Long-term Rates of Knee Arthroplasty in a Cohort of 830,000 Patients with a History of Arthroscopic Partial Meniscectomy

ABSTRACT

AIM

To determine the long-term risk of undergoing knee arthroplasty in a cohort of patients with meniscal tears who had undergone arthroscopic partial meniscectomy (APM).

METHODS

A retrospective national cohort of patients with a history of isolated APM were identified over a twenty-year period. Patients with prior surgery to the same knee were excluded. The primary outcome was knee arthroplasty. Hazard ratios were adjusted by patient age, sex, year of APM, Charlson comorbidity index, regional deprivation, rurality, ethnicity. Risk of arthroplasty in the index knee was compared to the patient's contralateral knee (with versus without a history of APM).

RESULTS

834,393 patients were included (mean age 50 years; 37% female). Of those with at least 15-years of follow up, 13.49% (16256/120493; 95% CI 13.30-13.69) underwent subsequent arthroplasty within this time. In women, 22.07% (95% confidence interval [CI] 21.64-22.51) underwent arthroplasty within 15 years in comparison to 9.91% men (95% CI 9.71-10.12), corresponding to a risk ratio (RR) of 2.00 (95% CI 1.95-2.06). Relative to the general population, patients with a history of APM were 10.27 times (RR; 95% CI 10.07-10.47) more likely to undergo arthroplasty rising to 39.62 times (RR; 95% CI 27.68-56.70) at a younger age (30-39-years). In patients with a history of APM in only one knee, the risk of arthroplasty in that knee was greatly elevated in comparison to the contralateral knee (no APM) (HR 2.99; 95% CI 2.95-3.02).

CONCLUSIONS

Patients developing a meniscal tear, undergoing APM, are at greater risk of knee arthroplasty than the general population and this risk is three-times greater in the patient's affected knee than the contralateral knee. Women in the cohort were at double the risk of progressing to knee arthroplasty versus men. These important new reference data will inform shared-decision making and enhanced approaches to treatment, prevention, and clinical surveillance.

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- Thirteen percent of patients underwent knee arthroplasty within 15-years of APM and patients with a history of APM were ten-times more likely to undergo knee arthroplasty annually as individuals without a history of APM.
- Women were twice as likely to undergo subsequent knee arthroplasty as men.
- 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).

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INTRODUCTION

Patients sustaining a meniscal tear in the knee are known to be at risk of osteoarthritis.[1–3] Despite the prevalence of meniscal injury, and a high-rate of surgical intervention, the long-term outcomes in this population are poorly defined.[4,5] 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.[6,7]

Small studies have investigated rates of radiographic progression in patients with meniscal damage, however radiographic findings may not reflect clinical symptoms.[8] In comparison, knee arthroplasty is an objective end-point that has been used as a surrogate marker for end-stage symptomatic osteoarthritis in surgical and pharmacological studies.[6,9–11] 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.[12,13] These studies were, however, limited by small study numbers, short follow up, incomplete data capture from insurance company or regional records, failure to identify surgical treatments undertaken, and failure to match by affected knee. An understanding of the risk factors for progressive osteoarthritis is required for individualised consent and to guide optimal care provision.

The purpose of this study was to determine the absolute and relative (versus general population data and the patient's other knee) risk of knee arthroplasty in patients with history of meniscal damage and APM. Differences in outcome associated with sex, age, comorbidity, deprivation, and ethnicity were investigated.

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METHODS

Data source

Data from the National Health Service (NHS) Hospital Episode Statistics (HES) database for England, UK, was provided by NHS Digital (application DARS-NIC-68703).[14] HES includes episodes of care delivered in treatment centres (including those in the independent sector) funded by the NHS, episodes of care in England where patients are resident outside of England, and privately funded patients treated within NHS hospitals. Where required, age-sex matched national population estimates were extracted from census publications.[15]

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 1).[16] 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 (first 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 identify and the time to repeat APM recorded. 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.[17] 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.

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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 (derived with maximum 5-year diagnosis code lookback period), year of treatment (APM), rurality, and ethnicity respectively.[18–21] 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 national 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.

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RESULTS

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 1). Extraction of the arthroplasty cohort is summarised in Appendix 2. The mean age of the APM cohort was 49.65 years (standard deviation [SD] 15.04); 36.97% female (Table 1). Overall, 9.78% (53272/544582; 95% confidence interval [CI] 9.70-9.86) underwent knee arthroplasty within 5 years, 12.16% (34215/281291; 95% CI 12.04-12.28) within 10 years, and 13.49% (16256/120493; 95% CI 13.30-13.69) within 15 years (Table 1).

The risk of arthroplasty was greater in women (adjusted hazard ratio [HR] 1.42; 95% CI 1.40-1.43; Table 2, Figure 2A, Figure 2B). At 15 years, females were twice as likely to have undergone knee arthroplasty (risk ratio 2.01; 95% CI 1.95-2.06), with an absolute proportion of 22.07% (95% CI 21.64-22.51) in comparison to 9.91% (95% CI 9.71-10.12) in males. The rate of arthroplasty over time by age-group and sex is shown in Figure 2B.

Older patients (when undergoing APM) were more likely to undergo subsequent arthroplasty (adjusted HR 1.37 per five years; 95% CI 1.37-1.37; Table 2). For patients aged 60-79 years, 34.80% (7449/21408; 95% CI 34.16-35.44) underwent arthroplasty within 15 years (Table 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 1.03-1.05). The risk of knee arthroplasty increased over the period of the study (adjusted HR 1.12 per five years; 95% CI 1.11-1.13). Patients in regions of increased deprivation and patients of white ethnicity were at greater risk of subsequent arthroplasty (Table 2).

After undergoing a first APM, overall 6.84% (57,060/834,393; 95% CI 6.78-6.89) 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 1.37-1.43). By age group, the 1-year repeat APM rates were 2.69% (587/21783; 95% CI 2.48-2.92) in the under 20 age group, 1.98% (3477/175,497; 95% CI 1.92-2.05) in the 20-39-year group, 1.42% (5310/374591; 95% CI 1.38-1.46) in the 40-59-year group, 0.78% (1613/206,230; 95% CI 0.74-0.82) in the 60-79-year group, and 0.38% (37/9690; 95% CI 0.27-0.53) in the 80-plus age group.

In 2016-17, the overall rate of knee arthroplasty was 1.81% (95% CI 1.78-1.84) in patients (aged 30 or older) with a recorded history of APM and approximately 0.17% (95% CI 0.17-0.17) 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 10.07-10.47) the general population. Although the absolute annual rate of knee arthroplasty was low, the relative risk of undergoing knee arthroplasty in a younger age

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group was elevated more than older age groups, as shown in Table 3. Patients aged 30-39 with a history of a previous APM were 39.62 times (RR; 95% CI 27.68-56.70) more likely to undergo knee arthroplasty than the general population, in comparison to 6.44 times (RR; 95% CI 6.22-6.67) more likely for the over 69 age group.

