
# *Understanding and Preventing Surgical Site Infection in Hand Trauma Surgery*

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*I dedicate this thesis to my wife Rebecca and to my two daughters, Nina and Olive, who were born during the course of my DPhil in April 2021 and December 2022.*

"We ought to define the hand as belonging exclusively to man – corresponding in sensibility and motion with that ingenuity which converts the being who is the weakest in natural defence, to the ruler over animate and inanimate nature."

*The hand : its mechanism and vital endowments as evincing design, Sir Charles Bell, 1883*

# DECLARATION

This thesis is submitted for the degree of Doctor of Philosophy. It is the result of my own work, and except where otherwise stated, describes my own research. Any figures that have been taken from other resources are clearly indicated. Any assistance I have received is declared within Appendix 32. I confirm that this thesis adheres to the University of Oxford Medical Sciences Division regulations on word limits on DPhil theses. It does not exceed the prescribed limit of 50,000 words, with a total word count of 36,331.

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Signed: 

Date: 3rd May 2023

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# SUMMARY

Hand and wrist injuries, known as hand trauma, are a common occurrence and account for a significant number of Emergency Department (ED) visits and operations in the UK each year. Surgical site infections (SSIs) in hand trauma surgery can lead to additional morbidity, prolonged hospital stays, and even amputation. Antimicrobial sutures have been found to prevent SSIs in other surgical fields, but their effectiveness in hand trauma surgery is unknown. The aim of this thesis was to estimate the risk of SSI in hand trauma surgery and to establish the feasibility of conducting interventional trials to moderate it. The thesis comprises a systematic review, meta-analysis and meta-regression of data from 315,618 patients, an innovative national cohort analysis of primary and secondary care real world data and a multi-centre, randomised, controlled, feasibility trial of antimicrobial sutures in hand trauma surgery. Through my systematic review and meta-analysis, novel summary statistics for overall SSI in hand trauma have been generated, indicating an overall risk of 5% but in the context of substantial variation in SSI reporting. National cohort analyses have added granularity to this summary statistic, demonstrating a risk of superficial SSI of 6.2% by 30 days and 14.4% at 90 days; the deep/organ space SSI risk is 1.4% by 30 days and 2.0% at 90 days. Following this, a feasibility trial of antimicrobial interventions in hand trauma surgery was designed and executed. In seven months, 116 participants were randomised across three sites, demonstrating solid recruitment, randomisation, and adherence. Difficulty was encountered in retention. Comprehensive retention strategies are necessary for future definitive trials in this population. This thesis supports the need for evidence-based prevention of SSI in hand trauma surgery, informed by clinical trials of antimicrobial interventions.

# SCIENTIFIC ABSTRACT


**Background**

The hand and wrist are important for occupational and recreational activities. Hand and wrist injuries account for 1-in-5 ED attendances, an incidence of 5 million injuries/year and 250,000 operations/year in the United Kingdom (UK). Hand trauma, which includes fractures of the hand and wrist bones, nerve injuries, tendon injuries and traumatic amputations, can cause significant short and long-term morbidity. Emergency surgery to repair the damage is key in maximising the chances of restoring function, allowing people to return to work and independence. SSI in hand trauma surgery can result in additional significant morbidity, further emergency surgery, prolonged hospital stay and even amputation. The risk of SSI following hand trauma surgery is unknown but may be as high as 20% based on the literature. Antimicrobial sutures might prevent SSI according to studies in other surgical fields. This cannot be extrapolated to hand trauma surgery, as the patients and clinical pathway are very different from existing study populations. Further investigation of antimicrobial sutures is warranted.

**Aim**

To increase our understanding of the risk of SSI in hand trauma surgery through high quality research, and to establish the feasibility of running interventional trials to moderate it.

**Objectives**

- To estimate the risk of SSI following hand trauma surgery

- To assess the feasibility and acceptability of conducting an RCT of antimicrobial sutures versus standard sutures in patients undergoing hand trauma surgery.

**Methods**

A systematic review and meta-analysis of hand trauma surgery research to determine the pooled risk of SSI and treatments in the published literature. This is followed by an analysis of routinely collected primary (CPRD) and secondary care (HES) data to better define the risk of SSI following hand trauma surgery. Having established SSI risk in this population, a multi-centre, randomised feasibility study of antimicrobial sutures in hand trauma surgery is designed and executed. This study includes 116 participants across three hand trauma units in England.

**Results**

Systematic review and meta-analysis of 201 studies synthesising 315,618 patients demonstrated that the risk of SSI following hand trauma surgery is approximately 5% and may be as high as 10%. Analysis of 3,088 primary care records of hand trauma patients revealed that 6.2% required treatment for infection in the community with SSI-appropriate antibiotics (superficial SSI) by 30 days following surgery, rising further to 14.4% at 90 days. Analysis of HES data found that admission for treatment of post-operative infection was the commonest adverse occurrence following surgery for hand trauma. Across all 280,747 admissions, the risk of serious post-operative infection requiring re-admission (deep, organ/space SSI) was 1.4% by 30 days and 2% by 90 days. In terms of feasibility for testing antimicrobial interventions in hand trauma, 116 participants were recruited across three sites in seven months. All participants were randomised and over 99% received the allocated treatment. Follow-up was challenging and is a target for future

definitive trials. SSI incidence within the trial was comparable to figures obtained in this thesis.

**Conclusions**

SSI following hand trauma surgery is more common than is routinely quoted, is the most common reason for re-admission following surgery and results in significant antibiotic prescription in the community. There is a clear rationale for evidence-based prevention of SSI in hand trauma surgery, informed by clinical trials of antimicrobial interventions. Such trials can recruit efficiently but require innovative follow-up strategies to maximise retention.

# List of Abbreviations and Acronyms

ACS NSQIP – American College of Surgeons National Surgical Quality Improvement Program

AFP – Academic foundation programme

APC – Admitted patient care

BAPRAS – British Association of Plastic, Reconstructive and Aesthetic Surgery

BMI – Body mass index

BNF – British National Formulary

BSSH – British Society for Surgery of the Hand

BWHQ – Bluebelle Wound Healing Questionnaire

CAT – Computer adaptive test

CDC – United States Centers for Disease Control and Prevention

CENTRAL – Cochrane Central Register of Controlled Trials

CI – Confidence interval, 95% throughout

CMCJ – Carpometacarpal joint

COVID-19 – Coronavirus Disease 2019

CPRD – Clinical Practice Research Datalink

CRF – Case report form

ED – Emergency Department

FDP – Flexor digitorum profundus

FDS – Flexor digitorum superficialis

FI – Fragility index

GP – General practitioner

HAI – Health-care associated infection

HAWAII – Hand And Wrist trauma: AntimIcrobials and Infection

HES – Hospital Episode Statistics

HRQoL – Health-related quality-of-life

HTA – Health Technology Assessment

ICD – International Classification of Disease

IMD – Index of Multiple Deprivation

ISRCTN – International Standard Randomised Controlled Trial Number

K-wire – Kirschner wire

MCPJ – Metacarpophalangeal joint

MeSH – Medical subject heading

NHS – National Health Service

NICE – National Institute for Health and Care Excellence

NIHR – National Institute for Health and Care Research

NSAID – Non-steroidal anti-inflammatory drug

OPCS – Office of Population Censuses and Surveys Classification of Interventions and Procedure

ORIF – Open reduction and internal fixation

PEM – Patient Evaluation Measure

PI – Primary investigator

PIS – Patient Information Sheet

PPI – Patient and public involvement

PRISMA – Preferred Reporting Items for Systematic Reviews and Meta-Analyses

PROM – Patient-reported outcome measure

PROMIS UE – Patient-Reported Outcomes Measurement Information System® Upper Extremity

RCSEng – Royal College of Surgeons of England

RCT – Randomised controlled trial

REML – Restricted maximum likelihood

RoB – Risk of bias

RSTN – Reconstructive Surgery Trials Network

SAE – Serious adverse event

SD – Standard deviation

SRMA – Systematic review and meta-analysis

SSI – Surgical site infection

STR – Soft tissue reconstruction

STROBE – Strengthening The Reporting of OBservational studies in Epidemiology

TKR – Total knee replacement

UK – United Kingdom

USA – United States of America

WHO – World Health Organisation

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# 1 INTRODUCTION

In this Chapter, I detail the anatomy and function of the hand and wrist to demonstrate the complexity of its structure and mechanics. It is important to start with this, so that the impact of injury and infection can be appreciated. Unlike other parts of the body, the critical structures of the hand and wrist are immediately under the skin. This means that injury to the hand and wrist will often damage important anatomical structures, resulting in functional impairment. This also means that infection can easily spread from the skin, i.e. superficial infection, to the deep structures that lie immediately beneath. This is quite different from the lower limb or abdomen, where there is extensive soft tissue between the skin and the deeper structures such as nerves and tendons. I then move on to describe the epidemiology of hand trauma to contextualise the importance of research in this socioeconomically active and under-researched population. SSI is defined and its pertinence to hand trauma is explained. I conclude this Chapter with a review of current management of hand trauma, focusing on existing techniques to try to optimise outcomes, including preventing SSI. I will lay out the gaps in evidence for SSI prevention across all surgery, finally demonstrating that even the existing evidence rarely pertains to hand trauma populations, thus rationalising this thesis.

## 1.1 Anatomy of the hand and wrist

"Through the hand, as through sight and hearing, we form a conception of the outside world. It is truly the extension of our brain into the surrounding world; it is the mirror of our innermost response to the outside world."

*'Functional and surgical anatomy of the hand', Emanuel B. Kaplan 1954*

An understanding of the anatomy of the hand and wrist is fundamental to the surgical care of patients with hand trauma. The goal of hand trauma surgery is primarily to restore function to this intricate musculoskeletal unit. Traumatic injury can result in damage to the skeleton of the hand, the tendons and muscles that enable movement or the nerves that supply sensibility. Injuries to the blood vessels are surgical emergencies and without urgent repair, can result in loss of the affected limb. Therefore, I will first describe the clinically relevant bony and soft tissue anatomy of the hand and wrist, which will contextualise the importance of surgical intervention and infection.

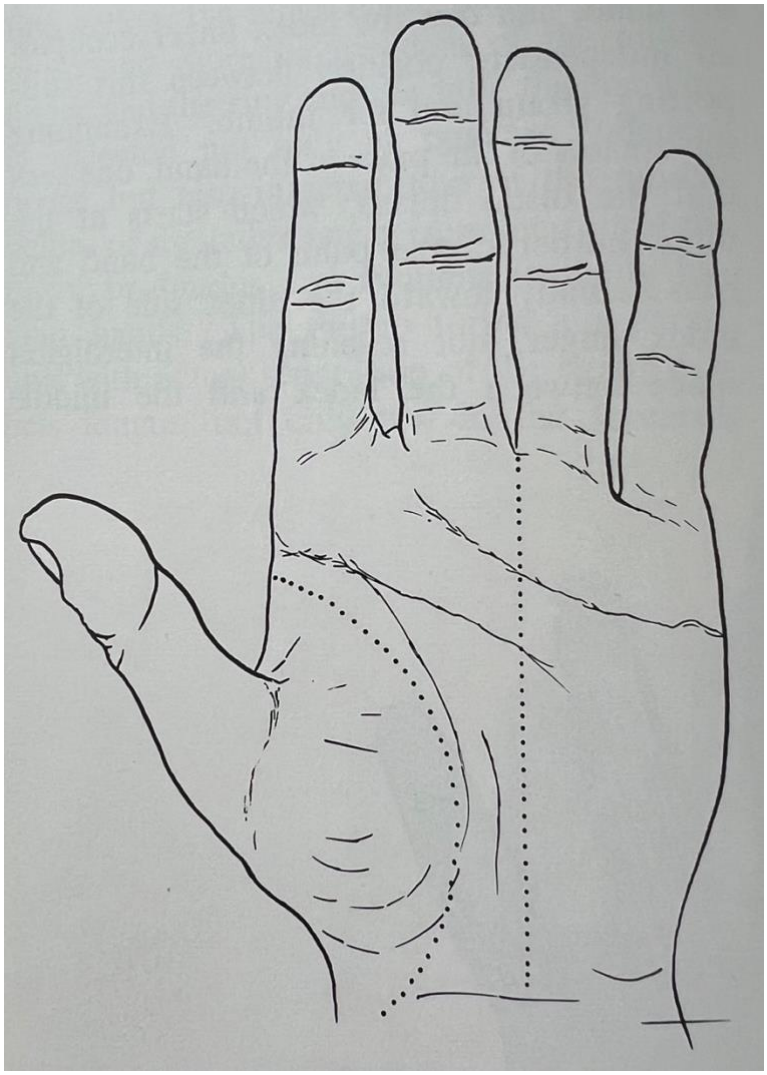
The hand and wrist form a composite functional unit that allows us to perform everything from our basic daily activities to complex manual tasks and impact our ability to earn a living. Through mammalian evolution, the human hand and wrist have formed from a complex arrangement of bones, ligaments, tendons, nerves, blood vessels, skin and nails that work synchronously to provide us with a super sensory and mobile limb, capable of highly sophisticated function. Each individual movement of this unit is accomplished by co-ordinated movements of an array of muscles and tendons, supplied by branches of the main nerves of the hand and wrist: median, ulnar and radial.

### 1.1.1 Functional anatomy of the hand

To understand the functional anatomy of the hand, it can be divided into three functional subunits(1):

- Unit 1: The thumb
- Unit 2: The index and middle fingers (radial half)
- Unit 3: The ring and little fingers (ulnar half)

**Figure 1. Three functional subunits of the hand**



*Adapted from 'Functional and surgical anatomy of the hand', Emanuel B. Kaplan 1954*

For most human activities, units 1 and 2 are most commonly employed with auxiliary support from the third unit. These functional units are physically separate in some ways, such as the thumb, whose flexor muscle (flexor pollicis longus) is separated from the other long flexor muscles of the hand. This separation of the thumb from the other digits is also seen in the bony anatomy as discussed below. This highly specialised anatomy results in an extraordinary range of movement at the thumb, consisting of abduction, adduction, flexion, extension, circumduction and critically, opposition. Our range of movement of opposition is one of the key differences between our hands and those of the great apes. Each finger of the hand has flexion, extension, circumduction, abduction and adduction. The wrist similarly has flexion, extension, circumduction, ulnar and radial deviation (adduction and abduction respectively).

The fundamental functions of the hand are its opening and closing. The anatomy of the hand and wrist is highly specialised to perform these two functions. Opening the hand involves extension at the metacarpophalangeal joints, abduction of the fingers, extension of the finger joints, extension and abduction of the thumb. The extensor tendon apparatus is deeply interconnected, which allows for a fast and co-ordinated transition to an open hand. Closing the hand relies on flexion and adduction of the finger joints and thumb, opposition of the thumb and flexion of the metacarpophalangeal joints of the fingers and thumb. In contrast to hand opening, this function primarily requires power – as such, the tendons that produce flexion are rounder, thicker and are contained within specialised tunnels to improve their biomechanical properties. This power is extremely precise however, and multiple small muscles within the hand are recruited to finely tune the execution of this power through the digits. Opening the hand is facilitated by flexion and ulnar deviation at the wrist, while closing the hand is accompanied by powerful but low range extension and radial deviation at the wrist.

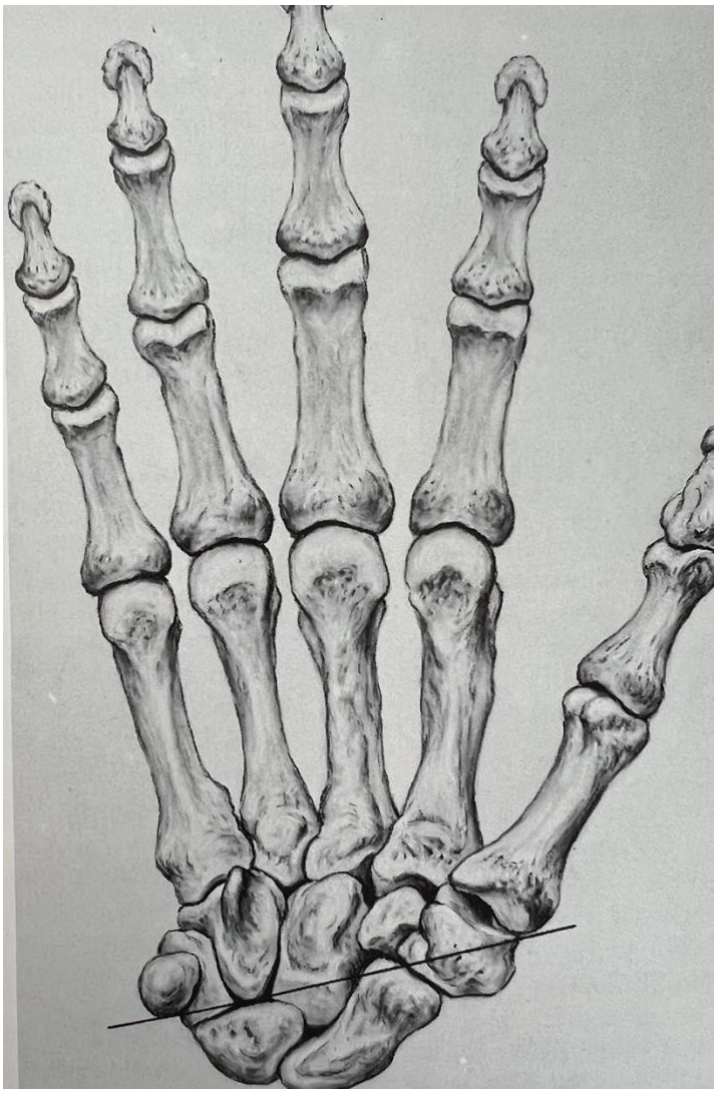
Injury to the aforementioned structures results in immediate functional attrition, either through pain or direct biomechanical deficit. Understanding functional anatomy of the hand and wrist is core to the operative management and rehabilitation of these injuries. If a patient develops SSI, then rehabilitation will be delayed, further pain and stiffness will occur and the overall functional recovery of the hand and wrist will be affected. Knowledge of hand and wrist function is also important in understanding the measurement of outcome following surgical intervention. Patient reported outcome measures (PROMs) are the gold standard for determining the effectiveness of treatments for hand conditions.(2) Contemporary PROMs have been developed such that they accurately capture change in hand function in a way that is relevant to patients. This is achieved through established methods of PROM design and development that involves patient input.

### 1.1.2 Skeleton of the hand and wrist

The skeleton of the hand begins at the distal forearm with the radius and ulnar and their articulation with the carpus at the radio-carpal joint.(1) The carpus consists of eight bones arranged into two rows of four bones each: the proximal row and the distal row. The proximal row contains the scaphoid, lunate, triquetrum and pisiform. The distal row contains the trapezium, trapezoid, capitate and hamate. The carpus then articulate with the metacarpal bones at the carpometacarpal joints (CMCJs). The index, middle, ring and little finger meta-carpals articulate with the respective proximal phalanges via the metacarpophalangeal joints (MCPJs). The three phalanges are the proximal, middle and distal phalanges, articulated by the proximal interphalangeal joints and distal interphalangeal joints. The first metacarpal articulates with the proximal phalanx of the thumb via the first MCPJ. The thumb has only two phalanges, proximal and distal, which articulate at the interphalangeal joint. These joints are encapsulated and supported by a

complex network of ligaments that allow wide range of movement without dislocation. An understanding of the articular anatomy of the hand is crucial in the diagnosis and treatment of fractures and dislocations. It is also relevant to SSI, as osteomyelitis is one of the most severe types of SSI that can occur following hand trauma surgery. It is most common after injury to the skeleton of the hand and wrist.

**Figure 2. Skeletal anatomy of the hand**



*Adapted from 'Functional and surgical anatomy of the hand',*

*Emanuel B. Kaplan 1954*

#### 1.1.2.1 The phalanges

The proximal, middle and distal phalanges of the index, middle, ring and little fingers are relatively similar to each other in terms of morphology. The proximal phalanges are the longest and most concave, with space on their volar concavity for passage of the flexor tendons. The middle phalanges and distal phalanges become progressively shorter and flatter in comparison. The middle finger has the longest phalanges, with the ring and/or index finger the second longest. Phalangeal fractures are very common and often require manipulation and fixation with Kirschner wires (K-wires). These wires come in various sizes and selecting the most appropriate thickness depends on the dimensions of the fractured bone and therefore knowledge of the dimensions of the phalanges is important from a surgical point of view. For example, the proximal phalanx shaft is between 6mm and 8mm thick, the middle phalanx shaft 4mm to 5mm thick and the distal phalanx just 2mm to 3mm thick. The K-wire thickness must be appropriate to the thickness of the bone in which the fracture occurs to achieve stable fixation without causing further injury. Fixation of a distal phalanx fracture requires a K-wire with a thickness of less than 1mm.(1)

#### 1.1.2.2 The metacarpus

The second to fifth metacarpals form the stable and relatively immobile part of the hand, in contrast to the relatively mobile first metacarpal. The second and third metacarpals are usually the longest, with the first being the shortest.

#### 1.1.2.3 The carpus

The carpus consists of a proximal row and a distal row, each containing four bones. The distal row consists of the trapezium, trapezoid, capitate and hamate. The proximal row contains the scaphoid, lunate, triquetrum and pisiform. Essentially, the

proximal row articulates with the distal radius, forming the wrist joint and the distal row articulate with the base of the metacarpals forming the CMCJs.(1,3) The carpus is reinforced by a complex array of ligaments.(3) Clinically the carpus is often the site of traumatic injury. Indeed, treatment of fracture of the scaphoid is the subject of one of the few, and most successful randomised control trials (RCTs) in hand surgery in the UK.(4) The CMCJs, particularly the 5$^{th}$ CMCJ is prone to fracture-dislocation in blunt force trauma, with operative treatment the usual treatment due to the deforming forces acting on the joint following this injury.(5,6)

#### 1.1.2.4 The distal radius

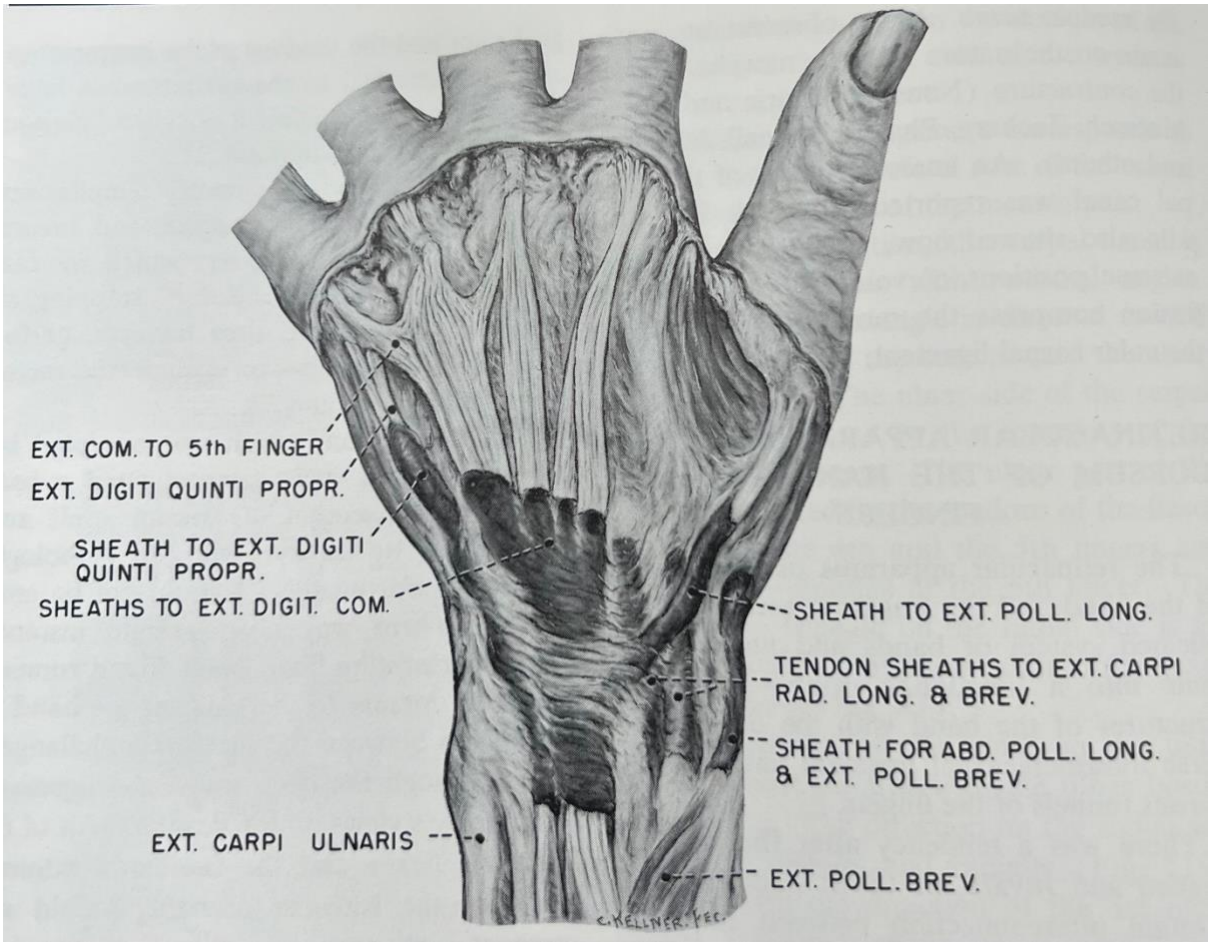
The functional unit of the hand and wrist ends with the proximal aspect of the wrist joint, formed by the articulation between the proximal row of the carpus and the distal radius. The distal ulna is not considered part of the wrist joint. The scaphoid, lunate and triquetrum form a convex articular surface which articulates with the concave distal radius. Fracture of the distal radius is one of the most common injuries that occur in the hand and wrist, and is the most common fracture that presents to ED.(7) There is a bimodal distribution in terms of age: the young, male population with high-energy injuries and the older, female population with low-energy fragility fractures.(8) Most distal radius fractures do not need operative treatment.(9) For those that may need operative treatment, a number of RCTs have been performed to determine the most cost-effective treatment.(10–12)

### 1.1.3 Musculotendinous anatomy of the hand and wrist

The actions of finger flexion and extension are the most important to consider from a trauma viewpoint. Injuries to the finger flexors are common and can result in complete loss of hand function unless timely reconstruction is performed. Similarly,

lacerations of the extensor tendons can also result in significant loss of hand function, although repair of these injuries is usually more straightforward.(8)

**Figure 3. Extensor tendons of the hand and wrist**




*Adapted from 'Functional and surgical anatomy of the hand', Emanuel B. Kaplan 1954*

1.1.3.1 Muscles of flexion

Flexion of the finger is produced by direct action of flexor digitorium profundus (FDP) and flexor digitorum superficialis (FDS), with adjunctive action from the interosseous and lumbrical muscles of the hand (the intrinsic muscles of the hand). The radial carpal extensors (extensor radialis brevis and longus), extensor carpi ulnaris and the extensors of the digits also indirectly contribute to finger flexion.

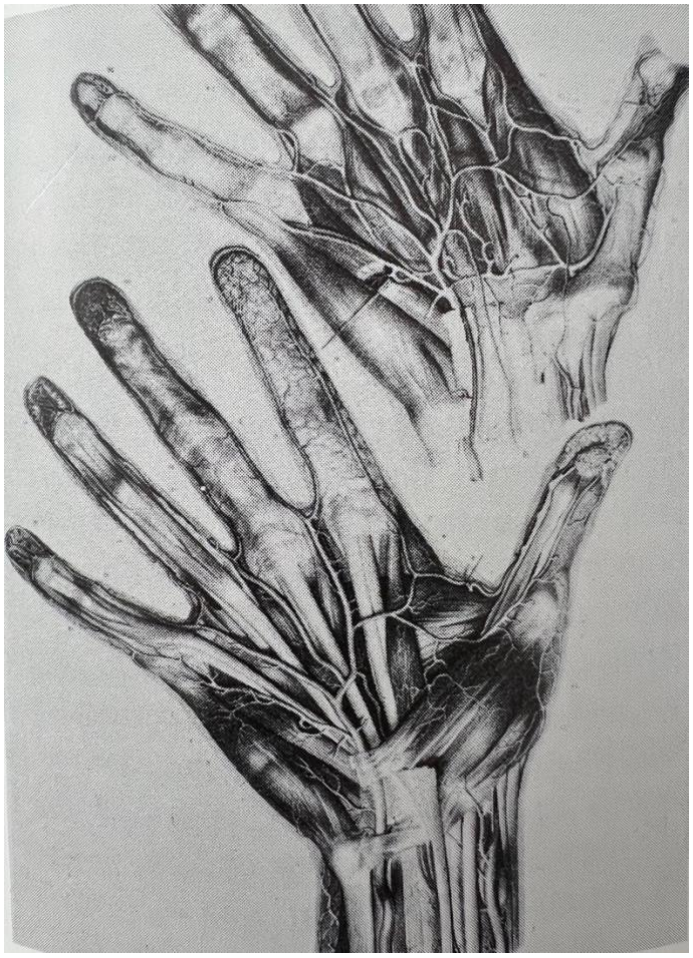
### 1.1.3.2 Muscles of extension

Finger extension is primarily actioned by the extensor digitorum communis muscles and tendons, the extensor indicis proprius and the extensor digiti minimi muscle and tendons. This action is also supported by the intrinsic muscles of the hand and the flexors of the wrist: flexor carpi radialis, flexor carpi ulnaris and palmaris longus.

### 1.1.3.3 Muscles of abduction and adduction

Abduction and adduction is primarily performed by the intrinsic muscles of the hand. Adduction is also generated through the action of abductor digiti minimi and the digital extensors.

**Figure 4. Vasculature of the hand and wrist**



*Adapted from 'Functional and surgical anatomy of the hand',*

*Emanuel B. Kaplan 1954*

## 1.1.4 Neurovascular anatomy of the hand and wrist

### 1.1.4.1 Neuroanatomy

Injuries to the nerves of the hand and wrist will result in immediate sensory disturbance and, if proximal to the hand, additional weakness or paralysis of the hand and wrist. Nerves are usually damaged in sharp injury to the hand and wrist, often in combination with vessel and tendon injury. Suspected nerve injury requires surgical exploration then nerve repair using microsurgical techniques. The goal is to restore nerve continuity before the nerve dies, thus maximising the chances of sensory and motor recovery. Patients will often require an operation if they have evidence of a nerve injury on clinical examination. As these injuries are usually open traumatic injuries, they are classified as contaminated wounds and may be at higher risk of SSI.

#### *1.1.4.1.1 Median nerve*

The median nerve arises through convergence of the medial and lateral trunks of the brachial plexus. It runs over the anteromedial aspect of the upper arm, then traverses the antecubital fossa in the midline. It then travels between the muscles of FDS and FDP in the forearm before entering the carpal tunnel, superficial to the index finger flexors before forming its terminal branches. Within the forearm it supplies both deep and superficial muscles of hand and wrist movement. The superficial branch supplies flexor carpi radialis, palmaris longus and flexor digitorum superficialis. The deep branch supplies flexor pollicis longus and the lateral (radial) portion of flexor digitorum profundus. Then, just before the carpal tunnel, the palmar cutaneous branch arises and supplies sensation of the volar skin of the wrist. Once the median nerve itself leaves the carpal tunnel, it forms its terminal branches: a lateral and medial branch. The lateral (radial) branch supplies power to the muscles of the thenar eminence (known also as the recurrent motor branch) and the sensory nerves to the thumb and radial half of the index finger, via the common digital

nerves. The medial branch supplies sensation to the ulnar half of the index finger, the middle finger and the radial half of the ring finger.

*1.1.4.1.2 Ulnar nerve*

The ulnar nerve begins at the medial cord of the brachial plexus, passes distally through the posterior compartment of the upper arm before traversing the cubital tunnel, posterior to the medial epicondyle of the humerus. Once it enters the forearm, it sits sandwiched between the FDP muscle (dorsally) and flexor carpi ulnaris (volarly). Within the forearm, the ulnar nerve supplies flexor carpi ulnaris and the ulnar part of FDP, also delivering the dorsal cutaneous branch of the hand. The dorsal cutaneous branch of the hand leaves the main ulnar nerve before the wrist then travels distally to provide sensation to the radio-carpal joint and the ulnar half of the hand. The main branch of the ulnar nerve is joined by the ulnar artery distally in the forearm, both reaching the pisiform, traversing Guyon's canal and entering the hand. Once in the hand, the main ulnar nerve divides into its terminal superficial and deep branches. The superficial branch is essentially sensory, supplying the dorsal skin of the little finger, the ulnar half of the palm and the volar skin of the little and ulnar half of the ring finger. The deep branch is essentially motor, supplying all the intrinsic muscles of the hand apart from the lateral two lumbrical muscles, which are supplied by the median nerve.

*1.1.4.1.3 Radial nerve*

One of the largest nerves arising from the brachial plexus, its posterior cord, runs distally through the posterior compartment of the upper arm, winding around the lower third of the humerus into the anterior compartment and then into the proximal forearm anterior to the lateral epicondyle. It supplies power to brachioradialis, extensor carpi radialis longus and usually extensor carpi radialis brevis, before forming its terminal branches: one large, deep motor branch and one small, superficial sensory branch. The

superficial branch travels the forearm distally towards the wrist before splitting into a medial and lateral branch. The lateral branch supplies sensation to the lateral (radial) dorsal skin of thumb and radial border of the wrist. The medial branch supplies sensation to the dorsal skin of the radial half of the hand, often interconnecting with the dorsal cutaneous branch of the ulnar nerve. The deep branch of the radial nerve supplies all the muscles of extension of the hand and wrist, both deep and superficial.

#### 1.1.4.2 Vascular anatomy

Injuries to the main arteries of the hand and wrist usually require urgent surgery to control bleeding and/or restore blood supply to the distant tissues. Major arterial injuries are open traumatic injuries that have a relatively high risk of SSI. They are often combined with other soft tissue injuries (nerve, tendon, muscle) but may also present alongside fractures in severe injuries. Venous injuries are not usually a stand-alone indication for surgical repair but will need repair as part of a replantation procedure to facilitate survival of the amputated part following revascularisation.

##### *1.1.4.2.1 Arterial anatomy*

The radial and ulnar arteries form the principal blood supply of the hand, with supplementary supply from the anterior interosseous and posterior interosseous arteries. The radial and ulnar arteries form the superficial and deep palmar arches of the hand, which in turn give rise to the common digital arteries. These then split to provide two arteries - one ulnar, one radial - for each digit. The deep palmar arch is formed by anastomosis of the terminal radial artery and the deep branch of the ulnar artery. The superficial branch is formed by anastomosis of the superficial radial artery and the terminal branch of the ulnar artery. The superficial arch supplies the 2$^{nd}$, 3$^{rd}$ and 4$^{th}$ intermetacarpal arteries which bifurcate to form the digital arteries of the majority of the digits. The deep

arch supplies the two digital arteries to the thumb. The arterial anatomy of the hand is variable.

*1.1.4.2.2 Venous anatomy*

The venous anatomy of the hand is less relevant from a surgical point of view, as surgical repair of veins is not commonly indicated. The venous system has superficial and deep components, corresponding to the arterial systems. The veins are usually doubled and of a smaller calibre with frequent anastomoses throughout the hand.

## 1.2 Hand trauma – injuries of the hand and wrist

The type of wound, structures involved, mechanism and location of injury can all have an impact on the extent of the surgical repair, the risk of subsequent SSI and overall recovery. This has both direct and indirect consequences for the individual, society and the economy. I will discuss the principles of hand trauma and its management, including the current care pathways to indicate where and how the risk of SSI could be moderated.

Due to the central role of the hand and wrist in our everyday lives, injury through occupation, recreation, habitual activity, accidents and altercations is common. All components of the hand and wrist are vulnerable to injury, from fractured bones to lacerated soft tissues and skin.(13,14) Hand and wrist injury, known as hand trauma, can have a substantial impact on an individual's ability to look after themselves and earn a living.(15,16) Many injuries to the hand and wrist can lead to long term physical and psychological disability, even with timely treatment and an uneventful recovery period.(17–19) In the elderly population, a wrist or hand fracture may render the injured person unable to care for themselves independently for a period of time or even permanently.(7,20)

### 1.2.1 Epidemiology of hand trauma

Injuries of the hand and wrist, known collectively as ‘hand trauma’, are common and are increasing year on year.(14) BSSH produced a report in 2018 that outlined the current status of hand surgery in the UK.(21) Data from NHS England revealed that in 2015/2016 there were 4.58 million patients who presented to ED with hand trauma. Over 900,000, or 1-in-5 patients required specialist care and 240,000 required surgery. These figures are similar across Europe, demonstrated by results from epidemiological studies in Holland, Denmark and Scotland.(13,16,22) Hand trauma accounted for over 25% of all injuries presenting to ED in these studies, and up to 1-in-5 of overall ED attendances.(13, 16,22) The high incidence results in substantial costs to health services. This was demonstrated by De Putter et al, costing hand trauma at £460 million/year – more than head injury (£223 million) and even more than hip fractures (£335 million), although the latter figure is much higher in UK data.(16,23) Direct healthcare costs accounted for 44% of this figure, the remainder consisting of indirect productivity costs. Substantial indirect costs arise since the majority of injuries occur in the young, working population (24-64 years old). Men are disproportionately affected (57%). The resulting disability causes loss of earnings, especially for those people that rely on their hands for work.(24,25)

### 1.2.2 Management of hand trauma

"Restoration of function…is essential. The task of the surgeon is to preserve this function, even in seemingly hopeless mutilations, because the demands and responses connected with the activity of the central nervous system produced extraordinary results of rehabilitation." *from 'Functional and surgical anatomy of the hand', Emanuel B. Kaplan 1954*

The optimal treatment of hand trauma was identified as one of the top ten priorities in the James Lind Alliance Priority Setting Partnership (JLA PSP) for Common Hand and Wrist Conditions in September 2017.(26) Common to all hand and wrist injuries is that they must be managed as an emergency to achieve the best outcome for patients, often in a specialist centre.(21) All injuries are seen by primary practitioners, most commonly in ED. Once first aid and assessment of the injury has been performed in ED, the patient may then be referred to a specialist hand unit, which may be run by plastic surgeons, orthopaedic surgeons or both. Although some injuries are managed non-operatively, many will require surgery to restore form and function. Surgery for hand trauma is variable and depends on the nature of the injury sustained.(8)

#### 1.2.2.1 Pre-operative management

The initial management of a patient with a hand or wrist injury is the same as for all trauma: triage and resuscitation if indicated by the Advanced Trauma Life Support guidelines of the RCSEng.(27) First the clinician must assess the patient as a whole, ensuring their safety and physiological stability. It is crucial to attend to life threatening associated injuries in the first instance. Once it is established that the patient is otherwise stable, management of the hand and wrist can begin. The first and most important

assessment is presence of limb ischaemia. If there is injury to the vascular supply of the hand, then this becomes a limb-threatening injury and urgent surgical intervention is needed. Similarly, if significant vascular injury to the arteries of the upper limb has occurred and there is uncontrolled active bleeding, urgent surgery is indicated.

Once safe to do so, a full history and examination pertaining to the hand and wrist is then performed to identify the diagnosis and assess the need for imaging and diagnostic tests. In this history, particular emphasis should be made on eliciting medical and social factors that can affect injury outcome, such as connective tissue disorders (Ehlers–Danlos syndrome, Marfan's syndrome, osteogenesis imperfecta), hypoalbuminaemia, osteoporosis and vitamin deficiencies.(28) Drug history is also important, as steroids and immunotherapy agents may also delay healing and tissue repair.

