in 4,239 cases (0.606%; 95% CI 0.588 to 0.624) and, of these, 944 procedures (0.135%; 95% CI 0.126 to 0.144) were performed for infection. Serious complications occurred in 2,218 cases (0.317%; 95% CI 0.304 to 0.330). The 90-day mortality rate for the full cohort was 0.031% (217 cases; 95% CI 0.027 to 0.035). Pulmonary embolism occurred in 546 cases (0.078%; 95% CI 0.072 to 0.085) of which 10 cases were fatal (0.001%; 95% CI 0.000 to 0.003).

Figure 7.1: Flow chart illustrating the inclusion and exclusion criteria for the cohort



*Note: * Same side or contralateral surgical procedures. Not mutually exclusive. Other procedures included: primary or revision total knee arthroplasty, unspecified meniscal surgery, total meniscectomy, meniscal transplant, fusion, interposition, washout, synovial or fat pad procedures.*

Table 7.1: Demographics and descriptive statistics

	All procedures		Serious complication †	
	n (procedures)	**% Total**	**n (events)**	**% Rate (95% CI)**
Total cohort				
Overall	699,965	100.0%	2,218	0.317% (0.304, 0.330)
Sex				
Male	453,726	64.82%	1,545	0.341% (0.324, 0.358)
Female	246,239	35.18%	673	0.273% (0.253, 0.295)
Age groups				
<20	21,798	3.11%	32	0.147% (0.100, 0.207)
20-39	172,636	24.66%	356	0.206% (0.185, 0.229)
40-59	330,752	47.25%	988	0.299% (0.280, 0.318)
60-79	167,287	23.90%	766	0.458% (0.426, 0.491)
80+	7,492	1.07%	76	1.014% (0.800, 1.268)
Charlson comorbidity index				
0	590,110	84.31%	1,660	0.281% (0.268, 0.295)
1 - 15	105,689	15.10%	497	0.470% (0.430, 0.513)
16 - 30	3,881	0.55%	52	1.340% (1.002, 1.753)
31 - 50	285	0.04%	9	3.158% (1.454, 5.910)
Index of multiple deprivation (quintile)				
1	168,715	24.10%	489	0.290% (0.265, 0.317)
2	156,657	22.38%	493	0.315% (0.288, 0.344)
3	145,000	20.72%	497	0.343% (0.313, 0.374)
4	123,913	17.70%	403	0.325% (0.294, 0.359)
5	100,320	14.33%	326	0.325% (0.291, 0.362)
Missing	5,360			
Rurality				
Urban	547,459	78.21%	1,712	0.313% (0.298, 0.328)
Rural	149,882	21.41%	504	0.336% (0.308, 0.367)
Missing	2,624			
Ethnic origin				
White	564,320	80.62%	1,911	0.339% (0.324, 0.354)
Asian	18,555	2.65%	51	0.275% (0.205, 0.361)
Black	11,222	1.60%	41	0.365% (0.262, 0.495)
Mixed	3,870	0.55%	13	0.336% (0.179, 0.574)
Other	6,547	0.94%	14	0.214% (0.117, 0.359)
Missing	95,451			

Note: † = At least one serious complication within 90 days, defined as either pulmonary embolism, myocardial infarction, stroke, infection requiring surgery, fasciotomy, neurovascular injury, or death.

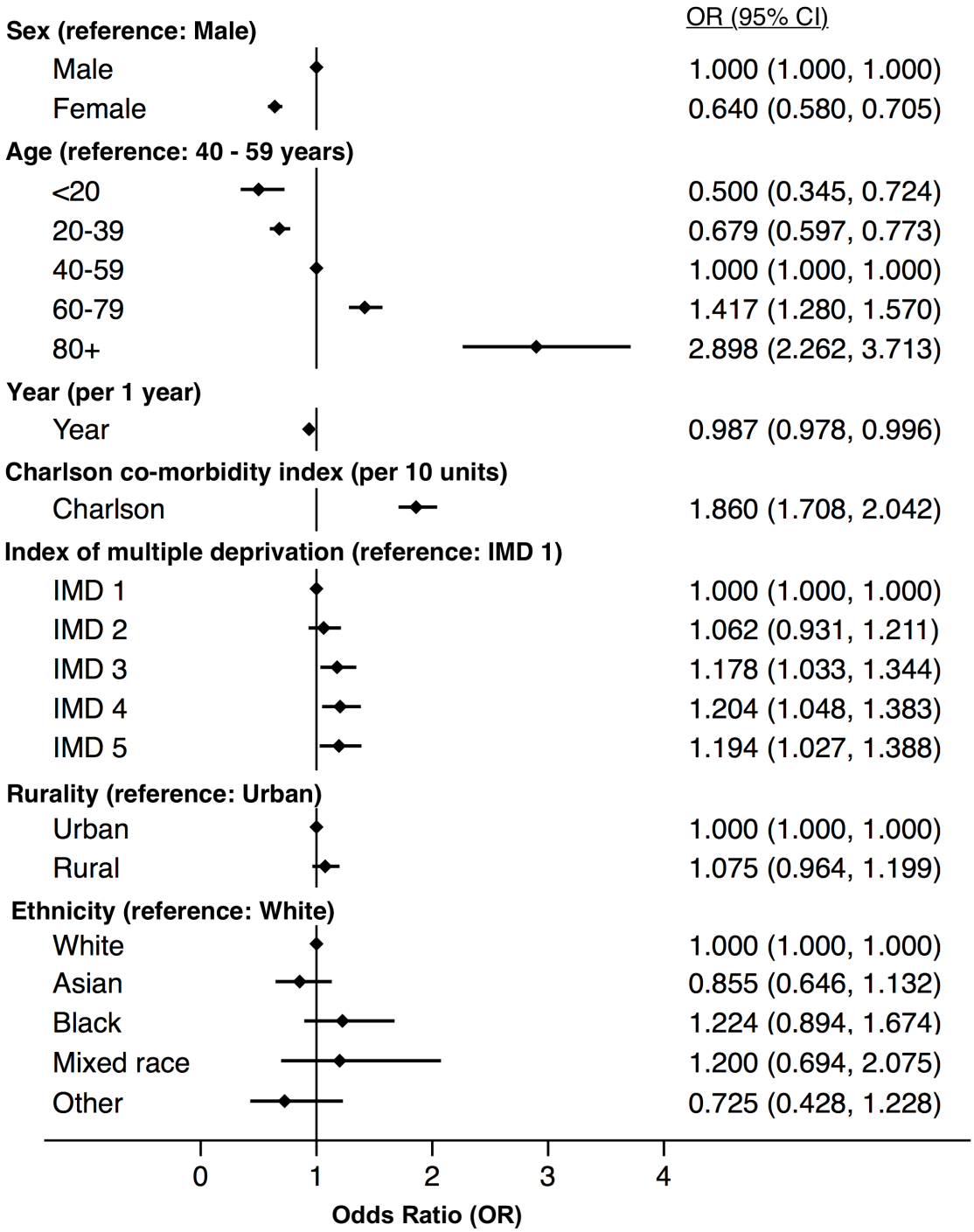
Table 7.2: Number of adverse events and rates per procedure (within 90 days)

	n events	**% Rate (95% CI)**
Event categories (at least one event per procedure)		
Any re-operation ‡	4239	0.606% (0.588, 0.624)
Serious complication †	2218	0.317% (0.304, 0.330)
Individual adverse events (not mutually exclusive; rates per procedure)		
Infection*	944	0.135% (0.126, 0.144)
Lower respiratory tract infection	931	0.133% (0.125, 0.142)
Urinary tract infection	647	0.092% (0.085, 0.100)
Pulmonary embolism	546	0.078% (0.072, 0.085)
Myocardial infarction	279	0.040% (0.035, 0.045)
Mortality	217	0.031% (0.027, 0.035)
Stroke	208	0.030% (0.026, 0.034)
Acute kidney injury	206	0.029% (0.026, 0.034)
Neurovascular injury	67	0.010% (0.007, 0.012)
Fasciotomy	33	0.005% (0.003, 0.007)
Fatal pulmonary embolus	10	0.001% (0.000, 0.003)

*Note: † = At least one serious complication within 90 days, defined as either pulmonary embolism, myocardial infarction, stroke, infection requiring surgery, fasciotomy, neurovascular injury, or death. * = Infection requiring surgery (open or arthroscopic washout of wound or joint). ‡ = Any procedure performed in the same knee (e.g. washout, meniscal repair, repeat meniscectomy, chondroplasty, ligamentous surgery, fasciotomy).*

The influence of patient and hospital factors on the risk of complications is summarised in Figure 7.2 and Table 7.3. Female sex was associated with a decreased risk of complications OR 0.640 (95% CI 0.580 to 0.705), driven in part by a greater risk of myocardial infarction and infection in male patients. Increasing age was associated with increased risk of serious complications (adjusted OR 1.247 per decade; 95% CI 1.208 to 1.288). Serious complications occurred in 1.014% of patients aged 80 years or greater, in comparison to 0.147% in patients aged under 20 years, a difference that corresponded to an adjusted odds ratio of 5.794 (95% CI 3.740 to 8.975). Increased comorbidity (Charlson comorbidity index) was associated with an increased risk of myocardial infarction, stroke, infection, death, and the overall risk of serious complications. Complications also occurred more frequently in areas of increased deprivation (IMD). Rurality and ethnicity did not affect the risk of serious complications occurring. The rate of serious complications fell slightly over the 20-year study period (OR 0.987 per year; 95% CI 0.978 to 0.996).

Figure 7.2: Forest plot of adjusted‡ odds of any serious complication within 90-days



Note: ‡ = procedure level multi-variable logistic regression model including sex, age group, year, Charlson comorbidity index, index of multiple deprivation, rurality, and ethnicity. OR = odds ratio; CI = confidence interval.

Table 7.3: Unadjusted and adjusted odds‡ of serious complications (continued overleaf)

	Serious complication †		**Pulmonary embolism**		**Myocardial infarction**	
	Crude OR (95% CI)	Adjusted OR (95% CI)	Crude OR (95% CI)	Adjusted OR (95% CI)	Crude OR (95% CI)	Adjusted OR (95% CI)
Sex						
Male	1.00	1.00	1.00	1.00	1.00	1.00
Female	0.802 (0.733,0.878)	0.640 (0.580,0.705)	1.311 (1.106,1.555)	1.021 (0.848,1.228)	0.571 (0.433,0.752)	0.406 (0.303,0.543)
Age groups						
<20	0.491 (0.345,0.698)	0.500 (0.345,0.724)	-	-	-	-
20-39	0.690 (0.611,0.779)	0.679 (0.597,0.773)	0.482 (0.369,0.631)	0.481 (0.358,0.646)	0.029 (0.007,0.116)	0.015 (0.002,0.109)
40-59	1.00	1.00	1.00	1.00	1.00	1.00
60-79	1.535 (1.397,1.688)	1.417 (1.280,1.570)	1.524 (1.270,1.829)	1.422 (1.166,1.734)	1.933 (1.518,2.462)	1.794 (1.377,2.338)
80+	3.420 (2.706,4.324)	2.898 (2.262,3.713)	1.328 (0.657,2.684)	1.122 (0.525,2.399)	4.654 (2.682,8.076)	4.065 (2.277,7.257)
Year of treatment (per year)						
Year	1.000 (0.992-1.008)	0.987 (0.978,0.996)	1.010 (0.994,1.027)	0.997 (0.979,1.016)	1.012 (0.989,1.035)	0.983 (0.958,1.009)
Charlson comorbidity index (per unit)						
Charlson index	1.083 (1.074,1.091)	1.064 (1.055,1.074)	1.048 (1.026,1.071)	1.023 (0.998,1.048)	1.113 (1.095,1.131)	1.081 (1.061,1.102)
Index of multiple deprivation (quintile)						
1	1.00	1.00	1.00	1.00	1.00	1.00
2	1.086 (0.958,1.231)	1.062 (0.931,1.211)	1.016 (0.788,1.309)	0.924 (0.702,1.218)	1.239 (0.876,1.751)	1.224 (0.850,1.761)
3	1.183 (1.044,1.341)	1.178 (1.033,1.344)	1.211 (0.945,1.551)	1.249 (0.961,1.624)	1.144 (0.799,1.639)	1.134 (0.774,1.661)
4	1.123 (0.984,1.281)	1.204 (1.048,1.383)	1.052 (0.805,1.375)	1.243 (0.939,1.646)	0.976 (0.660,1.444)	1.077 (0.709,1.636)
5	1.122 (0.975,1.291)	1.194 (1.027,1.388)	1.108 (0.837,1.466)	1.289 (0.952,1.744)	1.318 (0.899,1.930)	1.684 (1.123,2.526)
Rurality						
Urban	1.00	1.00	1.00	1.00	1.00	1.00
Rural	1.076 (0.974,1.188)	1.075 (0.964,1.199)	1.121 (0.920,1.367)	1.059 (0.849,1.323)	1.247 (0.952,1.633)	1.144 (0.846,1.548)
Ethnic origin						
White	1.00	1.00	1.00	1.00	1.00	1.00
Asian	0.811 (0.614,1.072)	0.855 (0.646,1.132)	0.388 (0.173,0.868)	0.407 (0.182,0.914)	1.273 (0.676,2.396)	1.490 (0.786,2.824)
Black	1.079 (0.792,1.471)	1.224 (0.894,1.674)	0.642 (0.287,1.436)	0.676 (0.300,1.520)	0.210 (0.030,1.499)	0.278 (0.039,1.990)
Mixed race	0.992 (0.574,1.713)	1.200 (0.694,2.075)	0.620 (0.155,2.488)	0.767 (0.191,3.083)	0.610 (0.086,4.349)	1.031 (0.144,7.374)
Other	0.631 (0.373, 1.068)	0.725 (0.428,1.228)	0.550 (0.177,1.712)	0.633 (0.203,1.975)	0.361 (0.051,2.570)	0.531 (0.074,3.792)

*Note: ‡ = procedure level multi-variable logistic regression model including sex, age group, year, Charlson comorbidity index, index of multiple deprivation, rurality, and ethnicity. OR = odds ratio; CI = confidence interval; † = At least one serious complication within 90 days, defined as either pulmonary embolism, myocardial infarction, stroke, infection requiring surgery, fasciotomy, neurovascular injury, or death; * = Infection requiring surgery (open or arthroscopic washout of wound or joint).*

Cont.

	Stroke		Infection*		Death	
	Crude OR (95% CI)	Adjusted OR (95% CI)	Crude OR (95% CI)	Adjusted OR (95% CI)	Crude OR (95% CI)	Adjusted OR (95% CI)
Sex						
Male	1.00	1.00	1.00	1.00	1.00	1.00
Female	1.325 (1.006,1.745)	0.818 (0.611,1.096)	0.492 (0.421,0.575)	0.454 (0.385,0.536)	1.210 (0.922,1.588)	0.852 (0.635,1.143)
Age groups						
<20	-	-	0.993 (0.677,1.455)	0.925 (0.617,1.387)	0.214 (0.030,1.538)	0.261 (0.036,1.883)
20-39	0.133 (0.054,0.329)	0.157 (0.063,0.392)	1.119 (0.957,1.308)	1.051 (0.891,1.239)	0.432 (0.251,0.743)	0.476 (0.269,0.841)
40-59	1.00	1.00	1.00	1.00	1.00	1.00
60-79	3.077 (2.288,4.137)	2.425 (1.761,3.340)	1.053 (0.897,1.237)	1.081 (0.911,1.282)	2.842 (2.099,3.847)	2.533 (1.814,3.536)
80+	11.677 (7.040,19.369)	6.941 (4.017,11.993)	1.032 (0.551,1.932)	1.119 (0.593,2.112)	16.846 (10.809,26.254)	11.620 (7.044,19.169)
Year of treatment (per year)						
Year	1.025 (0.998,1.053)	0.992 (0.962,1.023)	0.992 (0.980,1.004)	0.989 (0.976,1.002)	0.990 (0.965,1.016)	0.965 (0.937,0.994)
Charlson comorbidity index (per unit)						
Charlson index	1.144 (1.129,1.160)	1.110 (1.092,1.128)	1.027 (1.007,1.047)	1.030 (1.009,1.050)	1.133 (1.116,1.150)	1.099 (1.079,1.119)
Index of multiple deprivation (quintile)						
1	1.00	1.00	1.00	1.00	1.00	1.00
2	1.180 (0.776,1.792)	1.155 (0.748,1.783)	1.108 (0.916,1.341)	1.106 (0.908,1.346)	1.051 (0.680,1.624)	1.131 (0.718,1.781)
3	1.413 (0.939,2.126)	1.460 (0.958,2.224)	1.153 (0.951,1.397)	1.132 (0.928,1.382)	1.362 (0.898,2.067)	1.330 (0.849,2.082)
4	1.232 (0.794,1.911)	1.378 (0.873,2.177)	1.140 (0.933,1.394)	1.131 (0.917,1.396)	1.727 (1.147,2.601)	2.030 (1.310,3.145)
5	1.241 (0.780,1.975)	1.323 (0.800,2.186)	1.063 (0.854,1.321)	1.009 (0.800,1.273)	1.477 (0.944,2.311)	1.806 (1.107,2.944)
Rurality						
Urban	1.00	1.00	1.00	1.00	1.00	1.00
Rural	1.218 (0.890,1.667)	1.103 (0.780,1.558)	1.008 (0.863,1.177)	1.058 (0.895,1.250)	1.094 (0.797,1.500)	1.285 (0.908,1.816)
Ethnic origin						
White	1.00	1.00	1.00	1.00	1.00	1.00
Asian	0.835 (0.344,2.032)	0.964 (0.394,2.360)	0.924 (0.620,1.376)	0.929 (0.622,1.388)	0.840 (0.345,2.043)	0.967 (0.395,2.369)
Black	1.105 (0.410,2.977)	1.481 (0.541,4.055)	1.590 (1.076,2.350)	1.725 (1.160,2.565)	1.111 (0.413,2.994)	1.375 (0.504,3.751)
Mixed race	0.801 (0.112,5.720)	1.386 (0.193,9.931)	1.596 (0.827,3.081)	1.638 (0.846,3.171)	-	-
Other	0.474 (0.066,3.380)	0.761 (0.106,5.449)	0.419 (0.157,1.118)	0.419 (0.157,1.121)	1.905 (0.707,5.133)	2.756 (1.017,7.471)

*Note: ‡ = procedure level multi-variable logistic regression model including sex, age group, year, Charlson comorbidity index, index of multiple deprivation, rurality, and ethnicity. OR = odds ratio; CI = confidence interval; † = At least one serious complication within 90 days, defined as either pulmonary embolism, myocardial infarction, stroke, infection requiring surgery, fasciotomy, neurovascular injury, or death; * = Infection requiring surgery (open or arthroscopic washout of wound or joint).*

Table 7.4 summarises estimates of the relative risk of APM in comparison to the risk that has been reported for the general population. The risk of 90-day mortality was lower in this national cohort of patients undergoing APM in comparison to the national rate of mortality (excluding deaths from cancer) in all age groups. The risk of myocardial infarction and stroke for both males and females was comparable to national rates. The relative risk of pulmonary embolism was increased in the APM cohort (risk ratio [RR] 12.99; 95% CI 10.35 to 16.31), as was the risk of infection (septic arthritis; RR 110.21; 95% CI 81.19 to 149.60). These data were used to estimate the number of APM procedures needed to harm (NNH) in comparison to adverse events in the general population. For PE, the estimated NNH was 1,390 (95% CI 1,272 to 1,532). For native knee joint infection, the estimated NNH was 749 (95% CI 704 to 801). The rate of fatal PE in the series (1.8% per PE; 10/546) was comparable to other literature and resulted in an estimate of one attributable death from PE for every 77,519 APMs (95% CI 45,455 to 261,097).

Table 7.4: Risk in context (90-day adverse event rates reported in the general population in comparison to a matched sample of the study cohort)

	General population risk	**Study cohort risk**	**Relative risk**
	% (95% CI)	% (95% CI)	Risk ratio (95% CI)
Mortality			
Overall:	0.158% (0.157, 0.159) [349] *	0.031% (0.027, 0.035)	0.20 (0.17, 0.22)
Age < 20 years:	0.007% (0.007, 0.008) [349] *	-	-
Age 20 - 39 years:	0.011% (0.011, 0.012) [349] *	0.009% (0.005, 0.015)	0.81 (0.49, 1.32)
Age 40 - 59 years:	0.043% (0.042, 0.044) [349] *	0.021% (0.017, 0.027)	0.50 (0.40, 0.63)
Age 60 - 79 years:	0.233% (0.230, 0.236) [349] *	0.061% (0.050, 0.074)	0.26 (0.22, 0.32)
Age 80 + years:	2.043% (2.026, 2.060) [349] *	0.360% (0.238, 0.524)	0.18 (0.12, 0.26)
Myocardial infarction			
Men (age < 80):	0.058% (0.049, 0.067) [350]	0.046% (0.040, 0.052)	0.79 (0.64, 0.97)
Women (age < 80):	0.028% (0.022, 0.035) [350]	0.024% (0.019, 0.031)	0.88 (0.63, 1.23)
Pulmonary embolism			
Overall:	0.006% (0.005, 0.007) [351]	0.078% (0.072, 0.085)	12.99 (10.35, 16.31)
Stroke			
Age < 75 years:	0.034% (0.030, 0.039) [352]	0.025% (0.021, 0.029)	0.72 (0.59, 0.88)
Septic arthritis (native knee joint infection)			
Overall:	0.001% (0.001, 0.002) [353] ‡	0.135% (0.126, 0.144)	110.21 (81.19, 149.60)

*Note: - = suppressed; * = Office for National Statistics population level data for England (2016, excluding death due to cancer); ‡ = excluding iatrogenic causes.*

7.5 Discussion

7.5.1 Principal findings

The findings of the study reported in this chapter demonstrate that complications occur rarely following APM. Although the risk of certain complications was higher in older patients, those patients with comorbidities, and in male patients, the majority of adverse events occurred at a rate lower than in the general population (Table 7.4). There was a small but statistically significant decrease in mortality risk over the 20-year period, as has been previously reported for total joint arthroplasty surgery.[354,355] The risk of infection and PE, however, was increased following APM, with a number needed to harm of 1,390 APMs for PE, and 749 APMs for native knee joint infection. One death from PE could be prevented with 77,519 fewer APMs.

7.5.2 Comparison with other studies

This study extends previous work investigating the risk of adverse outcomes after arthroscopic knee surgery in a number of important ways. The analysis evaluated a wide range of serious complications and was limited to patients undergoing APM in isolation: more complex and multiple procedure cases were excluded as these procedures may be associated with a different risk profile. Despite this, the study is the largest reported single database cohort of knee arthroscopy procedures (699,965). APM was associated with a 0.317% risk of serious complications within 90-days (PE, myocardial infarction, stroke, fasciotomy, neurovascular injury, death). Further surgery for infection was performed in 0.135%, PE was diagnosed in 0.078%, myocardial infarction in 0.040%, stroke in 0.030%, death in 0.031%, neurovascular injury in 0.010%, fasciotomy was performed in 0.005%, and fatal PE occurred in 0.001%. Surgery was most commonly performed in patients aged 40-59 (330,752 procedures; 47%) and increasing age was associated with an increased risk of serious complications (adjusted OR 1.247 per decade; 95% CI 1.208 to 1.288). Female patients were at decreased risk of serious complications (adjusted odds ratio 0.640; 95% CI 0.580-0.705). In comparison to the general population, APM was associated with an increased risk of only the direct surgical complications (septic arthritis, neurovascular injury, fasciotomy) and pulmonary embolism (Table 7.4).

Multiple clinical trials of APM have now been published and their findings suggest that for many patient groups, exercise therapy may be an effective treatment (see Chapter 6).[196–200,202] The clinical trials published, so far, have aimed to recruit patients with 'degenerative' meniscal tears and the mean age of the patients recruited has ranged from 47 to 58. The trial evidence applicable to this population can now be interpreted in the context of risk and this study provides some indication of the potential morbidity associated with overuse of knee arthroscopy.

The absolute rate of PE, infection, and death in the present study was less than the pooled estimate reported by a meta-analysis of previous studies (see section 1.8.4).[207] This finding is likely to be related

to lesser heterogeneity in the analysis, which was limited to patients undergoing isolated APM, excluding more complex procedures such as anterior cruciate ligament reconstruction. Nevertheless, the present study estimated thirteen times greater risk of developing a PE following APM in comparison to the general population, likely reflecting the observation that only approximately 25% of PEs occur in unprovoked circumstances (without a history of surgery or cancer).[351,356] The risk of PE did not change in the cohort over time, despite modern attention to venous thromboembolism risk and prevention.[357] The rate of fatal PE in the series (1.8%; 10/546) is comparable to other series.[358] Although rare, the elevated risk is concerning as currently thromboprophylaxis is not advocated routinely for people undergoing knee arthroscopy.[359] As shown in studies of joint arthroplasty patients, venous thromboembolism may be preventable with mechanical and chemical prophylaxis, but this must be weighed against increased bleeding risk.[354,355] The findings of this study may inform a further review of thromboprophylaxis recommendations for patients undergoing APM, especially those in the higher risk groups.

The overall risk of undergoing further surgery for infection within 90 days was elevated, at 0.135%. Male patients and patients with comorbidities were more likely to undergo surgery for infection. There is debate about whether antibiotic prophylaxis should be routinely given prior to knee arthroscopy.[360,361] One study published in 1988 suggested that prophylactic antibiotics might be cost effective if the infection rate associated with knee arthroscopy is greater than 0.08%.[362] The findings of this study did confirm a rate of re-operation for infection slightly greater than this threshold, however it was not possible to determine whether patients received, or did not receive, antibiotic prophylaxis at the time of their index procedure. A contemporary cost-effectiveness analysis is warranted to support any recommendation regarding routine antibiotic prophylaxis in these patients.

For low risk procedures, it is important to consider how the detected rate of complications compares with the risk in the whole population. For example, the risk of myocardial infarction following APM observed in this study was similar to that reported for the general population, where the 90-day incidence is approximately 0.058% in men and 0.028% in women, under the age of 80 years.[350]

Similarly, stroke risk was very similar to the population rate over 90-days of 0.034%, under the age of 75.[352] APM in this cohort was most commonly performed in the 50-54 age group and the 90-day mortality rate in this age group was 0.012%, comparing favourably with the general population rate of 0.046% (excluding deaths from cancer) published by ONS for this group.[349] Although this comparison is relatively crude, the difference is similar to the 39-43% relative mortality reportedly recently for patients undergoing total knee or total hip arthroplasty in comparison to the general population.[363] The specific cause of the lower mortality rate observed relative to the general population is unknown but is most likely to be a 'healthy patient' selection bias, influenced by differences in healthcare seeking behaviour or access to surgical treatment.[364] This is likely to be a multi-factorial phenomenon and in the UK, for example, lower mortality has been reported in individuals with certain occupations.[365] Patients may seek medical attention less readily due to the relative severity of a coexisting condition or by socioeconomic status. Equally, surgeons or anaesthetists may less readily recommend surgery in patients considered to be of higher risk due to comorbid conditions. In a study of hip and knee arthroplasty patients, a lower rate of death from cancer was a key driver for the reduced mortality observed in these patients relative to the general population.[349,363] In the present cohort, however, the lower relative mortality was observed even after excluding deaths from cancer from the national population data, but could still have been driven, for example, by patients with severe cardiac or respiratory comorbidities being overrepresented in the general population in comparison to individuals undergoing APM.

7.5.3 Strengths and limitations

One of the major criticisms of previous studies into the risk of knee arthroscopy has been the analysis of cohorts combining simple, isolated, procedures such as APM with more complex and multiple procedures. No previous study has been limited to the single most commonly performed procedure: APM. To reduce heterogeneity, the analysis was limited to only isolated APM cases, excluding patients undergoing bilateral surgery or any concurrent procedures. Applying these criteria, 64% (699,965/1,088,782) of procedures were included, yet this study remains the largest APM cohort

reported. The large sample size of prospectively recorded data enabled control against potential confounding factors and increased the precision of the findings. It is likely that patient factors (especially age group, sex, comorbidity) are more important than the healthcare delivery setting in determining the risk of adverse events following this commonly performed procedure and therefore it is probable that the findings are broadly generalisable to other healthcare settings and countries. Potential sources of unmeasured confounding, however, include body mass index, smoking, and issues of data quality such as incomplete coding of comorbidity, indication, or procedure. It should also be acknowledged that these findings for APM cannot be generalised to patients undergoing more complex arthroscopic surgery.

For a further description of the strengths and limitations of HES data, see section 3.5.3 and 4.5.3. As stated previously, private hospital treatment is not recorded, however, as all included patients underwent their index procedure in the public-sector NHS, they are highly likely to have returned to an NHS hospital after developing any adverse event. As HES records hospital attendances across England, it is also unlikely that complications occurring within 90-days would be missed due to geographic migration.

This study included death certificate data from the ONS, which maintains a complete national record of both in-hospital and community deaths. The analysis was, however, restricted to hospital episodes and complications managed in the community were not available. For example, as a large proportion of patients with symptomatic deep vein thrombosis (DVT) are now diagnosed and treated in the community, DVT was not included as an outcome. Any analysis of DVT rates from hospital episodes is likely to underestimate the true rate of DVT. The purpose of this study was to determine the rate of serious complications diagnosed in hospital (with or without admission for treatment). The study comprehensively reports on the full range of these serious complications that may occur, rather than focussing on one or two specific complications as for previous studies.

This study compared the rate of adverse events observed in the cohort to the rate that has been reported in the general population. This comparison is a relatively crude but important analysis to inform patients and clinicians of the relative risk of undergoing APM.[63] Only the risk of pulmonary embolism and infection was greater in the cohort of patients undergoing APM. It should be noted, however, that no comparison group was available for rarer direct surgical complications (neurovascular injury, fasciotomy).

A patient's interpretation of this evidence will depend on their individual circumstances and attitudes to risk.[301,366] These circumstances and perceptions may change over time: for example, the patient that has not tried non-operative treatment for a meniscal tear is more likely to favour non-operative treatment initially to avoid the risk from undergoing APM, especially if they are naturally averse to risk or have a strong preference for avoiding surgery.[366] In comparison, a patient that has tried 3-6 months of non-surgical treatment already, may perceive APM more favourably as potentially beneficial versus the risks documented here, especially if their symptoms remain 'intolerable'.[301] Different patients will have a different "acceptable symptom state", which they might tolerate to avoid surgery.[301,367] Similarly, different patients may expect a different amount of benefit to be satisfied with a particular treatment. The impact of these patient preference factors in the shared-decision making process and outcome evaluation requires further investigation.

7.5.4 Conclusion

The findings reported in this chapter suggest that the majority of medical complications (including myocardial infarction, stroke, and death) occur more rarely following APM than in the general population. Pulmonary embolism and direct surgical complications (including infection), however, occur more frequently following APM than in the general population; neither risk has improved over time despite modern prophylactic methods. For every 1,500 fewer APMs performed, one pulmonary embolism and two native knee joint infections could be prevented. The proportion of PEs in this series

that were fatal was comparable to other series and resulted in an estimate of potentially one avoidable death from PE for every 77,519 fewer APMs.

These new data will inform patient decision making and consent. Patients and clinicians can use this new understanding of the risks in the shared decision-making process. The interpretation for most individuals is likely a decision not to proceed with APM where the anticipated benefit is low, or where alternative, non-operative, treatments may be effective (given the uncommon but potentially avoidable risks associated with APM). Where there is anticipated benefit and after alternative treatments have been tried, however, individuals may be more likely to favour APM on the balance of benefit and risk. The development of refined patient selection criteria is justified to help clarify this decision-making process and avoid exposure to potentially avoidable short-term risks. The next chapter provides more information to inform this decision-making process, reporting work investigating one important long-term undesirable outcome after APM: the rate of subsequent knee arthroplasty.

8 LONG-TERM RATES OF KNEE ARTHROPLASTY FOLLOWING ARTHROSCOPIC PARTIAL MENISCECTOMY††

8.1 Introduction

Patients sustaining a meniscal tear in the knee are known to be at risk of osteoarthritis (see section 1.6.3).[104,105,368] Despite the prevalence of meniscal injury, and a high-rate of surgical intervention, the long-term outcomes in this population are unclear.[369,370] Progressive osteoarthritis, especially requirement for subsequent knee arthroplasty, is an important and undesirable outcome, however patient factors, including sex, that may be associated with the risk of progression are poorly defined.[126,371] For patients undergoing APM for the treatment of a meniscal tear, the long-term rate of subsequent arthroplasty that might be anticipated has therefore been uncertain. This information is important to patients, clinicians, and ultimately for health-commissioners in the assessment of the long-term outcomes associated with the care pathway for patients with meniscal tears.

Small studies have investigated rates of radiographic progression in patients with meniscal damage, however radiographic findings may not reflect clinical symptoms.[131] In comparison, knee arthroplasty is an objective end-point that has been used as a surrogate marker for end-stage symptomatic osteoarthritis after arthroscopy and pharmacological studies.[371–374] Two previous studies of higher risk patients estimated between a three and fifteen times greater risk of knee arthroplasty after arthroscopic partial meniscectomy (APM) surgery or meniscal 'injury' respectively.[132,375] These studies were, however, limited by small study numbers, short follow up, incomplete data capture from insurance

†† *The content of this chapter has been accepted for publication, in part, as: Abram SGF, Judge A, Beard DJ, Carr AJ, Price AJ. Long-term rates of knee arthroplasty in a cohort of 834,393 patients with a history of arthroscopic partial meniscectomy. Bone Joint J. 2019 (Article in Press).*

company or regional records, failure to identify surgical treatments undertaken, and failure to match by affected knee.

At a population level, it has been found that women have a higher prevalence of symptomatic osteoarthritis than men, but may be less likely to undergo arthroplasty.[70] It has remained unclear what truly underlies these differences and no long-term study has been performed in a cohort of patients with comparable baseline characteristics. Knee arthroplasty is an important and undesirable outcome for patients and an understanding of the risk factors for progressive osteoarthritis following APM is required for individualised consent and to guide optimal care provision.

8.2 Aims

The purpose of the work reported in this chapter was to determine the absolute and relative (versus general population data) risk of progressive osteoarthritis from the point of undergoing APM, using knee arthroplasty as the outcome. Differences in outcome associated with sex, age, comorbidity, deprivation, and ethnicity are investigated. The risk of knee arthroplasty in the index knee undergoing APM was also compared to the contralateral knee (with versus without a history of APM).

8.3 Methods

Data source

See section 3.3.1.

Participants and exposure

All patients undergoing APM or knee arthroplasty between 1 April 1997 and 31 March 2017 were eligible for inclusion. All HES records for these patients were extracted after identification using the recorded Classification of Surgical Operations and Procedures (OPCS-4) procedure codes (Appendix A).[235] For patients undergoing either APM or knee arthroplasty at any point in the cohort period, all previous and subsequent records were also identified for the same patient and extracted. The index

exposure analysed was the first APM recorded, per patient. Only isolated APM cases were eligible for inclusion as index cases, with patients undergoing prior surgery to the same knee, simultaneous ligament reconstruction, or combined meniscal procedures being excluded.

Outcomes

The outcome analysed was knee arthroplasty (total or partial). Arthroplasty procedures were matched by the side of the procedures (OPCS-4 laterality codes) and the absolute rate of knee arthroplasty was determined over time following the index procedure (APM). Records of repeat APM were identified and the time to repeat APM recorded. Hazard ratios for subsequent knee arthroplasty were stratified and adjusted by age group, sex, year of treatment, comorbidity, regional deprivation, rurality, ethnicity, and repeat APM. The relative risk of knee arthroplasty in the population with a history of APM, versus the general population without a history of APM, was determined. Outcomes in the index knee (first knee undergoing an APM) were also compared to the other knee (contralateral knee) considering whether the patient had also undergone APM in the contralateral knee.

Statistical analysis

Stata v15.1 (StataCorp, College Station, Texas, USA) was used to perform all analysis. In accordance with ONS and NHS Digital guidance, small numbers were suppressed where required.[239] The absolute rate of knee arthroplasty was determined at 5 years, 10 years, and 15 years following APM as the proportion of the cohort with each respective minimum period of follow-up. Mortality adjusted Kaplan-Meier survival analysis (survival was defined as not undergoing knee arthroplasty) was performed and stratified by patient age group and sex.

A Cox proportional-hazards model was used first to calculate the unadjusted hazard ratio of knee arthroplasty over time by age group, sex, index of multiple deprivation (quintile derived from regional factors in England including average income, employment, education, housing, and crime; 1=least deprived area, 5=most deprived), ethnicity, modified Charlson comorbidity index (see Appendix L; derived with maximum 5-year diagnosis code lookback period), year of treatment (APM), rurality, and

ethnicity respectively.[248–250,348] The hazard ratios were then adjusted including all these variables in the model.

The relative risk (risk ratio) of knee arthroplasty in the population of patients with a history of APM in comparison to the general population (without a history of APM) was estimated for the year 2016-17. All patients undergoing knee arthroplasty in 2016-17 were identified and the number of these patients with a previously recorded APM (in the prior years of HES data) versus those without a history of APM made up the numerator for each respective population. The APM population denominator was the number of living patients with a history of APM that had not undergone a knee arthroplasty prior to 2016-17. The denominator for the non-APM population was the ONS mid-year population estimate less the APM population. To aid interpretation, both the absolute and relative risk estimates were stratified according to the age of the patient in 2016-17, irrespective of the year of APM, where applicable.

8.4 Results

Between 1 April 1997 and 31 March 2017, a total of 938,612 patients (1,088,782 procedures) were identified. After data cleaning and exclusion of patients undergoing concurrent ligament reconstruction, meniscal repair, or with a history of previous arthroscopic interventions, 834,393 patients were included (Figure 8.1). Extraction of the arthroplasty cohort is summarised in Appendix M. The mean age of the APM cohort was 49.65 years (standard deviation [SD] 15.04) and 36.97% were female (Table 8.1). Overall, 9.78% (53272/544582; 95% confidence interval [CI] 9.70 to 9.86) of patients underwent knee arthroplasty within 5 years, 12.16% (34215/281291; 95% CI 12.04 to 12.28) within 10 years, and 13.49% (16256/120493; 95% CI 13.30 to 13.69) within 15 years (Table 8.1).

The risk of arthroplasty was greater in women (adjusted hazard ratio [HR] 1.42; 95% CI 1.40 to 1.43; Table 8.2, Figure 8.2, Figure 8.3). At 15 years, females were twice as likely to have undergone knee arthroplasty (risk ratio 2.23; 95% CI 2.16 to 2.29), with an absolute proportion of 22.07% (95% CI

21.64 to 22.51) in comparison to 9.91% (95% CI 9.71 to 10.12) in males. The rate of arthroplasty over time by age-group and sex is shown in Figure 8.3.

Older patients (when undergoing APM) were more likely to undergo subsequent arthroplasty (adjusted HR 1.37 per five years; 95% CI 1.37 to 1.37; Table 8.2). For patients aged 60-79 years, 34.80% (7449/21408; 95% CI 34.16 to 35.44) underwent arthroplasty within 15 years (Table 8.1). Patients with a greater comorbidity index at the time of APM were also at increased risk of subsequently undergoing arthroplasty (adjusted HR 1.04 per five units Charlson index; 95% CI 1.03 to 1.05). The risk of knee arthroplasty increased over the period of the study (adjusted HR 1.12 per five years; 95% CI 1.11 to 1.13). Patients in regions of increased deprivation and patients of white ethnicity were at greater risk of subsequent arthroplasty (Table 8.2).

After undergoing a first APM, overall 6.84% (57,060/834,393; 95% CI 6.78 to 6.89) patients underwent a further APM at mean 1492 days (SD 1379). Of patients with at least 1-year of follow-up time, 1.40% underwent APM within 1 year (11,024/787,791; 95% CI 1.37 to 1.43). By age group, the 1-year repeat APM rates were 2.69% (587/21783; 95% CI 2.48 to 2.92) in the under 20 age group, 1.98% (3477/175,497; 95% CI 1.92 to 2.05) in the 20-39-year group, 1.42% (5310/374591; 95% CI 1.38 to 1.46) in the 40-59-year group, 0.78% (1613/206,230; 95% CI 0.74 to 0.82) in the 60-79-year group, and 0.38% (37/9690; 95% CI 0.27 to 0.53) in the 80-plus age group. Adding repeat APM to the fully adjusted hazards model, the hazard ratio for subsequent arthroplasty was 1.49 (95% CI 1.46 to 1.53) for patients with a record of a repeat APM (in the same knee) in comparison to patients with a record of only undergoing one APM.

In 2016-17, the overall rate of knee arthroplasty was 1.81% (95% CI 1.78 to 1.84) in patients (aged 30 or older) with a recorded history of APM and approximately 0.17% (95% CI 0.17 to 0.17) in patients without a record of APM. This corresponded to an overall relative risk of knee arthroplasty for the APM cohort patients of 10.27 times (risk ratio [RR]; 95% CI 10.07 to 10.47) the general population without a record of APM. Although the absolute annual rate of knee arthroplasty was low, the relative risk of

undergoing knee arthroplasty in a younger age group was elevated more than older age groups, as shown in Table 8.3. Patients aged 30-39 with a history of a previous APM were 39.62 times (RR; 95% CI 27.68 to 56.70) more likely to undergo knee arthroplasty than the general population, in comparison to 6.44 times (RR; 95% CI 6.22 to 6.67) more likely for the over 69 age group.

Results comparing the index knee with the contralateral knee are shown in Figure 8.4 and Figure 8.5. For patients with a history of APM in only one knee (the index knee) the risk of knee arthroplasty in that knee was significantly elevated in comparison to the contralateral knee (without a history of APM) as shown in Figure 8.4. This difference corresponds to an adjusted hazard ratio of 2.99 (95% CI 2.95-3.02). Figure 8.5 shows the outcome in each knee in patients with a history of bilateral APM (either staged or simultaneous). For these patients, the risk of knee arthroplasty was greater in both knees in comparison to the unilateral APM patients.

Table 8.1: Demographics and proportion of patients with at least 5, 10, and 15 years follow-up undergoing subsequent TKA in the period (continued overleaf)

	All index procedures		5-year outcome		
	n	**%**	**n**	**n TKA**	**% (95% CI)**
Total	834393	100.00	544,582	53272	9.78% (9.70, 9.86)
Sex					
Male	525877	63.03	349,854	23568	6.74% (6.65, 6.82)
Female	308516	36.97	194,728	29704	15.25% (15.09, 15.41)
Age group (years)					
< 20	22879	2.74	-	-	-
20 - 39	183585	22.00	137,852	361	0.26% (0.24, 0.29)
40 - 59	398883	47.81	259,726	18349	7.06% (6.97, 7.16)
60 - 79	218878	26.23	140,008	32702	23.36% (23.14, 23.58)
80 +	10168	1.22	6,996	1860	26.59% (25.55, 27.64)
Charlson comorbidity index					
0	692111	82.95	468,095	39989	8.54% (8.46, 8.62)
1 - 15	136544	16.36	73,652	12614	17.13% (16.86, 17.40)
16 - 30	5354	0.64	2,677	635	23.72% (22.12, 25.38)
31 - 50	384	0.05	158	34	21.52% (15.39, 28.75)
Index of multiple deprivation (quintiles)					
1 = least deprived	186631	22.37	123,658	12118	9.80% (9.63, 9.97)
2	182705	21.90	120,060	12205	10.17% (10.00, 10.34)
3	174721	20.94	115,137	11641	10.11% (9.94, 10.29)
4	152008	18.22	98,454	9400	9.55% (9.36, 9.73)
5 = most deprived	129817	15.56	82,092	7459	9.09% (8.89, 9.28)
Missing	8511	1.02			
Rurality					
Urban	637911	76.45	414,851	39885	9.61% (9.52, 9.70)
Rural	192136	23.03	127,627	13271	10.40% (10.23, 10.57)
Missing	4346	0.52			
Ethnicity					
White	735248	88.12	482,429	51048	10.58% (10.49, 10.67)
Asian	22557	2.70	12,633	1076	8.52% (8.04, 9.02)
Black	12136	1.45	6,861	300	4.37% (3.90, 4.88)
Mixed	4752	0.57	2,598	144	5.54% (4.69, 6.49)
Other	5404	0.65	3,136	84	2.68% (2.14, 3.31)
Missing	54296	6.51			

Note: - = suppressed due to small numbers; CI = confidence interval; TKA = total or partial knee arthroplasty; APM = arthroscopic partial meniscectomy.