Results comparing the index knee with the contralateral knee are shown in Figure 3. 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 3A. This difference corresponds to an adjusted hazard ratio of 2.99 (95% CI 2.95-3.02). Figure 3B 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. The greater risk of progressive osteoarthritis observed in the index knee in comparison to the contralateral knee was observed in both males and, to a greater extent, female patients, as shown in Figure 4.

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DISCUSSION

Principal findings

This study has defined the long-term risk of undergoing knee arthroplasty in patients with a meniscal tear 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.

Comparison with other studies

Previous studies investigating the overall relative risk of knee arthroplasty following meniscal damage 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.[12] The relative risk in our 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.[13] Unlike our study, however, 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.[13]

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.[6] The included studies were small and had relatively short periods of follow up, however these reported rates are similar to the findings in our study. The proportion of patients undergoing subsequent arthroplasty in our study was greater in older age groups (23.36% of patients aged 60-79 years) as may be expected from the higher rates of degenerative knee disease in this population.[22,23] 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.[24,25]

Although the absolute risk of undergoing a knee arthroplasty at a young age was low, the relative risk was markedly elevated for patients with a history of APM in comparison to the general population. This finding confirms that meniscal injury 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.[26] Our study utilised knee

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arthroplasty as the primary outcome rather than a radiographic outcome which is subjective and may not be correlated with symptomatology.[8,9] One previous study utilising a radiographic outcome, however, reported that half of patients have evidence of osteoarthritis radiographically 10-20 years after meniscectomy.[27] This corresponded to a ten times greater odds in comparison to an age-sex matched group without a history of knee injury and was therefore very similar to the relative risk of knee arthroplasty we observed in our cohort.[27] 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.[28]

Previous studies have suggested a higher prevalence of osteoarthritis, including knee osteoarthritis, in women in comparison to men.[23,29] Despite this, there is evidence that, at a population level, women may be less likely to undergo arthroplasty.[29,30] Our findings are different and women in our cohort of patients 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 our exclusion of patients undergoing previous knee surgery reduces this possibility and, furthermore, the sex difference in outcome was detected even after age-group matching and multi-variable adjustments. Our 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.[31,32]

Other patient factors associated with an increased risk of knee arthroplasty in our study were regional deprivation, 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.[33] The reasons for these observations are likely to be multi-factorial, related to differences in care seeking behaviour or differences in access to treatment.[34,35] Communication challenges and cultural differences may also play a role in access to healthcare.[36] It must be noted, however, that all patients in our cohort had already 'sought care', undergoing APM surgery at the point of inclusion, and therefore we caution that the observed differences in subsequent arthroplasty rates should not be solely attributed to differences in care seeking behaviour or access to healthcare.

Recently, the rate of adverse outcomes occurring within 90-days of APM has been reported in the same population as this study.[37] 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. It was concerning to find the rate of arthroplasty following APM has risen slightly over time. With refined treatment guidelines, fewer patients may undergo APM in future and a greater proportion may be treated with meniscal preservation strategies.[38,39] Our study will enable comparison of outcomes from newly

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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.

Strengths and limitations

Despite the exclusions of all patients with a history of a prior knee surgery or simultaneous arthroscopic procedures including ligament reconstruction, this is the largest cohort of meniscal injury or APM patients that has been reported. This large sample size of prospectively recorded longitudinal data enhances the precision of our findings and ability to investigate the influence of patient-specific factors.

We were able to calculate the relative risk of knee arthroplasty in comparison to individuals in the general population without a history of APM. There are, however, some potential sources of unmeasured confounding such as body mass index and severity of pre-existing osteoarthritis. We aimed to minimise the impact of these factors by the inclusion of Charlson comorbidity index and age-group in our analysis, and by using an objective criterion for inclusion (undergoing APM). Hospitals rely on procedure coding in HES for financial reimbursement, providing a strong incentive for coding accuracy.[14] The coding of arthroscopic and arthroplasty procedures has not been specifically validated but other validation studies are supportive.[40,41]

Our cohort of patients first sustained a meniscal tear and then underwent APM surgery, and the potential impact from both these events must be considered.[42–47] Comparing outcomes to the other knee in patients that had undergone unilateral APM versus bilateral APM we found 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.

Conclusion

Our findings confirm that patients with meniscal tears, undergoing APM, are a cohort at high-risk of progression to end-stage osteoarthritis and justify a need for careful surveillance of this population. Our study is the first to precisely inform patients and clinicians of the long-term outcomes following APM, but further study into the outcomes of non-operative treatment is still required. Women were found to be at greater risk of progressive osteoarthritis than men, but the biological, hormonal, genetic, or healthcare provision factors that might underlie this observation are unknown. 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.

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TABLES

TABLE 1:

Demographics and proportion of patients with at least 5, 10, and 15 years follow-up undergoing subsequent TKA in the period