One of the important aspects of the injury is whether it is open (i.e., there is a break in the skin) or closed (i.e., the skin is intact). If the injury is closed, the first aid requirements are less. The patient will require analgesia, the hand and wrist may be splinted or put into a cast and the limb should be elevated in a sling. If the injury is open, then more intensive first aid is required. Open injuries are generally at higher risk of wound infection.(29) This can theoretically be reduced through vigorous wound cleansing, debridement of de-vitalised tissue and removal of foreign material that has entered the wound at or since the time of injury. The basics of wound care as described by Galiano and Mustoe in Grabb and Smith’s Plastic Surgery are as follows(30):

- Optimize systemic parameters
- Debride non-viable tissue
- Reduce the wound bioburden
- Optimize blood flow

    - Warmth
    - Hydration
    - Surgical revascularization
- Reduce oedema
    - Elevation
    - Compression
- Use dressings appropriately, and selectively use biologic dressings, with attention to cost-effectiveness of overall treatment. Aims include:
    - Moist wound healing
    - Exudate removal
- Avoid trauma to wound or pain to patient with dressing changes
- Use pharmacologic therapy when necessary
- Close wounds surgically either primarily, with grafts or with flaps as indicated

The goals of the above in relation to hand trauma are to achieve timely wound healing, reduce risk of infection and expedite return to normal function. The key interventions that can be performed pre-operatively are wound irrigation, wound dressing, splinting and elevation of the hand. Thorough irrigation of the wound with clean fluids, water or saline may reduce the bacterial population within the open wound, as well as helping to remove foreign material. There is no evidence to support one type of fluid over another for this purpose.(31) The use of systemic prophylactic antibiotics in traumatic wounds forms a component of many national guidelines across trauma.(32,33) However, there is controversy over the use of systemic antibiotics in hand trauma, with no clear

evidence and wide variation in practice.(34–37) Tetanus prophylaxis is also routinely given for open wounds in the UK.(38)

#### 1.2.2.2 Operative management

Operative management of hand trauma may take place in the operating theatre, minor operation theatre, ED or Outpatient Clinic. Traditionally, most surgical procedures would have been performed in a main operating theatre, with or without laminar flow. During the COVID-19 pandemic, access to main theatres was substantially reduced due to the increased time taken for new anti-transmission procedures. Injuries to the hand and wrist were rife during the pandemic in the UK.(39–41) This was due to changes in working patterns, with substantially increased time spent at home and less time working. As a result, more amateur home improvement and do-it-yourself projects were undertaken, leading to a disproportionate level of hand and wrist injuries from bladed and power tools.(39–41) With reduced capacity in main theatres, more operations were performed outside of theatre, under local anaesthetic. As a result, we were able to operate on many more patients compared to the standard main theatre pathway. Upon request from the BSSH, work from Chapter 2 of this thesis was repurposed to explore SSI risk differences between main theatre and outside theatre operating in hand trauma. Although data were limited, an apparent increase in SSI was not seen. This led to the development of a national guideline that recommends that the majority of hand trauma operations can now be performed outside of the main operating theatre.(42)

Once the patient has been brought to the site of the operation, the hand and wrist is cleaned with sterile surgical solution, again to reduce the bioburden of the wound, or in case of closed injuries, the normal skin commensals that can lead to SSI, such as *Staphylococcus aureus*. The type of cleaning solution has been the subject of discussion,

with a 2015 Cochrane review finding limited evidence in clean surgical procedures.(43) More recently, and of specific relevance, is the work by Wade *et al.* and the RSTN that evaluated the four most common surgical antiseptic preparations. Wade et al's network meta-analysis found clear evidence that alcoholic chlorhexidine skin preparation in clean hand surgery was the most effective agent.(44) The CIPHUR study, a multi-centre prospective cohort study evaluating surgical prep choice and SSI in hand surgery in 2,454 patients supported this finding in both clean surgery and hand trauma surgery, although with less certainty for the latter.(45)

For open wounds, debridement of the wound reduces the bacterial count of the wound, increasing the availability of nutrients and oxygen in the wound environment for host tissues to regenerate. Critically, debridement also involves the removal of de-vitalised tissue, which would otherwise serve as the ideal substrate for bacterial populations to thrive upon. Although the concept of debridement is fully established in trauma surgery, there is very limited clinical evidence for its effectiveness.(46) Closed injuries do not need debridement as the skin and soft tissues are usually intact. Closed injuries require a surgical incision to access the injured tissue. Surgical incisions cause very little tissue damage, are made following skin antiseptic preparation and are performed in a sterile environment. The risk of SSI following these incisions is therefore low.(32)

Most open injuries will require repair of the injured underlying structures and then stitching, or suturing, of the injured skin. The best example of this is a knife wound to the palm with underlying injuries to the tendons and nerves. Both the underlying tendon and nerve injuries must be repaired, as well as the laceration to the skin. Conversely, the majority of closed injuries may not need an operation at all. For the closed injuries that do require surgery, a surgical wound must be made to access the underlying injured structures, and then the skin closed again at the end with sutures. An example of this is in a

severe wrist fracture where the skin is intact. Patients with hand trauma require a period of recovery and rehabilitation following surgical management. During this time the patient is not able to use their hand and wrist as normal, may be wearing a splint and will usually be undergoing a regime of physiotherapy for rehabilitation. Every step of the management of a hand and wrist injury, from first aid to the surgical procedure to the post-surgery recovery period, can influence the time to recovery and the level of recovery achieved.

## 1.3 Surgical site infection following hand trauma surgery

### 1.3.1 Principles of surgical site infection

Healthcare associated infections (HAIs), including SSI are one of the most commonly occurring adverse events affecting patient safety worldwide and are a significant issue for tackling antimicrobial resistance, an NIHR research priority.(47) Indeed, SSI is the most frequently occurring subtype of HAI globally, with up to one third of surgical patients developing an SSI.(48) Equivalent data from Europe suggests an SSI risk of up to 20%.(49) SSI statistics vary widely across different procedures, patients, surgeons, hospitals, countries and healthcare settings.(50) The Centers for Disease Control (CDC) National Nosocomial Infections Surveillance database indicates that SSI is the third most common nosocomial infection, accounting for around 15% of all hospital acquired infections.(51) This rises to 38% in surgical patients.(52)

Multiple exposures at every step of the patient pathway may contribute to the development of SSI and various interventions have been developed to target these exposures.(50,53) the National Institute for Health and Care Excellence (NICE) in the UK reports the incidence of SSI at 2–5% across specialties.(54) In England, 8% of inpatients develop a HAI, of which 14% are SSI.(53) However, this figure is likely to be underestimated as those SSIs that occur outside of hospital are not counted in these figures.

This is especially important in surgical fields with a high number of day-case procedures, such as hand and wrist surgery. This is demonstrated by a recent meta-analysis of surgical randomised clinical trials that reports much higher rates of SSI, ranging from 12-18.5%.(55) Acquiring an SSI doubles the length of hospital stay in some cases and leads to substantial additional direct healthcare costs of up to £6,626 per patient.(56,57) Indirect costs of SSI to the individual and society are also substantial but more difficult to quantify.(58)

#### 1.3.1.1 Pathogenesis

SSI occurs when the surgical wound, be it traumatic or iatrogenic, remains or becomes contaminated with pathogenic bacteria. There is a response of the host immune system to prevent proliferation of the bacterial population, and infection occurs when the bacterial load is able to surpass this immune response. The most common bacteria that are implicated in SSI are those of the patient's own endogenous flora, encountered on the skin, in the gut and upon the mucous membranes.(50) Gram positive cocci, *Staphylococcus aureus* in particular, are the most virulent bacteria most associated with skin and mucosal surface SSIs, although gram negative, anaerobic bacteria are often implicated in groin and perineal SSIs.(59) SSI following trauma is also most commonly caused by *Staphylococcus aureus,* with other pathogens including *Staphylococcus epidermidis*, *enterococcus* species, *Enterobacter* species, *Escherichia coli* and *Pseudomonas* species.(60) In general, a bacterial load count of >10,000 organisms per gram of tissue is highly associated with occurrence of SSI.(61) There are well known factors that will supress the host immune system and allow bacterial proliferation within a surgical wound. These can be described and classified as below(54,58,62–64):

*1.3.1.1.1 Surgical factors:*

- Poor sterility
- Inadequate pre-incision skin preparation (i.e. hair removal, type of fluid for skin cleaning)
- Prolonged operative time
- Intraoperative contamination
- Hypothermia

*1.3.1.1.2 Wound-related factors:*

- Contamination status of wound (see below)
- Devitalised tissue
- Haematoma
- Presence of ‘dead space’

*1.3.1.1.3 Patient factors:*

- Old age
- Malnutrition
- Obesity
- Dehydration
- Diabetes mellitus
- Renal failure
- AIDS
- Malignancy

- Liver cirrhosis
- Immunosuppressive medication (e.g. corticosteroids)
- Chemoradiotherapy

Tissue trauma, either from injury or surgery itself, also directly supresses local immunity through suppression of cell-mediated (polymorphonuclear leucocytes, monocytes and lymphocytes), antibody-mediated (IgG 5-8) and innate (complement and opsonic factors) immune responses.(65–67) Not only does the physical act of traumatic injury and surgery detrimentally affect the hosts defences against infection, many factors that are associated with the operation will also alter the response, such as type and length of anaesthesia, blood loss and blood transfusion and hypothermia.(62)

The contamination status of surgical wounds has been classified as follows by the CDC:(67,68)

*1.3.1.1.4 Clean*

Operative incisional wounds that follow non-penetrating (blunt) trauma. This would include surgical incisions for performing open reduction and internal fixation (ORIF) for closed fractures of the hand and wrist. Also includes, uninfected operative wounds in which no inflammation is encountered, where the respiratory, alimentary, genital or uninfected urinary tracts are not entered. Clean wounds are primarily closed and, if necessary, drained with closed drainage.

*1.3.1.1.5 Clean-contaminated*

Clean-contaminated wounds are not relevant to hand trauma as they relate to operative wounds in which the respiratory, alimentary, genital or urinary tracts are entered.

*1.3.1.1.6 Contaminated*

Open, fresh, accidental wounds. All open hand traumatic wounds are classified as contaminated. Also includes operations with major breaks in sterile technique and incisions in which acute, non-purulent inflammation is encountered, including necrotic tissue without evidence of purulent drainage.

*1.3.1.1.7 Dirty or infected*

Old traumatic wounds with retained devitalized tissue and those that involve existing clinical infection or perforated viscera. Implication that organisms causing postoperative infection were present in the operative field before the operation.

Closed traumatic injuries, most commonly fractures but also some soft tissue injuries, will most often fall under the 'clean' category as per the above classification. All open traumatic injuries will either be 'contaminated' if they present early, or 'dirty' if they are old. There is therefore a spectrum of potential risk of SSI within traumatic injuries.

## 1.3.2 Classification of surgical site infection

SSI is most commonly defined according to the CDC definitions, first published in 1988(69), then modified in 1992 and 2016 (70):

1.3.2.1 Superficial incisional SSI

Involves only skin and subcutaneous tissue of the incision

AND

The patient has at least one of the following:

i. Purulent drainage from the superficial incision.

ii. An organism(s) identified from an aseptically-obtained specimen from the superficial incision or subcutaneous tissue by a culture or nonculture based microbiologic testing method which is performed for purposes of clinical diagnosis or treatment.

iii. A superficial incision that is deliberately opened by a clinician and culture or non-culture based testing of the superficial incision or subcutaneous tissue is not performed AND patient has at least one of the following signs or symptoms: localized pain or tenderness; localized swelling; erythema; or heat.

iv. Diagnosis of a superficial incisional SSI by a clinician

In the hand and wrist, this manifests as a wound infection that does not extend to the key anatomical structures immediately deep to the skin and subcutaneous tissues.

1.3.2.2 Deep incisional SSI

Involves deep soft tissues of the incision (for example, fascial and muscle layers)

AND

The patient has at least one of the following:

i. Purulent drainage from the deep incision.

ii. A deep incision that is deliberately opened or aspirated by a clinician or spontaneously dehisces AND organism(s) identified from the deep soft tissues of the incision by a culture or non-culture based microbiologic testing method which is performed for purposes of clinical diagnosis or treatment (or culture or nonculture based microbiologic testing method is not performed. A culture or non-culture based test from the deep soft tissues of the incision that has a negative

finding does not meet this criterion AND patient has at least one of the following signs or symptoms: fever (>38°C); localized pain or tenderness.

iii. An abscess or other evidence of infection involving the deep incision detected on gross anatomical exam, histopathologic exam, or imaging test.

1.3.2.3 Organ or space SSI

Involves any part of the body deeper than the fascial/muscle layers that is opened or manipulated during the operative procedure

AND

The patient has at least one of the following:

i. Purulent drainage from a drain placed into the organ/space

ii. Organism(s) identified from fluid or tissue in the organ/space by a culture or non-culture based microbiologic testing method which is performed for purposes of clinical diagnosis or treatment

iii. An abscess or other evidence of infection involving the organ/space detected on gross anatomical exam or histopathologic exam, or imaging test evidence definitive or equivocal for infection.

iv. AND meets at least one criterion for a specific organ/space infection site – in the hand and wrist, this pertains to septic arthritis and osteomyelitis.

Septic arthritis results in rapid joint destruction. Emergency surgical washout with systemic antibiotic treatment is needed to preserve the affected joint. Osteomyelitis requires protracted systemic antibiotic treatment and often additional surgical debridement. If non-responsive to aggressive treatment then systemic sepsis can occur and amputation may be indicated. Amputation may also be indicated in either deep or organ/space SSI if

the infective process has rendered the hand functionless as a result of destroyed anatomical structures.

There is no consensus on which classification system should be used in clinical research. This is problematic for data synthesis and comparison across sites and healthcare systems.(71,72) The CDC classification is described above, other commonly used scores include ASEPSIS and the Southampton scale. The ASEPSIS score, developed by Wilson et al in 1986 for assessment of cardiothoracic wounds, is based on the following criteria: Additional treatment, Serous discharge, Erythema, Purulent exudate, Separation of deep tissues, Isolation of bacteria, and Stay as inpatient prolonged over 14 days.(73) It generates a continuous numerical score, which is then categorised as follows: satisfactory healing (0-10), disturbance of healing (11-20), minor SSI (21-30), moderate SSI (31-40), and severe SSI (>40).(73) The Southampton score consists of a grading system based on any wound omplications and their severity, originally designed by Bailey et al in 1992 to for hernia wound evaluation. There are six grades(grade 0 to grade V) with increasing severity up the scale.(74) All scores have pros and cons and have been compared in the literature in terms of their validity, utility and predictive value.(75)

More often than not, no definition of SSI is employed in clinical studies of surgical intervention, where infection is reported in a binary fashion: present or not. The use of specific interventions to treat SSI, such as systemic antibiotics or surgical intervention, are also used as a surrogate marker for presence of SSI, even within existing definitions. Part of the CDC definition for SSI considers the surgeon’s diagnosis of its presence. In the study by Wilson *et al* of 4773 surgical patients, the decision to start antibiotic treatment or to provide surgical treatment was a surrogate for this component of the classification.(76) In the context of antimicrobial stewardship and resistance, it is

logical that the end outcome – treatment with antibiotics or antimicrobial intervention - is a suitable surrogate for SSI.

### 1.3.3 Surgical site infection of the hand and wrist

The literature assessing SSI following hand trauma surgery is very limited, with few studies directly evaluating SSI incidence. One study from 1995 evaluated post-operative infection as their primary outcome and found an incidence of 9.7% following surgery for hand trauma. Other studies reporting SSI as a secondary outcome following surgery for hand trauma report rates of 3.6% to as high as 34.5% across a variety of injuries and interventions. Furthermore, there is no current understanding of how SSI of the hand and wrist impacts on outcomes that are meaningful to patients, such as patient-reported outcome measures.

### 1.3.4 Interventions to moderate risk of surgical site infection in hand trauma

In 2019, NICE published guidelines, which were updated in August 2020, recommending interventions and practices to reduce the risk of SSI across all surgical fields.(53) These are organised by pre-, intra- and post-operative phases.

#### 1.3.4.1 Pre-operative interventions

Most of the recommendations for pre-operative practices relate to patient preparation (nasal decolonisation, showering, hair removal etc.) and theatre practices (staff clothing, staff movement in theatre). There is more detailed guidance on the use of pre-operative antibiotic prophylaxis, originally described in the 2008 NICE guideline.(54) Antibiotic prophylaxis is recommended in clean-contaminated and contaminated surgery and in clean surgery where a prosthesis or implant is deployed. Additional antibiotic treatment (in addition to prophylaxis) is recommended in dirty or infected wounds. There

is mixed evidence supporting the use of antibiotics pre-operatively. In 2016, a meta-analysis of antibiotics in simple hand lacerations suggested no evidence of effectiveness of antibiotics in the reduction of SSI.(35) The meta-analysis, although comprehensive in terms of the included studies, erroneously pooled observational (8 cohort studies) and experimental data (5 RCTs) in a standard meta-analysis, rendering the quantitative results unreliable. None of the individual studies in the meta-analysis showed evidence of effect and nor did the pooled estimate.(35) In addition to this, a Cochrane review published in 2004, evaluated the the use of antibiotic prophylaxis in open limb fracture, demonstrating reduced SSI risk in this population.(29) Importantly, on subgroup analysis by fracture location, the effect was lost in hand fractures, despite being apparent on meta-analysis of other fracture locations.(29) It is therefore safe to say that there is no evidence supporting the use of antibiotics in hand trauma surgery, despite the presence of some, albeit unreliable, primary studies and data syntheses. This is a very important target area for future research in hand trauma trials. The use of antibiotics is poorly regulated in hand trauma, with wide variation in practice and there is no current consensus on their use. A future RCT comparing antibiotics with standard care or even placebo would provide much needed data to inform clinical guidelines.

#### 1.3.4.2 Intra-operative interventions

Intra-operative interventions include hand washing, the surgeon's gloves and gown, draping and antiseptic skin preparation. There was evidence to support most of these interventions, although there is no evidence to support sterile surgical gown use. Interestingly, there is evidence that disposable and re-usable gowns have equivalent SSI prevention.(78,79) There was similarly absent evidence to support single versus double gloving. There is no evidence to support these interventions in hand surgery. The use of antiseptic skin preparation has more evidence than other intra-operative interventions, and

the 2019 guidance has clear recommendations supporting the use of alcohol-based chlorhexidine over other preparations. Wade *et al*'s network meta-analysis and prospective cohort study provide reliable data to support this recommendation in hand surgery.(44,45) It is worth noting that the SSI reduction effect was not seen in hand trauma surgery and further evaluation is recommended.

Diathermy, haemostasis and wound irrigation are recommended and are fundamental practices in all surgical fields. Topical antiseptics and antibiotics are only recommended for use in clinical trials, apart from gentamicin-collagen implants which are recommended in cardiac surgery in the most recent guideline. There were no studies included that assessed the use of topic antimicrobials in hand trauma surgery.(80) There was contemporary evidence supporting the use of antimicrobial sutures to reduce the risk of SSI, although this was phrased as a 'consideration' rather than a recommendation. This was based on a NICE evidence review of 33 RCTs assessing various wound closure materials and techniques. None of the included studies evaluated hand trauma patients, or traumatic wounds at all. Two studies assessed different wound closure techniques (glue/staples vs. sutures) in elective hand surgery (n =50 and n=31) but did not provide reliable data to inform practice due to high risk of bias and underpowering, amongst other methodological concerns.(81,82) Antimicrobial sutures were evaluated in 11 RCTs of 7,648 participants and reduced the overall risk of SSI at 30 days after surgery, although the studies were of mixed quality. There was good evidence that antimicrobial sutures reduce SSI risk in paediatric surgery.(83) The evidence to support their use in cardiac, lower limb arterial, abdominal and colorectal surgery was deemed very low to moderate. The evidence to support their use in head and neck surgery was very low.(53) In terms of wound dressings, there was no evidence to support the use of dressings at all, although again this

is considered basic surgical care. There was certainly no evidence to support the use of antimicrobial dressings, although this has not been updated since 2008.

#### 1.3.4.3 Post-operative interventions

Post-operative interventions were broadly considered as topical wound care practices and antibiotic treatments. There was no evidence to support one wound care practice over another and no evidence that topical antimicrobial dressings had any effect on reducing SSI post-operatively. Again, no studies included hand surgery participants. The 2008 NICE guideline adopted a consensus/good practice approach to the use of antibiotic treatment of SSI, simply recommending appropriate treatment in the context of the severity of the infection and local guidelines.(77)

It is well recognised that robust clinical trials of interventions are required to inform cost-effectiveness of interventions. There are gaps in the evidence base for interventions to reduce SSI across all surgery. This is being improved for general surgery, where a number of RCTs have been recently published or are currently recruiting, such as FALCON and ROSSINI 1 and 2.(84–86) In hand trauma surgery, there are comparatively few RCTs overall, let alone those that evaluate antimicrobial interventions to reduce SSI risk.

## 1.4 Clinical trials in hand trauma

### 1.4.1 Evidence-based hand surgery

The quality of research in hand surgery is known to be historically deficient, with endemic community acceptance of case series as good evidence and paradoxical suspicion of RCTs.(87) However, there appears to be a shift towards an understanding that further robust evidence is needed for hand surgery interventions, along with a better understanding

of why quality trials should be conducted, disseminated and absorbed by clinicians.(88) There are relatively few experimental studies of interventions, with the vast majority observational studies of interventions with the associated biases.(89) The trials that do exist are mostly of low methodological quality. One systematic review of the quality of 125 RCTs in hand surgery (elective and trauma) revealed that only 30% conducted a power analysis and 8% an intention-to-treat analysis. Authors concluded that although the quantity of trials in hand surgery was increasing with time, the quality of these studies remained poor.(90) Of note, 42% of studies had substantial, unexplained loss to follow-up. This is important in terms of the fragility index (FI) of clinical trials.(91)

The FI is a gauge of the robustness of a clinical trial and indicates the number of participants in a trial arm that would transform a trial result from statistically significant to non-significant in terms of the alpha ($p \geq 0.05$).(91) If the FI is high, then the trial is more robust. Similarly, if the index is low, say one or two participants, then the results cannot be relied upon, regardless of the P-value. If the study retention is poor, and the number of participants lost to follow-up exceeds the FI then no conclusions can be drawn.(92) FI can only be calculated for studies with dichotomous outcomes, or continuous outcomes that have been dichotomised. Furthermore, where the event rate is low, such as with SSI, the FI becomes an even more critical consideration; losing one or two participants with the event in question can dramatically alter the conclusions of the statistical analysis of a trial if the sample size is insufficient.(93)

Ruzbarsky *et al* looked specifically at FI in five hand surgery RCTs, four of which had a FI of <4.(94) Two of these had higher loss to follow-up than the study FI, significantly reducing the validity of the results. Another review of 207 hand surgery RCTs applied the Cochrane Risk of Bias Tool to evaluate methodological rigour.(95) The vast majority of RCTs (179 trials, 86%) were single-centre and only 18% were

discoverable in trial registries. Only six trials (3%) had a protocol available for review.(95) Most of the included studies were in hand trauma (69%). The most common areas that resulted in high risk of bias were lack of blinding, lack of information on randomisation and unclear allocation concealment. In 77% of studies, blinding was not possible according to the original study authors. However, in the remaining 47 studies where blinding was feasible, it was only implemented in 16 studies.(95) The review authors performed meta-regression to determine the effect of bias on the effect sizes generated by the included studies. Only those with high risk of selection bias detected greater effect of the experimental intervention, whilst attrition bias and other biases had no effect.(95)

### 1.4.2 Evaluation of interventions to reduce risk of surgical site infection in hand trauma

The existing literature indicates that there is little evidence to support recommendations for interventions to reduce SSI pertaining to hand surgery. Searching for clinical trials of antimicrobial interventions in hand trauma elicited eight trials, of which five were evaluating systemic antibiotics in open hand trauma and three were evaluating SSI following K-wire fixation of hand and wrist fractures.(38,96–102) All of these trials were at moderate or high risk of bias as presented later in Chapter 2. Meta-analysis of both randomised and non-randomised studies evaluating the effectiveness of antibiotics in open hand trauma found no statistically significant difference but was critically hampered by low quality data.(36) No meaningful conclusions could be drawn that would influence clinical practice. Meta-analysis of K-wire interventions was similarly flawed by lack of reliable primary data.(103) There are no RCTs of pre-operative interventions to reduce SSI in hand trauma surgery. There is some evidence, albeit primarily observational, that the type of surgical preparation influences SSI risk in hand surgery.(45) Burying K-wires following hand and wrist fracture fixation may reduce SSI risk, but the RCTs were at high

risk of bias and so practice remains uninformed.(103) Although trials of post-operative interventions exist, they are not sufficiently robust to inform clinical practice.(36)

## 1.5 Summary

In this introductory chapter, I have described the anatomy and function of the hand and wrist, demonstrating its importance to our function in society. Hand trauma predominantly affects a young, working population and is highly prevalent as a condition. It is therefore logical that hand trauma is costly both to the individual and to society. Many injuries will require surgery to restore form and function. All surgery carries a risk of SSI, but we currently have insufficient data to quantify this risk. Many interventions exist that could reduce the risk of SSI in hand trauma surgery, but there are no robust clinical trials assessing their effectiveness.

# 2 SURGICAL SITE INFECTION IN HAND TRAUMA: A SYSTEMATIC REVIEW AND META-ANALYSIS

The first step in understanding SSI risk in hand trauma surgery is to look back at the existing literature. Although there are no single definitive studies that report robust SSI information for hand trauma surgery, I hypothesised that by collating and synthesising all studies of hand trauma surgery that report infection, I could generate an accurate summary statistic that described SSI risk. Whilst the robustness of this statistic would reflect the quality of the included studies, risk of bias evaluation and methodological and clinical subgroup analyses could facilitate useful interpretation. This Chapter describes a systematic review of primary studies that provide data on infection following a surgical intervention for hand or wrist injury. Data are synthesised across all studies, weighted by study size, and pooled in a meta-analysis to give an overall summary risk statistic. Subgroup analyses and meta-regression are then performed to explore different variables on SSI risk.

## 2.1 Abstract

**Background**

SSI is the most common HAI. SSI following hand trauma surgery results in increased antibiotic prescription, re-operation, hospital re-admission, delayed rehabilitation and can result in amputation. Hand trauma is bimodal, occurring in the young working population and the frail elderly. This has substantial socioeconomic implications. There are 250,000 operations for hand and wrist injury in the UK per annum and the risk of SSI following hand trauma surgery is unclear. This study aims to determine an overall SSI risk through systematic review and meta-analysis of all primary studies of surgery for hand and wrist injuries.

**Methods**

A systematic review and meta-analysis using methodology adapted from the Cochrane Handbook for Systematic Reviews of Interventions (PROSPERO CRD42020215825). Searches included MEDLINE, Embase, CINAHL, CENTRAL, Google Scholar and clinicaltrials.gov. The primary outcome was risk of SSI, calculated as a proportion for each study then compared across all studies through meta-analysis using R.

**Results**

In total, 8,836 abstracts and included 201 full studies of 315,618 participants in total. Meta-analysis indicated a summary risk statistic of 5.0% [95%CI 4.1 – 6.4]. The risk was highest in RCTs at 10.1% [9.0 – 11.4]. Subgroup analyses and meta-regression for clinical and methodological variables indicated variability in this risk across subgroups.

There was substantial variability in the classification and reporting of SSI across included studies. Most were at high risk of bias.

**Conclusions**

The pooled risk of SSI following surgery for hand trauma is approximately 5% and may be as high as 10%. This provides an overall risk, including all types of SSI, with the highest risks seen in RCTs. These figures must be contextualised in terms of variable SSI reporting, including limited use of established SSI classification and unclear outcome reporting. Further research to determine severity of SSI is warranted.

## 2.2 Introduction

SSI is the most common healthcare associated infection (HAI).(67) The baseline risk of SSI following all surgery is estimated to be 3-5% in the UK according to NICE.(53) SSIs lead to increased morbidity and mortality beyond the original indication for surgery and are potentially preventable. As such, research into reducing the risk of SSI is a global research priority.(67) Existing SSI statistics that are quoted in guidelines are often based on large observational studies in general surgical populations.(52,72) Data on the risk of SSI in hand surgery, particularly hand trauma surgery, is sparse. SSI following hand surgery leads to the need for additional interventions, including further surgery and delayed rehabilitation.(104) This in turn leads to impaired functional recovery, which is critical in a predominantly young and working population.(16) Prevention and cost-effective treatment of SSI following hand surgery is essential in terms of antibiotic stewardship, as there are over 250,000 hand trauma operations per year in the UK alone.(26) The importance of evaluating SSI risk in limb trauma was highlighted as the first priority in the James Lind Alliance Priority Setting Partnership for complex fractures.(105) This is especially important in hand trauma as fractures make up approximately 50% of all injuries.(14)

Without knowing the baseline risk of SSI for hand trauma surgery, it is difficult to provide fully informed consent for surgery – especially where non-operative interventions present an alternative option.(106) Furthermore, it is impossible to prioritise research on SSI in hand trauma surgery if we do not know the scale of the problem.(25) This review quantitatively summarises the risk of SSI in hand trauma surgery, entailing a comprehensive systematic review of all existing literature and a meta-analysis of proportions that generates meaningful summary risk statistics, informing both clinical practice and future research.

## 2.3 Methods

A systematic review using methodology adapted from the Cochrane Handbook for Systematic Review of Interventions, reported in accordance with the PRISMA statement.(107,108) A protocol was developed *a priori* and registered on the PROSPERO database (CRD42020215825).

### 2.3.1 Search strategy

Two search strategies were developed for each database: a text-term strategy and a database-specific MeSH term strategy (Appendix 1. Search strategies). These search strategies were uploaded prospectively onto the PROSPERO record. No date or language limits were applied. The search strategy was applied to the following bibliographic databases using the NHS Evidence Search engine: Medline, EMBASE and CINAHL provided by the NICE Healthcare Databases Advanced Search interface, the CENTRAL and clinicaltrials.gov. Searches were run from database inception to January 2021: MEDLINE (1946- January 2021), EMBASE (1974- January 2021), CINAHL (1981- January 2021). The reference lists of included articles were scrutinised for further relevant publications. EndNote version X8 (Thomas Reuters, New York City, NY, USA) was used to combine and organise the text term and MeSH/ Emtree term searches from each database and then to filter duplicate articles. The grey literature was searched at the same time as the primary search via Google Scholar. A top-up search was performed in July 2022 to ensure all studies were captured since the original search date. Search terms and databases were identical for the top-up search. A study attrition chart was created to display the results of the search strategy and subsequent screening process in accordance with the PRISMA statement.(107)

### 2.3.2 Study eligibility

The inclusion and exclusion criteria were established during protocol development, according to the PICO framework. All prospective studies, both experimental and observational that met the following criteria were included:

#### 2.3.2.1 Participants

Adult participants (≥18 years old) with hand and/or wrist injuries.

#### 2.3.2.2 Intervention and Comparator

Any surgical intervention, with or without a control arm.

#### 2.3.2.3 Outcomes

Reported surgical site infection by any classification system or diagnostic method.

#### 2.3.2.4 Study types

Studies of mixed adult and paediatric populations were included if the data was reported separately for each population. Case reports, opinion pieces, systematic reviews and meta-analyses, narrative and scoping reviews and anatomical, cadaveric, laboratory and biomechanical studies were excluded. Cohort studies were defined by inclusion criteria of the particular study, i.e., if the inclusion criteria was based on a population characteristic such as distal radius fracture. Case series were defined as studies that included participants based on intervention, i.e., patients who underwent external fixation of distal radius fracture.

### 2.3.3 Data extraction

Abstracts were screened in duplicate to identify potential studies for review, using a pre-specified checklist of the criteria for inclusion (Appendix 2. Abstract decision tree).

Data were extracted in duplicate onto a predefined electronic form. The unit of analysis was the patient rather than the hand/wrist.(109)

### 2.3.4 Data analysis

A descriptive analysis was performed first to summarise the elements of the included study characteristics, such as the number of individual study designs and types, the total number of patients in the included studies and the total number of reported SSIs, along with other clinically relevant characteristics.

Meta-analysis of proportions was then performed to determine pooled risk of SSI across study populations.(110) R version 4.0.3 (2020-10-10) was used with the 'meta' (version 5.2-0) and 'metafor' (version 3.4-0) packages.(108,109) Sub-group analyses were performed for methodological (study design, study type, infection classification) and clinical subgroups (injury site, injury type, intervention). Where an outcome has a proportion (i.e. risk of SSI) of between 20% and 80%, meta-analysis of raw proportions is reasonable. However, when the risk is less than 20% or higher than 80%, the data should be log-transformed. If the included studies have low sample sizes and/or proportions close to zero/one, then the double-arcsine method is better.(110) As the majority of studies were large and the reported SSI risk was <20%, the logit transformation was selected. Statistical heterogeneity was assessed using the $Chi^2$ test ($P < 0.10$ = statistically significant heterogeneity) and the $I^2$ measure.(113) Due to the broad inclusion criteria for this review, including multiple study types and designs, statistical heterogeneity was not used as a determining factor for pooling, e.g. no pre-specified $I^2$ cut-off. Both common (fixed) and random-effects models are reported. For the random-effects models, between-study variance ($tau^2$) was modelled using REML throughout.

A mixed-effects meta-regression was employed to explore heterogeneity in the clinical and methodological variables of interest. The following categorical fixed effects were used for univariable models in the first instance: study design, study type, infection definition, the risk of methodological bias, injury site, injury type and intervention. Thereafter, to explore whether the method of fixation was independently associated with the risk of SSI, a multivariable meta-regression model was set up including all of the above factors. After computing the variance inflation factors (used to quantify potential multicollinearity), 'study design' (RCT vs. cohort study vs. case-control) was removed given that it was strongly co-linear with study type (retrospective vs. prospective). Odds ratios (OR) with 95% confidence intervals were generated (Appendix 3 – R code for meta-analysis).

## 2.3.5 Risk of bias assessment

### 2.3.5.1 Experimental study designs

Cochrane Risk of Bias 2 tool (RoB 2), described in the Cochrane Handbook for Systematic Reviews of Interventions, was used to assess risk of bias in RCTs and quasi-RCTs.(114) RCTs were then classified as low risk, moderate risk or high risk of bias.

### 2.3.5.2 Observational study designs

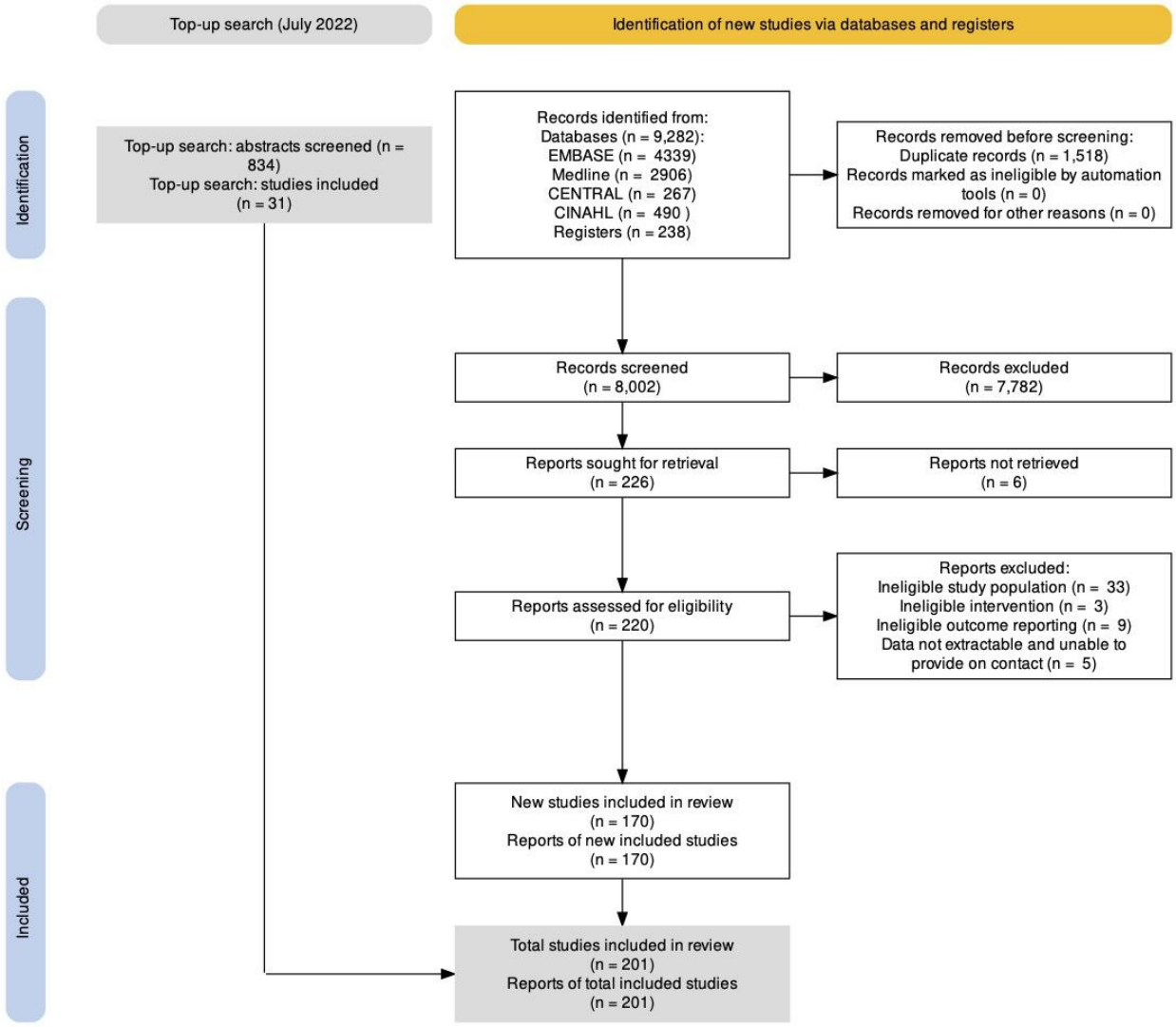
The risk of bias for cohort studies, case control studies and case series was assessed using the National Institute of Health - National Heart, Lung and Blood Institute Study Assessment Tools for the respective study designs.(115) Based on pre-specified domains, each study is assessed and given an overall rating: good, fair or poor. To be consistent with RoB 2, this was converted to low, moderate or high risk of bias.

## 2.4 Results

### 2.4.1 Search results

The search identified 9,520 studies of which 1518 were duplicates. In total, 8,002 abstracts were screened against pre-defined eligibility criteria to determine potential for inclusion. Of these, 7,782 records were excluded and 226 retrieved for full text screening. Six records were not available despite library requests, and so the remaining 220 full-text articles were evaluated in detail for eligibility. Google Translate was used where articles were not in English to determine eligibility.(116) Following scrutiny, 170 studies were deemed eligible for inclusion in the review, and 50 were found ineligible. In July 2022, an additional top-up search was run using the same search strategy outlined above. Another 834 abstracts were screened and an additional 31 eligible studies were included. This resulted in a total of 201 included studies in the review.

**Figure 5. PRISMA flow chart of study attrition**



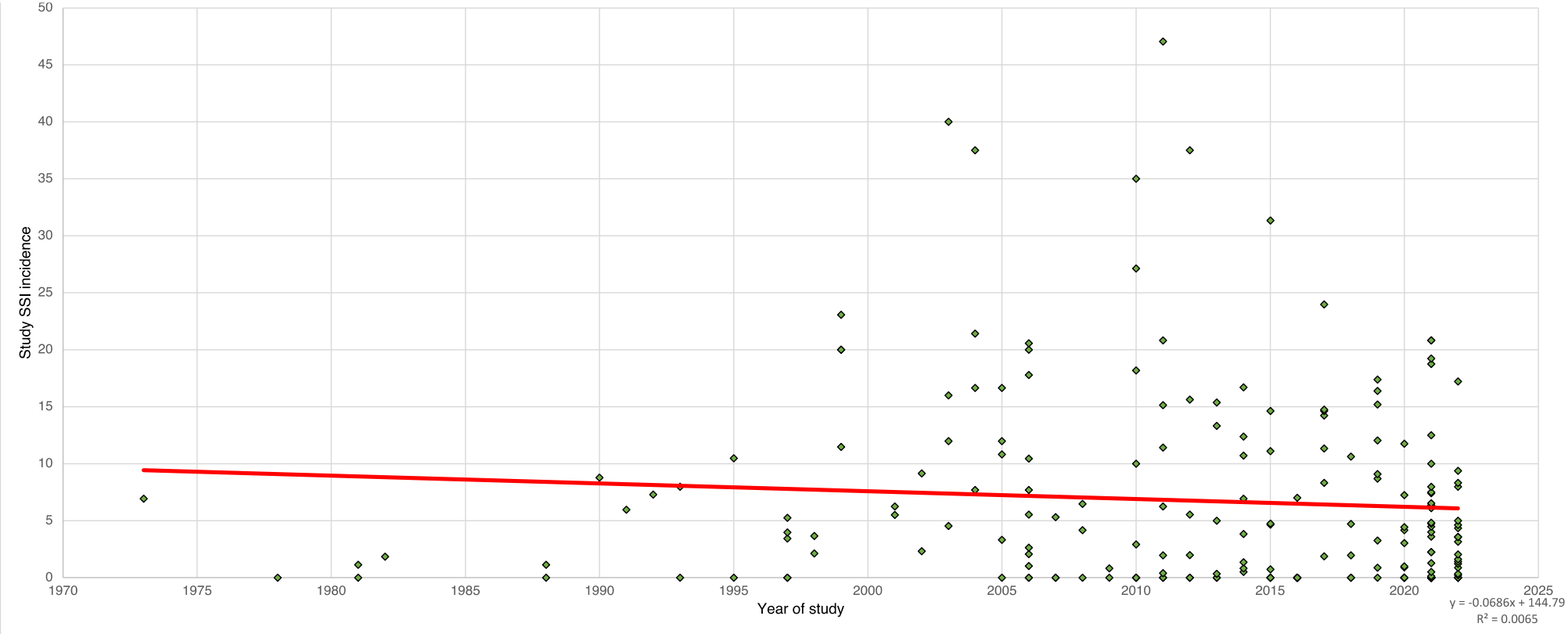

## 2.4.2 Characteristics of included studies

There were 315,618 study participants across all included studies and 3,131 individual incidences of SSI (Appendix 4. References to all included studies). The individual proportion of cases that developed an SSI in each study ranged from 0% to 47%. The included studies were published between 1973 and 2022, and derived from Europe, America, Asia, Africa and Australia. Study populations ranged from three participants to 132,650 participants. Between 1973 and 2022 there was no discernible

change in incidence of SSI in the published literature (Figure 6. SSI incidence over time). Of the 201 included studies, 27 were RCTs and 174 were observational studies (79 cohort studies, two case-control studies and 93 case series). The majority of studies were retrospective (129, 60%), with 70 being prospective (40%) and 14 studies used a recognised classification or definition for surgical site infection (14, 7%). The majority of studies simply reported infection as a clinical entity (142, 71%) with 45 studies not reporting how infection was defined (22%) (Table 1. Characteristics of included studies).