Cont.

	10-year outcome			15-year outcome		
	n	**n TKA**	**% (95% CI)**	**n**	**n TKA**	**% (95% CI)**
Total	281,291	34215	12.16% (12.04, 12.28)	120,493	16256	13.49% (13.30, 13.69)
Sex						
Male	189,731	16226	8.55% (8.43, 8.68)	85,048	8432	9.91% (9.71, 10.12)
Female	91,560	17989	19.65% (19.39, 19.91)	35,445	7824	22.07% (21.64, 22.51)
Age group (years)						
< 20	-	-	-	-	-	-
20 - 39	87,414	588	0.67% (0.62, 0.73)	44,719	666	1.49% (1.38, 1.61)
40 - 59	130,109	14152	10.88% (10.71, 11.05)	53,323	7860	14.74% (14.44, 15.04)
60 - 79	60,536	18567	30.67% (30.30, 31.04)	21,408	7449	34.80% (34.16, 35.44)
80 +	3,232	908	28.09% (26.55, 29.68)	1,043	281	26.94% (24.27, 29.74)
Charlson comorbidity index						
0	254,369	28371	11.15% (11.03, 11.28)	112,851	14522	12.87% (12.67, 13.07)
1 - 15	26,042	5626	21.60% (21.11, 22.11)	7,449	1688	22.66% (21.71, 23.63)
16 - 30	834	207	24.82% (21.92, 27.90)	193	46	23.83% (18.01, 30.48)
31 - 50	46	11	23.91% (12.59, 38.77)	-	-	-
Index of multiple deprivation (quintiles)						
1 = least deprived	64,509	8001	12.40% (12.15, 12.66)	27,054	3805	14.06% (13.65, 14.48)
2	62,701	8141	12.98% (12.72, 13.25)	26,509	3797	14.32% (13.90, 14.75)
3	59,596	7491	12.57% (12.30, 12.84)	25,420	3565	14.02% (13.60, 14.46)
4	50,609	5960	11.78% (11.50, 12.06)	22,227	2882	12.97% (12.53, 13.41)
5 = most deprived	41,618	4437	10.66% (10.37, 10.96)	18,420	2156	11.70% (11.24, 12.18)
Missing						
Rurality						
Urban	215,014	25567	11.89% (11.75, 12.03)	92,915	12118	13.04% (12.83, 13.26)
Rural	65,297	8611	13.19% (12.93, 13.45)	27,046	4117	15.22% (14.80, 15.66)
Missing						
Ethnicity						
White	246,714	32876	13.33% (13.19, 13.46)	103,915	15692	15.10% (14.88, 15.32)
Asian	5,165	598	11.58% (10.72, 12.48)	1,722	231	13.41% (11.84, 15.12)
Black	2,805	193	6.88% (5.97, 7.88)	1,083	88	8.13% (6.57, 9.92)
Mixed	1,017	93	9.14% (7.44, 11.09)	291	33	11.34% (7.94, 15.56)
Other	1,495	39	2.61% (1.86, 3.55)	755	19	2.52% (1.52, 3.90)
Missing						

Note: - = suppressed due to small numbers; CI = confidence interval; TKA = total or partial knee arthroplasty; APM = arthroscopic partial meniscectomy.

Table 8.2: Hazard ratios (subsequent TKA within maximum of 20 years) of APM

	Unadjusted Risk Subsequent TKA		**Adjusted Risk Subsequent TKA**	
	HR	**95% CI**	**HR**	**95% CI**
Sex				
Male	1.00	1.00	1.00	1.00
Female	2.21	2.18, 2.24	1.42	1.40, 1.43
Age (years; per five years) ‡				
Age	1.41	1.41, 1.41	1.37	1.37, 1.37
Year of treatment (APM; per five years)				
Year	1.28	1.27, 1.29	1.12	1.11, 1.13
Charlson comorbidity index (per five units)				
Charlson index	1.41	1.40, 1.42	1.04	1.03, 1.05
Index of multiple deprivation (quintile)				
1 = least	1.00	1.00	1.00	1.00
2	1.04	1.02, 1.06	1.07	1.05, 1.09
3	1.02	1.00, 1.04	1.11	1.09, 1.13
4	0.96	0.94, 0.98	1.15	1.13, 1.18
5 = most	0.91	0.89, 0.93	1.20	1.18, 1.23
Rurality				
Urban	1.00	1.00	1.00	1.00
Rural	1.11	1.09, 1.13	1.01	1.00, 1.03
Ethnicity				
White	1.00	1.00	1.00	1.00
Asian	0.78	0.75, 0.81	0.94	0.90, 0.99
Black	0.41	0.38, 0.45	0.54	0.50, 0.58
Mixed	0.55	0.49, 0.62	0.77	0.69, 0.86
Other	0.23	0.20, 0.27	0.37	0.32, 0.43

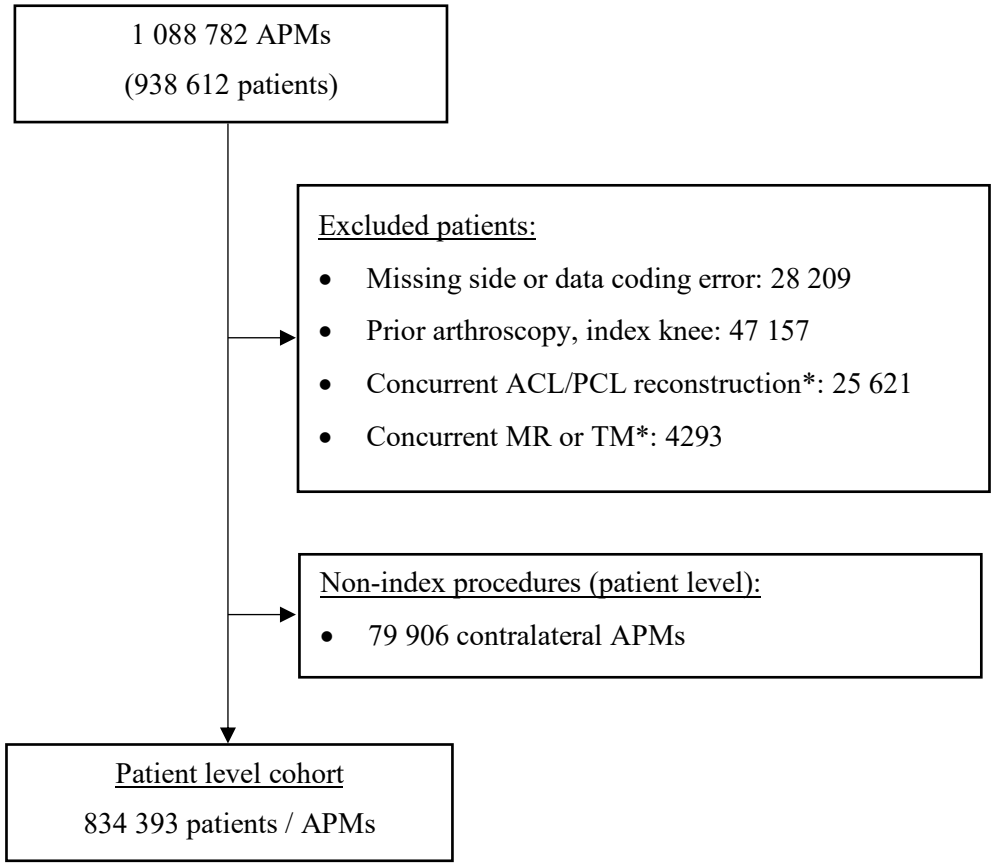
*Note: HR = hazard ratio; CI = confidence interval; TKA = total or partial knee arthroplasty; - suppressed due to small numbers; *adjusted by all variables in the table; ‡ age <20 years suppressed due to small numbers*

Table 8.3: Rates and relative risk of undergoing TKA with previous APM (within prior 20 years) by age at TKA in 2016-17

	Prior APM		**Without Prior APM**		**Relative Risk**	
Age at TKA (years)	**Annual Rate TKA /100k**	**95% CI**	**Annual Rate TKA /100k**	**95% CI**	**RR**	**95% CI**
30 - 39	59.69 (0.06%)	42.84, 80.96 (0.04%, 0.08%)	1.51 (0.00%)	1.24, 1.81 (0.00%, 0.00%)	39.62	27.68, 56.70
40 - 49	490.48 (0.49%)	454.28, 528.79 (0.45%, 0.53%)	16.24 (0.02%)	15.33, 17.18 (0.02%, 0.02%)	30.07	27.37, 33.03
50 - 59	1725.09 (1.73%)	1667.14, 1784.51 (1.67%, 1.78%)	105.70 (0.11%)	103.34, 108.11 (0.10%, 0.11%)	16.06	15.42, 16.73
60 - 69	2859.27 (2.86%)	2778.80, 2941.42 (2.78%, 2.94%)	333.79 (0.33%)	329.11, 338.52 (0.33%, 0.34%)	8.36	8.10, 8.62
70 +	3190.51 (3.19%)	3085.56, 3298.02 (3.09%, 3.30%)	482.41 (0.48%)	477.05, 487.82 (0.48%, 0.49%)	6.44	6.22, 6.67
Overall (30 +)	1808.22 (1.81%)	1776.35, 1840.50 (1.78%, 1.84%)	173.21 (0.17%)	171.81, 174.61 (0.17%, 0.17%)	10.27	10.07, 10.47

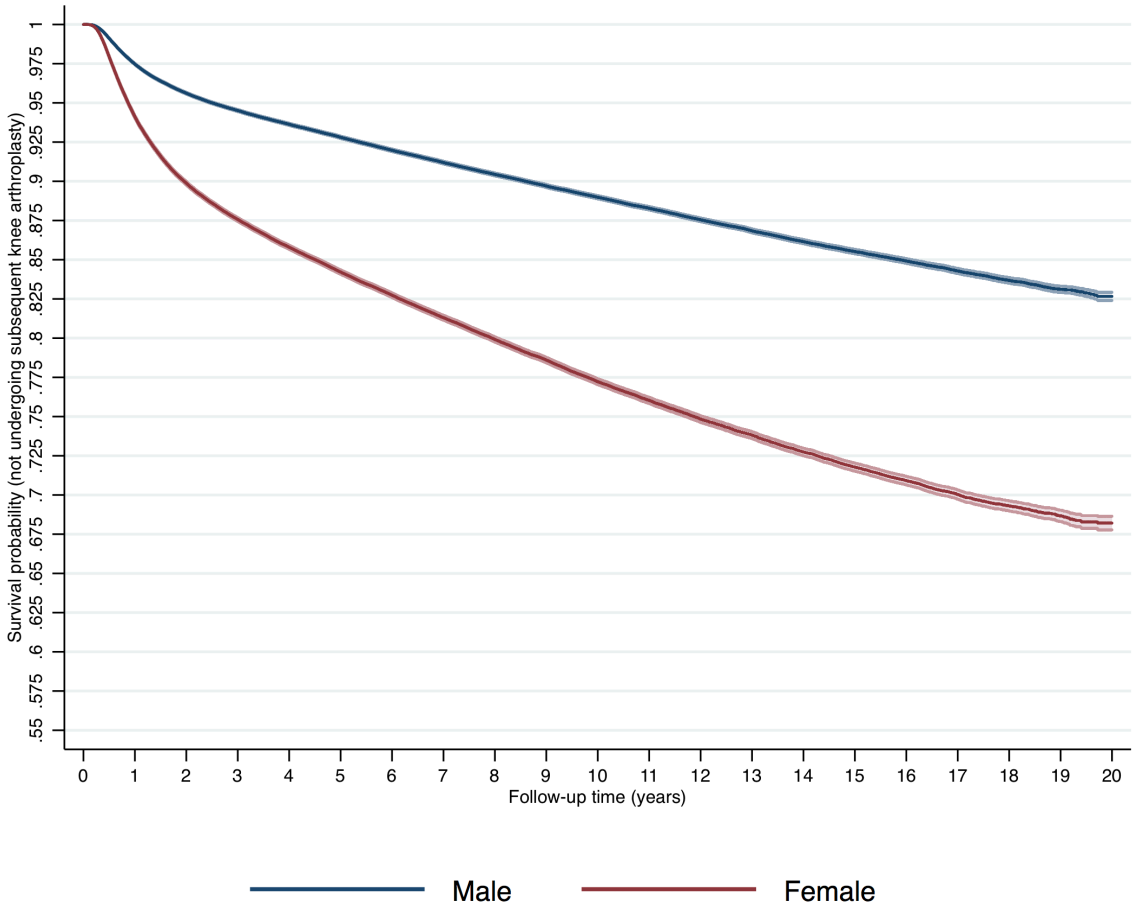
Note: TKA = total or partial knee arthroplasty; APM = arthroscopic partial meniscectomy; CI = confidence interval; RR = risk ratio.

Figure 8.1: Flow chart illustrating extraction of patient level cohort



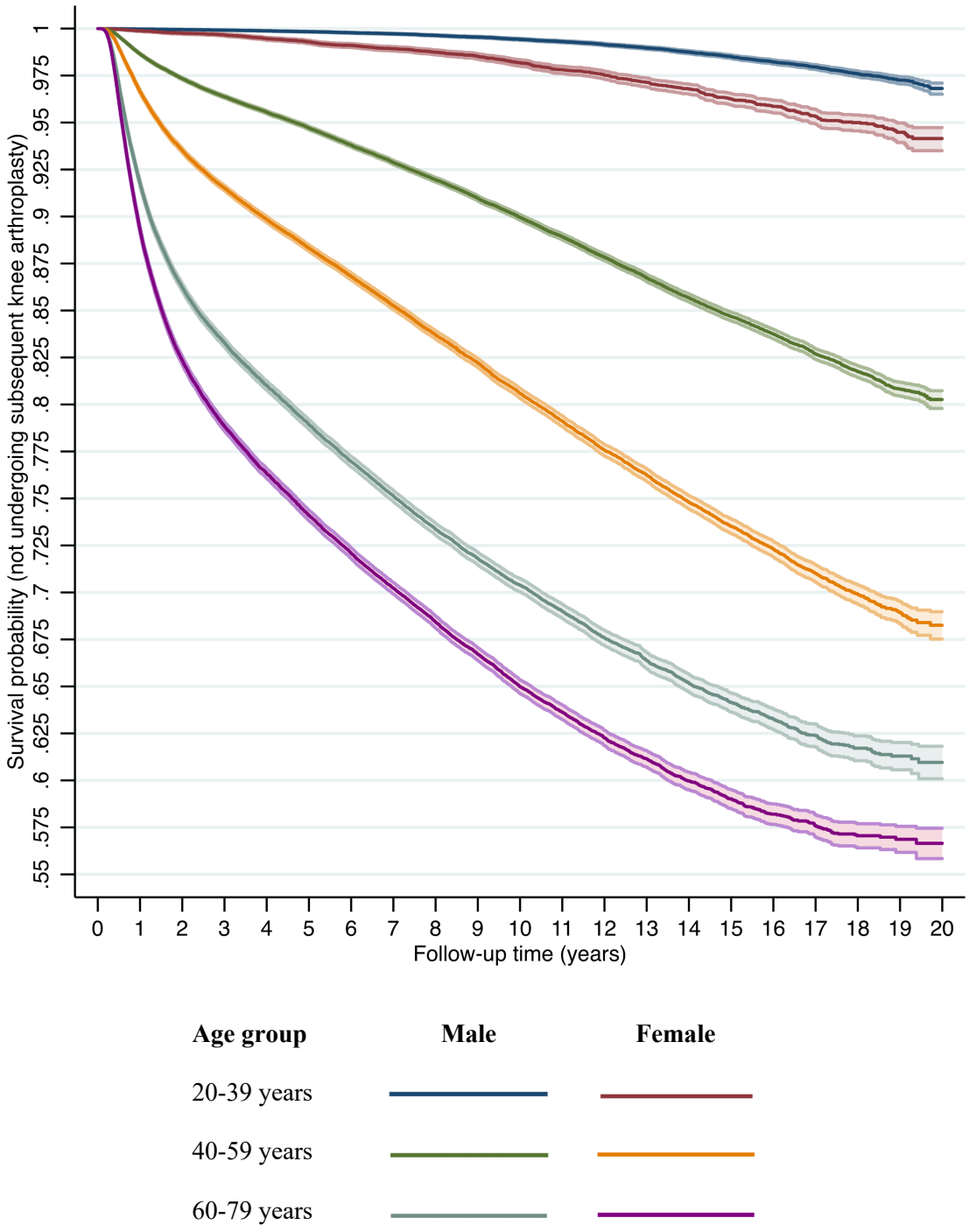
*Note: * not mutually exclusive; ACL = anterior cruciate ligament; PCL = posterior cruciate ligament; MR = meniscal repair; TM = total meniscectomy.*

*Figure 8.2: Survival curve (knee not undergoing subsequent knee arthroplasty after APM) by sex **



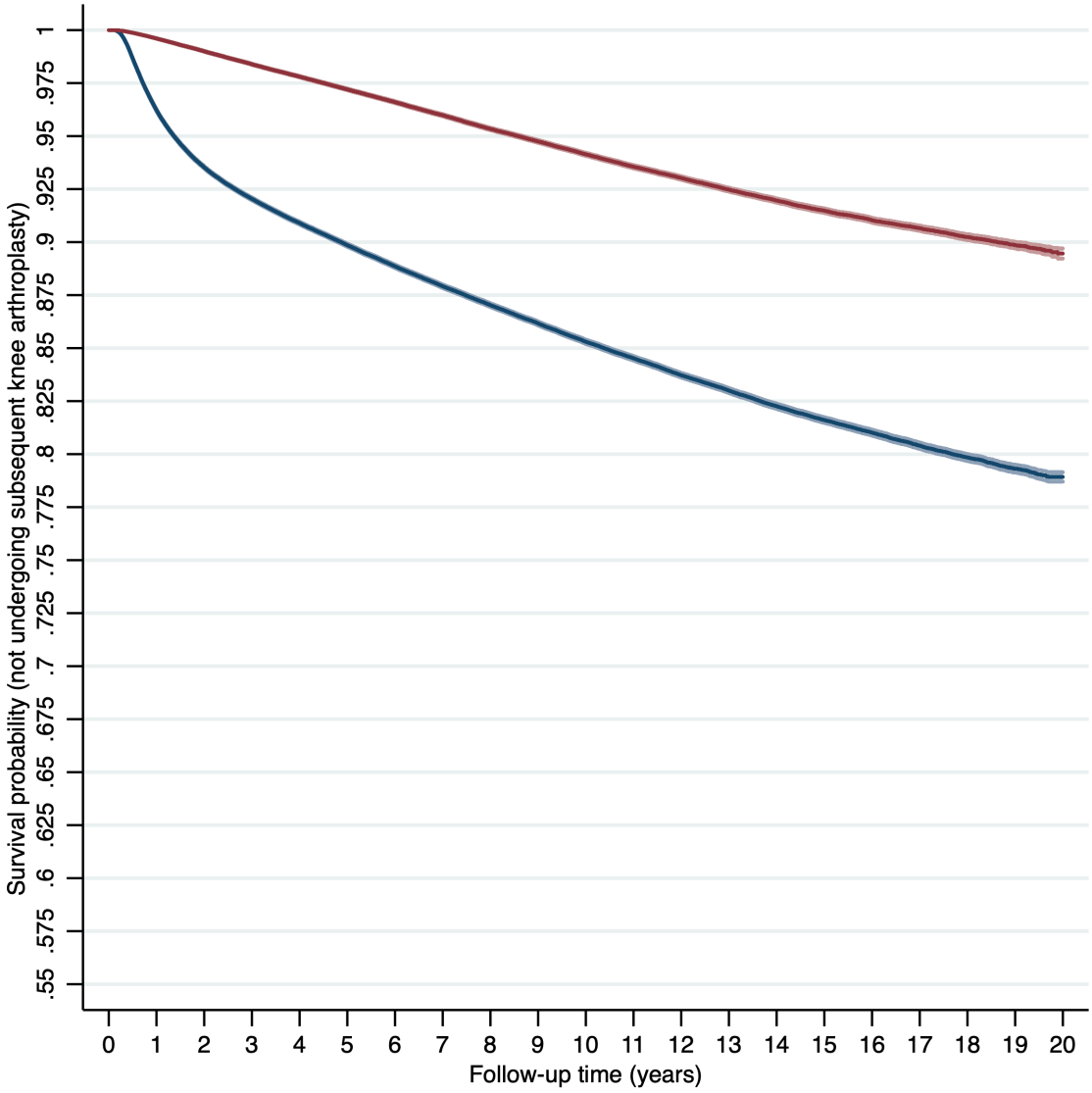
*Note: * Age group < 20 years suppressed due to small numbers*

*Figure 8.3: Survival curve (knee not undergoing subsequent knee arthroplasty after APM) by age and sex **



*Note: * Age group < 20 years and 80+ suppressed due to small numbers*

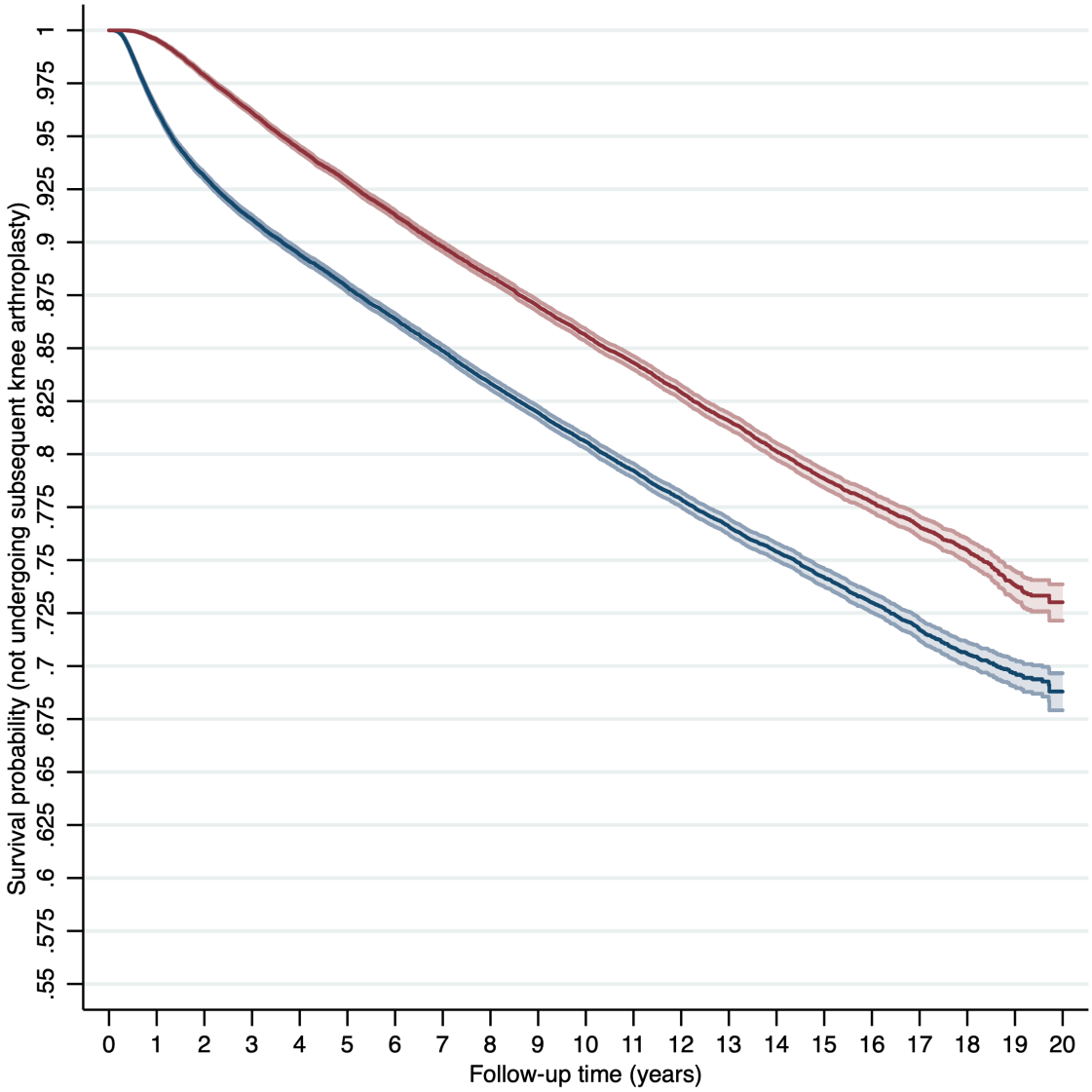
*Figure 8.4: Rate of subsequent arthroplasty in patients undergoing unilateral APM: Index knee versus contralateral knee (no APM) **



	Contralateral Knee (no APM)
	Index Knee (APM)

*Note: * Age group < 20 years and 80+ suppressed due to small numbers*

*Figure 8.5: Rate of subsequent arthroplasty in patients undergoing bilateral APM: Index knee versus contralateral knee (simultaneous or staged APM) **



	Contralateral Knee (simultaneous or staged APM)
	Index Knee (APM)

*Note: * Age group < 20 years and 80+ suppressed due to small numbers*

8.5 Discussion

8.5.1 Principal findings

This chapter has defined the long-term risk of undergoing knee arthroplasty in a cohort of patients with meniscal lesions who had undergone APM. Overall, 13.5% of patients underwent knee arthroplasty within 15-years and women were twice as likely as men to progress to this end-stage outcome. The annual rate of arthroplasty was 1.81% for patients aged 30 years or greater with a history of APM, corresponding to a ten times greater relative risk of knee arthroplasty in comparison to the general population without a recorded history of APM. The risk of subsequent arthroplasty has increased over time, and was greater in older patients, patients from deprived regions, and patients of white ethnicity. In patients with a history of APM in only one knee, the risk of knee arthroplasty was greatly elevated in comparison to the other knee without a history of APM.

8.5.2 Comparison with other studies

Previous studies investigating the overall relative risk of knee arthroplasty following meniscal damage in comparison to the general population are scarce. In one relatively small, high risk cohort, patients with meniscal tears, undergoing APM, were found to be at three-times increased risk of knee arthroplasty.[375] The relative risk in the present study was higher than this in all age groups, but lower than one recent case-control study utilising primary care data, where patients with meniscal 'injury' were found to have an overall fifteen times greater risk of knee arthroplasty.[132] This case-control study may have over-estimated this outcome due to limitations from a failure to control for prior knee surgery, no record of surgical interventions performed, and knee 'laterality' was not known, precluding matching by knee side.[132]

In a recent systematic review of knee arthroplasty rates after knee 'arthroscopy', the absolute annual rate of arthroplasty varied from 1.99% overall to 4.13% in patients with more severe osteoarthritis.[371] The included studies were small and had relatively short periods of follow up, however these reported rates are similar to the findings in this study. The proportion of patients undergoing subsequent

arthroplasty in the present study was greater in older age groups as may be expected from the higher rates of degenerative knee disease in this population.[252,253] In the cohort, 23.36% of patients aged 60-79 years underwent knee arthroplasty within 5-years of APM. Other studies have also reported higher rates of knee arthroplasty in older patients, at 20.1% within two years for patients aged over 65 in an Australian knee arthroscopy and 13.7% within three years for knee arthroscopy patients over the age of 50 years in the United States.[190,251]

Although the absolute risk of undergoing a knee arthroplasty at a young age was low, the relative risk of undergoing arthroplasty was markedly elevated for patients with a history of APM in comparison to the general population without a history of APM. This finding suggests that meniscal injury (in patients undergoing APM) may accelerate osteoarthritic progression, causing individuals to reach an endpoint of advanced, painful, osteoarthritis at a younger age than otherwise susceptible individuals in the general population. Indeed, it has previously been reported that isolated meniscal pathology is associated with an increased odds of radiographic osteoarthritis even within 2 years.[376] The present study utilised knee arthroplasty as the primary outcome rather than a radiographic outcome which is subjective and may not be correlated with symptomatology.[131,372] Another interesting study of primary care data estimated an approximately six times increased consultation rate for 'knee osteoarthritis' in patients with a history of APM, in comparison to the general population.[377]

Previous studies have suggested a higher prevalence of osteoarthritis, including knee osteoarthritis, in women in comparison to men.[70,253] Despite this, there is evidence that, at a population level, women may be less likely to undergo arthroplasty.[70,378] The findings reported in the present study are different and women were twice as likely as men to undergo arthroplasty within fifteen-years of APM for a meniscal tear. One possible reason for the higher rate of progressive osteoarthritis in women could have been pre-existent osteoarthritis at the time of APM, however the exclusion of patients undergoing previous knee surgery lessens this possibility and, furthermore, the sex difference in outcome was detected in all age-groups.

Previously, women over fifty have been shown to be at higher risk of knee arthroplasty at two years following general knee arthroscopy in limited US data.[251] In the present study, the difference in arthroplasty rates in women was observed over time even after age-group matching and multi-variable adjustments. Taken together, the findings suggest that women are more susceptible to progressive osteoarthritis than men. The study does not determine the causative pathobiology that may underlie this observation, but hormonal influences are one proposed mechanism underlying observed differences in musculoskeletal pain and osteoarthritis in women and this should be a focus for further research.[379,380] Indeed, potentially in support of this hypothesis, a greater risk difference for women in a peri-menopausal age group (40-59-years) was observed in comparison to pre-menopausal and post-menopausal groups. These could also, however, be explained by different thresholds for knee arthroplasty in this age group for patients and/or clinicians.

Other patient factors associated with an increased risk of knee arthroplasty were regional deprivation, and white ethnicity. Patients with a higher comorbidity score were also slightly more likely to undergo subsequent arthroplasty, as has previously been shown following ACL reconstruction.[381] The reasons for these observations are likely to be multi-factorial, related to differences in care seeking behaviour or differences in access to treatment. Previous studies have reported care seeking attitudes are influenced by culture, social and economic status, occupation, and perceptions of symptom severity or disability.[71,72] Communication challenges and cultural differences may also play a role in access to healthcare, particularly at the point of interaction with clinicians.[73] It must be noted, however, that all patients included in the reported cohort had already 'sought care', undergoing APM surgery at the point of inclusion, and therefore caution is required before attributing the observed differences in subsequent arthroplasty rates solely to differences in care seeking behaviour or access to healthcare.

In light of the latest clinical trial evidence suggesting a need for narrower indications for APM, it was concerning to find the rate of arthroplasty following APM has risen slightly over time (as also shown for the early rate of arthroplasty reported in Chapter 4).[209,212,219,223,382] With refined treatment guidelines, fewer patients may undergo APM in future and a greater proportion may be treated conservatively or,

in carefully selected cases, with meniscal repair.[383,384] Meniscal repair aims to preserve torn meniscal tissue and additionally to restore meniscal function.[383,384] It is hoped that this evolving treatment strategy will lead to lower rates of osteoarthritis but this awaits further data.

The previous chapter (Chapter 7) reported the rate of adverse outcomes occurring within 90-days of APM in the same population as this chapter. For patients with persistently symptomatic meniscal tears, considering undergoing APM, the findings from the present study complement these data and this information will be important to informed consent discussion and shared decision making between patients and clinicians. Non-operative treatments and meniscal preservation surgery is increasingly recommended and should be targeted at higher-risk groups.[383,384] The present study findings will enable the monitoring and comparison of outcomes from newly implemented treatment strategies, including the use of meniscal repair and non-operative treatments, especially those aimed at improving outcomes in women and other high-risk patients.

8.5.3 Strengths and limitations

This study was limited to patients with meniscal tears, undergoing APM, and is therefore of relevance to the large number of patients with meniscal tears where APM may be recommended as the treatment. The data was strengthened by the exclusion of all patients with a history of prior knee surgery or simultaneous arthroscopic procedures including ligament reconstruction. Despite the exclusions, this is the largest cohort of meniscal injury or APM patients that has been reported and this large sample size of prospectively recorded longitudinal data enhances the precision of the findings and ability to investigate the influence of patient-specific factors. The relative risk of knee arthroplasty in comparison to individuals in the general population without a history of APM was calculated. There are, however, some potential sources of unmeasured confounding to note, such as body mass index and severity of pre-existing osteoarthritis. Attempts to minimise the impact of these factors were made by the inclusion of Charlson comorbidity index and age-group in the analysis, and by the use of a consistent and

objective criterion for the point of inclusion in the cohort (undergoing APM). For a discussion of the general strengths and limitations of HES data, please see also sections 3.5.3 and 4.5.3.

This study used the endpoint of knee arthroplasty as the primary outcome. Use of radiological grading as an outcome may not reflect pain symptomatology, and symptoms alone may have other underlying causes than osteoarthritis.[104,372] Knee arthroplasty is more objective, combining both symptoms and radiological assessments and has been used as an outcome in studies of pharmacological interventions for knee osteoarthritis.[373,374] This outcome will, however, under-estimate the overall health burden of painful knee disease in this population.

The study cohort first sustained a meniscal tear and then underwent APM surgery, and the potential impact from both these events must be considered in the interpretation of the findings reported in this chapter. Damage to meniscal tissue results in the loss of the ability of the meniscus to resist displacement from compressive load, leading in many cases to extrusion of the meniscus from the joint.[49–51] Normally, the meniscus acts to protect the chondral surfaces of the tibiofemoral joint by acting as load-sharer, however complete loss of meniscal tissue more than doubles contact pressures (see section 1.4.3).[30,52] Whilst the success of APM is generally measured by the improvement in knee pain and other symptoms, there is a possibility that APM itself may cause further damage to the function of the meniscus.[195,207,209,213,232,233] Comparing outcomes to the other knee in patients that had undergone unilateral APM versus bilateral APM it was observed that patients with history of APM in only one knee were three times more likely to undergo knee arthroplasty in that knee in comparison to the contralateral knee without a history of APM. This comparison attempted to control for an individual's innate risk of progressive osteoarthritis and the difference between the index knee and the contralateral knee was observed in both males and females. Patients with a history of bilateral APM were at greater risk of undergoing subsequent knee arthroplasty in both knees in comparison to unilateral APM patients. This interesting finding could be due to this population having a greater anatomical or biological predisposition to progressive osteoarthritis or meniscal injury in both knees. It was not possible in the present study, however, to determine the relative risk for these patients had they not undergone

surgery.[233] The study did not intend to answer this question and this would require a large randomised controlled trial comparing the long-term outcome of patients undergoing APM to those managed non-operatively.

8.5.4 Conclusion

The national cohort study reported in this chapter had an objective criterion for entry, at the point of undergoing APM for a meniscal tear, and also an objective endpoint, undergoing knee arthroplasty. The findings confirm that patients with meniscal tears, undergoing APM, are a cohort at high-risk of progression to end-stage osteoarthritis (using knee arthroplasty as the outcome marker) and this justifies a need for careful surveillance of this population and treatment, where appropriate, aimed at reducing this risk.

The study is the first to precisely inform patients and clinicians of the long-term outcomes following APM, but further investigation into the outcomes of non-operative treatment is still required and the possibility that APM itself might be detrimental should be explored. The findings also highlight a need for investigation of the pathophysiology underlying the differences in rates of progressive osteoarthritis between patient groups. Women were found to be at greater risk than men, but the biological, hormonal, genetic, or healthcare provision factors that might underlie this observation are unknown. These findings will inform shared decision making and may help in the development of more patient-specific treatment strategies. Comparison of the outcomes from emerging treatments aimed at reducing the risk of osteoarthritis must await further data but, informed by this study, these treatment strategies should be targeted especially to women and other high-risk groups.

9 CONSENSUS ON THE DEFINITION, INVESTIGATION, AND CLASSIFICATION OF MENISCAL LESIONS[‡‡]

9.1 Introduction

Chapter 3 documents an increase in the rate of APM being performed in England and associated age-group and regional variation in practice. Chapter 4 reports that a significant proportion of patients, especially those over the age of 60 years, are subsequently undergoing knee arthroplasty within one or two years, and again reports considerable age group variation in this outcome, suggesting inconsistent treatment selection. These findings provide a rationale for developing new clinical guidance (see section 1.5 for a description of care pathways and guideline development). There is a need to improve and standardise the care pathway for these patients. For effective clinical guidance, there is a need for clear terminology: the definitions and classifications relevant to the population of interest (see section 1.5.5). For patients with meniscal lesions, however, no such terminology exists.[212]

As described in the Background (section 1.8.3) and in Chapter 5-6, interpretation of the clinical evidence for APM has been hampered by inconsistent and broad study inclusion criteria, with specialists arguing that the patients selected for inclusion in clinical trials would not be considered eligible for surgery in contemporary practice.[208,223,339] Surgeons currently must estimate the likely benefit from APM based upon a patient's symptoms, signs, the pattern of meniscal tear detected using, for example, MRI imaging, and other factors such as severity of any underlying osteoarthritis, duration of symptoms, and previous history. Stratifying patients in this way has previously been challenging as there has been no agreement on how to define and classify these factors. The pattern of symptoms, especially corresponding "mechanical symptoms", is thought to be critical to the identification of patients with knee pain of meniscal origin.[211,212,223,230,311,313,332] Despite this, no definition for these symptoms has been

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agreed.[208] Furthermore, given that many meniscal tears are asymptomatic, the importance of the anatomical pattern of meniscal tear and the presence or absence of radiographic osteoarthritis has also been highlighted.[111,304] Certain patterns of meniscal tear are thought to be more likely to cause symptoms due to their mechanical 'instability' and some attempts have previously been made to classify the radiological appearances of such meniscal lesions, but there has been a lack of agreement.[109–111]

9.2 Aims

The aim of the work reported in this chapter was to deliver standardised terminology according to expert consensus, in order to facilitate consistent identification, description, and comparison of patients with meniscal pathology in clinical practice, research, and the development of treatment guidance.

9.3 Methods

An introduction to consensus methods is included in the Background Chapter (section 1.5.6). For the work reported in this chapter, a combination of nominal group techniques and the Delphi method was utilised (as described below), in accordance with the development of consensus statements published by other groups.[87,88,385–387] As the intended output was specialist terminology to describe and classify clinical factors including symptoms, signs, and radiological findings, for use by surgeons in hospital practice, an expert panel was selected and recruited.

9.3.1 Composition of the consensus panel

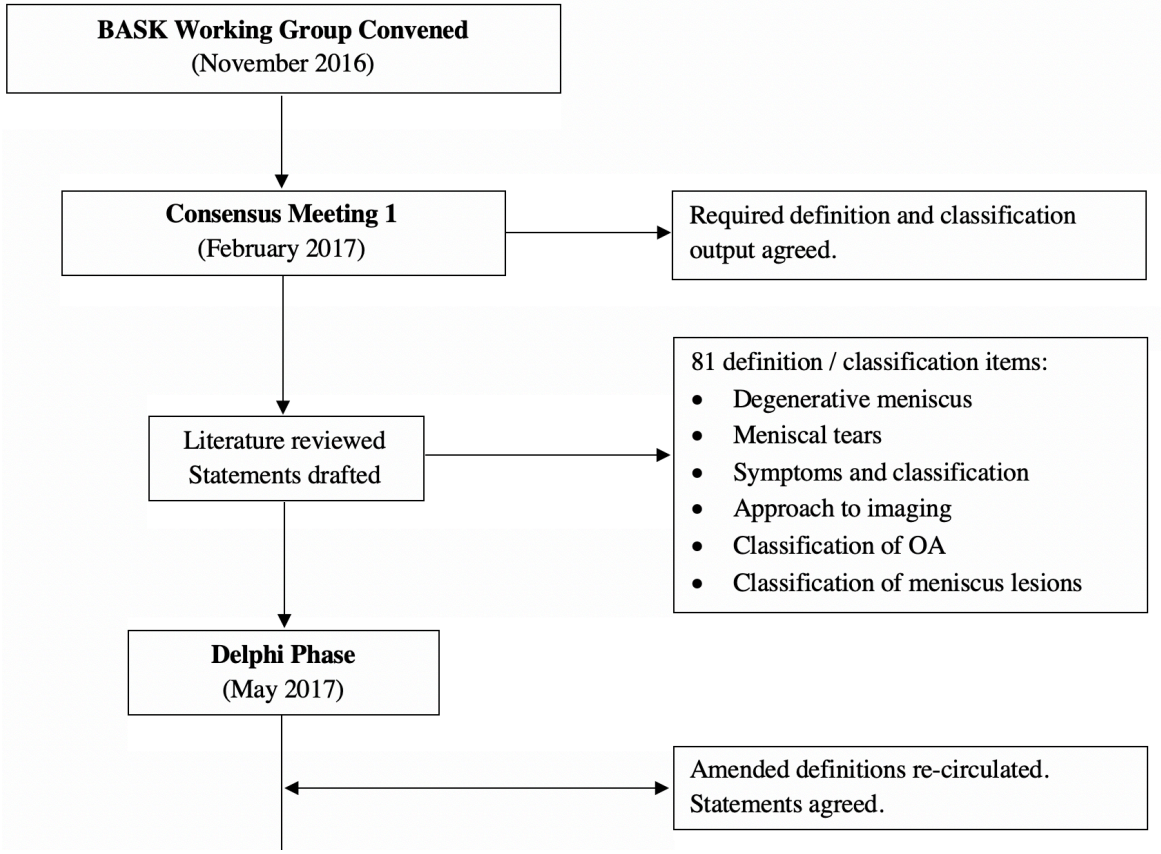
In November 2016, twenty-five experts were invited to participate in a "British Association for Surgery of the Knee (BASK) Meniscal Working Group". These individuals were selected due to a combination of their: (1) research interests and publication history, (2) clinical specialism, and (3) peer-recognition and recommendations. As part of this process, consideration was given to the importance of inviting members practicing in as wide a range of geographic regions as possible.

9.3.2 Methodology

An overview of the process is summarised in Figure 9.1. Twenty-one surgeons agreed to participate and fifteen were available and attended the first scoping meeting of the group in February 2017. The BASK Meniscal Working Group participants are listed in Appendix N. The meeting was chaired by an independent senior academic and physiotherapist (DJB).

Prior to the meeting, a literature review was performed to identify previous guideline documents on the topic of meniscus lesions. Previous clinical trials were identified using a comprehensive search strategy as part of a (at that time ongoing) systematic review (Chapter 6). All literature was circulated electronically to the group and new publications and other relevant documents identified by any member of the group were circulated regularly to all members during the consensus process. At the first meeting, following an introduction to the process and introductions from participants, a presentation was given summarising the currently published evidence, followed by discussions to agree the topics to be covered and planned scope of the process. When available, existing definitions identified from the literature review were presented as a starting point for discussions. Throughout the process, each member of the group was encouraged to contribute any further topics for discussion.

Figure 9.1: Consensus process on terminology (Chapter 9)



Note: Consensus process continues in Chapter 10 (see Figure 10.1).