	All index procedures		5-year outcome			10-year outcome			15-year outcome		
	n	%	n	n TKA	% (95% CI)	n	n TKA	% (95% CI)	n	n TKA	% (95% CI)
Total	834393	100.00	544,582	53272	9.78% (9.70, 9.86)	281,291	34215	12.16% (12.04, 12.28)	120,493	16256	13.49% (13.30, 13.69)
Sex											
Male	525877	63.03	349,854	23568	6.74% (6.65, 6.82)	189,731	16226	8.55% (8.43, 8.68)	85,048	8432	9.91% (9.71, 10.12)
Female	308516	36.97	194,728	29704	15.25% (15.09, 15.41)	91,560	17989	19.65% (19.39, 19.91)	35,445	7824	22.07% (21.64, 22.51)
Age group (years)											
< 20	22879	2.74	-	-	-	-	-	-	-	-	-
20 - 39	183585	22.00	137,852	361	0.26% (0.24, 0.29)	87,414	588	0.67% (0.62, 0.73)	44,719	666	1.49% (1.38, 1.61)
40 - 59	398883	47.81	259,726	18349	7.06% (6.97, 7.16)	130,109	14152	10.88% (10.71, 11.05)	53,323	7860	14.74% (14.44, 15.04)
60 - 79	218878	26.23	140,008	32702	23.36% (23.14, 23.58)	60,536	18567	30.67% (30.30, 31.04)	21,408	7449	34.80% (34.16, 35.44)
80 +	10168	1.22	6,996	1860	26.59% (25.55, 27.64)	3,232	908	28.09% (26.55, 29.68)	1,043	281	26.94% (24.27, 29.74)
Charlson comorbidity index											
0	692111	82.95	468,095	39989	8.54% (8.46, 8.62)	254,369	28371	11.15% (11.03, 11.28)	112,851	14522	12.87% (12.67, 13.07)
1 - 15	136544	16.36	73,652	12614	17.13% (16.86, 17.40)	26,042	5626	21.60% (21.11, 22.11)	7,449	1688	22.66% (21.71, 23.63)
16 - 30	5354	0.64	2,677	635	23.72% (22.12, 25.38)	834	207	24.82% (21.92, 27.90)	193	46	23.83% (18.01, 30.48)
31 - 50	384	0.05	158	34	21.52% (15.39, 28.75)	46	11	23.91% (12.59, 38.77)	-	-	-
Index of multiple deprivation (quintiles)											
1 = least deprived	186631	22.37	123,658	12118	9.80% (9.63, 9.97)	64,509	8001	12.40% (12.15, 12.66)	27,054	3805	14.06% (13.65, 14.48)
2	182705	21.90	120,060	12205	10.17% (10.00, 10.34)	62,701	8141	12.98% (12.72, 13.25)	26,509	3797	14.32% (13.90, 14.75)
3	174721	20.94	115,137	11641	10.11% (9.94, 10.29)	59,596	7491	12.57% (12.30, 12.84)	25,420	3565	14.02% (13.60, 14.46)
4	152008	18.22	98,454	9400	9.55% (9.36, 9.73)	50,609	5960	11.78% (11.50, 12.06)	22,227	2882	12.97% (12.53, 13.41)
5 = most deprived	129817	15.56	82,092	7459	9.09% (8.89, 9.28)	41,618	4437	10.66% (10.37, 10.96)	18,420	2156	11.70% (11.24, 12.18)
Missing	8511	1.02									
Rurality											
Urban	637911	76.45	414,851	39885	9.61% (9.52, 9.70)	215,014	25567	11.89% (11.75, 12.03)	92,915	12118	13.04% (12.83, 13.26)
Rural	192136	23.03	127,627	13271	10.40% (10.23, 10.57)	65,297	8611	13.19% (12.93, 13.45)	27,046	4117	15.22% (14.80, 15.66)
Missing	4346	0.52									
Ethnicity											
White	735248	88.12	482,429	51048	10.58% (10.49, 10.67)	246,714	32876	13.33% (13.19, 13.46)	103,915	15692	15.10% (14.88, 15.32)
Asian	22557	2.70	12,633	1076	8.52% (8.04, 9.02)	5,165	598	11.58% (10.72, 12.48)	1,722	231	13.41% (11.84, 15.12)
Black	12136	1.45	6,861	300	4.37% (3.90, 4.88)	2,805	193	6.88% (5.97, 7.88)	1,083	88	8.13% (6.57, 9.92)
Mixed	4752	0.57	2,598	144	5.54% (4.69, 6.49)	1,017	93	9.14% (7.44, 11.09)	291	33	11.34% (7.94, 15.56)
Other	5404	0.65	3,136	84	2.68% (2.14, 3.31)	1,495	39	2.61% (1.86, 3.55)	755	19	2.52% (1.52, 3.90)
Missing	54296	6.51									

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

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TABLE 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

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*

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TABLE 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

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

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FIGURES

FIGURE 1: Flow chart illustrating extraction of patient level cohort

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

FIGURE 2A: Survival curve (not undergoing knee arthroplasty) by gender*

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

FIGURE 2B: Survival curve (not undergoing knee arthroplasty) by age and gender*

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

FIGURE 3A: Unilateral APM: Index knee versus contralateral knee (no APM) *

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

FIGURE 3B: Bilateral APM: Index knee versus contralateral knee (simultaneous or staged APM) *

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

FIGURE 4: Index knee versus contralateral knee † for male versus female patients *

** Age group < 20 years due to small numbers; † with or without a simultaneous or staged bilateral APM.*

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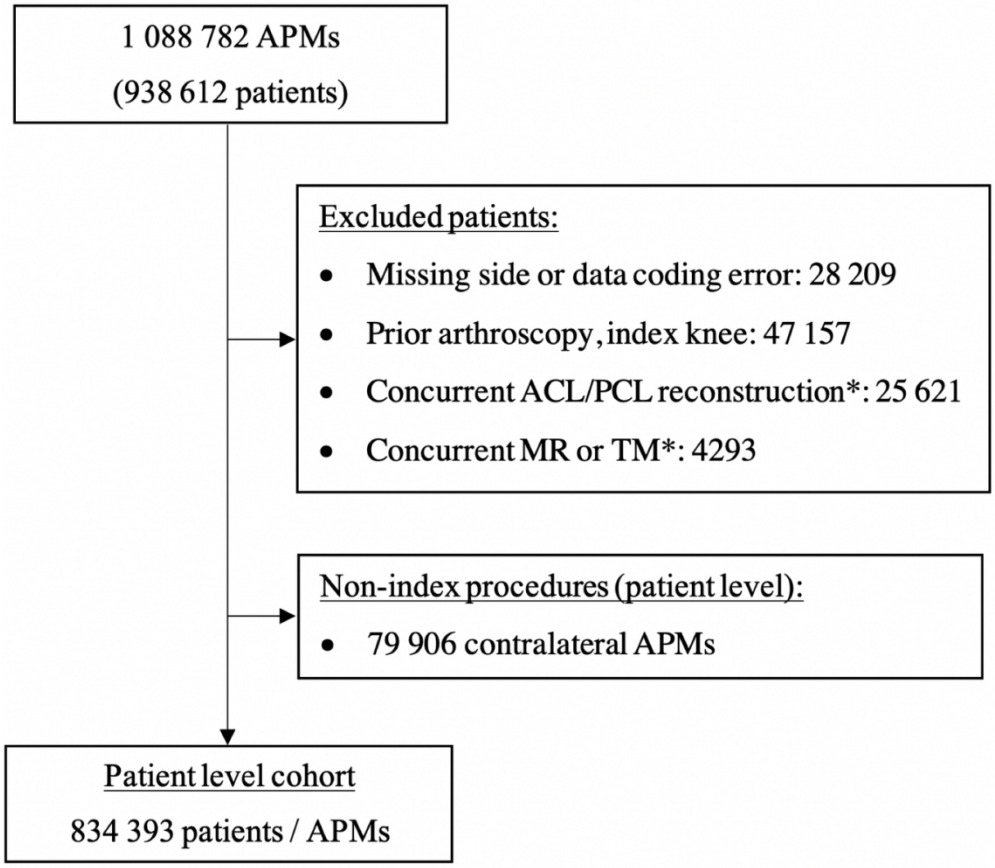