Study participants with hand injuries were evaluated in 105 of the included studies (52%). Participants with wrist injuries were evaluated in 81 of the included studies (40%), with the remaining 15 studies evaluating populations with mixed hand and wrist injuries (7.5%). Closed injuries were investigated in 90 studies (45%), open injuries in 56 studies (28%) and mixed open and closed injuries in 55 studies (27%). Of the surgical interventions that were evaluated in the included studies, 21 studies assessed outcomes following external fixation (11%), 43 following K-wire fixation (21%), 53 following ORIF (26%), 37 following soft tissue reconstruction (19%) and 47 studies assessed multiple interventions (23%). (Appendix 5. Characteristics of included RCTs, Appendix 6. Characteristics of included cohort studies, Appendix 7. Characteristics of included case-control studies, Appendix 8. Characteristics of included case series

**Figure 6. SSI incidence over time**



## Table 1. Characteristics of Included Studies

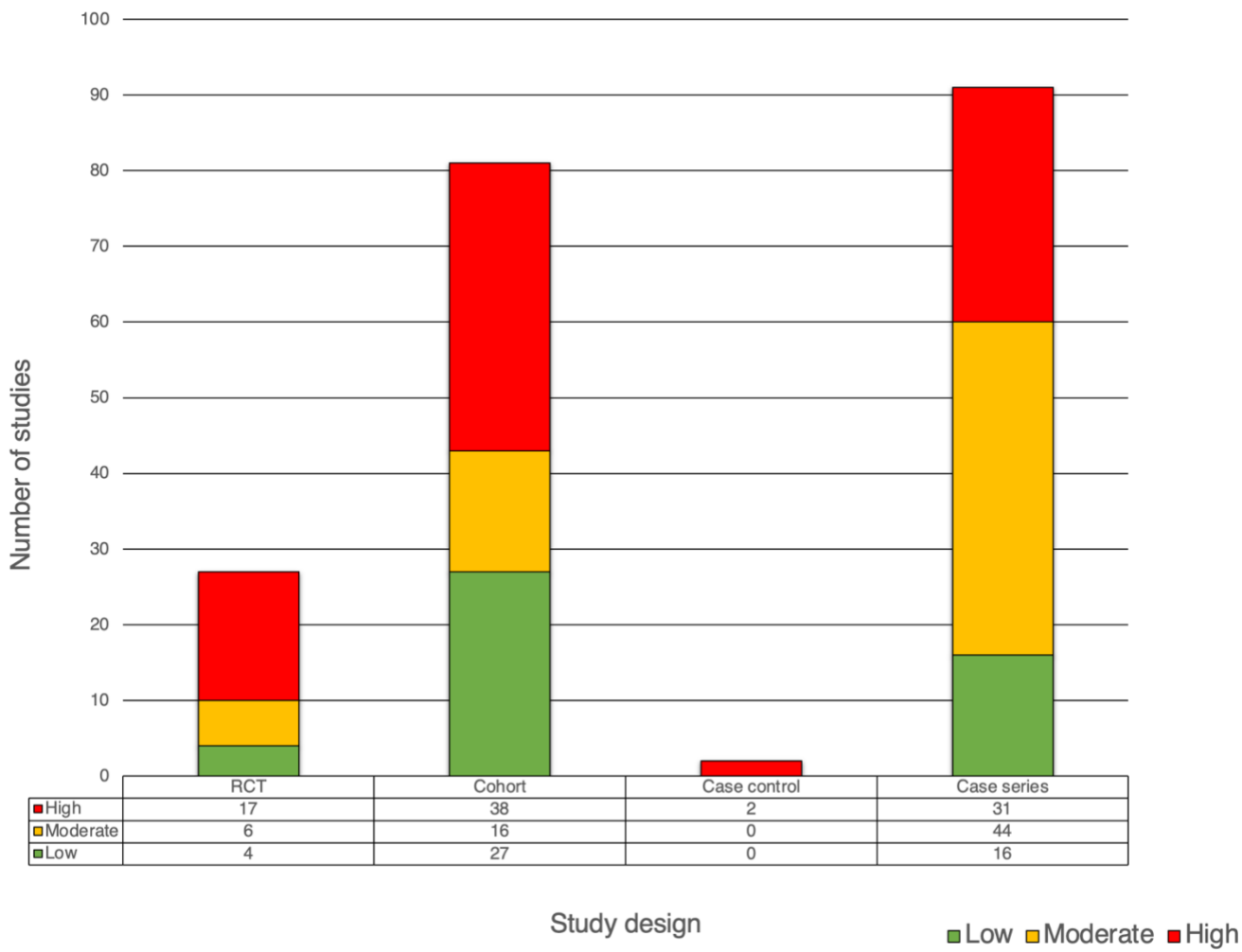
RCT = randomised control trial, n total = total participants in study design population, SSI = surgical site infection, 95%CI = confidence interval

| Study design | n studies | n total | SSI risk | 95%CI lower | 95%CI upper | Risk of Bias (% studies) |
|---|---|---|---|---|---|---|
| *RCT* | 27 | 3,867 | 10.1 | 9.0 | 11.4 | *15* / *22* / *63* |
| *Cohort* | 79 | 306,244 | 1.5 | 1.5 | 1.6 | *33* / *31* / *48* |
| *Case control* | 2 | 37 | NA | NA | NA | *100* |
| *Case series* | 93 | 5,264 | 8.6 | 7.7 | 9.6 | *17* / *48* / *34* |
| **Overall** | **201** | **315,618** | **5.0** | **3.9** | **6.1** | ***23*** / ***33*** / ***44*** |

### 2.4.3 Risk of bias of included studies

Of the 201 included studies, 88 were at high risk of bias (44%), 66 were at moderate risk of bias (33%) and 47 were at low risk of bias (23%) (Figure 7. Risk of bias of included studies). Of the 27 included RCTs, only four were at low risk of bias (15% of RCTs). Another six were at moderate risk of bias (22%), and the remaining 17 were at high risk of bias (63%). Of the 81 included cohort studies, 27 were at low risk of bias (33%), 25 studies were at moderate risk (31%) and 39 were at high risk of bias (48%). Both case control studies were at high risk of bias. Of the 91 included case series, 16 were at low risk of bias (17%), 44 were at moderate risk (48%) and 30 were at high risk of bias (34%).

**Figure 7. Risk of bias of included studies**



### 2.4.4 Meta-analysis of risk of surgical site infection

All studies were eligible for inclusion in the meta-analysis. The summary risk of SSI across all studies was 5.0% [CI 3.9 – 6.1] (Table 2. Meta-analysis of SSI risk in hand trauma, Appendix 9. Meta-analysis of all included studies). There was statistical heterogeneity as demonstrated by high $I^2$ statistics. Random effects analyses handled the heterogeneity better than common (fixed) effects and so only the former are discussed.

**Table 2. Meta-analysis of SSI risk in hand trauma**

| | | | | | Pooled SSI risk (%) | | Meta-regression | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | No. of studies | No. of patients | SSI risk | 95% CI | OR | 95% CI | P-value | |
| **Methodological variables** | Study design | RCT | 27 | 3,867 | 10.1 | 9.0 – 11.4 | 0.3 | 0.1 – 1.8 | 0.19 | * |
| | | Cohort | 79 | 306,224 | 1.5 | 1.5 – 1.6 | 0.2 | 0.0 – 1.1 | 0.06 | * |
| | | Case series | 93 | 5,264 | 8.6 | 7.7 – 9.6 | 0.3 | 0.0 – 1.5 | 0.23 | * |
| | | Case control | 2 | 37 | 21.8 | 11.3 – 38.0 | 0.3^ | 0.0 – 1.5 | 0.12 | * |
| | Study type | Retrospective | 129 | 307,857 | 4.7 | 3.6 – 6.0 | 0.8 | 0.5 – 1.3 | 0.41 | ** |
| | | Prospective | 70 | 7,555 | 6.0 | 4.2 – 8.3 | 0.4^ | 0.1 – 2.7 | 0.35 | ** |
| | Infection definition | Unknown | 45 | 8,128 | 4.4 | 2.7 – 7.2 | 1.9 | 0.8 – 4.3 | 0.12 | ** |
| | | Clinical | 142 | 264,420 | 5.3 | 4.1 – 6.9 | 1.9 | 0.9 – 3.7 | 0.07 | ** |
| | | Definition | 14 | 42,864 | 4.1 | 1.9 – 8.8 | 0.4^ | 0.1 – 2.7 | 0.35 | ** |
| | Risk of Bias | Low | 47 | 37,841 | 4.1 | 2.4 – 6.8 | 0.9 | 0.5 – 1.6 | 0.81 | ** |
| | | Moderate | 66 | 271,453 | 4.4 | 3.1 – 6.3 | 0.8 | 0.5 – 1.2 | 0.31 | ** |
| | | High | 88 | 6,118 | 6.1 | 4.4 – 8.3 | 0.4^ | 0.1 – 2.7 | 0.35 | ** |
| **Clinical variables** | Injury site | Wrist | 81 | 299,805 | 4.5 | 3.3 – 6.2 | 0.7 | 0.4 – 1.1 | 0.15 | ** |
| | | Mixed | 15 | 3,806 | 5.6 | 2.9 – 10.7 | 0.8 | 0.4 – 1.6 | 0.52 | ** |
| | | Hand | 105 | 11,801 | 5.5 | 4.1 – 7.2 | 0.4^ | 0.1 – 2.7 | 0.35 | ** |
| | Injury type± | Open | 56 | 7,005 | 4.9 | 2.6 – 9.3 | 1.3 | 0.3 – 1.1 | 0.41 | ** |
| | | Closed | 90 | 154,564 | 4.2 | 2.7 – 6.4 | 0.4^ | 0.1 – 2.7 | 0.35 | ** |
| | Intervention± | STR | 37 | 2,460 | 4.6 | 2.8 – 8.5 | 0.3 | 0.1 – 0.8 | 0.02§ | ** |
| | | ORIF | 53 | 169,098 | 2.0 | 1.2 – 3.1 | 0.2 | 0.1 – 0.3 | <0.001 | ** |
| | | K-wire | 43 | 5,739 | 7.0 | 4.7 – 10.4 | 0.5 | 0.3 – 1.1 | 0.11 | ** |
| | | Ex-Fix | 21 | 1,127 | 15.4 | 7.7 – 28.6 | 0.4^ | 0.1 – 2.7 | 0.35 | ** |
| **Overall** | | | **201** | **315,618** | **5.0** | **3.9 – 6.1** | | | | |

*Unadjusted; Heterogenity: $I^2$ 95.5%, p=<0.0001 ** Adjusted, heterogenity: $I^2$ 90.3%, p=<0.0001 ± mixed study populations excluded from analyses § not significant with mixed study populations excluded ^ intercept

STR – soft tissue reconstruction

2.4.4.1 Meta-analysis of risk of surgical site infection: subgroup analyses by methodology (Figure 8. Risk fo SSI by methodological subgroup analysis)

*2.4.4.1.1 Study design*

Subgroup analysis by study design elicited unexpected and interesting findings (Appendix 10. Meta-analysis: subgroup analysis by study design). The risk of SSI in the RCT study population (n=3,867) was substantially higher than that found in the overall analysis above: 10.1% [CI 9.0 – 11.4]. The risk of SSI in case series population (n=5,412) was also higher than the overall summary statistic: 8.6% [95%CI 7.7 – 9.6]. The cohort study population (n=306,136) had an extremely low summary risk of SSI: 1.5% [CI 1.5 – 1.6]. The two case-control studies (n=37) were small and at high risk of bias and so were excluded from the study design analysis. Univariate meta-regression showed that study design did not account for the observed heterogeneity in the dataset (p=0.06 to 0.23).

*2.4.4.1.2 Study type*

Subgroup analysis by study type (retrospective vs. prospective) elicited a similar SSI risk in prospective study populations: 6.0% [CI 4.2 – 8.3], compared to retrospective studies: 4.7% [CI 3.6 – 6.0]; multivariate meta-regression (p=0.41). (Appendix 11. Meta-analysis: subgroup analysis by study type)

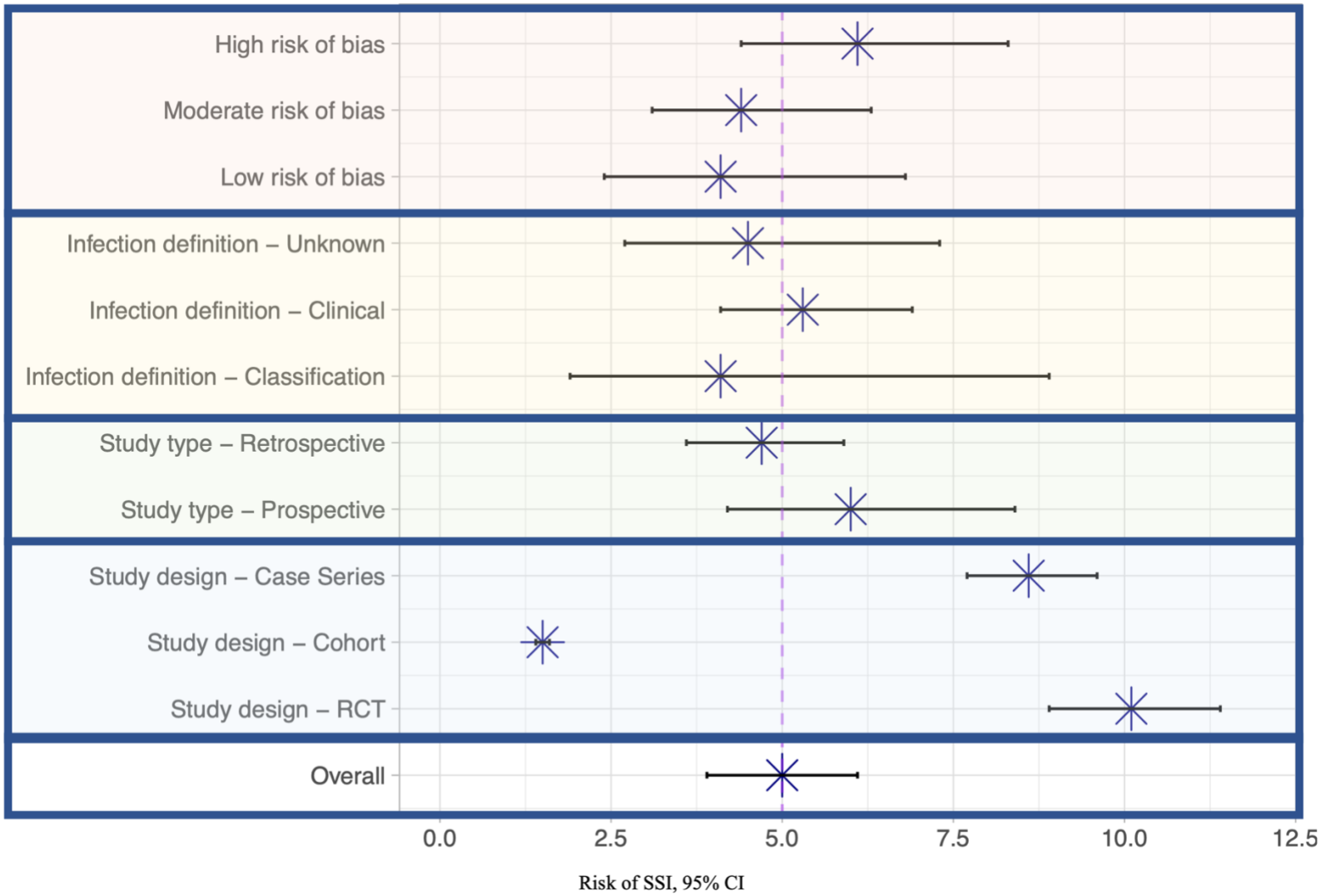
*2.4.4.1.3 Infection definition*

Infection definition did not dramatically affect the risk of SSI in the study populations. Where an established definition of infection was used, the risk of SSI was 4.1% [CI 1.9 – 8.8]. Where a ‘clinical’ definition was used, the risk was 5.3% [CI 4.1 – 6.9] and where no definition was described, the risk was 4.4% [CI 2.7 – 7.2], although the difference was not significant (p=0.07). (Appendix 12. Meta-analysis: subgroup analysis by infection definition).

*2.4.4.1.4 Risk of bias*

The SSI risk in studies at low risk of bias was 4.1% [CI 2.4 – 6.8]. The SSI risk in studies at moderate risk of bias was 4.4% [CI 3.1 – 6.3]. Studies at high risk of bias had an overall SSI risk of 6.1% [CI 4.4 – 8.3]. These differences were not statistically significant (p=0.31, p=0.81). (Appendix 13. Meta-analysis: subgroup analysis by risk of bias).

**Figure 8. Risk of SSI by methodological subgroup analysis**



2.4.4.2 Meta-analysis of risk of surgical site infection: subgroup analysis by clinical factors (Figure 9. Risk of SSI by clinical subgroup analysis)

*2.4.4.2.1 Injury site*

In terms of the anatomical site of injury, the risk of SSI was highest in the hand population: 5.5% [CI 4.1 – 7.2] and in the mixed hand and wrist populations: 5.6% [CI 2.9 – 10.7]. The risk in the wrist injury population was 4.5% [CI 3.3 – 6.2]. This difference was not significant (p=0.15, p=0.52). (Appendix 14. Meta-analysis: subgroup analysis by injury site)

*2.4.4.2.2 Injury type*

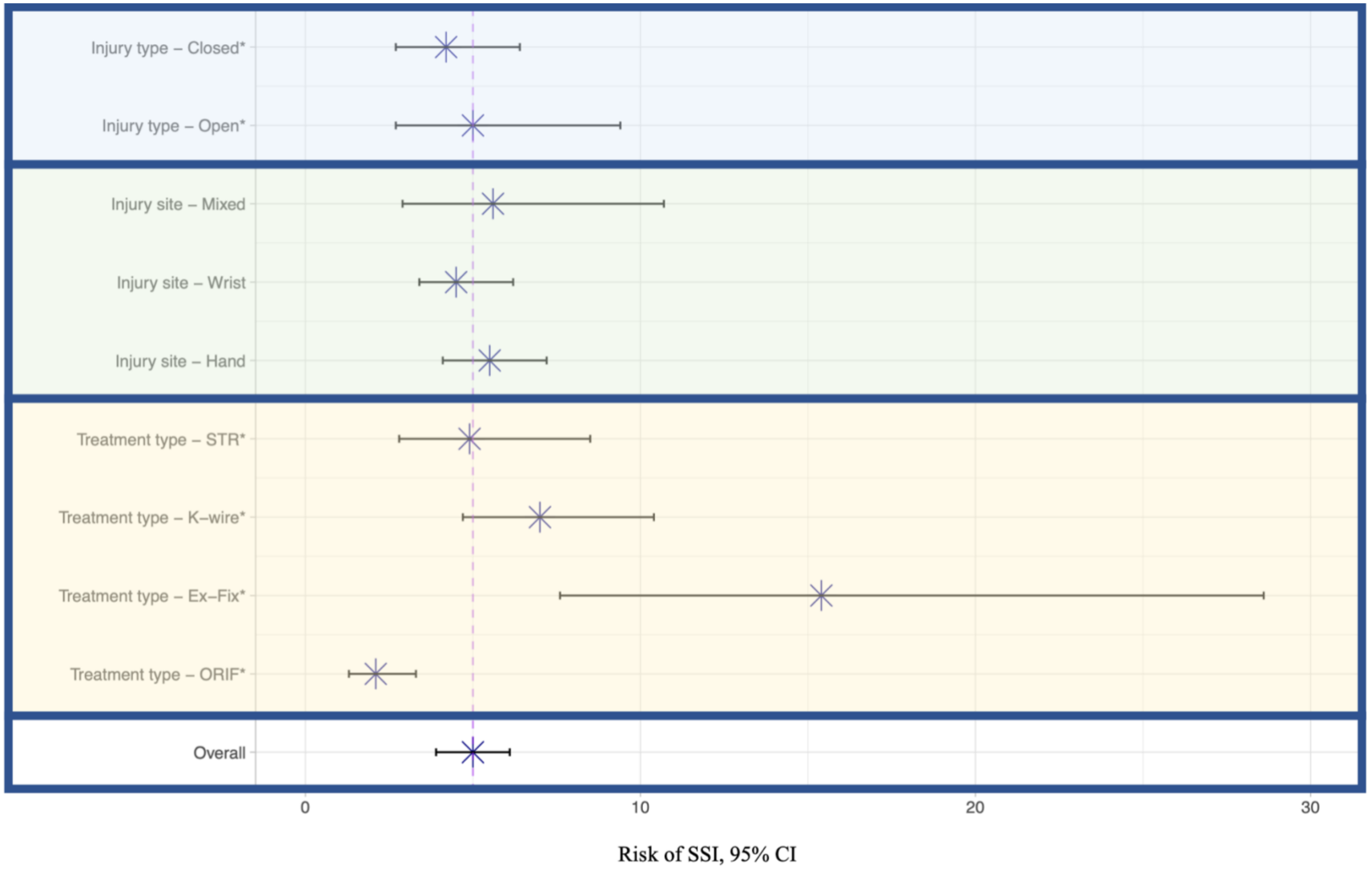
The mixed population studies were excluded for the injury type (open vs. closed) subgroup analysis to ensure the different risk statistics were an accurate representation of the populations. The SSI risk in closed injuries was 4.2% [CI 2.7 – 6.4] whilst open injuries was 4.9% [CI 2.6 – 9.3]. This difference was not significant (p=0.45). (Appendix 15. Meta-analysis: subgroup analysis by injury type).

*2.4.4.2.3 Intervention*

As per 'Injury type', studies of multiple interventions were excluded from this subgroup analysis so that the summary risks were specific to each intervention. For study participants who underwent soft tissue reconstruction only, i.e. no bony reconstruction, the SSI risk was 4.6% [CI 2.8 – 8.5]. For the remaining participants who underwent fracture fixation, the SSI risk for ORIF was: 2.0% [CI 1.2 – 3.1], for K-wire fixation was: 7.0% [CI 4.7 – 10.4] and for external fixation was: 15.4% [CI 7.7 – 28.6] and these differences were statistically significant (p=<0.01). After controlling for other factors using multivariate meta-regression, it appeared that ORIF has an 80% lower risk of SSI (OR 0.2, p=<0.001

[CI 0.1 – 0.3]) compared to external fixation, the lowest of all surgical interventions. This suggests that a proportion of the heterogeneity seen in the dataset is due to true differences in SSI risk for different interventions. (Appendix 16. Meta-analysis: subgroup analysis by intervention)

**Figure 9. Risk of SSI by clinical subgroup analysis**



## 2.5 Discussion

This systematic review is an inclusive overview of all studies of surgical intervention for hand trauma that report post-operative infection as an outcome, synthesising data from 315,618 patients. Through meta-analysis, summary statistics have been generated that can be used to infer risk of SSI for both clinical and research purposes. The overall risk of SSI for hand trauma surgery is approximately 5% but the true risk may be higher, as demonstrated in the studies with fewest methodological flaws. This means that the risk is at least as high as the UK NICE estimate of 3-5%, and probably higher.(53) Moreover, it is generally accepted that national SSI statistics are underestimated as SSIs that occur outside the hospital are often not counted.(72) The statistics generated through meta-analysis should be interpreted cautiously, as SSI reporting was hugely variable across studies, with few using established SSI classification systems.

A higher SSI risk was found in RCT populations which is mirrored in RCTs in other surgical fields. A meta-analysis of 21 RCTs evaluating antimicrobial sutures in abdominal wounds had pooled SSI risks of over 10% in both intervention and control groups.(54) The ‘true’ risk of SSI for hand trauma surgery probably lies between 5% (overall risk) and 10% (risk in RCTs) based on our current understanding of SSI research. SSIs in hand surgery are poorly documented in the medical notes, and thus may be missed in studies that rely on retrospective case review.(117) It is unlikely to be lower than 5%, despite the low SSI risk seen in the cohort study subgroup analysis. That subgroup analysis is influenced by very large, retrospective registry studies which are unreliable for detecting SSI as they rely solely on valid record keeping and coding.(118,119) Looking at the largest included studies, the SSI risk ranges from 0.1% to 2.3% in studies with over 10,000 participants.(120–123) These four studies all evaluate distal radius fracture fixation,

mostly ORIF and all are retrospective. These studies carry considerable weight in the meta-analysis due to their large study populations and will therefore influence the overall SSI risk, but particularly the risk in the study design and intervention subgroup analyses.

Other than study design, aspects of research design and quality did not appear to result in substantially different risks of SSI. The use of a pre-defined infection classification system (CDC, most commonly) did not change the SSI risk: 4.2% compared to 4.4% where no definition was stated (Appendix 12. Meta-analysis: subgroup analysis by infection definition). Similarly, studies that were at high risk of bias had only a marginally higher risk of SSI compared to those at moderate or low risk of bias (6% compared to 4%). One explanation for the highest SSI risk in RCTs could be that they are all prospective, have lower attrition and utilise pre-defined criteria which reduces measurement bias, translating to more reliable data. Meta-regression was employed to determine the effect of study type (retrospective vs. prospective) on study design in terms of SSI risk. The prospective nature of a study did not explain the higher risk of SSI in RCTs and therefore other variables associated with clinical trials must account for the increased risk, such as improved overall study quality. (Appendix 17. Meta-regression output).

There were a number of expected findings in the subgroup analyses, such as a lower risk of SSI in patients undergoing ORIF, where the incisions are usually made in a controlled surgical environment with optimal sterility to protect the implant. In contrast, a higher rate of SSI was observed in those who had external fixation for hand and wrist fractures. Again, this is in keeping with clinical experience, where usually the most severe injuries require external fixation and therefore may have a higher baseline risk of infection. The risk of SSI for those undergoing K-wire fixation of hand and wrist fractures was 7%, which is consistent with existing meta-analyses.(103,124,125) The SSI risk for injuries

requiring soft-tissue reconstruction was 5%, equal to the overall risk generated in this dataset and the existing literature.(126,127)

A higher risk of infection in open injuries compared to closed injuries is expected, but this was not borne out in these results. One theory is that because of the perceived elevated risk of infection (drawn from non-upper limb literature), open injuries may undergo debridement faster and receive adjuvant antimicrobial interventions.(128,129) In contrast, closed injuries, which are thought to have a lower baseline risk of SSI, may receive less antimicrobial prophylaxis. It was unsurprising that the SSI risk was slightly higher in the hand surgery population compared to the wrist surgery population, as the latter had a substantially larger number of ORIF studies, which have an independently lower risk of SSI.

There is good evidence that SSI risk is higher in developing countries based on the GlobalSurg 2 international audit, where the incidence of SSI following gastrointestinal resection was as high as 39.8% in low middle income countries (LMICs), compared to 9.4% in high income countries.(130) The overall risk of SSI in the recently published FALCON trial, based in 54 developing countries and containing 5,788 participants, was 22%, increasing to 30% in dirty wounds.(86) It is likely that the risk of SSI following hand trauma would be similarly increased in developing countries and should be a future priority for global health research in hand trauma.

### 2.5.1 Strengths and limitations

The key limitation of this meta-analysis is the poor reporting of SSI within included studies. Most studies were at high risk of bias and the minority employed an established classification of SSI. Follow-up time varied across studies, as did peri-operative antimicrobial use. In terms of strengths, rigorous methodology was imposed to

maximise the robustness of this systematic review and as such this has improved the reliability of the results. A protocol was developed *a priori* and registered on the PROSPERO database to improve transparency. Meta-regression was employed, which was not initially planned at the protocol stage. There were otherwise no differences between the protocol and review. The design of the review has resulted in a very large dataset, enabling the research question to be answered with a high level of statistical precision. The search strategy was comprehensive and was updated in July 2022. However, it is possible that some studies will have been missed. A small group trainee collaborative model was used to reduce burden and fatigue in the abstract screening, data extraction and risk of bias stages of the review. This has improved the quality of the scrutiny at each stage and has also upskilled a new group of systematic reviewers. The statistical analyses of this review have been performed by the lead author with oversight from an established medical statistician.

The review is limited to some extent by the heterogeneity of the included studies. A different approach could involve selectively pooling studies that had similar methodological or clinical characteristics to reduce heterogeneity and improve reliability of the summary statistics. For example, only pooling RCTs of fracture fixation, or only pooling studies with over 100 participants. Another option could be to use an $I^2$ cut off to determine pooling, e.g. <20%. These approaches may yield different results from those generated here. Pooling all in one meta-analysis with subgroup analyses may predispose to potentially less valid results, as very small and low quality studies will contribute towards the summary statistics. There was no clear evidence of publication bias based on funnel plot analysis (Appendix 18. Meta-analysis – funnel plot).

A final limitation of this meta-analysis is that I am unable to determine the severity of SSI from the pooled statistics. This was poorly reported in the original studies

and therefore it was impossible to get this granularity. Different severities of SSI, superficial and deep, will require different treatment strategies and will result in different outcomes. Superficial SSI is usually treated with minor procedures such as suture removal and oral antibiotics. Deep SSI will often require hospital admission and further surgery, delaying recovery and rehabilitation and resulting in a poor outcome. Understanding the risk of these two types of SSI is therefore important.

## 2.6 Conclusion

The pooled risk of SSI following surgery for hand trauma is approximately 5% and may be as high as 10%. This provides summary statistics that can be used clinically, for informed consent and shared decision making and to inform power calculations for future clinical studies of antimicrobial interventions in hand trauma surgery. This should however be on the understanding that there was substantial heterogeneity in the included studies, with predominantly poor outcome reporting. Further work is needed to determine the severity and type of SSIs that usually occur following hand trauma surgery.

# 3 SUPERFICIAL SURGICAL SITE INFECTION IN HAND TRAUMA: ANALYSIS OF NHS PRIMARY CARE ELECTRONIC MEDICAL RECORDS

Having established an overall risk for SSI across all types and severities in the previous Chapter, here I describe the first workstream to add granularity to this statistic. SSIs may be superficial, deep or organ/space in nature in order of increasing severity. Superficial SSI affects the skin incision and surrounding superficial tissues. It is usually treated with oral, systemic antibiotics or a minor surgical intervention, such as removing sutures. The existing literature that reports SSI following hand trauma is almost exclusively set in secondary care, where patients return to hospital for treatment for their infections. It is logical that a proportion of patients will seek treatment for superficial SSI in primary care. There were no data currently exploring SSI in primary care following hand trauma surgery. This Chapter describes an analysis of nationwide electronic patient records in the primary care setting to test the hypothesis that there is a group of hand trauma surgery patients who are treated for superficial SSI in the community.

# 3.1 Abstract

**Background**

Chapter 2 has identified an overall risk of SSI at 5%, but it is not clear how severe these SSIs are. The CDC define SSI as either superficial, deep or organ space. Superficial SSI is most commonly treated with oral antibiotics, and may be treated only in primary care following surgery. I aimed to explore this by examining electronic patient care records based in primary care, employing antibiotic prescriptions as a surrogate for superficial SSI.

**Methods**

A cohort study using NHS UK-wide GP records, based on the Clinical Practice Research Datalink (CPRD) GOLD database to investigate the treatment of superficial SSI following hand trauma surgery. An initial hand trauma cohort was identified using relevant Read codes. Cohort characterisation was performed to attain demographic and treatment data for this primary cohort. A second Read code list of hand trauma surgical interventions was then applied to the primary cohort to generate a highly specific cohort of patients who underwent hand trauma surgery. Demographics, cohort characterisation and prescription data was analysed to determine the incidence of superficial SSI, ascertained by treatment with clinically appropriate oral antibiotics at 30 days and 90 days. Descriptive analyses are used for SSI and other complications, reported as proportions (%) with 95% confidence intervals.

**Results**

The hand trauma cohort comprised 641,223 patient records, a predominantly male (57.3%), healthy population with a mean age (SD) of 34.9 (13). By 30 days post-injury, 5.2%, (CI [5.2 – 5.3]) had been prescribed an antibiotic clinically-appropriate for treating

SSI, rising to 13.9% (CI[13.8 – 14.0]) by 90 days. The cohort that underwent surgery for hand or wrist injury contained 3,088 patients, predominantly male (65.4%), healthy, with a mean age (SD) of 39.2 (21.5). By 30 days, 6.2% had been prescribed antibiotics appropriate for SSI, rising to 14.4%, CI[13.2 – 15.8]) by 90 days. Flucloxacillin was prescribed in 2.2% of this cohort by 30 days and 4.5% by 90 days. Higher rates of NSAID and opiate prescription were seen in the surgical cohort.

**Conclusions**

Using the prescription of clinically appropriate antibiotics within 30 days and 90 after surgery as a surrogate, the risk of superficial SSI is 6.2% (30 days, CI[5.4 – 7.1]) and 14.4% (90 days, CI[13.2 – 15.8]). This indicates that although the overall risk is 5.0%, the risk of superficial SSI is actually higher at both 30 and 90 days after surgery.

## 3.2 Introduction

The overall risk of SSI following hand trauma surgery is likely to be approximately 5.0% to 10%, based on the pooled literature in the previous Chapter. We do not know the types or severity of the SSIs that are counted within this figure. The CDC define superficial SSI as occurring within 30 days (or 90 days if a surgical implant is used) and involves only skin and subcutaneous tissue of the incision.(132) The patient must have at least met one of these criteria: pus from the superficial incision, the superficial wound deliberately opened by a clinician, a microbiological diagnosis and or symptoms of superficial SSI (redness, pain, swelling etc.).

Many SSIs in the hand and wrist may be superficial, without systemic morbidity, and therefore patients may prefer to present to their GP rather than return to hospital. Hand trauma surgery patients are usually ambulatory and are managed in an outpatient, day-case surgery setting the majority of the time.(26) Patients are counselled to contact the hand trauma team if they develop post-operative complications. Previous studies of SSI in hand trauma surgery have relied on patients re-presenting to secondary care for treatment. This may underestimate the incidence of SSI in hand trauma and may overestimate the severity. Unlike in other musculoskeletal surgery, such as hip fracture or knee arthroplasty, the proportion of patients presenting to primary care is likely to be relatively high. I therefore hypothesise that there is a contingency of hand trauma surgery patients who solely present to primary care with SSI and require antibiotic treatment. This Chapter describes a UK-wide cohort analysis of primary care electronic data records via the CPRD platform to determine the risk of superficial SSI following hand trauma surgery.

# 3.3 Methods

## 3.3.1 Study design

An observational study design within the CPRD database to investigate the treatment of post-operative infection following surgery for hand trauma within primary care. Data derived from CPRD GOLD was used, comprising deidentified primary care data of 21 million patients. CPRD GOLD is representative of the UK population in terms of age, sex, ethnicity and BMI. The study is reported in accordance with the STROBE checklist.(133)

## 3.3.2 Participants

A Read code list was developed that generated a cohort of patients who had sustained injuries to the hand and/or wrist (Appendix 19. Read code list – hand trauma). Patients were eligible for entry into the 'hand trauma cohort' if they had a relevant condition Read code within their medical record that indicated an injury to the hand or wrist. The hand trauma cohort includes patients who have sustained open and closed hand and wrist fractures, dislocations and subluxations, all soft-tissue injuries to the hand and wrist, including 465 specific read codes for nerve, tendon, vessel and ligament injuries.

A second Read code list was then developed, consisting of procedural Read codes that relate to operations for a hand/wrist injury, including soft tissue closure, reconstruction of tendons and nerves, removal of foreign bodies and fracture and joint manipulation and fixation (Appendix 20. Read code list – hand trauma surgery) Patients were eligible to enter the 'hand trauma surgery' cohort if they underwent a relevant operative procedure within ten days of injury. This cohort was generated by applying this criterion to the existing 'hand trauma cohort', so that only those who definitely underwent

surgery could be analysed. This surgical cohort was defined using 159 Read codes, of which 67 pertained to soft tissue reconstruction (30 tendon repair, 14 soft tissue reconstruction, 8 amputation/terminalisation, 15 other) and 93 pertained to fracture fixation (44 open reduction, 33 closed reduction, 16 other). Prior to analysis, cohort diagnostics were run to ensure both code lists were comprehensive and included all relevant codes pertaining to hand trauma surgery. Cohort diagnostics was then used to identify potentially missing codes via in-build machine learning algorithms. Missing codes were reviewed and included if relevant.

### 3.3.3 Outcomes

For both cohorts, characterisation analyses were performed to determine population demographics (age and sex), injury types and prevalence, types and frequency of surgical procedures. Prescription data were extracted for up to 30 days and up to 90 days to ascertain treatment with antibiotics in these time periods following surgery. Prescription of antibiotics in the time-periods specified is a valid surrogate for post-operative infection based on the existing literature.(134–138) This method was further validated for this study by refining the type of antibiotic prescribed compared with pre-injury prescription rates and only analysing those potentially relevant to superficial wound infection. As these are solely oral antibiotic prescriptions, we can infer that the type of SSI that is being treated is superficial SSI. Deep or joint space SSIs would require admission for intravenous antibiotics and/or surgery, whereas superficial SSI would be managed with oral antibiotics alone in the majority of cases.

The number of incident prescriptions was used to determine new cases of superficial SSI by 30 days and by 90 days. First all antibiotic prescriptions were quantified. I then extracted prescriptions of antibiotics most commonly prescribed for

superficial skin and soft-tissue infections. I then further analysed flucloxacillin (floxacillin) prescription alone, analysing pre- and post-operative prescription rates to determine clinically meaningful change in its prescription. Flucloxacillin is commonly prescribed in primary care for superficial SSI, as *Staphylococcus aureus* is the most common pathogenic organism.(139,140) I also explored prescription of analgesia following surgery and follow-up data ostensibly pertaining to wound care:

| **All antibiotics** | | |
|---|---|---|
| Floxacillin | Norfloxacin | Ciprofloxacin |
| Amoxicillin | Polymyxin B | Minocycline |
| Clavulanate | Cefuroxime | Gentamicin |
| Erythromycin | Cefaclor | Nitrofurantoin |
| Fusidate | Oxytetracycline | Cephradine |
| Clarithromycin | Clindamycin | Ampicillin |
| Trimethoprim | Cephalexin | Azithromycin |
| Neomycin | Doxycycline | Sulfamethoxazole |
| Metronidazole | Lymecycline | Tetracycline |
| Penicillin V | Chloramphenicol | Cefixime |

| **SSI antibiotics** |
|---|
| Floxacillin |
| Amoxicillin |
| Clavulanate |
| Erythromycin |
| Clarithromycin |
| Clindamycin |
| Doxycycline |
| Ciprofloxacin |
| Chloramphenicol |

| **NSAIDs** |
|---|
| Ibuprofen |
| Diclofenac |
| Naproxen |

| **Opiates** |
|---|
| Codeine |
| Dihydrocodeine |
| Tramadol |

## 3.3.4 Data source

CPRD is a data source containing national electronic healthcare data, is based in primary care and holds anonymised electronic health record data from collaborating general practices, with all patients registered at those practices included in the dataset, unless they have opted out.(141) The GP practices involved form a UK-wide network of over 2,000 practices, including over 68 million patients. Over 25% of the included patients have longitudinal follow-up data of over 20 years. Currently, over 3000 peer-reviewed publications have been produced through CPRD data analysis, with an increasing number

focusing on surgical conditions.(142–145) The following data are recorded for patients within CPRD:

- Demographic data
- Diagnoses and symptoms
- Prescription and vaccination record
- Medical investigations and measurements
- Referrals to secondary care and specialists

When patients are seen in primary care, the GP or practice nurse conduct a consultation, usually involving a history, examination and administration of treatment. Data are entered by the clinician into the patients' electronic record during or immediately after the consultation. The data are recoded using Read codes, a clinical classification system of over 90,000 codes. Any number of combinations of Read codes may be used by the clinician to record the details of the consultation, including those pertaining to a patients symptoms, presenting complaint, medical history, smoking status and healthcare interventions. Drug prescriptions are accurately recorded with the specific product name and BNF code, dose and amount prescribed. In addition, data from secondary care is fed back to the primary care clinicians and is entered, via Read codes, onto the patient record. This is often data from hospital discharge letters or clinic letters that will contain details of operative interventions, medication started or stopped during an admission, and any complications or new diagnoses.(146) Each patient record within CPRD therefore has rich data from both primary and secondary care, organised by standardised Read codes. Cohorts are generated by creating Read code lists that will result in data cuts of certain patient groups. These cohorts can then be explored through characterisation analyses to determine demographics, disease or injury characteristics and treatment details.

CPRD can also be used as a tool to recruit participants into clinical trials. This has been successful in a number of trials at various stages from pharmacogenetic studies to pragmatic RCTs.(147–149) Data-linked trials, which can link HES, CPRD or both can use routinely collected healthcare data to supplement baseline data collection and to augment post-intervention outcome data collection.(150) CPRD data have been used in epidemiological studies of hand osteoarthritis and carpal tunnel syndrome. (144,151,152) Burkard *et al* investigated whether use of hormone replacement therapy was associated with hand osteoarthritis using a nested case-control design of 3440 cases and 13,760 controls.(151) Frey *et al* similarly assessed the association between hyperlipidaemia and hand osteoarthritis, also using a case-control design of 19,590 cases and 19,590 controls within a CPRD dataset. Burton evaluated trends in surgical decompression of the carpal tunnel over a ten-year period in a CPRD dataset over 20 years, between 1993 and 2013.(143)

### 3.3.5 Risk of bias

CPRD is validated and quality checked before release for analysis. This reduces missingness and biases that may arise as a result. National coverage is not complete as only certain practices may contribute data, subject to process and quality control.(146) However, the data contained within CPRD is representative of the UK population. Misclassification of injuries and procedures is a potential area for bias, as Read codes may be attributed to patient records by those not familiar with the speciality area.