All relevant definitions were refined by discussion and the level of group agreement was assessed by voting. Each proposed modification to a definition was put to a vote and the level of agreement was recorded. A pre-defined and accepted agreement threshold of 80% (12/15) or more of the group was required before progressing to a new topic.[385]

Following this first meeting, the minutes were used to prepare a modified list of topics and proposed definitions for all the patient selection factors highlighted as important by the group. Then, an electronic survey was prepared inviting anonymous voting and comments on each proposed topic using proprietary software (SurveyMonkey Inc., San Matteo, California USA). Two types of questions were used: 'Likert-type', assessing level of agreement, and 'categorisation' type questions. The level of agreement was measured on a scale from 1 (disagree) to 10 (agree). [385] A box for comments was always

available and when a participant voted 7 or less, the participant was asked "What's the minimum change in wording for you to agree strongly?"[385] Consensus agreement was defined, in accordance with other published work, as a predetermined mean score of 7 or greater (with fewer than 20% outliers – defined as a score of 4 or less).[386,387]

Where considered clinically important by the group, definitions were further placed into categories to facilitate their usage in clinical practice and guideline development. For example, in classifying symptoms and signs, it was felt to be important to distinguish those likely to be 'meniscal' in origin, from those more likely to be associated with osteoarthritis. In these cases, respondents were asked to place statements into one of 2 or 3 proposed categories or a "not applicable (remove)" category. A threshold agreement of greater that 50% was required (10 votes) to agree the placement of a definition into a category.

The questionnaire was circulated to all members of the group for voting throughout May 2017 with a response rate of 90% (19/21). A revised list of proposed topics, definitions, and categories was prepared by the steering committee and circulated to the group for further feedback in July 2017. At this stage, each individual member was asked to highlight any area of strong disagreement that would have triggered another round of voting, but this was not required. Finally, the group met again in November 2017 (17 attendees) to agree the definitive output.

9.4 Results

Following conclusion of the three phases of the process, analysis of the results confirmed agreement on 47/47 definitions. Of these, thirty-four definitions were in topics the group decided should be further classified to aid clinical practice and guideline development. Thirty-two (/34) of these items were classified successfully in the first round of voting using the pre-determined threshold for agreement. The two items that were not categorised and all minor amendments to wording and other comments were reviewed and considered by the steering group (SA/DJB/AJP). All items including amended

definitions were circulated to the group for further discussion and finally approved at the meeting in November 2017.

The definitions of a degenerative meniscus and meniscal 'tears' were agreed as shown in Table 9.1. Table 9.2 summarises the agreed definitions of symptoms and signs and their categorisation. Four symptoms and signs were categorised as 'strongly suggestive' of a treatable meniscal lesion – highly likely to be meniscal in origin. Eight symptoms and signs were defined and categorised as being potentially suggestive of a treatable meniscal lesion – possibly meniscal in origin. Finally, based upon the ACR diagnostic criteria for osteoarthritis, five findings were defined and categorised as osteoarthritic – highly unlikely to be meniscal in origin.[11] One additional finding within this category – "inactivity pain and stiffness" – is analogous to what some authors have termed "gelling", however it was felt by the group that using this specific term might lead to misuse or confusion and therefore the purely descriptive terminology was accepted.[388]

A general approach to radiological imaging was discussed and agreed. This approach to imaging is summarised in Table 9.3 with plain radiography being recommended as first line in patients when osteoarthritis is suspected and MRI being recommended in all other patients with suspected treatable meniscal pathology. The severity of structural osteoarthritis was defined and classified based on either plain radiographs or MRI imaging as summarised in Table 9.4. Three categories were accepted: (1) early or no structural osteoarthritis, (2) mild to moderate structural osteoarthritis, and (3) advanced structural osteoarthritis.

Finally, meniscal findings on MRI imaging were defined and classified as shown in Table 9.5. The group defined 'bucket-handle' meniscal tears and agreed these represent a clear treatment target along with displaced meniscal tears (definitively unstable) and cases of meniscal root failure. All patterns of undisplaced meniscal tears were defined by the group and then categorised as representing possible targets for meniscal surgery. It was highlighted, however, that surgeons must exercise caution when interpreting a report of findings from a static knee MRI, given that dynamic movements of the knee

may cause tear displacement. Finally, MRI appearances of meniscal contour abnormality, isolated meniscal extrusion, or cases where MRI demonstrated no tear were defined and categorised in a 'no target' category.

Table 9.1: Consensus statements – Degenerative meniscus and meniscal tears

Degenerative meniscus and meniscal tears
A degenerative meniscus develops progressively with degradation of meniscal tissue and this may be revealed by intra-meniscal high signal on MRI imaging. A meniscal 'tear' is a defect or split in the meniscocapsular complex, which can occur in a degenerative or non-degenerative meniscus. Degenerative meniscal lesions (high signal or tear) are frequent in the general population and are often incidental findings on knee MRI. There may or may not be a memorable history of knee injury.

Table 9.2: Consensus statements – Symptoms and signs of meniscal lesions

Strongly Suggestive of a Treatable Meniscal Lesion
Locked knee: sudden onset, complete mechanical block to flexion or extension of the knee, detected on clinical examination and which does not resolve despite adequate analgesia. Locking: An intermittent block to normal range of movement of the knee (commonly a block to extension) with an associated unlocking movement. Knee returns to near normal after unlocking. Catching: the sensation of something intermittently out of place in the knee and interfering with joint movement. Tender, palpable meniscal tissue: the finding on clinical examination of a discrete, tender lump, close to the joint line.
Potentially Suggestive of a Treatable Meniscal Lesion
Episodic sharp knee pain: sharp, intermittent knee pain, occurring with sudden onset. Intermittent knee swelling: symptom of periodic swelling of the knee, lasting for hours to days, that has occurred over a period of weeks or months. Knee effusion: a clinically detectable intra-articular fluid collection of the knee joint. Activity avoidance: the active avoidance of specific, potentially provoking, movements or activity e.g. twisting. Squatting pain: knee pain that is exacerbated by deep flexion when weight bearing (may be reported by the patient or elicited during clinical examination). Clicking +/- pain: • Clicking: a clicking noise or sensation when moving the knee. • Painful clicking: a clicking noise or sensation when moving the knee that is associated with pain. Meniscal provocation tests: • McMurray's meniscal provocation test: Positive when a click, or familiar pain, can be reproduced, heard, and/or felt on joint line palpation, when the knee is bent beyond 90°

flexion and the tibia is rotated on the femur into full internal rotation then full external rotation (to test the lateral and medial meniscus respectively).

- Thessaly meniscal provocation test: Examiner supports the patient by holding the patient's outstretched hands while he/she stands flatfooted on the floor. The patient then rotates his or her knee and body, internally and externally, three times, keeping the knee in slight flexion (20°). Positive when the patient experiences medial or lateral joint line pain.
- Apley's meniscal provocation test: Patient lies prone and the knee flexed to 90°. The tibia is then compressed onto the knee joint while being externally rotated. If this manoeuvre produces pain, this constitutes a positive test.

Joint line point tenderness:

- Joint line point tenderness: point tenderness on the joint line, detected on clinical examination.
- Posteromedial joint line tenderness: tenderness on deep palpation of the joint line, from mid medial collateral ligament posteriorly, corresponding to the location of the commonest posteromedial degenerative meniscal lesion.

Osteoarthritic Symptoms and Signs

Inactivity pain and stiffness: the temporary, subjective sensation of stiffness on initiation of movement, often with pain, after periods of immobility (e.g. sleeping, prolonged sitting).

Crepitus: crunching, grating or creaking detected clinically on active movement of the knee.

Bony enlargement: abnormal shape of the normal knee bony contour visible on inspection or detected on clinical examination.

Bony tenderness: tenderness on clinical palpation of the bone adjacent to the joint.

Aching pain: constant knee pain during and after activity.

Table 9.3: Consensus statements – Approach to imaging for patients with a suspected meniscal lesion

Approach to imaging
The following secondary care imaging was agreed: 1. Plain radiographs (weight-bearing AP and lateral +/- Rosenberg +/- skyline view) are the first line investigation when OA is suspected. 2. In patients where OA is not suspected, MRI is the first line investigation*. 3. If plain radiographs do not demonstrate advanced osteoarthritis (K-L 4) and meniscal symptoms predominate, then MRI imaging is indicated. **In certain cases, when clinical findings are conclusive (e.g. locked knee), clinicians may apply their own judgement on the need for MRI imaging.*

Table 9.4: Consensus statements – Classifying the severity of structural osteoarthritis

Classification of structural osteoarthritis
Early or No Structural OA: Kellgren-Lawrence Grade 0 or 1 on plain radiographs and/or Normal MRI, or MRI with possible chondral signal change and no chondral loss. Mild to Moderate Structural OA: Kellgren-Lawrence Grade 2 or 3 on plain radiographs and/or Partial thickness chondral loss on MRI. Advanced to End-stage Structural OA: Kellgren-Lawrence Grade 4 on plain radiographs and/or significant areas of full thickness chondral loss on MRI*. **Excluding cases of contained full thickness cartilage / osteochondral defects.*

Table 9.5: Consensus statements – Meniscal findings from magnetic resonance imaging (MRI)

Classification of meniscal lesions on MRI
Target (Treatable Lesion: meniscal surgery may be indicated based on appearance)
"Bucket-handle" tear: a longitudinal tear or peripheral separation involving MORE than 25% of meniscus length (either displaced or undisplaced). Displaced meniscal tear: a meniscal lesion with meniscal fragments displaced from their usual anatomical position. Meniscal root failure: a complete tear or avulsion of the meniscal root.
Possible Target (Indeterminate Lesion: meniscal surgery may be indicated based on appearance)

Undisplaced meniscal tears:
• Radial tear:
  o Radial flap tear: a vertical and oblique meniscal tear lesion (parrot beak type).
  o Complete radial split tear: a radial meniscal tear lesion that extends to the meniscocapsular junction.
  o Partial radial split tear: a radial tear that does not extend to meniscocapsular junction.
• Horizontal tear +/- cyst:
  o Horizontal cleavage tear and meniscal cyst: a horizontal meniscal cleavage lesion that is associated with a meniscal cyst.
  o Horizontal cleavage tear in isolation: meniscal horizontal cleavage lesion without an associated cyst.
• Complex meniscal lesion: a meniscal lesion with more than 1 plane of tear in continuity.
• Short longitudinal tear: a longitudinal meniscal tear lesion involving LESS than 25% of the overall meniscus length.

No Target (Unlikely Treatable: meniscal surgery not indicated based on appearance)
Contour abnormality: a meniscus with an abnormal edge contour and very minor tear only. Isolated meniscal extrusion: extension of the meniscus beyond the tibial margins without any associated meniscal tear. No tear.

9.5 Discussion

9.5.1 Principal findings

This chapter summarises the results of a national consensus exercise on the definition and classification of meniscal lesions based on symptoms, signs, and radiological imaging. This is the first time that key terminology used in the management of meniscal pathology has been defined by consensus and represents a critical step in the standardisation of patient selection in clinical practice and research.

9.5.2 Comparison with other studies

As introduced in section 1.8.5, meniscal treatment guidelines have previously been issued by surgical expert groups including the American Orthopaedic Society for Sports Medicine (AOSSM) and Arthroscopy Association of North America (AANA),[230] the European Society of Sports Traumatology, Knee Surgery and Arthroscopy (ESSKA),[209] and International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine (ISAKOS).[208] These statements were previously limited by a lack of agreement on the terminology applicable to their target population. The work reported in this chapter aimed to simplify and enhance future guideline development, including that reported in the following chapter (Chapter 10).

The importance of this national expert consensus regarding the important patient selection factors cannot be overstated. One non-specialist group recently issued guidance for the management of all patients “with or without meniscal tears”, “mechanical symptoms”, or “mild to severe osteoarthritis” as a single population.[185] Generalising such a heterogeneous population in this way is potentially harmful to a large number of patients for which no high-quality evidence exists.[339]

9.5.3 Strengths and limitations

The findings reported in this chapter were delivered in accordance with accepted consensus methodology.[87,88,385] There are, however, a number of potential limitations. It cannot be proven that the group has identified and highlighted all the variables that might be important in treatment selection for

this population, and further research may highlight other important factors that may be important for treatment selection and patient outcomes. The aim of a rigorously performed consensus process is to deliver the best possible output from the evidence available at the time, but this cannot guarantee that the output is 'correct'.[389,390] A period of validation is required followed by modification if indicated to be required by new evidence.

Panel composition is critically important to ensure the output from a consensus group is of value and valid.[385] The downside of a consensus group composed of experts in the field is the perceived bias from the point of view of other stakeholder groups – given that there is evidence that higher volume surgeons are consistently more likely to recommend surgery for comparable indications due to their belief in the surgery.[230] The lack of 'equipoise' has been termed the "enthusiasm hypothesis", reflecting the observation that a surgeon is more likely to recommend a surgical procedure if they believe strongly in the effectiveness of that procedure.[64,65] The purpose of this study, however, was to deliver definitions for the important clinical and radiological features that stratify patient presentations in clinical practice, for use in patient selection and guideline development. An expert group of surgeons with a specialist interest in this topic was considered the optimal group composition for this purpose. This decision is supported by the high level of agreement achieved within the group, but it must also be acknowledged that other specialists (e.g. physiotherapists, rheumatologists) may have identified other items, modified the definitions, or ranked the included items differently for use in their own area of practice.

9.5.4 Conclusion

This chapter summarises new, standardised, terminology for the clinical and radiological factors that are considered important in the stratification of patients with meniscal pathology in the knee, as agreed using validated consensus methodology. These definitions will enable more consistent clinical practice and improve the design and interpretation of future research aimed at addressing the remaining uncertainty surrounding the treatment of this heterogeneous population of patients.

10 TREATMENT APPROPRIATENESS AND DEVELOPMENT OF A NATIONAL TREATMENT GUIDELINE[§§]

10.1 Introduction

No treatment guidance applicable to the management of patients with meniscal lesions has been previously accepted for use in the United Kingdom (see section 1.8.5). The rationale for developing new clinical guidance has been summarised in section 9.1 and is supported by the work reported in Chapters 3-4. Chapter 9 reports the first stage in the process of developing new guidance, by delivering standardised terminology around the definitions and classifications required to consistently describe patients presenting in clinical practice with a meniscal lesion. The next stage required is an evaluation of the appropriateness of arthroscopic meniscal surgery in different clinical scenarios. In undertaking a treatment appropriateness exercise (see section 1.5.6.3), evidence regarding the anticipated benefits and potential risks of the evaluated treatment in different circumstances is required. Work developing this evidence to inform and support the process is reported in Chapters 5-8. Chapter 6 stratifies evidence for the anticipated benefits from APM by some patient factors, but also demonstrates the lack of evidence in some populations (for example, patients failing a trial of non-surgical treatment with an unstable meniscal lesion and without osteoarthritis). Although future clinical trials may fill some of the evidence gaps, this may not always be feasible (see section 1.5.6.3 and 10.5.2 below), and could take many years to recruit and report. A treatment appropriateness exercise is appropriate in this context, as it is a process for delivering treatment recommendations that is informed by the evidence but not reliant on evidence where none is available (see section 1.5.6.3).

[§§] The content of this chapter has been published, in part, as: Abram SGF, Beard DJ, Price AJ. Arthroscopic meniscal surgery: a national society treatment guideline and consensus statement. Bone Joint J. 2019 Jun;101-B(6):652–9.

10.2 Aims

The aim of the work reported in this chapter was to deliver consensus recommendations regarding the appropriateness of APM in a range of simulated clinical scenarios, based upon the standardised terminology reported in Chapter 9, and the other evidence regarding anticipated benefits and potential harms reported in Chapter 5-8. These recommendations were used as the basis for the creation of a new national treatment guideline document.

10.3 Methods

As the clinical treatment guidance was intended for use by orthopaedic specialists in hospital practice (secondary care), the same expert group composition was maintained, as previously described in Chapter 9 (section 9.3.1). An overview of the full consensus process is summarised in Figure 10.1. The RAM methodology used was introduced in Chapter 1 (section 1.5.6.3) and further detail follows below.

10.3.1 Evidence synthesis

At the start and throughout the process reported in this chapter, members of the consensus group were provided with the new evidence reported in this thesis, specifically the trends in arthroscopic intervention rates (Chapter 3), early rates of knee arthroplasty after APM (Chapter 4), the systematic review and meta-analysis of trials for benefit from APM (Chapter 6), and the new evidence on the risks associated with undergoing APM (Chapter 7), and long-term rates of arthroplasty (Chapter 8). In addition, other published and unpublished information was freely provided to all members of the group when identified and suggested for circulation by any of the participants.

10.3.2 Surgical appropriateness exercise

Following the conclusion of the Delphi rounds, population and patient selection factors had been defined and agreed, as reported in the previous Chapter 9.[259] Based upon these, mutually-exclusive case scenarios were prepared from combinations of patient selection factors to make up a range of simulated ‘patients’ for the consensus panel to evaluate. Forty-five clinical scenarios were voted on by members

of the group during the RAM exercise. The scenarios were created from a combination of (1) severity of meniscal symptoms and signs [locked knee / meniscal predominant / possibly meniscal / arthritic / mixed arthritic and meniscal], (2) severity of structural osteoarthritis [early-no OA / mild-moderate OA / advanced OA], and (3) meniscal findings on MRI [target / possible target / no target].[259] The first round of RAM was conducted anonymously between group meetings (Figure 10.1).

An introduction and standardised patient history (Appendix O) were presented for the purposes of the voting. Members of the group were then asked: "Do you think meniscal surgery is appropriate in this patient? (To what extent do you believe arthroscopic meniscal surgery would benefit symptoms and quality of life AND outweigh the risks of surgery / benefit of an alternative, more appropriate, treatment option" (Appendix O). A rating for each clinical scenario was requested on a scale from 1 (inappropriate) to 9 (appropriate) (see Appendix P). In accordance with published standards, the degree of agreement between participants was measured by evaluating the median and spread of rating.[99,391,392] A median rating ≥7 without disagreement was defined *a priori* as appropriate and a median rating ≤3, without disagreement, inappropriate. Disagreement was defined as more than one third of votes ≤3 with a median ≥7, or greater than one-third of votes ≥7 with a median ≤3. Uncertainty was recorded for median scores between 4 and 6.

Participants were also invited to make treatment recommendations, in a modified 'necessity' rating exercise.[99] For a procedure such as arthroscopic meniscectomy, the risk of the procedure may be considered so low that it could be rated 'appropriate' even when clinical value is uncertain, and this exercise aimed to overcome this potential limitation.[99] Four options were provided. (1) "Urgent" arthroscopic meniscal surgery: where the expected benefit is not small and it would be considered 'improper' not to offer the treatment; (2) "Routine" arthroscopic meniscal surgery: appropriate but not urgent; (3) "Non-surgical treatment and re-assess": where benefit from meniscal surgery is uncertain; and (4) "No arthroscopy" where no benefit is anticipated, or harms exceed anticipated benefits. Agreement on this treatment recommendation item was defined at greater than 50% (majority threshold).

Following the first round of RAM voting, the group met to discuss the results (Figure 10.1). At this meeting, each participant was provided with a document showing their own rating and the summary ratings from the other participants.[99] The results were discussed, focussing on areas of disagreement or uncertainty. Scenarios with disagreement were clarified and all relevant evidence was discussed in this context. At the meeting, each participant then re-rated each scenario, so that each participant had rated every scenario twice. The intention of two rounds of voting is to distinguish true clinical disagreement ("real" disagreement) from fatigue or misunderstanding ("artefactual" disagreement).[99]

On completion of the RAM exercise, 11/45 scenarios (24%) were rated appropriate for arthroscopic meniscal surgery, 24/45 (53%) were rated inappropriate and 10/45 (22%) uncertain. Treatment recommendations exceeded the 50% majority classification threshold in 43/45 cases (96%). The remaining two cases were discussed by the steering group (SA/DJB/AJP) and recommendations decided based upon the spread of votes and other ratings. Of the eleven appropriate cases, 5/11 (45%) were rated eligible for urgent surgery and 6/11 (55%) routine surgery. Of the twenty-four inappropriate cases, 17/24 (71%) were rated for no arthroscopy and 7/24 (29%) were rated for re-assessment after further non-operative treatment. All ten (100%) uncertain cases were rated for re-assessment after further non-operative treatment.

10.3.3 Preparing the treatment guideline

The output from the RAM exercise was used to prepare a management guideline for patients with radiologically confirmed meniscal tears. In preparing the guideline document, the RAM scenarios were grouped based upon the clinical features and ratings to create a smaller number of representative clinical presentations and treatment recommendations. The agreed definitions, approach to imaging investigations, and classification of meniscal tears and osteoarthritis from the work reported in the previous chapter was summarised on the second page of the full guideline document (Appendix Q).

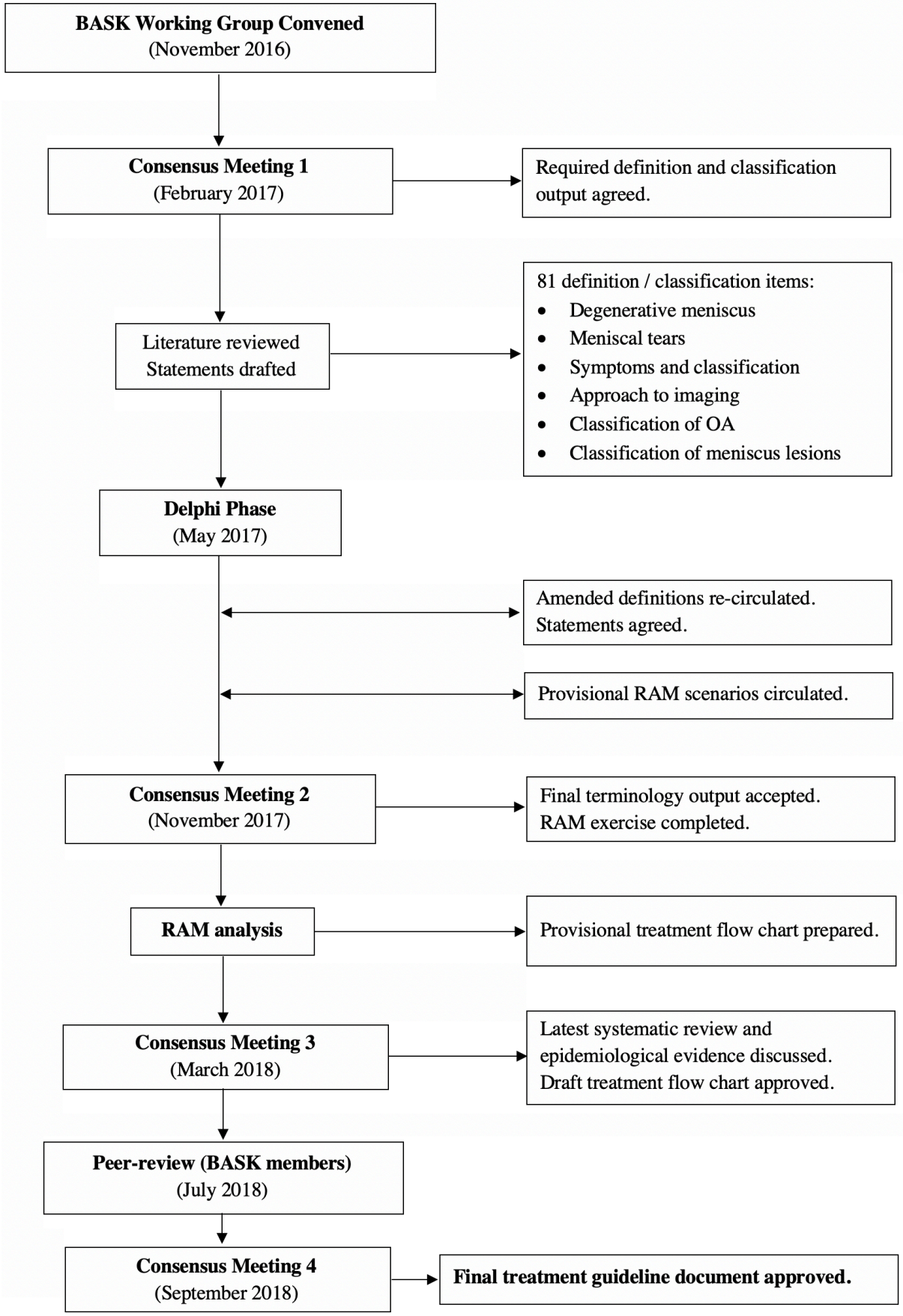
The representative clinical presentations and treatment recommendations were used as the basis of a draft flow-diagram style treatment guideline, which was circulated to the whole group for feedback electronically. Based upon this feedback, amendments were made prior to discussion again at a meeting in March 2018. At this meeting, the guideline was discussed in detail in the context of an update on the latest evidence including the completed systematic review of clinical trial evidence stratified by the important patient factors, and a new analysis of the risks of arthroscopic knee surgery using national epidemiological data (Chapters 6 and 7).[393] Changes agreed by the group at this meeting were made to the guideline and this was then presented at the annual BASK congress in March 2018 to introduce the guideline and the planned request for feedback from the membership of BASK.

10.3.4 Peer-review, feedback, and final approval

Following production of the draft guideline, this was subjected to peer review. Firstly, the guideline, accompanying definitions, and case management examples, was circulated electronically to the full membership of BASK for feedback. Of the 195 full active members of BASK with valid consent and contact details to receive surveys, 117 members (60%) completed the survey in full. Of these, 87 (74%) agreed with the treatment guideline without changes, a further 28 (24%) with minor changes, and 2 disagreed with major changes (2%). Overall, 113 (97%) respondents agreed to practice according to this guideline even with no further changes. Specific comments were received from 34 respondents (12 from no changes group, 21 from minor changes, 1 from major changes). Of the comments, 13 confirmed support leaving 21 responses with suggestions for changes. The only major comment was to highlight the importance of surgeon discretion and patient treatment preferences and one minor comment also made this point. Of the other minor comments, nine of these suggested small amendments to the definitions and descriptions, two comments related to introducing age cut-offs, four comments related to highlighting rare but important cases where meniscal surgery may be appropriate despite advanced osteoarthritis, and four related to improving the clarity or wording of the guideline itself.

All comments and the ratings were reviewed by the steering committee and the Working Group and, based upon these, further minor changes were made. Patient and public involvement (PPI) feedback from a previously established group was also sought and considered. The final guideline was reviewed and approved by the Working Group in September 2018.

Figure 10.1: The consensus process



10.4 Results

10.4.1 Terminology and guideline eligibility

The agreed terminology reported in the previous chapter was published and included on the second page of the guideline document (Appendix Q).[259] It was agreed that to be eligible for treatment, according to the flow chart, an MRI for radiological confirmation of a meniscal tear would be necessary.

Meniscal lesions were previously classified based upon appearances on MRI into (1) Target, (2) Possible target, (3) No target.[259] The target group represented 'treatable' meniscal lesions where the group agreed that meniscus surgery may be indicated based on appearance. As stated in Chapter 9, the need for some caution in the interpretation of a static knee MRI was highlighted given the potential for tear displacement on dynamic movement.

Three categories of structural osteoarthritis severity were previously defined, however, the clinical ratings exercise and subsequent discussions indicated that only advanced structural osteoarthritis was considered a major contraindication to arthroscopic meniscal surgery. Therefore, the treatment recommendations for all patients with early, mild, or moderate structural osteoarthritis (Appendix Q) were the same – that is, based upon the pattern of the meniscal lesion, corresponding symptoms/signs, duration of symptoms, and prior treatment history. It was agreed that no age specifications would be included because the other criteria defined were considered more important for making treatment recommendations, however the guideline was not designed for use in the paediatric population.

10.4.2 Common clinical presentations

Based upon summary responses (treatment appropriateness; treatment recommendations), an initial total of forty-five clinical scenarios were rationalised to just five common and discriminative clinical presentations. It was recognised that clinician judgement is still required, however, especially where patient presentations do not fit clearly into one of these categories. The five accepted presentations

were: (1) Locked knee, (2) Acute knee injury with a meniscal target lesion, (3) Meniscal target lesion with corresponding symptoms and signs, (4) Possible meniscal target lesion with corresponding symptoms and signs; (5) Advanced structural osteoarthritis.

10.4.3 Treatment recommendations

The group agreed to four possible treatment recommendations for meniscal lesions: (1) urgent arthroscopic meniscal surgery; (2) consider arthroscopic meniscal repair; (3) consider non-urgent APM; (4) optimised non-surgical treatment and re-assessment. Patients with advanced osteoarthritis were included in a fifth category recommendation for "no arthroscopic meniscal surgery" and may need assessment of other pathology that may require treatment on an alternative treatment pathway, for example, osteotomy or arthroplasty. The recommendations for each of the clinical presentations is shown on the first page of the guideline document (Appendix Q).

Urgent arthroscopic surgery was recommended for patients with a locked knee. In most cases, these patients will have a confirmed diagnosis of a displaced meniscal tear from MRI, however it was accepted by the group that for patients presenting with a locked knee, clinicians may apply their own judgement on the need for pre-operative MRI imaging.

Meniscal repair was recommended to preserve the meniscus when a repairable meniscal target lesion is identified following an acute injury. A decision to proceed in these cases requires clinician judgement on the potential for healing, based upon patient, anatomical, biomechanical, and biological factors. No recommendation on the urgency of intervention was included as it was agreed that this should be a decision to be made by the clinician on a case by case basis, in careful consultation with the patient. Further consensus work to refine guidance on this treatment decision is planned.

In the majority of patients, according to the guideline, at least three months should have elapsed from the onset of symptoms before arthroscopic meniscal surgery is considered. Only patients with

"meniscal" or "possibly meniscal" symptoms and signs were considered eligible for arthroscopic meniscal surgery (Appendix Q). In patients with "meniscal" symptoms and signs and a "meniscal target", routine arthroscopic meniscal surgery may be considered three months from the onset of symptoms. In some cases, earlier surgery may be appropriate and it was advised that a second opinion from an appropriately experienced colleague be sought and documented before proceeding with arthroscopic meniscal surgery in these cases. In patients with "possibly meniscal" symptoms and signs or a "possible meniscal target", further optimised non-surgical treatment for an additional three months was recommended (on first assessment in secondary care). Optimised non-surgical treatment was agreed to be patient and condition specific, however, the group suggested this may include providing patient education, structured physiotherapy, and, in some cases, an intra-articular steroid injection (Appendix Q).

Arthroscopic meniscal surgery was judged to be inappropriate in nearly all patients with advanced structural osteoarthritis or with arthritic symptoms and signs only (Appendix Q). It was acknowledged, however, that there are some uncommon special cases, and, in these cases, it was advised that a second opinion from an appropriately experienced colleague be sought and documented before proceeding with arthroscopic meniscal surgery.

Finally, there was universal agreement that patient treatment preferences must always be considered; the guideline document should support, not substitute for, shared decision-making.

10.5 Discussion

10.5.1 Principal findings

This chapter reports the output from a consensus exercise to deliver recommendations on the appropriateness of APM in a range of clinical scenarios. The results reported led to the development of a meniscal tear management guideline in collaboration with the British Association for Surgery of the Knee (BASK). In patients with a locked knee, urgent arthroscopic meniscal surgery was recommended.

For patients sustaining an acute traumatic injury to the knee that results in a target meniscal lesion, arthroscopic meniscal repair should be considered to preserve this meniscal tissue if possible. For all other patients, a minimum period of 3 months non-surgical therapy was recommended before considering arthroscopic meniscal surgery. An additional 3 months of optimised, non-surgical therapy (including physiotherapy) was recommended for all patients without a clear meniscal tear target lesion with correlating meniscal symptoms on first assessment in secondary care. For patients with advanced structural osteoarthritis on radiological imaging or arthritic symptoms only, arthroscopic meniscal surgery was not recommended.

10.5.2 Comparison with other studies

Through the development of this guideline, several areas of uncertainty were highlighted. Firstly, as previously identified by other groups, no clinical trial has been performed in patients with a meniscal tear and a locked knee.[185,209] A locked knee is functionally disabling and given the high ratings for surgical appropriateness for this indication, recruitment to such a trial may not be feasible due to strong patient preferences and a lack of equipoise. For patients with advanced osteoarthritis, RCT evidence indicates that knee arthroscopy is unlikely to be effective (see also Chapter 6).[207] For patients considered eligible for meniscal repair (to preserve meniscal tissue after an acute injury) there were high ratings of surgical appropriateness, but no relevant high-level evidence was identified and this should be a priority area for further research.[211,394–397]

The consensus view, based primarily on the clinical trial evidence (Chapter 6), was that the majority of patients should receive a minimum of three months of non-operative treatment before undergoing surgery. For patients with only a possible meniscal target lesion or possible meniscal symptoms, first-line non-operative treatment was recommended in all cases.

Regarding the harms of arthroscopic meniscal surgery, a new analysis of national epidemiology data from patients that had undergone APM informed the decisions of the Working Group (Chapter 7).[393]

The guideline recommendations were prepared in the context of this new evidence, with the evidence for benefits weighed against anticipated risk of harms (Chapters 6 and 7).[393] Regarding other clinical treatment guidelines that have been published, see previous discussions (sections 1.8.5 and 9.5.2).

10.5.3 Strengths and limitations

The aim of the consensus project reported in this chapter was to distil the current evidence and expert opinion (where there was a lack of evidence, or uncertainty). The development of the guideline was informed throughout by high quality published and previously unpublished evidence regarding the benefits and harms associated with undergoing arthroscopic meniscal surgery. Any rigorously performed consensus process aims to deliver the best possible output from the evidence available at the time, but this does not guarantee that the output is 'correct' or indeed that there is a 'correct' output.[389,390] A period of validation is required followed by modification if indicated to be required in response to new evidence.

As also discussed in the previous chapter (section 9.5.3 and also section 1.5.6.4), panel composition is important to ensure the output of a consensus group is valid and of value.[385] The aim of this study was to produce a 'best-practice' guideline for use by surgeons and their patients in secondary (hospital) care practice, but the work may also inform a coordinated treatment approach with primary (general practice) care practitioners and physiotherapists. For the intended purpose, it was decided that the output from a group of recognised expert surgeons would be most likely to become the accepted standard of practice for surgeons in secondary care. Indeed, the high level of agreement observed within the group and the feedback ratings from the BASK membership support this reasoning. One potential criticism of a consensus group composed of experts in the field, however, as previously stated, is that high volume surgeons are more likely to recommend surgery due to their belief in an intervention.[230] Such a lack of 'equipoise' has been termed the 'enthusiasm hypothesis'.[64,65] Nevertheless, all members of the group had self-reported a change in their own practice, directly in response to the publication of evidence favouring the effectiveness of physiotherapy in many patients with meniscal tears. It must be

acknowledged that other groups (for example, general practitioners, rheumatologists, physiotherapists) may interpret the evidence differently for their own areas of practice, but this study was not designed to directly change the practice of these groups and further work to deliver collaborative recommendations from all involved groups would be beneficial. Certainly, further validation work is required and there was a clearly identified need for further clinical evidence in several areas; for example, no previous clinical trial has limited recruitment to patients eligible for meniscal surgery according to these new standards, and this should be a priority area for new research.[339]

Although guidelines have been published by other groups, these have presented conflicting recommendations, suffered from a number of limitations, and not yet been accepted into practice (see sections 1.8.5 and 9.5.2).[185,208,209,230,398] In contrast, on peer-review, 97% (113/117) of specialist knee surgeons agreed to practice according to the guideline presented here and, with the support of the national knee society, BASK, and also the NHS Getting It Right First Time (GIRFT) programme in the United Kingdom, adoption into routine clinical practice and secondary care commissioning guidance should be anticipated.

10.5.4 Conclusion

The treatment appropriateness exercise and management guidance reported in this chapter represents current expert surgical opinion regarding the appropriate management of patients with meniscal lesions. It was delivered using a series of consensus exercises and is endorsed in its current form by the national knee society, BASK, and the NHS Getting It Right First Time (GIRFT) programme. The aim of the guideline is to standardise treatment and facilitate best-practice based upon current evidence. Validation in clinical practice is now required and, where uncertainty was highlighted, there is an urgent need for more evidence.

11 SUMMARY OF FINDINGS AND FUTURE WORK

11.1 Summary of main findings

This thesis reports (1) the arthroscopic partial meniscectomy intervention rate and variation in practice in England to 31st March 2017; (2) the rate of knee arthroplasty within one-year and regional variation in this outcome over the same time period: one potential marker of overuse; (3) a systematic appraisal of the evidence for the validity of patient reported outcome measures in patients with meniscal tears; (4) in this context, and in the context of potential sub-populations of patients with meniscal tears that may derive greater benefit from APM, a systematic review of the evidence for the effectiveness of APM; (5) the short-term attributable risk of serious adverse events following APM; (6) the long-term rates of knee arthroplasty following APM in patient groups stratified by demographic factors; (7) new standardised terminology for the description and classification of clinical and radiological findings associated with meniscal tears; and (8) an assessment of the appropriateness of APM for the treatment of meniscal tears in a range of patient scenarios which was used as the basis of new national treatment guidance that has been supported and endorsed by the national knee society (BASK) and NHS commissioning groups.

A review of the literature (Chapter 1) demonstrated that in many countries rates of arthroscopic partial meniscectomy were increasing until at least 2012, but the latest trends in intervention rate were unknown and the potential impact from the publication of relevant clinical trial evidence was uncertain. An analysis of national epidemiological data for England (Chapter 3) was required and although the overall rate of arthroscopic partial meniscectomy was found to have increased by about 130% over a twenty-year period, the intervention rate has declined between 1st April 2013 and 31st March 2017. There was, however, regional variation and 10.6% of clinical commissioning group regions performed at least twice the national average rate of meniscectomy in 2016-17.

In the context of the overall rising rate of intervention and concerns about the effectiveness of APM in patients with osteoarthritis, it was important to investigate potential markers of overuse. One such marker is the rate of knee arthroplasty within one-year of APM (Chapter 4), suggesting that the APM may have been performed in the context of pre-existent advanced osteoarthritis. The proportion of patients undergoing APM and then arthroplasty within one-year increased over the twenty-year study period and with patient age. Of patients undergoing APM over the age of 60-years in 2015-16, 9.91% underwent subsequent arthroplasty within one-year. There was ten-fold variation in the rate of subsequent arthroplasty by CCG region, with 7.7% of CCGs having a rate of arthroplasty at least 50% greater than the national average in 2015-16. The increasing rate of arthroplasty over time and the ten-fold regional variation suggested that there was a need to improve and standardise treatment selection in this population.

Before considering evidence regarding the effectiveness of APM, there was a need to consider the measurement of outcome (Chapter 5). In addition to hard endpoint outcomes such as subsequent rates of knee arthroplasty, patient-reported outcome measurement is also important. Although a number of patient-reported outcome measures (PROMs) have been collected and reported in series of patients with meniscal tears, the quality of the validation evidence supporting the use of these measures has been uncertain. In Chapter 5, a systematic search for studies evaluating the measurement properties of any PROM in a meniscal tear population was performed. Using the COSMIN criteria, the measurement properties reported in these studies were evaluated in the context of the quality and completeness of the validation study methodology. The findings from Chapter 5 suggest there is relatively incomplete and poor-quality evidence to support the validity of PROMs in the population of patients with meniscal tears. Limited evidence supports the selection of either the Lysholm Knee Scale, International Knee Documentation Committee Subjective Knee Form, the Knee injury and Osteoarthritis Outcome Score, or Western Ontario Meniscal Evaluation Tool (WOMET) in this population. Of all the PROMs evaluated, WOMET has the strongest evidence for content validity.

In the context of the rising trend in APM intervention rate, variation (Chapter 3), and possible overuse of APM in some patients with osteoarthritis (Chapter 4), there was a need to thoroughly appraise the evidence for the clinical effectiveness of APM for the treatment of meniscal tears in different patient groups. No previous systematic review had stratified the clinical trial evidence applicable to sub-groups of patients that might be more or less likely to derive benefit. This systematic review and meta-analysis (reported in Chapter 6) suggested that when patients with osteoarthritis were excluded, studies reported a greater benefit from APM in comparison to physiotherapy at 6-12 months (pain, function, knee-specific quality of life) but confidence intervals were wide. Although the trials selected PROMs with some supporting validation evidence as primary outcome measures, Chapter 5 shows there is still a need for caution in the interpretation of this evidence, as these PROMs might not truly reflect the symptoms, function and quality of life of these patients and the minimum clinically important difference (MCID) is still unknown for this population. In trials randomising patients to physiotherapy, up to 30% of patients subsequently chose to undergo APM. Perhaps the most important finding of this review was that no trials have been performed (or registered) in patients with any more specific clinical or radiological criteria than knee pain and any pattern of meniscal tear. Some recent guidelines only recommend APM in patients with clinical and radiological findings consistent with an unstable meniscal tear (such as "mechanical symptoms"). There has been, however, no agreement on the definition of terms such as these and it was clear that there was a need for work to define the terminology used to describe the clinical and radiological features that may be important in deciding the best management strategy for patients with meniscal lesions (addressed in Chapter 9).

Chapter 6 summarises the clinical trial level evidence for the clinical effectiveness of APM and highlighted a number of important deficiencies in this evidence. Applicable evidence for benefit must, however, also be considered alongside evidence for risk. Few studies have reported complications following APM and previous studies have been limited by inclusion of a mixed cohort of other arthroscopic procedures (such as ligament reconstruction), small numbers, incomplete adverse event reporting, and limited regional or insurer only databases. Accurate estimation of the risk of an adverse event following APM is important to inform patients and clinicians considering this treatment option.

For low-risk procedures, it is also important to consider the possibility that any subsequent adverse events may be incidental and not directly attributable to undergoing the procedure itself. To investigate this, national population level data is required for comparison with matched patients undergoing the intervention. These data are crucial for the development of clinical guidelines and for shared-decision making, where the balance of benefit and risk is such an important consideration. In Chapter 7, a cohort of almost 700,000 patients undergoing APM in isolation was extracted from twenty-years of routinely collected hospital episode data. Serious adverse events (pulmonary embolism, myocardial infarction, stroke, fasciotomy, neurovascular injury, infection requiring surgery, or death) occurring within 90-days were identified and stratified by patient-related factors including age group, sex, index of multiple deprivation, ethnicity, modified Charlson comorbidity index, year of treatment, ethnicity, and rurality. At least one serious adverse event occurred in 0.317% of patients within 90-days and the risk was greater in male patients, older patients, and those with a greater comorbidity index. Comparative general population data was available for mortality (excluding cancer), myocardial infarction, stroke, pulmonary embolism, and septic arthritis. Only pulmonary embolism (RR 12.99; NNH 1390) and septic arthritis (RR 110.21; NNH 749) occurred at a higher rate in the APM cohort than in the general population.

Although Chapter 7 reports the short-term risk of adverse events following APM, the long-term outcomes are also poorly defined and, specifically, the long-term rate of subsequently requiring a knee arthroplasty was uncertain. Whilst Chapter 4 reports the rate of early conversion to knee arthroplasty within one or two years, which may reflect overuse of APM in patients with pre-existent osteoarthritis, Chapter 8 reports the rate of knee arthroplasty up to twenty-years following APM with comparison to general population and contralateral knee data. Relative to the general population (without a history of APM and excluding patients under the age of 30-years from both cohorts), patients undergoing APM were ten times more likely to undergo knee arthroplasty annually (RR 10.27 in 2016-17). In patients undergoing APM in only one knee, the rate of subsequent arthroplasty in that knee was three-times that of the other knee (not undergoing APM). These new data provide an important reference for patients

that do undergo APM and will also facilitate comparisons with cohorts of patients managed non-operatively and patients treated with techniques such as meniscal repair.