FIGURE 1: Flow chart illustrating extraction of patient level cohort

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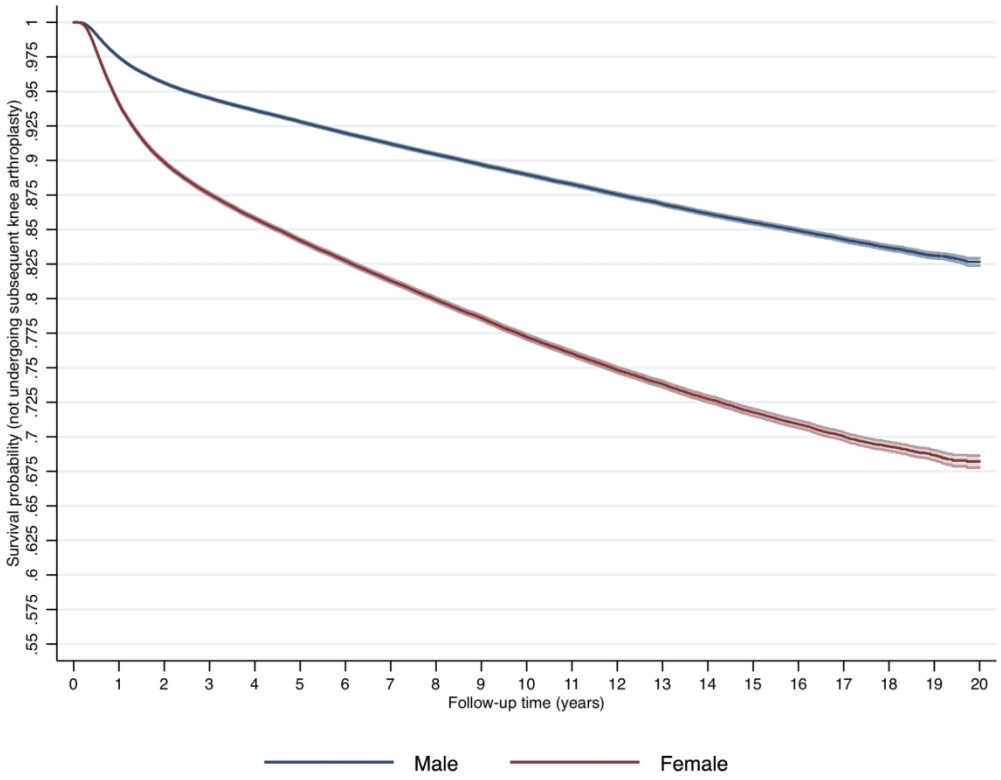


FIGURE 2A: Survival curve (not undergoing knee arthroplasty) by gender

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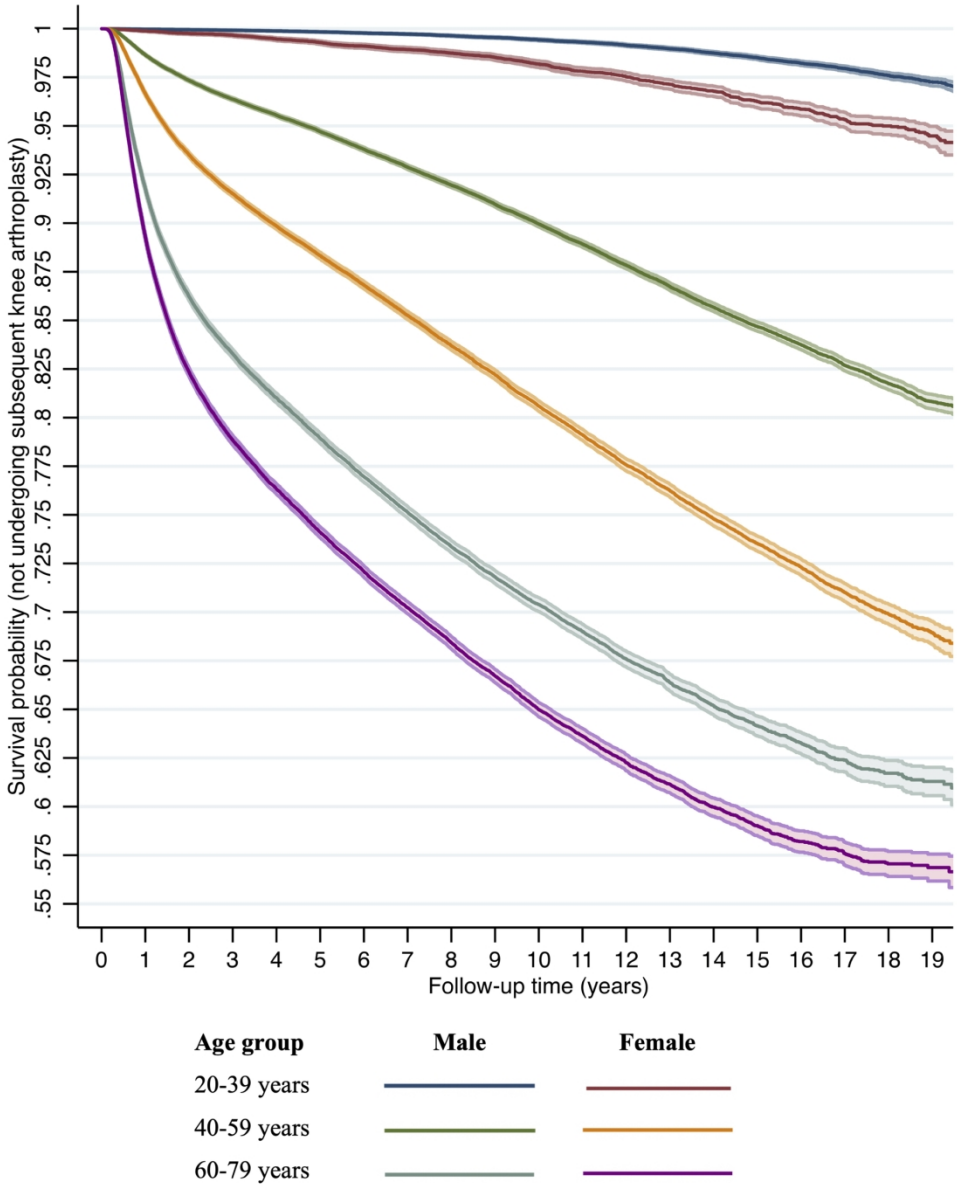