### 3.3.6 Sample size and statistical analyses

This is a descriptive study and therefore a formal sample size calculation was not necessary. Descriptive analyses are used to summarise demographic, treatment and

prescription data. Sex was analysed as proportion of males and females (%) with 95% CIs. Age was presented as a mean (SD). Prescription data for antibiotics, NSAIDs and opioids was analysed as a proportion (%) of those that had been prescribed each drug out of the total cohorts: hand trauma, and hand trauma surgery. All 95% CIs were calculated using binomial exact calculation using Microsoft Excel version 16.71.(153)

### 3.3.7 Ethics approval

Studies using non-identifiable records from CPRD are exempt from research ethics committee approval. This study was approved via the Electronic Research Applications Portal subsection of the Medicines and Healthcare Regulatory Agency associated with CPRD-based research (Project ID 21_000336).

## 3.4 Results

The current CPRD source population includes 21,096,867 patient records, of which 3,012,712 are currently registered as of the 15th November 2022 when this analysis was performed. This represents 4.5% of the UK population.

### 3.4.1 Hand trauma cohort

This section describes data for the entire cohort of hand trauma, who may or may not have undergone surgery. Following application of the 'hand trauma' Read code list, 641,223 patient records were extracted, generating the hand trauma cohort.

#### 3.4.1.1 Baseline data

The sex distribution of this cohort was 57.3% males versus 42.7% (CI[42.6 – 42.8]) females. The mean (SD) age was 34.9(22.2). (Table 3. Demographic data for CPRD Cohorts, Figure 11. Demographic data for CPRD Cohorts) The population was generally

healthy with most co-morbidities recorded as <1%. The most common co-morbidity was acute respiratory disease, present in 9.1% of the cohort, followed by visual disorders in 5.8% and depressive disorders in 3%. Over 40% of the population had been prescribed antibiotics previously, 22.4% had been prescribed NSAIDs and 14.7% had been prescribed opioids.

**Figure 10. Flow chart of study attrition (CPRD)**

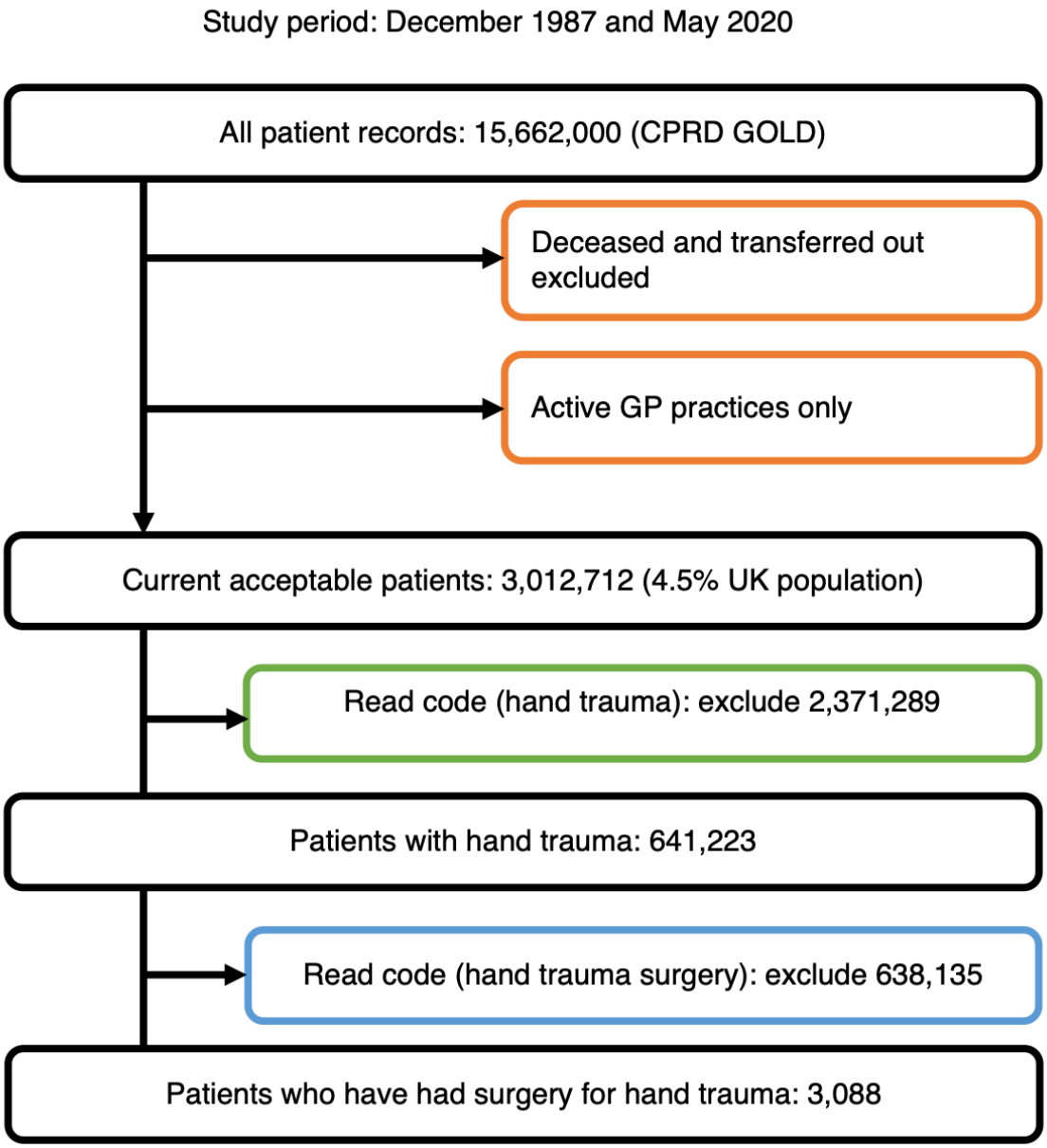
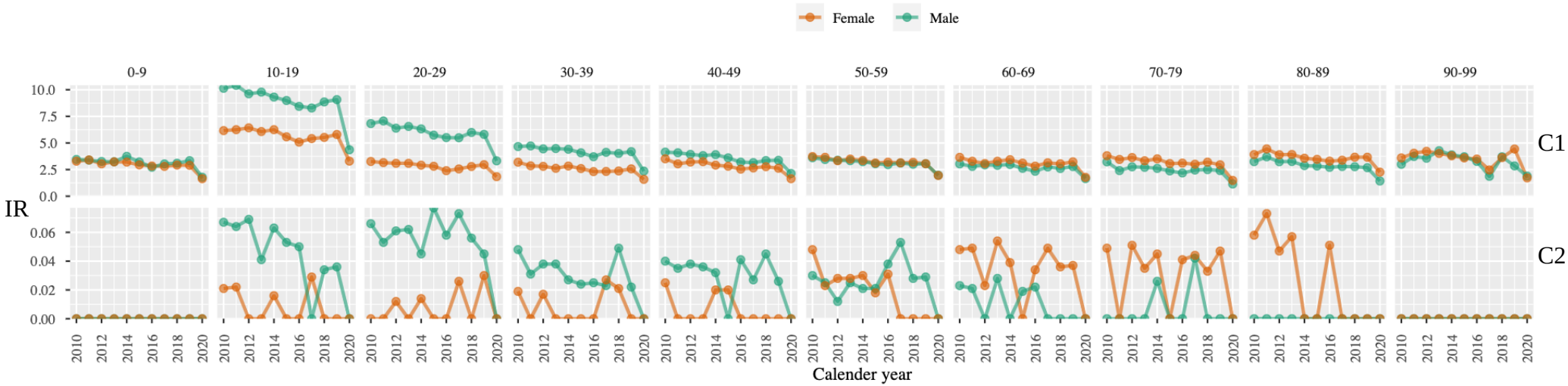


**Table 3. Demographic data for CPRD cohorts**

| | Hand trauma cohort | 95%CI | Hand trauma surgery cohort | 95%CI |
|---|---|---|---|---|
| **Total n** | 641,223 | – | 3,088 | – |
| **Sex: Female (%)** | 273,920 (42.7) | 42.6 – 42.8 | 1068 (34.6) | 32.9 – 36.3 |
| **Sex: Male (%)** | 367,303 (57.2) | 57.2 – 57.4 | 2020 (65.4) | 63.7 – 67.1 |
| **Mean age, years (SD)** | 34.9 (22.2) | 34.9 – 35.0 | 39.2 (21.5) | 38.4 – 40.0 |

**Figure 11. Demographic data for CPRD cohorts**




IR – Incidence rate (per 1000 person years)

C1 – hand trauma cohort C2 – hand trauma surgery cohort

#### 3.4.1.2 Treatment data

A total of 67 types of antibiotics were prescribed in this cohort. As this cohort have not all undergone surgery, these prescription rates are not referred to as SSIs. By 30 days, 39,633 hand trauma patients (6.2%, CI[6.1 – 6.2]) had been prescribed an antibiotic and by 90 days, this number had risen to 99,137 (15.5%, CI[15.4 – 15.6]) (Table 4 – Antibiotic, NSAID and Opiate prescription following hand trauma). Upon selecting the antibiotics most commonly used in wound or skin infections, this figure was 33,796 patients (5.2%, CI [5.2 – 5.3]). By 90 days this number had increased to 89,301 (13.9%, CI[13.8 – 14.0]). Flucloxacillin was prescribed in 7,429 patients (1.2%, CI[1.1 – 1.2]) by 30 days, rising to 15,094 patients (2.4%, CI[2.3 – 2.4]) by 90 days. Pre-injury, the rate of prescription was 0.8% (CI [0.8 – 0.8]), indicating a meaningful increase in prescription in this group. The next most commonly prescribed antibiotic was amoxicillin, indicated in many infections, such as respiratory infections. At 30 days this was prescribed in 11,392 patients (1.8%, CI[1.7 – 1.8]), rising to 33,160 (5.2%, CI[5.1 – 5.2]) by 90 days. Ibuprofen, diclofenac and naproxen were prescribed rarely (1% or less) and their prescription did not appear to increase after hand and wrist injury.

Opioid analgesics: codeine, dihydrocodeine and tramadol were prescribed in 15,921 patients (2.5%, CI[2.4 – 2.5]) within 30 days, rising to 33,260 patients (5.2%, CI[5.1 – 5.2]) by 90 days. In terms of follow-up in primary care in the first 30 days, patients were most commonly reviewed for wound dressings (2.8%, CI[2.7 – 2.8]), followed by general review (2.7%, CI[2.6 – 2.8]) then removal of sutures (1.2%, CI[1.1 – 1.3]).

**Table 4. Antibiotic, NSAID and Opioid prescription following hand trauma (surgery and no surgery, n=641,223)**

| | 30 days | | 90 days | |
|---|---|---|---|---|
| | **n** | **% (95% CI)** | **n** | **% (95% CI)** |
| **Antibiotics** | | | | |
| Floxacillin | 7,429 | 1.2 | 15,094 | 2.4 |
| Amoxicillin | 11,392 | 1.8 | 33,160 | 5.2 |
| Clavulanate | 3,061 | 0.5 | 6,668 | 1.0 |
| Fusidate | 2,795 | 0.4 | 8,012 | 1.2 |
| Erythromycin | 3,723 | 0.6 | 10,008 | 1.6 |
| Clarithromycin | 1,327 | 0.2 | 3,706 | 0.6 |
| Clindamycin | 461 | 0.1 | 1,401 | 0.2 |
| Doxycycline | 1,120 | 0.2 | 3,630 | 0.6 |
| Ciprofloxacin | 805 | 0.1 | 2,289 | 0.4 |
| Chloramphenicol | 1,683 | 0.3 | 5,333 | 0.8 |
| ***Total*** | **33,796** | **5.2 (5.2 – 5.3)** | **89,301** | **13.9 (13.8-14.0)** |
| **NSAIDs** | | | | |
| Ibuprofen | 6,473 | 1.0 | 15,920 | 2.5 |
| Diclofenac | 4,840 | 0.8 | 12,093 | 1.9 |
| Naproxen | 2,317 | 0.4 | 5,912 | 0.9 |
| ***Total*** | **13,630** | **2.1 (2.1 – 2.2)** | **33,925** | **5.3 (5.2 - 5.4)** |
| **Opioids** | | | | |
| Codeine | 10,154 | 1.6 | 20,981 | 3.3 |
| Dihydrocodeine | 3,752 | 0.6 | 7,864 | 1.2 |
| Tramadol | 2,015 | 0.3 | 4,415 | 0.7 |
| ***Total*** | **15,921** | **2.5 (2.4 – 2.5)** | **33,260** | **5.2 (5.1 – 5.2)** |

## 3.4.2 Hand trauma surgery cohort

Following application of the eligibility criteria described above, a highly specific population was generated of those patients with hand and wrist injuries who had undergone surgery.

### 3.4.2.1 Baseline data

This cohort contained 3,088 patients. The sex distribution of this cohort was 65.4% males versus 34.6%. The mean (SD) age was 39.2(21.5). (Table 5. Demographic data for CPRD Cohorts, Figure 11 – Demographic data for CPRD Cohorts) Again this surgical population was generally healthy with most co-morbidities recorded as <1%. Acute respiratory disease (6.9%), visual disorders (4.3%) and depressive disorders (3.1%) were the most common co-morbidities but were less common in this cohort, indicating a slightly healthier population. Antibiotics had been prescribed previously in 36% of the population, while 24% had been prescribed NSAIDs and nearly 20% had been prescribed opioids.

### 3.4.2.2 Treatment data

All of these patients will have sustained an injury to the hand and wrist and have subsequently undergone surgery. A total of 32 types of antibiotic were prescribed by 30 and 90 days. By 30 days post-surgery, 246 patients (8.0%, CI[7.0 – 9.0]) had been prescribed an antibiotic and by 90 days, this number had risen to 620 (20.0%, CI[18.7 – 21.5]). As this cohort had all undergone surgery for their injuries, the following antibiotic prescriptions imply treatment for SSI. Upon selecting the antibiotics most commonly used in wound or skin infections, this figure was 192 (6.2%, CI[5.4 – 7.1]) by 30 days, rising to 447 (14.5%, CI[13.2 – 15.8]) by 90 days (Table 5. Antibiotic, NSAID and Opiate

prescription following hand trauma surgery). Flucloxacillin was prescribed in 68 hand trauma surgery patients (2.2%, CI[1.7 – 2.8]) by 30 days, rising to 140 patients (4.5%, CI[3.8 – 5.3]) by 90 days. Pre-injury, the rate of prescription was 1.1% (CI [0.7 – 1.4]), indicating a clinically and statistically significant increase in prescription in the post-operative group ($X^2$ =11.5, $p$ =<0.005) and when compared to the less specific hand and wrist cohort (30 day, 1.2% and 90 day, 2.4%). At 30 days amoxicillin, a less specific antibiotic, was prescribed in 46 post-operative patients (1.5%, CI[1.1 – 2.0]), rising to 127 patients (4.2%, CI[3.4 – 4.9]) by 90 days. Ibuprofen, diclofenac and naproxen were prescribed more commonly following surgery for hand trauma: in 130 post-operative patients by 30 days (4.2%, CI[3.5 – 5.0]), increasing to 237 patients by 90 days (7.7%, CI[6.8 – 8.7]).

Opioid analgesics (codeine, dihydrocodeine and tramadol) were prescribed in 308 patients (10.0%, CI[8.9 – 11.1) by 30 days. This increased to 425 patients (13.8%, CI[12.6 – 15.0) by 90 days for the post-operative group. Wound dressings were performed in primary care in 4.4% (CI 2.8 – 5.2) of patients by 30 days, decreasing to 2.9% (CI[2.4 – 3.6]) thereafter. Suture removal was required in 3.4% (CI[2.8 – 4.1]) of cases, again reducing to 2.0% (CI[1.5 – 2.6]) after 30 days. Removal of K-wires was required in 1.7% (CI[1.3 – 2.2]) of cases, increasing to 2.4% (CI[1.9 – 3.0]) after 30 days.

**Table 5. Antibiotic, NSAID and Opioid prescription following hand trauma surgery (n=3,088)**

| | 30 days | | 90 days | |
|---|---|---|---|---|
| | n | % (95% CI) | n | % |
| **Antibiotics** | | | | |
| Floxacillin | 68 | 2.2 | 140 | 4.5 |
| Amoxicillin | 46 | 1.5 | 127 | 4.1 |
| Clavulanate | 26 | 0.8 | 41 | 1.3 |
| Fusidate | 10 | 0.3 | 31 | 1 |
| Erythromycin | 12 | 0.4 | 31 | 1 |
| Clarithromycin | 10 | 0.3 | 26 | 0.8 |
| Clindamycin | 5 | 0.2 | 8 | 0.3 |
| Doxycycline | 5 | 0.2 | 15 | 0.5 |
| Ciprofloxacin | 4 | 0.1 | 10 | 0.3 |
| Chloramphenicol | 6 | 0.2 | 18 | 0.6 |
| ***Total*** | **192** | **6.2 (5.4 – 7.1)** | **447** | **14.4 (13.2-15.8)** |
| **NSAIDs** | | | | |
| Ibuprofen | 59 | 1.9 | 110 | 3.6 |
| Diclofenac | 54 | 1.7 | 81 | 2.6 |
| Naproxen | 17 | 0.6 | 46 | 1.5 |
| ***Total*** | **130** | **4.2 (3.5 – 5.0)** | **237** | **7.7 (6.8 – 8.7)** |
| **Opioids** | | | | |
| Codeine | 186 | 6 | 255 | 8.3 |
| Dihydrocodeine | 68 | 2.2 | 89 | 2.9 |
| Tramadol | 54 | 1.7 | 81 | 2.6 |
| ***Total*** | **308** | **10.0 (8.9 – 11.1)** | **425** | **13.8 (12.6 – 15.0)** |

### 3.4.3 Summary

Using the prescription of clinically appropriate antibiotics within 30 days and 90 after surgery as a surrogate for SSI, we can see that the risk of SSI by 30 days is 6.2% (CI[5.4 – 7.1]). This rises further to 14.4%, CI[13.2 – 15.8]) by 90 days. Looking at flucloxacillin prescription, the most commonly prescribed antibiotic in wound infection, this increase is mirrored suggesting this is a clinically meaningful result. The prescription of opioid analgaesics was higher than anticipated, 13.8% (CI[12.6 – 15.0]), warranting further investigation.

## 3.5 Discussion

Having previously established the overall risk of SSI through meta-analysis of existing data, this Chapter has added granularity through analysis of electronic healthcare records in primary care that has generated descriptive risk figures for superficial SSI following hand trauma surgery. The risk of SSI requiring treatment in primary care with antibiotics, essentially superficial SSI, is 6.2% by 30 days and 14.4% by 90 days. There is clear variability in the reported literature, some of which has been handled through meta-analysis and meta-regression in the previous Chapter. The SSI risks generated through CPRD analysis sit on the upper end of the spectrum of SSI risk, suggesting that superficial SSI is common, indeed more common than the NICE estimate of 2-5% for all SSIs in the UK.(53)

Studies of musculoskeletal trauma within CPRD appear to have higher SSI incidences compared to those in other studies of national databases. Wolf *et al* found an SSI risk of 3.5% following surgical fixation of clavicular fracture, while Galvain *et al* found a risk of 11.7% following intramedullary nail fixation of tibial fractures.(145,154) In

arthroplasty, incidences of up to 4.1% were found in TKR using CPRD.(155) In contrast, the figures from the National Joint Registry, a secondary care dataset, of TKR outcomes found that post-operative infection was the reason for revision surgery in 412 in 341,749 operations, equating to a deep infection risk of 0.1%.(156) I have found a similarly high incidence of SSI in hand trauma in CPRD. This supports the theory that secondary care datasets are suitable for investigating the most serious SSI events, but may underestimate the overall SSI risk for a population or procedure. The alternative explanation for the higher treatment rates seen in this analysis is over-prescribing of antibiotics, either for prophylaxis or over-treatment of non-infections. Over-prescribing is known to be an issue in primary care, and is a major concern regarding antibiotic resistance.(156–159) In terms of SSI, I was unable to find evidence that general practitioners commonly diagnose SSI incorrectly, which would in turn result in over-prescription of antibiotics. There is some, albeit variable, evidence that patient's self-diagnosis of SSI can be at least as accurate as a surgeon's diagnosis, or indeed more so.(134,160)

There are both observational and experimental studies evaluating the use of oral antibiotics to prevent SSI in hand trauma surgery. An existing systematic review and meta-analysis of these studies found insufficient evidence to support use in simple hand trauma.(35) This Chapter described antibiotic treatment for SSI, rather than prophylaxis, and on this there is much less in the literature. From secondary care-based studies, it appears that the majority of hand trauma SSIs that present to the hospital are managed successfully with oral antibiotics alone. In Parvan *et al*'s retrospective series of 638 hand trauma patients, 19 developed SSI and 14 of these required oral antibiotics alone.(161) In Davies *et al*'s series of 983 hand trauma patients, 41 developed SSI and 33 required oral antibiotics alone.(126) In another series of 556 hand trauma patients, 20 developed SSI and all received antibiotics, although 12 also required surgery.(127) Considering the proportion

of patients who will only require oral antibiotics for hand trauma SSI, it is unsurprising that I have found incidences of 6.2% by 30 days in primary care. The higher incidence (14.4%) at 90 days is concerning, as many patients will have been discharged from hospital-based case by this point. This is a new finding and warrants further investigation. It is also worth noting that this analysis only includes those who have, at least initially, received oral antibiotics for SSI and therefore have superficial infections. The next Chapter explores the incidence of deep and joint space SSIs through analysis of secondary care admission data and so builds on the current findings.

There is strong evidence that prescription of codeine and tramadol is deleterious to health and well-being, with the latter being particularly harmful in certain populations.(162) I found high prevalence of opiate analgesic prescriptions in the surgical cohort. By 30 days, 10.0% had been prescribed codeine, dihydrocodeine or tramadol and by 90 days this had increased to 13.8%. In the USA, over-prescription of opiate analgesia has resulted in crisis, and prescription of opiates after minor surgical procedures has contributed to this.(163) There is evidence that a proportion of patients continue to use opiate analgesia over 90 days after simple elective hand surgical procedures in the USA.(164) There is further data from the USA exploring reasons for prolonged opiate use following non-hand musculoskeletal surgery.(165) As such, the hand surgery community in the USA are attempting to reduce opiate use by generating evidence for alternative analgesic strategies.(166) It is concerning that this new data shows a similar pattern for hand trauma patients in the UK. Although we do not currently have an opiate analgesia addiction crisis in the NHS, stewardship must be sought to prevent one. This is in addition to the direct aforementioned risks to patients from opiate analgesia.(162) NSAID prescription was comparatively low and did not differ as much between the primary cohort and the surgical cohort. This may reflect patients' ability to get NSAIDs over the counter

rather than through prescription, rather than truly lower usage. Management of post-operative pain following hand trauma surgery, especially reducing opiate prescriptions, is an urgent area for future research.

### 3.5.1 Strengths and limitations

This analysis provides new data indicating that a significant proportion of patients will present to their GP requiring antibiotic treatment that is consistent with soft tissue infection following surgery for hand trauma. The logical conclusion is that these patients are presenting with SSI, however there may be patients who have co-morbid skin infections that are unrelated. This number is likely to be small. We should therefore interpret these results as a signal, rather than a definite statistic. There will also be an unknown proportion of patients who are prescribed antibiotics for a wound that is inflamed, rather than infected – i.e. suspected SSI. There is a narrative that implies SSIs are often overtreated due to the treating clinician's inability to distinguish between post-operative inflammation and post-operative infection. This is further implied in the CDC criteria for SSI that suggest that it must be a surgeon, infectious disease physician, emergency physician, other physician on the case, or physician's designee (nurse practitioner or physician's assistant) who makes the diagnosis.(132) This group, along with those that have non-SSI skin infections, will form a small proportion of the hand trauma surgery cohort.

The two cohorts are heterogenous, in terms of injuries and operations, so some granularity is lost. It would be possible to further interrogate these data to pick out specific clinical groups, such as hand fractures or flexor tendon injuries, and is a future avenue of work. CPRD includes patients from across the UK so external validity is good, however not all practices are included which reduces the total patient dataset.

CPRD itself does not have standardised definitions for clinical data, these must therefore be defined by each research team that uses the platform, as I have done here for my two cohorts. Because these are bespoke cohorts for this study, there is a risk of inconsistent definitions (and therefore results) if another group were to explore this area. My Read code lists will be available to other researchers to avoid this. The coding of patient records relies on the expertise of the general practitioners and may therefore be generally more accurate than in other datasets, such as HES, where the coding is often done by administrators rather than clinicians. Information that has not been coded in the patient record is not available within CPRD. This includes any data that is written as free text due to risk of de-identification. To improve the comprehensiveness of my Read code lists, I performed cohort diagnostics which identified potentially missing codes via in-built machine learning algorithms. I screened both code lists on multiple occasions to ensure their accuracy and representativeness of the breadth of hand trauma surgery. Coding of antibiotic interventions is highly accurate and complete in CPRD, as options are chosen from a drop down system that is linked directly to the BNF.

## 3.6 Conclusions

The risk of superficial SSI, determined by oral antibiotic treatment after hand trauma surgery, is 6.2% by 30 days and 14.4% at 90 days. These data can be used to add granularity to the summary statistics presented in Chapter 2 and can be used to counsel patients before surgery for hand trauma. Now we understand the overall risk and the risk of superficial SSI, the next step is to understand the risk of deep and organ/space SSIs, i.e. more severe SSIs, following hand trauma surgery.

# 4 DEEP AND ORGAN/SPACE SURGICAL SITE INFECTION IN HAND TRAUMA: AN ANALYSIS OF ADMINISTRATIVE SECONDARY CARE DATA

Deep and organ/space SSIs are the most severe subtype of SSI according to the CDC definitions. Deep infection of the hand and wrist can be severely debilitating, usually requiring emergency admission for surgical debridement and washout, often more than once and systemic antibiotic treatment. In the case of organ/space SSI of the hand and wrist, this clinically manifests as osteomyelitis and septic arthritis. Septic arthritis requires emergency joint washout to prevent joint destruction while osteomyelitis may require debridement and protracted treatment with systemic antibiotics. In severe cases, these types of SSI will result in amputation of the affected limb to save life. The remaining unknown is the risk of deep and organ/space SSI following hand trauma surgery. Hospital Episode Statistics (HES) data comprises routinely collected secondary care data from hospitals in the NHS in England. The primary purpose of the data are for reimbursement, but it can also be harnessed for research. In this Chapter, HES data are used to determine deep and organ/space SSI risk, using re-admission and re-operation for post-operative infection as a surrogate.

## 4.1 Abstract

**Background**

Despite the high number of surgical procedures for hand trauma, the risk of severe SSI is largely unknown. HES data have been used in the study of hand surgery or hand surgical conditions, and can be used to determine outcomes requiring re-admission or re-operation after a primary surgery, including SSI. Deep and organ/space SSI require intervention in secondary care due to their relative severity. To understand the risk of these types of SSI, I aimed to evaluate their incidence using HES data, a source of routinely collected healthcare data from NHS hospitals in England.

**Methods**

A national, prospective cohort study including all patients who had been admitted to hospital for surgery for hand trauma in the NHS in England between 1st April 1997 and 31st March 2019, provided by NHS Digital. The primary outcome was re-admission for post-operative infection following hand trauma surgery, as a surrogate for deep SSI. Secondary outcomes were relevant to specific operations, including removal of metalwork and tenolysis. Re-admission for post-operative infection, as defined by ICD version 10 (ICD-10) and OPCS version 4.9 (OPCS-4.9) codes, was evaluated at 30 days and 90 days to align with the national outcome framework in England that enables comparison of outcomes following all procedures within the NHS.

**Results**

There was a total of 280,747 admissions for surgery for common hand injuries across the study period. Hand fracture fixation was the most commonly performed procedure, followed by flexor tendon repair, extensor tendon repair and nerve repair. Patients were generally healthy, usually in their fourth decade of life and predominantly

male. There were 4,013 post-operative infections, including SSI, septic arthritis and osteomyelitis, requiring intervention within secondary care by 30 days and 5,563 by 90 days. This implies a risk of deep or organ/space SSI of 1.4% (CI [1.4 – 1.5]) by 30 days and 2.0% (CI[1.9 – 2.0]) by 90 days following surgery for common hand trauma.

**Conclusions**

The risk of deep and organ/space SSI following hand trauma surgery is 1.4% by 30 days, rising to 2% by 90 days. This completes the understanding of the risks of the different types of SSI, where superficial SSI risk is 6.2% at 90 days and 14.4% at 90 days and the overall risk is 5.0%. This new data can be used to inform patients of their risk and can be used in power calculations in trials of antimicrobial interventions in hand trauma surgery.

## 4.2 Introduction

The exploration of the risk of SSI lends itself to observational research. Observational study designs, such as cohort and case-control, are employed to investigate potential associations between various factors (or independent variables) and development of a clinical condition or disease (dependent variable).(167) National studies with large numbers of patients at different centres have the potential to generate accurate and generalisable epidemiological data for disease states, and this is true of SSI.

The use of administrative healthcare data, also known as routinely collected or real-world data have been used to generate large-scale, national and international cohorts of patients who can be used for epidemiological analyses. Administrative data refers to data collected by health-care systems, healthcare insurance companies with the primary purpose of reimbursement of health-care costs.(145,168) Data from national registries can also be considered as routinely collected or administrative healthcare data, although the primary purpose is usually not for reimbursement but for monitoring performance and safety. An example of this is the National Joint Registry in the UK, from which a number of epidemiological studies have been generated.(169) HES is used across England and Wales for reimbursement of healthcare costs accrued in secondary care. HES has a number of distinct data platforms, including APC, Outpatient and ED statistics. HES APC contains data on all patients who have been admitted to NHS hospitals in England and Wales and has been used as a source for epidemiological research since the Korner report ‘Data for Management’ in 1982.(170) It is therefore possible to generate large, national, historical cohorts with sufficient longitudinal follow-up to investigate certain outcomes following admission.

HES data have been used in the study of hand surgery or hand surgical conditions. In terms of hand trauma, our own work using freely available HES data evaluating temporal trends in hand trauma over time, showing an increase in all injuries, but especially hand fractures in the elderly.(14) Similar work has been published, evaluating temporal trends in osteoarthritis, including osteoarthritis of the hand.(171) Lane *et al* used HES data to evaluate serious post-operative outcomes after 855,832 carpal tunnel decompressions, including wound infection and re-operation.(172) Haque *et al* evaluated the incidence of venous thromboembolic events after hand surgery between 2010 and 2012 in 334,211 patients, identifying an incidence of 0.006%.(173)

SSI is difficult to measure using administrative data. A study by Parthasarathy *et* al found poor correlation between occurrence of post-operative complications, including SSI, and these being correctly coded in HES.(174) In this same study, the coding for the original operations was highly accurate, indicating that this problem is specific to post-operative complications, such as SSI. Interventions, including surgery, are classified in HES using OPCS-4.9. Disease or condition diagnoses are classified using ICD-10. Combinations of relevant interventions within OPCS-4.9 and conditions within ICD-10 can be used to define SSI, deep infection and joint-space infections, mapping intuitively to the CDC criteria for SSI.(175) There are specific ICD-10 codes for SSI, septic arthritis and osteomyelitis. When these are combined with the correct anatomical codes for hand and wrist and the relevant procedural codes, these outcomes can be assessed following surgical procedures.

Indeed, a number of studies have used HES to report incidence of SSI after surgery. Jen *et al* found a risk of 1.4% in over two million orthopaedic procedures using a HES dataset and the ICD codes for SSI to detect its occurrence after the index procedure.(176) Wolf *et al* used HES linked to CPRD to evaluate post-operative

complications in 21,340 patients who had undergone clavicle fracture fixation, finding an SSI risk of 3-4%, again using solely ICD codes.(145) SSI was one of the post-operative outcomes evaluated in Lane *et al*'s cohort analysis of carpal tunnel decompressions, finding a risk of 0.005% by 90 days. Lane *et al* used both ICD and OPCS to define SSI.(172) Abram *et al* also used a combination of ICD and OPCS to define SSI within a HES analysis for partial menisectomy, with a risk of 0.1% in 666,442 patients.(177) In general, the risk of SSI in HES data analyses appears to be substantially lower than the UK estimate by NICE of 3-5%. This could represent the populations that have been studied; elective hand surgery typically is low risk for SSI.(178) HES has not been used to explore risk of SSI in patients undergoing surgery for hand trauma.

## 4.3 Methods

### 4.3.1 Study design and setting

A national, prospective cohort study including all patients who had been admitted to hospital for surgery for hand trauma in the NHS in England between 1st April 1997 and 31st March 2019, provided by NHS Digital. The primary outcome was re-admission for post-operative infection following hand trauma surgery. Secondary outcomes were relevant to specific operations, including removal of metalwork and tenolysis. Re-admission for post-operative infection, as defined by ICD-10 and OPCS 4.9 codes was evaluated at 30 days and 90 days to align with the national outcome framework in England that enables comparison of outcomes following all procedures within the NHS. The study is reported in accordance with the STROBE checklist.(133)

### 4.3.2 Participants

Patients were eligible for entry into the cohort if they had an admission for any of the OPCS 4.9 and ICD-10 codes pertaining to common hand trauma surgery as their main diagnosis and/or index procedure during the study period. A bespoke extract had been generated prior to this specific study comprising HES APC data for all patients who had been admitted for treatment of all upper limb injury or infection, including day case admissions for surgery. This dataset was developed using combinations of OPCS 4.9 and ICD-10 codes, and containing individual-level patient data with all episodes of NHS patient care in the entire dataset for all individuals with an index (first recorded) admission for treatment of upper limb injury or infection. The OPCS 4.9 and ICD-10 codes used to build this extract are available in Appendix 21. Once the patient was flagged as eligible for inclusion, all their admission episodes were linked via their NHS number, enabling identification of subsequent admissions due to complications or revision procedures across the NHS in England. The dataset was linked to the Office of National Statistics mortality data. For this study, this dataset was further refined to create four separate cohorts for patients who had only been admitted for surgical management of the most common hand injuries: hand fracture, flexor tendon injury, extensor tendon injury and nerve injury.(14)

### 4.3.3 Outcomes

Outcomes were defined using previously validated OPCS 4.9 and ICD-10 codes and were measured at specific timepoints, depending on the cohort of interest. For all injuries, systemic post-operative complications and surgical complications were recorded if they occurred within 30 or 90 days (Appendix 22. HES APC outcomes and timepoints). Demographic data were analysed for the patient cohorts, including: age and sex distribution, index of multiple deprivation (a government-generated score of relative

deprivation based on geographical location within England), ethnicity, Charlson co-morbidity index, and laterality of injury. The modified Charlson co-morbidity index is a composite score based on the presence of 12 distinct co-morbidities (17 in the original version) that are then given weighted scores to give an overall score that predicts in-hospital mortality for a patient during an admission.(179) All final codes used to determine outcomes were decided by consensus amongst three clinicians (two plastic surgeons, one orthopaedic surgeon). The codes used for diagnosis of post-operative infection were further piloted on the flexor tendon injury cohort before being run for all cohorts. Most were combinations of ICD-10 and OPCS-4.9, although SSI was found to be best defined by ICD-10 alone when piloted.

#### 4.3.3.1 Primary outcome

Post-operative infection was defined as re-admission with codes pertaining to SSI, septic arthritis or osteomyelitis by 30 and 90 days following hand trauma surgery. These diagnoses inherently map to the ‘deep – SSI requiring admission/ surgery’ and ‘organ/space – osteomyelitis and septic arthritis’ CDC SSI criteria and were defined by the following code combinations:

| | | | OPCS 4.9 Procedure | | | OPCS 4.9 Anatomical | | | ICD-10 | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Deep SSI** | ***SSI req. admission*** | **Any of:** | | | | | | **AND any of:** | ICD10 Code | ICD10 Code Name |
| | | | | | | | | | T814 | Infection following a procedure NEC |
| | | | | | | | | | L024 | Cutaneous abscess of limb |
| | | | | | | | | | L025 | Cutaneous abscess of hand |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| **Organ/space SSI** | | **Any of:** | OPCS Code | OPCS Code Name | **AND any of:** | OPCS Code | OPCS Code Name | **OR** | ICD10 Code | ICD10 Code Name |
| | | | W336 | Debridement of bone NEC | | Z89.6 | Finger | | M8613 | Other acute osteomyelitis forearm |
| | | | W337 | Lavage of bone | | Z89.4 | Hand | | M8614 | Other acute osteomyelitis hand |
| | | | W338 | Other specified other open operations on bone | | Z89.8 | Multiple digits of hand | | M8623 | Subacute osteomyelitis forearm |
| | | | W339 | Unspecified other open operations on bone | | Z89.5 | Thumb | | M8624 | Subacute osteomyelitis hand |
| | | | W181 | Fenestration of cortex of bone | | Z73.1 | First metacarpal | | M8693 | Osteomyelitis unspecified forearm |
| | | | W182 | Saucerisation of bone | | Z73.2 | Metacarpal | | M8694 | Osteomyelitis unspecified hand |
| | | | W183 | Sequestrectomy of bone | | Z73.3 | Phalanx of thumb | | T846 | Infection and inflammatory reaction due to internal fixation device (any site) |
| | | | W184 | Decompression of fourage of bone | | Z73.4 | Phalanx of finger | | T847 | Infection and inflammatory reaction due to other internal orthopaedic devices, implants and grafts |
| | | | W185 | Insertion of drainage system into bone | | Z73.8 | Specified bone of hand NEC | | | |
| | | | W188 | Other specified drainage of bone | | Z73.9 | Bone of hand NEC | | | |
| | | | W189 | Unspecified drainage of bone | | | | | | |
| | ***Septic arthritis*** | **Any of:** | OPCS Code | OPCS Code Name | **AND any of:** | OPCS Code | OPCS Code Name | **OR** | ICD10 Code | ICD10 Code Name |
| | | | W801 | Open debridement and irrigation of joint | | Z83.1 | MCPJ thumb | | M003 | Staphylococcal arthritis forearm |
| | | | W802 | Open debridement of joint NEC | | Z83.2 | MCPJ finger | | M004 | Staphylococcal arthritis hand |
| | | | W803 | Open irrigation of joint NEC | | Z83.3 | IPJ thumb | | M0013 | Pneumococcal arthritis forearm |
| | | | W808 | Open specified debridement and irrigation of joint | | Z83.4 | PIPJ finger | | M0014 | Pneumococcal arthritis hand |
| | | | W809 | Unspecified debridement and irrigation of joint | | Z83.5 | DIPJ finger | | M0023 | Other streptococcal arthritis forearm |
| | | | W813 | Drainage of joint NEC | | Z83.6 | IPJ finger NEC | | M0024 | Other streptococcal arthritis hand |
| | | | W814 | Incision of joint NEC | | Z83.8 | Specified joint of finger NEC | | M0093 | Pyogenic arthritis forearm |
| | | | | | | Z83.9 | Joint of finger NEC | | M0094 | Pyogenic arthritis hand |
| | | | | | | | | | T845 | Infection and inflammatory reaction due to internal joint prosthesis |
| | | | | | | | | | T846 | Infection and inflammatory reaction due to internal fixation device (any site) |
| | | | | | | | | | T847 | Infection and inflammatory reaction due to other internal orthopaedic devices, implants and grafts |

#### 4.3.3.2 Secondary outcomes

Other outcomes of interest were similarly defined using combinations of the relevant ICD-10 and OPCS 4.9 codes (Appendix 23. HES APC outcome codes). Of note, only outcomes that result in admission to secondary care can be detected in the HES APC dataset. This would include re-admission after surgery for re-operation, but also for the most major post-operative complications such as SSI and systemic complications such as myocardial infarction.(180) Code lists for generating cohorts and outcomes are developed using a consensus approach to maximise sensitivity and specificity, internal and external validity.(172,177) HES APC data have been widely used in epidemiological studies of medical, and more recently, surgical interventions.(172,177,181)

### 4.3.4 Data sources

The HES APC dataset includes those admitted for day-case procedures and includes those that are admitted to private/independent facilities providing services on behalf of the NHS.(168) The admission of a patient to hospital and their subsequent discharge is classified as an episode within HES. A patient will often have multiple episodes throughout their lifetime. Patients who undergo procedures in the ED or Outpatient setting would not appear in any datasets generated from HES APC. Between September 2021 and August 2022 there were 19.4 million episodes collected on the HES APC database. Over 11million of these (58.6%) were episodes where a procedure or intervention had been performed, with 6.9 million day case episodes.(182) There were 15.9 million admission episodes, of which 6.0 million were emergency admissions. HES records contain the following information on individual patients admitted to an NHS hospital.(183)

- Diagnoses: based on the ICD-10 coding system
- Operations: based on the OPCS-4.9 coding system
- Demographics: age group, gender and ethnicity
- Dates and methods of admission and discharge
- Geographical data and socioeconomic data via IMD

Cohorts can be generated by designing inclusion and exclusion criteria based on OPCS-4.9 coding system and ICD-10 codes. Combinations of these codes can be used to generate specific cohorts of patients, defined by both condition (i.e. finger flexor tendon injury) and procedure (i.e. finger flexor tendon repair). Cohorts can be further defined using demographic data, such as age (i.e. adult versus paediatric populations).