The clear need for consistent terminology in the description of patients with meniscal pathology was highlighted earlier. To deliver this terminology, Chapter 9 describes the formation of a national, expert surgeon, consensus group supported by the British Association for Surgery of the Knee (BASK). Following modified Delphi and nominal group consensus methodology, the important clinical and radiological findings believed to be important when considering treatment selection for patients with meniscal lesions were generated, refined, and agreed. These new, standardised, terms will be crucial for the consistent design and interpretation of clinical studies and also in clinical guideline development, as documented in Chapter 10, and should now be tested in clinical practice.

Chapter 10 reports a treatment 'appropriateness exercise' informed by all the prior chapters, especially the systematic review of benefits (Chapter 5 and 6), reported rates of adverse events (Chapter 7), and new standardised terminology (Chapter 9). This exercise was used to produce a national treatment guideline document that stratifies patients based upon a classification of symptoms, signs, radiological imaging findings, duration of symptoms, and previous treatment history. Forty-five simulated clinical scenarios were refined to five common clinical presentations and corresponding treatment recommendations. The guideline developed was subsequently shown to be acceptable to both the membership of the British Association for Surgery of the Knee and also members of a patient involvement group.

11.2 Clinical Implications

The findings reported in this thesis have many important clinical implications for improving the management of the large population of patients with meniscal lesions of the knee. These findings will be impactful for patients, clinicians, and health commissioners.

- New evidence regarding regional and age-group intervention rates will allow clinicians to compare their own practice and is also likely to lead health commissioners to be able to identify 'outlier' practice, where the regional intervention rate is higher than expected. With the introduction of the new treatment guidance reported in Chapter 10, it may be possible to estimate the 'appropriate' intervention rate at the population level, based upon findings from a prospective evaluation of regional data, where all patients are selected according to the new guidance. Once this data is available, it may be possible to determine the expected impact of the new guidance on the overall number of procedures performed, including the cost saving to the health service that might be anticipated.
- The data reported on one-year arthroplasty conversion rates has already been of interest to health commissioners via the NHS Getting It Right First Time (GIRFT) programme. Early arthroplasty conversion may suggest that APM was performed in a patient with already advanced osteoarthritis. This approach is unlikely to be beneficial and contradicts the new guidance reported in Chapter 10. Given that APM is generally not considered beneficial for patients with advanced osteoarthritis, routine monitoring of arthroplasty conversion rates may be considered as a potential marker of ineffective care commissioning in the future.
- The review of the use of PROMs in patients with meniscal tears indicates that there is still uncertainty about the measurement of outcome in this population. Clinicians should be cautious in interpreting PROM data but can be informed that there is currently limited evidence that does support the use of the Lysholm Knee Scale, IKDC, KOOS, or WOMET. These findings will also inform the design and interpretation of future clinical studies, including future PROM validation and development work.
- The benefit from APM in different patient groups is reported in Chapter 6 and underpins the design of the new clinical guidance reported in Chapter 10. Clinicians may use these data to inform patients of the variability in outcome and importance of trying non-surgical treatment, including physiotherapy, first, in most circumstances, before considering APM.

- The potential attributable risks associated with undergoing APM are reported for the first time. These findings will be especially important in the shared-decision making process between patients and clinicians in clinical practice. Although adverse events are uncommon, some serious complications (notably infection and pulmonary embolism) can be provoked by APM; this should inform discussions, especially when non-surgical treatment or alternative treatments would be recommended in the context of the review of anticipated benefits.
- For patients that do undergo APM, the likelihood of subsequently requiring a knee arthroplasty in the longer term has been unclear. Chapter 8 reports these data with comparison to the rate of arthroplasty in the general population without a history of APM, and to the other knee of patients undergoing APM in only one knee. These patients can now be informed of the absolute and relative risk of knee arthroplasty after undergoing APM. These data will also be important for future comparison of outcomes from a treatment approach that limits the use of APM in patients with pre-existent osteoarthritis, or other approaches to treatment such as meniscal repair.
- New standardised clinical terminology is reported for the definition and classification of meniscal tears and knee symptoms, signs, and radiological findings. This terminology will be crucial for communication in clinical practice, for the design and interpretation of clinical studies, and also for the consistent identification and treatment of patients in the following treatment guidance.
- Finally, new clinical treatment guidance is reported which has been endorsed by the national knee society, BASK, and NHS GIRFT programme. Previously, when a meniscal lesion was detected on MRI in a patient with knee pain, or other knee symptoms, APM was generally recommended to excise this meniscal lesion as the likely cause of the pain. Together, the implications of the work reported in this thesis demonstrate that this practice is now inappropriate and a change in the care pathway to match the more refined treatment indications reported here is required. Based on the new standardised terminology, treatment recommendations are provided for patients presenting with specific combinations of clinical

and radiological findings. Clinicians will now have clear guidance on when APM (versus non-surgical and alternative treatments) should be recommended to patients, and a change in clinical practice in response to this clinical guidance is anticipated.

11.3 Recommendations for future work

The new treatment guidance and evidence delivered in this thesis will support patients as they navigate the care pathway with a meniscal lesion, by supporting shared-decision making in clinical practice. The reported findings will also help clinicians, decision makers and commissioning bodies considering the value of meniscal surgery. Whilst a change in practice is now expected, with less variation in intervention rates, appraisal of the outcomes associated with this new approach to care will be required. There are a number of remaining areas of uncertainty, and further work is recommended to address some of these important, unanswered, questions.

Firstly, as highlighted in Chapter 6 and Chapter 10, no RCT has been performed or registered recruiting patients meeting the latest clinical and radiological criteria to be eligible for APM in contemporary practice. This thesis reports new standardised terminology and national treatment guidance (Chapter 9 and Chapter 10) and it is now important that the clinical effectiveness of this approach to treatment is tested in clinical practice. Care will need to be taken in the design of an RCT testing this approach given the limited validation evidence currently available to support the use of PROMs in this population (Chapter 5). A feasibility study may be required or further PROM validation studies with patients eligible for APM according to the new guidance. It will be important that any such RCT tests not only the clinical effectiveness of APM but is also designed to evaluate the cost-effectiveness of the proposed approach to treatment in clinical practice. For health commissioning at a population level, whether the small to moderate benefit anticipated from undergoing APM in some patient groups (Chapter 6) is cost-effective will be under particular scrutiny, and patient treatment preferences related to the magnitude and rate of improvement also warrant further investigation.

In addition to testing the clinical and cost-effectiveness of the treatment guidance, further work is recommended to adapt the treatment guidance to be suitable for use directly by patients, general practitioners, physiotherapists and other non-specialists. Although feedback from patients with lived-experience of APM was sought, the guideline in its current form was not intended for use by patients. It is now recommended that the guidance is modified into a "decision aid" type format to inform patients before they reach secondary care of the treatment options that may be offered. Consultation on the guidance with other stakeholders such as general practitioners and physiotherapists is also recommended and a modified version of the document for use by these groups may be created as a result of such a process.

A key finding of the work in this thesis (especially highlighted in Chapter 3 and 4) is the need for more consistency in treatment selection and outcomes. Endorsement of the new guidance by BASK and the NHS GIRFT programme is one important step towards adoption of the treatment recommendations, but engagement with other stakeholder groups is now planned and recommended. This approach aims to maximise the reach of the guidance, but factors limiting the rate of change in clinical practice in response to new clinical evidence and guidelines is an important topic that requires more research. Assessment of the change in clinical practice that follows the introduction of the new guidance reported in this thesis will be an interesting area of investigation. A rapid response in terms of the impact on intervention rates, variation, and outcomes (such as arthroplasty conversion rates) would be desirable, but, nevertheless, this is unlikely to occur universally. The factors limiting the response to new high-quality evidence and issuance of new treatment guidance is an important area of investigation in these circumstances. Work to identify barriers and incentives to the suggested change in practice is recommended, perhaps comparing regions where a rapid change in practice is observed to regions where little change is observed in the year following introduction. To some extent, patient population and referral practices might lead to regional differences in intervention rate or a key factor might be the rate of translation of national recommendations into regional commissioning rules and guidelines. Exploring this area might be beneficial in informing future work aimed at improving the care pathway and health commissioning for this patient population and others.

Chapter 8 reported new information regarding the long-term rate of knee arthroplasty after APM, however these patients' risk of arthroplasty had they not undergone APM is still unclear, and it remains possible that APM could itself have a detrimental effect on this outcome. There is a need to understand the long-term rate of knee arthroplasty in patients with a meniscal tear treated non-operatively in comparison to those treated with APM. This question may be answered with long-term follow up of an RCT designed to answer this question or new information may be provided from prospective cohort studies. The prospective evaluation of patients treated according to the new guidance is recommended, not least with the aim of estimating the corresponding 'appropriate' APM intervention rate, as mentioned earlier (section 11.2). As stated, with an understanding of the approximate intervention rate anticipated when a population of patients is treated according to the new guidance it may be possible for health commissioners to more readily identify any 'outlier' practice and investigate whether a change in practice is necessary to address this variation. Ideally, all institutions should record and feedback not only their intervention rate but also collect procedure outcome data, which may include PROMs (Chapter 5). As discussed in Chapter 4, the proportion of patients treated with APM and then subsequently undergoing knee arthroplasty within one-year may be an indicator of overuse of the procedure in patients with advanced osteoarthritis. It is likely that this outcome may occur in some patients even after appropriate treatment and further work should focus on considering when variation in treatment and outcome may be expected and acceptable in good clinical practice.

Finally, in addition to APM, there are other emerging specialist arthroscopic treatment options for patients with meniscal lesions of the knee, such as meniscal repair and meniscal transplant. In comparison to APM, these procedures are performed rarely, and the indications are narrow. More work is required to deliver evidence-based treatment recommendations to support appropriate use of these techniques. The suitability of a sub-group of patients sustaining an acute meniscal injury for meniscal repair was highlighted in the treatment guidance reported in Chapter 10, but more work is necessary and planned to refine this recommendation. Meniscal transplant was until recently considered an experimental procedure for use in patients sustaining injuries that resulted in total excision of their

native meniscus. Encouraging results have been reported and the role of this technique and other emerging treatments that may further improve the overall management of the population of patients with meniscal lesions must be kept under review.

A - OPCS-4 Code Table

Procedure	v4.2	v4.3	v4.4	v4.5	v4.6	v4.7	Description
APM	W82.2	W82.2	W82.2	W82.2	W82.2	W82.2	Endoscopic resection of semilunar cartilage NEC
Diagnostic	W87.1	W87.1	W87.1	W87.1	W87.1	W87.1	Diagnostic endoscopic examination of knee joint and biopsy of lesion of knee joint
Diagnostic	W87.8	W87.8	W87.8	W87.8	W87.8	W87.8	Other specified diagnostic endoscopic examination of knee joint
Diagnostic	W87.9	W87.9	W87.9	W87.9	W87.9	W87.9	Unspecified diagnostic endoscopic examination of knee joint
Diagnostic *	W88.1	W88.1	W88.1	W88.1	W88.1	W88.1	Diagnostic endoscopic examination of joint and biopsy of lesion of joint NEC
Diagnostic *	W88.8	W88.8	W88.8	W88.8	W88.8	W88.8	Other specified diagnostic endoscopic examination of other joint
Diagnostic *	W88.9	W88.9	W88.9	W88.9	W88.9	W88.9	Unspecified diagnostic endoscopic examination of other joint
Washout *	W81.8	W80.8	W80.8	W80.8	W80.8	W80.8	Other specified debridement and irrigation of joint
Washout *	W81.9	W80.9	W80.9	W80.9	W80.9	W80.9	Unspecified debridement and irrigation of joint
Washout	W85.2	W85.2	W85.2	W85.2	W85.2	W85.2	Endoscopic irrigation of knee joint
Chondroplasty *	W83.3	W83.3	W83.3	W83.3	W83.3	W83.3	Endoscopic shaving of articular cartilage
Chondroplasty *	W83.8	W83.8	W83.4	W83.4	W83.4	W83.4	Endoscopic articular abrasion chondroplasty
Chondroplasty *	W83.8	W83.8	W83.5	W83.5	W83.5	W83.5	Endoscopic articular thermal chondroplasty
Chondroplasty *	W83.8	W83.8	W83.6	W83.6	W83.6	W83.6	Endoscopic excision of articular cartilage NEC
Chondroplasty *	W83.8	W83.8	W89.1	W89.1	W89.1	W89.1	Endoscopic chondroplasty NEC
Ligament *	W74.2	W74.2	W74.2	W74.2	W74.2	W74.2	Reconstruction of intra-articular ligament NEC
Ligament *	W84.1	W84.1	W84.1	W84.1	W84.1	W84.1	Endoscopic repair of intra-articular ligament
Ligament *	W84.2	W84.2	W84.2	W84.2	W84.2	W84.2	Endoscopic reattachment of intra-articular ligament
Ligament *	W72.3	W72.3	W72.3	W72.3	W72.3	W72.3	Primary prosthetic replacement of intra-articular ligament
Ligament *	W72.4	W72.4	W72.4	W72.4	W72.4	W72.4	Prosthetic replacement of intra-articular ligament NEC
Arthroplasty *	W43.1	W43.1	W43.1	W43.1	W43.1	W43.1	Primary total prosthetic replacement of joint using cement NEC
Arthroplasty *	W44.1	W44.1	W44.1	W44.1	W44.1	W44.1	Primary total prosthetic replacement of joint not using cement NEC
Arthroplasty *	W44.8	W44.8	W44.8	W44.8	W44.8	W44.8	Other specified total prosthetic replacement of other joint not using cement

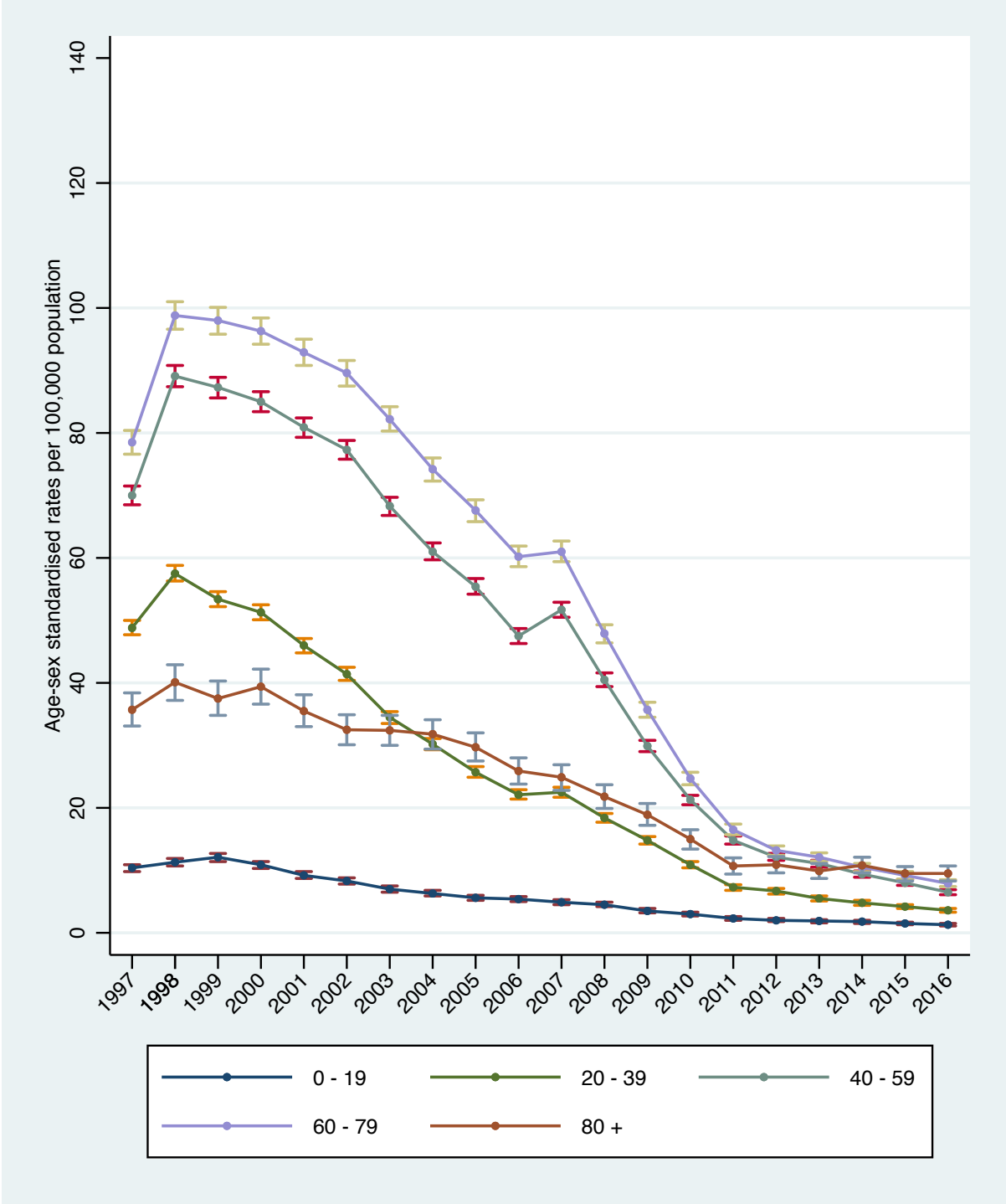
Arthroplasty *	W44.9	W44.9	W44.9	W44.9	W44.9	W44.9	Unspecified total prosthetic replacement of other joint not using cement
Arthroplasty *	W45.1	W45.1	W45.1	W45.1	W45.1	W45.1	Primary total prosthetic replacement of joint NEC
Arthroplasty *	W45.8	W45.8	W45.8	W45.8	W45.8	W45.8	Other specified other total prosthetic replacement of other joint
Arthroplasty *	W45.9	W45.9	W45.9	W45.9	W45.9	W45.9	Unspecified other total prosthetic replacement of other joint
Arthroplasty *	W53.8	W53.8	W53.8	W53.8	W53.8	W53.8	Other specified prosthetic replacement of articulation of other bone not using cement
Arthroplasty	W40.1	W40.1	W40.1	O18.1	O18.1	O18.1	Primary hybrid prosthetic replacement of knee joint using cement
Arthroplasty	W40.8	W40.8	W40.8	O18.8	O18.8	O18.8	Other specified hybrid prosthetic replacement of knee joint using cement
Arthroplasty	W40.9	W40.9	W40.9	O18.9	O18.9	O18.9	Unspecified hybrid prosthetic replacement of knee joint using cement
Arthroplasty	W40.1	W40.1	W40.1	W40.1	W40.1	W40.1	Primary total prosthetic replacement of knee joint using cement
Arthroplasty	W40.8	W40.8	W40.8	W40.8	W40.8	W40.8	Other specified total prosthetic replacement of knee joint using cement
Arthroplasty	W40.9	W40.9	W40.9	W40.9	W40.9	W40.9	Unspecified total prosthetic replacement of knee joint using cement
Arthroplasty	W41.1	W41.1	W41.1	W41.1	W41.1	W41.1	Primary total prosthetic replacement of knee joint not using cement
Arthroplasty	W41.8	W41.8	W41.8	W41.8	W41.8	W41.8	Other specified total prosthetic replacement of knee joint not using cement
Arthroplasty	W41.9	W41.9	W41.9	W41.9	W41.9	W41.9	Unspecified total prosthetic replacement of knee joint not using cement
Arthroplasty	W42.1	W42.1	W42.1	W42.1	W42.1	W42.1	Primary total prosthetic replacement of knee joint NEC
Arthroplasty	W42.8	W42.8	W42.8	W42.8	W42.8	W42.8	Other specified other total prosthetic replacement of knee joint
Arthroplasty	W42.9	W42.9	W42.9	W42.9	W42.9	W42.9	Unspecified other total prosthetic replacement of knee joint
Arthroplasty *	W58.1	W58.1	W58.1	W58.1	W58.1	W58.1	Primary resurfacing arthroplasty of joint
Washout/Debridement	W85.2	W85.2	W85.2	W85.2	W85.2	W85.2	Endoscopic irrigation of knee joint
Washout/Debridement *	W18.1	W18.1	W18.1	W18.1	W18.1	W18.1	Fenestration of cortex of bone
Washout/Debridement *	W18.2	W18.2	W18.2	W18.2	W18.2	W18.2	Saucerisation of bone

Washout/Debridement *	W18.3	W18.3	W18.3	W18.3	W18.3	W18.3	Sequestrectomy of bone
Washout/Debridement *	W18.4	W18.4	W18.4	W18.4	W18.4	W18.4	Decompression of fourage of bone
Washout/Debridement *	W18.5	W18.5	W18.5	W18.5	W18.5	W18.5	Insertion of drainage system into bone
Washout/Debridement *	W33.8	W33.6	W33.6	W33.6	W33.6	W33.6	Debridement of bone NEC
Washout/Debridement *	W33.8	W33.7	W33.7	W33.7	W33.7	W33.7	Lavage of bone
Washout/Debridement *	W33.8	W33.8	W33.8	W33.8	W33.8	W33.8	Other specified other open operations on bone
Washout/Debridement *	W33.9	W33.9	W33.9	W33.9	W33.9	W33.9	Unspecified other open operations on bone
Washout/Debridement *	W69.1	W69.1	W69.1	W69.1	W69.1	W69.1	Total synovectomy
Washout/Debridement *	W69.2	W69.2	W69.2	W69.2	W69.2	W69.2	Subtotal synovectomy
Washout/Debridement *	W69.3	W69.3	W69.3	W69.3	W69.3	W69.3	Partial synovectomy
Washout/Debridement *	W69.4	W69.4	W69.4	W69.4	W69.4	W69.4	Open biopsy of synovial membrane of joint
Washout/Debridement *	W71.3	W71.3	W71.3	W71.3	W71.3	W71.3	Forage of joint
Washout/Debridement *	-	W80.1	W80.1	W80.1	W80.1	W80.1	Open debridement and irrigation of joint
Washout/Debridement *	-	W80.2	W80.2	W80.2	W80.2	W80.2	Open debridement of joint NEC
Washout/Debridement *	-	W80.3	W80.3	W80.3	W80.3	W80.3	Open irrigation of joint NEC
Washout/Debridement *	-	W80.8	W80.8	W80.8	W80.8	W80.8	Other specified debridement and irrigation of joint
Washout/Debridement *	-	W80.9	W80.9	W80.9	W80.9	W80.9	Unspecified debridement and irrigation of joint
Washout/Debridement *	W81.3	W81.3	W81.3	W81.3	W81.3	W81.3	Drainage of joint
Washout/Debridement *	W81.4	W81.4	W81.4	W81.4	W81.4	W81.4	Incision of joint NEC
Washout/Debridement *	-	W81.7	W81.7	W81.7	W81.7	W81.7	Insertion of therapeutic spacer into joint
Fasciotomy	T55.3	T55.3	T55.3	T55.3	T55.3	T55.3	Release fasciotomy of thigh
Fasciotomy	T55.4	T55.4	T55.4	T55.4	T55.4	T55.4	Release fasciotomy of anterior compartment of lower leg
Fasciotomy	T55.5	T55.5	T55.5	T55.5	T55.5	T55.5	Release fasciotomy of posterior compartment of lower leg
Fasciotomy	T55.6	T55.6	T55.6	T55.6	T55.6	T55.6	Release fasciotomy of leg NEC
Meniscal Repair	W82.3	W82.3	W82.3	W82.3	W82.3	W82.3	Endoscopic repair of semilunar cartilage
Total Meniscectomy	W82.1	W82.1	W82.1	W82.1	W82.1	W82.1	Endoscopic total excision of semilunar cartilage

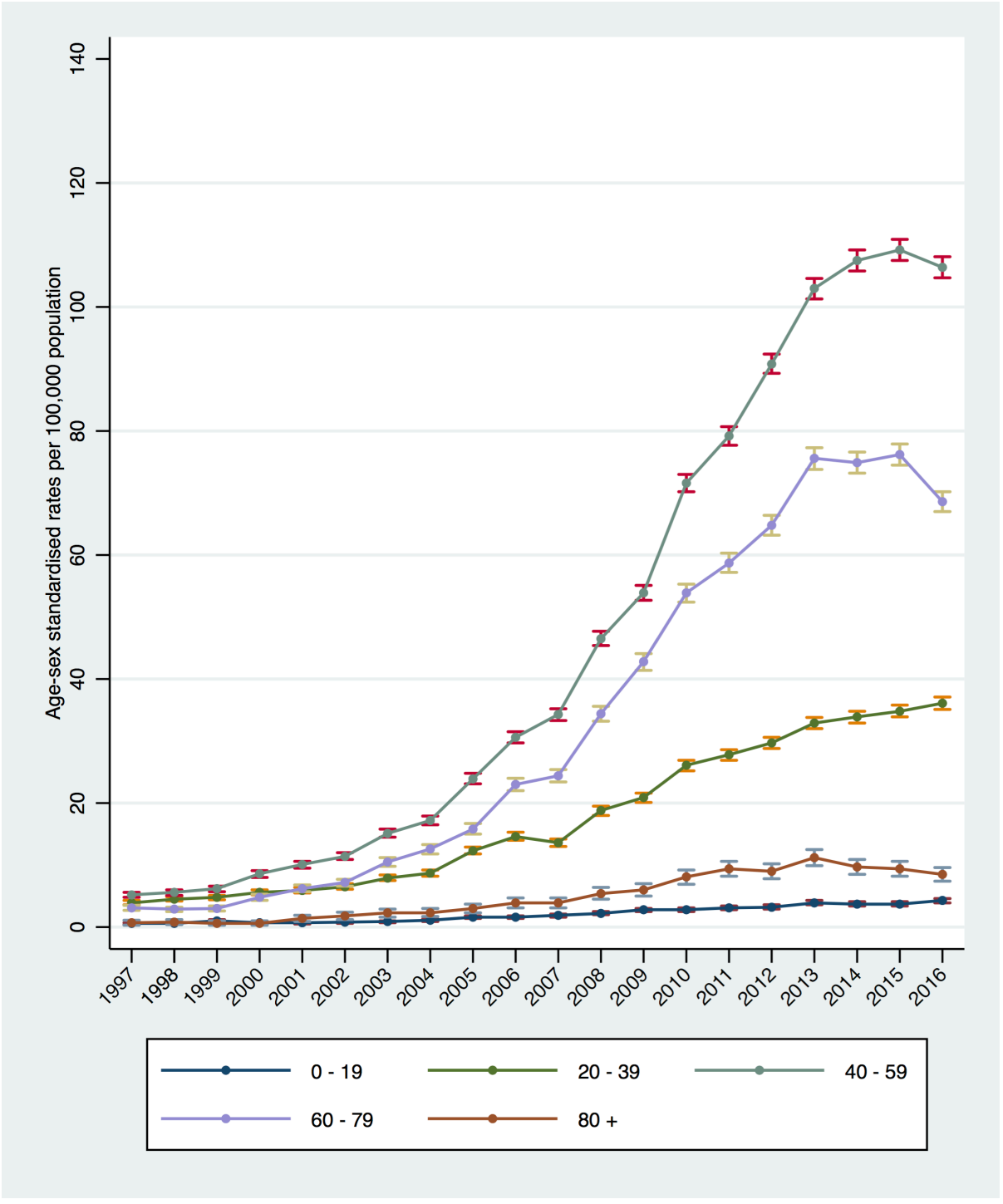
**: Additional site-specific knee code required (Z846, Z765, Z845, Z844, Z774, or Z787)*

B - Supplementary Analyses (Chapter 3)

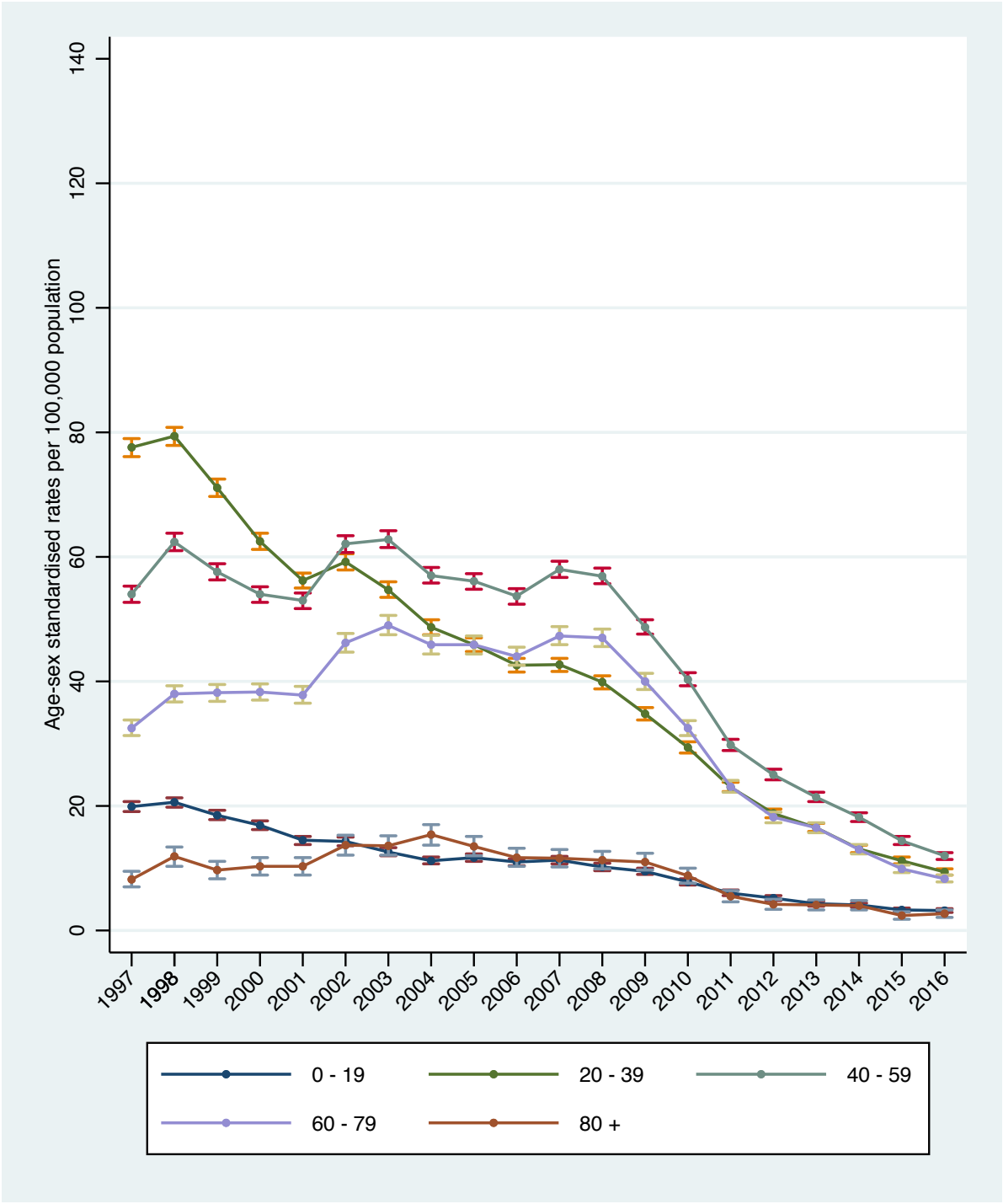
S1: Gender standardised rates of arthroscopic washout / lavage per 100,000 population by age group and year



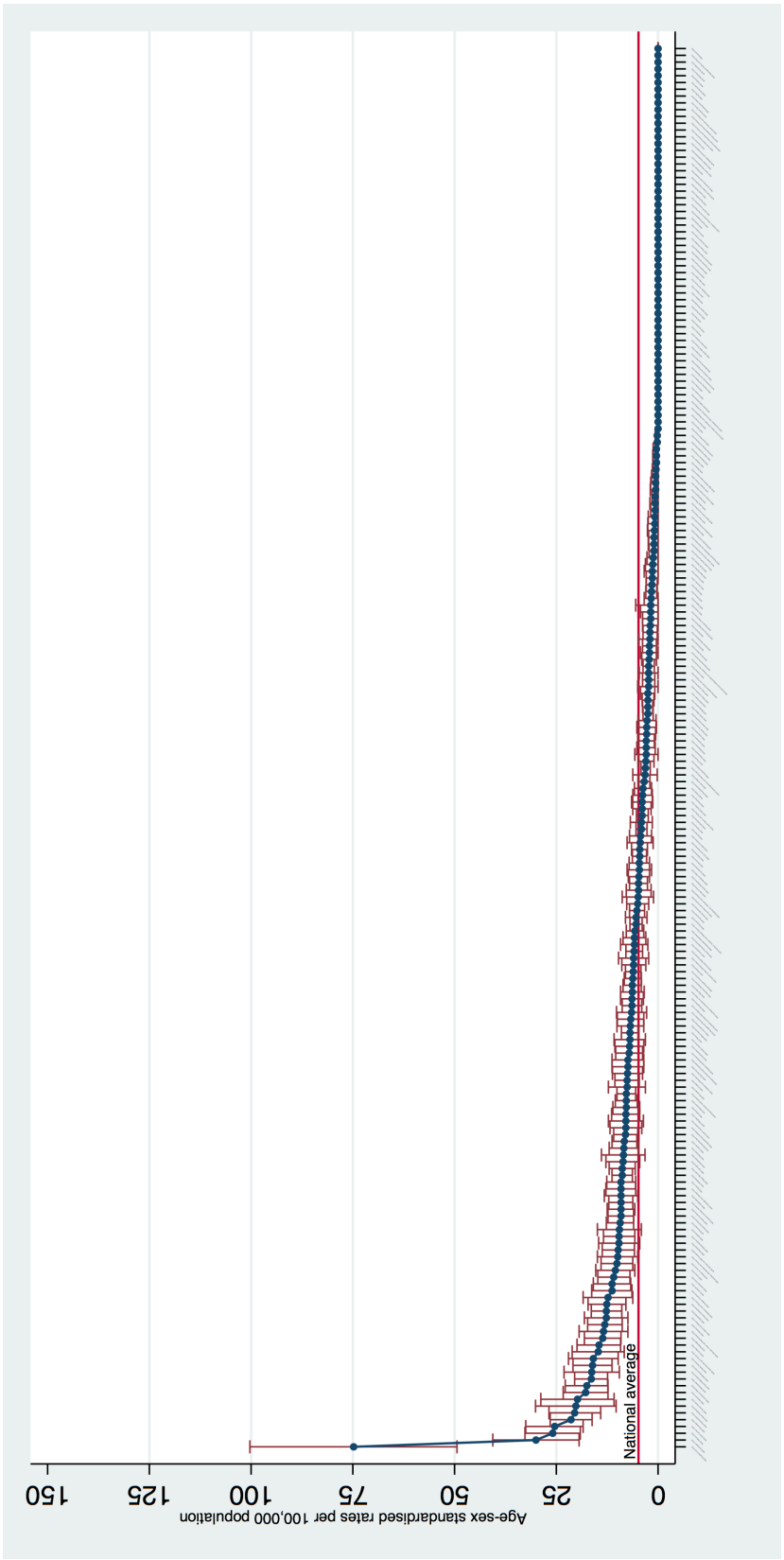
S2: Gender standardised rates of chondroplasty per 100,000 population by age group and year



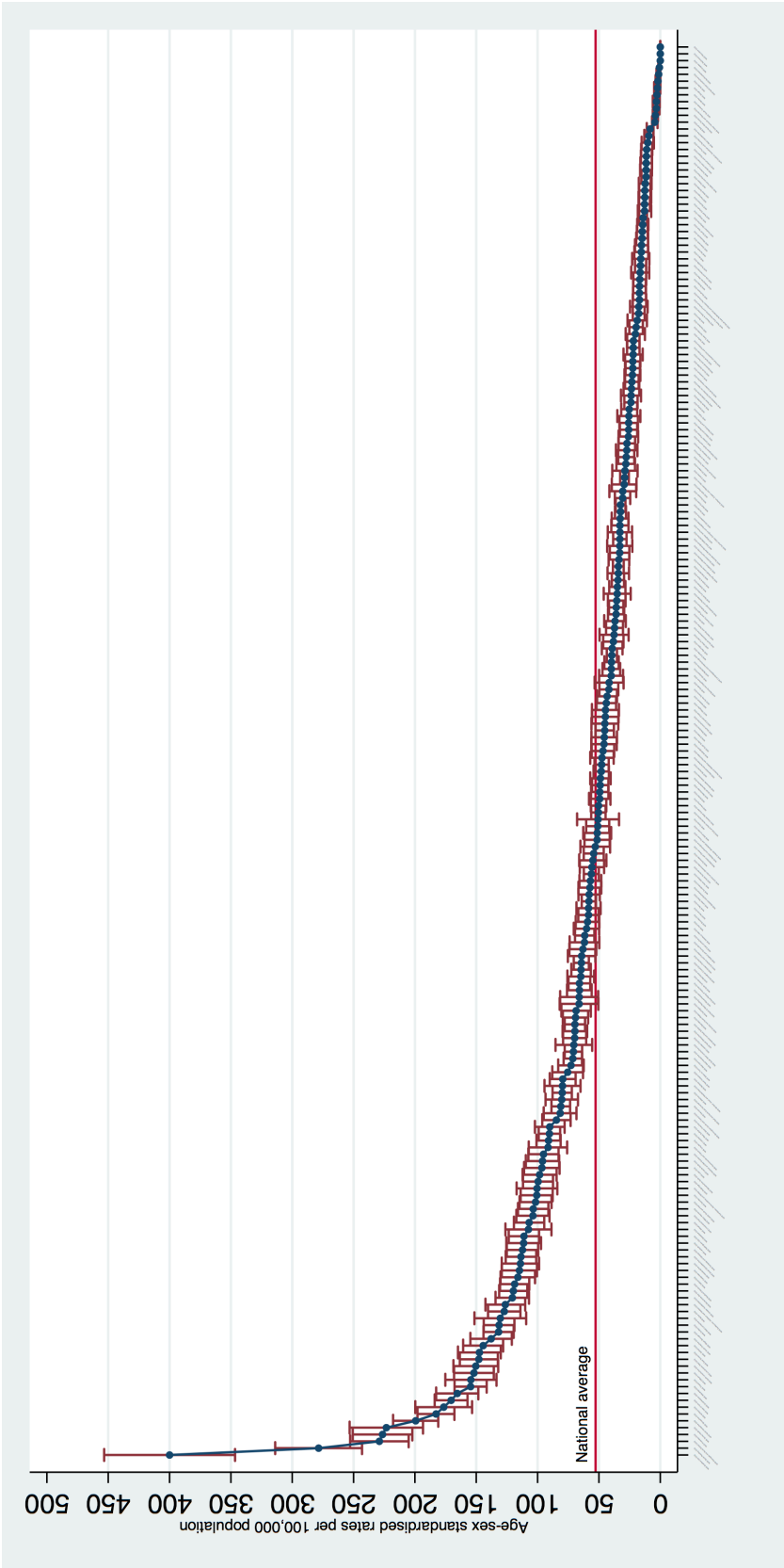
S3: Gender standardised rates of diagnostic arthroscopy per 100,000 population by age group and year



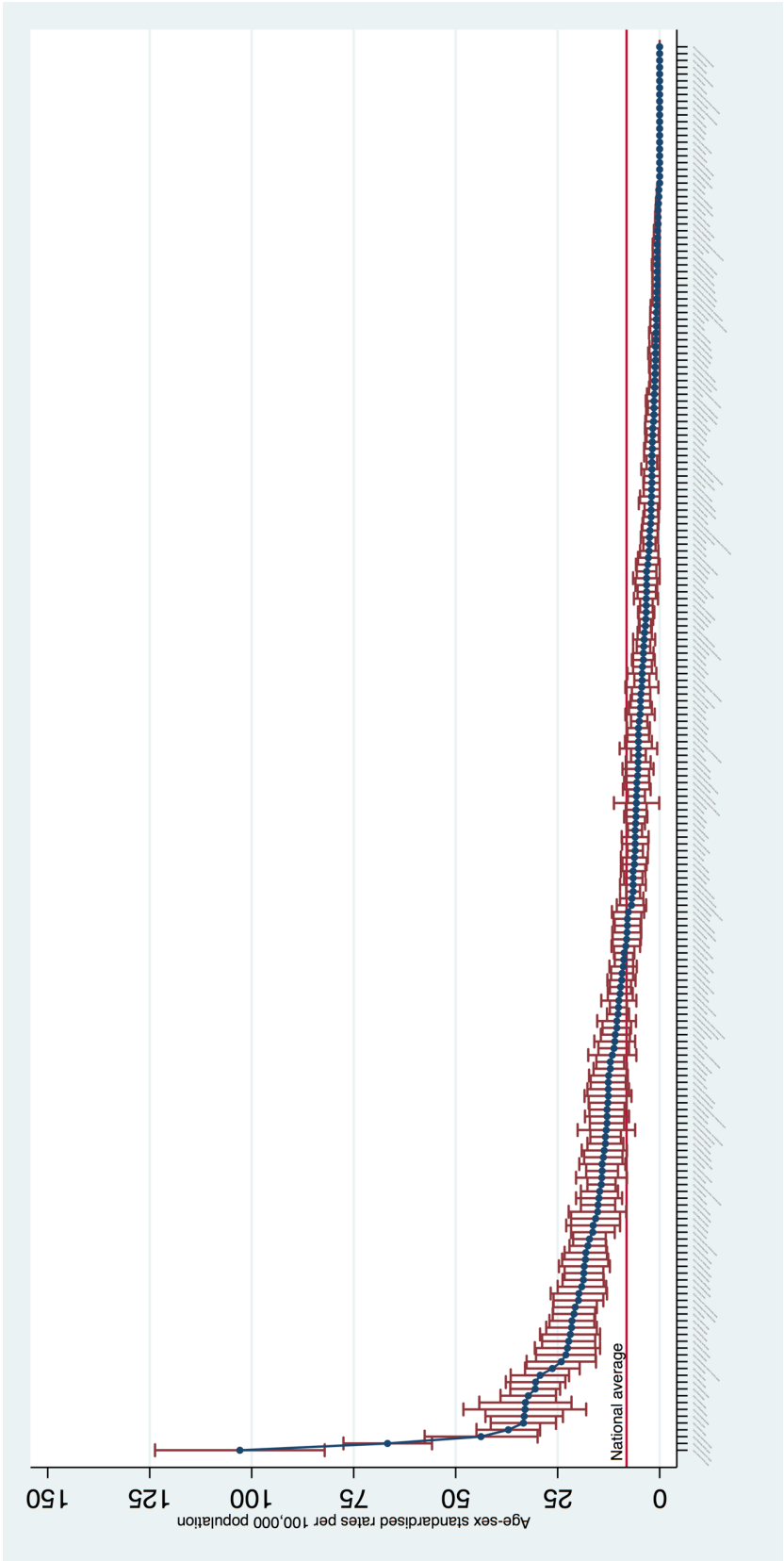
S4: Plot summarising the variation in the rate of washout / lavage /100,000 population by CCG in 2016-17



S5: Plot summarising the variation in the rate of chondroplasty /100,000 population by CCG in 2016-17



S6: Plot summarising the variation in the rate of diagnostic arthroscopy /100,000 population by CCG in 2016-17



C - Additional Reference Table (Chapter 3)

Lavage / Washout

1993	**RCT**	Chang RW, Falconer J, Stulberg SD, Arnold WJ, Manheim LM, Dyer AR. A randomized, controlled trial of arthroscopic surgery versus closed-needle joint lavage for patients with osteoarthritis of the knee. Arthritis Rheum 1993;36:289-96.
1999	**RCT**	Ravaud P, Moulinier L, Giraudeau B et al. Effects of joint lavage and steroid injection in patients with osteoarthritis of the knee: results of a multicenter, randomized, controlled trial. Arthritis Rheum 1999;42: 475–82.
2000	**RCT**	Kalunian KC, Moreland LW, Klashman DJ et al. Visually-guided irrigation in patients with early knee osteoarthritis: a multicenter randomized, controlled trial. Osteoarthritis Cartilage 2000;8:412–18.
2002	**RCT**	Bradley JD, Heilman DK, Katz BP, Gsell P, Wallick JE, Brandt KD. Tidal irrigation as treatment for knee osteoarthritis: a sham-controlled, randomized, double-blinded evaluation. Arthritis Rheum 2002;46: 100–8.
2002	**RCT**	Moseley JB, O'Malley K, Petersen NJ et al. A controlled trial of arthroscopic surgery for osteoarthritis of the knee. N Engl J Med 2002;347:81–8.
2003	**RCT**	Smith MD, Wetherall M, Darby T et al. A randomized placebo-controlled trial of arthroscopic lavage versus lavage plus intra-articular corticosteroids in the management of symptomatic osteoarthritis of the knee. Rheumatology 2003;42:1477–85.
2004	**RCT**	Frias G, Caracuel MA, Escudero A et al. Assessment of the efficacy of joint lavage versus joint lavage plus corticoids in patients with osteoarthritis of the knee. Curr Med Res Opin 2004;20:861–7.
2007	**National Guideline (NICE)**	Arthroscopic knee washout, with or without debridement, for the treatment of osteoarthritis (IPG230)
2008	**RCT**	Kirkley A, Birmingham TB, Litchfield RB, Giffin JR, Willits KR, Wong

		CJ, et al. A randomized trial of arthroscopic surgery for osteoarthritis of the knee. N Engl J Med 2008;359:1097-107
2009	**SR**	Avouac et. al. Rheumatology
2010	**SR**	Cochrane: Joint lavage for osteoarthritis of the knee
2014	**National Guideline (NICE)**	Osteoarthritis: care and management (CG177)
2015	**SR***	Thorlund JB, Juhl CB, Roos EM, et al. Arthroscopic surgery for degenerative knee: systematic review and meta-analysis of benefits and harms. BMJ 2015;350:h2747.