FIGURE 2B: Survival curve (not undergoing knee arthroplasty) by age and gender

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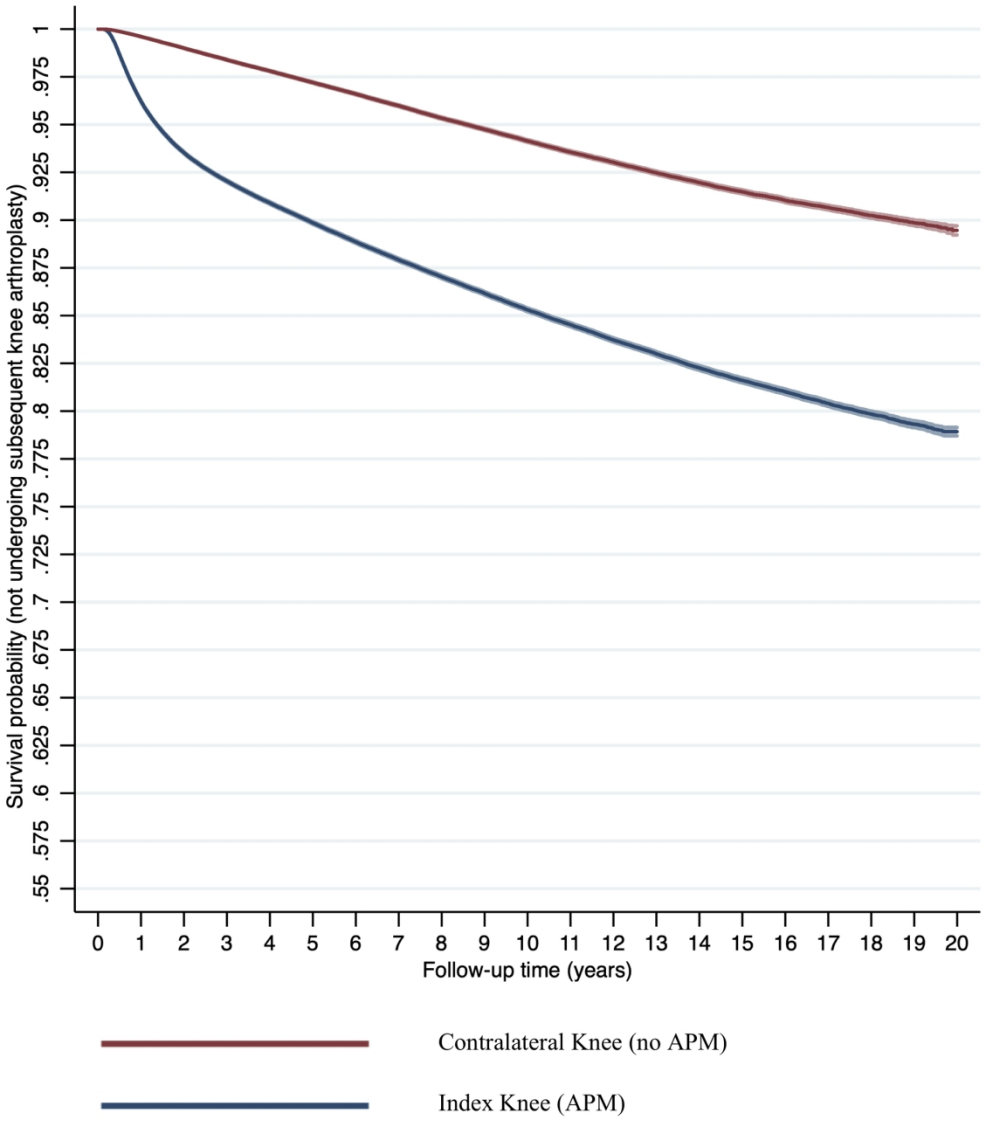


FIGURE 3A: Unilateral APM: Index knee versus contralateral knee (no APM)

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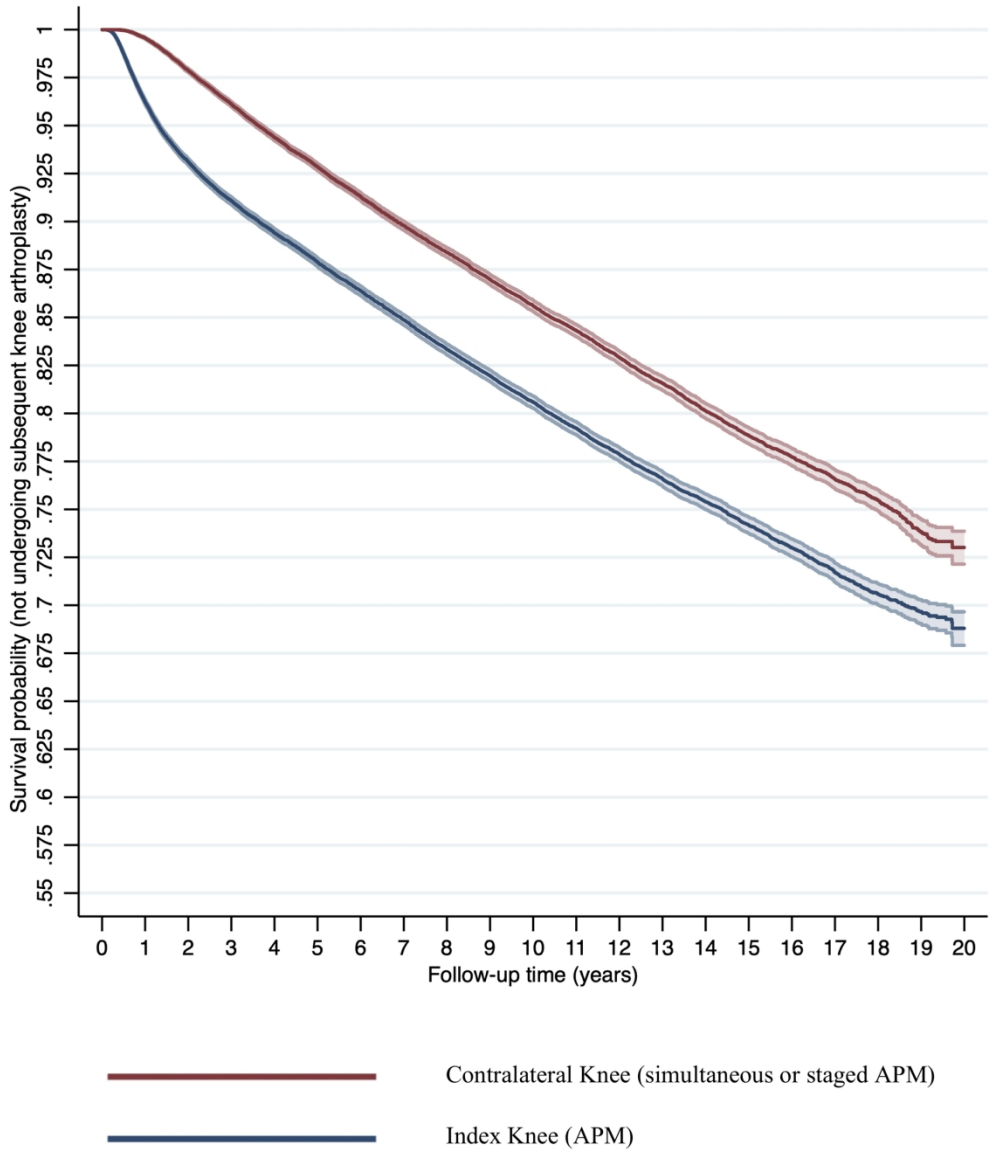