### 4.3.5 Risk of bias

HES data are designed for healthcare system remuneration and not primarily for research, potentially resulting in over-representation of higher-cost/higher-remuneration procedures and diagnosis. By definition, HES APC does not include patients who are not admitted for treatment, such as those who have minor surgical intervention in the clinic or ED setting. It does include admissions to independent sector providers (private or charitable hospitals), but only those paid for by the NHS.(168)

### 4.3.6 Sample size and statistical analysis

Descriptive analyses are used to summarise demographic, operative and outcome data. Incidence was calculated as events per 100,000 population per year with 95%CIs, calculated using Byar's method based on the Poisson distribution.(184) Demographics are presented as proportions with 95% CIs calculated using binomial exact calculation using Microsoft Excel version 16.71.(153) Complications that occurred in >1% of patients were

reported as proportions (%) with 95% CIs. Complications that occurred in <1% are reported where relevant.

### 4.3.7 Ethics approval

Studies using non-identifiable records from HES are exempt from research ethics committee approval. This research was approved by an NHS Data Access Advisory Group based on an NHS Digital Data Sharing Agreement *(*DARS-NIC-295342-W3Z6L).

## 4.4 Results

### 4.4.1 Overview

280,747 admissions for treatment of common hand trauma conditions were identified from the master HES APC dataset (Figure 12. Flow chart of study attrition (HES). Of these, 143,357 were for treatment of hand fractures, comprising 51.1% of the common hand trauma cohort. Flexor tendon injuries were the next most common injury, with 91,239 episodes recorded (32.5%). Extensor tendon injury surgery comprised 9.4% of the cohort with 26,316 episodes. Lastly, there were 19,835 episodes of surgery for hand or wrist nerve injury, comprising 7.1% of the overall cohort.(Table 6. Demographics of HES cohorts) Cohorts were defined by having had an operation/admission for the injury of interest 30 days before the primary assessment of complications, with data pulled for 90 day and 2-year outcomes. Data was mostly complete for all baseline demographics (Appendix 24. HES APC missing data).

**Figure 12. Flow chart of study attrition (HES)**

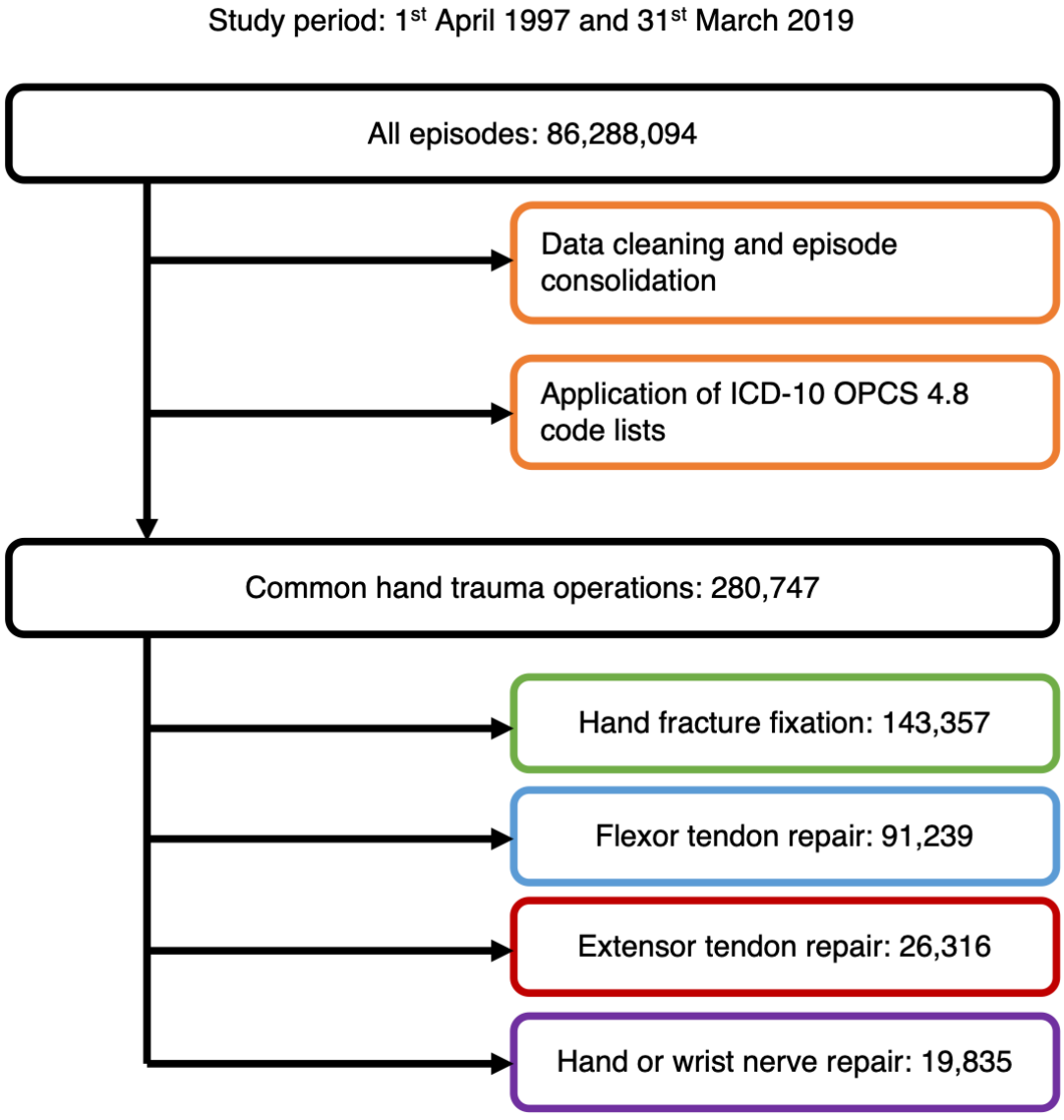
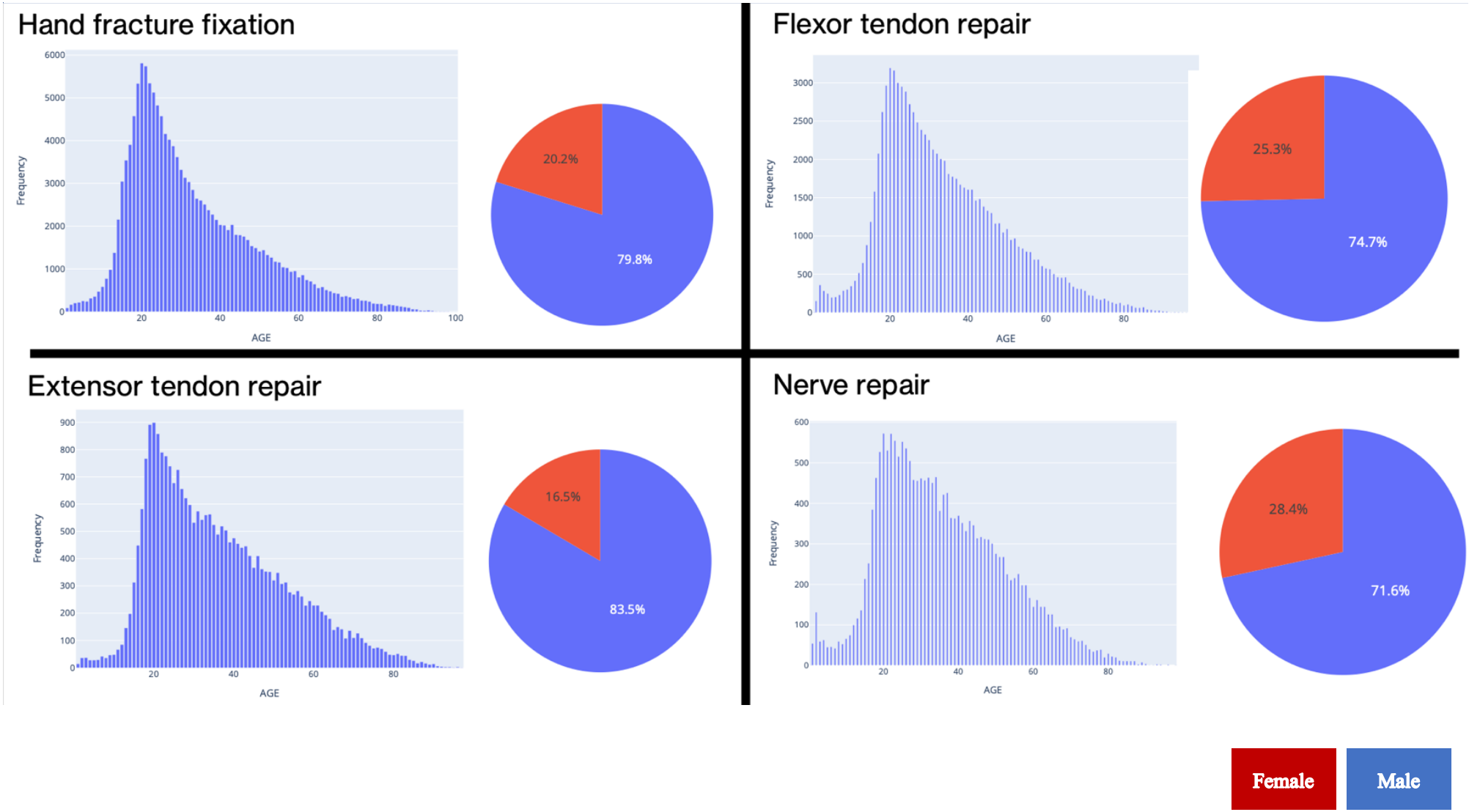


**Table 6. Demographics of HES Cohorts**

| | Hand fracture fixation | 95%CI | Flexor tendon repair | 95%CI | Extensor tendon repair | 95%CI | Hand/digital nerve repair | 95%CI | Wrist nerve repair | 95%CI |
|---|---|---|---|---|---|---|---|---|---|---|
| **Total n** | 143,357 | – | 91,239 | – | 26,316 | – | 19,835 | – | 20,103 | – |
| **Sex: Male (%)** | 114,407 (79.8) | 79.6 – 80.0 | 68,093 (74.6) | 74.4 – 74.9 | 21,961 (83.4) | 83.0 – 83.9 | 14,199 (71.6) | 71.0 – 72.2 | 14799 (73.6) | 73.0 – 74.2 |
| **Sex: Female (%)** | 28,930 (20.2) | 20.0 – 20.4 | 23,109 (25.3) | 25.1 – 25.6 | 4,347 (16.5) | 16.1 – 17.0 | 5,630 (28.4) | 27.8 – 29.0 | 5297 (26.4) | 25.7 – 27.0 |
| **Mean age , years (SD)** | 32.7 (16.0) | 32.6 – 32.8 | 33.7 (15.8) | 33.6 – 33.8 | 36.3 (16.8) | 36.1 – 36.5 | 35.8 (16.3) | 35.6 – 36.0 | 33.8 (16.5) | 33.6 – 34.0 |

**Figure 13. Demographics data for HES cohorts**



### 4.4.2 Hand fractures

During the study period, there were 143,357 admissions to secondary care for management of hand fractures in England and Wales. The incidence of hand fractures increased from 5.8 (CI[5.6 – 6.1]) per 100,000 in 1998 to 14.4 (CI[14.2 – 14.8]) per 100,000 in 2018. Male patients comprised 79.8% (CI[79.6 – 80.0]) of the population. The mean age (SD) was 32.7 (16.0) In terms of ethnicity, 65.6% (CI[65.3 – 65.8]) of patients were White British, 8.4% (CI[8.2 – 8.5]) were other white, 1.9% (CI[1.8 – 1.9]) were other ethnic, 1.2% ([CI[1.1 – 1.2]) were Pakistani, 1.1% ([CI[1.1 – 1.2]) Indian and the remainder were <1% across a variety of ethnicities. Ethnicity was unknown in 17.0% (CI[16.8 – 17.2]). The Index of Multiple Deprivation analysis showed that the largest proportion of patients (13.5%, (CI[13.3 – 13.7]) were in the most deprived decile. The proportions in each IMD decile decreased monotonically as deprivation decreased, with 7.6% (CI[7.4 – 7.7]) in the least deprived decile. The mean (SD) for length of stay in hospital in days was 1 (4).

By 30 days following surgery for hand fracture, 2,698 patients (1.9%, CI [1.8 – 2.0]) had been re-admitted for treatment for a complication and by 90 days 4,567 patients (3.2%, CI [3.1 – 3.3]) had been re-admitted for treatment for a complication. Systemic complications were very rare: <0.1%. The commonest complications at 30 days were post-operative infections (n=2,509, 1.8%, CI [1.7-1.8]), with SSI occurring in 652 cases (0.5%, CI [0.4 – 0.5]), septic arthritis in 923 cases (0.6%, CI [0.6 – 0.7]) and osteomyelitis in 934 cases (0.7%, CI [0.6 – 0.7]). By 90 days, SSI had occurred in 1,019 patients (0.7%, CI [0.7 – 0.8]) and osteomyelitis in 1,528 patients (1.1%, CI [1.0 – 1.1]). Septic arthritis had increased very slightly by 90 days to 998 patients (0.7%, CI [0.7 – 0.7]). At 90 days, there were 3,545 post-operative infections (2.5%, CI [2.4 – 2.6]) in the cohort. The remaining

complications at 30 and 90 days were very rare (<0.1%). By two years, 2,708 hand fracture patients had undergone a tenolysis procedure (1.9%, CI [1.8 – 2.0]) and 18,952 had undergone further operations to remove metalwork for fracture fixation (13.2%, CI [13.1 – 13.4]).

### 4.4.3 Flexor tendon injury

There were 91,239 admissions for repair of flexor tendon injury during the study period. The incidence of flexor tendon injury requiring surgery was 6.8 (CI[6.5 – 7.0]) per 100,000 in 1998 and 6.7 (CI[6.5 – 6.9]) per 100,000 in 2018, fluctuating over the study period. Male patients made up 74.6% ([CI[74.4 – 75.0]) of this cohort and the mean age (SD) was 33.7(15.8). White British people made up 55.5% ([CI[55.1 – 55.8]) of patients, 12.6% ([CI[12.4 – 12.8]) were other white, 2.2% ([CI[2.1 – 2.3]) were other ethnic, 1.1% ([CI[1.0 – 1.1]) were Pakistani, 1.1% ([CI[1.1 – 1.2]) Indian and the remainder were <1% across a variety of ethnicities. Ethnicity was unknown in 22%. Again, the largest proportion of patients (15.6%, CI[15.3 – 15.8]) were in the most deprived decile, decreasing across deciles to 6.3% (CI[6.1 – 6.5]) in the least deprived decile. The mean (SD) for length of stay in hospital in days was 1.3 (2.2) with a range from 0 to 140 days.

At 30 days, 4,180 patients (4.6%, CI [4.5 – 4.7]) had developed a complication and by 90 days 6,264 patients (6.9%, CI [6.7 – 7.0]) had developed a complication. Systemic complications were very rare: <0.1%. The commonest complication at 30 days was SSI occurring in 909 patients (1%, CI [1.0 – 1.1]). By 90 days, SSI had occurred in 1,175 patients (1.3% CI [1.2 – 1.4]). Post-operative infection (SSI, septic arthritis and osteomyelitis) occurred in 986 patients (1.1%, CI [1.0 – 1.1]) at 30 days and 1,305 patients (1.4% CI [1.4 – 1.5]) at 90 days. Re-rupture and subsequent re-repair of the flexor tendon was required in 2,820 patients (3.1%, CI [3.0 – 3.2]) by 30 days, and in 4,187 patients

(4.6%, CI[4.5 – 4.7]) by 90 days. All other complications at 30 and 90 days were very rare (<0.1%). By two years, 2,680 of flexor repair patients (2.9%, CI [2.8 – 3.1]) had undergone a tenolysis procedure.

### 4.4.4 Extensor tendon injury

There were 26,316 incidences of extensor tendon injury repair during the study period. The incidence of this injury appears to have reduced over time, from around 2.3 (CI[2.2 – 2.5]) per 100,000 to 1.2 (CI[1.2 – 1.3]) per 100,000.(43) Males comprised 83.4% (CI[83.0 – 83.9]) of the extensor tendon injury cohort. The mean age (SD) was 36.3 (16.8). Again, the majority of patients were White British (54.5%, CI[53.9 – 55.1]), 12.2% (CI[11.9 – 12.7]) were other white and 1.5% (CI[1.3 – 1.6]) were other ethnic. The remainder were <1% across a variety of ethnicities. Ethnicity was unknown in 26% (CI[25.7 – 26.8]). As per the above, the largest proportion of patients (14.9%, (CI[14.4 – 15.3]) were in the most deprived decile, decreasing across deciles to 6.7% (CI[6.4 – 7.1]) in the least deprived decile. The mean (SD) for length of stay in hospital in days was 1 (2.2).

Complications by 30 days occurred in 384 (1.5%, CI [1.3 – 1.6]) extensor tendon injury patients, rising to 659 (2.5%, CI [2.3 – 2.7]) by 90 days. The most common complication at 30 days was SSI occurring in 151 patients (0.6%, CI[0.5 – 0.7]), which rose to 211 (0.8%, CI [0.7 – 0.9]) at 90 days. Osteomyelitis occurred in only 22 patients at 30 days but increased to 48 patients (0.2%, CI[0.1 – 0.2]) by 90 days. Septic arthritis occurred in 38 and 39 patients at 30 days and 90 days respectively (0.1%, CI [0.1 – 0.2]). Post-operative infections therefore occurred in 211 (0.8%, CI [0.7 – 0.9]) at 30 days and 298 (1.1%, CI [1.0 – 1.3]) at 90 days. All other complications at 30 and 90 days, including

systemic complications, occurred in <0.1% of patients. By two years, 287 patients (1.0%, CI [0.9 – 1.2]) had undergone tenolysis.

## 4.4.5 Nerve injury

Nerve injury was subdivided into hand/digital nerve injury cohort and a wrist nerve injury cohort, which reflects the severity and clinical relevance of these injuries.

### 4.4.5.1 Hand and digital nerve injury

There were 19,835 hand or digital nerve injuries in the study period, with an incidence of 1.7 (CI[1.6 – 1.8]) per 100,000 in 1998 to 1.6 (CI[1.5 – 1.7]) per 100,000 in 2018. Males comprised 71.6% (CI[71.0 – 72.2]) of the study population and the mean age (SD) was 35.8(16.3). White British patients were the majority (56.2%, (CI[55.5 – 56.9]), 13.1% (CI[12.6 – 13.6]) were other white and 2.1% (CI[1.9 – 2.3]) were other ethnic. The remainder were 1% or less across a variety of ethnicities. Ethnicity was unknown in 22.0% (CI[21.3 – 22.5]). The largest proportion of patients (14.2%, CI[13.7 – 14.7]) were in the most deprived decile and decreased across deciles to 6.8% (CI[6.4 – 7.1]) in the least deprived decile. The mean (SD) for length of stay in hospital in days was 1 (2.1).

Post-operative complications occurred in 199 hand/digital nerve patients (1.0%, CI[0.9 – 1.2]) by 30 days and 309 (1.6%, CI[1.4 – 1.7]) by 90 days. SSI was again the most common complication in hand/digital nerve injury, occurring in 125 patients by 30 days (0.6%, CI[0.5 – 0.8]), and 165 (0.8%, CI[0.7 – 1.0]) by 90 days. Post-operative infection, including SSI, septic arthritis and osteomyelitis, occurred in 161 patients (0.8%, CI[0.7 – 1.0]) at 30 days and 214 patients (1.1%, CI[0.7 – 1.2]) at 90 days after hand/digital nerve repair. By two years, 59 (0.3%) of these patients had undergone excision of neuroma and 216 had also undergone tenolysis (1.0%, CI[1.0 – 1.2]).

#### 4.4.5.2 Wrist nerve injury

Wrist nerve injuries occurred in 20,103 patients, with an incidence of 1.4 (CI[1.3 – 1.5]) per 100,000 in 1998 to 1.6 (CI[1.5 – 1.7]) per 100,000 in 2018. The mean age (SD) was 33.8 (16.5) and most were males (73.6%, CI[73.0 – 74.2]). White British patients were the majority (54.0%, (CI[53.3 – 54.7]), 12.9% (CI[12.4 – 13.3]) were other white and 2.7% (CI[2.5 – 2.9]) were other ethnic. The remainder were 1% or less across a variety of ethnicities. Ethnicity was unknown in 22.5% (CI[22.0 – 23.1]). The largest proportion of patients (15.3%, CI[14.9 – 15.9]) were in the most deprived decile, decreasing across deciles to 6.4% (CI[6.1 – 6.8]) in the least deprived decile. The mean (SD) length of stay in hospital in days was 2 (5).

Post-operative complications occurred in 205 (1.0%, CI[0.9 – 1.2]) wrist nerve injury patients at 30 days and 297 (1.5%, CI[1.3 – 1.7]) at 90 days. SSI was again the most common complication occurring in 125 (0.6%, CI[0.5 – 0.7]) wrist nerve injury patients and 169 (0.8%, CI[0.7 – 1.0]) at 90 days. After wrist nerve repair, post-operative infection, including SSI, septic arthritis and osteomyelitis, occurred in 146 (0.7%, CI[0.6 – 0.9]) at 30 days and 201 (1.0%, CI[0.9 – 1.1]) at 90 days. By two years, 68 (0.3%) wrist nerve injury patients had undergone excision of neuroma and 324 (1.6%, CI[1.4 – 1.6]) had undergone tenolysis. All other complications at 30 and 90 days, including systemic complications, occurred in <0.1% of patients.

### 4.4.6 Summary of SSI in HES APC data

Admission for treatment of post-operative infection was the most common adverse occurrence following surgery for common hand trauma (Table 7. Deep and organ/space SSI following hand trauma surgery). SSI was the most common specific infectious complication in soft-tissue injury with osteomyelitis most common in the hand

fracture cohort, closely followed by SSI. The SSI risk ranged from 0.5% (hand fracture at 30 days) to 1.2% (flexor tendon at 90 days). Across all 280,747 admissions for hand trauma surgery, there were 4013 post-operative infections, including SSI, septic arthritis and osteomyelitis, requiring intervention within secondary care by 30 days and 5563 by 90 days. This implies a risk of deep or organ/space SSI of 1.4% (CI [1.4 – 1.5]) by 30 days and 2% (CI[1.9 – 2.0]) by 90 days following surgery for common hand trauma.

**Table 7. Deep and organ/space SSI following hand trauma surgery**

| | | | | | Deep SSI | | Organ/space SSI | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | All post-operative infection | | SSI | | Osteomyelitis | | Septic arthritis | |
| Cohort | n | Time (days) | *n* | *% (95% CI)* | *n* | *% (95% CI)* | *n* | *% (95% CI)* | *n* | *% (95% CI)* |
| All | 280,747 | 30 | 4,013 | 1.4 (1.4 – 1.5) | 1,962 | 0.7 (0.7 – 0.7) | 1,024 | 0.4 (0.3 – 0.4) | 1,081 | 0.4 (0.3 – 0.4) |
| | | 90 | 5,563 | 2.0 (1.9 – 2.0) | 2,739 | 1.0 (0.9 – 1.0) | 1,664 | 0.6 (0.6 – 0.6) | 1,106 | 0.4 (0.4 – 0.4) |
| Hand fracture fixation | 143,357 | 30 | 2,509 | 1.8 (1.7 – 1.8) | 652 | 0.5 (0.4 – 0.5) | 934 | 0.7 (0.6 – 0.7) | 923 | 0.6 (0.6 – 0.7) |
| | | 90 | 3,545 | 2.5 (2.4 – 2.6) | 1,019 | 0.7 (0.7 – 0.8) | 1,528 | 1.1 (1.0 – 1.1) | 998 | 0.7 (0.7 – 0.7) |
| Flexor tendon repair | 91,239 | 30 | 986 | 1.1 (1.0 – 1.1) | 909 | 1 (1.0 – 1.1) | 40 | <0.1 | 91 | <0.1 |
| | | 90 | 1,305 | 1.4 (1.4 – 1.5) | 1,175 | 1 (1.2 – 1.4) | 37 | <0.1 | 39 | <0.1 |
| Extensor tendon repair | 26,316 | 30 | 211 | 0.8 (0.7 – 0.9) | 151 | 0.6 (0.5 – 0.7) | 22 | <0.1 | 38 | 0.1 (0.1 – 0.2) |
| | | 90 | 298 | 1.1 (1.0 – 1.3) | 211 | 0.8 (0.7 – 0.9) | 48 | 0.2 (0.1 – 0.2) | 39 | 0.1 (0.1 – 0.2) |
| Wrist nerve repair | 20,103 | 30 | 146 | 0.7 (0.6 – 0.9) | 125 | 0.6 (0.5 – 0.7) | 10 | <0.1 | 11 | <0.1 |
| | | 90 | 201 | 1.0 (0.9 – 1.1) | 169 | 0.8 (0.7 – 1.0) | 20 | <0.1 | 12 | <0.1 |
| Hand/digital nerve repair | 19,835 | 30 | 161 | 0.8 (0.7 – 1.0) | 125 | 0.6 (0.5 – 0.8) | 18 | <0.1 | 18 | <0.1 |
| | | 90 | 214 | 1.1, (0.7 – 1.2) | 165 | 0.8 (0.7 – 1.0) | 31 | 0.1 | 18 | <0.1 |

## 4.5 Discussion

This Chapter describes an analysis of routinely collected secondary care data, generating descriptive risk figures for deep and organ/space SSI following surgery for common hand trauma. Hand fractures comprised 52% of the common hand trauma cohort, in keeping with existing literature on injury prevalence.(14) The remaining operations were for flexor and extensor tendon injury and nerve injury. The risk of deep or organ/space SSI is 1.4% by 30 days, increasing to 2% by 90 days. By using HES APC data, all patients in this analysis had to have been admitted to secondary care. Therefore, the re-admissions following hand trauma surgery represent the most serious post-operative infections, requiring re-admission either for further surgery, further antibiotic treatment or a combination of both. These types of infection in the hand and wrist are extremely deleterious in terms of functional recovery and can result in substantial resection of tissues to effectively treat the infection – even amputation in extreme cases or death in the most extreme.(105,185,186) These new findings sit within the summary risk statistics generated in Chapter 2 and complement the superficial SSI risk statistics generated in Chapter 3. The SSI risks that have been generated through HES analysis in this Chapter sit on the lower end of the spectrum of risk, indicating an expected lower risk of the deep and organ/space SSIs following hand trauma surgery.

Although there are no existing publications that report SSI risk in HES APC datasets for hand trauma, studies of other musculoskeletal surgery show similarly low SSI prevalence across their populations. Jen *et al* found a re-admission rate risk of 1.4% for SSI following orthopaedic surgery in a HES APC analysis of over 2-million procedures.(176) Abram *et al* evaluated 699,965 arthroscopic partial meniscectomies, 0.13% of which required re-operation for SSI.(177) Lane *et al* found an exceptionally low

risk of re-admission for SSI following carpal tunnel decompression at 0.005% by 90 days.(172) Studies in other administrative healthcare datasets, such as Medicare in the USA, have also been used to explore infection following musculoskeletal surgery, although existing data on trauma surgery infection risk remains sparse. A study of 83,011 total knee replacements found a periprosthetic joint infection risk of around 4%.(187)

Interrogation of administrative healthcare data in the USA has resulted in a number of large-scale cohort studies in wrist trauma. The ACS NSQIP database contains data on patients who have had surgery at over 700 hospitals in the USA.(188) Data are collected from patient medical records, rather than insurance company records, which improves accuracy of the post-operative outcome data, particularly SSI.(189) One study of operatively managed 16,158 distal radius fractures within ACS NSQIP found an SSI risk of 2.3%. The study population contained patients who had undergone ORIF for distal radius fracture, and it is unclear what proportion of injuries were open versus closed. Of the SSIs that occurred, the majority (2.2%) were deep infections, with superficial infections occurring rarely.(121) Wei *et al* also used ACS NSQIP to evaluate the effect of diabetes mellitus on complications following ORIF for distal radius fracture. The risk of SSI was very low in this cohort, at 0.2% and presence of diabetes was not associated with a higher risk. Systemic complications were extremely low also at <0.5% which is consistent with my findings in this population.(122)

Data from insurance company claims has also been used to study outcomes following distal radius fracture, although as previously discussed the detection of SSI is more nebulous in this type of data. The PearlDiver (PearlDiver, Inc) patient database contains over 175 million patient records from privately insured patients in the USA across both inpatient and outpatient settings. Constantine *et al* evaluated outcomes following surgical intervention for distal radius fracture in 87,168 patients.(123) The cohort consisted

of mostly closed fractures managed with ORIF (86.2%). The minority of patients had open fractures (4.9%) and the minority received K-wires (13.8%). The SSI risk was 0.9%, with a higher risk in those who received K-wires. This finding is consistent with the results from Chapter 2. Mahmood *et al* also used the PearlDriver database to explore risk factors for SSI following ORIF for distal radius fracture. The study population was 132,650 and had a low SSI risk at 0.3%.(124) Female sex, obesity, depression and hypertension were associated with a higher risk of SSI. The strength of HES APC data are its national coverage and context within the standards of care within the NHS. Cohorts generated from HES data are likely to have received similar care across the entire cohort, whereas there are known disparities in healthcare access in the USA. It is interesting that the larger the study population appears to be, the lower the prevalence of SSI (also discussed in Chapter 2). This is likely to be due to loss of granularity and over-reliance on record keeping/coding in big data. Prospective clinical trials will have more robust and reliable data collection processes that will improve detection of SSI. This theory is strengthened by the results from my CPRD analysis in Chapter 3. The risk of SSI in 3,088 hand trauma surgery patients is more in keeping with the summary statistics seen in hand trauma surgery RCTs than that those seen in cohort studies.

### 4.5.1 Strengths and limitations

This is a large prospective cohort study of SSI following hand trauma surgery to date, encompassing nationwide data with long-term follow-up. This strengthens the study in terms of external validity, as the findings are generalisable to all patients within the NHS and large, national healthcare systems in the developed nations. The methods employed have also resulted in a large study population, with each cohort containing the largest number of patients with common hand injuries to date. Accurate summary

estimates with narrow confidence intervals can therefore be generated that can be used to inform care and future research. The most significant limitation of this study, and HES data studies generally, is the fidelity of the diagnoses and outcomes. This is pertinent to SSI in particular, as capturing this as a post-operative outcome relies entirely on the accuracy of its documentation in the patient record. It is not possible to determine which of the CDC criteria result in a diagnosis of SSI in this study. By selected codes that are specific for SSI requiring surgery, septic arthritis and osteomyelitis, we can be confident that deep and organ/space SSI will be detected as outcomes, thus retrospectively mapping directly to the CDC criteria.

Nonetheless, some cases of deep or organ/space SSI will be missed in this study, and it is equally possible that some cases may have been coded as deep or organ/space SSI erroneously. For example, we see an incidence of osteomyelitis in 934 cases (0.7%, CI [0.6 – 0.7]) by 30 days following hand fracture surgery. Although osteomyelitis of the hand comprises around 1%–6% of all hand infections, it can be difficult to diagnose, requiring a combination of clinical, microbiological and radiological assessments.(190,191) X-ray changes can be seen from one week but usually appear around three to four weeks after infection, complicating the temporal aspect of diagnosis.(192) It is however feasible that hand trauma patients, at relatively high baseline risk of osteomyelitis based on the contamination status of their wounds, could present and have radiological/ microbiological indicators of osteomyelitis within 30 days, and certainly by 90 days.(193)

A further limitation is that the HES dataset exists for remuneration within the NHS and was not designed for research purposes. Only those complications that result in re-admission will be collected in this dataset. We can determine the number of patients who are re-admitted to hospital following an index procedure of surgery for hand trauma. We can also determine the reasons for those re-admissions, and by using specific code

combinations, we can determine a signal for the number of patients re-admitted to hospital post-operative infections. Another limitation is that patients who undergo minor operations in settings that do not require formal hospital admission will be missed from this cohort. This has been mitigated through analysis of CPRD data in the previous chapter, which would contain follow-up data for these patients. Lastly, older HES datasets are known to be lower fidelity than more recent datasets. This could be mitigated in future analyses by performing sensitivity analyses, comparing SSI risk in contemporary data (i.e. 2017 – 2018) to older data (1998 – 2000) to determine statistically significant differences.

Based on these strengths and limitations, the data presented here can give us a reasonable and useful signal in terms of the number of deep and organ/space SSIs that occur following surgery for hand trauma.

## 4.6 Conclusions

The risk of re-admission for deep or organ/space SSI following hand trauma surgery is 1.4% by 30 days and 2% by 90 days. These data can be used to add granularity to the summary statistics presented in Chapter 2 and the superficial SSI risk statistics in Chapter 3. The combination of these figures can be used to inform patients about their likely risk of the different types of infection following surgery, and can also be used to inform future observational and experimental studies of antimicrobials and SSI in hand trauma.

# 5 PREVENTING SURGICAL SITE INFECTION IN HAND TRAUMA: A PROTOCOL FOR A FEASIBILITY STUDY OF ANTIMICROBIAL SUTURES

We know now that most patients will sustain superficial SSIs and a small proportion will develop deep or organ/space SSIs by 30 and 90 days respectively. These new figures indicate that SSI is a pertinent issue in hand trauma surgery and steps should be taken to reduce its risk. Although there is evidence that interventions can reduce SSI, these interventions have never been tested in hand trauma populations. The first step in improving this, is feasibility work to ascertain the logistical and methodological considerations of performing robust clinical trials in hand trauma surgery and SSI. Antimicrobial sutures have been tested in RCTs in a number of surgical fields with variable evidence supporting their effectiveness in terms of SSI prevention. As an intervention, their provenance in surgical trials lends them to evaluation in a new population such as hand trauma. I therefore propose a feasibility RCT, centred around antimicrobial sutures in hand trauma surgery. I have chosen to include this Chapter to demonstrate my learning in terms of trial development and my understanding of real-world trial logistics.

## 5.1 Abstract

**Background**

Antimicrobial sutures have been recognised by both WHO and NICE as potentially effective for reducing SSI. They have never been studied in hand trauma surgery: a completely different patient group and clinical pathway to previous RCTs of these sutures. Antimicrobial sutures are expensive and further research in hand trauma is warranted before they become standard of care. Before antimicrobial sutures can be evaluated in a definitive RCT, feasibility work is needed to determine methodological and logistical parameters.

**Objective**

To conduct a feasibility study of antimicrobial sutures in patients undergoing hand trauma surgery to establish acceptability, surgeon compliance and retention for a definitive trial.

**Methods**

A two-arm, multi-centre feasibility RCT of 116 adult participants with hand and wrist injuries, randomised to either antimicrobial sutures or standard sutures. Study participants and outcome assessors will be blinded to treatment allocation. Outcome measures will be recorded at baseline (pre-operatively), 30 days, 90 days and six months and will include SSI, PROMs and return to work.

**Anticipated impact and dissemination**

This will inform a definitive trial of antimicrobial sutures in the hand and wrist and will help to inform future upper limb trauma trials. The results of this research will be shared with the medical community through high impact publication and presentation.

## 5.2 Introduction

The consequences of SSI following hand trauma surgery include increased antibiotic prescription, re-operation, hospital admission, delayed rehabilitation and in severe cases, loss of all or part of the affected limb.(34,185,186) Already incapacitated by the injury, SSI can further postpone or prohibit return to work and independent living. The combined effects of SSI after surgery increase both the direct and indirect socioeconomic costs to the patient, the health and care services and the wider UK economy.(23) NICE report the UK incidence of SSI to be between 3-5% across all surgical procedures.(53) We now know from this thesis, that the risk of SSI in hand trauma is 5% overall, with a 2% risk of severe infection by 90 days and 14.4% risk of non-severe infection by 90 days. Having established that this risk is indeed higher than national and international estimates, it is worth reminding ourselves that currently there is no robust data on antimicrobial interventions that can guide practice in this population. The existing NICE and WHO guidelines for preventing SSI are based on studies, not one of which pertains to patients with injuries of the hand and wrist.(67,77)

It is widely accepted that surgical suture material is a common source of bacterial wound infection.(196) Sutures coated in triclosan, an antimicrobial agent, can reduce SSI in major abdominal and vascular surgery procedures by around 28% (meta-analysis of 21 RCTs).(54) These 'antimicrobial sutures' are more expensive than standard sutures: approximately £10 more per suture pack (£14.80 vs. £4.71). However, a recent economic evaluation of RCTs found antimicrobial sutures to be cost-effective in specific patient populations.(197) In these RCTs, the study populations are undergoing major, invasive surgery to the abdomen (e.g. laparotomy) with long operative times, adjunctive courses of intravenous antibiotics and long inpatient hospital stays.(198–200) These study populations are not comparable to hand trauma patients and so the results are not

generalisable. Furthermore, the incidence of SSI is theoretically very high in abdominal surgery: up to 12% in high-income countries and as high as 39.8% in low income countries.(201) Evaluating effectiveness of antimicrobial interventions, and indeed cost-effectiveness is inherently more practicable in this population. Work undertaken during this thesis supported the development of the latest NICE guideline update on antimicrobial sutures. In their own evidence review, they found a cost-effective reduction in SSI risk when the data was pooled across all trials, regardless of study quality and notwithstanding the heterogenous study populations: pilonidal surgery, dental surgery and laparotomy etc. This led to the 2021 recommendation: 'When using sutures, consider using antimicrobial triclosan-coated sutures, especially for paediatric surgery, to reduce the risk of surgical site infection' (National guidelines, (202)). I found this recommendation surprising considering the data on which it was based. Since this recommendation, the FALCON trial has been published in the Lancet.(86) FALCON is a 2×2 factorial RCT evaluating the effectiveness of surgical prep (alcoholic chlorhexidine vs. aqueous povidone-iodine) and suture type (antimicrobial or not) in abdominal surgery, stratified by wound contamination status. They randomised 5788 patients in 54 hospitals in seven low-income and middle-income countries, by far the largest RCT on the subject. They found no evidence of effect in terms of reducing SSI for alcoholic chlorhexidine and/or antimicrobial sutures, even in a high risk population.(86) The same research unit also published a meta-analysis of only high-quality RCTs evaluating these two interventions, finding no evidence of effect and directly contradicting the NICE recommendations a year before.(203)

Although the evidence supporting the use of antimicrobial sutures is contradictory, there is at least a relatively large number of trials for an antimicrobial intervention across some surgical fields. Now we have evidence that SSI is a significant post-operative problem in hand trauma, it is logical that we should begin to rigorously

evaluate antimicrobial interventions in this field to provide evidence that can inform patient care. Antimicrobial sutures have precedent in surgical RCTs and therefore are a reasonable intervention to first evaluate. If antimicrobial sutures are effective in reducing hand trauma SSI, they could facilitate timely and more complete return of hand function. This would directly benefit patients in terms of earlier return to work and independent living, reducing burden on the health service and economy. The first step in evaluating the effectiveness of antimicrobial sutures in hand trauma is a feasibility study. This will allow us to ascertain the feasibility of a large-scale definitive trial of this potentially beneficial intervention for hand trauma patients. Furthermore, research into methods to prevent SSI was longlisted in the James Lind Alliance Priorities for Common Hand and Wrist Conditions.(25)

Based on existing RCTs of antimicrobial sutures, we can see an effect of around 30% reduction in SSI in the intervention groups compared to control.(54) Looking at the meta-analysis of RCTs in Chapter 2 and the CPRD analysis in Chapter 3 pertaining to superficial SSI, we would expect an SSI incidence of at least 10%, which sits within the overall estimates established across all studies. If we take this as the baseline SSI risk in an antimicrobial trial in hand trauma surgery, and wish to test whether an intervention can reduce this risk to within national estimates (3-5%) then we would want to see a risk reduction of 50%. With a significance level of 5% and 90% power, this would require a total sample size of 750 participants, 375 in each group.(204) To conduct such a large RCT, we would need to adopt a multi-centre approach with a pragmatic design and efficient delivery. To enrol sufficient sites, we would need good community ‘buy-in’ from surgeons, addressing issues of equipoise. Patients would need the trial to be acceptable and important to them. We would need to be able to recruit quickly and easily, utilising the existing research infrastructure (clinical research networks) and the trainee research

networks. Follow-up should be efficient and low-burden to the sites and central trial team. We must deploy the most accurate outcome measures while minimising questionnaire burden and research waste.

There is therefore a number of key feasibility parameters that pertain to evaluating antimicrobial sutures in hand trauma surgery:

- Equipoise: does the apparent equipoise expressed by the community translate into willingness and effectiveness at recruiting?
- Recruitment: can we screen and recruit into hand trauma trials?
- Surgeon compliance: can we deliver the intervention?
- Retention: can we follow-up patients?
- Outcome measurement: can we record SSI and can we practically measure hand and overall recovery using PROMs?

Due to the lack of multi-centre randomised trials assessing SSI in hand trauma surgery, we are unable to answer the above questions without a bespoke feasibility RCT. I therefore now outline a multi-centre, randomised feasibility clinical trial of antimicrobial sutures in patients with hand and wrist injuries that require surgery with sutures. This will firstly inform a definitive RCT of antimicrobial sutures, provide critical feasibility for further RCTs of antimicrobial interventions in hand trauma and will ascertain the feasibility of trials in this population more generally.