Partial meniscectomy

2007	**RCT**	Herrlin S, Hallander M, Wange P, Weidenhielm L, Werner S. Arthroscopic or conservative treatment of degenerative medial meniscal tears: a prospective randomised trial. Knee Surg Sports Traumatol Arthrosc 2007;15:393-401.
2012	**RCT**	Østeras H, Østeras B, Torstensen TA. Medical exercise therapy, and not arthroscopic surgery, resulted in decreased depression and anxiety in patients with degenerative meniscus injury. J Bodyw Mov Ther 2012;16:456-63. 12
2012	**National Guideline (AOSSM/AANA)**	Lyman S, Oh LS, Reinhardt KR, et al. Surgical Decision Making for Arthroscopic Partial Meniscectomy in Patients Aged Over 40 Years. Arthrosc J Arthrosc Relat Surg 2012; 28: 492501.e1.
2013	**RCT**	Katz JN, Brophy RH, Chaisson CE, de Chaves L, Cole BJ, Dahm DL, et al. Surgery versus physical therapy for a meniscal tear and osteoarthritis. N Engl J Med 2013;368:1675-84.
2013	**RCT**	Vermesan D, Prejbeanu R, Laitin S, Damian G, Deleanu B, Abbinante A, et al. Arthroscopic debridement compared to intra-articular steroids in treating degenerative medial meniscal tears. Eur Rev Med Pharmacol Sci

		2013;17:3192-6.
2013	**RCT**	Yim JH, Seon JK, Song EK, Choi JI, Kim MC, Lee KB, et al. A comparative study of meniscectomy and nonoperative treatment for degenerative horizontal tears of the medial meniscus. Am J Sports Med 2013;41:1565-70.
2013	**RCT**	Sihvonen R, Paavola M, Malmivaara A, Itala A, Joukainen A, Nurmi H, et al. Arthroscopic partial meniscectomy versus sham surgery for a degenerative meniscal tear. N Engl J Med 2013;369:2515-24. 15
2014	**RCT**	Gauffin H, Tagesson S, Meunier A, Magnusson H, Kvist J. Knee arthroscopic surgery is beneficial to middle-aged patients with meniscal symptoms: a prospective, randomised, single-blinded study. Osteoarthritis Cartilage 2014;22:1808-16.
2014	**SR**	Khan M, Evaniew N, Bedi A, Ayeni OR, Bhandari M. Arthroscopic surgery for degenerative tears of the meniscus: a systematic review and meta-analysis. CMAJ 2014;186:1057-64. doi:10.1503/ cmaj.140433.
2015	**SR***	Thorlund JB, Juhl CB, Roos EM, et al. Arthroscopic surgery for degenerative knee: systematic review and meta-analysis of benefits and harms. BMJ 2015;350:h2747.
2016	**RCT**	Kise NJ, Risberg MA, Stensrud S, et al. Exercise therapy versus arthroscopic partial meniscectomy for degenerative meniscal tear in middle aged patients: randomised controlled trial with two year follow-up. BMJ 2016;354:i3740.
2016	**SR**	Lamplot JD, Brophy RH. The role for arthroscopic partial meniscectomy in knees with degenerative changes: a systematic review. Bone Joint J 2016; 98–B: 934–8.
2016	**SR**	van de Graaf VA, Wolterbeek N, Mutsaerts ELAR, et al. Arthroscopic Partial Meniscectomy or Conservative Treatment for Nonobstructive Meniscal Tears: A Systematic Review and Meta-analysis of Randomized Controlled Trials. Arthrosc J Arthrosc Relat Surg 2016; 32: 1855–

		1865.e4.
2016	**National Guideline (ESSKA)**	Beaufils P, Becker R, Kopf S, et al. Surgical management of degenerative meniscus lesions: the 2016 ESSKA meniscus consensus. Knee Surgery, Sport Traumatol Arthrosc 2017; 25: 335–46.
2017	**National Guideline (ISAKOS)**	Stone JA, Salzler MJ, Parker DA, Becker R, Harner CD. Degenerative meniscus tears - assimilation of evidence and consensus statements across three continents: state of the art. J ISAKOS Jt Disord Orthop Sport Med 2017; 2: 108–19.
2017	**National Guideline (BMJ)**	Siemieniuk RAC, Harris IA, Agoritsas T, et al. Arthroscopic surgery for degenerative knee arthritis and meniscal tears: a clinical practice guideline. Bmj 2017; 357: j1982.
2018	**SR**	Abram SGF, Hopewell S, Monk AP, Bayliss LE, Beard DJ, Price AJ. Arthroscopic partial meniscectomy or non-surgical treatment for meniscal tears of the knee: A systematic review and meta-analysis. 2018. Article in Press.

<u>Chondroplasty</u>

2002	**RCT**	Stein DT, Ricciardi CA, Viehe T. The effectiveness of the use of electrocautery with chondroplasty in treating chondromalacic lesions: a randomized prospective study. Arthroscopy 2002;18:190–3.
2002	**RCT**	Owens BD, Stickles BJ, Balikian P, et al. Prospective analysis of radiofrequency versus mechanical debridement of isolated patellar chondral lesions. Arthroscopy 2002;18:151–5.
2006	**RCT**	Barber FA, Iwasko NG. Treatment of Grade III Femoral Chondral Lesions: Mechanical Chondroplasty Versus Monopolar Radiofrequency Probe. Arthrosc - J Arthrosc Relat Surg 2006; 22: 1312–7.
2008	**RCT**	Kang RW, Gomoll AH, Nho SJ, Pylawka TK, Cole BJ. Outcomes of mechanical debridement and radiofrequency ablation in the treatment of chondral defects: a prospective randomized study. J Knee Surg 2008;

		21:116–121
2010	**RCT**	Spahn G, Klinger HM, Mückley T, Hofmann GO. Four-Year Results From a Randomized Controlled Study of Knee Chondroplasty With Concomitant Medial Meniscectomy: Mechanical Debridement Versus Radiofrequency Chondroplasty. Arthrosc J Arthrosc Relat Surg 2010; 26: S73–80.
2014	**National Guideline (NICE)**	Arthroscopic radiofrequency chondroplasty for discrete chondral defects of the knee (IPG493)
2016	**SR**	Rocco P, Lorenzo DB, Guglielmo T, Michele P, Nicola M, Vincenzo D. Radiofrequency energy in the arthroscopic treatment of knee chondral lesions: A systematic review. Br Med Bull 2016; 117: 149–56.

*Note: RCT = randomized controlled clinical trial; SR = systematic review; * = "degenerative knee disease" population; AOSSM = American Orthopaedic Society for Sports Medicine; AANA = Arthroscopy Association of North America; BMJ = British Medical Journal; ESSKA = European Society of Sports Traumatology, Knee Surgery & Arthroscopy; ISAKOS = International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine; NICE = National Institute for Health and Care Excellence.*

D - COSMIN Search Strategy

Databases: Medline, EMBASE, AMED, PsycInfo

#1 Condition

menis*.af

#2 Construct

("quality of life" OR qol OR func* OR HR-PRO OR HRPRO OR HRQOL OR QL OR disab* OR wellbeing OR "well being" OR subjective OR utility OR utilities OR priorit* OR outcome* OR health).af

#3 Instrument

(score* OR measure* OR PROM OR index* OR indices OR scale* OR questionnaire* OR instrument* OR survey* OR profile* OR apprais* OR status OR reported OR reporting OR rated OR rating* OR assessment*).af

#4 Measurement Properties

"Validation Studies".pt OR instrumentation.af OR ("observer variation" OR "psychometrics" OR "reproducibility of results" OR "discriminant analysis").mh OR (agreement OR precision OR imprecision OR "precise values" OR repeatab* OR ((replicab* OR repeated) AND (measure OR measures OR findings OR result OR results OR test OR tests))).af OR (reproducib* OR psychometr* OR clinimetr* OR clinometr* OR observer AND variation OR reliab* OR valid* OR coefficient OR "internal consistency" OR (cronbach* AND (alpha OR alphas)) OR "item correlation" OR "item correlations" OR "item selection" OR "item selections" OR "item reduction" OR "item reductions" OR test?retest OR (test AND retest) OR (reliab* AND (test OR retest)) OR stability OR interrater OR inter-rater OR intrarater OR intra-rater OR intertester OR inter-tester OR intratester OR intra-tester OR

interobserver OR inter-observer OR intraobserver OR intra-observer OR intertechnician OR intertechnician OR intratechnician OR intra-technician OR interexaminer OR inter-examiner OR intraexaminer OR intra-examiner OR inter-assay OR inter-assay OR intraassay OR intra-assay OR interindividual OR inter-individual OR intraindividual OR intra-individual OR interparticipant OR inter-participant OR intraparticipant OR intra-participant OR kappa OR kappa?s OR "coefficient of variation" OR generaliza* OR generalisa* OR concordance OR (intraclass AND correlation*) OR discriminative OR "known group" OR "factor analysis" OR "factor analyses" OR "factor structure" OR "factor structures" OR dimensionality OR subscale* OR "multitrait scaling analysis" OR "multitrait scaling analyses" OR "item discriminant" OR "interscale correlation" OR "interscale correlations" OR ((error OR errors) AND (measure* OR correlat* OR evaluat* OR accuracy OR accurate OR precision OR mean)) OR "individual variability" OR "interval variability" OR "rate variability").ti,ab NOT ("addresses" OR "biography" OR "case reports" OR "comment" OR "directory" OR "editorial" OR "festschrift" OR "interview" OR "lectures" OR "legal cases" OR "legislation" OR "letter" OR "news" OR "newspaper article" OR "patient education handout" OR "popular works" OR "congresses" OR "consensus development conference" OR "consensus development conference, nih" OR "practice guideline").pt

#5 (#1 AND #2 AND #3 AND #4)

#5 Remove Duplicates

E - Quality criteria for measurement properties

Property	Rating[266]	Quality Criteria[266]
Reliability		
Internal consistency	+	Cronbach's alpha(s) ≥ 0.70
	?	Cronbach's alpha not determined or dimensionality unknown
	-	Cronbach's alpha(s) < 0.70
Reliability	+	ICC / weighted Kappa ≥ 0.70 OR Pearson's r ≥ 0.80
	?	Neither ICC / weighted Kappa, nor Pearson's r determined
	-	ICC / weighted Kappa < 0.70 OR Pearson's r < 0.80
Measurement error	+	MIC > SDC OR MIC outside the LOA
	?	MIC not defined
	-	MIC ≤ SDC OR MIC equals or inside LOA
Validity		
Content validity	+	All items are considered to be relevant for the construct to be measured, for the target population, and for the purpose of the measurement AND the questionnaire is considered to be comprehensive
	?	Not enough information available
	-	Not all items are considered to be relevant for the construct to be measured, for the target population, and for the purpose of the measurement OR the questionnaire is considered not to be comprehensive
Construct validity – Structural validity	+	Factors should explain at least 50% of the variance
	?	Explained variance not mentioned
	-	Factors explain < 50% of the variance
Construct validity – Hypothesis testing	+	Correlations with instruments measuring the same construct ≥ 0.50 OR at least 75% of the results are in accordance with the hypotheses AND correlations with related constructs are higher than with unrelated constructs
	?	Solely correlations determined with unrelated constructs
	-	Correlations with instruments measuring the same construct < 0.50 OR < 75% of the results are in accordance with the hypotheses OR correlations with related constructs are lower than with unrelated constructs

Construct validity – Cross-cultural validity	+	No differences in factor structure OR no important DIF between language versions
	?	Multiple group factor analysis not applied AND DIF not assessed
	-	Differences in factor structure OR important DIF between language versions
Responsiveness		
Responsiveness	+	Correlation with changes on instruments measuring the same construct ≥ 0.50 OR at least 75% of the results are in accordance with the hypotheses OR AUC ≥ 0.70 AND correlations with changes in related constructs are higher than with unrelated constructs
	?	Solely correlations determined with unrelated constructs
	-	Correlations with changes on instruments measuring the same construct < 0.50 OR < 75% of the results are in accordance with the hypotheses OR AUC < 0.70 OR correlations with changes in related constructs are lower than with unrelated constructs

Note: MIC = minimal important change, SDC = smallest detectable change, LoA = limits of agreement, ICC = intraclass correlation coefficient, DIF = differential item functioning, AUC = area under the curve. + = positive rating, ? = indeterminate rating, - = negative rating.

F - APM Systematic Review Search Strategy

MEDLINE

1	Menisci, Tibial/
2	(tear* adj3 medial*).ti,ab.
3	(menisc* adj3 tear*).ti,ab.
4	(menisc* adj3 injur*).ti,ab.
5	1 or 2 or 3 or 4
6	Arthroscopy/
7	arthroscop*.ti,ab.
8	meniscectom*.mp.
9	6 or 7 or 8
10	(random$ or placebo$ or single blind$ or double blind$ or triple blind$).ti,ab.
11	Randomized controlled trial.pt.
12	Controlled clinical trial.pt.
13	Clinical trials as topic/
14	trial.ti.
15	Comparative Study/
16	cohort*.ti,ab.
17	10 or 11 or 12 or 13 or 14 or 15 or 16
18	5 and 9 and 17

Embase

1	knee meniscus/
2	(tear* adj3 medial*).ti,ab.
3	(menisc* adj3 tear*).ti,ab.
4	(menisc* adj3 injur*).ti,ab.
5	1 or 2 or 3 or 4
6	Arthroscopy/
7	arthroscop*.ti,ab.
8	meniscectom*.mp.
9	8 or 6 or 7

10 exp Randomized Controlled Trial/ or exp Single Blind Procedure/ or exp Double Blind Procedure/ or Crossover Procedure/

11 (random* or RCT or placebo or allocat* or crossover* or 'cross over' or trial or (doubl* adj1 blind*) or (singl* adj1 blind*)).ti,ab.

12 Comparative Study/

13 cohort*.ti,ab.

14 10 or 11 or 12 or 13

15 5 and 9 and 14

CENTRAL

1 MeSH descriptor: [Menisci, Tibial] this term only

2 menisc*:ti,ab,kw (Word variations have been searched)

3 knee or tibia* (Word variations have been searched)

4 2 and 3

5 1 or 4

6 MeSH descriptor: [Sprains and Strains] this term only

7 MeSH descriptor: [Athletic Injuries] this term only

8 MeSH descriptor: [Knee Injuries] this term only

9 tear* or injur* or lesion*:ti,ab,kw (Word variations have been searched)

10 Any MeSH descriptor with qualifier(s): [Injuries - IN, Surgery - SU]

11 6 or 7 or 8 or 9 or 10

12 5 and 11

Scopus

1 (TITLE-ABS-KEY (tear* W/3 medial*)) OR (TITLE-ABS-KEY (menisc* W/3 tear*)) OR (TITLE-ABS-KEY (menisc* W/3 injur*))) AND (TITLE-ABS-KEY (arthroscop* OR meniscectom*)) AND ((TITLE-ABS-KEY ((random* OR rct OR placebo OR allocat* OR crossover* OR "cross over" OR trial OR (doubl* W/1 blind*) OR (singl* W/1 blind*)))) OR (TITLE-ABS-KEY (control* W/1 trial*)) OR (TITLE-ABS-KEY (cohort*)))

Web of Science Core Collection

1 TOPIC: (tear* near/3 medial*) OR TITLE: (tear* near/3 medial*)

2 TOPIC: (menisc* near/3 tear*) OR TITLE: (menisc* near/3 tear*)

3	TOPIC: (menisc* near/3 injur*) OR TITLE: (menisc* near/3 injur*)
4	OR/1-3
5	TOPIC: (arthroscop* OR meniscectom*) OR TITLE: (arthroscop* OR meniscectom*)
6	TOPIC: (random* OR rct OR placebo OR allocat* OR crossover* OR "cross over" OR trial OR (doubl* near/1 blind*) OR (singl* near/1 blind*)) OR TITLE: (random* OR rct OR placebo OR allocat* OR crossover* OR "cross over" OR trial OR (doubl* near/1 blind*) OR (singl* near/1 blind*))
7	TOPIC: (control* near/1 trial*) OR TITLE: (control* near/1 trial*)
8	TOPIC: (cohort*) OR TITLE: (cohort*)
9	OR/6-8
10	4 AND 5 AND 9

G - APM Systematic Review: Excluded Studies

Article	Reason for exclusion
Andro C, Dubrana F, Marcillaud G, et al. Painful medial knee compartment syndrome in over-45 year-olds: I - Medical or surgical management: A series of 174 patients. Orthop Traumatol Surg Res 2011; 97: S21–6.	Population
Biedert RM. Treatment of intrasubstance meniscal lesions: a randomized prospective study of four different methods. Knee Surg Sports Traumatol Arthrosc 2000; 8: 104–8.	Population
Englund M, Zhang F, Guermazi A, Roemer FW, Losina E, Katz JN. The Effect of Arthroscopic Partial Meniscectomy in Patients with Osteoarthritis on Meniscal Body Extrusion [abstract]. In: Arthritis and Rheumatology. 2015. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=emed17&AN=72096265 NS -.	Outcome
Englund M, Roos EM, Lohmander LS. Impact of type of meniscal tear on radiographic and symptomatic knee osteoarthritis: A sixteen-year followup of meniscectomy with matched controls. Arthritis Rheum 2003; 48: 2178–87.	Study design
Hare KB, Lohmander LS, Christensen R, et al. Arthroscopic partial meniscectomy in middle-aged patients with mild or no knee osteoarthritis: a protocol for a double-blind, randomized sham-controlled multi-centre trial. BMC Musculoskelet Disord 2013; 14: 71.	Protocol (terminated study)
Katz JN, Spindler K, Safran-Norton C, et al. Predictors and outcomes of cross-over to surgery in a randomized trial of surgery vs. physical therapy for meniscal tear and osteoarthritis. Osteoarthr Cartil 2015; 23: A36–7.	Population
Katz JN, Wright J, Spindler KP, et al. Predictors and Outcomes of Crossover to Surgery from Physical Therapy for Meniscal Tear and Osteoarthritis. J Bone Jt Surg - Am Vol 2016; 98: 1890–6.	Population
Li R, Borrero C, Casagranda B, Harner CD, Irrgang JJ. Predictors of cartilage loss in individuals with degenerative meniscus tear: Data from the osteoarthritis initiative. Arthrosc - J Arthrosc Relat Surg 2013; 29: e68–9.	Outcome
Marsh JD, Birmingham TB, Giffin JR, et al. Cost-effectiveness analysis of arthroscopic surgery compared with non-operative management for osteoarthritis of the knee. BMJ Open 2016; 6: e009949.	Population
Marsh JD, Birmingham TB, Giffin JR, et al. Cost-effectiveness analysis of arthroscopic surgery compared with non-operative management for osteoarthritis of the knee. In: Osteoarthritis and Cartilage. 2015: A26–81.	Population
Merchan ECR, Galindo E. Arthroscope-guided surgery versus nonoperative treatment for limited degenerative osteoarthritis of the femorotibial joint in patients over 50 years of age: A prospective comparative study. Arthroscopy 1993; 9: 663–7.	Population
Rathleff CR, Cavallius C, Jensen HP, et al. Successful conservative treatment of patients with MRI-verified meniscal lesions. Knee Surg Sports Traumatol Arthrosc 2015; 23: 178–83.	Intervention
Rimington T, Mallik K, Evans D, Mroczek K, Reider B. A prospective study of the nonoperative treatment of degenerative meniscus tears. Orthopedics 2009; 32: 1–8.	Population
Stensrud S, Risberg MA, Roos EM. Effect of exercise therapy compared with arthroscopic surgery on knee muscle strength and functional performance in middle-aged patients with degenerative meniscus tears. Am J Phys Med Rehabil 2015; 94: 1–14.	Outcome

H - APM Systematic Review: Ongoing and Terminated Studies

NCT01931735

Title	Prospective Trial of Arthroscopic Meniscectomy for Degenerative Meniscus Tears[324]
Identifier	NCT01931735
Status (13th April 2018)	"This study is ongoing, but not recruiting participants."
Methods	Randomized controlled trial
Participants	Inclusion • Veteran • Age between 45 and 70 years • Degenerative meniscus tear as seen on standard clinical MRI scan • Complaint of "mechanical symptoms" which would include popping, catching, or locking of the knee • Persistent symptoms for a minimum of three months despite conservative management • Patient is enrolled for arthroscopic meniscectomy • Subject agrees to the study follow-up schedule and signs informed consent. Exclusion • Radiographic osteoarthritis of the knee in any compartment greater than KL grade 2 • Prior knee arthroscopy within two years of study enrolment • Unable to have an MRI scan • Does not agree to participate
Intervention	Arthroscopic partial meniscectomy
Comparator	Arthroscopy and lavage
Registration date	August 2013
Estimated completion date	September 2017
Contact details	Nicholas J. Giori VA Palo Alto Health Care System, Palo Alto, CA, United States

NCT02995551

Title	Danish Rct on Exercise Versus Arthroscopic Meniscal Surgery for Young Adults (DREAM)[323]
Identifier	NCT02995551
Status (13th April 2018)	"This study is currently recruiting participants."
Methods	Randomized controlled trial
Participants	Inclusion • Adults aged 18 to 40 years with knee pain • Clinical history and symptoms consistent with meniscal tear and meniscal tear verified on magnetic resonance imaging (MRI) • Deemed eligible for meniscal surgery (i.e. repair or resection) by the examining orthopedic surgeon • Willing to participate in 12 weeks of supervised exercise twice a week or undergo surgery for the meniscal tear as soon as possible Exclusion • Previous knee surgery on the affected knee • Clinical suspicion (acute locking of knee AND/OR extension deficit) of displaced bucket-handle tear confirmed by MRI • Fracture of the affected extremity within the previous 6 months • Complete rupture of one or more knee ligaments. • Participation in supervised systematic exercise for knee problems within the last 3 months prior to recruitment • Other reasons for exclusion (Unable to understand Danish, mentally unable to participate, etc.)
Intervention	Arthroscopic meniscal repair or resection
Comparator	Exercise and Education
Registration date	December 2016
Estimated completion date	April 2019
Contact details	Søren T. Skou University of Southern Denmark and Næstved-Slagelse-Ringsted Hospitals, Denmark

NCT02113280

Title	DEMAND - DEgenerative Meniscal Tears - Arthroscopy vs. Dedicated Exercise (DEMAND)[326]
Identifier	NCT02113280
Status (13th April 2018)	"This study is not yet open for participant recruitment."
Methods	Randomised controlled trial
Participants	Inclusion • Age over 45 years • Knee pain in the presence of a medial meniscal tear on MRI. Exclusion • History of trauma to the knee or ipsilateral lower limb in the past 2 years • Inability to engage in postoperative rehabilitation • Lacking capacity to consent • Evidence of infection • Previous knee surgery other than arthroscopy (diagnostic or partial meniscectomy) Neurological disease • Inflammatory arthritis • Loose bodies • Ligament injuries causing symptomatic instability • Women who are pregnant • Have current signs or symptoms of severe, progressive or uncontrolled renal, hepatic, haematological, gastrointestinal, endocrine, pulmonary, cardiac, neurologic, or cerebral disease. • Uncontrolled disease states, such as moderate/severe asthma, COPD or inflammatory bowel disease, where flares are commonly treated with oral or parenteral corticosteroids, or recurrent infections.
Intervention	Knee arthroscopy and meniscal debridement
Comparator	Outpatient standardised physiotherapy regime with focus on exercise therapy
Registration date	October 2013
Estimated completion date	December 2018
Contact details	Sarah Johnson-Lynn Northumbria Healthcare NHS Foundation Trust, UK

I - APM Review: Included Study Characteristics

Gauffin 2014

Location	Sweden
Funding	None reported
Participants	Inclusion • 45-64yrs • Symptom duration over 3 months • Standing x-ray Ahlbäck grade 0 • Prior physiotherapy • Understand Swedish Exclusion • Locked knee • Joint lockings for more than 2s more over than once per week • Rheumatic or neurological disease • Fibromyalgia • Replacement of hip or knee joints • Contraindicated to day surgery (BMI >35, serious illness)
Intervention	Arthroscopic partial meniscectomy • Within 4 weeks of randomisation. • Surgeon 'judged, according to their experience, whether a meniscal resection or any other surgical treatment was indicated'. • Exercise programme before and after.
Comparator	Exercise programme • Twice per week for 3 months • Participants asked to perform the exercise programme in the gym, without supervision from a physio. Home based exercise programme provided an alternative. • Aim to increase muscle function and postural control.

Herrlin 2007

Location	Sweden
Funding	None reported
Participants	Inclusion • 45-64yrs • Knee pain daily or almost daily during last 2-6 months • No trauma • Knee OA Ahlbäck grade 0 or 1 • Medial meniscal tear on MRI • Understanding of Swedish language Exclusion • Traumatic meniscal injury • Neurological or rheumatic inflammatory diseases • Loose bodies, ligament injuries, osteochondral defects and tumours (MRI) • Earlier knee surgery, prosthetic replacements of hip or knee and fractures to lower extremities less than 1 year old • Contraindication to physical training
Intervention	Arthroscopic partial meniscectomy • No further details.
Comparator	Exercise programme • Twice a week for 8 weeks. • Standardised programme, possible for individual adaptation. • Exercises for muscle strength, endurance, muscle flexibility as well as balance and proprioception. Increasing weights and higher resistance.

Katz 2013

Location	United States
Funding	Grants (R01AR055557, K24AR057827, and P60AR047782) from the National Institute of Arthritis and Musculoskeletal and Skin Diseases of the National Institutes of Health
Participants	Inclusion • Age 45 years or greater • Symptoms for at least four weeks, managed with one or more of: medications, activity limitations or PT • Symptoms consistent with torn meniscus (at least one of the following: clicking, catching, popping, giving way, pain with pivot or torque, pain that is episodic, pain that is acute and localized to one joint line) • Availability of knee radiograph and MRI • Evidence on knee MRI of osteophytes or full-thickness cartilage defect; or plain radiographic evidence of osteophytes or joint space narrowing • Evidence on knee MRI of a meniscal tear that extends to the surface of the meniscus • Willingness to undergo randomization and ability to understand and sign an informed consent document Exclusion • Chronically locked knee (e.g. patient cannot flex or extend the knee; a clear indication for APM) • Kellgren-Lawrence Grade 4 • Inflammatory arthritis or clinically symptomatic chondrocalcinosis • Injection with viscosupplementation in past four weeks in index knee • Contraindication to surgery or physical therapy • Bilateral symptomatic meniscal tears - Prior surgery on index knee
Intervention	Arthroscopic partial meniscectomy • Trimming of damaged meniscus back to a stable rim. • Removal of loose fragments of cartilage or bone. • Post-op physiotherapy as per control protocol.
Comparator	Exercise programme • Three-stage programme with attendance at physio session 1-2 times per week and additional home exercises. • Average duration 6 weeks.

Kise 2016

Location	Norway
Funding	Sophies Minde Ortopedi AS, Swedish Rheumatism Association, Swedish Scientific Council, Region of Southern Denmark, Danish Rheumatism Association, and the Health Region of South-East Norway
Participants	Inclusion • 35-60 years • Unilateral knee pain for over two months • No major trauma (sudden onset of knee pain resulting from a single physical impact event) • Medial degenerative meniscal tear confirmed on MRI (an intrameniscal linear magnetic resonance imaging signal penetrating one or both surfaces of the meniscus) • Kellgren-Lawrence Grade 2 or less • Eligible for arthroscopy • Able to participate in exercise therapy • Understand Norweigan Exclusion • Acute trauma • Locked knee • Ligament injury • Knee injury in the index knee during previous 2 years
Intervention	Arthroscopic partial meniscectomy • Standard: general anaesthetic with or without thigh tourniquet. • Diagnostic arthroscopy followed by resection of unstable meniscal tissue. • Written and oral instructions of for simple home exercises were given and patient advised to perform 2-4 times per day.
Comparator	Exercise programme • Progressive neuromuscular and strength exercises over 12 weeks, performed during a minimum of two and a maximum of three sessions each week (24-36 sessions).

Østeras 2012

Location	Norway
Funding	None reported
Participants	Inclusion • Knee pain > 3 months • Age 35-60yrs • 'Eligible' for APM • MRI demonstrating degenerative meniscal tear Exclusion • ACL rupture requiring acute trauma surgery • Kellgren-Lawrence grade 3 or 4 • Haemathrosis • Locked • Symptomatic pain in contrary extremities • Musculoskeletal comorbidities severely affecting lower extremity muscle function • Unable to speak or read 'language of interest'
Intervention	Arthroscopic partial meniscectomy • "Standard" APM following by non-structured physiotherapy.
Comparator	Exercise programme • 3 times per week for 3 months • Combination of global aerobic exercises using a stationary ergometer cycle, a treadmill, or step machine, and semi-global and local exercises to modulate pain and increase range of movement using specially designed exercise equipment: wall pulleys, quadriceps and hamstrings muscle strength training apparatus, including squats, leg extension, leg flexion.

Roos 2018

Location	Denmark
Funding	Research Fund of Hospital South, Region Zealand; Region Zealand Health Scientific Research Fund; Edith and Henrik Henriksens Memorial Fund; The Danish Rheumatism Association. The Parker Institute, Bispebjerg and Frederiksberg Hospital (R. Christensen and S.M. Nielsen) is supported by a core grant from the Oak Foundation (OCAY-13-309).
Participants	<u>Inclusion</u> • Patients with knee pain for more than 2 months without significant trauma (only the index knee will be included) • MRI-confirmed medial meniscus lesion (patients with a medial meniscus lesion AND a lateral lesion will also be included) • Age 35-55 years • Eligible for outpatient surgery - ASA score 1-2 <u>Exclusion</u> • Patients in need of acute surgery e.g. locking knees, high-energy trauma • Symptoms associated with other musculoskeletal comorbidities overriding the symptoms of the knee • Grade 3 or 4 knee OA on the Kellgren-Lawrence classification • Knee surgery within the last 2 years • Obese patients with BMI > 35 • Patients with ischemic heart disease • Patients with diabetic late-complications • Patients with thrombophilia • Pregnancy • Patients unable to speak Danish • Patients with drug or alcohol abuse
Intervention	<u>Arthroscopic partial meniscectomy</u> • The arthroscopic partial meniscectomy will be performed on an outpatient basis by experienced surgeons at a level of at least attending physicians or at the last year of residency. All arthroscopies will be performed in general anaesthesia combined with local anaesthesia. After general anaesthesia is induced, the knee will be examined for stability. Thereafter two standard portals on the lateral and medial side of the ligamentum patella will be created but no outflow cannula inserted. An arthroscope will be used with a pressure-controlled irrigation system. Tourniquet use will be according to surgeon preference. The strategy for the meniscectomy will be to preserve as much tissue as possible. A standard operation protocol will be used to document possible findings in cartilage, ligaments, synovium and the medial and lateral meniscus. Meniscus lesions and type of will be registered and changes in the articular cartilage will be classified according to the ICRS classification
Comparator	<u>Sham arthroscopy</u>

	• The placebo procedure will be performed under the same conditions as above. The patient will be fully sedated in general anaesthesia. As above, the stability of the knee will be examined. Local anaesthetic will be applied as above and 2 skin incisions will be made at the same location and the same size as above. Then the knee will be manipulated as if a real arthroscopy were being done, the spillage of water and all the other equipment needed for an arthroscopy will be used and manipulated. No instruments will enter the portals for arthroscopy to avoid the possibility of osteochondral lesions and unwanted interventions by the surgeon.

Sihvonen 2013

Location	Finland
Funding	Sigrid Juselius Foundation, the Competitive Research Fund of Pirkanmaa Hospital District, and Academy of Finland
Participants	Inclusion • Age: 35 to 65 years • Persistent (> 3 months) pain on the medial joint line of the knee • Pain provoked by palpation or compression (forced flexion) of the medial tibiofemoral joint line or a positive McMurray sign • MRI showing signals characteristic of medial meniscus injury • Arthroscopically-verified degenerative medial meniscus tear Exclusion • Obvious trauma-induced onset of symptoms • Locked knee (that cannot be straightened normally) • Previous surgical procedure on the affected knee • Clinical knee OA (ACR Criteria) • Radiographic knee OA (Kellgren-Lawrence grade > 1)* • Acute (within the previous year) fracture of the affected extremity • Decreased range of motion of the knee • Instability of the knee • MRI assessment shows pathology other than degenerative knee disease requiring treatment other than APM • Arthroscopic examination reveals pathology other than a degenerative injury to the medial meniscus requiring intervention other than APM
Intervention	Arthroscopic partial meniscectomy • Damaged and loose parts of the meniscus were removed until solid meniscal tissue was reached.
Comparator	Placebo arthroscopy • Simulated APM. • Patient was kept in theatre for expected duration, same instruments asked for, manipulated knee, mechanical shaver simulated, and irrigation fluid running.

Vermesan 2013

Location	Italy
Funding	None reported
Participants	Inclusion • MRI with degenerative lesions medial compartment (meniscus and cartilage) Exclusion • None stated.
Intervention	Arthroscopic partial meniscectomy • No further details.
Comparator	Intra-articular steroid injection • 1ml betamethasone in 4ml 1% lignocaine.

Yim 2013

Location	South Korea
Funding	None reported
Participants	Inclusion • Degenerative horizontal tear of the posterior horn of the medial meniscus on MRI • Non-traumatic knee pain • Daily knee pain medial side of knee • 'Mechanical symptoms' affecting ADLs despite primary care management during previous month Exclusion • History of definite trauma • Previous knee surgery • Ligament deficiency • Systemic arthritis • Osteonecrosis • Kellgren-Lawrence Grade 2, 3 or 4
Intervention	Arthroscopic partial meniscectomy • 5.5mm 30-degree scope, pressure controlled irrigation. • Resection with limited debridement of the articular surface lesion. • Additional procedures were excluded (e.g. curettage, abrasion arthroplasty, subchondral drilling). • No patient had total meniscectomy or repair. • Followed by analgesia and 8 weeks of home exercises (the same as unsupervised component of comparator treatment).
Comparator	Exercise programme • 3 times weekly for 3 weeks (60 minutes per session). • Home exercise program for 8 weeks: daily isometric and isotonic muscle exercises.

Van de Graaf 2018

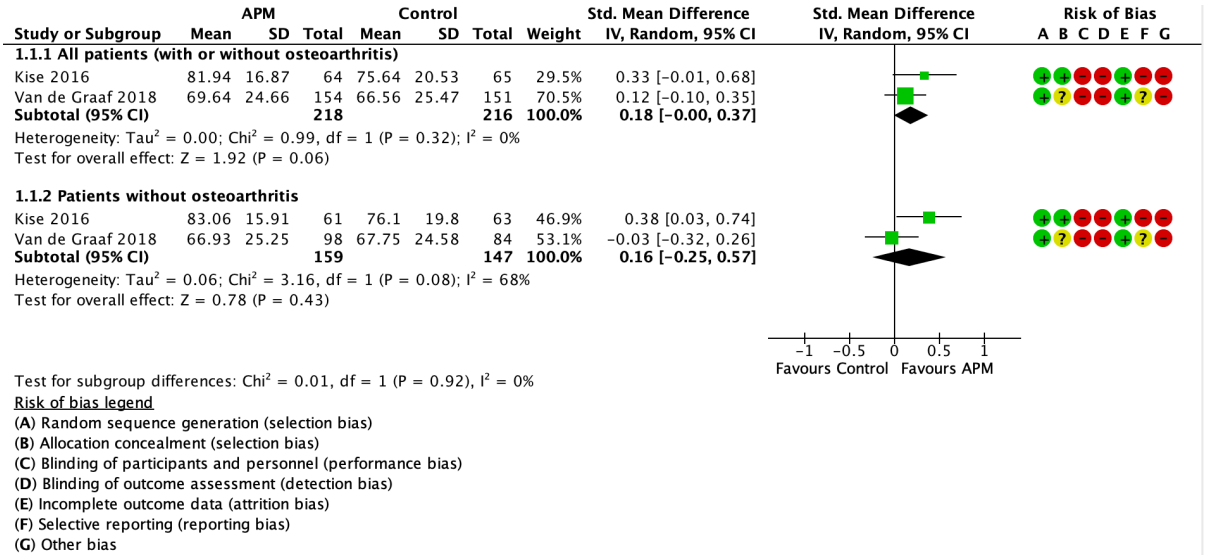
Location	Netherlands
Funding	Netherlands Organisation for Health Research and Development and the Foundation of Medical Research of OLVG, Amsterdam
Participants	<u>Inclusion</u> • Patients between 45 and 70 years of age at presentation. • A meniscal tear visualized on MRI. The meniscal tear can either be isolated or combined with a partial asymptomatic Anterior Cruciate Ligament (ACL) injury or an asymptomatic degenerative ACL shown on MRI with no abnormal clinical findings (a negative Lachman test and Pivot Shift). • Mental Competence. • Willingness to comply with follow up schedule. • Written informed consent. <u>Exclusion</u> • Knee locking or trauma leading to acute surgery. • One of the following associated injuries on the index knee: • A symptomatic partial ACL rupture or any total ACL rupture determined by clinical examination (positive Lachman test and/or positive Pivot Shift) and shown on MRI; • A complete Posterior Cruciate Ligament (PCL) injury; • Cartilage change down to bone; grade 4 of the Kellgren Lawrence Grading Scale for Osteoarthritis visualized on X-ray; • An injury to the lateral/posterolateral ligament complex with significantly increased laxity. • A history of knee surgery other than diagnostic arthroscopy on the index knee. • Tumors on MRI suspected for a malignancy. • Obese patients with Body Mass Index (BMI) > 35. • ASA 4-5 patients which can severely interfere with rehabilitation. • General disease that effects physical function or systemic medication/abuse of steroids (e.g., rheumatoid arthritis, psoriatic arthritis, systemic lupus erythematosus, gout, pseudogout) • Any other medical condition or treatment interfering with the completion or assessment of the trial, e.g. contraindications to MRI or surgery. • Drugs or alcohol abuse. • Patients unable to speak or read Dutch.
Intervention	<u>Arthroscopic partial meniscectomy</u> • Arthroscopic partial APM is performed within 4 weeks in day-care. No standard physical therapy is prescribed after surgery, as advised by the Dutch Orthopaedic Association Guidelines.
Comparator	<u>Exercise programme</u> • Conservative treatment consist of 16 sessions PT and a home exercise program. These programs are developed for our population, 45-70 years, with a focus on closed-chain strength exercises and cardiovascular exercises.