FIGURE 3B: Bilateral APM: Index knee versus contralateral knee (simultaneous or staged APM)

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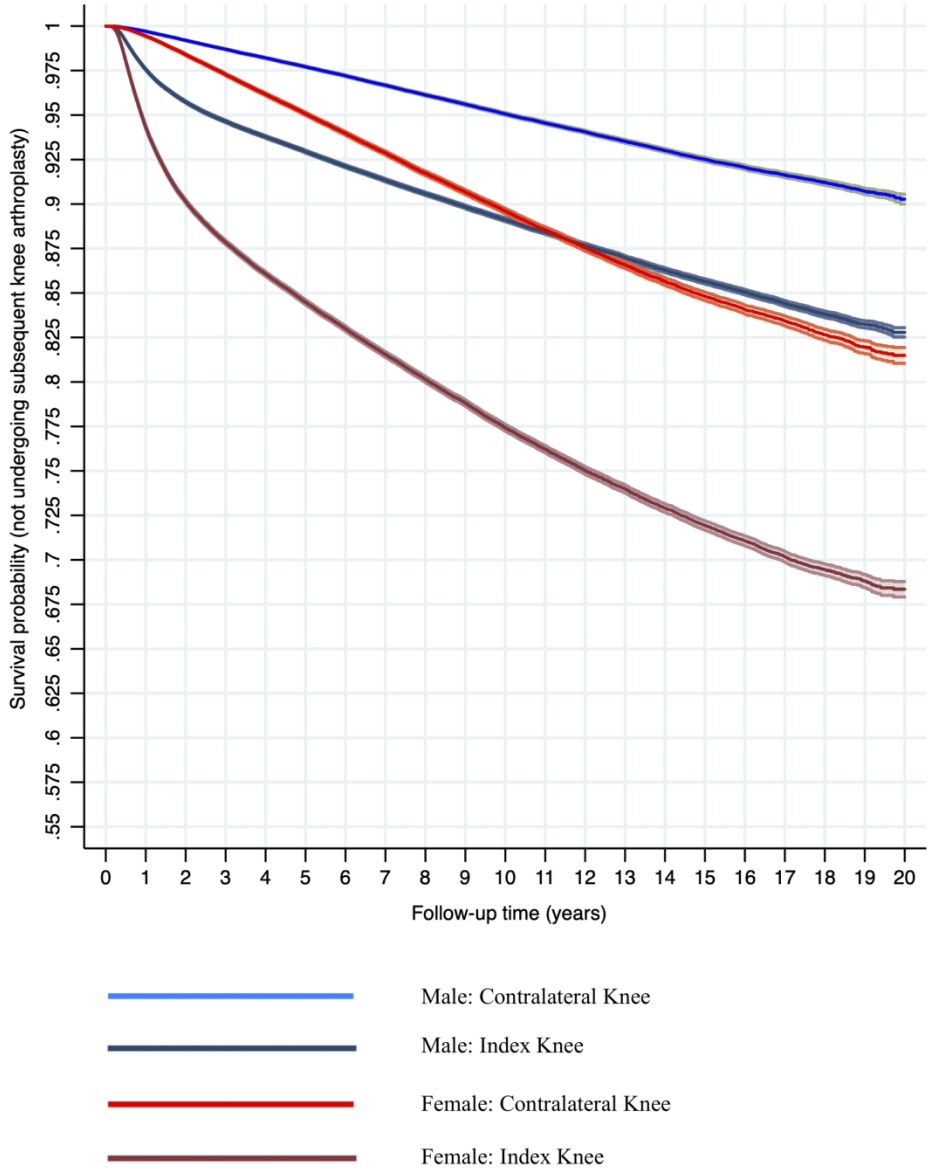


FIGURE 4: Index knee versus contralateral knee † for male versus female patients

175x224mm (300 x 300 DPI)

Appendix 1: OPCS procedure code list

PROCEDURE	OPCS 4.2	OPCS 4.3	OPCS 4.4	OPCS 4.5	OPCS 4.6	OPCS 4.7	Description
APM (inclusion)	W82.2	W82.2	W82.2	W82.2	W82.2	W82.2	Endoscopic resection of semilunar cartilage NEC
ACL/PCL (exclusion)	W74.2	W74.2	W74.2	W74.2	W74.2	W74.2	Reconstruction of intra-articular ligament NEC
ACL/PCL (exclusion)	W84.1	W84.1	W84.1	W84.1	W84.1	W84.1	Endoscopic repair of intra-articular ligament
ACL/PCL (exclusion)	W84.2	W84.2	W84.2	W84.2	W84.2	W84.2	Endoscopic reattachment of intra-articular ligament
ACL/PCL (exclusion)	W72.3	W72.3	W72.3	W72.3	W72.3	W72.3	Primary prosthetic replacement of intra-articular ligament
ACL/PCL (exclusion)	W72.4	W72.4	W72.4	W72.4	W72.4	W72.4	Prosthetic replacement of intra-articular ligament NEC
MR (exclusion)	W82.3	W82.3	W82.3	W82.3	W82.3	W82.3	Endoscopic repair of semilunar cartilage
TM (exclusion)	W82.1	W82.1	W82.1	W82.1	W82.1	W82.1	Endoscopic total excision of semilunar cartilage
Arthroplasty (outcome)*	W43.1	W43.1	W43.1	W43.1	W43.1	W43.1	Primary total prosthetic replacement of joint using cement NEC
Arthroplasty (outcome)*	W44.1	W44.1	W44.1	W44.1	W44.1	W44.1	Primary total prosthetic replacement of joint not using cement NEC
Arthroplasty (outcome)*	W44.8	W44.8	W44.8	W44.8	W44.8	W44.8	Other specified total prosthetic replacement of other joint not using cement
Arthroplasty (outcome)*	W44.9	W44.9	W44.9	W44.9	W44.9	W44.9	Unspecified total prosthetic replacement of other joint not using cement
Arthroplasty (outcome)*	W45.1	W45.1	W45.1	W45.1	W45.1	W45.1	Primary total prosthetic replacement of joint NEC
Arthroplasty (outcome)*	W45.8	W45.8	W45.8	W45.8	W45.8	W45.8	Other specified other total prosthetic replacement of other joint
Arthroplasty (outcome)*	W45.9	W45.9	W45.9	W45.9	W45.9	W45.9	Unspecified other total prosthetic replacement of other joint
Arthroplasty (outcome)*	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 (outcome)	W40.1	W40.1	W40.1	O18.1	O18.1	O18.1	Primary hybrid prosthetic replacement of knee joint using cement
Arthroplasty (outcome)	W40.8	W40.8	W40.8	O18.8	O18.8	O18.8	Other specified hybrid prosthetic replacement of knee joint using cement
Arthroplasty (outcome)	W40.9	W40.9	W40.9	O18.9	O18.9	O18.9	Unspecified hybrid prosthetic replacement of knee joint using cement
Arthroplasty (outcome)	W40.1	W40.1	W40.1	W40.1	W40.1	W40.1	Primary total prosthetic replacement of knee joint using cement
Arthroplasty (outcome)	W40.8	W40.8	W40.8	W40.8	W40.8	W40.8	Other specified total prosthetic replacement of knee joint using cement
Arthroplasty (outcome)	W40.9	W40.9	W40.9	W40.9	W40.9	W40.9	Unspecified total prosthetic replacement of knee joint using cement
Arthroplasty (outcome)	W41.1	W41.1	W41.1	W41.1	W41.1	W41.1	Primary total prosthetic replacement of knee joint not using cement
Arthroplasty (outcome)	W41.8	W41.8	W41.8	W41.8	W41.8	W41.8	Other specified total prosthetic replacement of knee joint not using cement