## 5.3 Aim

The aim of this multi-centre randomised feasibility RCT is to determine the key indicators of feasibility for a definitive trial of antimicrobial sutures versus standard sutures in hand trauma surgery.

### 5.3.1 Feasibility objectives

To establish key feasibility parameters to inform a definitive trial of antimicrobial sutures versus standard sutures in hand trauma surgery:

- Number of eligible participants
- Number of participants who consent to be included in the study
- Number of eligible participants who are randomised to either the intervention or control
- Number of participants with completed outcome measures at the set time points:
    - SSI recorded at 30 days
    - SSI recorded at 90 days
    - PROMs completed at 30 days
    - PROMs completed at 90 days
    - PROMs completed at six months
- The number of participants who suffer a complication

### 5.3.2 The full trial objectives are:

- To quantify differences in the rate of SSI in hand trauma surgery within 30 days and 90 days post-surgery between the treatment groups
- To quantify the differences in hand function at 30 days, 90 days and six months post-surgery between the treatment groups.
- To quantify differences in HRQoL at 30 days, 90 days and six months post-surgery between the treatment groups
- To quantify the differences in costs and comparative cost-effectiveness between the treatment groups over the first six months post-surgery

## 5.4 Methods

This multi-centre feasibility study will inform a definitive, large-scale randomised clinical trial that will compare antimicrobial sutures versus standard sutures for prevention of SSI following surgery for hand trauma. The aim is to determine key feasibility parameters for consent, recruitment and surgeon compliance to inform a definitive trial.

When the participant attends the emergency clinic for assessment, they will be identified by the clinical team and approached by the research associate for consent and recruitment. The participants will be randomly assigned to either antimicrobial sutures or conventional sutures via a secure online randomisation process following consent. Once they have been recruited, the research team will collect baseline demographic data and both pre-injury and post-injury functional data using the PEM Part 2 and the Patient-Reported Outcomes Measurement Information System® Upper Extremity (PROMIS UE) PROMs, as well as pre-injury health-related quality of life using the EuroQoL EQ-5D-5L. When the participant attends for their operation, the research associate will collect and input operative data as per the operation note. Screening logs will be kept at each site to determine the number of patients assessed for eligibility and reasons for any exclusion. In addition, the number of eligible and recruited patients, and the number of patients who decline consent/withdraw, will be recorded.

During surgery, participants will receive either standard or antimicrobial sutures depending on their allocation. Both suture types are currently available on the shelf in operating theatres in the UK. By necessity, the surgeon will not be blinded to the allocation. The participant will be blinded to the allocation. Both before and after the suturing procedure, the participant will receive standard care for their injury as per the

local hospital and NHS practice. Further follow-up after the operation will be as per usual clinical care at each site.

The participant will then be contacted by email or text at 30 days and asked to complete the next set of outcome measures, including identification of SSI. The same will then occur at 90 days. The participants will be contacted at six months and asked to complete PROMs and an employment questionnaire. Once these have been collected, follow-up will be complete.

### 5.4.1 Ethics approval

This study has been reviewed and was approved by the National Research Ethics Service Committee (21/SC/0334, IRAS 292544) on the 30th November 2021. The research will be carried out in compliance with the Helsinki Declaration.

### 5.4.2 Study registration

This study is registered with the International Standard Randomised Controlled Trial Number Register (ISRCTN10771059).

### 5.4.3 Study participants

Adults with hand and wrist injuries that require a surgical intervention that includes the use of surgical sutures.

#### 5.4.3.1 Inclusion criteria

Adults (>18) undergoing hand trauma surgery requiring sutures and providing informed consent.

#### 5.4.3.2 Exclusion Criteria

- Unable to give informed consent to participate
- Allergic to triclosan (active coating in antimicrobial sutures)
- Adults with infected wounds
- Adults with wounds not amenable to closure with sutures
- Finger nailbed injuries
- Unable to complete study procedures, including the completion of a patient questionnaire in English

### 5.4.4 Recruitment

The study will be run across three centres for hand trauma in the UK:

- Oxford University Hospitals NHS Foundation Trust
- Buckinghamshire Healthcare NHS Trust
- Royal Cornwall Hospitals NHS Trust

Screening of potentially eligible participants will be performed by a member of the local clinical team, who will then alert the research team. All potentially eligible patients will be screened and assessed for eligibility for entry into the study by a member of the research team delegated to conduct screening. If an eligible participant is identified, then they will be approached by a trained member of the research team who will provide them with written study information to consider and then asked for their written informed consent (Appendix 25. HAWAII participant information sheet, Appendix 26. HAWAII consent form). All written study information has been reviewed by the project-specific PPI group before trial commencement.

### 5.4.5 Timeline

Recruitment is planned to commence in January 2022 with a period of three months for recruitment based on audit data of potentially eligible participants.

### 5.4.6 Feasibility progression criteria

| Feasibility Outcome | Green | Amber | Red |
|---|---|---|---|
| Screening | Screen ≥200 patients per month | Screen ≥120 patients per month | Screen <120 patients per month |
| Recruitment | Recruit ≥40 participants per month | Recruit ≥24 participants per month | Recruit <24 participants per month |
| Retention | ≥80% retention of participants | ≥50% retention of participants | <50% retention of participants |
| Compliance | ≥80% participant compliance | ≥50% participant compliance | <50% participant compliance |

These criteria and timeline are generated based on audit data rather than previous RCT data so may overestimate figures. Meeting green criteria will be considered as measures of sufficient feasibility for a definitive trial. Amber criteria will trigger a review of study processes by the trial steering committee. Red criteria will indicate that a definitive study may not be feasible.

### 5.4.7 Consent

Once eligibility for the study has been confirmed, informed consent will be sought. In order to standardise the information provided to the patients, written recruitment materials will be made available to the research team at all sites. The potential participant will be given a participant information sheet explaining the study and the study procedures. The research team will also be able to answer any additional questions that the

patient might have. This will then lead on to an informed consent discussion. Patients will be given as much time as possible to consider the information and discuss it with relatives/carers. It will be clearly stated that the participant is free to withdraw from the study at any time for any reason without prejudice to future care, without affecting their legal rights, and with no obligation to give the reason for withdrawal. Before any study related procedures or data are collected, participants will complete the latest approved version of the consent form electronically. They will be asked to provide their contact details if they are willing to consent in order for an electronic copy of the form to be sent to them immediately. The person performing the consent procedure must be suitably qualified and experienced and have been authorised to do so by the Principal Investigator. The local research team will be able to download a copy to place in the participant's medical notes. If the participant does not have access to email then a paper copy of their consent form will be provided by the local research team instead. The trial website will be maintained until the study archive period has reached completion.

### 5.4.8 Post-recruitment withdrawals and exclusions

During the course of the trial a participant may choose to withdraw early from the study at any time, without giving reasons, and without prejudicing their clinical care. Participants will not have the option to withdraw the data collected up until the point of withdrawal, as the data will be required for the intention-to-treat analysis and safety analysis. The options for withdrawal will be explained clearly in the PIS (Appendix 25). The type of withdrawal and reason for withdrawal, if the participant is willing to provide one, will be recorded in the withdrawal Case Report Form (CRF).

### 5.4.9 Treatment allocation

Those patients who consent to take part in the trial will have their treatment allocated using a secure, centralised, online randomisation service. All hospital treatment areas have access to online resources and so will be able to access the randomisation service in real time ensuring no delay in the treatment of the participant. The randomisation service will be open 24 hours each day to facilitate the inclusion of all potentially eligible patients. Randomisation will be on a 1:1 basis, stratified by age of the patient and whether the injury was open or closed. Stratification by age will be used to ensure that there are equivalent numbers of age groups in each treatment arm. Open soft tissue trauma of the hand and wrist is more common in younger working male populations, often sustained at work or during recreation, although its incidence is increasing in older populations too. Closed fractures of the wrist are more common in older female patients, most often from a mechanical fall. Closed hand fractures occur in both age groups, increasingly so in the older population. As fracture of the distal radius is the most common age-related injury, the stratification will be above and below 50 years of age. A study by Court-Brown and Caeser, assessed over 1000 patients with a fracture of the distal radius, confirming a bimodal distribution for this type of fracture according to the age of the patient.(205) The crossover of the two peaks of incidence was around 50 years of age. These studies provide strong evidence that patients over the age of 50 become increasingly vulnerable to fragility fractures of the distal radius. Therefore, I have chosen an age +/- 50 as the stratification criterion for this trial.

### 5.4.10 Blinding

Participants will be blinded to the allocation of treatment. Outcome measurement will be completed remotely and electronically by the participants themselves. Therefore

outcome assessment will be blinded. If a procedure is performed under local anaesthetic, the operating teams will be briefed on not disclosing the allocation while the participant is able to hear, a method in use in another NIHR funded hand trauma trial.(206) Data analysis will be performed by the trial team.

## 5.5 Interventions

### 5.5.1 Antimicrobial sutures

The intervention will be antimicrobial sutures provided by Ethicon (e.g. Monocryl Plus, PDS Plus). These are sutures coated in triclosan, which is a routinely used antimicrobial agent. The amount of triclosan required to convey an antimicrobial effect to a suture is extremely small in comparison to the amounts used in commercial and environmental products.(196, 197) Although mild allergy can occur with triclosan, there have been no reports of any adverse reaction with antimicrobial sutures in the last 13 years.

### 5.5.2 Standard sutures

The control will be standard, non-antimicrobial sutures of any kind as per standard practice at each site.

### 5.5.3 Other treatments

Participants will receive usual pre-, peri- and post-operative care according to site routine practice. Usual care data will be recorded and analysed from a feasibility point of view.

## 5.6 Follow-up

### 5.6.1 Clinic visit

Participants will attend a routine follow-up visit to check wound healing, approximately one week after their injury depending on local clinical practice. During this visit their dressing will be removed, the wound inspected and swabbed if indicated. They will then usually be referred to hand therapy for rehabilitation. The local clinical team will record any early complications that have occurred at this appointment.

### 5.6.2 Remote follow-up

Subsequent data collection will be via email and/or text link to the online questionnaires to be completed remotely. If the BWHQ identifies an SSI at 30 or 90 days, a review of the medical notes by the local PI team will be triggered, to confirm the presence of an SSI and its management. PROMs will be deployed electronically at baseline, 30 days, 90 days and at six months as per the schedule below. If a participant is unable to complete the PROMs electronically (i.e. unable to type due to loss of hand/wrist function), then they will be offered an opportunity to complete them over the phone with a member of the research team.

### 5.6.3 Schedule

Baseline and pre-injury PROMs will be collected at recruitment. PROMs and the BWHQ will be deployed at 30 days and 90 days. PROMs and an employment status questionnaire will be deployed at six months.

## 5.7 Outcomes

### 5.7.1 Primary Outcomes

The primary outcomes for this study are measures of feasibility that will inform recruitment, surgeon compliance and retention for a definitive study.

### 5.7.2 Secondary Outcomes

#### 5.7.2.1 Surgical Site Infection

I will use the BWHQ to detect occurrence of SSI at 30 days and 90 days. The BWHQ is a disease-specific PROM that has been developed using contemporary methods to detect presence of SSI in surgical wounds.(207) It maps to the CDC definition of SSI and has been validated for use in UK populations and for completion by participant or observer.(208) If a participant's score on the BWHQ indicates presence of an SSI (score >5), this will trigger a medical notes review by the local PI team to confirm the presence of SSI.

#### 5.7.2.2 Hand and wrist function

My PPI representatives strongly endorsed the use of PROMs to assess the patient-centred aspects of hand and wrist function in the feasibility study. I will use two PROMs to measure hand and wrist function: the PEM Part 2 and PROMIS UE.

The PEM Part 2 is an established PROM for assessing hand function in clinical trials and has been in use since its development in 1995.(209) Despite some gaps in the evidence for its overall validity, it has been successfully used in previous NIHR studies.(210) The PEM consists of ten questions, addressing different aspects of hand function. Each question is scored using a seven-point scale, with 1 being the best and 7

being the worst. A lower score is therefore indicative of better function and symptoms and conversely a higher score indicates worse function.(209)

PROMIS UE is a contemporary PROM that measures upper limb function, developed using item response theory. It is being used in more recent NIHR-funded clinical trials in upper limb trauma and correlates well with commonly used hand function PROMs.(211–213) PROMIS UE can be administered via a CAT or a short form. With a CAT, participant responses guide the system's choice of subsequent items from the full item bank (165 items in total in adult bank). Although items differ across respondents taking CAT, scores are comparable across participants.(214) Items on the PROMIS UE have a five-point scale with 5 being the best and 1 being the worst. This means a higher score indicates better function and lower score indicates worse function.

#### 5.7.2.3 Quality of life and return to work

I will collect the EQ-5D-5L, an established measure of health-related quality of life that is NICE recommended.(215–217) The EQ-5D-5L has five dimensions: mobility, self-care, usual activities, pain/discomfort and anxiety/depression. Each dimension is then rated from 1 to 5, with 1 being the best score and 5 being the worst score: no problems, slight problems, moderate problems, severe problems and extreme problems. The scores for the five dimensions are then combined into a 5-digit number that describes the patient's health state.(215) The EQ-5D-5L will be administered at baseline, 30 days, 90 days and six months to capture changes in health-related quality of life. Employment status will be assessed at six months.

## 5.8 Power and sample size

A sample size of 116 is required to determine acceptable 95% CIs for compliance and retention, providing usable estimates for a definitive study. The 95% CI (Wilson's method) will have maximum width of .18 given 116 participants. The width could be as small as .12 (12%) depending upon the event proportion. I have conducted prior audit work that indicated a total of 58 potentially eligible patients per week across the three sites. Based on experience in previous hand trauma trials, 20% of this number will be successfully recruited (80% unwilling or not randomised/allocated).(124) This results in a conservative estimate of 12 recruited per week across all sites, requiring a recruitment period of 10-12 weeks.

## 5.9 Statistical analysis

I will perform descriptive summaries of the data both overall and also by treatment group. No formal statistical comparison between groups is planned given the nature of the study. The number of eligible participants in total, the number of participants who consented for inclusion and the number of eligible participants randomised will be reported descriptively. The follow-up rates at each time point will also be reported. The proportion of participants randomised and those retained at six months will be reported with 95% CIs to inform a definitive study.

## 5.10 Study reporting

The full trial will be reported according to the CONsolidated Standards Of Reporting Trials (CONSORT) extension for randomised feasibility studies.(217) This protocol has been reported in accordance with the SPIRIT statement (Appendix 27. HAWAII protocol – SPIRIT checklist).(219)

## 5.11 Summary

This Chapter outlines the rationale, aims, objectives and methods for the HAWAII Feasibility Study. Antimicrobial sutures are an intervention that has been evaluated in a large number of surgical RCTs and therefore is an appropriate intervention to test in hand trauma from a feasibility point of view. There are distinct feasibility questions pertaining to conducting trials in hand trauma populations and the results of the outlined study will be a step towards answering them.

# 6 The Hand And Wrist: AntImicrobials and Infection (HAWAII) trial: A feasibility study of antimicrobial sutures in hand trauma

The previous chapter outlined the inception, design and development of the HAWAII Feasibility Study. This Chapter is the full study report of the feasibility RCT, including the logistic and methodological outcomes collected that can inform future definitive trials of antimicrobials in hand trauma surgery.

# 6.1 Abstract

**Background**

Hand trauma, comprising injuries to both the hand and wrist, affects over five million people per year in the NHS, and results in around 250,000 operations per year. SSI following hand trauma surgery results in increased antibiotic prescription, reoperation, hospital admission, delayed rehabilitation, and, in severe cases, loss of all or part of the affected limb. The risk of SSI following hand trauma surgery is approximately 14% by 90 days, including both superficial, deep and joint space infections. Sutures coated in triclosan, an antimicrobial agent, can reduce SSI in major abdominal and vascular surgery procedures by around 28% but have never been tested in hand trauma surgery. I aimed to perform a feasibility study to ascertain whether a definitive RCT of antimicrobial sutures in hand trauma surgery is achievable.

**Methods**

A randomised, parallel, multi-centre feasibility controlled trial involving adults undergoing surgery for hand trauma. Participants were randomised to antimicrobial sutures or standard sutures on a 1:1 basis. The primary objective was to evaluate feasibility for a definitive trial in terms of key feasibility outcomes: screening, recruitment, randomisation, surgeon compliance (i.e. were the allocated sutures deployed) and retention. Secondary objectives were incidence of SSI in both groups, hand function measured with PROMs, HRQoL and change in employment. Treatment was allocated using a secure, centralized, 24-hour online randomisation service. Randomisation was performed on a 1:1 basis, stratified by age of the patient and whether the injury was open or closed. Participants were blinded to allocation.

**Results**

Between March 2022 and November 2022, 116 participants were randomised: 60 to the intervention group and 56 to the control group. Screening, recruitment and randomisation were expeditious across all three sites, such that the study closed to recruitment one month early. Of the 227 screened, most were eligible (89.5%), and most who were approached agreed to be included in the study (84.7%), indicating acceptability to patients and clinicians. Retention was low: 57.5% at 30 days, 52% at 90 days and 45.1% at six months. Incidence of SSI was approximately 20% in both groups. Hand function deteriorated after injury but recovered to near pre-injury levels during the study period.

**Conclusions**

A definitive RCT of antimicrobial sutures in hand trauma surgery is feasible, as long as retention of study participants to the primary endpoint can be attained. Retention strategies including monetary incentives, efficient PROMs, real world data linkage and enhanced participant communications could be utilised. Data from this study can be used to inform future trials of antimicrobial interventions in hand trauma populations.

**Trial registration**

ISRCTN10771059

**Funding**

This study is funded by the NIHR Doctoral Research Fellowship (NIHR301793). This research is also funded by BAPRAS, BSSH and RCSEng.

## 6.2 Introduction

SSI in hand trauma is prevalent, exceeding the NICE estimate for SSI across all surgical fields. Despite this, interventions to reduce SSI risk remain unevaluated in this population. This is important as hand trauma predominantly affects a young, socioeconomically active population, who will often require surgery for their injuries. SSI following hand trauma can be highly deleterious, especially in cases of deep and organ/space SSI. Surgical suture material is a common source of bacterial wound infection.(196) Sutures coated in triclosan, an antimicrobial agent, can reduce SSI in major abdominal and vascular surgery procedures by around 28% (meta-analysis of 21 RCTs.(54) These 'antimicrobial sutures' are more expensive than standard sutures: approximately £10 more per suture pack (£14.80 vs. £4.71). However, a recent economic evaluation of RCTs found antimicrobial sutures to be cost-effective in specific patient populations.(197) In these RCTs, the study populations are undergoing major, invasive surgery to the abdomen (e.g. laparotomy). These study populations are not comparable to hand trauma patients and so the results are not generalisable. If antimicrobial sutures are effective in reducing hand trauma SSI, they could facilitate timely and more complete return of hand function. This would directly benefit patients in terms of earlier return to work and independent living, reducing the burden on the health service and economy. The first step in evaluating the effectiveness of antimicrobial sutures in hand trauma is a feasibility study. This will allow us to ascertain the feasibility of a large-scale definitive trial of this potentially beneficial intervention for hand trauma patients.

### 6.2.1 Aims

The aim of this multicentre, randomised, feasibility RCT is to determine the key indicators of feasibility for a definitive trial of antimicrobial sutures versus standard sutures in hand trauma surgery.

## 6.3 Objectives

### 6.3.1 Feasibility objectives

To establish key feasibility parameters to inform a definitive trial of antimicrobial sutures versus standard sutures in hand trauma surgery:

i. Number of eligible participants;

ii. Number of participants who consent to be included in the study;

iii. Number of eligible participants who are randomised to either the intervention or control; and

iv. Number of participants with completed patient reported outcome measures (PROMs) at the set time points:

    a. SSI recorded at 30 days;

    b. SSI recorded at 90 days;

    c. PROMs completed at 30 days;

    d. PROMs completed at 90 days; and

    e. PROMs completed at six months

v. Number of participants who develop a complication, including SSI.

### 6.3.2 Full trial objectives

i. To quantify differences in the rate of SSI in hand trauma surgery within 30 days and 90 days post-surgery between the treatment groups;

ii. To quantify the differences in hand function at 30 days, 90 days, and six months post-surgery between the treatment groups;

iii. To quantify differences in HRQoL at 30 days, 90 days, and six months post-surgery between the treatment groups.

## 6.4 Methods

HAWAII is a multi-centre, randomised, controlled feasibility trial. The study was conducted at three sites in the UK: Royal Cornwall Hospital NHS Trust (RCHT), Oxford University Hospitals NHS Foundation Trust (OUH) and Buckinghamshire Healthcare NHS Trust (BHT). The trial was coordinated by the Oxford Trauma and Emergency Care Group, within NDORMS at the University of Oxford, UK. A Trial Management Group met fortnightly to assess and troubleshoot procedures. A trainee collaborative model was employed, whereby trainees could collect 'HAWAII points' by recruiting and randomising participants, as well as completing baseline CRFs (Appendix 27. HAWAII Case Report Forms). If trainees collected sufficient points they were included as a collaborative author (PubMed citable) on the final manuscript (Appendix 28. Trainee collaborative author criteria). This study has been reviewed by the National Research Ethics Service Committee (21/ SC/0334) and was carried out in compliance with the Helsinki Declaration. HAWAII is registered with the International Standard Randomised Controlled Trial Number Register (ISRCTN10771059). A full protocol is published and available open access (Research papers).(219) This study is reported in accordance with the CONSORT 2010

statement: extension to randomised pilot and feasibility trials (Appendix 29. CONSORT Checklist: HAWAII Feasibility Study).(218)

## 6.4.1 Patients

Patients aged 18 or older with any hand or wrist injury requiring an operation that included the use of sutures were eligible for inclusion. Adults who were unable to give informed consent, who were allergic to triclosan (active coating in antimicrobial sutures) or who were unable to complete study procedures, including the completion of a patient questionnaire in English were excluded. Patients with infected wounds, wounds that could not be closed primarily with sutures or with finger nailbed injuries were also excluded.

## 6.4.2 Trial design

### 6.4.2.1 Screening

Potentially eligible patients were screened and approached in the ED, hand trauma clinics or pre-operative assessment areas. Both research nurses and clinicians recruited participants to the trial and conducted initial trial procedures. Screening logs were kept at each site to determine the number of patients assessed for eligibility and reasons for any exclusion. In addition, the number of eligible and recruited patients, and the number of patients who decline consent/withdraw, were recorded.

### 6.4.2.2 Data collection

Once eligibility was confirmed, informed consent was sought. Written recruitment materials were made available to the research team at all sites. Potential participants were given a PIS explaining the study and the study procedures. Electronic CRFs were used throughout HAWAII; only the PIS and consent forms were available in paper format. Following consent, baseline demographic data, pre-injury PROMs, post-

injury PROMs were collected from participants, usually via tablet. Participants were then randomly assigned to receive either antimicrobial sutures or conventional sutures via a secure online randomisation process. Randomisation was performed on a 1:1 basis, stratified by age of the patient and whether the injury was open or closed. The allocation was displayed on the online randomisation portal and was concealed from the treating surgeon until the sutures were required. The operating teams were briefed on not disclosing the allocation to the participant, to prevent this affecting the participants' judgement when completing the follow-up outcome measurements, which were completed remotely and electronically by the participants themselves. The operating team were informed of the allocation once sutures were required intra-operatively by the research team. Following surgery, the operation CRF was completed by the clinical research team. The participant was then contacted by email or text at 30 days and asked to complete the next set of outcome measures, including identification of SSI. The same then occurred at 90 days. Finally, the participants were contacted at six months and asked to complete their PROMs and an employment questionnaire.

#### 6.4.2.3 Interventions

The intervention arm received antimicrobial sutures produced by Ethicon (e.g. Monocryl Plus, PDS Plus). They are essentially standard sutures coated in Triclosan, an antimicrobial agent. These sutures are in routine clinical use in the NHS and according to NICE, should be considered as a wound closure intervention to reduce SSI. The control arm received standard, non-antimicrobial sutures of any kind as per standard practice at each site. Participants received usual pre-, peri- and post-operative care according to site routine practice. Usual care data was recorded to inform feasibility of future antimicrobial studies in hand trauma.

### 6.4.3 Treatment allocation

Treatment was allocated using a secure, centralised, 24-hour online randomisation service. Randomisation was performed on a 1:1 basis, stratified by age of the patient and whether the injury was open or closed. Both before and after the suturing procedure, the participant received standard care for their injury as per the local hospital and NHS practice. Standard care usually involves basic initial wound care (wound washout, application of a dressing, elevation in a sling, tetanus prophylaxis). Prophylactic antibiotics are often prescribed pre-operatively, although this can be variable. Participants undergoing fracture fixation commonly receive induction antibiotics, usually intravenously. The surgical field is prepared with a sterile cleaning solution, which is commonly chlorhexidine or iodine based and either alcoholic or aqueous. Post-operative prescription of systemic antibiotics is not uncommon and is variable across the NHS. Further follow-up after the operation was as per usual clinical care at each site.

### 6.4.4 Blinding

Participants were blinded to the allocation of treatment. Outcome measurement was completed remotely and electronically by the participants themselves. Operating surgeons were aware of the allocation by necessity but were not involved in patient follow-up.

### 6.4.5 Outcome measures

#### 6.4.5.1 Primary outcomes

The primary outcomes for this study were measures of feasibility that will inform recruitment, surgeon compliance, and retention for a definitive study.

### 6.4.5.2 Secondary outcomes

#### *6.4.5.2.1 Surgical site infection*

The BWHQ was used to detect occurrence of SSI at 30 days and 90 days. It maps to the CDC definition of SSI and has been validated for use in UK populations and for completion by participant or observer.(208) The BWHQ contains 18 questions on a single scale. Ten questions relate to symptoms and signs of SSI (e.g. *Has any part of the wound leaked thick and yellow/green fluid (pus/purulent exudate)*) and are rated on a four item verbal scale (not at all, a little, quite a bit, a lot). There are then eight further yes/no questions that pertain to treatment of SSI (e.g. *Have you been given antibiotics for a problem with your wound?).* An overall score is calculated by summing all the scores for each item, ranging from 0 to 41. A score of 0 indicates no problems with wound healing. A score of 6 – 8 has been found to indicate presence of SSI in prior validation work.(208) For this study, a conservative estimate of 8 was used as a threshold to determine presence of SSI, with consideration of the participant's responses to the questions relating to treatment of SSI. The BWHQ was deployed remotely, electronically via REDCap at 30 days and 90 days.

#### *6.4.5.2.2 Hand and wrist function*

Two PROMs were deployed to measure hand and wrist function: the PEM Part 2 and PROMIS UE. The PEM is an established PROM for assessing hand function in clinical trials and has been in use since its development in 1995.(209) The PEM consists of ten questions, addressing different aspects of hand function. Each question is scored using a seven-point scale, with 1 being the best and 7 being the worst. A lower score is therefore indicative of better function and symptoms and conversely a higher score indicates worse function. PROMIS UE is a contemporary PROM that measures upper limb function, developed using item response theory.(211,214) PROMIS UE can be administered via a

CAT, where participant responses guide the system's choice of subsequent items from the full item bank (165 items in total in adult bank). Although items differ across respondents taking CAT, scores are comparable across participants. Items on the PROMIS UE have a five-point scale with 5 being the best and 1 being the worst. A higher score indicates better function and lower score indicates worse function. The PEM and PROMIS UE were deployed remotely, electronically via REDCap at 30 days, 90 days and at six months.

*6.4.5.2.3 Health-related quality of life and return to work.*

HRQoL was measured using the EQ- 5D-5L.(211-213) The EQ-5D-5L has five dimensions: mobility, self-care, usual activities, pain/discomfort and anxiety/depression. Each dimension is then rated from 1 to 5, with 1 being the best score and 5 being the worst score: no problems, slight problems, moderate problems, severe problems and extreme problems. The scores for the five dimensions are then combined into a five-digit number that describes the patient's health state. The EQ-5D-5L was administered at baseline, 30 days, 90 days, and six months remotely, electronically via REDCap to capture changes in HRQoL. Employment status was assessed at six months only also via REDCap.

## 6.4.6 Power and sample size

A sample size of 116 was required to determine acceptable 95% confidence intervals (CIs) for compliance and retention, providing usable estimates for a definitive study. The 95% CI (Wilson's method) has a maximum CI width of 0.18 given 116 participants.

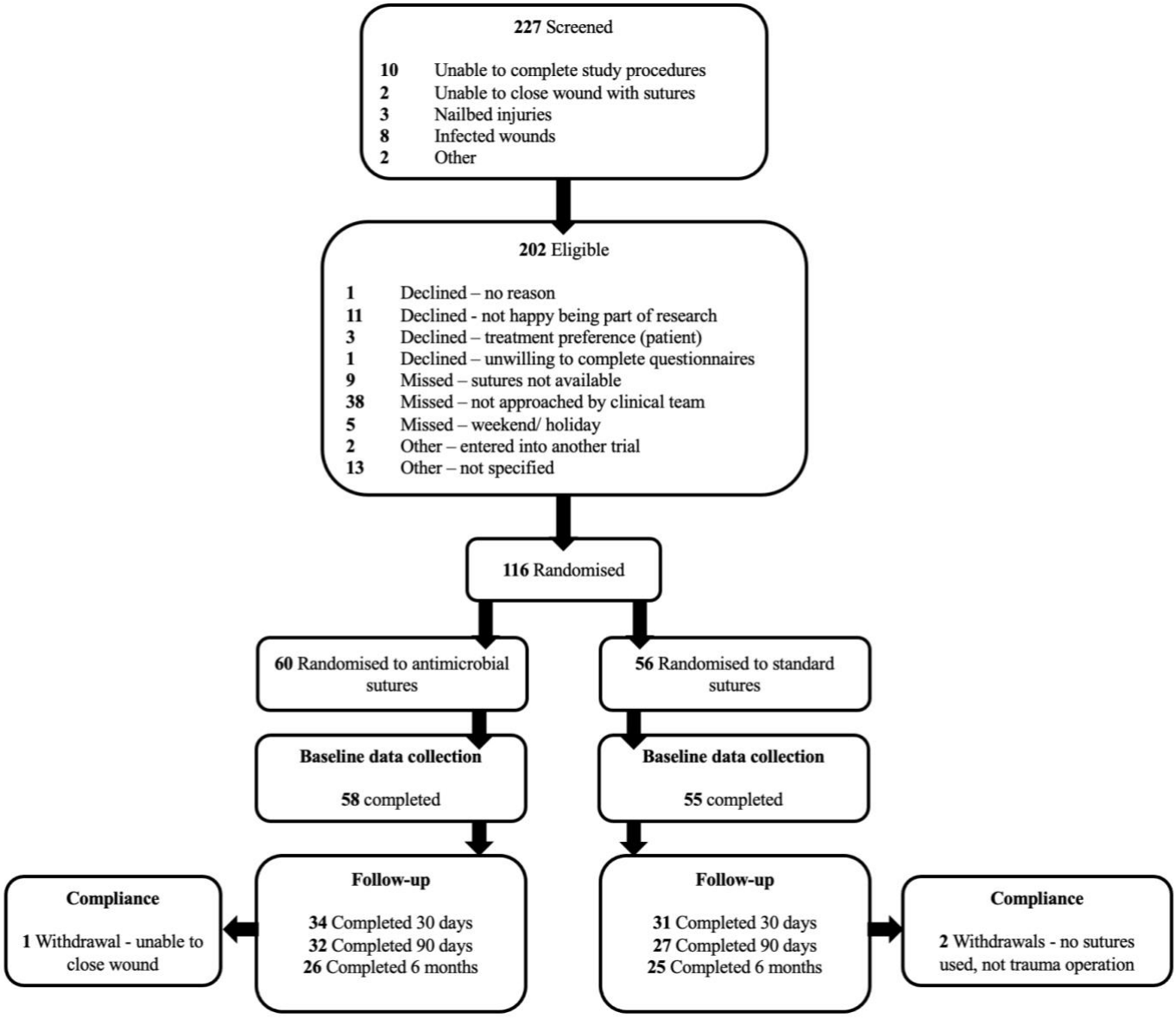
## 6.4.7 Statistical analysis

Descriptive summaries of the data were generated and displayed according to treatment group. No formal statistical comparison between groups was planned or

executed given the nature of the study. The number of eligible participants in total, the number of participants who consented for inclusion and the number of eligible participants randomised were reported descriptively as proportions with 95% CIs. Full trial outcome data were reported descriptively. For continuous data, the means and SD were calculated with 95% CIs and for categorical data, proportions as percentages with 95% CIs. A full statistical analysis plan was developed *a priori*.

## 6.5 Results

**Figure 14. CONSORT flow chart**



## 6.5.1 Patients

### 6.5.1.1 Demographics (Table 8)

From 10th March 2022 to 2nd November 2022, 116 participants were randomly assigned to receive either antimicrobial sutures (60) or standard sutures (56) alone (Figure 14. CONSORT flow chart). Follow-up for the primary outcome was completed in January 2023 and final follow-up was completed in May 2023. Demographics and injury characteristics were comparable at baseline. The population was predominantly men in their forties. There were more smokers in the control group (31.3% vs. 16.7%). There were few patients with diabetes or on immunosuppressive therapy in both groups and were just above normal BMI on average. Most worked full time (74.1%) and most needed to use their hands for their work (56.3%).

### 6.5.1.2 Injuries (Table 9)

Injuries were most commonly sharp lacerations or resulting from falls in both groups. Hands were more commonly injured than wrists, and usually the non-dominant limb. Injured structures were comparable between the two groups, with the majority of injuries open and contaminated. Closed injuries accounted for approximately 30% in both groups.

### 6.5.1.3 Surgical management (Table 10)

Operative management was comparable between groups, with predominantly registrar led procedures occurring in main theatres or minor operating settings. Over 80% of procedures were performed under local anaesthetic in both groups. Alcoholic chlorhexidine with full sterile prep and drape was usually employed. The surgical procedures performed reflected the injury types, with most patients undergoing debridement and washout, followed by either tendon or nerve repair and/or ORIF.

Antimicrobial sutures were deployed in the intervention group for most skin closures (83.0%) and for a small proportion of structural repairs (18.6%). A combination of antimicrobial and standard sutures was commonly employed in the intervention group. For example, some participants received standard sutures for repair of an injured structure (e.g. tendon) but received antimicrobial sutures for skin closure. All participants allocated to antimicrobial sutures received them (100% adherence). One participant in the control group mistakenly received antimicrobial sutures (1% cross-over). Standard non-adherent dressings were used to protect the surgical wound in the majority of cases. Antimicrobial dressings were used rarely (n=6, 5.2%). Splints and slings were used with variable frequency in both groups.

6.5.1.4 Antibiotic management (Table 11. Antibiotic treatment)

Over 40% of patients in both groups (50 patients across both groups), including open soft tissue injuries and open bony injuries, received systemic oral antibiotics in the ED, most commonly amoxicillin with clavulanic acid (i.e. co-amoxiclav). A further 19 patients received oral antibiotics in the hand trauma clinic, also usually co-amoxiclav. Induction antibiotics were used in a third of cases, some in addition to those already commenced on antibiotics pre-operatively. Post-operative antibiotics were prescribed in a relatively small proportion of patients.