J - APM Review: Non-primary meta-analyses

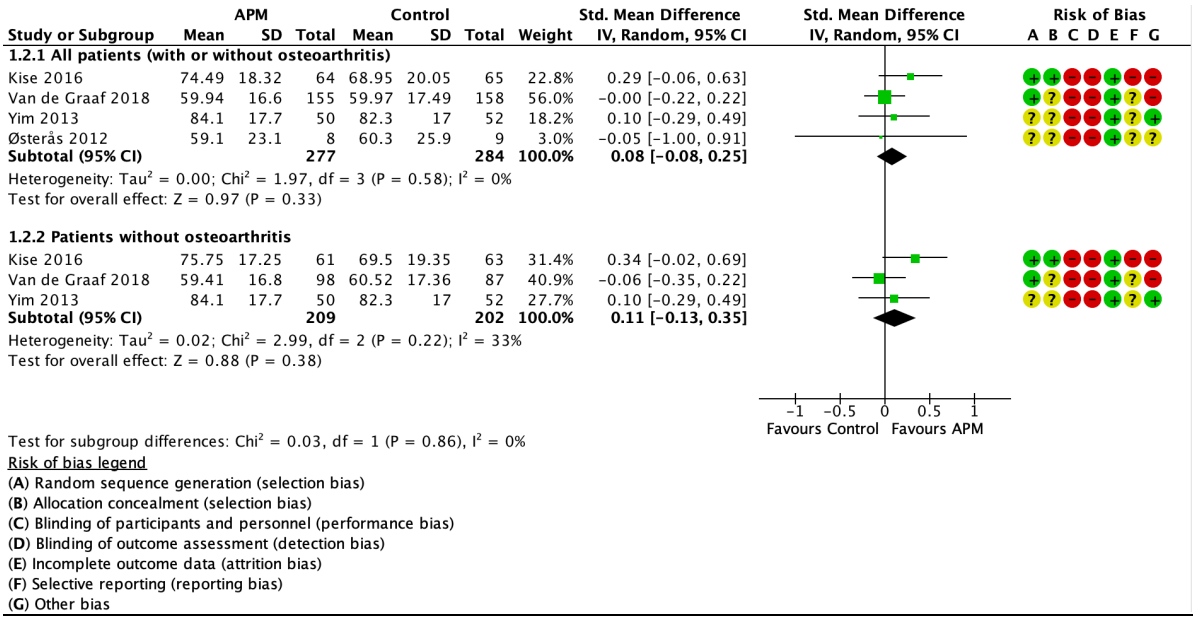
J.1 APM versus non-surgical comparators

J.1.1 Under 6 months

Pain

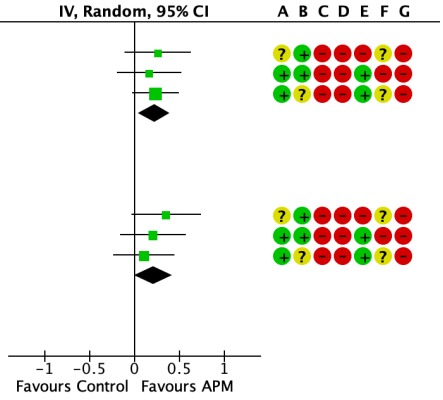


Function



J.1.2 Over 12 months

Pain

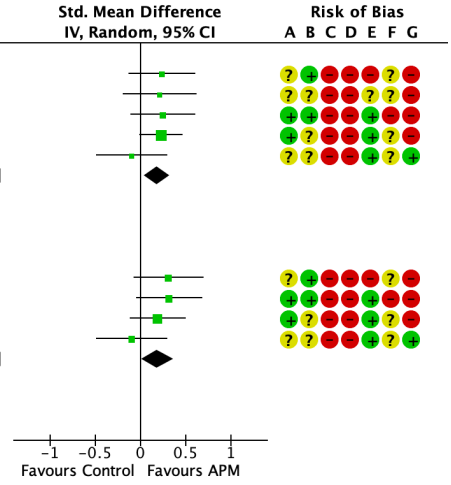


Test for subgroup differences: Chi² = 0.01, df = 1 (P = 0.94), I² = 0%

Risk of bias legend

(**A**) Random sequence generation (selection bias)
(**B**) Allocation concealment (selection bias)
(**C**) Blinding of participants and personnel (performance bias)
(**D**) Blinding of outcome assessment (detection bias)
(**E**) Incomplete outcome data (attrition bias)
(**F**) Selective reporting (reporting bias)
(**G**) Other bias

Function

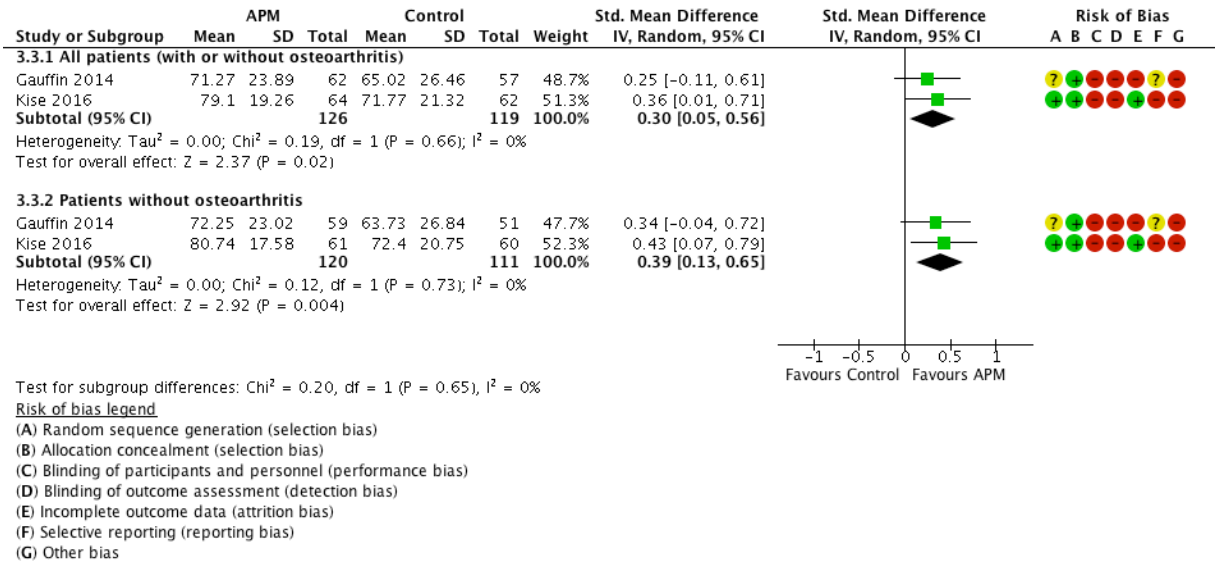


Test for subgroup differences: Chi² = 0.00, df = 1 (P = 0.98), I² = 0%

Risk of bias legend

(**A**) Random sequence generation (selection bias)
(**B**) Allocation concealment (selection bias)
(**C**) Blinding of participants and personnel (performance bias)
(**D**) Blinding of outcome assessment (detection bias)
(**E**) Incomplete outcome data (attrition bias)
(**F**) Selective reporting (reporting bias)
(**G**) Other bias

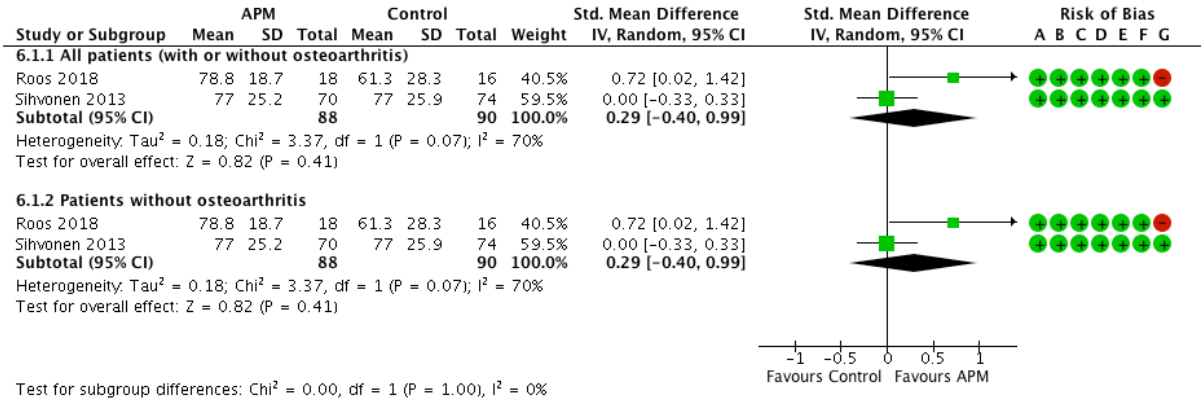
Knee-specific quality of life



J.2 APM versus surgical comparators

J.2.1 Over 12 months

Pain

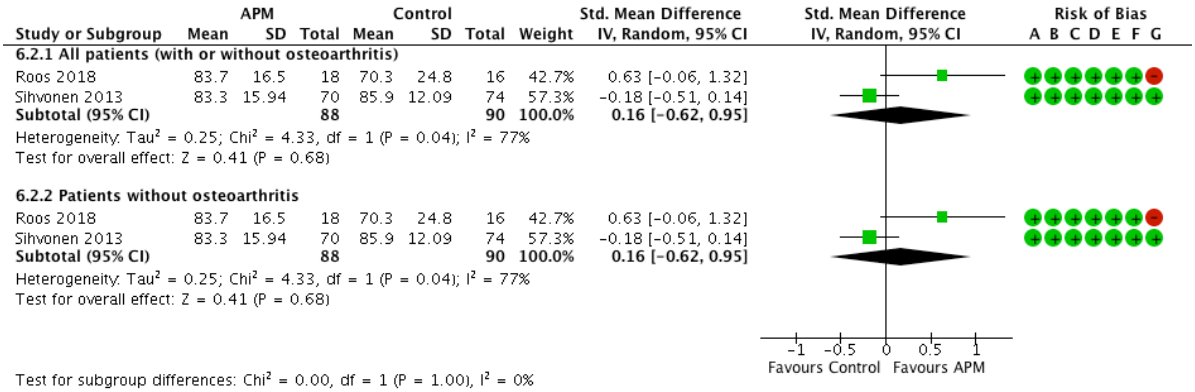


Test for subgroup differences: Chi² = 0.00, df = 1 (P = 1.00), I² = 0%

Risk of bias legend

(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

Function

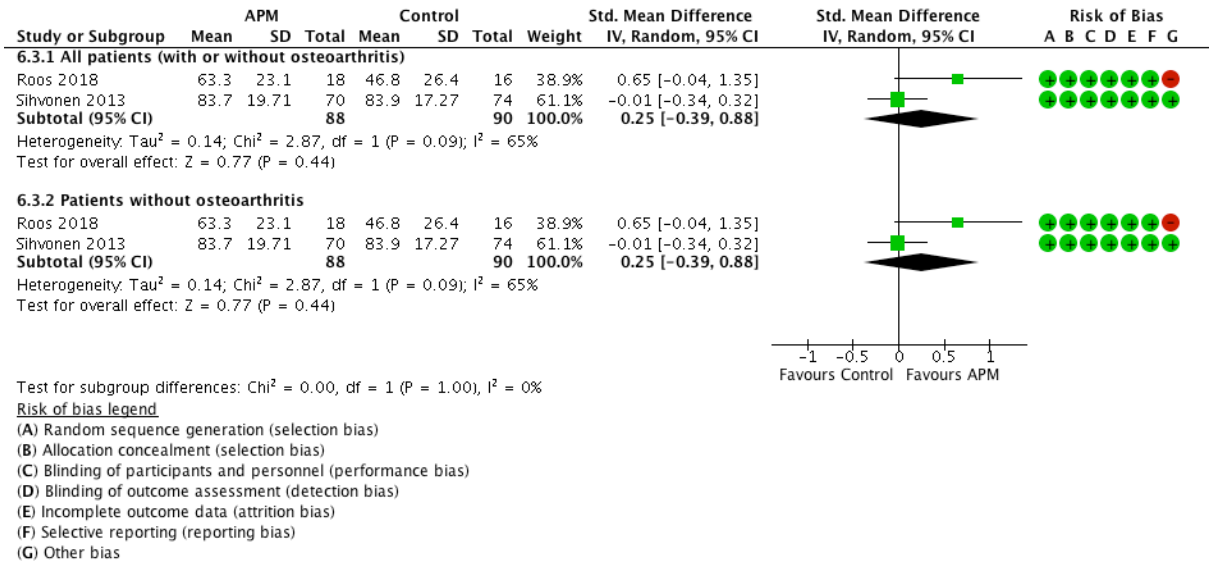


Test for subgroup differences: Chi² = 0.00, df = 1 (P = 1.00), I² = 0%

Risk of bias legend

(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

Knee-specific quality of life



Test for subgroup differences: Chi² = 0.00, df = 1 (P = 1.00), I² = 0%

Risk of bias legend

(**A**) Random sequence generation (selection bias)
(**B**) Allocation concealment (selection bias)
(**C**) Blinding of participants and personnel (performance bias)
(**D**) Blinding of outcome assessment (detection bias)
(**E**) Incomplete outcome data (attrition bias)
(**F**) Selective reporting (reporting bias)
(**G**) Other bias

K - ICD-10 Outcomes Code Table

Pulmonary embolism	
I822	Embolism and thrombosis of vena cava
I823	Embolism and thrombosis of renal vein
I260	Pulmonary embolism with mention of acute cor pulmonale
I269	Pulmonary embolism without mention of acute cor pulmonale
Acute myocardial infarction	
I210	Acute transmural myocardial infarction of anterior wall
I211	Acute transmural myocardial infarction of inferior wall
I212	Acute transmural myocardial infarction of other sites
I213	Acute transmural myocardial infarction of unspecified site
I214	Acute subendocardial myocardial infarction
I219	Acute myocardial infarction, unspecified
I220	Subsequent myocardial infarction of anterior wall
I221	Subsequent myocardial infarction of inferior wall
I228	Subsequent myocardial infarction of other sites
I229	Subsequent myocardial infarction of unspecified site
Lower respiratory tract infection	
J12	Viral pneumonia, not elsewhere classified
J13	Pneumonia due to Streptococcus pneumoniae
J14	Pneumonia due to Haemophilis influenzae
J15	Bacterial pneumonia, not elsewhere classified
J16	Pneumonia due to other infectious organisms, not elsewhere classified
J18	Pneumonia, organism unspecified
J20	Acute bronchitis
J22	Unspecified acute lower respiratory infection
J86	Pyothorax
J440	Chronic obstructive pulmonary disease with acute lower respiratory infection
J441	Chronic obstructive pulmonary disease with acute exacerbation, unspecified
J851	Abscess of lung with pneumonia
J852	Abscess of lung without pneumonia
J690	Aspiration pneumonia
Stroke	
I60	Subarachnoid haemorrhage
I61	Subarachnoid haemorrhage
I62	Subarachnoid haemorrhage
I63	Subarachnoid haemorrhage

I64	Stroke, not specified as haemorrhage or infarction
I610	Intracerebral haemorrhage in hemisphere, subcortical
I611	Intracerebral haemorrhage in hemisphere, cortical
I612	Intracerebral haemorrhage in hemisphere, unspecified
I613	Intracerebral haemorrhage in brain stem
I614	Intracerebral haemorrhage in cerebellum
I615	Intracerebral haemorrhage, intraventricular
I616	Intracerebral haemorrhage, multiple localized
I618	Other intracerebral haemorrhage
I619	Intracerebral haemorrhage, unspecified
I630	Cerebral infarction due to thrombosis of precerebral arteries
I631	Cerebral infarction due to embolism of precerebral arteries
I632	Cerebral infarction due to unspecified occlusion or stenosis of precerebral arteries
I633	Cerebral infarction due to thrombosis of cerebral arteries
I634	Cerebral infarction due to embolism of cerebral arteries
I635	Cerebral infarction due to unspecified occlusion or stenosis of cerebral arteries
I636	Cerebral infarction due to cerebral venous thrombosis, nonpyogenic
I638	Other cerebral infarction
I639	Cerebral infarction, unspecified
Acute kidney injury	
N170	Acute renal failure with tubular necrosis
N171	Acute renal failure with acute cortical necrosis
N172	Acute renal failure with medullary necrosis
N178	Other acute renal failure
N179	Acute renal failure, unspecified
Urinary tract infection	
N300	Acute cystitis
N308	Other cystitis
N309	Cystitis, unspecified
N390	Urinary tract infection, site not specified
Neurovascular injury	
T812	Accidental puncture and laceration during a procedure, not elsewhere classified (covers vessel/nerve/organ)
Septic arthritis	
M00	Pyogenic arthritis

L - Modified Charlson Comorbidity Index

HSCIC Summary Hospital-level Mortality Indicator (SHMI) Specification[248,249]

MYOCARDIAL INFARCTION (+5)	
I21	Acute myocardial infarction
I22	Subsequent myocardial infarction
I23	Certain current complications following acute myocardial infarction
I252	Old myocardial infarction
I258	Other forms of chronic ischaemic heart disease
CEREBROVASCULAR DISEASE (+11)	
G46	Vascular syndromes of brain in cerebrovascular diseases
I60	Subarachnoid haemorrhage
I61	Intracerebral haemorrhage
I62	Other nontraumatic intracranial haemorrhage
I63	Cerebral infarction
I64	Stroke, not specified as haemorrhage or infarction
I65	Occlusion and stenosis of precerebral arteries, not resulting in cerebral infarction
I66	Occlusion and stenosis of cerebral arteries, not resulting in cerebral infarction
I67	Other cerebrovascular diseases
I68	Cerebral arteritis in infectious and parasitic diseases classified elsewhere
I69	Sequelae of cerebrovascular disease
G450	Vertebro-basilar artery syndrome
G451	Carotid artery syndrome (hemispheric)
G452	Multiple and bilateral precerebral artery syndromes
G454	Transient global amnesia
G458	Other transient cerebral ischaemic attacks and related syndromes
G459	Transient cerebral ischaemic attack, unspecified
CONGESTIVE HEART FAILURE (+13)	
I50	Heart failure
CONNECTIVE TISSUE DISORDER (+4)	
M05	Seropositive rheumatoid arthritis
M32	Systemic lupus erythematosus
M34	Systemic sclerosis
M060	Other rheumatoid arthritis
M063	Rheumatoid nodule
M069	Rheumatoid arthritis, unspecified
M332	Dermatopolymyositis

M353	Polymyalgia rheumatica
DEMENTIA (+14)	
F00	Dementia in Alzheimer's disease
F01	Vascular dementia
F02	Dementia in other diseases classified elsewhere
F03	Unspecified dementia
F051	Delirium superimposed on dementia
DIABETES WITHOUT CHRONIC COMPLICATIONS (+3)	
E101	Insulin-dependent diabetes mellitus - With ketoacidosis
E105	Type 1 diabetes mellitus (With peripheral circulatory complications)
E106	Insulin-dependent diabetes mellitus with other spec comps
E108	Insulin-dependent diabetes mellitus with unspec comps
E109	Insulin-dependent diabetes mellitus without complications
E111	Non-insulin-dependent diabetes mellitus - With ketoacidosis
E115	Type 2 diabetes mellitus (With peripheral circulatory complications)
E116	Non-insulin-depend diabetes mellitus with other spec comp
E118	Non-insulin-dependent diabetes mellitus with unspec comps
E119	Non-insulin-dependent diabetes mellitus - Without complications
E131	Other specified diabetes mellitus - With ketoacidosis
E135	Other specified diabetes mellitus (With peripheral circulatory complications)
E136	Other specified diabetes mellitus with other spec comps
E138	Other specified diabetes mellitus with unspecified comps
E139	Other specified diabetes mellitus without complications
E141	Unspecified diabetes mellitus - With ketoacidosis
E145	Unspecified diabetes mellitus (With peripheral circulatory complications)
E146	Unspecified diabetes mellitus with other specified comps
E148	Unspecified diabetes mellitus with unspecified complications
E149	Unspecified diabetes mellitus - Without complications
LIVER DISEASE (+8)	
K73	Chronic hepatitis, not elsewhere classified
K74	Fibrosis and cirrhosis of liver
K702	Alcoholic fibrosis and sclerosis of liver
K703	Alcoholic cirrhosis of liver
K717	Toxic liver disease with fibrosis and cirrhosis of liver
PEPTIC ULCER DISEASE (+9)	
K25	Gastric ulcer
K26	Duodenal ulcer
K27	Peptic ulcer, site unspecified

K28	Gastrojejunal ulcer
PERIPHERAL VASCULAR DISEASE (+6)	
I71	Aortic aneurysm and dissection
R02	Gangrene, not elsewhere classified
I739	Peripheral vascular disease, unspecified
I790	Aneurysm of aorta in diseases classified elsewhere
Z958	Presence Of Other Cardiac And Vascular Implants And Grafts
Z959	Presence Of Cardiac And Vascular Implant And Graft
PULMONARY DISEASE (+4)	
J40	Bronchitis, not specified as acute or chronic
J41	Simple and mucopurulent chronic bronchitis
J42	Unspecified chronic bronchitis
J43	Emphysema
J44	Other chronic obstructive pulmonary disease
J45	Asthma
J46	Status asthmaticus
J47	Bronchiectasis
J60	Coalworker pneumoconiosis
J61	Pneumoconiosis due to asbestos and other mineral fibres
J62	Pneumoconiosis due to dust containing silica
J63	Pneumoconiosis due to other inorganic dusts
J64	Unspecified pneumoconiosis
J65	Pneumoconiosis associated with tuberculosis
J66	Airway disease due to specific organic dust
J67	Hypersensitivity pneumonitis due to organic dust
CANCER (+8)	
C00	Malignant neoplasm of lip
C01	Malignant neoplasm of base of tongue
C02	Malignant neoplasm of other and unspecified parts of tongue
C03	Malignant neoplasm of gum
C04	Malignant neoplasm of floor of mouth
C05	Malignant neoplasm of palate
C06	Malignant neoplasm of other and unspecified parts of mouth
C07	Malignant neoplasm of parotid gland
C08	Malignant neoplasm of other and unspecified major salivary glands
C09	Malignant neoplasm of tonsil
C10	Malignant neoplasm of oropharynx
C11	Malignant neoplasm of nasopharynx

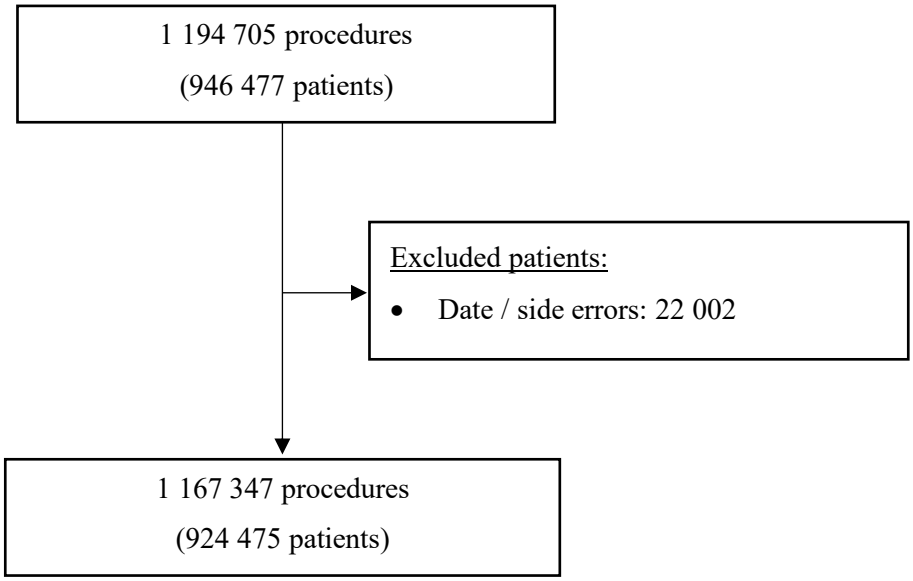
C12	Malignant neoplasm of piriform sinus
C13	Malignant neoplasm of hypopharynx
C14	Malignant neoplasm of other and ill-defined sites in the lip, oral cavity and pharynx
C15	Malignant neoplasm of oesophagus
C16	Malignant neoplasm of stomach
C17	Malignant neoplasm of small intestine
C18	Malignant neoplasm of colon
C19	Malignant neoplasm of rectosigmoid junction
C20	Malignant neoplasm of rectum
C21	Malignant neoplasm of anus and anal canal
C22	Malignant neoplasm of liver and intrahepatic bile ducts
C23	Malignant neoplasm of gallbladder
C24	Malignant neoplasm of other and unspecified parts of biliary tract
C25	Malignant neoplasm of pancreas
C26	Malignant neoplasm of other and ill-defined digestive organs
C30	Malignant neoplasm of nasal cavity and middle ear
C31	Malignant neoplasm of accessory sinuses
C32	Malignant neoplasm of larynx
C33	Malignant neoplasm of trachea
C34	Malignant neoplasm of bronchus and lung
C37	Malignant neoplasm of thymus
C38	Malignant neoplasm of heart, mediastinum and pleura
C39	Malignant neoplasm of other and ill-defined sites in the respiratory system and intrathoracic organs
C40	Malignant neoplasm of bone and articular cartilage of limbs
C41	Malignant neoplasm of bone and articular cartilage of other and unspecified sites
C43	Malignant melanoma of skin
C45	Mesothelioma
C46	Kaposi sarcoma
C47	Malignant neoplasm of peripheral nerves and autonomic nervous system
C48	Malignant neoplasm of retroperitoneum and peritoneum
C49	Malignant neoplasm of other connective and soft tissue
C50	Malignant neoplasm of breast
C51	Malignant neoplasm of vulva
C52	Malignant neoplasm of vagina
C53	Malignant neoplasm of cervix uteri
C54	Malignant neoplasm of corpus uteri
C55	Malignant neoplasm of uterus, part unspecified
C56	Malignant neoplasm of ovary

C57	Malignant neoplasm of other and unspecified female genital organs
C58	Malignant neoplasm of placenta
C60	Malignant neoplasm of penis
C61	Malignant neoplasm of prostate
C62	Malignant neoplasm of testis
C63	Malignant neoplasm of other and unspecified male genital organs
C64	Malignant neoplasm of kidney, except renal pelvis
C65	Malignant neoplasm of renal pelvis
C66	Malignant neoplasm of ureter
C67	Malignant neoplasm of bladder
C68	Malignant neoplasm of other and unspecified urinary organs
C69	Malignant neoplasm of eye and adnexa
C70	Malignant neoplasm of meninges
C71	Malignant neoplasm of brain
C72	Malignant neoplasm of spinal cord, cranial nerves and other parts of central nervous system
C73	Malignant neoplasm of thyroid gland
C74	Malignant neoplasm of adrenal gland
C75	Malignant neoplasm of other endocrine glands and related structures
C76	Malignant neoplasm of other and ill-defined sites
C81	Hodgkin's disease
C82	Follicular [nodular] non-Hodgkin's lymphoma
C83	Diffuse non-Hodgkin's lymphoma
C84	Peripheral and cutaneous T-cell lymphomas
C85	Other and unspecified types of non-Hodgkin's lymphoma
C86	Other specified types of T/NK-cell lymphoma
C88	Malignant immunoproliferative diseases
C90	Multiple myeloma and malignant plasma cell neoplasms
C91	Lymphoid leukaemia
C92	Myeloid leukaemia
C93	Monocytic leukaemia
C94	Other leukaemias of specified cell type
C95	Leukaemia of unspecified cell type
C96	Other and unspecified malignant neoplasms of lymphoid, haematopoietic and related tissue
C97	Malignant neoplasms of independent (primary) multiple sites
DIABETES WITH CHRONIC COMPLICATIONS (-1)	
E102	Insulin-dependent diabetes mellitus - With renal complications
E103	Insulin-dependent diabetes mellitus - With ophthalmic complications
E104	Insulin-dependent diabetes mellitus - With neurological complications

E107	Insulin-dependent diabetes mellitus - With multiple complications
E112	Non-insulin-dependent diabetes mellitus - With renal complications
E113	Non-insulin-dependent diabetes mellitus - With ophthalmic complications
E114	Non-insulin-dependent diabetes mellitus - With neurological complications
E117	Non-insulin-dependent diabetes mellitus - With multiple complications
E132	Other specified diabetes mellitus - With renal complications
E133	Other specified diabetes mellitus - With ophthalmic complications
E134	Other specified diabetes mellitus - With neurological complications
E137	Other specified diabetes mellitus - With multiple complications
E142	Unspecified diabetes mellitus - With renal complications
E143	Unspecified diabetes mellitus - With ophthalmic complications
E144	Unspecified diabetes mellitus - With neurological complications
E147	Unspecified diabetes mellitus - With multiple complications
PARAPLEGIA (+1)	
G81	Hemiplegia
G041	Tropical spastic paraplegia
G820	Paraplegia and tetraplegia
G821	Spastic paraplegia
G822	Paraplegia, unspecified
RENAL DISEASE (+10)	
I12	Hypertensive renal disease with renal failure
I13	Hypertensive heart and renal disease with renal failure
N01	Rapidly progressive nephritic syndrome
N03	Chronic nephritic syndrome
N18	Chronic kidney disease
N19	Unspecified kidney failure
N25	Disorders resulting from impaired renal tubular function
N052	Diffuse membranous glomerulonephritis
N053	Diffuse mesangial proliferative glomerulonephritis
N054	Diffuse endocapillary proliferative glomerulonephritis
N055	Diffuse mesangiocapillary glomerulonephritis
N056	Unspecified nephritic syndrome, dense deposit disease
N072	Hereditary nephropathy (Diffuse membranous glomerulonephritis)
N073	Hereditary nephropathy (Diffuse mesangial proliferative glomerulonephritis)
N074	Hereditary nephropathy (Diffuse endocapillary proliferative glomerulonephritis)
METASTATIC CANCER (+14)	
C77	Secondary and unspecified malignant neoplasm of lymph nodes
C78	Secondary malignant neoplasm of respiratory and digestive organs

C79	Secondary malignant neoplasm of other and unspecified sites
C80	Malignant neoplasm, without specification of site
SEVERE LIVER DISEASE (+18)	
K721	Chronic hepatic failure
K729	Hepatic failure, unspecified
K766	Portal hypertension
K767	Hepatorenal syndrome
HIV (+2)	
B20	Human immunodeficiency virus [HIV] disease resulting in infectious and parasitic diseases
B21	Human immunodeficiency virus [HIV] disease resulting in malignant neoplasms
B22	Human immunodeficiency virus [HIV] disease resulting in other specified diseases
B23	Human immunodeficiency virus [HIV] disease resulting in other conditions
B24	Unspecified human immunodeficiency virus [HIV] disease
O987	Human immunodeficiency virus [HIV] disease complicating pregnancy, childbirth and the puerperium

M - Arthroplasty Population Cohort Extraction



N - BASK Meniscal Working Group Members

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O - Appropriateness Voting Reference

"Appropriateness" of surgery

A procedure may be rated "appropriate" when the benefits (in comparison to alternatives) exceed the risks by a sufficient margin to make it worth doing.

Please rate on the scale from 1-9, the extent to which you believe arthroscopic meniscal surgery would benefit this specific patient's symptoms and quality of life, in excess of the potential benefits from alternative treatment options AND also outweigh the risks of the arthroscopic surgery and the impact from the necessary recovery period.

Patient History

Please consider the following anchor patient description for each case:

- The patient has been referred from primary care for assessment in your secondary care clinic.
- The onset of symptoms was 3 months previously (without specific injury).
- The patient is in "equipoise" – has no preference towards surgery or non-surgical treatment.

The following categories of findings have been used to construct the scenarios:

Predominant Symptoms/Signs

The classification for predominance of symptoms is proposed as follows (five categories). Please see the summary document for the extended definitions.

"Predominance" of Symptoms / Signs	
LOCKED *(trumps all other findings for predominance)*	• Locked knee
MENISCAL *(a patient with 'strongly suggestive' symptoms and signs. May also have some 'possibly suggestive' symptoms/signs but without arthritic symptoms/signs – see 'mixed' below)*	• Locking • Catching • Tender, palpable meniscal tissue
POSSIBLY MENISCAL	• Episodic sharp knee pain

(a patient with 'possibly suggestive' symptoms and signs only: without any 'strongly suggestive' or 'arthritic' symptoms/signs)	• Intermittent knee swelling • Knee effusion • Activity avoidance • Squatting pain • Clicking +/- pain • Meniscal provocation tests • Joint line point tenderness
ARTHRITIC *(a patient with arthritic symptoms and signs: may also have 'possibly suggestive' symptoms/signs)*	• Inactivity pain and stiffness • Crepitus • Bony enlargement • Bony tenderness • Aching pain
MIXED ARTHRITIC & MENISCAL	*A mix of arthritic and meniscal symptoms/signs without clear predominance.*

OA Severity

OA Severity	Definition
EARLY-NONE	**Early or No Structural OA** • Kellgren-Lawrence Grade 0 or 1 on plain radiographs. • and/or Normal MRI. • and/or MRI with possible chondral signal change but no chondral loss.
MILD-MODERATE	**Mild to Moderate Structural OA** • Kellgren-Lawrence Grade 2 or 3 on plain radiographs. • and/or Partial thickness chondral loss on MRI.
ADVANCED	**Advanced to End-stage Structural OA** • Kellgren-Lawrence Grade 4 on plain radiographs. • and/or Full thickness chondral loss on MRI.

Meniscal Findings on MRI

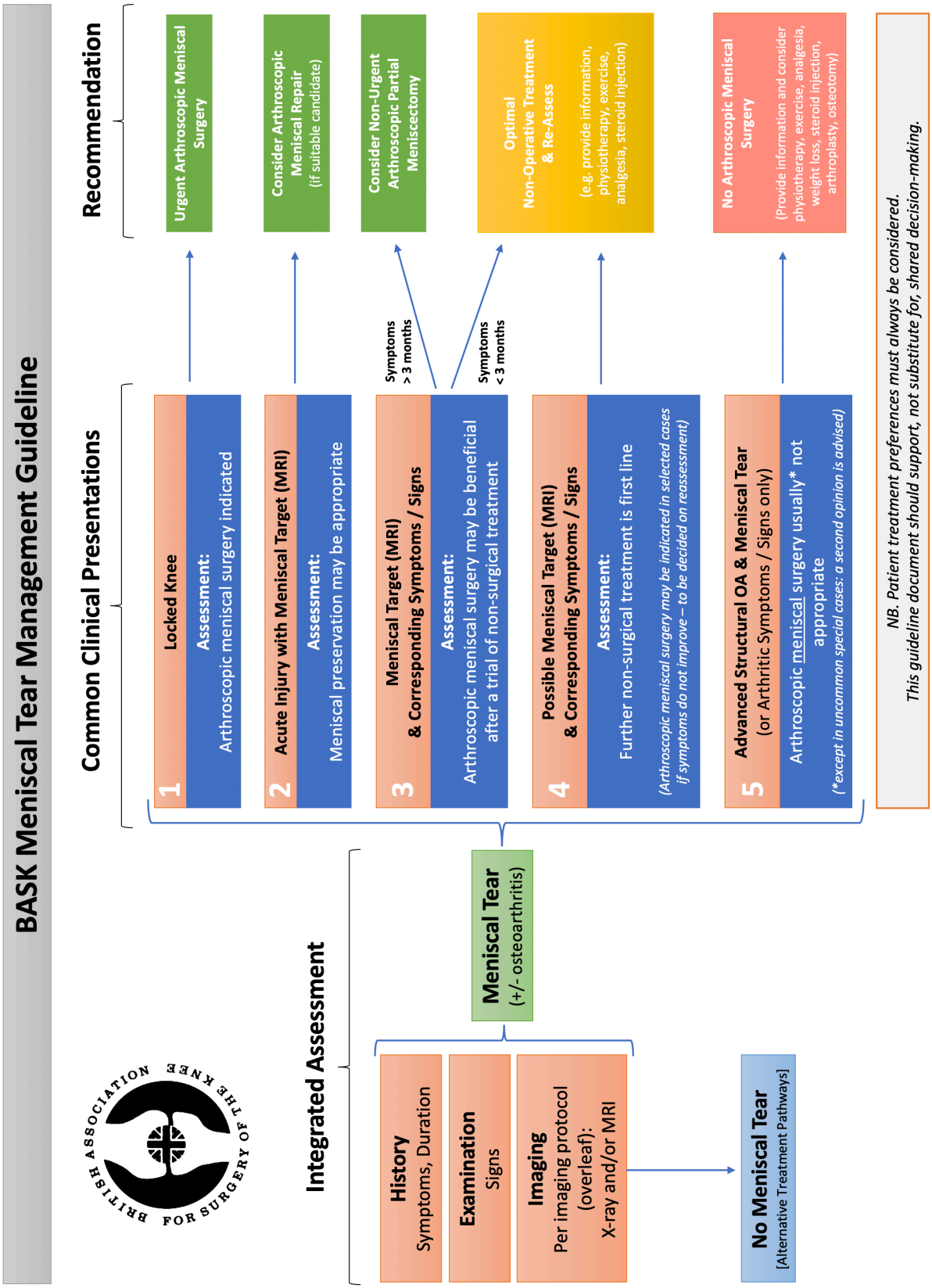
Lesion	Definitions
TARGET	• Bucket-handle tear (displaced or undisplaced) • Displaced meniscal tear • Meniscal root avulsion
POSSIBLE TARGET	• Undisplaced tears (radial, horizontal +/- cyst, complex, short longitudinal)
NO TARGET	• No tear

P - Appropriateness Voting Document

Predominant Symptoms/Signs (see guide)	**OA Severity** (see guide)	**Meniscal Findings on MRI** (see guide)	**Do you think meniscal surgery is appropriate in this patient?** *(To what extent do you believe arthroscopy would benefit symptoms and quality of life AND outweigh the risks of surgery / benefit of an alternative, more appropriate, treatment option - see guide)* **(1=inappropriate; 9= appropriate)**									**Overall, what is your treatment recommendation (today)?** 1. URGENT surgery 2. ROUTINE LISTING for surgery 3. DELAY, RE-ASSESS & List if no improvement 4. NO SCOPE (e.g. physio, knee replacement, etc.)			
LOCKED	EARLY-NONE	TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
LOCKED	EARLY-NONE	POSSIBLE TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
LOCKED	EARLY-NONE	NO TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
LOCKED	MILD-MODERATE	TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
LOCKED	MILD-MODERATE	POSSIBLE TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
LOCKED	MILD-MODERATE	NO TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
LOCKED	ADVANCED	TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
LOCKED	ADVANCED	POSSIBLE TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
LOCKED	ADVANCED	NO TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
MENISCAL +/- EQUIVOCAL	EARLY-NONE	TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
MENISCAL +/- EQUIVOCAL	EARLY-NONE	POSSIBLE TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
MENISCAL +/- EQUIVOCAL	EARLY-NONE	NO TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
MENISCAL +/- EQUIVOCAL	MILD-MODERATE	TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
MENISCAL +/- EQUIVOCAL	MILD-MODERATE	POSSIBLE TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
MENISCAL +/- EQUIVOCAL	MILD-MODERATE	NO TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
MENISCAL +/- EQUIVOCAL	ADVANCED	TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
MENISCAL +/- EQUIVOCAL	ADVANCED	POSSIBLE TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
MENISCAL +/- EQUIVOCAL	ADVANCED	NO TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
EQUIVOCAL	EARLY-NONE	TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
EQUIVOCAL	EARLY-NONE	POSSIBLE TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
EQUIVOCAL	EARLY-NONE	NO TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
EQUIVOCAL	MILD-MODERATE	TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE

EQUIVOCAL	MILD-MODERATE	POSSIBLE TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
EQUIVOCAL	MILD-MODERATE	NO TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
EQUIVOCAL	ADVANCED	TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
EQUIVOCAL	ADVANCED	POSSIBLE TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
EQUIVOCAL	ADVANCED	NO TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
ARTHRITIC + MENISCAL	EARLY-NONE	TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
ARTHRITIC + MENISCAL	EARLY-NONE	POSSIBLE TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
ARTHRITIC + MENISCAL	EARLY-NONE	NO TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
ARTHRITIC + MENISCAL	MILD-MODERATE	TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
ARTHRITIC + MENISCAL	MILD-MODERATE	POSSIBLE TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
ARTHRITIC + MENISCAL	MILD-MODERATE	NO TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
ARTHRITIC + MENISCAL	ADVANCED	TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
ARTHRITIC + MENISCAL	ADVANCED	POSSIBLE TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
ARTHRITIC + MENISCAL	ADVANCED	NO TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
ARTHRITIC +/- EQUIVOCAL	EARLY-NONE	TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
ARTHRITIC +/- EQUIVOCAL	EARLY-NONE	POSSIBLE TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
ARTHRITIC +/- EQUIVOCAL	EARLY-NONE	NO TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
ARTHRITIC +/- EQUIVOCAL	MILD-MODERATE	TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
ARTHRITIC +/- EQUIVOCAL	MILD-MODERATE	POSSIBLE TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
ARTHRITIC +/- EQUIVOCAL	MILD-MODERATE	NO TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
ARTHRITIC +/- EQUIVOCAL	ADVANCED	TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
ARTHRITIC +/- EQUIVOCAL	ADVANCED	POSSIBLE TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE
ARTHRITIC +/- EQUIVOCAL	ADVANCED	NO TARGET	1	2	3	4	5	6	7	8	9	URGENT	ROUTINE	RE-ASSESS	NO SCOPE

Q - BASK Meniscal Treatment Guideline



Definitions and terminology:

Degenerative meniscus and meniscal tears

- A degenerative meniscus develops progressively with degradation of meniscal tissue and this may be revealed by intra-meniscal high signal on MRI imaging.
- A meniscal 'tear' is a defect or split in the meniscocapsular complex, which can occur in a degenerative or non-degenerative meniscus.
- Degenerative meniscal lesions (high signal or tear) are frequent in the general population and are often incidental findings on knee MRI. There may or may not be a memorable history of knee injury.

Approach to imaging (secondary care imaging protocol)

1. Plain radiographs (weight-bearing AP and lateral +/- Rosenberg +/- skyline view) are the first line investigation when OA is suspected.
2. In patients where OA is not suspected, MRI is the first line investigation*.
3. If plain radiographs do not demonstrate advanced osteoarthritis (Kellgren-Lawrence-L 4) and meniscal symptoms predominate, then MRI imaging is indicated.

*In certain cases, when clinical findings are conclusive (e.g. locked knee), clinicians may apply their own judgement on the need for MRI imaging.

Classification of structural osteoarthritis (OA)

- **Early or No Structural OA:** Kellgren-Lawrence Grade 0 or 1 on plain radiographs and/or normal MRI, or MRI with possible chondral signal change and no chondral loss.
- **Mild to Moderate Structural OA:** Kellgren-Lawrence Grade 2 or 3 on plain radiographs and/or partial thickness chondral loss on MRI.
- **Advanced to End-stage Structural OA:** Kellgren-Lawrence Grade 4 on plain radiographs and/or significant areas of full thickness chondral loss on MRI*.

*Excluding cases of contained full thickness cartilage / osteochondral defects.

Classification of meniscal lesions

TARGET (Treatable Lesion: meniscal surgery may be indicated based on appearance)

- **"Bucket-handle" tear:** a longitudinal tear or peripheral separation involving MORE than 25% of meniscus length (either displaced or undisplaced).
- **Displaced meniscal tear:** a meniscal lesion with meniscal fragments displaced from their usual anatomical position.
- **Meniscal root failure:** a complete tear or avulsion of the meniscal root.

POSSIBLE TARGET (Indeterminate Lesion: meniscal surgery may be indicated based on appearance)

- **Undisplaced meniscal tears:**
  - Radial tear:
    - Radial flap tear: a vertical and oblique meniscal tear lesion (parrot beak type).
    - Complete radial split tear: a radial meniscal tear lesion that extends to the meniscocapsular junction.
    - Partial radial split tear: a radial tear that does not extend to meniscocapsular junction.
  - Horizontal tear +/- cyst:
    - Horizontal cleavage tear and meniscal cyst: a horizontal meniscal cleavage lesion that is associated with a meniscal cyst.
    - Horizontal cleavage tear in isolation: meniscal horizontal cleavage lesion without an associated cyst.
  - Complex meniscal lesion: a meniscal lesion with more than 1 plane of tear in continuity.
  - Short longitudinal tear: a longitudinal meniscal tear lesion involving LESS than 25% of the overall meniscus length.

NO TARGET (Unlikely Treatable: meniscal surgery not indicated based on appearance)

- **Contour abnormality:** a meniscus with an abnormal edge contour and very minor tear only.
- **Isolated meniscal extrusion:** extension of the meniscus beyond the tibial margins without any associated meniscal tear.
- **No tear.**

Classification of symptoms and signs

MENISCAL: Strongly Suggestive of a Treatable Meniscal Lesion

- **Locked knee:** sudden onset, complete mechanical block to flexion or extension of the knee, detected on clinical examination and which does not resolve despite adequate analgesia.
- **Locking:** An intermittent block to normal range of movement of the knee (commonly a block to extension) with an associated unlocking movement. Knee returns to near normal after unlocking.
- **Catching:** the sensation of something intermittently out of place in the knee and interfering with joint movement.
- **Tender, palpable meniscal tissue:** the finding on clinical examination of a discrete, tender lump, close to the joint line.

POSSIBLY MENISCAL: Potentially Suggestive of a Treatable Meniscal Lesion

- **Episodic sharp knee pain:** sharp, intermittent knee pain, occurring with sudden onset.
- **Intermittent knee swelling:** symptom of periodic swelling of the knee, lasting for hours to days, that has occurred over a period of weeks or months.
- **Knee effusion:** a clinically detectable intra-articular fluid collection of the knee joint.
- **Activity avoidance:** the active avoidance of specific, potentially provoking, movements or activity e.g. twisting.
- **Squatting pain:** knee pain that is exacerbated by deep flexion when weight bearing (may be reported by the patient or elicited during clinical examination).
- **Clicking +/- pain:** Clicking: a clicking noise or sensation when moving the knee. Painful clicking: a clicking noise or sensation when moving the knee that is associated with pain.
- **Meniscal provocation tests:** e.g. McMurray's, Apley's, Thessaly.
- **Joint line point tenderness:** point tenderness on the joint line, detected on clinical examination.
- **Posteromedial joint line tenderness:** tenderness on deep palpation of the joint line, from mid medial collateral ligament posteriorly, corresponding to the location of the commonest posteromedial degenerative meniscal lesion.