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Arthroplasty (outcome)	W41.9	W41.9	W41.9	W41.9	W41.9	W41.9	Unspecified total prosthetic replacement of knee joint not using cement
Arthroplasty (outcome)	W42.1	W42.1	W42.1	W42.1	W42.1	W42.1	Primary total prosthetic replacement of knee joint NEC
Arthroplasty (outcome)	W42.8	W42.8	W42.8	W42.8	W42.8	W42.8	Other specified other total prosthetic replacement of knee joint
Arthroplasty (outcome)	W42.9	W42.9	W42.9	W42.9	W42.9	W42.9	Unspecified other total prosthetic replacement of knee joint
Arthroplasty (outcome)*	W58.1	W58.1	W58.1	W58.1	W58.1	W58.1	Primary resurfacing arthroplasty of joint

**: Additional matched site-specific (knee) code required (Z846, Z765, Z845, Z844, Z774, or Z787); APM = arthroscopic partial meniscectomy; MR = meniscal repair; TM = total meniscectomy.*

Previous arthroscopy screening list (case exclusion)

OPCS 4.2	OPCS 4.3	OPCS 4.4	OPCS 4.5	OPCS 4.6	OPCS 4.7	Description
W74.2	W74.2	W74.2	W74.2	W74.2	W74.2	Reconstruction of intra-articular ligament NEC
W84.1	W84.1	W84.1	W84.1	W84.1	W84.1	Endoscopic repair of intra-articular ligament
W84.2	W84.2	W84.2	W84.2	W84.2	W84.2	Endoscopic reattachment of intra-articular ligament
W72.3	W72.3	W72.3	W72.3	W72.3	W72.3	Primary prosthetic replacement of intra-articular ligament
W72.4	W72.4	W72.4	W72.4	W72.4	W72.4	Prosthetic replacement of intra-articular ligament NEC
W74.3	W74.3	W74.3	W74.3	W74.3	W74.3	Reconstruction of extra-articular ligament NEC
W72.5	W72.5	W72.5	W72.5	W72.5	W72.5	Primary prosthetic replacement of extra-articular ligament
W72.6	W72.6	W72.6	W72.6	W72.6	W72.6	Prosthetic replacement of extra-articular ligament NEC
W74.8	W74.8	W74.8	W74.8	W74.8	W74.8	Other specified other reconstruction of ligament
W74.9	W74.9	W74.9	W74.9	W74.9	W74.9	Unspecified other reconstruction of ligament
W77.8	W77.8	W77.8	W77.7	W77.7	W77.7	Transposition of ligament for stabilisation of joint
W77.8	W77.8	W77.8	W77.8	W77.8	W77.8	Other specified stabilising operations on joint
W72.1	W72.1	W72.1	W72.1	W72.1	W72.1	Primary prosthetic replacement of multiple ligaments
W72.8	W72.8	W72.8	W72.8	W72.8	W72.8	Other specified prosthetic replacement of ligament
W72.9	W72.9	W72.9	W72.9	W72.9	W72.9	Unspecified prosthetic replacement of ligament
W73.1	W73.1	W73.1	W73.1	W73.1	W73.1	Primary extra-articular prosthetic augmentation of intra-articular ligament NEC
W73.2	W73.2	W73.2	W73.2	W73.2	W73.2	Extra-articular prosthetic augmentation of intra-articular ligament NEC
W73.3	W73.3	W73.3	W73.3	W73.3	W73.3	Primary prosthetic reinforcement of intra-articular ligament NEC
W73.4	W73.4	W73.4	W73.4	W73.4	W73.4	Prosthetic reinforcement of intra-articular ligament NEC
W73.8	W73.8	W73.8	W73.8	W73.8	W73.8	Other specified prosthetic reinforcement of ligament
W73.9	W73.9	W73.9	W73.9	W73.9	W73.9	Unspecified prosthetic reinforcement of ligament
W74.8	W74.8	W74.8	W74.8	W74.8	W74.8	Other specified other reconstruction of ligament
W74.9	W74.9	W74.9	W74.9	W74.9	W74.9	Unspecified other reconstruction of ligament
W77.8	W77.8	W77.8	W77.7	W77.7	W77.7	Transposition of ligament for stabilisation of joint
W77.8	W77.8	W77.8	W77.8	W77.8	W77.8	Other specified stabilising operations on joint