## Table 8. Characteristics of participants

| | Antimicrobial sutures | Standard sutures |
|---|---|---|
| | n=60 | n=56 |
| **Demographics** | | |
| Mean age (SD) | 44.8 (17.5) | 47.2 (20.0) |
| Male sex (%) | 46 (76.7) | 36 (64.3) |
| Smoker (%) | 9 (16.7) | 15 (31.3) |
| Diabetes (%) | 4 (7.4) | 2 (4.2) |
| Immunosuppression (%) | 1 (1.9) | 2 (4.2) |
| Height (SD) | 174.3 (9.3) | 174 (10.6) |
| Weight (SD) | 80.0 (17.7) | 80 (17.1) |
| BMI (SD) | 26.3 (5.2) | 26.4 (4.8) |
| **Employment** | | |
| Working FT (%) | 40 (74.1) | 27 (56.3) |
| Working PT (%) | 4 (7.4) | 4 (8.3) |
| Not working (%) | 10 (18.5) | 17 (35.4) |
| Work requiring use of hands (%) | 43 (79.6) | 35 (72.9) |
| Self-employed (%) | 14 (25.9) | 13 (27.1) |
| **Residential status** | | |
| Own home (%) | 50 (92.6) | 44 (93.6) |
| Other (%) | 4 (7.4) | 3 (6.4) |

SD – standard deviation FT – full time PT – part time

## Table 9. Characteristics of hand and wrist injury

| | Antimicrobial sutures | Standard sutures |
|---|---|---|
| | n=60 | n=56 |
| **Injury type and mechanism** | | |
| Blunt (%) | 3 (5.6) | 6 (12.5) |
| Sharp (%) | 29 (53.7) | 24 (50) |
| Crush (%) | 8 (14.8) | 3 (6.3) |
| Fall (%) | 10 (18.5) | 10 (20.8) |
| Sport (%) | 6 (11.1) | 3 (6.3) |
| Confrontation (%) | 0 (0) | 0 (0) |
| Other (%) | 1 (1.9) | 4 (8.3) |
| Missing (%) | 6 (10) | 7 (12.7) |
| **Injury site** | | |
| Hand (%) | 45 (76.3) | 42 (76.4) |
| Wrist (%) | 13 (22) | 13 (23.6) |
| Both (%) | 1 (1.7) | 0 (0) |
| Dominant limb (%) | 27 (45.8) | 24 (43.6) |
| Missing (%) | 1 (1.7) | 1 (1.8) |
| **Injured structures** | | |
| Skin (%) | 38 (64.4) | 38 (69.1) |
| Tendon (%) | 15 (25.4) | 15 (27.3) |
| Nerve (%) | 12 (20.3) | 10 (18.2) |
| Artery (%) | 5 (8.5) | 2 (3.6) |
| Muscle (%) | 8 (13.6) | 2 (3.6) |
| Ligament (%) | 2 (3.4) | 3 (5.5) |
| Joint (%) | 2 (3.4) | 3 (5.5) |
| Bone (%) | 25 (42.4) | 21 (38.2) |
| Missing (%) | 1 (1.7) | 1 (1.8) |
| **Injury type** | | |
| Open (%) | 40 (67.8) | 38 (69.1) |
| Contaminated (%) | 36 (61) | 36 (65) |
| Dirty (%) | 4 (6.7) | 2 (3.6) |
| Closed (%) | 19 (32.2) | 17 (30.9) |
| Missing (%) | 1 (1.7) | 1 (1.8) |
| **Destination** | | |
| Admitted (%) | 7 (11.9) | 8 (14.5) |
| Discharged TCI (%) | 52 (88.1) | 47 (85.5) |

TCI – ‘to come in’

## Table 10. Operative management

| | Antimicrobial sutures | Standard sutures |
|---|---|---|
| | n=59 | n=55 |
| **Grade of surgeon** | | |
| Consultant (%) | 16 (27.1) | 14 (25.5) |
| Associate specialist (%) | 8 (13.6) | 8 (14.5) |
| Registrar (%) | 28 (47.5) | 26 (47.3) |
| CT/SHO (%) | 6 (10.2) | 6 (10.9) |
| ANP (%) | 1 (1.7) | 1 (1.8) |
| **Setting** | | |
| Main theatres (%) | 39 (66.1) | 38 (69.1) |
| MOPS (%) | 18 (30.5) | 17 (30.9) |
| Clinic (%) | 1 (1.7) | 0 (0) |
| ED (%) | 1 (1.7) | 0 (0) |
| **Anaesthetic** | | |
| GA (%) | 14 (23.3) | 10 (18.2) |
| LA (%) | 49 (81.7) | 45 (81.8) |
| Other (%) | 1 (1.7) | 3 (5.5) |
| **Surgical preparation fluid** | | |
| Alcoholic chlorhexidine (%) | 33 (56.9) | 40 (72.7) |
| Alcoholic betadine (%) | 8 (13.8) | 3 (5.5) |
| Aqueous chlorhexidine (%) | 11 (19) | 8 (14.5) |
| Aqueous betadine (%) | 0 (0) | 2 (3.6) |
| Other (%) | 6 (10.3) | 2 (3.6) |
| **Sterile field preparation** | | |
| Full sterile draping (%) | 36 (62.1) | 35 (63.6) |
| Aperture drape (%) | 21 (36.2) | 13 (34.5) |
| None (%) | 1 (1.7) | 0 (0) |
| Other (%) | 0 (0) | 1 (1.8) |
| **Operative details** | | |
| Debridement (%) | 34 (57.6) | 34 (61.8) |
| Washout (%) | 45 (76.3) | 42 (76.4) |
| Joint washout (%) | 5 (8.5) | 6 (11.1) |
| Nerve repair (%) | 12 (20.3) | 4 (7.4) |
| Tendon repair (%) | 12 (20.3) | 12 (22.2) |
| Artery repair (%) | 0 (0) | 1 (1.9) |
| MUA (%) | 1 (1.7) | 1 (1.9) |
| ORIF (%) | 18 (30.5) | 14 (25.9) |
| Open reduction K-wire (%) | 2 (3.4) | 3 (5.6) |
| External fixation (%) | 0 (0) | 0 (0) |
| **Repair of internal structures** | | |
| Suture repair of internal structures (%) | 25 (42.4) | 27 (49.1) |
| *Antimicrobial sutures* (%) | 11 (18.6) | 0 (0) |
| *Standard sutures* (%) | 14 (23.7) | 27 (100) |
| **Repair of skin** | | |
| Suture repair of skin (%) | 59 (100) | 54 (98.2) |
| *Antimicrobial sutures* (%) | 49 (83.0) | 1 (1.8) |
| *Standard sutures* (%) | 8 (23.7) | 52 (95.0) |
| **Wound dressing** | | |
| Standard non-adherent (%) | 46 (85.7) | 49 (92.5) |
| Antimicrobial (%) | 5 (8.9) | 1 (1.9) |
| Other (%) | 3 (5.4) | 3 (5.7) |
| **Splint** | | |
| Plaster of paris cast (%) | 26 (44) | 22 (40) |
| Bandage (%) | 0 (0) | 2 (3.6) |
| Zimmer splint (%) | 2 (3.3) | 3 (5.4) |
| Other (%) | 1 (1.7) | 0 (0) |
| None (%) | 30 (53.6) | 0 (0) |
| **Sling** | | |
| High-arm sling (%) | 27 (45.8) | 21 (38.2) |
| Other (%) | 18 (30.5) | 21 (38.2) |
| None (%) | 14 (23.7) | 13 (23.6) |

CT – core trainee SHO – senior house officer ANP – advanced nurse practitioner MOPS – minor operations

ED – emergency department GA – general anaesthetic LA – local anaesthetic MUA – manipulation under anaesthesia

## Table 11. Antibiotic treatment

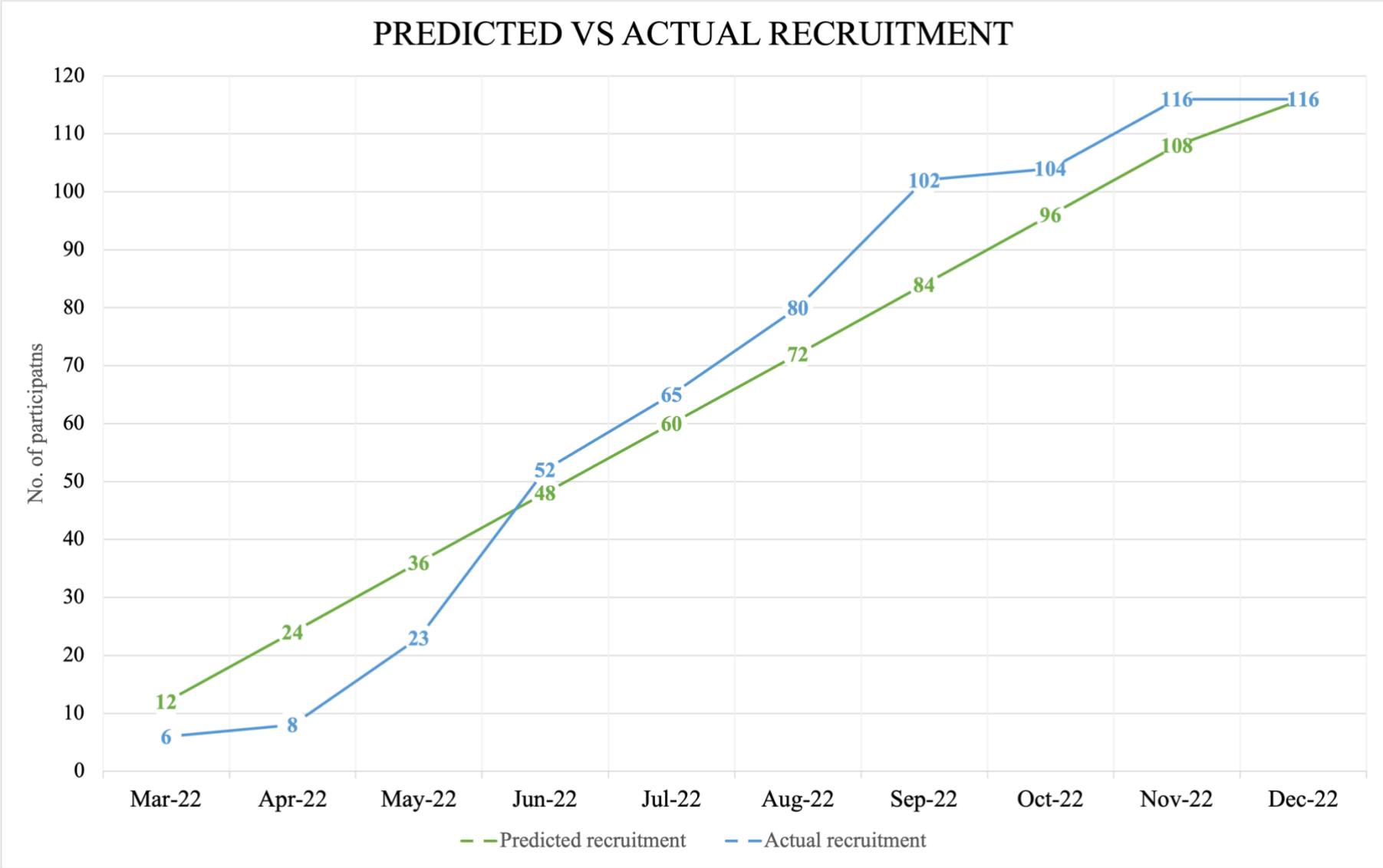
| | Antimicrobial sutures (%) | Standard sutures (%) |
|---|---|---|
| | n=60 | n=56 |
| **Emergency Department antibiotics** | | |
| Yes (%) | 25 (41.7) | 25 (45.5) |
| *Co-amoxiclav* (%) | 21 (35.0) | 23 (41.0) |
| *Flucloxacillin* (%) | 2 (3.3) | 1 (1.8) |
| *Clindamycin* (%) | 0 (0) | 0 (0) |
| *Other* (%) | 1 (1.6) | 0 (0) |
| No (%) | 34 (56.7) | 29 (52.7) |
| Unknown (%) | 1 (1.6) | 1 (1.8) |
| **Hand trauma clinic antibiotics** | | |
| Yes (%) | 11 (18.3) | 8 (14.3) |
| *Co-amoxiclav* (%) | 9 (15.0) | 7 (12.5) |
| *Flucloxacillin* (%) | 1 (1.6) | 1 (1.8) |
| *Clindamycin* (%) | 0 (0) | 0 (0) |
| *Other* (%) | 1 (1.6) | 0 (0) |
| No (%) | 48 (80.0) | 45 (80.3) |
| Unknown (%) | 0 (0) | 2 (3.6) |
| **Induction antibiotics** | | |
| Yes (%) | 21 (35.6) | 19 (34.5) |
| *Co-amoxiclav* (%) | 6 (10.2) | 5 (9.0 |
| *Flucloxacillin* (%) | 8 (13.6) | 7 (12.7) |
| *Other* (%) | 7 (11.9) | 7 (12.7) |
| No (%) | 31 (52.5) | 35 (63.6) |
| Unknown (%) | 7 (11.9) | 1 (1.8) |
| **Post-operative antibiotics** | | |
| Yes (%) | 19 (17.5) | 9 (16.4) |
| *Co-amoxiclav* (%) | 8 (13.6) | 8 (14.5) |
| *Flucloxacillin* (%) | 0 (0) | 1 (1.8) |
| *Other* (%) | 1 (1.6) | 0 (0) |
| No - already prescribed (%) | 23 (40.4) | 20 (36.4) |
| No - not indicated (%) | 24 (42.1) | 26 (47.3) |
| **Received prophylactic antibiotics** (%) | 36 (60.0) | 32 (58.2) |
| **Received induction antibiotics only** (%) | 20 (33.3) | 19 (33.9) |
| **Received antibiotics** (%) | 56 (93.3) | 51 (91.1) |

## 6.5.2 Feasibility outcomes

### 6.5.2.1 Recruitment (Table 12. Feasibility outcomes)

In total, 227 patients were screened for eligibility. Of these, 116 (51.1%, CI[44.4 – 57.8] were recruited and randomised over seven months and 23 days (237 days), equating to one randomisation every two days (Figure 15. Recruitment graph). Screening varied by site: 130 vs. 64 vs. 33, with a mean total screening of 75.7 (CI[69.2 – 82.2]) patients per site. Recruitment and randomisation also varied by site: 67 vs. 26 vs. 23, with a mean total recruitment of 38.7 (CI[34.2 – 43.2]) participants per site. Of 227 screened, 202 (89.5%, CI[84.2 – 92.7]) were potentially eligible for inclusion. Of these, 137 (67.8%, CI[60.9 – 74.2]) patients were approached for recruitment with 116 (84.7%, CI[77.5 – 90.3] being recruited into the trial. Participants were recruited by research nurses, consultants and trainees at all three sites. Each site had a designated PI and at least one NIHR Associate PI. The PIs were all consultant hand surgeons. Two NIHR Associate PIs were consultants at one site, one was a trainee and one advanced clinical practitioner.

**Figure 15. Recruitment graph**



#### 6.5.2.2 Compliance

Baseline data collection was completed for 114 participants (98.3%, CI[39.9 – 99.8]). Pre- and post-injury PROMs were completed by 112 participants (96.6%, CI[31.4 – 99.1]). Operative data was completed for 114 participants (98.3%, CI[39.9 – 99.8]). Almost all participants received their assigned intervention, with one cross-over from standard sutures to antimicrobial. Three patients were withdrawn (2.6%, CI[0.5 – 7.4]), two as sutures were not used in surgery and one underwent an elective operation (carpal tunnel decompression). There were four complications reported by sites: three incidences of SSI (2.7%, CI[0.5 – 7.6]) and one of wound dehiscence (0.9%, CI[0.0 – 4.7]). There was one SAE and no deaths. The SAE related to a participant who sustained a secondary injury from their wound dressing becoming caught in machinery and resulting in a digital amputation.

#### 6.5.2.3 Retention

At 30 days, 65 participants (57.5%, CI[47.9 – 66.8]) completed PROMs, including the BWHQ, PEM, PROMIS UE and EQ5D5L. If participants did complete their PROMs, then they completed all questionnaires. At 90 days, 59 participants (52.2%, CI[42.6 – 61.7] had completed PROMs. At six months and final follow-up, 51 participants (45.1%, CI[35.8 – 54.8) had responded. Follow-up varied across sites at 30 days, where completion rates were 34.6% vs. 59.1% vs. 66.7%. At 90 days there was less variation: 50.0% vs. 52.3% vs. 54.6%. By six months, completion was similar across sites at 42.3% vs. 46.1% vs. 46.5%.

## Table 12. Feasibility outcomes

| | | n | % | CI lower | CI upper |
|---|---|---|---|---|---|
| **Screened** | | 227 | 100 | – | – |
| **Randomised** | | 116 | 51.1 | 44.4 | 57.8 |
| **Baseline data** | | 114 | 98.3 | 39.9 | 99.8 |
| **Pre-injury PROMs** | | 112 | 96.6 | 31.4 | 99.1 |
| **Post-injury PROMs** | | 112 | 96.6 | 31.4 | 99.1 |
| **Operation data** | | 114 | 98.3 | 39.9 | 99.8 |
| | | | | | |
| **BWHQ** | *30 days* | 65 | 57.5 | 47.9 | 66.8 |
| | *90 days* | 59 | 52.2 | 42.6 | 61.7 |
| | | | | | |
| **Hand function PROMs** | *30 days* | 65 | 57.5 | 47.9 | 66.8 |
| | *90 days* | 59 | 52.2 | 42.6 | 61.7 |
| | *6 months* | 51 | 45.1 | 35.8 | 54.8 |
| | | | | | |
| **Complications** | | 4 | 3.5 | 1.0 | 8.8 |
| **Wound infection** | | 3 | 2.7 | 0.5 | 7.6 |
| **Wound dehiscence** | | 1 | 0.9 | 0.2 | 4.8 |

## 6.5.3 Full trial outcomes

### 6.5.3.1 Surgical site infection (Table 13. Full trial outcomes – surgical site infection)

At 30 days, the mean (SD, CIs) BWHQ score was 6.4 (5.4, CI[4.5 – 8.3]) in the intervention group compared to 5.0 (3.7, CI[3.2 – 6.7]) in the control group. Using a conservative threshold score of 8 points to determine presence of SSI, eight participants (22.9%, CI[10.8 – 41.2]) of those in the intervention group met this score compared to seven participants (22.6%, CI[9.6 – 41.1]) in the control group. At 90 days, the intervention group had a BWHQ score of 4.6 (CI[3.2 – 6]) and the control group a score of 3.4 (CI[2.2 – 4.6]). According to the BWHQ scores (8 or more indicating SSI), eight participants (25.0%, CI[11.5 – 43.4]) developed SSI in the intervention group, compared to just two in the control group (7.4%, CI[0.9 – 24.3]).

At 30 days, seven participants in the intervention group required treatment for SSI (20.6%, CI[8.7 – 37.9]), of which four required antibiotics alone and five required surgical intervention. In the control group, eight participants required treatment for SSI (25.8%, CI[11.9 – 44.6]), four with antibiotics alone and six requiring surgery. By 90 days, ten participants required treatment for SSI in the intervention group (31.3%, CI[16.1 – 50.0]), of which eight required surgical intervention. Only two required treatment in the control group (7.4%, CI[0.9 – 24.3]). There was no signal of a beneficial effect of antimicrobial sutures in terms of SSI, with poorer BWHQ scores in the intervention group and higher proportions of participants who required treatment for SSI.

### 6.5.3.2 Hand function, HRQoL and Employment (Table 14. Full trial outcomes – hand function and HRQoL)

Similar trends were seen in the PEM and PROMIS UE scores across the study (Figure 16a. PEM scores at follow-up time points, Figure 16b. PROMIS UE scores at

follow-up time points). Participants in both groups experienced worsening scores from pre-injury to post-injury time points, with subsequent improvement in scores up to final follow-up at six months. The EQ5D5L scores followed a similar, but less marked pattern, with an intial drop followed by recovery over the study period (Figure 16c. EQ5D5L VAS scores at follow-up time points). By final follow-up, scores across all three measures had not reach pre-injury levels across all outcome measures. There were more self-reported SSIs in the antimicrobial sutures group, paralleled by slightly worse PROMIS UE (48.9 vs. 44) and EQ5D5L VAS scores (77.5 vs. 81.8) at 90 days compared to the control group. The average time taken off work was 20.6 days in the antimicrobial sutures group vs.16.5 days in the standard sutures group. A small proportion in both groups had to change their type of work as a result of their injury (11.5%, antimicrobial vs. 8.0%, standard). Similarly to SSI, there was no evidence of beneficial effect in the antimicrobial group, with generally poorer scores across outcome measures.

#### 6.5.3.3 Harms

No harms in either group arose as a result of treatment allocation.

## Table 13. Full trial outcomes – surgical site infection

| | Antimicrobial sutures | | | | Standard sutures | | | |
|---|---|---|---|---|---|---|---|---|
| **30 day** | **n=34** | | | | **n=31** | | | |
| | ***Mean*** | ***SD*** | ***CI lower*** | ***CI upper*** | ***Mean*** | ***SD*** | ***CI lower*** | ***CI upper*** |
| BWHQ Score | 6.4 | 5.4 | 4.5 | 8.3 | 5.0 | 3.7 | 3.2 | 6.7 |
| | ***n*** | ***%*** | ***CI lower*** | ***CI upper*** | ***n*** | ***%*** | ***CI lower*** | ***CI upper*** |
| BWHQ SSI | 8 | 22.9 | 10.8 | 41.2 | 7 | 22.6 | 9.6 | 41.1 |
| Treated for SSI | 7 | 20.6 | 8.7 | 37.9 | 8 | 25.8 | 11.9 | 44.6 |
| Required antibiotics (%) | 4 | 11.4 | 3.3 | 27.5 | 4 | 12.9 | 3.6 | 29.8 |
| Required antibiotics +/- surgery (%) | 5 | 14.7 | 4.9 | 31.1 | 6 | 19.4 | 7.4 | 37.5 |
| **90 Day** | **n=32** | | | | **n=27** | | | |
| | ***Mean*** | ***SD*** | ***CI lower*** | ***CI upper*** | ***Mean*** | ***SD*** | ***CI lower*** | ***CI upper*** |
| BWHQ Score | 4.6 | 3.9 | 3.2 | 6 | 3.4 | 3.0 | 2.2 | 4.6 |
| | ***n*** | ***%*** | ***CI lower*** | ***CI upper*** | ***n*** | ***%*** | ***CI lower*** | ***CI upper*** |
| BWHQ SSI (%) | 8 | 25 | 11.5 | 43.4 | 2 | 7.4 | 0.9 | 24.3 |
| Treated for SSI (%) | 10 | 31.3 | 16.1 | 50 | 2 | 7.4 | 0.9 | 24.3 |
| Required antibiotics (%) | 5 | 15.6 | 5.3 | 32.8 | 1 | 3.7 | 0.9 | 18.7 |
| Required antibiotics +/- surgery (%) | 8 | 25 | 11.5 | 43.4 | 2 | 7.4 | 0.9 | 24.3 |

## Table 14. Full trial outcomes – hand function and HRQoL

| | Antimicrobial sutures | | | | Standard sutures | | | |
|---|---|---|---|---|---|---|---|---|
| | n=60 | | | | n-56 | | | |
| | | SD | 95% CI L | 95% CI U | | SD | 95% CI L | 95% CI U |
| **Pre-injury** | n=58 | | | | n=54 | | | |
| PEM | 12.4 | 3.6 | 11.5 | 13.5 | 13.4 | 7.1 | 11.5 | 15.3 |
| PROMIS UE | 57.3 | 5.6 | 55.8 | 58.8 | 56.1 | 5.4 | 54.6 | 57.6 |
| EQ 5D 5L index | 0.9 | 0.1 | 0.9 | 0.9 | 0.9 | 0.2 | 0.9 | 1 |
| EQ 5D 5L LSS | 5.8 | 1.8 | 5.3 | 6.3 | 6.2 | 2.1 | 5.6 | 6.8 |
| EQ 5D 5L VAS | 83 | 15.4 | 82 | 90.1 | 83.9 | 12.4 | 80.5 | 87.3 |
| **Post-injury** | n=57 | | | | n=55 | | | |
| PEM | 49 | 13.2 | 45.5 | 52.5 | 46.3 | 16.2 | 41.9 | 50.7 |
| PROMIS UE | 31.3 | 2.7 | 30.6 | 32 | 31.2 | 2.8 | 30.4 | 32 |
| EQ 5D 5L index | 0.6 | 0.2 | 0.6 | 0.7 | 0.6 | 0.2 | 0.6 | 0.7 |
| EQ 5D 5L LSS | 10.6 | 3.1 | 9.8 | 11.4 | 10.6 | 2.8 | 9.8 | 11.4 |
| EQ 5D 5L VAS | 66.4 | 19.2 | 61.3 | 71.5 | 69.6 | 18.3 | 64.7 | 74.6 |
| **30 days** | n=34 | | | | n=31 | | | |
| PEM | 34.1 | 12.4 | 29.8 | 38.43 | 31.7 | 13.8 | 26.6 | 36.8 |
| PROMIS UE | 38.3 | 2.9 | 37.2 | 39.3 | 38.2 | 3 | 37.1 | 39.3 |
| EQ 5D 5L index | 0.7 | 0.2 | 0.6 | 0.8 | 0.7 | 0.2 | 0.6 | 0.8 |
| EQ 5D 5L LSS | 8.8 | 3 | 7.8 | 9.8 | 8.4 | 2.7 | 7.4 | 9.4 |
| EQ 5D 5L VAS | 74.1 | 16.2 | 68.5 | 79.8 | 74.7 | 18.1 | 68.1 | 81.3 |
| **90 days** | n=32 | | | | n=27 | | | |
| PEM | 24.3 | 10 | 20.7 | 27.9 | 26.7 | 14.2 | 21.1 | 32.3 |
| PROMIS UE | 48.9 | 4.2 | 47.4 | 50.4 | 44 | 3.6 | 42.6 | 45.4 |
| EQ 5D 5L index | 0.8 | 0.1 | 0.8 | 0.8 | 0.8 | 0.2 | 0.7 | 0.9 |
| EQ 5D 5L LSS | 6.6 | 1.4 | 6.1 | 7.1 | 7.5 | 2.2 | 6.6 | 8.4 |
| EQ 5D 5L VAS | 77.5 | 18.3 | 70.9 | 84.1 | 81.8 | 15.4 | 75.7 | 87.9 |
| **6 months** | n=26 | | | | n=25 | | | |
| PEM | 21.4 | 10.5 | 17.2 | 25.6 | 24.8 | 15.6 | 18.4 | 31.2 |
| PROMIS UE | 52.0 | 10.5 | 47.8 | 56.2 | 48.2 | 11.4 | 43.5 | 52.9 |
| EQ 5D 5L index | 0.9 | 0.1 | 0.8 | 0.9 | 0.8 | 0.2 | 0.7 | 0.9 |
| EQ 5D 5L LSS | 6.2 | 1.2 | 5.7 | 6.7 | 7.1 | 2.3 | 6.2 | 8.1 |
| EQ 5D 5L VAS | 79.9 | 13.8 | 74.3 | 85.5 | 80.8 | 14.8 | 74.7 | 86.9 |
| Days off work | 20.6 | 29.4 | 8.7 | 32.5 | 16.5 | 30.5 | 3.9 | 29.1 |
| Changed employment | 3 | 11.5 | 2.5 | 30.2 | 2 | 8.0 | 1.0 | 26.0 |

## Figure 16. PROM scores at follow-up time points

Figure 16a. PEM scores at follow-up time points

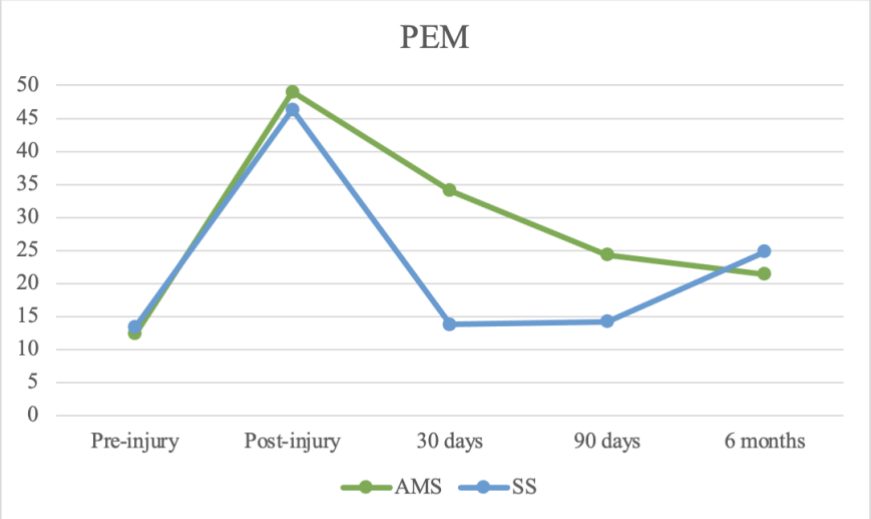



Figure 16b. PROMIS UE scores at follow-up time points

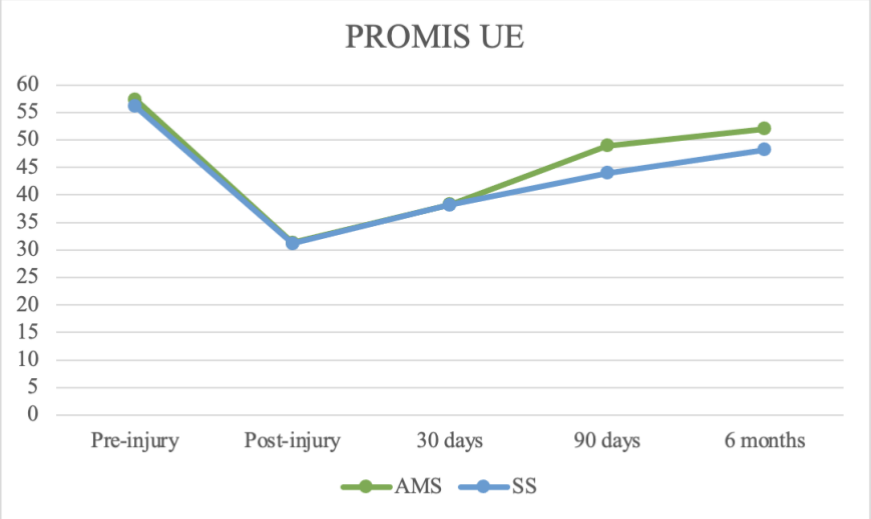
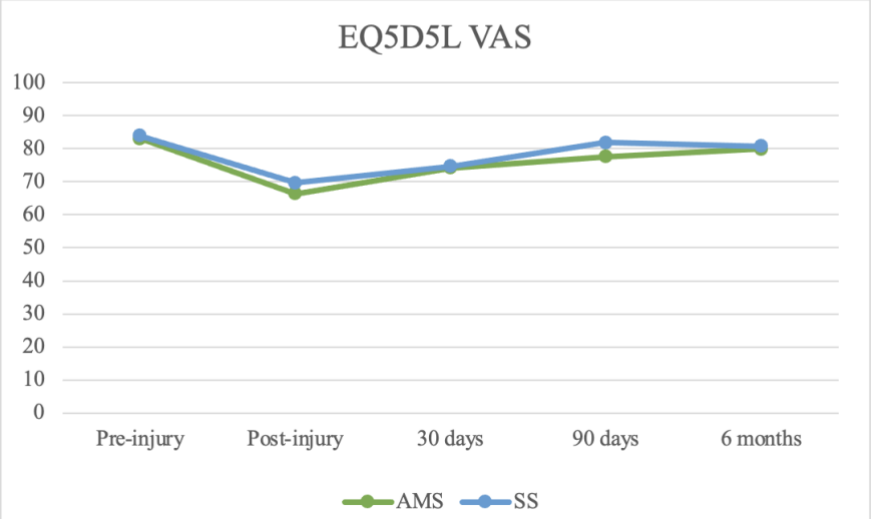



Figure 16c. EQ5D5L VAS scores at follow-up time points




AMS – antimicrobial sutures SS – standard sutures

## 6.6 Discussion

This feasibility study has demonstrated that the recruitment and randomisation of hand trauma patients to antimicrobial sutures is expeditious and achievable. Despite delays in site set-up resulting from the COVID-19 pandemic, we were able to recruit our target number within eight months, closing the study to recruitment earlier than anticipated. This finding is particularly critical in hand trauma trials, where two NIHR HTA RCTs have recently been closed due to slow recruitment as part of the 'Future of UK Clinical Research Delivery: 2022 to 2025 implementation plan'.(222–224)

Recruitment rates varied across sites. The highest number of randomisations took place in a site with a high level of trainee and research nurse engagement. Trial activity, including recruitment to HAWAII was managed via WhatsApp, an established methodology in trial co-ordination, between consultants, research nurses and trainees to ensure potentially eligible patients were approached as often as possible.(225) Recruitment was relatively less rapid in the two other departments, where the clinical departments were more fragmented across sites, there was a less apparent clinical research culture, with less clinician buy-in and reduced research nurse availability. For example, at one of the lower recruiting sites, hand trauma was managed across two separate hospital sites and by two different clinical departments. This complicated the patient pathway and made it more difficult for research nurses and trainees to approach potentially eligible participants. The process was improved during the trial by the appointment of a dedicated academic trainee who recruited at one site, while the research nurses covered the other site. The online systems for baseline data collection and randomisation worked well and there were no system failures throughout the study. We had very high completion rates for baseline and operative data collection across all sites.

Intervention fidelity and adherence were excellent. One participant in the control group mistakenly received antimicrobial sutures. In the intervention group, all participants received antimicrobial sutures for either skin closure, structural repair or both. There were no issues of equipoise and no occurrences of unblinding of participants. There were six protocol deviations in total, of which one was the aforementioned use of antimicrobial sutures in a participant allocated to standard, one pertained to incorrect data entry and the remainder related to pre-injury PROMs being completed after surgery.

Retention was the key issue in terms of feasibility in this study. At the primary analysis for a potential full trial, 30 days post operation, we had only 57.5% completion of remote electronic PROMs by participants. This dropped to 52.2% by 90 days and 45.1% by six months. While this is concerning and falls well below the target of >90% or more, it is worth noting that the HAWAII feasibility study was run outside of a dedicated surgical trials unit and without the full support that this infrastructure brings. Participants were emailed or texted (SMS) at the follow-up time points with automated reminders every 48 hours up to four days after initial contact. After this and when available, the CI attempted contact with non-responders via email or phone. Using this strategy alone, i.e. primarily automated, electronic, remote follow-up, we were able to achieve nearly 60% retention at 30 days. With the full backing of a surgical trials unit, dedicated staff to chase participants routinely, I would be optimistic that an additional 20% could be achieved. Hand trauma affects a young, predominantly male population and therefore it is realistic to expect difficulties in following up this hard-to-reach population.(226,227) As such, a follow-up rate of 80% is potentially both achievable and useful in terms of establishing evidence of effectiveness, especially considering the high numbers of SSI that we have found.

In terms of progression to a full definitive trial, parameters for screening, recruitment and retention were set in the protocol stage.(228,229) The red criteria for

screening and recruitment were met (screen <120 patients per month, recruit <24 participants per month). The amber criterion for retention was met (>50% retention). The green criterion for surgeon compliance was met (>80% compliance). In hindsight, this demonstrates that progression criteria set on routine clinical audit data, rather than previous RCT activity, are not reliable sources to generate targets.

Screening and recruitment were successful in terms of feasibility, whereas retention was the major issue we encountered in this study. Brueton et al published best practice guidance for improving retention in RCTs in 2017.(230) This guidance was focused on postal questionnaire responses rather than the contemporary electronic methods employed in HAWAII, although many strategies are applicable. Monetary incentivisation is identified as a potentially useful strategy to improve questionnaire response, supported by reliable evidence.(231) This could certainly be incorporated into a definitive RCT in hand trauma and may be beneficial, considering most common hand trauma occurs in the most deprived sections of society (see Chapter 4). An incentive valued at £5–£20 was recommended.(230) There was dissent in in the evidence and qualitative analysis regarding enhanced communication, including repeated reminders. We employed a system of electronic reminders in HAWAII and would do so again, based on possible gain without evidence of issues. We would also deploy a more comprehensive system of reminders, including phone calls, emails and texts depending on participant preference. The use of validated and efficient questionnaires was recommended by evidence and workshop discussion. We used contemporary PROMs, delivered electronically. For PROMIS UE, we used the CAT version to improve efficiency and reduce questionnaire burden. Since this study, I have been involved in research to develop a CAT for PEM, which could be incorporated into a future definitive study to potentially improve responses.(232) A combination of strategies, co-designed with patient and public involvement

representatives, must be employed in future trials of antimicrobials in hand trauma. This is an area for future work.

Despite poor retention, useful follow-up data was attained that can inform a definitive study. All participants who responded completed all questionnaires sent to them, resulting in complete data for those that did respond. Three wound infections were reported by sites, all occurring in participants allocated to standard sutures. One occurred in a wound distant to the trial wound but on the same limb, The other two were superficial SSIs requiring oral antibiotics only. Using only this data, the wound infection risk in this study would be approximately 3%, in line with the findings from HES in Chapter 4. At 30 days, 65 participants had completed the BWHQ. This includes self-reporting of interventions to treat SSI and so gives a different angle to the site reported figures, likely including those that had been managed in primary care (Chapter 3). Across both groups, 15 participants reported having received an intervention for SSI by 30 days: 23.1%. Of these, 11 required a surgical intervention, whist eight required antibiotics alone. By 90 days, 59 had completed the BWHQ and 12 had reported receiving interventions for SSI, 20.3%, ten of whom underwent a physical intervention and six had oral antibiotics. We know from Chapter 2 that RCTs report higher incidences of SSI compared to other study designs, as seen here also. The site reported figures are similar to those seen in HES in Chapter 3, while the participant-reported figures are even higher than in CPRD.

The use of adjunctive antimicrobial interventions, including antibiotics, provides useful feasibility data for future studies in this area. A meta-analysis of antibiotics in hand trauma found no evidence of effect in terms of reducing SSI, although this review was limited by low quality primary data.(35) Despite the findings of this review, and the previous lack of data on the baseline risk of SSI, systemic antibiotics are routinely used in hand trauma. In the present study, over 90% of participants received systemic antibiotics,

with 40% receiving antibiotic prophylaxis in the ED. Considering the lack of evidence supporting the effectiveness of this strategy and the commonality of hand trauma, this raises concerns regarding antibiotic stewardship and resistance.(36,37,47,233) The use of topical antimicrobial prophylaxis was comparatively rare, with only six participants receiving antimicrobial dressings. As there is no evidence to support the use of antimicrobial dressings in hand trauma, this is somewhat reassuring.(234) Promisingly, the most commonly used surgical preparatory fluid was alcoholic chlorhexidine. Recent research has identified this as the most effective fluid for preventing SSI in hand surgery, although the data pertaining to hand trauma was inconclusive.(44,45,235) Further work is needed to establish evidence based guidelines that can be successfully implemented into clinical practice.

In terms of improving efficiency of a future definitive trial of antimicrobials in hand trauma surgery, the use of linked real world data, including the data types described in Chapter 2 and Chapter 3, could be advantageous.(236) A 2022 systematic review described datal-linked RCTs in surgery, with two of the 19 included RCTs using data-linkage for outcome data collection.(237) I have used antibiotic prescription as a surrogate for superficial SSI (CPRD) and re-admission/re-operation for infection of the hand/wrist as a surrogate for deep and organ/space SSI (HES APC). It is therefore reasonable to consider using these surrogates in a future data-linked trial. To improve the reliability of this proposed data-link method, these surrogates could be validated in a proportion of patients during the pilot stage of a definitive study. As with the limitations of the analyses in this thesis, the fidelity of the data to which the trial is linked must be considered.(236)

## 6.7 Conclusions

A definitive RCT of antimicrobial sutures in hand trauma surgery may be feasible, as long as retention of study participants to the primary endpoint can be attained. Retention strategies including monetary incentives, efficient PROMs, real world data linkage and enhanced participant communications could be utilised. Data from this study can be used to inform future trials of antimicrobial interventions in hand trauma populations.

# 7 RESEARCH SUMMARY

# 7.1 Understanding SSI following Hand Trauma Surgery

## 7.1.1 SSI following hand trauma surgery – overall risk

In the introduction to this thesis, I outlined the lack of reliable data informing our understanding of the risk of SSI following surgical intervention for hand trauma. To summarise the pre-existing literature and synthesise the published data, I performed a systematic review of all primary studies evaluating surgical interventions for hand trauma, that reported infection as a post-operative outcome. I compiled 201 studies in total, including 315,618 hand trauma patients. Meta-analysis of SSI incidence across all 201 studies resulted in an overall SSI risk of 5.0%. A higher risk was seen in prospective RCTs 10.1%, whilst cohort studies had the lowest risk of 1.5%. SSI risk varied across clinical subgroups, with the highest risk of SSI in K-wire and external fixation of fractures, and the lowest in ORIF. The remaining subgroups had SSI risks proximate to the overall risk of 5%. The reporting of SSI was poor across almost all studies. There was scant use of established classification systems of SSI, with few studies stating how post-operative infection was diagnosed, when it occurred or how it was treated. This context is important to consider when interpreting the statistics generated in this meta-analysis. The second important point is that we cannot establish the type of SSI from this pooled data, which is crucial from a clinical and research point of view.

## 7.1.2 SSI following hand trauma surgery – superficial SSI

The CDC define superficial SSI as occurring within 30 days (or 90 days if a surgical implant is used) and involves only skin and subcutaneous tissue of the incision.(132) The patient must have met at least one of these criteria: pus from the superficial wound, the superficial wound deliberately opened by a clinician, a microbiological diagnosis and/or symptoms of superficial SSI (skin redness, pain,

localised swelling etc.).(132) Superficial SSI is typically treated with oral antibiotics, the prescription of which has been routinely used as a surrogate for SSI diagnosis in previous research. Consequently, prescription of SSI-appropriate oral antibiotics can be used as a surrogate for the CDC definition of superficial SSI. I retrieved 3,088 primary care records of patients who had undergone surgery for hand trauma via the CPRD Gold platform. I analysed baseline characteristics and analysed post-operative prescription records. By 30 days, 6.2% of patients had been prescribed antibiotics that were clinically appropriate for SSI treatment. By 90 days this figure had risen to 14.4%. These figures add granularity to the overall SSI risk statistics, indicating that the risk of superficial SSI is 6.2% by 30 days and 14.4% by 90 days.

### 7.1.3 SSI following hand trauma surgery – deep and organ/space SSI

Deep incisional SSI is defined by the CDC as SSI involving deep soft tissues of the incision (for example, fascial and muscle layers) AND at least one of the following: pus from the deep incision, deliberately opened deep incision (or one that dehisces), microbiological confirmation and/or patient signs, such as fever and pain, or signs of abscess.(132) Organ/space infection is generally as per the above but the site of infection is deep to the deep incision and must involve specific anatomical areas or tissues.(132) In the hand and wrist this equates to osteomyelitis and joint infection/septic arthritis. I acquired a bespoke, individual patient dataset from the HES APC platform to explore the risk of re-admission and re-operation for SSI requiring hospital treatment, osteomyelitis and septic arthritis following surgery for four common hand injuries: hand fracture, flexor tendon injury, extensor tendon injury and injury of the hand and wrist nerves. SSI requiring admission indicates a deep or severe SSI that cannot be managed with oral antibiotics alone, thus mapping to the CDC definition for deep SSI. Osteomyelitis and septic arthritis

directly map to the CDC definition for organ/space SSI. Across all 280,747 admissions for hand trauma surgery, there were 4013 post-operative infections, including SSI, septic arthritis and osteomyelitis, requiring intervention within secondary care by 30 days and 5563 by 90 days. This implies a risk of deep or joint space SSI of 1.4% by 30 days and 2% by 90 days following surgery for common hand trauma.

### 7.1.4 Conclusions

SSI following hand surgery is a significant concern, with a considerable proportion of patients experiencing both superficial and deep/organ-space infections within 30 and 90 days post-surgery. The available evidence suggests that the incidence of SSI after hand trauma surgery is relatively high, with better quality studies reporting even higher risks. The risk of superficial infections is higher than that of deep/organ-space infections, with the former often treated with antibiotics and the latter requiring readmission to the hospital.

## 7.2 Preventing SSI following Hand Trauma Surgery

### 7.2.1 Developing an RCT of antimicrobial sutures in hand trauma surgery

Having established the risk of SSI in hand trauma surgery, identifying that the overall risk is in line with NICE estimates for all surgery and higher for superficial SSIs, I proceeded to explore evidence for interventions to moderate this risk. Antimicrobial sutures are available on most operating room shelves in the NHS and there is some evidence that they are cost-effective in terms of reducing SSI in major abdominal surgery. NICE guidelines state that surgeons should ‘consider using antimicrobial triclosan-coated sutures, especially for paediatric surgery, to reduce the risk of surgical site infection’.(53) There is no data on the use of antimicrobial sutures in hand trauma, a profoundly different

surgical population from those in which these sutures had been tested. As such, I developed a protocol for a multi-centre feasibility RCT of antimicrobial sutures versus standard sutures in hand trauma surgery.(220) I aimed to randomise 116 participants who required surgery for any kind of hand trauma that used sutures across three sites. The intervention was antimicrobial sutures and the control, standard sutures. Assessing feasibility outcomes were the primary focus of the study: screening, recruitment, randomisation, surgeon compliance and retention. I also measured occurrence of SSI, hand function and HRQoL, plus changes in employment across three time points: 30 days, 90 days and six months. The protocol was developed in collaboration with the Oxford Trauma Research Group, with support from a senior trial manager, programmer and senior researchers. The study was approved by the National Ethics Committee in February 2022, was registered on the ISRCTN and was ultimately published open access.

### 7.2.2 The HAWAII Feasibility Study

On the 10th March 2022, I opened the HAWAII Feasibility Study to recruitment at the first site, with the two other sites opening subsequently. By the 2nd November 2022 we had recruited 116 participants, equating to one randomisation every 48 hours. Of these, 60 received antimicrobial sutures and 56 received standard sutures. In total, 227 potentially eligible participants were screened. Of those screened, 202 were potentially eligible for inclusion. Of these, 137 (67.8%) patients were approached for recruitment with 116 (84.7%) being recruited into the trial. Screening and recruitment data shows that the study was acceptable to both clinicians and patients. We encountered no issues of equipoise. Surgeon compliance was excellent, all participants in the intervention arm received antimicrobial sutures. One participant in the control group mistakenly received

antimicrobial sutures. In terms of trial delivery, a definitive study is eminently feasible based on this data.

Issues arose with follow-up, where only 57.5% of participants completed remote electronic follow-up questionnaires at the primary end-point of 30 days. This dropped to 52.% at 90 days and 45.1% at six months. This would severely impact the internal validity of a definitive trial, so steps must be taken to improve this. I outlined a number of strategies that I would employ in Chapter 6. Interestingly, I saw high numbers of self-reported SSI in both arms of this study. In both groups, over 20% of participants reported SSI by 30 days (n=8, intervention vs. n=7, control). By 90 days, a further eight patients had developed SSI in the intervention group, whilst just two had in the control group (n=2). Only three wound infections were reported by sites, just 2.7% of the study population. Use of antimicrobials, including antibiotics, was similar between the two groups and provides important feasibility data for future antimicrobial trials in hand trauma surgery.