ARTHRITIC: Osteoarthritic Symptoms and Signs

- **Inactivity pain and stiffness:** the temporary, subjective sensation of stiffness on initiation of movement, often with pain, after periods of immobility (e.g. sleeping, prolonged sitting).
- **Crepitus:** crunching, grating or creaking detected clinically on active movement of the knee.
- **Bony enlargement:** abnormal shape of the normal knee bony contour visible on inspection or detected on clinical examination.
- **Bony tenderness:** tenderness on clinical palpation of the bone adjacent to the joint.
- **Aching pain:** constant knee pain during and after activity.

Clinical Case Examples:

	Recommendation
Case 1 **Onset:** 1 week ago, twisting injury **Symptoms/Signs:** Locked Knee **Imaging:** Bucket handle meniscal tear	**Urgent Arthroscopic Meniscal Surgery**
Case 2 **Onset:** 6 months ago, no injury **Symptoms/Signs:** Arthritic only **Imaging:** Advanced structure OA +/- Meniscal tear	**No Arthroscopic Meniscal Surgery**
Case 3 **Onset:** 1 week ago, twisting injury **Symptoms/Signs:** Meniscal **Imaging:** Longitudinal tear in repairable zone of meniscus.	**Consider Arthroscopic Meniscal Repair** (if suitable candidate)
Case 4 **Onset:** 1 month ago **Symptoms/Signs:** Meniscal **Imaging:** Displaced parrot beak tear. Moderate OA.	**Optimal Non-Operative Treatment & Re-Assess**
Case 5 **Onset:** 4 months ago **Symptoms/Signs:** Meniscal **Imaging:** Displaced parrot beak tear. Moderate OA.	**Consider Non-Urgent Arthroscopic Partial Meniscectomy**
Case 6 **Onset:** 6 months ago **Symptoms/Signs:** Possibly meniscal **Imaging:** Complex posterior horn tear.	**Optimal Non-Operative Treatment & Re-Assess**

REFERENCES

1 Iwaki H, Pinskerova V, Freeman MAR. Tibiofemoral movement 1: the shapes and relative movements of the femur and tibia in the unloaded cadaver knee. *J Bone Jt Surg* 2000; **82**: 1189–95.

2 Hill PF, Vedi V, Williams A, Iwaki H, Pinskerova V, Freeman MAR. Tibiofemoral movement 2: the loaded and unloaded living knee studied by MRI. *J Bone Jt Surg* 2000; **82**: 1196–8.

3 Makris EA, Hadidi P, Athanasiou KA. The knee meniscus: Structure–function, pathophysiology, current repair techniques, and prospects for regeneration. *Biomaterials* 2011; **32**: 7411–31.

4 Lankester BJA, Cottam HL, Pinskerova V, Eldridge JDJ, Freeman MAR. Variation in the anatomy of the tibial plateau. *J Bone Joint Surg Br* 2008; **90-B**: 330–3.

5 Tyler P, Datir A, Saifuddin A. Magnetic resonance imaging of anatomical variations in the knee : Part 2: Miscellaneous. *Skeletal Radiol* 2010; **39**: 1175–86.

6 Yue B, Varadarajan KM, Ai S, Tang T, Rubash HE, Li G. Differences of Knee Anthropometry Between Chinese and White Men and Women. *J Arthroplasty* 2011; **26**: 124–30.

7 Smith PN, Refshauge KM, Scarvell JM. Development of the Concepts of Knee Kinematics. *Arch Phys Med Rehabil* 2003; **84**: 1895–902.

8 Glyn-Jones S, Palmer AJRR, Agricola R, *et al.* Osteoarthritis. *Lancet* 2015; **386**: 376–87.

9 Deveza LA, Melo L, Yamato TP, Mills K, Ravi V, Hunter DJ. Knee osteoarthritis phenotypes and their relevance for outcomes: a systematic review. *Osteoarthr Cartil* 2017; **25**: 1926–41.

10 Zhang W, Likhodii S, Zhang Y, *et al.* Classification of osteoarthritis phenotypes by metabolomics analysis. *BMJ Open* 2014; **4**: 1–7.

11 Altman R, Asch E, Bloch D, *et al.* Development of criteria for the classification and reporting of osteoarthritis: Classification of osteoarthritis of the knee. *Arthritis Rheum* 1986; **29**: 1039–49.

12 Kellgren JH, Lawrence JS. Radiological Assessment of Osteo-Arthrosis. *Ann Rheum Dis* 1957; **16**: 494–502.

13 Kohn MD, Sassoon AA, Fernando ND. Classifications in Brief: Kellgren-Lawrence Classification of Osteoarthritis. *Clin Orthop Relat Res* 2016; **474**: 1886–93.

14 Wright RW, Ross JR, Haas AK, *et al.* Osteoarthritis Classification Scales: Interobserver Reliability and Arthroscopic Correlation. *J Bone Jt Surgery-American Vol* 2014; **96**: 1145–51.

15 Mehta VM, Paxton LW, Fornalski SX, Csintalan RP, Fithian DC. Reliability of the international knee documentation committee radiographic grading system. *Am J Sports Med* 2007; **35**: 933–5.

16 Altman RD, Gold GE. Atlas of individual radiographic features in osteoarthritis, revised. *Osteoarthr Cartil* 2007; **15 Suppl A**: A1-56.

17 Guermazi A, Niu J, Hayashi D, *et al.* Prevalence of abnormalities in knees detected by MRI in adults without knee osteoarthritis: Population based observational study (Framingham Osteoarthritis Study). *BMJ* 2012; **345**: 1–13.

18 Peterfy C., Guermazi A, Zaim S, *et al.* Whole-Organ Magnetic Resonance Imaging Score (WORMS) of the knee in osteoarthritis. *Osteoarthr Cartil* 2004; **12**: 177–90.

19 Hunter DJ, Lo GH, Gale D, Grainger AJ, Guermazi A, Conaghan PG. The reliability of a new scoring system for knee osteoarthritis MRI and the validity of bone marrow lesion assessment: BLOKS (Boston–Leeds Osteoarthritis Knee Score). *Ann Rheum Dis* 2008; **67**: 206–11.

20 Hunter DJ, Guermazi A, Lo GH, *et al.* Evolution of semi-quantitative whole joint assessment of knee OA: MOAKS (MRI Osteoarthritis Knee Score). *Osteoarthr Cartil* 2011; **19**: 990–1002.

21 Kornaat PR, Ceulemans RYT, Kroon HM, *et al.* MRI assessment of knee osteoarthritis: Knee Osteoarthritis Scoring System (KOSS) - Inter-observer and intra-observer reproducibility of a compartment-based scoring system. *Skeletal Radiol* 2005; **34**: 95–102.

22 Dwyer T, Martin CR, Kendra R, *et al.* Reliability and Validity of the Arthroscopic International Cartilage Repair Society Classification System: Correlation With Histological Assessment of Depth. *Arthrosc - J Arthrosc Relat Surg* 2017; **33**: 1219–24.

23 Outerbridge RE. Further Studies on the Etiology of Chondromalacia Patellae. *J Bone Joint Surg Br* 1964; **46**: 179–90.

24 Mithoefer K, Saris DBF, Farr J, *et al.* Guidelines for the Design and Conduct of Clinical Studies

in Knee Articular Cartilage Repair. *Cartilage* 2011; **2**: 100–21.

25 meniscus, n. : Oxford English Dictionary. http://www.oed.com/view/Entry/116455 (accessed Sept 12, 2018).

26 Béclard PA, Knox R. Elements of General Anatomy: Translated from the last edition of the French of P.A. Béclard. Maclachlan & Stewart, 1830 https://books.google.co.uk/books?id=AwJeAAAAcAAJ.

27 Gardner E, O'Rahilly R. The early development of the knee joint in staged human embryos. *J Anat* 1968; **102**: 289–99.

28 Clark CR, Ogden JA. Development of the menisci of the human knee joint. Morphological changes and their potential role in childhood meniscal injury. *J Bone Joint Surg Am* 1983; **65**: 538–47.

29 Arnoczky SP, Warren RF. Microvasculature of the human meniscus. *Am J Sport Med* 1982; **10**: 90–5.

30 Ahmed AM, Burke DL. In-vitro measurement of static pressure distribution in synovial joints - Part I: Tibial surface of the knee. *J Biomech Eng* 1983; **105**: 216–25.

31 Kohn D, Moreno B. Meniscus insertion anatomy as a basis for meniscus replacement: A morphological cadaveric study. *Arthrosc J Arthrosc Relat Surg* 1995; **11**: 96–103.

32 Fox AJS, Wanivenhaus F, Burge AJ, Warren RF, Rodeo SA. The human meniscus: A review of anatomy, function, injury, and advances in treatment. *Clin Anat* 2015; **28**: 269–87.

33 Standring S, editor. Gray's Anatomy: The Anatomical Basis of Clinical Practice, 40th edn. Elsevier, 2008.

34 Bintoudi a, Natsis K, Tsitouridis I. Anterior and posterior meniscofemoral ligaments: MRI evaluation. *Anat Res Int* 2012; **2012**: 839724.

35 Johannsen AM, Civitarese DM, Padalecki JR, Goldsmith MT, Wijdicks CA, LaPrade RF. Qualitative and Quantitative Anatomic Analysis of the Posterior Root Attachments of the Medial and Lateral Menisci. *Am J Sports Med* 2012; **40**: 2342–7.

36 Petersen W, Tillmann B. Collagenous fibril texture of the human knee joint menisci. *Anat Embryol (Berl)* 1998; **197**: 317–24.

37 Herwig J, Egner E, Buddecke E. Chemical changes of human knee joint menisci in various stages of degeneration. *Ann Rheum Dis* 1984; **43**: 635–40.

38 Ghosh P, Taylor TK. The knee joint meniscus. A fibrocartilage of some distinction. *Clin Orthop Relat Res* 1987; : 52–63.

39 Ghadially FN, Lalonde JM, Wedge JH. Ultrastructure of normal and torn menisci of the human knee joint. *J Anat* 1983; **136**: 773–91.

40 Arnoczky SP, Warren RF, Spivak JM. Meniscal repair using an exogenous fibrin clot. An experimental study in dogs. *J Bone Joint Surg Am* 1988; **70**: 1209–17.

41 McDevitt CA, Webber RJ. The ultrastructure and biochemistry of meniscal cartilage. *Clin Orthop Relat Res* 1990; **30**: 8–18.

42 Ingman AM, Ghosh P, Taylor TKF. Variation of Collagenous and Non-Collagenous Proteins of Human Knee Joint Menisci with Age and Degeneration. *Gerontology* 1974; **20**: 212–23.

43 Day B, Mackenzie WG, Shim SS, Leung G. The vascular and nerve supply of the human meniscus. *Arthrosc J Arthrosc Relat Surg* 1985; **1**: 58–62.

44 Danzig L, Resnick D, Gonsalves M, Akeson WH. Blood supply to the normal and abnormal menisci of the human knee. *Clin Orthop Relat Res* 1983; : 271–6.

45 Kennedy JC, Alexander IJ, Hayes KC. Nerve supply of the human knee and its functional importance. *Am J Sports Med* 1982; **10**: 329–35.

46 Zimny ML, Albright DJ, Dabezies E. Mechanoreceptors in the Human Medial Meniscus. *Cells Tissues Organs* 1988; **133**: 35–40.

47 Gardner E. The innervation of the knee joint. *Anat Rec* 1948; **101**: 109–30.

48 Aspden RM. A Model for the Function and Failure of the Meniscus. *Eng Med* 1985; **14**: 119–22.

49 Spencer Jones R, Keene GCR, Learmonth DJA, *et al.* Direct measurement of hoop strains in the intact and torn human medial meniscus. *Clin Biomech* 1996; **11**: 295–300.

50 Costa CR, Morrison WB, Carrino JA. Medial meniscus extrusion on knee MRI: Is extent associated with severity of degeneration or type of tear? *Am J Roentgenol* 2004; **183**: 17–23.

51 Lerer DB, Umans HR, Hu MX, Jones MH. The role of meniscal root pathology and radial

meniscal tear in medial meniscal extrusion. *Skeletal Radiol* 2004; **33**: 569–74.

52 Baratz ME, Fu FH, Mengato R. Meniscal tears: the effect of meniscectomy and of repair on intraarticular contact areas and stress in the human knee. A preliminary report. *Am J Sports Med* 1986; **14**: 270–5.

53 Koh JL, Yi SJ, Ren Y, Zimmerman TA, Zhang L. Tibiofemoral Contact Mechanics with Horizontal Cleavage Tear and Resection of the Medial Meniscus in the Human Knee. *J Bone Jt Surg* 2016; **98**: 1829–36.

54 Levy IM, Torzilli PA, Warren RF. The effect of medial meniscectomy on anterior-posterior motion of the knee. *J Bone Joint Surg Am* 1982; **64**: 883–8.

55 Levy IM, Torzilli PA, Gould JD, Warren RF. The effect of lateral meniscectomy on motion of the knee. *J Bone Joint Surg Am* 1989; **71**: 401–6.

56 Bird MD, Sweet MB. A system of canals in semilunar menisci. *Ann Rheum Dis* 1987; **46**: 670–3.

57 Nakagawa S, Kadoya Y, Todo S, *et al.* Tibiofemoral movement 3: full flexion in the living knee studied by MRI. *J Bone Joint Surg Br* 2000; **82**: 1199–200.

58 Komistek RD, Dennis DA, Mahfouz M. In vivo fluoroscopic analysis of the normal human knee. *Clin Orthop Relat Res* 2003; : 69–81.

59 Hallén LG, Lindahl O. The “Screw-Home” Movement in the Knee-Joint. *Acta Orthop Scand* 1966; **37**: 97–106.

60 Thompson WO, Thaete FL, Fu FH, Dye SF. Tibial meniscal dynamics using three-dimensional reconstruction of magnetic resonance images. *Am J Sports Med* 1991; **19**: 210–5; discussion 215-216.

61 Brantigan OC, Voshell AF. THE MECHANICS OF THE LIGAMENTS AND MENISCI OF THE KNEE JOINT. *J Bone Jt Surg - Am Vol* 1941; **23**: 44–66.

62 European Pathway Association | CARE PATHWAYS. http://e-p-a.org/care-pathways/ (accessed April 29, 2019).

63 Chan SW, Tulloch E, Cooper ES, Smith A, Wojcik W, Norman JE. Montgomery and informed consent: where are we now? *BMJ* 2017; **2224**: j2224.

64 Chassin MR. Explaining geographic variations. The enthusiasm hypothesis. *Med Care* 1993; **31**: YS37-44.

65 Dunn WR, Schackman BR, Walsh C, *et al.* Variation in orthopaedic surgeons' perceptions about the indications for rotator cuff surgery. *J Bone Joint Surg Am* 2005; **87**: 1978–84.

66 Mcculloch P, Nagendran M, Campbell WB, *et al.* Variation in Surgery 2 Strategies to reduce variation in the use of surgery. *Lancet* 2013; **382**: 1130–9.

67 Birkmeyer JD, Reames BN, McCulloch P, Carr AJ, Campbell WB, Wennberg JE. Understanding of regional variation in the use of surgery. *Lancet* 2013; **382**: 1121–9.

68 Public Health England. Atlas of Variation. https://fingertips.phe.org.uk/profile/atlas-of-variation (accessed April 29, 2019).

69 The National Hip Fracture Database. NHFD 2018 Annual Report. https://www.nhfd.co.uk/docs/reports2018 (accessed April 29, 2019).

70 Hawker GA, Wright JG, Coyte PC, *et al.* Differences between Men and Women in the Rate of Use of Hip and Knee Arthroplasty. *N Engl J Med* 2000; **342**: 1016–22.

71 Adamson J, Ben-Shlomo Y, Chaturvedi N, Donovan J. Ethnicity, socio-economic position and gender - Do they affect reported health-care seeking behaviour? *Soc Sci Med* 2003; **57**: 895–904.

72 Chaturvedi N, Rai H, Ben-Shlomo Y. Lay diagnosis and health-care-seeking behaviour for chest pain in south Asians and Europeans. *Lancet* 1997; **350**: 1578–83.

73 FitzGerald C, Hurst S. Implicit bias in healthcare professionals: a systematic review. *BMC Med Ethics* 2017; **18**: 19.

74 Bayliss LE, Culliford D, Monk AP, *et al.* The effect of patient age at intervention on risk of implant revision after total replacement of the hip or knee: a population-based cohort study. *Lancet* 2017; **389**: 1424–30.

75 van de Graaf VA, Scholtes VAB, Wolterbeek N, *et al.* Cost-effectiveness of Early Surgery versus Conservative Treatment with Optional Delayed Meniscectomy for Patients over 45 years with non-obstructive meniscal tears (ESCAPE study): protocol of a randomised controlled trial. *BMJ Open* 2016; **6**: e014381.

76 Brazier JE, Harper R, Munro J, Walters SJ, Snaith ML. Generic and condition-specific outcome measures for people with osteoarthritis of the knee. *Rheumatology* 1999; **38**: 870–7.

77 Guyatt GH, Bombardier C, Tugwell PX. Measuring disease-specific quality of life in clinical trials. *CMAJ* 1986; **134**: 889–95.

78 Mokkink LB, Terwee CB, Stratford PW, *et al.* Evaluation of the methodological quality of systematic reviews of health status measurement instruments. *Qual Life Res* 2009; **18**: 313–33.

79 Williamson PR, Altman DG, Blazeby JM, *et al.* Developing core outcome sets for clinical trials: issues to consider. *Trials* 2012; **13**: 132.

80 Hersh WR. Medical Informatics. *JAMA* 2002; **288**: 1955.

81 Cimino JJ. Desiderata for controlled medical vocabularies in the twenty-first century. *Methods Inf Med* 1998; **37**: 394–403.

82 National Joint Registry 14th Annual report. http://www.njrcentre.org.uk/njrcentre/Reports-Publications-and-Minutes/Annual-reports (accessed April 4, 2019).

83 What we do | About | NICE. https://www.nice.org.uk/about/what-we-do (accessed April 30, 2019).

84 Lomas J, Anderson GM, Domnick-Pierre K, Vayda E, Enkin MW, Hannah WJ. Do Practice Guidelines Guide Practice? *N Engl J Med* 1989; **321**: 1306–11.

85 Shiffman RN, Liaw Y, Brandt CA, Corb GJ. Computer-based Guideline Implementation Systems: A Systematic Review of Functionality and Effectiveness. *J Am Med Informatics Assoc* 1999; **6**: 104–14.

86 Greco PJ, Eisenberg JM. Changing Physicians' Practices. *N Engl J Med* 1993; **329**: 1271–4.

87 Murphy MK, Black NA, Lamping DL, *et al.* Consensus development methods, and their use in clinical guideline development. *Health Technol Assess* 1998; **2**: i–iv, 1–88.

88 Jones J, Hunter D. Consensus methods for medical and health services research. *BMJ* 1995; **311**: 376–80.

89 Hsu C, Sandford B. The delphi technique: making sense of consensus. *Pract Assessment, Res Eval* 2007; **12**: 1–8.

90 Linstone HA, Turoff M. The Delphi Method: Techniques and Applications. Addison-Wesley

Pub. Co., Advanced Book Program, 1975.

91 Delbecq AL, Van de Ven AH. A Group Process Model for Problem Identification and Program Planning. *J Appl Behav Sci* 1971; **7**: 466–92.

92 Griffin EA. Groupthink. A First Look at Communication Theory. New York: McGrawHill, 2012.

93 Asch, S. E., & Guetzkow H. Effects of group pressure upon the modification and distortion of judgments. *Groups, leadership, men* 1951; : 222–36.

94 Hawker G, Bohm ER, Conner-Spady B, *et al.* Perspectives of Canadian stakeholders on criteria for appropriateness for total joint arthroplasty in patients with hip and knee osteoarthritis. *Arthritis Rheumatol* 2015; **67**: 1806–15.

95 Riddle DL, Jiranek WA, Hayes CW. Use of a validated algorithm to judge the appropriateness of total knee arthroplasty in the United States: A multicenter longitudinal cohort study. *Arthritis Rheumatol* 2014; **66**: 2134–43.

96 Brook RH. Assessing the Appropriateness of Care—Its Time Has Come. *JAMA* 2009; **302**: 997.

97 Brownlee S, Chalkidou K, Doust J, *et al.* Evidence for overuse of medical services around the world. *Lancet* 2017; **390**: 156–68.

98 Lawson EH, Gibbons MM, Ko CY, Shekelle PG. The appropriateness method has acceptable reliability and validity for assessing overuse and underuse of surgical procedures. *J Clin Epidemiol* 2012; **65**: 1133–43.

99 Fitch K, Bernstein SJJ, Aguilar MDD, *et al.* The RAND / UCLA Appropriateness Method User's Manual. 2001 http://www.rand.org.

100 Dalkey N, Helmer O. An Experimental Application of the Delphi Method to the Use of Experts. Manage. Sci. 1963; **9**: 458–67.

101 Nilsen ES, Myrhaug HT, Johansen M, Oliver S, Oxman AD. Methods of consumer involvement in developing healthcare policy and research, clinical practice guidelines and patient information material. *Cochrane Database Syst Rev* 2006; : 1–34.

102 Greis PE, Bardana DD, Holmstrom MC, Burks RT. Meniscal injury: I. Basic science and evaluation. *J Am Acad Orthop Surg* 2002; **10**: 168–76.

103 Laprade RF, Quinter BM, Veenstra MA, Hodgman CG. The Prevalence of Abnormal Magnetic Resonance Imaging Findings in Asymptomatic Knees. *Am J Sports Med* 1994; **22**: 739–45.

104 Englund M, Guermazi A, Gale D, *et al.* Incidental meniscal findings on knee MRI in middle-aged and elderly persons. *N Engl J Med* 2008; **359**: 1108–15.

105 Bhattacharyya T, Gale D, Dewire P, *et al.* The Clinical Importance of Meniscal Tears Demonstrated by Magnetic Resonance Imaging in Osteoarthritis of the Knee. *J Bone Jt Surgery, Am Vol* 2003; **85**: 4–9.

106 Metcalf MH, Barrett GR. Prospective Evaluation of 1485 Meniscal Tear Patterns in Patients With Stable Knees. *Am J Sports Med* 2004; **32**: 675–80.

107 Christoforakis J, Pradhan R, Sanchez-Ballester J, Hunt N, Strachan RK. Is there an association between articular cartilage changes and degenerative meniscus tears? *Arthrosc - J Arthrosc Relat Surg* 2005; **21**: 1366–9.

108 Anderson AF. The ISAKOS Classification of Meniscal Tears. *ISAKOS Newsl* 2010; : 11–3.

109 Vande Berg BC, Malghem J, Poilvache P, Maldague B, Lecouvet FE. Meniscal tears with fragments displaced in notch and recesses of knee: MR imaging with arthroscopic comparison. *Radiology* 2005; **234**: 842–50.

110 Vande Berg BC, Poilvache P, Duchateau F, *et al.* Lesions of the menisci of the knee: value of MR imaging criteria for recognition of unstable lesions. *Am J Roentgenol* 2001; **176**: 771–6.

111 Vande Berg BC, Lecouvet FE, Poilvache P, *et al.* Dual-detector spiral CT arthrography of the knee: accuracy for detection of meniscal abnormalities and unstable meniscal tears. *Radiology* 2000; **216**: 851–7.

112 Weiss CB, Lundberg M, Hamberg P, DeHaven KE, Gillquist J. Non-operative treatment of meniscal tears. *J Bone Joint Surg Am* 1989; **71**: 811–22.

113 Cooper DE, Arnoczky SP, Warren RF. Meniscal repair. *Clin Sports Med* 1991; **10**: 529–48.

114 Smith JP, Barrett GR. Medial and Lateral Meniscal Tear Patterns in Anterior Cruciate Ligament-Deficient Knees. *Am J Sports Med* 2001; **29**: 415–9.

115 Smillie IS. The current pattern of the pathology of meniscus tears. *Proc R Soc Med* 1968; **61**: 44–5.

116 Dandy DJ. The arthroscopic anatomy of symptomatic meniscal lesions. *J Bone Joint Surg Br* 1990; **72**: 628–33.

117 Antony B, Driban JBB, Price LLL, *et al.* The relationship between meniscal pathology and osteoarthritis depends on the type of meniscal damage visible on magnetic resonance images: data from the Osteoarthritis Initiative. *Osteoarthr Cartil* 2017; **25**: 76–84.

118 Hunter DJ, Zhang YQ, Tu X, *et al.* Change in joint space width: Hyaline articular cartilage loss or alteration in meniscus? *Arthritis Rheum* 2006; **54**: 2488–95.

119 Guermazi A, Niu J, Hayashi D, *et al.* Prevalence of abnormalities in knees detected by MRI in adults without knee osteoarthritis: population based observational study (Framingham Osteoarthritis Study). *BMJ* 2012; **345**: e5339.

120 Ding C, Martel-pelletier J, Pelletier JP, *et al.* Meniscal tear as an osteoarthritis risk factor in a largely non-osteoarthritic cohort: A cross-sectional study. *J Rheumatol* 2007; **34**: 776–84.

121 Englund M, Guermazi A, Roemer FW, *et al.* Meniscal tear in knees without surgery and the development of radiographic osteoarthritis among middle-aged and elderly persons: The multicenter osteoarthritis study. *Arthritis Rheum* 2009; **60**: 831–9.

122 Kumm J, Roemer FW, Guermazi A, Turkiewicz A, Englund M. Natural History of Intrameniscal Signal Intensity on Knee MR Images: Six Years of Data from the Osteoarthritis Initiative. *Radiology* 2016; **278**: 164–71.

123 Raynauld J, Martel-pelletier J, Haraoui B, *et al.* Risk factors predictive of joint replacement in a 2-year multicentre clinical trial in knee osteoarthritis using MRI: results from over 6 years of observation. *Ann Rheum Dis* 2011; **70**: 1382–8.

124 Fairbank TJ. Knee Joint Changes After Meniscectomy. *J Bone Jt Surg* 1948; **30-B**: 664–70.

125 Allen PR, Denham R a, Swan a V. Late degenerative changes after meniscectomy. Factors affecting the knee after operation. *J Bone Joint Surg Br* 1984; **66**: 666–71.

126 Papalia R, Del Buono A, Osti L, Denaro V, Maffulli N. Meniscectomy as a risk factor for knee osteoarthritis: A systematic review. *Br Med Bull* 2011; **99**: 89–106.

127 Roos H, Laurén M, Adalberth T, Roos EM, Jonsson K, Lohmander LS. Knee osteoarthritis after meniscectomy: Prevalence of radiographic changes after twenty-one years, compared with

matched controls. *Arthritis Rheum* 1998; **41**: 687–93.

128 Glasson SS, Blanchet TJ, Morris EA. The surgical destabilization of the medial meniscus (DMM) model of osteoarthritis in the 129/SvEv mouse. *Osteoarthr Cartil* 2007; **15**: 1061–9.

129 Jackson JP. Degenerative changes in the knee after meniscectomy. *Br Med J* 1968; **2**: 525–7.

130 Goodfellow J. He who hesitates is saved. *J Bone Joint Surg Br* 1980; **62-B**: 1–2.

131 Petty CA, Lubowitz JH. Does arthroscopic partial meniscectomy result in knee osteoarthritis? A systematic review with a minimum of 8 years' follow-up. *Arthrosc - J Arthrosc Relat Surg* 2011; **27**: 419–24.

132 Khan T, Alvand A, Prieto-Alhambra D, *et al.* ACL and meniscal injuries increase the risk of primary total knee replacement for osteoarthritis: a matched case-control study using the Clinical Practice Research Datalink (CPRD). *Br J Sports Med* 2018; : bjsports-2017-097762.

133 Jones LD, Mellon SJ, Kruger N, Monk AP, Price AJ, Beard DJ. Medial meniscal extrusion: a validation study comparing different methods of assessment. *Knee Surgery, Sport Traumatol Arthrosc* 2018; **26**: 1152–7.

134 Crema MD, Roemer FW, Felson DT, *et al.* Factors Associated with Meniscal Extrusion in Knees with or at Risk for Osteoarthritis: The Multicenter Osteoarthritis Study. *Radiology* 2012; **264**: 494–503.

135 Rennie WJ, Finlay DBL. Meniscal extrusion in young athletes: Associated knee joint abnormalities. *Am J Roentgenol* 2006; **186**: 791–4.

136 Swamy N, Wadhwa V, Bajaj G, Chhabra A, Pandey T. Medial meniscal extrusion: Detection, evaluation and clinical implications. *Eur J Radiol* 2018; **102**: 115–24.

137 Urwin M, Symmons D, Allison T, *et al.* Estimating the burden of musculoskeletal disorders in the community: the comparative prevalence of symptoms at different anatomical sites, and the relation to social deprivation. *Ann Rheum Dis* 1998; **57**: 649–55.

138 Peat G, McCarney R, Croft P. Knee pain and osteoarthritis in older adults: a review of community burden and current use of primary health care. *Ann Rheum Dis* 2001; **60**: 91–7.

139 Knott JF. On Hey's 'Internal Derangement of the Knee-Joint'. *Dublin J Med Sci* 1882; : 479–90.

140 Blyth M, Anthony I, Francq B, *et al.* Diagnostic accuracy of the Thessaly test, standardised clinical history and other clinical examination tests (Apley's, McMurray's and joint line tenderness) for meniscal tears in comparison with magnetic resonance imaging diagnosis. *Health Technol Assess (Rockv)* 2015; **19**: 1–62.

141 Solomon DH, Simel DL, Bates DW, Katz JN, Schaffer JL. Does this patient have a torn meniscus or ligament of the knee? Value of the physical examination. *J Am Med Assoc* 2001; **286**: 1610–20.

142 Fowler PJ, Lubliner JA. The predictive value of five clinical signs in the evaluation of meniscal pathology. *Arthrosc J Arthrosc Relat Surg* 1989; **5**: 184–6.

143 DAMASK Team. Cost-effectiveness of magnetic resonance imaging of the knee for patients presenting in primary care. *Br J Gen Pract* 2008; **58**: 10–6.

144 Solomon DH, Katz JN, Carrino JA, *et al.* Trends in knee magnetic resonance imaging. *Med Care* 2003; **41**: 687–92.

145 Mackenzie R, Palmer CR, Lomas DJ, Dixon AK. Magnetic resonance imaging of the knee: diagnostic performance studies. *Clin Radiol* 1996; **51**: 251–7.

146 Lefevre N, Naouri JF, Herman S, Gerometta A, Klouche S, Bohu Y. A Current Review of the Meniscus Imaging: Proposition of a Useful Tool for Its Radiologic Analysis. *Radiol Res Pract* 2016; **2016**: 1–25.

147 De Smet AA, Tuite MJ, Norris MA, Swan JS. MR diagnosis of meniscal tears: analysis of causes of errors. *Am J Roentgenol* 1994; **163**: 1419–23.

148 Lee SY, Jee W-H, Kim J-M. Radial Tear of the Medial Meniscal Root: Reliability and Accuracy of MRI for Diagnosis. *Am J Roentgenol* 2008; **191**: 81–5.

149 Krych AJ, Wu IT, Desai VS, *et al.* High Rate of Missed Lateral Meniscus Posterior Root Tears on Preoperative Magnetic Resonance Imaging. *Orthop J Sport Med* 2018; **6**: 1–6.

150 Uthman OA, van der Windt DA, Jordan JL, *et al.* Exercise for lower limb osteoarthritis: systematic review incorporating trial sequential analysis and network meta-analysis. *Bmj* 2013; **347**: f5555.

151 Zhang W, Moskowitz RW, Nuki G, *et al.* OARSI recommendations for the management of hip

and knee osteoarthritis, Part II: OARSI evidence-based, expert consensus guidelines. *Osteoarthr Cartil* 2008; **16**: 137–62.

152 Koyonos L, Yanke AB, McNickle AG, *et al.* A randomized, prospective, double-blind study to investigate the effectiveness of adding depoMedrol to a local anesthetic injection in postmeniscectomy patients with osteoarthritis of the knee. *Am J Sports Med* 2009; **37**: 1077–82.

153 Rathleff CR, Cavallius C, Jensen HP, *et al.* Successful conservative treatment of patients with MRI-verified meniscal lesions. *Knee Surg Sports Traumatol Arthrosc* 2015; **23**: 178–83.

154 Brinker MR, O'Connor DP, Pierce P, Woods GW, Elliott MN. Utilization of orthopaedic services in a capitated population. *J Bone Joint Surg Am* 2002; **84-A**: 1926–32.

155 Hospital Admitted Patient Care Activity, 2015-16 - NHS Digital, England. https://digital.nhs.uk/data-and-information/publications/statistical/hospital-admitted-patient-care-activity/2015-16 (accessed June 13, 2018).

156 Rath E, Richmond JC. The menisci: basic science and advances in treatment. *Br J Sports Med* 2000; **34**: 252–7.

157 Katz JN, Martin SD. Meniscus - Friend or foe: Epidemiologic observations and surgical implications. *Arthritis Rheum* 2009; **60**: 633–5.

158 Shakespeare DT, Rigby HS. The bucket-handle tear of the meniscus. A clinical and arthrographic study. *J Bone Joint Surg Br* 1983; **65**: 383–7.

159 Bolano LE, Grana WA. Isolated arthroscopic partial meniscectomy. Functional radiographic evaluation at five years. *Am J Sports Med* 1993; **21**: 432–7.

160 Nawabi DH, Cro S, Hamid IP, Williams A. Return to play after lateral meniscectomy compared with medial meniscectomy in elite professional soccer players. *Am J Sports Med* 2014; **42**: 2193–8.

161 Ahmed A, Burke DL, Yu A. In-vitro measurement of static pressure distribution in synovial joints--Part II: Retropatellar surface. *J Biomech Eng* 1983; **105**: 226–36.

162 Annandale T. An operation for displaced semilunar cartilage. *Bmj* 1885; **1**: 779.

163 Cassidy RE, Shaffer AJ. Repair of peripheral meniscus tears. *Am J Sports Med* 1981; **9**: 209–14.

164 Abrams GD, Frank RM, Gupta AK, Harris JD, McCormick FM, Cole BJ. Trends in Meniscus Repair and Meniscectomy in the United States, 2005-2011. *Am J Sports Med* 2013; **41**: 2333–9.

165 Milachowski KA, Weismeier K, Wirth CJ. Homologous meniscus transplantation - Experimental and clinical results. *Int Orthop* 1989; **13**: 1–11.

166 Smith N a., Costa ML, Spalding T. Meniscal allograft transplantation: Rationale for treatment. *Bone Joint J* 2015; **97-B**: 590–4.

167 Shaffer B, Kennedy S, Klimkiewicz J, Yao L. Preoperative sizing of meniscal allografts in meniscus transplantation. *Am J Sports Med* 2000; **28**: 524–33.

168 Rathert P, Lutzeyer W, Goddwin WE. Philipp Bozzini (1773–1809) and the Lichtleiter. *Urology* 1974; **3**: 113–8.

169 Herr HW. Max Nitze, the Cystoscope and Urology. *J Urol* 2006; **176**: 1313–6.

170 Moran ME. The Light Bulb, Cystoscopy, and Thomas Alva Edison. *J Endourol* 2010; **24**: 1395–7.

171 Kieser CW, Jackson RW. Severin Nordentoft: The First Arthroscopist. *Arthrosc J Arthrosc Relat Surg* 2001; **17**: 532–5.

172 Jackson RW. A History of Arthroscopy. *Arthrosc J Arthrosc Relat Surg* 2010; **26**: 91–103.

173 Takagi K. Arthroscope. Kenji Takagi. J. Jap. Orthop. Assoc. 14.359, 1939 (translated). *Clin Orthop Relat Res* 1982; : 6–8.

174 Kreuscher PH. Semilunar Cartilage Disease: A Plea For The Early Recognition By Means Of The Arthroscope And The Early Treatment Of This Condition. *Ill Med J* 1925; **47**: 290–2.

175 Burman MS. Arthroscopy or the direct visualization of joints: an experimental cadaver study. 1931. *Clin Orthop Relat Res* 2001; **11**: 5–9.

176 Watanabe M. Memories of the early days of arthroscopy. *Arthrosc J Arthrosc Relat Surg* 1986; **2**: 209–14.

177 Lohmander LS, Thorlund JB, Roos EM. Routine knee arthroscopic surgery for the painful knee in middle-aged and old patients—time to abandon ship. *Acta Orthop* 2016; **87**: 2–4.

178 Järvinen TLN, Guyatt GH. Arthroscopic surgery for knee pain. *Bmj* 2016; **3934**: i3934.

179 Kirkley A, Birmingham TB, Litchfield RB, *et al.* A Randomized Trial of Arthroscopic Surgery for Osteoarthritis of the Knee. *N Engl J Med* 2008; **359**: 1097–107.

180 Moseley JB, O'Malley K, Petersen NJ, *et al.* A controlled trial of arthroscopic surgery for osteoarthritis of the knee. *N Engl J Med* 2002; **347**: 81–8.

181 Aaron RK, Skolnick AH, Reinert SE, Ciombor DM. Arthroscopic Débridement for Osteoarthritis of the Knee. *J Bone Jt Surg* 2006; **88**: 936–43.

182 Amin NH, Hussain W, Ryan J, Morrison S, Miniaci A, Jones MH. Changes Within Clinical Practice After a Randomized Controlled Trial of Knee Arthroscopy for Osteoarthritis. *Orthop J Sport Med* 2017; **5**: 1–6.

183 Lazic S, Boughton O, Hing C, Bernard J. Arthroscopic washout of the knee: A procedure in decline. *Knee* 2014; **21**: 631–4.

184 Jameson SS, Dowen D, James P, *et al.* The burden of arthroscopy of the knee: a contemporary analysis of data from the English NHS. *J Bone Joint Surg Br* 2011; **93**: 1327–33.

185 Siemieniuk RAC, Harris IA, Agoritsas T, *et al.* Arthroscopic surgery for degenerative knee arthritis and meniscal tears: a clinical practice guideline. *Bmj* 2017; **357**: j1982.

186 Mattila VM, Sihvonen R, Paloneva J, Felländer-Tsai L. Changes in rates of arthroscopy due to degenerative knee disease and traumatic meniscal tears in Finland and Sweden. *Acta Orthop* 2016; **87**: 5–11.

187 Kim S, Bosque J, Meehan JP, Jamali A, Marder R. Increase in Outpatient Knee Arthroscopy in the United States: A Comparison of National Surveys of Ambulatory Surgery, 1996 and 2006. *J Bone & Jt Surg* 2011; **93**: 994 LP – 1000.

188 Hamilton DF, Howie CR. Knee arthroscopy : influence of systems for delivering healthcare on procedure rates. *Bmj* 2015; **351**: 1–4.

189 Hawker G, Guan J, Judge A, Dieppe P. Knee arthroscopy in England and Ontario: patterns of use, changes over time, and relationship to total knee replacement. *J Bone Joint Surg Am* 2008; **90**: 2337–45.

190 Harris IA, Madan NS, Naylor JM, Chong S, Mittal R, Jalaludin BB. Trends in knee arthroscopy and subsequent arthroplasty in an Australian population: a retrospective cohort study. *BMC*

Musculoskelet Disord 2013; **14**: 1–6.

191 Judge A, Murphy RJ, Maxwell R, Arden NK, Carr AJ. Temporal trends and geographical variation in the use of subacromial decompression and rotator cuff repair of the shoulder in England. *Bone Jt J* 2014; **96 B**: 70–4.

192 Thorlund JB, Hare KB, Lohmander LS. Large increase in arthroscopic meniscus surgery in the middle-aged and older population in Denmark from 2000 to 2011. *Acta Orthop* 2014; **85**: 287–92.

193 Kim Y-M, Lee CA, Matava MJ. Clinical Results of Arthroscopic Single-Bundle Transtibial Posterior Cruciate Ligament Reconstruction. *Am J Sports Med* 2011; **39**: 425–34.

194 Holmes R, Moschetti W, Martin B, Tomek I, Finlayson S. Effect of Evidence and Changes in Reimbursement on the Rate of Arthroscopy for Osteoarthritis. *Am J Sports Med* 2013; **41**: 1039–43.

195 Abram SGF, Judge A, Beard DJ, Wilson HA, Price AJ. Temporal trends and regional variation in the rate of arthroscopic knee surgery in England: analysis of over 1.7 million procedures between 1997 and 2017. Has practice changed in response to new evidence? *Br J Sports Med* 2018; : bjsports-2018-099414.

196 Katz JN, Brophy RH, Chaisson CE, *et al.* Surgery versus physical therapy for a meniscal tear and osteoarthritis. *N Engl J Med* 2013; **368**: 1675–84.

197 Sihvonen R, Paavola M, Malmivaara A, *et al.* Arthroscopic partial meniscectomy versus sham surgery for a degenerative meniscal tear. *N Engl J Med* 2013; **369**: 2515–24.

198 Kise NJ, Risberg MA, Stensrud S, Ranstam J, Engebretsen L, Roos EM. Exercise therapy versus arthroscopic partial meniscectomy for degenerative meniscal tear in middle aged patients: randomised controlled trial with two year follow-up. *BMJ* 2016; **354**: i3740.

199 Gauffin H, Tagesson S, Meunier A, Magnusson H, Kvist J. Knee arthroscopic surgery is beneficial to middle-aged patients with meniscal symptoms: a prospective, randomised, single-blinded study. *Osteoarthr Cartil* 2014; **22**: 1808–16.

200 Herrlin S, Hållander M, Wange P, Weidenhielm L, Werner S. Arthroscopic or conservative treatment of degenerative medial meniscal tears: A prospective randomised trial. *Knee Surgery,*

Sport Traumatol Arthrosc 2007; **15**: 393–401.

201 Vermesan D, Prejbeanu R, Laitin S, *et al.* Arthroscopic debridement compared to intra-articular steroids in treating degenerative medial meniscal tears. *Eur Rev Med Pharmacol Sci* 2013; **17**: 3192–6.

202 Yim J-H, Seon J-K, Song E-K, *et al.* A comparative study of meniscectomy and nonoperative treatment for degenerative horizontal tears of the medial meniscus. *Am J Sports Med* 2013; **41**: 1565–70.

203 Osteras H, Osteras B, Torstensen TA. Medical exercise therapy, and not arthroscopic surgery, resulted in decreased depression and anxiety in patients with degenerative meniscus injury. *J Bodyw Mov Ther* 2012; **16**: 456–63.

204 Lamplot JD, Brophy RH. The role for arthroscopic partial meniscectomy in knees with degenerative changes: a systematic review. *Bone Joint J* 2016; **98-B**: 934–8.

205 Khan M, Evaniew N, Bedi A, Ayeni OR, Bhandari M. Arthroscopic surgery for degenerative tears of the meniscus: A systematic review and meta-analysis. *CMAJ* 2014; **186**: 1057–64.

206 Brignardello-Petersen R, Guyatt GH, Buchbinder R, *et al.* Knee arthroscopy versus conservative management in patients with degenerative knee disease: a systematic review. *BMJ Open* 2017; **7**: e016114.

207 Thorlund JB, Juhl CB, Roos EM, Lohmander LS. Arthroscopic surgery for degenerative knee: systematic review and meta-analysis of benefits and harms. *Bmj* 2015; **350**: h2747–h2747.

208 Stone JA, Salzler MJ, Parker DA, Becker R, Harner CD. Degenerative meniscus tears - assimilation of evidence and consensus statements across three continents: state of the art. *J ISAKOS Jt Disord Orthop Sport Med* 2017; **2**: 108–19.