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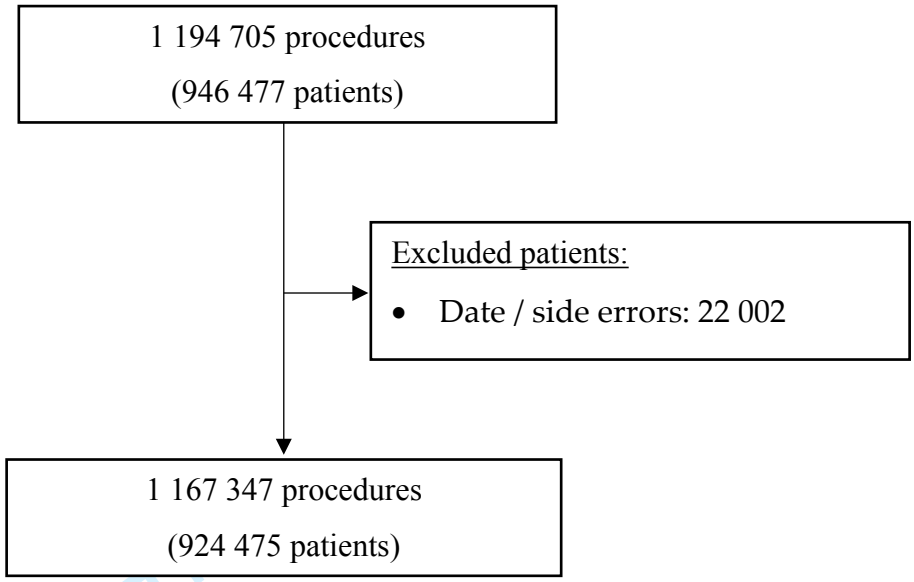
W84.8	W84.8	W84.8	O19.1	O19.1	O19.1	Endoscopic autologous matrix induced chondrogenesis of joint
W83.8	W83.8	W83.7	W83.7	W83.7	W83.7	Endoscopic osteochondral autograft
-	-	-	W89.2	W89.2	W89.2	Endoscopic harvest of autologous chondrocytes
W85.8	W85.3	W85.3	W85.3	W85.3	W85.3	Endoscopic autologous chondrocyte implantation of knee joint
W83.1	W83.1	W83.1	W83.1	W83.1	W83.1	Endoscopic drilling of lesion of articular cartilage
W83.2	W83.2	W83.2	W83.2	W83.2	W83.2	Endoscopic fixation of lesion of articular cartilage
W83.3	W83.3	W83.3	W83.3	W83.3	W83.3	Endoscopic shaving of articular cartilage
W83.8	W83.8	W83.4	W83.4	W83.4	W83.4	Endoscopic articular abrasion chondroplasty
W83.8	W83.8	W83.5	W83.5	W83.5	W83.5	Endoscopic articular thermal chondroplasty
W84.8	W84.8	W83.6	W83.6	W83.6	W83.6	Endoscopic excision of articular cartilage NEC
W83.8	W83.8	W83.8	W83.8	W83.8	W83.8	Other specified therapeutic endoscopic operations on other articular cartilage
W83.9	W83.9	W83.9	W83.9	W83.9	W83.9	Unspecified therapeutic endoscopic operations on other articular cartilage
W84.8	W84.8	W84.4	W84.4	W84.4	W84.4	Endoscopic decompression of joint
W84.8	W84.8	W84.5	W84.5	W84.5	W84.5	Endoscopic drilling of epiphysis for repair of articular cartilage
W83.8	W83.8	W89.1	W89.1	W89.1	W89.1	Endoscopic chondroplasty NEC
W83.8	W83.8	W89.8	W89.8	W89.8	W89.8	Other specified other therapeutic endoscopic operations on other articular cartilage
W83.9	W83.9	W89.9	W89.9	W89.9	W89.9	Unspecified other therapeutic endoscopic operations on other articular cartilage
W88.1	W88.1	W88.1	W88.1	W88.1	W88.1	Diagnostic endoscopic examination of joint and biopsy of lesion of joint NEC
W88.8	W88.8	W88.8	W88.8	W88.8	W88.8	Other specified diagnostic endoscopic examination of other joint
W88.9	W88.9	W88.9	W88.9	W88.9	W88.9	Unspecified diagnostic endoscopic examination of other joint
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
W87.8	W87.8	W87.8	W87.8	W87.8	W87.8	Other specified diagnostic endoscopic examination of knee joint
W87.9	W87.9	W87.9	W87.9	W87.9	W87.9	Unspecified diagnostic endoscopic examination of knee joint
W82.8	W82.8	W82.8	W82.8	W82.8	W82.8	Other specified therapeutic endoscopic operations on semilunar cartilage
W82.9	W82.9	W82.9	W82.9	W82.9	W82.9	Unspecified therapeutic endoscopic operations on semilunar cartilage
W82.2	W82.2	W82.2	W82.2	W82.2	W82.2	Endoscopic resection of semilunar cartilage NEC
W82.3	W82.3	W82.3	W82.3	W82.3	W82.3	Endoscopic repair of semilunar cartilage
W82.1	W82.1	W82.1	W82.1	W82.1	W82.1	Endoscopic total excision of semilunar cartilage
W84.8	W84.8	W84.8	O19.8	O19.8	O19.8	Other specified other therapeutic endoscopic operations on other joint structure
W84.9	W84.9	W84.9	O19.9	O19.9	O19.9	Unspecified other therapeutic endoscopic operations on other joint structure
W84.3	W84.3	W84.3	W84.3	W84.3	W84.3	Endoscopic division of synovial plica
W84.8	W84.8	W84.6	W84.6	W84.6	W84.6	Endoscopic excision of synovial plica
W84.8	W84.8	W84.8	W84.8	W84.8	W84.8	Other specified therapeutic endoscopic operations on other joint structure
W84.9	W84.9	W84.9	W84.9	W84.9	W84.9	Unspecified therapeutic endoscopic operations on other joint structure
W86.1	W86.1	W86.1	W86.1	W86.1	W86.1	Endoscopic removal of loose body from joint NEC
W86.8	W86.8	W86.8	W86.8	W86.8	W86.8	Other specified therapeutic endoscopic operations on cavity of other joint

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W86.9	W86.9	W86.9	W86.9	W86.9	W86.9	Unspecified therapeutic endoscopic operations on cavity of other joint
-	-	-	O19.2	O19.2	O19.2	Endoscopic excision of infrapatellar fat pad
W85.1	W85.1	W85.1	W85.1	W85.1	W85.1	Endoscopic removal of loose body from knee joint
W85.8	W85.8	W85.8	W85.8	W85.8	W85.8	Other specified therapeutic endoscopic operations on cavity of knee joint
W85.9	W85.9	W85.9	W85.9	W85.9	W85.9	Unspecified therapeutic endoscopic operations on cavity of knee joint
-	W80.8	W80.8	W80.8	W80.8	W80.8	Other specified debridement and irrigation of joint
-	W80.9	W80.9	W80.9	W80.9	W80.9	Unspecified debridement and irrigation of joint
W85.2	W85.2	W85.2	W85.2	W85.2	W85.2	Endoscopic irrigation of knee joint

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Appendix 2: Flow chart illustrating the extraction of the knee arthroplasty cohort



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