209 Beaufils P, Becker R, Kopf S, *et al.* Surgical management of degenerative meniscus lesions: the 2016 ESSKA meniscus consensus. *Knee Surgery, Sport Traumatol Arthrosc* 2017; **25**: 335–46.

210 van de Graaf VA, Wolterbeek N, Mutsaerts ELAR, *et al.* Arthroscopic Partial Meniscectomy or Conservative Treatment for Nonobstructive Meniscal Tears: A Systematic Review and Meta-analysis of Randomized Controlled Trials. *Arthrosc J Arthrosc Relat Surg* 2016; **32**: 1855-1865.e4.

211 Monk P, Garfjeld Roberts P, Palmer AJR, *et al.* The Urgent Need for Evidence in Arthroscopic Meniscal Surgery: A Systematic Review of the Evidence for Operative Management of Meniscal Tears. *Am J Sports Med* 2017; **45**: 965–73.

212 Buchbinder R, Harris I a., Sprowson A. Management of degenerative meniscal tears and the role of surgery. *Br J Sports Med* 2016; **50**: 1413–6.

213 Buchbinder R. Meniscectomy in Patients with Knee Osteoarthritis and a Meniscal Tear? *N Engl J Med* 2013; **368**: 1741–3.

214 Whelan DB. Editorial Commentary: Book? … Book Report? … or Just a New Chapter in an Ongoing Story?: Knee Partial Meniscectomy Has Limited Benefit for "Nonobstructive" Meniscal Tears, but We Need to Know if Patients Have Osteoarthritis. *Arthrosc J Arthrosc Relat Surg* 2016; **32**: 1866–7.

215 Sadoghi P, Gomoll AH. New England Journal of Medicine Article Evaluating the Usefulness of Meniscectomy Is Flawed. Arthrosc. J. Arthrosc. Relat. Surg. 2014; **30**: 659–60.

216 Lubowitz JH, Provencher MT, Rossi MJ. Could the New England Journal of Medicine Be Biased Against Arthroscopic Knee Surgery? Part 2. Arthrosc. J. Arthrosc. Relat. Surg. 2014; **30**: 654–5.

217 Hwang YG, Kent Kwoh C. The METEOR trial: No rush to repair a torn meniscus. *Cleve Clin J Med* 2014; **81**: 226–32.

218 Slomski A. Surgery No Benefit to Patients With Meniscal Tears. *JAMA* 2016; **316**: 1250.

219 Katz JN, Jones MH. Treatment of Meniscal Tear: The More We Learn, the Less We Know. *Ann Intern Med* 2016; **164**: 503.

220 Bollen SR. Is arthroscopy of the knee completely useless? *Bone Joint J* 2015; **97-B**: 1591–2.

221 Gandhi R, Perruccio a. V., Kakar S, Haddad FS. Putting the baby back in the bathwater: the interpretation of randomised trials in surgery. *Bone Joint J* 2015; **97-B**: 1456–7.

222 Carr A. Arthroscopic surgery for degenerative knee. *BMJ* 2015; **350**: h2983.

223 Price AJ, Beard D. Arthroscopy for degenerate meniscal tears of the knee. *Bmj* 2014; **2382**: 1–2.

224 Murphy RF, Heyworth B, Kramer D, *et al.* Symptomatic Venous Thromboembolism After

Adolescent Knee Arthroscopy. *J Pediatr Orthop* 2016; **00**: 1–2.

225 Lau BC, Jagodzinski J, Pandya NK. Incidence of Symptomatic Pulmonary Embolus and Deep Vein Thrombosis After Knee Arthroscopy in the Pediatric and Adolescent Population. *Clin J Sport Med* 2017; : 1.

226 Cancienne JM, Mahon HS, Dempsey IJ, Miller MD, Werner BC. Patient-related risk factors for infection following knee arthroscopy: An analysis of over 700,000 patients from two large databases. *Knee* 2017; **24**: 594–600.

227 Li QP, Wu HL, Yan M, Guo JJ. Prevalence and potential risk factor of deep vein thrombosis in chinese patients undergoing knee arthroscopy surgery without thromboprophylaxis in routine clinical practice: A retrospective study. *Biomed Res* 2017; **28**: 1408–12.

228 Balato G, Di Donato SL, Ascione T, *et al.* Knee septic arthritis after arthroscopy: Incidence, risk factors, functional outcome, and infection eradication rate. *Joints* 2017; **5**: 107–13.

229 Shah CK, Keswani A, Boodaie BD, Yao DH, Koenig KM, Moucha CS. Myocardial Infarction Risk in Arthroplasty vs Arthroscopy: How Much Does Procedure Type Matter? *J Arthroplasty* 2017; **32**: 246–51.

230 Lyman S, Oh LS, Reinhardt KR, *et al.* Surgical Decision Making for Arthroscopic Partial Meniscectomy in Patients Aged Over 40 Years. *Arthrosc J Arthrosc Relat Surg* 2012; **28**: 492-501.e1.

231 National Institute for Health and Care Excellence. Arthroscopic knee washout, with or without debridement, for the treatment of osteoarthritis (IPG230). NICE, 2007 https://www.nice.org.uk/guidance/ipg230 (accessed Jan 8, 2018).

232 Katz JN, Losina E. Arthroscopic partial meniscectomy for degenerative tears: Where do we stand? *Osteoarthr Cartil* 2014; **22**: 1749–51.

233 Bennell KL, Katz JN. Potential harms of isolated arthroscopic partial meniscectomy. *Lancet* 2018; **6736**: 9–10.

234 NHS Digital. Hospital Episode Statistics. http://content.digital.nhs.uk/hes (accessed Dec 4, 2017).

235 NHS Digital. National clinical coding standards. Stationery Office, 2017.

236 About CCGs - NHS Clinical Commissioners. https://www.nhscc.org/ccgs/ (accessed Dec 4, 2017).

237 Clinical Commissioning Groups (April 2017) Names and Codes in England (Version 3). https://data.gov.uk/dataset/clinical-commissioning-groups-april-2017-names-and-codes-in-england-version-31 (accessed Dec 4, 2017).

238 APHO. Commonly used public health statistics and their confidence intervals. 2010 https://fingertips.phe.org.uk/profile/guidance.

239 NHS Digital. Hospital Episode Statistics (HES) Analysis Guide. 2015. http://content.digital.nhs.uk/media/1592/HES-analysis-guide/pdf/HES_Analysis_Guide_March_2015.pdf (accessed Dec 4, 2017).

240 Office for National Statistics. Clinical Commissioning Groups (April 2017) Boundaries (Version 4). http://geoportal.statistics.gov.uk/ (accessed Dec 4, 2017).

241 Chang RW, Falconer J, Stulberg SD, Arnold WJ, Manheim LM, Dyer AR. A randomized, controlled trial of arthroscopic surgery versus closed-needle joint lavage for patients with osteoarthritis of the knee. *Arthritis Rheum* 1993; **36**: 289–96.

242 Abram SGF, Price AJ, Judge A, Beard DJ. Anterior cruciate ligament (ACL) reconstruction and meniscal repair rates have both increased in the past 20 years in England: hospital statistics from 1997 to 2017. *Br J Sports Med* 2019; : bjsports-2018-100195.

243 Spahn G, Kahl E, Mückley T, Hofmann GO, Klinger HM. Arthroscopic knee chondroplasty using a bipolar radiofrequency-based device compared to mechanical shaver: Results of a prospective, randomized, controlled study. *Knee Surgery, Sport Traumatol Arthrosc* 2008; **16**: 565–73.

244 Spahn G, Klinger HM, Mückley T, Hofmann GO. Four-Year Results From a Randomized Controlled Study of Knee Chondroplasty With Concomitant Medial Meniscectomy: Mechanical Debridement Versus Radiofrequency Chondroplasty. *Arthrosc J Arthrosc Relat Surg* 2010; **26**: S73–80.

245 Spahn G, Hofmann GO, von Engelhardt LV. Mechanical debridement versus radiofrequency in knee chondroplasty with concomitant medial meniscectomy: 10-year results from a randomized

controlled study. *Knee Surgery, Sport Traumatol Arthrosc* 2016; **24**: 1560–8.

246 National Institute for Health and Care Excellence (NICE). Arthroscopic radiofrequency chondroplasty for discrete chondral defects of the knee | Guidance and guidelines | NICE. NICE, 2014 https://www.nice.org.uk/guidance/ipg493 (accessed Jan 10, 2018).

247 UK Health Accounts 2016 - Office for National Statistics. 2016 https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthcaresystem/bulletins/ukhealthaccounts/2016 (accessed June 5, 2018).

248 HSCIC. Summary Hospital-level Mortality Indicator (SHMI). Indicator Specification. Version 1.25. 2017 https://www.digital.nhs.uk/SHMI.

249 Charlson ME, Pompei P, Ales KL, MacKenzie R. A new method of classifying prognostic in longitudinal studies: development and validation. J. Chronic Dis. 1987; **40**: 373–83.

250 Zhang JX, Iwashyna TJ, Christakis NA. The performance of different lookback periods and sources of information for Charlson comorbidity adjustment in Medicare claims. *Med Care* 1999; **37**: 1128–39.

251 Boyd JA, Gradisar IM. Total Knee Arthroplasty After Knee Arthroscopy in Patients Older Than 50 Years. *Orthopedics* 2016; **39**: 1–4.

252 Loeser RF. Age-Related Changes in the Musculoskeletal System and the Development of Osteoarthritis. *Clin Geriatr Med* 2010; **26**: 371–86.

253 Arden N, Nevitt MC. Osteoarthritis: Epidemiology. *Best Pract Res Clin Rheumatol* 2006; **20**: 3–25.

254 Jiang L, Tian W, Wang Y, *et al.* Body mass index and susceptibility to knee osteoarthritis: A systematic review and meta-analysis. *Jt Bone Spine* 2012; **79**: 291–7.

255 Nguyen UDT, Zhang Y, Zhu Y, Niu J, Zhang B, Felson DT. Increasing prevalence of knee pain and symptomatic knee osteoarthritis: survey and cohort data. *Ann Intern Med* 2011; **155**: 725–32.

256 Yu D, Jordan KP, Bedson J, *et al.* Population trends in the incidence and initial management of osteoarthritis: age-period-cohort analysis of the Clinical Practice Research Datalink, 1992–2013. *Rheumatology* 2017; **56**: 1902–17.

257 Crooks CJ, West J, Card TR. A comparison of the recording of comorbidity in primary and secondary care by using the Charlson Index to predict short-term and long-term survival in a routine linked data cohort. *BMJ Open* 2015; **5**: 1–9.

258 Wright FL, Green J, Canoy D, Cairns BJ, Balkwill A, Beral V. Vascular disease in women: comparison of diagnoses in hospital episode statistics and general practice records in England. *BMC Med Res Methodol* 2012; **12**: 161.

259 Abram SGF, Beard DJ, Price AJ. National consensus on the definition, investigation, and classification of meniscal lesions of the knee. *Knee* 2018; **25**: 834–40.

260 Van Meer BL, Meuffels DE, Van Eijsden WA, Verhaar JAN, Bierma-Zeinstra SMA, Reijman M. Which determinants predict tibiofemoral and patellofemoral osteoarthritis after anterior cruciate ligament injury? A systematic review. *Br J Sports Med* 2015; **49**: 975–83.

261 Hamilton TW, Pandit HG, Lombardi A V., *et al.* Radiological Decision Aid to determine suitability for medial unicompartmental knee arthroplasty: development and preliminary validation. *Bone Joint J* 2016; **98-B**: 3–10.

262 Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Bmj* 2009; **339**: b2535.

263 Mokkink LB, Terwee CB, Patrick DL, *et al.* The COSMIN study reached international consensus on taxonomy, terminology, and definitions of measurement properties for health-related patient-reported outcomes. *J Clin Epidemiol* 2010; **63**: 737–45.

264 Mokkink LB, Terwee CB, Knol DL, *et al.* The COSMIN checklist for evaluating the methodological quality of studies on measurement properties: a clarification of its content. *BMC Med Res Methodol* 2010; **10**: 22.

265 Briggs KK, Kocher MS, Rodkey WG, Steadman JR. Reliability, Validity, and Responsiveness of the Lysholm Knee Score and Tegner Activity Scale for Patients with Meniscal Injury of the Knee. *J Bone Jt Surg* 2006; **88**: 698–705.

266 Terwee CB, Bot SDMM, de Boer MR, *et al.* Quality criteria were proposed for measurement properties of health status questionnaires. *J Clin Epidemiol* 2007; **60**: 34–42.

267 Terwee CB, Jansma EP, Riphagen II, De Vet HCW. Development of a methodological PubMed

search filter for finding studies on measurement properties of measurement instruments. *Qual Life Res* 2009; **18**: 1115–23.

268 Terwee CB, Mokkink LB, Knol DL, Ostelo RWJGJG, Bouter LM, De Vet HCWW. Rating the methodological quality in systematic reviews of studies on measurement properties: A scoring system for the COSMIN checklist. *Qual Life Res* 2012; **21**: 651–7.

269 Mokkink LB, Terwee CB, Patrick DL, *et al.* The COSMIN checklist for assessing the methodological quality of studies on measurement properties of health status measurement instruments: An international Delphi study. *Qual Life Res* 2010; **19**: 539–49.

270 Schellingerhout JM, Verhagen AP, Heymans MW, Koes BW, De Vet HC, Terwee CB. Measurement properties of disease-specific questionnaires in patients with neck pain: A systematic review. *Qual Life Res* 2012; **21**: 659–70.

271 Van Tulder M, Furlan A, Bombardier C, Bouter L. Updated Method Guidelines for Systematic Reviews in the Cochrane Collaboration Back Review Group. *Spine (Phila Pa 1976)* 2003; **28**: 1290–9.

272 Goodwin PC, Ratcliffe J, Morris J, Morrissey MC. Using the knee-specific Hughston Clinic Questionnaire, EQ-5D and SF-6D following arthroscopic partial meniscectomy surgery: A comparison of psychometric properties. *Qual Life Res* 2011; **20**: 1437–46.

273 Crawford K, Briggs KK, Rodkey WG, Steadman JR. Reliability, Validity, and Responsiveness of the IKDC Score for Meniscus Injuries of the Knee. *Arthrosc - J Arthrosc Relat Surg* 2007; **23**: 839–44.

274 van de Graaf V a, Wolterbeek N, Scholtes V a B, Mutsaerts EL a R, Poolman RW. Reliability and Validity of the IKDC, KOOS, and WOMAC for Patients With Meniscal Injuries. *Am J Sports Med* 2014; **42**: 1408–16.

275 Roos EM, Roos HP, Ekdahl C, Lohmander LS. Knee injury and Osteoarthritis Outcome Score (KOOS)--validation of a Swedish version. *Scand J Med Sci Sports* 1998; **8**: 439–48.

276 Garratt M, Brealey S, Robling M, *et al.* Development of the knee quality of life (KQoL-26) 26-item questionnaire: data quality, reliability, validity and responsiveness. *Health Qual Life Outcomes* 2008; **6**: 48.

277 Kirkley A, Griffin S, Whelan D. The development and validation of a quality of life-measurement tool for patients with meniscal pathology: the Western Ontario Meniscal Evaluation Tool (WOMET). *Clin J Sport Med* 2007; **17**: 349–56.

278 Sihvonen R, Järvelä T, Aho H, Järvinen TL. Validation of the Western Ontario Meniscal Evaluation Tool (WOMET) for Patients with a Degenerative Meniscal Tear. *J Bone Jt Surgery-American Vol* 2012; **94**: 1–8.

279 Celik D, Demirel M, Kuş G, Erdil M, Özdinçler AR. Translation, cross-cultural adaptation, reliability and validity of the Turkish version of the Western Ontario Meniscal Evaluation Tool (WOMET). *Knee Surgery, Sport Traumatol Arthrosc* 2015; **23**: 816–25.

280 Tong WW, Wang W, Xu WD. Development of a Chinese version of the Western Ontario Meniscal Evaluation Tool: cross-cultural adaptation and psychometric evaluation. *J Orthop Surg Res* 2016; **11**: 90.

281 Van Der Wal RJPP, Heemskerk BTJJ, Van Arkel ERAA, Mokkink LB, Thomassen BJWW. Translation and Validation of the Dutch Western Ontario Meniscal Evaluation Tool. *J Knee Surg* 2016; **1**: 314–22.

282 Flandry F, Hunt JP, Terry GC, Hughston JC. Analysis of subjective knee complaints using visual analog scales. *Am J Sports Med* 1991; **19**: 112–8.

283 Irrgang JJ, Anderson AF, Boland AL, *et al.* Development and validation of the international knee documentation committee subjective knee form. *Am J Sports Med* 2001; **29**: 600–13.

284 Roos EM, Roos HP, Lohmander LS, Ekdahl C, Beynnon BD. Knee Injury and Osteoarthritis Outcome Score (KOOS)—Development of a Self-Administered Outcome Measure. *J Orthop Sport Phys Ther* 1998; **28**: 88–96.

285 Lysholm J, Gillquist J. Evaluation of knee ligament surgery results with special emphasis on use of a scoring scale. *Am J Sports Med* 1982; **10**: 150–4.

286 Tegner Y, Lysholm J. Rating systems in the evaluation of knee ligament injuries. *Clin Orthop Relat Res* 1985; : 43–9.

287 Bellamy N. The WOMAC Knee and Hip Osteoarthritis Indices: development, validation, globalization and influence on the development of the AUSCAN Hand Osteoarthritis Indices.

Clin Exp Rheumatol 2014; **23**: 148–53.

288 Euroqol-Group. EuroQol - a new facility for the measurement of health-related quality of life. *Health Policy (New York)* 1990; **16**: 199–208.

289 Braizer J, Roberts J, Deverill M. The Estimation of a Preference-Based Measure of Health Form the SF-36. *Journall Heal Econ* 2002; **21**: 271–92.

290 Bellamy N, Buchanan WW, Goldsmith CH, Campbell J, Stitt LW. Validation study of WOMAC: a health status instrument for measuring clinically important patient relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of the hip or knee. *J Rheumatol* 1988; **15**: 1833–40.

291 Wang D, Jones H, Khair M, Miniaci A. Patient-reported outcome measures for the knee. *J Knee Surg* 2010; **23**: 137–51.

292 Thorborg K, Tijssen M, Habets B, *et al.* Patient-Reported Outcome (PRO) questionnaires for young to middle-aged adults with hip and groin disability: a systematic review of the clinimetric evidence. *Br J Sports Med* 2015; **49**: 812.

293 Thoomes-de Graaf M, Scholten-Peeters GGM, Schellingerhout JM, *et al.* Evaluation of measurement properties of self-administered PROMs aimed at patients with non-specific shoulder pain and activity limitations: a systematic review. *Qual Life Res* 2016; **25**: 2141–60.

294 Green A, Liles C, Rushton A, Kyte DG. Measurement properties of patient-reported outcome measures (PROMS) in Patellofemoral Pain Syndrome: A systematic review. *Man Ther* 2014; **19**: 517–26.

295 Terwee CB, Bouwmeester W, van Elsland SL, de Vet HCW, Dekker J. Instruments to assess physical activity in patients with osteoarthritis of the hip or knee: A systematic review of measurement properties. *Osteoarthr Cartil* 2011; **19**: 620–33.

296 Gagnier JJ, Mullins M, Huang H, *et al.* A Systematic Review of Measurement Properties of Patient-Reported Outcome Measures Used in Patients Undergoing Total Knee Arthroplasty. *J Arthroplasty* 2017; **32**: 1688–97.

297 Kroman SL, Roos EM, Bennell KL, Hinman RS, Dobson F. Measurement properties of performance-based outcome measures to assess physical function in young and middle-aged

people known to be at high risk of hip and/or knee osteoarthritis: A systematic review. *Osteoarthr Cartil* 2014; **22**: 26–39.

298 Dobson F, Hinman RS, Hall M, Terwee CB, Roos EM, Bennell KL. Measurement properties of performance-based measures to assess physical function in hip and knee osteoarthritis: A systematic review. *Osteoarthr Cartil* 2012; **20**: 1548–62.

299 Tijssen M, van Cingel R, van Melick N, de Visser E. Patient-Reported Outcome questionnaires for hip arthroscopy: a systematic review of the psychometric evidence. *BMC Musculoskelet Disord* 2011; **12**: 117.

300 Beard DJ, Harris K, Dawson J, *et al.* Meaningful changes for the Oxford hip and knee scores after joint replacement surgery. *J Clin Epidemiol* 2015; **68**: 73–9.

301 Kvien TK, Heiberg T, Hagen KB. Minimal clinically important improvement/difference (MCII/MCID) and patient acceptable symptom state (PASS): What do these concepts mean? *Ann Rheum Dis* 2007; **66**: 40–1.

302 Collins NJ, Misra D, Felson DT, Crossley KM, Roos EM. Measures of knee function: International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form, Knee Injury and Osteoarthritis Outcome Score (KOOS), Knee Injury and Osteoarthritis Outcome Score Physical Function Short Form (KOOS-PS)... *Arthritis Care Res (Hoboken)* 2011; **63 Suppl 1**: S208-28.

303 Haviv B, Bronak S, Kosashvili Y, Thein R. Arthroscopic meniscectomy of traumatic versus atraumatic tears in middle aged patients: is there a difference? *Arch Orthop Trauma Surg* 2016; **136**: 1297–301.

304 Thorlund JB, Englund M, Christensen R, *et al.* Patient reported outcomes in patients undergoing arthroscopic partial meniscectomy for traumatic or degenerative meniscal tears: comparative prospective cohort study. *BMJ* 2017; **356**: j356.

305 Mokkink LB, Terwee CB, Gibbons E, *et al.* Inter-rater agreement and reliability of the COSMIN (COnsensus-based Standards for the selection of health status Measurement Instruments) Checklist. *Med Res Methodol* 2010; **10**: 1–11.

306 McKenna SP. Measuring patient-reported outcomes: moving beyond misplaced common sense

to hard science. *BMC Med* 2011; **9**: 86.

307 Higgins JP, Green S. Cochrane Handbook for Systematic Reviews of Interventions (Version 5.1.0). 2011. http://handbook.cochrane.org/.

308 Vande Berg BC, Lecouvet FE, Poilvache P, *et al.* Dual-Detector Spiral CT Arthrography of the Knee: Accuracy for Detection of Meniscal Abnormalities and Unstable Meniscal Tears. *Radiology* 2000; **216**: 851–7.

309 Katz JN, Smith SR, Yang HY, *et al.* Value of History, Physical Examination, and Radiographic Findings in the Diagnosis of Symptomatic Meniscal Tear Among Middle-Aged Subjects With Knee Pain. *Arthritis Care Res* 2017; **69**: 484–90.

310 Sihvonen R, Englund M, Turkiewicz A, Järvinen TLN. Mechanical symptoms as an indication for knee arthroscopy in patients with degenerative meniscus tear: a prospective cohort study. *Osteoarthr Cartil* 2016; **24**: 1367–75.

311 Sihvonen R, Englund M, Turkiewicz A, Järvinen TLN. Mechanical Symptoms and Arthroscopic Partial Meniscectomy in Patients With Degenerative Meniscus Tear. *Ann Intern Med* 2016; **164**: 449.

312 Wartolowska K, Judge A, Hopewell S, *et al.* Use of placebo controls in the evaluation of surgery: systematic review. *Bmj* 2014; **348**: g3253–g3253.

313 Abram SGF, Middleton R, Beard DJ, Price AJ, Hopewell S. Patient-reported outcome measures for patients with meniscal tears: a systematic review of measurement properties and evaluation with the COSMIN checklist. *BMJ Open* 2017; **7**: e017247.

314 Roos EM, Lohmander LS. The Knee injury and Osteoarthritis Outcome Score (KOOS): from joint injury to osteoarthritis. *Health Qual Life Outcomes* 2003; **1**: 64.

315 KOOS User Guide 2012. 2012. http://www.koos.nu/KOOSusersguide2012.pdf.

316 Devji T, Guyatt GH, Lytvyn L, *et al.* Application of minimal important differences in degenerative knee disease outcomes: A systematic review and case study to inform BMJ Rapid Recommendations. *BMJ Open* 2017; **7**: 1–12.

317 Higgins JPT, Altman DG, Gøtzsche PC, *et al.* The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *Bmj* 2011; **343**: 889–93.

318 Wan X, Wang W, Liu J, Tong T. Estimating the sample mean and standard deviation from the sample size, median, range and/or interquartile range. *BMC Med Res Methodol* 2014; **14**: 135.

319 Schünemann H, Brożek J, Guyatt G, Oxman A. GRADE handbook for grading quality of evidence and strength of recommendation. Version 3.2 [updated March 2009]. GRADE Work. Gr. 2009. https://gradepro.org/handbook/%0A.

320 Roos EM, Hare KB, Nielsen SM, Christensen R, Lohmander LS. Better outcome from arthroscopic partial meniscectomy than skin incisions only? A sham-controlled randomised trial in patients aged 35-55 years with knee pain and an MRI-verified meniscal tear. *BMJ Open* 2018; **8**: 1–10.

321 Graaf VA van de, Noorduyn JCA, Willigenburg NW, *et al.* Effect of Early Surgery vs Physical Therapy on Knee Function Among Patients With Nonobstructive Meniscal Tears: The ESCAPE Randomized Clinical Trial. *JAMA* 2018; **320**: 1328–37.

322 Hare KB, Lohmander LS, Christensen R, Roos EM. Arthroscopic partial meniscectomy in middle-aged patients with mild or no knee osteoarthritis: a protocol for a double-blind, randomized sham-controlled multi-centre trial. *BMC Musculoskelet Disord* 2013; **14**: 71.

323 Skou ST. Danish Rct on Exercise Versus Arthroscopic Meniscal Surgery for Young Adults (DREAM) (NCT02995551). ClinicalTrials.gov. 2016. https://clinicaltrials.gov/ct2/show/NCT02995551.

324 Giori NJ. Prospective Trial of Arthroscopic Meniscectomy for Degenerative Meniscus Tears (NCT01931735). ClinicalTrials.gov. 2013. https://clinicaltrials.gov/ct2/show/NCT01931735.

325 Hare K. The Benefit of Arthroscopic Partial Meniscectomy in Middle-Aged Patients (SLAMSHAM) (NCT01264991). ClinicalTrials.gov. 2010. https://www.clinicaltrials.gov/ct2/show/NCT01264991.

326 Johnson-Lynn S. DEMAND - DEgenerative Meniscal Tears - Arthroscopy vs. Dedicated Exercise (NCT02113280). ClinicalTrials.gov. 2013. https://clinicaltrials.gov/ct2/show/record/NCT02113280.

327 Osteras H, Osteras B, Torstensen TA. Medical Exercise Therapy is Effective After Arthroscopic Surgery of Degenerative Meniscus of the Knee: A Randomized Controlled Trial. *J Clin Med*

Res 2012; **4**: 378–84.

328 El Ghazaly SA, Rahman AAA, Yusry AH, Fathalla MM. Arthroscopic partial meniscectomy is superior to physical rehabilitation in the management of symptomatic unstable meniscal tears. *Int Orthop* 2015; **39**: 769–75.

329 Herrlin S V., Wange PO, Lapidus G, Hållander M, Werner S, Weidenhielm L. Is arthroscopic surgery beneficial in treating non-traumatic, degenerative medial meniscal tears? A five year follow-up. *Knee Surgery, Sport Traumatol Arthrosc* 2013; **21**: 358–64.

330 Harris K, Dawson J, Gibbons E, *et al.* Systematic review of measurement properties of patient-reported outcome measures used in patients undergoing hip and knee arthroplasty. *Patient Relat Outcome Meas* 2016; **7**: 101–8.

331 Katz JN, Chaisson CE, Cole B, *et al.* The Meteor Trial: Preliminary Results of an RCT of Arthroscopic Partial Meniscectomy Vs. Physical Therapy in Patients greater Than 45. In: ACR Meeting Abstracts. 2012: S1123.

332 Katz JN, Wright J, Mandl LA, *et al.* Influence of mechanical symptoms on treatment outcomes for meniscal tear in the setting of osteoarthritis. In: ACR Meeting Abstracts. 2013. DOI:10.1002/art.2013.65.issue-s10.

333 Osteras H, Torstensen T, Selven E, Haugerud E. High dosage medical exercise therapy or arthroscopic treatment for patients with degenerative meniscus injury: A pilot study. In: Physiotherapy. 2011: eS946–7.

334 Gauffin H, Sonesson S, Meunier A, Magnusson H, Kvist J. Knee Arthroscopic Surgery in Middle-Aged Patients With Meniscal Symptoms: A 3-Year Follow-up of a Prospective, Randomized Study. *Am J Sports Med* 2017; **45**: 2077–84.

335 Järvinen T, Sihvonen R, Paavola M, *et al.* Arthroscopic Partial Meniscectomy vs Sham Surgery for Degenerative Meniscus Tear. In: Arthroscopy: The Journal of Arthroscopic & Related Surgery. 2014: e38.

336 Sihvonen R, Paavola M, Malmivaara A, *et al.* Arthroscopic partial meniscectomy versus placebo surgery for a degenerative meniscus tear: a 2-year follow-up of the randomised controlled trial. *Ann Rheum Dis* 2018; **77**: 188–95.

337 Järvinen T, Sihvonen R, Englund M, Turkiewicz A. Mechanical symptoms and arthroscopic partial meniscectomy in patients with degenerative meniscus tear: A secondary analysis of a randomized, placebo controlled trial. In: Arthroscopy - Journal of Arthroscopic and Related Surgery. 2016: e24.

338 Katz JN, Losina E. The cost-effectiveness of arthroscopic partial meniscectomy: comparing apples and oranges. *Osteoarthr Cartil* 2018; **26**: 152–3.

339 Liebs TR, Ziebarth K, Berger S. Randomized Controlled Trials for Arthroscopy in Degenerative Knee Disease: Was Conservative Therapy Appropriately Tried Prior to Arthroscopy? *Arthrosc J Arthrosc Relat Surg* 2018; **34**: 1680-1687.e6.

340 Lubowitz JH, D'Agostino Jr. RB, Provencher MT, Rossi MJ, Brand JC. Can We Trust Knee Meniscus Studies? One-Way Crossover Confounds Intent-to-Treat Statistical Methods. *Arthrosc - J Arthrosc Relat Surg* 2016; **32**: 2187–90.

341 Katz JN, Wright J, Spindler KP, *et al.* Predictors and Outcomes of Crossover to Surgery from Physical Therapy for Meniscal Tear and Osteoarthritis. *J Bone Jt Surg - Am Vol* 2016; **98**: 1890–6.

342 Buldu MT, Marsh JL, Arbuthnot J. Mechanical Symptoms of Osteoarthritis in the Knee and Arthroscopy. *J Knee Surg* 2015; **29**: 396–402.

343 Sihvonen R, Paavola M, Malmivaara A, *et al.* Supplementary Appendix: Arthroscopic partial meniscectomy versus sham surgery for a degenerative meniscal tear. *N Engl J Med* 2013; **369**: 2515–24.

344 Holihan JL, Flores-Gonzalez JR, Mo J, Ko TC, Kao LS, Liang MK. How Long Is Long Enough to Identify a Surgical Site Infection? *Surg Infect (Larchmt)* 2017; **18**: 419–23.

345 Mise Y, Day RW, Vauthey J-N, *et al.* After Pancreatectomy, the "90 Days from Surgery" Definition Is Superior to the "30 Days from Discharge" Definition for Capture of Clinically Relevant Readmissions. *J Gastrointest Surg* 2016; **20**: 77–84.

346 Lankiewicz JD, Yokoe DS, Olsen MA, *et al.* Beyond 30 Days: Does Limiting the Duration of Surgical Site Infection Follow-up Limit Detection? *Infect Control Hosp Epidemiol* 2012; **33**: 202–4.

347 World Health Organisation. International Statistical Classification of Diseases and Related Health Problems 10th Revision. WHO. 2016. http://apps.who.int/classifications/icd10/browse/2016/en (accessed Jan 12, 2018).

348 Noble M, Wright G, Smith G, Dibben C. Measuring Multiple Deprivation at the Small-Area Level. *Environ Plan A Econ Sp* 2006; **38**: 169–85.

349 Deaths - Office for National Statistics. 2018 https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths (accessed Jan 16, 2018).

350 Volmink JA, Newton JN, Hicks NR, Sleight P, Fowler GH, Neil HA. Coronary event and case fatality rates in an English population: results of the Oxford myocardial infarction incidence study. The Oxford Myocardial Infarction Incidence Study Group. *Heart* 1998; **80**: 40–4.

351 Spencer FA, Emery C, Joffe SW, *et al.* Incidence rates, clinical profile, and outcomes of patients with venous thromboembolism. The Worcester VTE study. *J Thromb Thrombolysis* 2009; **28**: 401–9.

352 Feigin VL, Forouzanfar MH, Krishnamurthi R, *et al.* Global and regional burden of stroke during 1990-2010: findings from the Global Burden of Disease Study 2010. *Lancet (London, England)* 2014; **383**: 245–54.

353 Geirsson ÁJ, Statkevicius S, Víkingsson A. Septic arthritis in Iceland 1990-2002: Increasing incidence due to iatrogenic infections. *Ann Rheum Dis* 2008; **67**: 638–43.

354 Hunt LP, Ben-Shlomo Y, Clark EM, *et al.* 45-day mortality after 467779 knee replacements for osteoarthritis from the National Joint Registry for England and Wales: An observational study. *Lancet* 2014; **384**: 1429–36.

355 Hunt LP, Ben-Shlomo Y, Clark EM, *et al.* 90-day mortality after 409 096 total hip replacements for osteoarthritis, from the National Joint Registry for England and Wales: A retrospective analysis. *Lancet* 2013; **382**: 1097–104.

356 Silverstein MD, Heit JA, Mohr DN, Petterson TM, O'Fallon WM, Melton LJ. Trends in the Incidence of Deep Vein Thrombosis and Pulmonary Embolism. *Arch Intern Med* 1998; **158**: 585.

357 Kearon C, Akl EA, Comerota AJ, *et al.* Antithrombotic Therapy for VTE Disease Antithrombotic Therapy and Prevention of Thrombosis , 9th ed : American College of Chest Physicians. *Chest* 2012; **141**: e419S-e496S.

358 Douketis JD, Kearon C, Bates S, Duku EK, Ginsberg JS. Risk of Fatal Pulmonary Embolism in Patients With Treated Venous Thromboembolism. *Jama* 1998; **279**: 458–62.

359 NICE 2018. Reducing venous thromboembolism risk: orthopaedic surgery. 2018 https://pathways.nice.org.uk/pathways/venous-thromboembolism/reducing-venous-thromboembolism-risk-orthopaedic-surgery (accessed June 15, 2018).

360 Wyatt RWB, Maletis GB, Lyon LL, Schwalbe J, Avins AL. Efficacy of Prophylactic Antibiotics in Simple Knee Arthroscopy. *Arthrosc - J Arthrosc Relat Surg* 2017; **33**: 157–62.

361 Kurzweil PR. Antibiotic Prophylaxis for Arthroscopic Surgery. *Arthrosc - J Arthrosc Relat Surg* 2006; **22**: 452–4.

362 D'Angelo GL, Ogilvie-Harris DJ. Septic arthritis following arthroscopy, with cost/benefit analysis of antibiotic prophylaxis. *Arthrosc J Arthrosc Relat Surg* 1988; **4**: 10–4.

363 Hunt LP, Ben-Shlomo Y, Whitehouse MR, Porter ML, Blom AW. The Main Cause of Death Following Primary Total Hip and Knee Replacement for Osteoarthritis. *J Bone Jt Surg* 2017; **99**: 565–75.

364 Goddard M, Smith P. Equity of access to health care services : Theory and evidence from the UK. *Soc Sci Med* 2001; **53**: 1149–62.

365 Katikireddi SV, Leyland AH, McKee M, Ralston K, Stuckler D. Patterns of mortality by occupation in the UK, 1991–2011: a comparative analysis of linked census and mortality records. *Lancet Public Heal* 2017; **2**: e501–12.

366 Thornton JG, Lilford RJ, Johnson N. Decision analysis in medicine. *BMJ* 1992; **304**: 1099–103.

367 Tubach F, Ravaud P, Baron G, *et al.* Evaluation of clinically relevant states in patient reported outcomes in knee and hip osteoarthritis: The patient acceptable symptom state. *Ann Rheum Dis* 2005; **64**: 34–7.

368 Zanetti M, Pfirrmann CW a, Schmid MR, Romero J, Seifert B, Hodler J. Patients with Suspected Meniscal Tears : Prevalence of Abnormalities Seen. *Am J Radiol* 2003; **181**: 635–41.

369 Englund M, Roemer FW, Hayashi D, Crema MD, Guermazi A. Meniscus pathology, osteoarthritis and the treatment controversy. *Nat Rev Rheumatol* 2012; **8**: 412–9.

370 Beaufils P, Becker R, Kopf S, Matthieu O, Pujol N. The knee meniscus: management of traumatic tears and degenerative lesions. *EFORT Open Rev* 2017; **2**: 195–203.

371 Winter AR, Collins JE, Katz JN. The likelihood of total knee arthroplasty following arthroscopic surgery for osteoarthritis: a systematic review. *BMC Musculoskelet Disord* 2017; **18**: 408.

372 Parry E, Ogollah R, Peat G. Significant pain variability in persons with, or at high risk of, knee osteoarthritis: preliminary investigation based on secondary analysis of cohort data. *BMC Musculoskelet Disord* 2017; **18**: 1–11.

373 Raynauld J-P, Martel-Pelletier J, Haraoui B, *et al.* Risk factors predictive of joint replacement in a 2-year multicentre clinical trial in knee osteoarthritis using MRI: results from over 6 years of observation. *Ann Rheum Dis* 2011; **70**: 1382–8.

374 Bruyere O, Pavelka K, Rovati LC, *et al.* Total joint replacement after glucosamine sulphate treatment in knee osteoarthritis: results of a mean 8-year observation of patients from two previous 3-year, randomised, placebo-controlled trials. *Osteoarthr Cartil* 2008; **16**: 254–60.

375 Rongen JJ, Rovers MM, van Tienen TG, *et al.* Increased risk for knee replacement surgery after arthroscopic surgery for degenerative meniscal tears: a multi-center longitudinal observational study using data from the osteoarthritis initiative. *Osteoarthr Cartil* 2017; **25**: 23–9.

376 Roemer FW, Kent Kwoh C, Hannon MJ, *et al.* What comes first? multitissue involvement leading to radiographic osteoarthritis: Magnetic resonance imaging-based trajectory analysis over four years in the osteoarthritis initiative. *Arthritis Rheumatol* 2015; **67**: 2085–96.

377 Persson F, Turkiewicz A, Bergkvist D, Neuman P, Englund M. The risk of symptomatic knee osteoarthritis after arthroscopic meniscus repair vs partial meniscectomy vs the general population. *Osteoarthr Cartil* 2018; **26**: 195–201.

378 Borkhoff CM, Hawker GA, Kreder HJ, Glazier RH, Mahomed NN, Wright JG. The effect of patients' sex on physicians' recommendations for total knee arthroplasty. *Cmaj* 2008; **178**: 681–7.

379 Dugan SA, Powell LH, Kravitz HM, Everson Rose SA, Karavolos K, Luborsky J.

Musculoskeletal Pain and Menopausal Status. *Clin J Pain* 2006; **22**: 325–31.

380 Watt FE. Musculoskeletal pain and menopause. *Post Reprod Heal* 2018; **24**: 34–43.

381 Leroux T, Ogilvie-Harris D, Dwyer T, *et al.* The risk of knee arthroplasty following cruciate ligament reconstruction : A population-based matched cohort study. *J Bone Jt Surg - Ser A* 2014; **96**: 2–10.

382 Beard D, Rees J, Rombach I, *et al.* The CSAW Study (Can Shoulder Arthroscopy Work?) - a placebo-controlled surgical intervention trial assessing the clinical and cost effectiveness of arthroscopic subacromial decompression for shoulder pain: study protocol for a randomised controlled trial. *Trials* 2015; **16**: 210.

383 Lubowitz JH, Poehling GG. Save the meniscus. *Arthrosc - J Arthrosc Relat Surg* 2011; **27**: 301–2.

384 Beaufils P, Pujol N. Management of traumatic meniscal tear and degenerative meniscal lesions. Save the meniscus. *Orthop Traumatol Surg Res* 2017; **103**: S237–44.

385 List D. The Consensus Group Technique in Social Research. *Field methods* 2001; **13**: 277–90.

386 Fearon K, Strasser F, Anker SD, *et al.* Definition and classification of cancer cachexia: An international consensus. *Lancet Oncol* 2011; **12**: 489–95.

387 Kalson NS, Borthwick LA, Mann DA, *et al.* International consensus on the definition and classification of fibrosis of the knee joint. *Bone Joint J* 2016; **98-B**: 1479–88.

388 Hunter DJ, Mcdougall JJ, Keefe FJ, *et al.* The symptoms of OA and the genesis of pain. *Rheum Dis Clin North Am* 2009; **34**: 1–19.

389 Keeney S, Hasson F, McKenna HP. A critical review of the Delphi technique as a research methodology for nursing. *Int J Nurs Stud* 2001; **38**: 195–200.

390 Powell C. The Delphi technique: Myths and realities. *J Adv Nurs* 2003; **41**: 376–82.

391 McAlindon TE, Bannuru RR, Sullivan MC, *et al.* OARSI guidelines for the non-surgical management of knee osteoarthritis. *Osteoarthr Cartil* 2014; **22**: 363–88.

392 Crossley KM, van Middelkoop M, Callaghan MJ, Collins NJ, Rathleff MS, Barton CJ. 2016 Patellofemoral pain consensus statement from the 4th International Patellofemoral Pain Research Retreat, Manchester. Part 2: recommended physical interventions (exercise, taping,

bracing, foot orthoses and combined interventions). *Br J Sports Med* 2016; **50**: 844–52.

393 Abram SGF, Judge A, Beard DJ, Price AJ. Adverse outcomes after arthroscopic partial meniscectomy: a study of 700 000 procedures in the national Hospital Episode Statistics database for England. *Lancet* 2018; **392**: 2194–202.

394 Mosich GM, Lieu V, Ebramzadeh E, Beck JJ. Operative Treatment of Isolated Meniscus Injuries in Adolescent Patients: A Meta-Analysis and Review. *Sport Heal A Multidiscip Approach* 2018; **10**: 311–6.

395 Kaminski R, Kulinski K, Kozar-Kaminska K, *et al.* A Prospective, Randomized, Double-Blind, Parallel-Group, Placebo-Controlled Study Evaluating Meniscal Healing, Clinical Outcomes, and Safety in Patients Undergoing Meniscal Repair of Unstable, Complete Vertical Meniscal Tears (Bucket Handle) Augmented wit. *Biomed Res Int* 2018; **2018**: 1–9.

396 Biedert RM. Treatment of intrasubstance meniscal lesions: a randomized prospective study of four different methods. *Knee Surg Sports Traumatol Arthrosc* 2000; **8**: 104–8.

397 Xu C, Zhao J. A meta-analysis comparing meniscal repair with meniscectomy in the treatment of meniscal tears: the more meniscus, the better outcome? *Knee Surg Sports Traumatol Arthrosc* 2015; **23**: 164–70.

398 Ardern CL, Ekas G, Grindem H, *et al.* 2018 International Olympic Committee Consensus Statement on Prevention, Diagnosis, and Management of Pediatric Anterior Cruciate Ligament Injuries. *Orthop J Sport Med* 2018; **6**: 20.