## 7.3 Project Conclusions

I have synthesised the available evidence for the risk of SSI following surgery for hand trauma. The overall risk is 5%, in keeping with the upper limit of the NICE estimate. However, the risk of superficial SSI is substantially higher and is at least 10%, whilst the risk of deep and organ/space SSI is lower at approximately 2%. In Chapter 2, we saw a 10% risk of SSI in RCTs, and this is also seen in the HAWAII feasibility study, although the incidence is even higher. RCTs will detect all types of SSI through their prospective design and rigorous data collection methods, hence identifying the superficial, deep and organ/space SSIs. Cohort studies based in secondary care are likely to only detect the deep

and organ/space SSIs, explaining the low summary risk for this study design in Chapter 2. This is also reflected in the site-reported SSIs in HAWAII.

Now we have established that SSI is an important and prevalent problem in hand trauma surgery, we must develop the evidence base for antimicrobial interventions. I have shown that a definitive randomised controlled trial of antimicrobial sutures in hand trauma surgery is feasible, as long as retention of study participants to the primary endpoint can be attained. The next steps include design and execution of multi-centre RCTs of antimicrobial interventions, targeted at common hand trauma conditions, co-designed with patient and public representatives and surgical trials units to maximise internal and external validity.

# 8 FUTURE WORK

# 8.1 Clinical trials in hand trauma and infection

## 8.1.1 HAWAII: Hand and Wrist Trauma – Antimicrobials and Infection

### 8.1.1.1 HAWAII Service Evaluation (HAWAII SE)

There are two principal issues arising from this thesis: 1. The risk of SSI in hand trauma is poorly defined in the literature but is likely to be high overall, although deep and organ/space SSI risk is relatively low. 2. There is no evidence for antimicrobial interventions, including antibiotics, in this population. I have generated feasibility data that can inform future RCTs of antimicrobial interventions in hand trauma surgery. Now, to better understand the types of antimicrobial interventions that are currently in use, I will perform an international service evaluation of hand trauma surgery, focused on pre-, intra- and post-operative antimicrobial use. I will run this through the national trainee collaborative network for hand and plastic surgery, the RSTN. We will recruit as many centres as possible using our existing global network and will employ a trainee collaborative research model to collect a comprehensive dataset. Data from this cross-sectional study can then be used to identify those antimicrobial interventions currently in use across hand trauma. This process will also develop a network of clinicians who will be engaged in future HAWAII studies, which will be essential for trial success. This service evaluation is also serving as a training opportunity for a junior doctor whom I am currently supervising. It will lead into an MSc project for this individual, for whom I plan to act as primary supervisor.

## 8.1.2 HAWAII: Systematic reviews and network meta-analyses

To explore the evidence of effectiveness for antimicrobial interventions in hand trauma surgery, I plan a programme of systematic reviews and meta-analyses (SRMAs).

#### 8.1.2.1 Antibiotics to prevent SSI in hand trauma surgery

The first systematic review will establish the evidence for peri-operative oral antibiotics in hand trauma surgery, with SSI as the primary outcome. A network meta-analysis is planned, with type and timing of antibiotic as the variables of interest. This project will involve formal training in network meta-analysis at the University of Oxford. For this review, I am supervising an AFP doctor on the NIHR Integrated Academic Training Programme. They will complete this work under my supervision as part of their academic blocks.

#### 8.1.2.2 Antimicrobial sutures to prevent SSI in surgery

The second SRMA is underway and again involves a group of trainees and senior clinicians I am leading. This is a Cochrane review of antimicrobial sutures across all surgical wounds. There is a pressing need for this review as both HAWAII and the aforementioned FALCON trial will be eligible for inclusion.(86) Both were not included in pre-existing reviews and NICE guidance. The results from this SRMA will provide contemporary evidence for antimicrobial sutures that will feed into future RCTs of antimicrobials in hand trauma. The protocol for this review is published in the Cochrane library.(238)

#### 8.1.2.3 Antimicrobial dressings in trauma surgery

Antimicrobial dressings are widely available on the shelves of NHS hospitals and are in use in hand trauma surgery, albeit in a minority of HAWAII participants. There may be a role of antimicrobial dressings across all traumatic wounds. The first step is to examine the existing evidence for their effectiveness through SRMA. Evidence pertaining to antimicrobial dressing use in hand trauma surgery will directly feed into future HAWAII trials, whilst non hand trauma data will be relevant to trials in other traumatic

injuries, such as the lower limb. For this review, I am supervising another AFP doctor on the NIHR Integrated Academic Training Pathway. They will complete this work under my supervision as part of their academic blocks.

### 8.1.3 The Definitive HAWAII Trial:

To definitively generate robust evidence for the use of antimicrobials in hand trauma surgery, I plan to design a multi-arm, multi-stage randomised study. The study PICO will be as follows:

#### 8.1.3.1 Participants

- Adults with traumatic soft-tissue injury to the hand and wrist

#### 8.1.3.2 Interventions and Comparator

- Alcoholic chlorhexidine surgical prep vs. aqueous chlorhexidine surgical prep
- Antimicrobial sutures vs. standard sutures
- Antimicrobial dressing vs. standard dressing
- Post-operative antibiotics vs. placebo

#### 8.1.3.3 Outcomes

- SSI at 30 days
- SSI at 90 days

This will enable me to answer multiple relevant questions within a single study, which although is ambitious, would be far more cost and time efficient than individual head to head trials. A similar study is currently underway in laparotomy wounds, proving that this is possible. The HAWAII SE will establish a strong network of trainees and consultants

who can act as NIHR associate PIs and Local PIs to facilitate this trial. Each intervention will have a robust SRMA underpinning its current evidence for effectiveness. To successfully deliver this trial, a multi-disciplinary trial team is needed, including statisticians, health economists, trialists, surgeons and PPI representatives. Collaboration with a surgical trials unit would be crucial. I would apply for funding via the NIHR HTA scheme once the preceding work streams had been completed.

### 8.1.4 HAWAII WIRE: Reducing infection in hand fracture fixation

In Chapter 2, high incidences of SSI were seen in K-wire fracture fixation and external fixation of fractures. The highest individual risk of osteomyelitis was also seen in this group, at 1% by 90 days. The high incidence seen in external fixation is logical considering this intervention is usually employed in severe open fractures. The figure for external fixation is also based on only nine studies. In contrast, the high incidence of SSI in K-wire fixation is based on meta-analysis of 44 studies including 5739 patients.

I have previously undertaken research on K-wire fixation of hand fractures, in particular the surgical technique employed to either bury the end of the wire following fracture fixation, or leave it exposed. Two meta-analyses, one in adults and one in paediatric upper extremity fractures, found similarly high incidences of SSI, especially in K-wires that were left exposed.(103,125) In the adult population, the risk of SSI with exposed wires was 13.5% compared to 6.1% in the buried group.(103) In the paediatric population, including lateral condyle humeral fractures only, the risk with exposed wires is 9.4% (n=138) compared to 5.4% (n=296) in the buried group.(125) All studies included in both meta-analyses were at high risk of bias, bar one.(98) Therefore, although a clear signal can be seen in terms of SSI risk between the two groups, the existing data are not sufficiently reliable to inform clinical practice. Further research is needed in this area.

Following these reviews, we performed a national survey of clinician practice and patient experience regarding the use of K-wires in hand fracture fixation. (239) The choice of whether to bury the wire ends or not was primarily based on the specialty and grade of the operating surgeon (plastic vs. orthopaedic). Those that buried wires did so due to perceived reduced risk of SSI. Those that preferred exposed wires stated that ease of removal swung their choice. Cost did not affect the decision, nor did patient preference. Hand therapists were primarily concerned about infection and patient-related outcomes. Patients were most concerned about wire-related problems and pain.

Building on the new data from Chapter 2 and Chapter 4, I now want to perform an RCT of buried versus exposed K-wires in hand and wrist fractures to determine the differences in SSI risk and associated costs. Burying K-wires requires an additional operative procedure to remove them but conveys a lower SSI risk. Exposed wires are quick and easy to remove in clinic, but have a high SSI risk. A formal randomised comparison across hand and wrist fractures with health economic analysis could definitively answer this question. I plan to apply for an NIHR Research for Patient Benefit grant in July 2023 as trainee chief investigator to fund an external pilot RCT with a view to continuing to a full multi-centre trial. This will involve collaboration with the Oxford Trauma and Surgical Intervention Trials Units, with formal health economic support. I intend to expand my own expertise in understanding cost-effectiveness by undertaking further training in the evaluation of cost-effectiveness of interventions as part of this work.

## 8.2 Hand trauma PPI network

PPI is essential to the design and delivery of research. HAWAII was co-designed with two PPI representatives and the research plans laid out above will continue to involve patients and the public. I am the current PPI lead for BSSH and plan to develop a Hand

Surgery PPI Network as part of my post-doctoral work strategy. Patients and members of the public can be recruited to the network via the national NIHR Be Part of Research infrastructure, as well as during routine clinical practice.(240) I will maintain the network database with administrative support via the BSSH. The key issue raised in the HAWAII feasibility study was retention. Once the network is active, I will invite PPI members to a focus group session to discuss retention strategies for future hand trauma trials. This will directly inform the design of the hand trauma trials going forwards. New research proposals which require PPI input will first be vetted by myself before being passed on to the network members if appropriate. This will provide a much needed portal for new hand surgery research to access PPI and ensure relevance to all stakeholders.

## 8.3 Summary of future work

My intention is to continue clinical academic activity as a post-doctoral researcher, whilst completing my training as a plastic and reconstructive surgeon. My focus is on developing and executing definitive RCTs in trauma and reconstruction, primarily of the hand and upper limb. The time I have spent on the work presented in this thesis has highlighted two RCTs that can definitively inform our practice in terms of reducing SSI following hand trauma surgery. The hand is integral to a person's quality of life and ability to function in society. It is therefore crucial that my planned future work has meaningful input from patients and the public. By developing a hand surgery PPI network, there will be new infrastructure to ensure this is both practical and efficient. I am building a team of likeminded clinical academics who are interested in trials in hand surgery, trauma and reconstruction. I intend on leading this team in developing evidence for hand surgery that will improve outcomes for patients, including reducing SSI.

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# 10 APPENDICES

## 10.1 Appendix 1. Search strategies

Search Name: Hand trauma SSI

Date Run: 16/08/2021 14:21:06

Comment:

| ID | Search | Hits |
|---|---|---|
| #1 | hand | 36217 |
| #2 | trauma2 | 0149 |
| #3 | injury5 | 3872 |
| #4 | infection | 98211 |
| #5 | #2 OR #3 | 66688 |
| #6 | #1 and #5 | 3624 |
| #7 | #4 and #6 | 857 |

**HDAS** Export **16 Aug 21 - 13:13**

**Strategy** 1063692/285 See full search strategy

| # | Database | Search term | Results |
|---|---|---|---|
| 285 | CINAHL | (infect*).ti,ab AND (((((hand*).ti,ab OR (finger*).ti,ab OR (thumb*).ti,ab OR (wrist*).ti,ab OR (phalang*).ti,ab OR (metacarpal*).ti,ab OR (carpal*).ti,ab OR (radius*).ti,ab OR (ulna*).ti,ab) AND ((nerve*).ti,ab OR (neuro*).ti,ab OR (vasc*).ti,ab OR (arter*).ti,ab OR (vessel*).ti,ab OR (tendon*).ti,ab OR (ligament*).ti,ab OR (joint*).ti,ab OR (capsul*).ti,ab OR (volar*).ti,ab OR (musc*).ti,ab)) AND ((trauma*).ti,ab OR (injur*).ti,ab OR (lacerat*).ti,ab OR (fracture*).ti,ab OR (crush*).ti,ab OR (wound*).ti,ab)) AND ((surg*).ti,ab OR (operati*).ti,ab OR (intervent*).ti,ab OR (procedur*).ti,ab OR (repair*).ti,ab OR (fix*).ti,ab OR (reconstruct*).ti,ab OR (debride*).ti,ab OR (closur*).ti,ab OR (dressing*).ti,ab)) | 490 |

**Contents** 50 of 490 results on CINAHL - (infect*).ti,ab AND (((((hand*).ti,ab OR (finger*).ti,ab OR (thumb*).ti,ab OR (wrist*).ti,ab OR (phalang*).ti,ab OR (metacarpal*).ti,ab OR (carpal*).ti,ab OR (radius*).ti,ab OR (ulna*).ti,ab) AND ((nerve*).ti,ab OR (neuro*).ti,ab OR (vasc*).ti,ab OR (arter*).ti,ab OR (vessel*).ti,ab OR (tendon*).ti,ab OR (ligament*).ti,ab OR (joint*).ti,ab OR (capsul*).ti,ab OR (volar*).ti,ab OR (musc*).ti,ab)) AND ((trauma*).ti,ab OR (injur*).ti,ab OR (lacerat*).ti,ab OR (fracture*).ti,ab OR (crush*).ti,ab OR (wound*).ti,ab)) AND ((surg*).ti,ab OR (operati*).ti,ab OR (intervent*).ti,ab OR (procedur*).ti,ab OR (repair*).ti,ab OR (fix*).ti,ab OR (reconstruct*).ti,ab OR (debride*).ti,ab OR (closur*).ti,ab OR (dressing*).ti,ab))

1. Allograft Interposition Bone Graft for First Metatarsal Phalangeal Arthrodesis: Salvage After Bone Loss and Shortening of the First Ray. Page 4

2. Clinical efficacy of closed reduction and percutaneous parallel K-wire interlocking fixation of first metacarpal base fracture. Page 4

3. A Practical Approach to the Management of Digital Ulcers in Patients With Systemic Sclerosis: A Narrative Review. Page 5

4. Inclusion of Olecranon Osteotomy With the Posterior Approach for Fixation of Distal Humerus Fractures (OTA/AO 13) Does Not Increase Surgical Complications. Page 6

5. Antegrade intramedullary fixation for adolescent fifth metacarpal neck fracture and its impact on epiphyseal growth. Page 7

6. Comparison of lateral entry and crossed entry pinning for pediatric supracondylar humeral fractures: a meta-analysis of randomized controlled trials. Page 7

7. Open total dislocation of ankle joint without fractures: A case report. Page 8

8. A review of the Turned-down Onto Pericapsular-tissue Hemisectioned Amputated Toe (TOPHAT) flap for wound coverage during ray amputations of the toes. Page 9

9. High Rates of Spacer Fracture in the Setting of Extended Trochanteric Osteotomy With a Specific Thin-Core Articulating Antibiotic Hip Spacer. Page 9

10. Technique and Outcomes of Hand-Assist Laparoscopic Continent Cutaneous Ileocecocystoplasty. Page 10

**HDAS** Export
**Search Strategy** MEDLINE MeSH SSI

**09 Feb 21 - 10:53**

**Strategy** 977736/60

See full search strategy

| # | Database | Search term | Results |
|---|---|---|---|
| 60 | Medline | ((exp "METACARPAL BONES"/ OR exp "FINGER PHALANGES"/ OR exp "CARPAL BONES"/ OR exp "HAND BONES"/ OR exp METACARPUS/ OR exp FINGERS/ OR exp HAND/ OR exp "METACARPOPHALANGEAL JOINT"/ OR exp "FINGER JOINT"/ OR exp "CARPOMETACARPAL JOINTS"/ OR exp "CARPAL JOINTS"/ OR exp "HAND JOINTS"/ OR exp WRIST/ OR exp "WRIST JOINT"/) AND (exp "FINGER INJURIES"/ OR exp "HAND INJURIES"/ OR exp "WRIST INJURIES"/ OR exp "ACCIDENTAL INJURIES"/ OR exp "WOUNDS AND INJURIES"/ OR exp "WOUNDS, PENETRATING"/ OR exp "WOUNDS, NONPENETRATING"/ OR exp "VASCULAR SYSTEM INJURIES"/ OR exp "TRAUMA, NERVOUS SYSTEM"/ OR exp "TENDON INJURIES"/ OR exp "SURGICAL WOUND"/ OR exp "SOFT TISSUE INJURIES"/ OR exp REINJURIES/ OR exp "MULTIPLE TRAUMA"/ OR exp LACERATIONS/ OR exp "JOINT DISLOCATIONS"/ OR exp "HAND INJURIES"/ OR exp "FRACTURES, CARTILAGE"/ OR exp "FRACTURES, BONE"/ OR exp "FOREIGN BODIES"/ OR exp "CRUSH INJURIES"/ OR exp "ATHLETIC INJURIES"/ OR exp "ARM INJURIES"/ OR exp "AMPUTATION, TRAUMATIC"/)) AND (exp "GRAM-POSITIVE BACTERIAL INFECTIONS"/ OR exp "GRAM-NEGATIVE BACTERIAL INFECTIONS"/ OR exp "BACTERIAL INFECTIONS"/ OR exp "STAPHYLOCOCCAL INFECTIONS"/ OR exp INFECTIONS/ OR exp "WOUND INFECTION"/ OR exp TOXEMIA/ OR exp "SOFT TISSUE INFECTIONS"/ OR exp "SKIN DISEASES, INFECTIOUS"/ OR exp SEPSIS/ OR exp "BONE DISEASES, INFECTIOUS"/ OR exp "BACTERIAL INFECTIONS AND MYCOSES"/ OR exp "ARTHRITIS, INFECTIOUS"/) | 1061 |

**Contents** 50 of 1061 results on Medline - ((exp "METACARPAL BONES"/ OR exp "FINGER PHALANGES"/ OR exp "CARPAL BONES"/ OR exp "HAND BONES"/ OR exp METACARPUS/ OR exp FINGERS/ OR exp HAND/ OR exp "METACARPOPHALANGEAL JOINT"/ OR exp "FINGER JOINT"/ OR exp "CARPOMETACARPAL JOINTS"/ OR exp "CARPAL JOINTS"/ OR exp "HAND JOINTS"/ OR exp WRIST/ OR exp "WRIST JOINT"/) AND (exp "FINGER INJURIES"/ OR exp "HAND INJURIES"/ OR exp "WRIST INJURIES"/ OR exp "ACCIDENTAL INJURIES"/ OR exp "WOUNDS AND INJURIES"/ OR exp "WOUNDS, PENETRATING"/ OR exp "WOUNDS, NONPENETRATING"/ OR exp "VASCULAR SYSTEM INJURIES"/ OR exp "TRAUMA, NERVOUS SYSTEM"/ OR exp "TENDON INJURIES"/ OR exp "SURGICAL WOUND"/ OR exp "SOFT TISSUE INJURIES"/ OR exp REINJURIES/ OR exp "MULTIPLE TRAUMA"/ OR exp LACERATIONS/ OR exp "JOINT DISLOCATIONS"/ OR exp "HAND INJURIES"/ OR exp "FRACTURES, CARTILAGE"/ OR exp "FRACTURES, BONE"/ OR exp "FOREIGN BODIES"/ OR exp "CRUSH INJURIES"/ OR exp "ATHLETIC INJURIES"/ OR exp "ARM INJURIES"/ OR exp "AMPUTATION, TRAUMATIC"/)) AND (exp "GRAM-POSITIVE BACTERIAL INFECTIONS"/ OR exp "GRAM-NEGATIVE BACTERIAL INFECTIONS"/ OR exp

**HDAS** Export
**Search Strategy** EMBASE MeSH SSI

**02 Feb 21 - 12:31**

**Strategy** 974100/49

See full search strategy

| # | Database | Search term | Results |
|---|---|---|---|
| 49 | EMBASE | ((exp HAND/ OR exp WRIST/ OR exp FINGER/ OR exp THUMB/) AND (exp "ACCIDENTAL INJURY"/ OR exp "BATTLE INJURY"/ OR exp "BLOOD VESSEL INJURY"/ OR exp "BLUNT TRAUMA"/ OR exp "CRUSH TRAUMA"/ OR exp "LIMB INJURY"/ OR exp "NERVOUS SYSTEM INJURY"/ OR exp "MUSCULOSKELETAL INJURY"/ OR exp "SKIN INJURY"/ OR exp "SOFT TISSUE INJURY"/ OR exp "SPORT INJURY"/ OR exp "SURGICAL INJURY"/ OR exp "TISSUE INJURY"/ OR exp "TRAUMATIC AMPUTATION"/ OR exp WOUND/ OR exp INJURY/)) AND (exp "INFECTION BURDEN"/ OR exp SUPPURATION/ OR exp "SOFT TISSUE INFECTION"/ OR exp "SKIN INFECTION"/ OR exp SEPSIS/ OR exp PUS/ OR exp "PRIMARY INFECTION"/ OR exp "PERSISTENT INFECTION"/ OR exp "MUSCULOSKELETAL INFECTION"/ OR exp "INFECTIONS ASSOCIATED WITH OTHER INFECTIONS OR CONDITIONS"/ OR exp "INFECTION RATE"/ OR exp "INFECTION COMPLICATION"/ OR exp "HOSPITAL INFECTION"/ OR exp "HEALTHCARE ASSOCIATED INFECTION"/ OR exp "HAND INFECTION"/ OR exp "GRAFT INFECTION"/ OR exp "DEVICE INFECTION"/ OR exp "BACTERIAL INFECTION"/ OR exp ABSCESS/ OR exp INFECTION/) | 2551 |

**Contents** 50 of 2551 results on EMBASE - ((exp HAND/ OR exp WRIST/ OR exp FINGER/ OR exp THUMB/) AND (exp "ACCIDENTAL INJURY"/ OR exp "BATTLE INJURY"/ OR exp "BLOOD VESSEL INJURY"/ OR exp "BLUNT TRAUMA"/ OR exp "CRUSH TRAUMA"/ OR exp "LIMB INJURY"/ OR exp "NERVOUS SYSTEM INJURY"/ OR exp "MUSCULOSKELETAL INJURY"/ OR exp "SKIN INJURY"/ OR exp "SOFT TISSUE INJURY"/ OR exp "SPORT INJURY"/ OR exp "SURGICAL INJURY"/ OR exp "TISSUE INJURY"/ OR exp "TRAUMATIC AMPUTATION"/ OR exp WOUND/ OR exp INJURY/)) AND (exp "INFECTION BURDEN"/ OR exp SUPPURATION/ OR exp "SOFT TISSUE INFECTION"/ OR exp "SKIN INFECTION"/ OR exp SEPSIS/ OR exp PUS/ OR exp "PRIMARY INFECTION"/ OR exp "PERSISTENT INFECTION"/ OR exp "MUSCULOSKELETAL INFECTION"/ OR exp "INFECTIONS ASSOCIATED WITH OTHER INFECTIONS OR CONDITIONS"/ OR exp "INFECTION RATE"/ OR exp "INFECTION COMPLICATION"/ OR exp "HOSPITAL INFECTION"/ OR exp "HEALTHCARE ASSOCIATED INFECTION"/ OR exp "HAND INFECTION"/ OR exp "GRAFT INFECTION"/ OR exp "DEVICE INFECTION"/ OR exp "BACTERIAL INFECTION"/ OR exp ABSCESS/ OR exp INFECTION/)

1. 24960 Botryomycosis in an immunocompromised adult male ..... Page 4
2. 25959 Clinical and histopathologic evolution of inflammatory linear verrucous epidermal nevus in a pediatric patient ..... Page 4
3. 27910 A sporotrichoid rash in a landscaper and fish owner ..... Page 5
4. Incident bone fracture and mortality in a large HIV cohort outpatient study, 2000-2017, USA ..... Page 6

**HDAS** Export
**Search Strategy** SSI hand and wrist

**26 Jan 21 - 10:47**

**Strategy** 970556/81

See full search strategy

| # | Database | Search term | Results |
|---|---|---|---|
| 81 | EMBASE | (infect*).ti,ab AND (((((hand*).ti,ab OR (finger*).ti,ab OR (thumb*).ti,ab OR (wrist*).ti,ab OR (phalang*).ti,ab OR (metacarpal*).ti,ab OR (carpal*).ti,ab OR (radius*).ti,ab OR (ulna*).ti,ab) AND ((nerve*).ti,ab OR (neuro*).ti,ab OR (vasc*).ti,ab OR (arter*).ti,ab OR (vessel*).ti,ab OR (tendon*).ti,ab OR (ligament*).ti,ab OR (joint*).ti,ab OR (capsul*).ti,ab OR (volar*).ti,ab OR (musc*).ti,ab)) AND ((trauma*).ti,ab OR (injur*).ti,ab OR (lacerat*).ti,ab OR (fracture*).ti,ab OR (crush*).ti,ab OR (wound*).ti,ab)) AND ((surg*).ti,ab OR (operati*).ti,ab OR (intervent*).ti,ab OR (procedur*).ti,ab OR (repair*).ti,ab OR (fix*).ti,ab OR (reconstruct*).ti,ab OR (debride*).ti,ab OR (closur*).ti,ab OR (dressing*).ti,ab)) | 3367 |

**Contents** 50 of 3367 results on EMBASE - (infect*).ti,ab AND (((((hand*).ti,ab OR (finger*).ti,ab OR (thumb*).ti,ab OR (wrist*).ti,ab OR (phalang*).ti,ab OR (metacarpal*).ti,ab OR (carpal*).ti,ab OR (radius*).ti,ab OR (ulna*).ti,ab) AND ((nerve*).ti,ab OR (neuro*).ti,ab OR (vasc*).ti,ab OR (arter*).ti,ab OR (vessel*).ti,ab OR (tendon*).ti,ab OR (ligament*).ti,ab OR (joint*).ti,ab OR (capsul*).ti,ab OR (volar*).ti,ab OR (musc*).ti,ab)) AND ((trauma*).ti,ab OR (injur*).ti,ab OR (lacerat*).ti,ab OR (fracture*).ti,ab OR (crush*).ti,ab OR (wound*).ti,ab)) AND ((surg*).ti,ab OR (operati*).ti,ab OR (intervent*).ti,ab OR (procedur*).ti,ab OR (repair*).ti,ab OR (fix*).ti,ab OR (reconstruct*).ti,ab OR (debride*).ti,ab OR (closur*).ti,ab OR (dressing*).ti,ab))

1. Mini-invasive Osteotomy for Pediatric Distal Radius Malunion ..... Page 4

2. Allograft Interposition Bone Graft for First Metatarsal Phalangeal Arthrodesis: Salvage After Bone Loss and Shortening of the First Ray ..... Page 4

3. Robotic Kidney Transplant: The Modern Era Technical Revolution ..... Page 5

4. Non traumatic, single channel, low flow peroneal arteriovenous fistula leading to toe gangrene: An extremely rare observation ..... Page 5

5. A Practical Approach to the Management of Digital Ulcers in Patients with Systemic Sclerosis: A Narrative Review ..... Page 6

6. Top 20 Research Studies of 2020 for Primary Care Physicians ..... Page 7

7. One-stage Distal Interphalangeal Joint Fusion With External Fixator for the Treatment of Septic Joint Arthritis ..... Page 8

8. Vascularised fibular graft in the management of non-union of fracture shaft of radius: a less ventured entity ..... Page 8

9. Upper extremity Histoplasma capsulatum treatment with isavuconazole ..... Page 8

10. Long-term results after modified Burton-Pellegrini's technique in 24 cases affected by advanced rhizarthrosis ..... Page 9

11. Efficacy of 2-stage revision using a prosthesis of antibiotic-loaded acrylic cement spacer with or without cortical strut allograft in infected total elbow arthroplasty ..... Page 10

12. Hemiarthroplastik der Hufte uber den direkten anterioren ZugangHemiarthroplasty of the hip using the direct anterior approach ..... Page 11

**HDAS** Export
**Search Strategy** SSI hand and wrist

**26 Jan 21 - 10:47**

**Strategy** 970556/242

See full search strategy

| # | Database | Search term | Results |
|---|---|---|---|
| 242 | Medline | (infect*).ti,ab AND (((((hand*).ti,ab OR (finger*).ti,ab OR (thumb*).ti,ab OR (wrist*).ti,ab OR (phalang*).ti,ab OR (metacarpal*).ti,ab OR (carpal*).ti,ab OR (radius*).ti,ab OR (ulna*).ti,ab) AND ((nerve*).ti,ab OR (neuro*).ti,ab OR (vasc*).ti,ab OR (arter*).ti,ab OR (vessel*).ti,ab OR (tendon*).ti,ab OR (ligament*).ti,ab OR (joint*).ti,ab OR (capsul*).ti,ab OR (volar*).ti,ab OR (musc*).ti,ab)) AND ((trauma*).ti,ab OR (injur*).ti,ab OR (lacerat*).ti,ab OR (fracture*).ti,ab OR (crush*).ti,ab OR (wound*).ti,ab)) AND ((surg*).ti,ab OR (operati*).ti,ab OR (intervent*).ti,ab OR (procedur*).ti,ab OR (repair*).ti,ab OR (fix*).ti,ab OR (reconstruct*).ti,ab OR (debride*).ti,ab OR (closur*).ti,ab OR (dressing*).ti,ab)) | 2014 |

**Contents** 50 of 2014 results on Medline - (infect*).ti,ab AND (((((hand*).ti,ab OR (finger*).ti,ab OR (thumb*).ti,ab OR (wrist*).ti,ab OR (phalang*).ti,ab OR (metacarpal*).ti,ab OR (carpal*).ti,ab OR (radius*).ti,ab OR (ulna*).ti,ab) AND ((nerve*).ti,ab OR (neuro*).ti,ab OR (vasc*).ti,ab OR (arter*).ti,ab OR (vessel*).ti,ab OR (tendon*).ti,ab OR (ligament*).ti,ab OR (joint*).ti,ab OR (capsul*).ti,ab OR (volar*).ti,ab OR (musc*).ti,ab)) AND ((trauma*).ti,ab OR (injur*).ti,ab OR (lacerat*).ti,ab OR (fracture*).ti,ab OR (crush*).ti,ab OR (wound*).ti,ab)) AND ((surg*).ti,ab OR (operati*).ti,ab OR (intervent*).ti,ab OR (procedur*).ti,ab OR (repair*).ti,ab OR (fix*).ti,ab OR (reconstruct*).ti,ab OR (debride*).ti,ab OR (closur*).ti,ab OR (dressing*).ti,ab))

1. [Clinical effects of ulnar artery perforator chain flaps in repairing wounds on distal forearm or wrist with vascular anastomosis]. ..... Page 4

2. [Wound repair and functional reconstruction of high-voltage electrical burns in wrists]. ..... Page 5

3. [The pedicled groin flap for defect closure of the hand]. ..... Page 5

4. Complications associated with volar locking plate fixation for distal radius fractures in 1955 cases: A multicentre retrospective study. ..... Page 6

5. [Kirschner wire fixation in three joints combined with bone anchor repair for treatment of acute perilunate injury ]. ..... Page 7

6. Volar plate fixation for the treatment of distal radius fractures: analysis of adverse events. ..... Page 8

7. [Clinical application of free peroneal perforator-based sural neurofasciocutaneous flap]. ..... Page 9

8. Role of a spanning plate as an internal fixator in complex distal radius fractures. ..... Page 9

9. Indications and functional outcome of the use of integra® dermal regeneration template for the management of traumatic soft tissue defects on dorsal hand, fingers and thumb. ..... Page 10

10. [Vascularised Fibula and Tendon Transfer in the Comprehensive Treatment of Forearm Fracture with Gas Gangrene Complication]. ..... Page 11

11. [Mini locked-plate trans-carpometacarpal joint internal fixation for treating comminuted fracture of base of the fifth metacarpal]. ..... Page 11

## 10.2 Appendix 2. Abstract decision tree

| Step | Criteria | Decision |
|---|---|---|
| 1 | Is it a primary clinical study of human participants? | Yes – move to step 2<br><br>No – exclude |
| 2 | Is it a study of surgery for acute hand or wrist injuries?<br><br>Acute defined as surgery within 4 weeks of injury | Yes – move to step 3<br><br>No - exclude |
| 3 | Does the study report infection as an outcome? | Yes – move to step 4<br><br>No – exclude |
| 4 | Confirm that the study reports infection following surgery for acute hand/wrist injury | Yes – include, extract data<br><br>No – revisit 1-3 |
| 5 | Extract the following data:<br><br>• Author<br>• Year<br>• Study design (case series, case control, cohort, RCT)<br>• Study type (retrospective or prospective)<br>• Total study participants<br>• Total surgical participants<br>• Injury site (hand, wrist, mixed)<br>• Injury type (open, closed, mixed)<br>• Treatment type (soft tissue reconstruction, external fixation, K-wire, ORIF, mixed)<br>• Number of infections in surgical participants<br>• Infection diagnosis (classification, clinical, unknown) | |

## 10.3 Appendix 3. R code for meta-analysis of proportions

```
install.packages(c("metafor", "meta"))
install.packages("minqa", dependencies=TRUE)
install.packages("CompQuadForm", dependencies=TRUE)
install.packages("meta", dependencies=TRUE)
yes
library(metafor)
library(meta)
dat=read.csv("data7.csv", header=T, sep=",")

#meta-analysis
#add=0 as some studies have 0 events

ies.logit=escalc(xi=cases, ni=total, measure="PLO", data=dat, add=0)
pes.logit=rma(yi, vi, data=ies.logit, method="DL", level=95)
pes=predict(pes.logit, transf=transf.ilogit)
print(pes, digits=6)

#heterogeneity

print(pes.logit, digits=4)
confint(pes.logit, digits=2)

#forest plots

pes.summary=metaprop(cases, total, authoryear, data=dat, sm="PLO")
forest(pes.summary)

#nice forest plot

pes.summary=metaprop(cases, total, authoryear, data=dat, sm="PLO",
                     method.tau="DL", method.ci="NAsm")
forest(pes.summary,
      xlim=c(0,50),
```

```
    pscale=100,
    rightcols=FALSE,
    leftcols=c("studlab", "event", "n", "effect", "ci"),
    leftlabs=c("Study", "Cases", "Total", "Risk of SSI", "95% C.I."),
    xlab="Risk of SSI", smlab="",
    weight.study="random", squaresize=0.5, col.square="navy",
    col.square.lines="navy",
    col.diamond="maroon", col.diamond.lines="maroon",pooled.totals=FALSE,
    comb.fixed=FALSE,
    fs.hetstat=10,
    print.tau2=TRUE,
    print.Q=TRUE,
    print.pval.Q=TRUE,
    print.I2=TRUE,
    digits=2)

### This graph shows that the proprotion risk is higher when studies are larger and more
precise ###

precision=sqrt(ies.logit$vi)

sortvar=precision

pes.summary=metaprop(cases, total, authoryear, data=dat, sm="PLO",
                     method.tau="REML", method.ci="NAsm")
forest(pes.summary,
    xlim=c(0,50),
    pscale=100,
    rightcols=FALSE,
    leftcols=c("studlab", "event", "n", "effect", "ci"),
    leftlabs=c("Study", "Cases", "Total", "SSI", "95% C.I."),
    xlab="Risk of SSI", smlab="",
    weight.study="random", squaresize=0.5, col.square="navy",
    col.square.lines="navy",
    col.diamond="maroon", col.diamond.lines="maroon",pooled.totals=FALSE,
```

```
      comb.fixed=FALSE,
      fs.hetstat=10,
      print.tau2=TRUE,
      print.Q=TRUE,
      print.pval.Q=TRUE,
      print.I2=TRUE,
      digits=2,
      sortvar)

## Subgroup analysis 1 - Study design


pes.logit.RCT=rma(yi, vi, data=ies.logit,
              subset=Studydesign=="RCT",
              method="REML")
pes.logit.Cohort=rma(yi, vi, data=ies.logit,
                subset=Studydesign=="Cohort",
                method="REML")
pes.logit.CaseSeries=rma(yi, vi, data=ies.logit,
                    subset=Studydesign=="Case series",
                    method="REML")
pes.RCT=predict(pes.logit.RCT, transf=transf.ilogit, digits=2)
pes.Cohort=predict(pes.logit.Cohort, transf=transf.ilogit, digits=2)
pes.CaseSeries=predict(pes.logit.xCaseSeries, transf=transf.ilogit, digits=2)
dat.diffvar=data.frame(estimate=c(pes.logit.RCT$b, pes.logit.Cohort$b,
pes.logit.CaseSeries$b),
                  stderror=c(pes.logit.RCT$se, pes.logit.Cohort$se, pes.logit.CaseSeries$se),
                  Studydesign=c("RCT", "Cohort", "Case series"),
                  tau2=round(c(pes.logit.RCT$tau2,
                               pes.logit.Cohort$tau2,
                               pes.logit.CaseSeries$tau2), 3))

subganal.Studydesign=rma(estimate, sei=stderror, data=dat.diffvar,
                    mods=~Studydesign, method="FE")
pes.logit.Studydesign=rma(estimate, sei=stderror, method="REML", data=dat.diffvar)
```

```
pes.Studydesign=predict(pes.logit.Studydesign, transf=transf.ilogit)
print(pes.RCT, digits=2); print(pes.logit.RCT, digits=3)
print(pes.Cohort, digits=2); print(pes.logit.Cohort, digits=3)
print(pes.CaseSeries, digits=2); print(pes.logit.CaseSeries, digits=3)
print(subganal.Studydesign, digits=2)
print(pes.Studydesign, digits=2)


subganal.studydesign=rma(yi, vi, data=ies.logit, mods=~Studydesign, method="DL")
pes.summary=metaprop(cases, total, authoryear, data=dat,
                     sm="PLO",
                     method.tau="DL",
                     method.ci="NAsm",
                     subgroup=Studydesign,
                     tau.common=FALSE,
                     tau.preset=sqrt(subganal.Studydesign$tau2))
forest(pes.summary,
      xlim=c(0,50),
      pscale=100,
      rightcols=FALSE,
      leftcols=c("studlab", "effect", "ci"), leftlabs=c("Study", "Risk of SSI", "95% C.I."),
      xlab=, xlab.pos=25, smlab="", weight.study="random", squaresize=1,
col.square="navy", col.diamond="maroon", col.diamond.lines="maroon",
pooled.totals=TRUE,
      comb.random=TRUE,
      fs.hetstat=7.5,
      print.tau2=TRUE,
      print.Q=TRUE,
      print.pval.Q=TRUE,
      print.I2=TRUE,
      digits=2,
      overall=FALSE, overall.hetstat = FALSE)


## Subgroup analysis 2 - Study Type
```

```
pes.logit.Retrospective=rma(yi, vi, data=ies.logit,
                    subset=Studytype=="Retrospective",
                    method="REML")
pes.logit.Prospective=rma(yi, vi, data=ies.logit,
                  subset=Studytype=="Prospective",
                  method="REML")
pes.Retrospective=predict(pes.logit.Retrospective, transf=transf.ilogit, digits=5)
pes.Prospective=predict(pes.logit.Prospective, transf=transf.ilogit, digits=5)
dat.diffvar=data.frame(estimate=c(pes.logit.Retrospective$b, pes.logit.Prospective$b),
                  stderror=c(pes.logit.Retrospective$se, pes.logit.Prospective$se),
                  Studytype=c("Retrospective", "Prospective"),
                  tau2=round(c(pes.logit.Retrospective$tau2,
                          pes.logit.Prospective$tau2), 3))
subganal.Studytype=rma(estimate, sei=stderror, data=dat.diffvar,
                    mods=~Studytype, method="FE")
pes.logit.Studytype=rma(estimate, sei=stderror, method="FE", data=dat.diffvar)
pes.Studytype=predict(pes.logit.Studytype, transf=transf.ilogit)
print(pes.Retrospective, digits=6); print(pes.logit.Retrospective, digits=3)
print(pes.Prospective, digits=6); print(pes.logit.Prospective, digits=3)
print(subganal.Studytype, digits=3)
print(pes.Studytype, digits=6)


subganal.Studytype=rma(yi, vi, data=ies.logit, mods=~Studytype, method="DL")
pes.summary=metaprop(cases, total, authoryear, data=dat,
                  sm="PLO",
                  method.tau="DL",
                  method.ci="NAsm",
                  subgroup=Studytype,
                  tau.common=TRUE,
                  tau.preset=sqrt(subganal.Studytype$tau2))
forest(pes.summary,
     xlim=c(0,50),
     pscale=100,
     rightcols=FALSE,
```

```
    leftcols=c("studlab", "effect", "ci"), leftlabs=c("Study", "Risk of SSI", "95% C.I."),
    xlab="Risk of SSI", smlab="", weight.study="random", squaresize=0.5,
col.square="navy", col.diamond="maroon", col.diamond.lines="maroon",
pooled.totals=TRUE,
    comb.fixed=TRUE,
    fs.hetstat=10,
    print.tau2=TRUE,
    print.Q=TRUE,
    print.pval.Q=TRUE,
    print.I2=TRUE,
    digits=2,
    overall=FALSE, overall.hetstat = FALSE)


## Subgroup analysis 3 - Injury Site


pes.logit.Hand=rma(yi, vi, data=ies.logit,
                   subset=Site=="Hand",
                   method="REML")
pes.logit.Wrist=rma(yi, vi, data=ies.logit,
                    subset=Site=="Wrist",
                    method="REML")
pes.logit.Mixed=rma(yi, vi, data=ies.logit,
                    subset=Site=="Mixed",
                    method="REML")
pes.Hand=predict(pes.logit.Hand, transf=transf.ilogit, digits=5)
pes.Wrist=predict(pes.logit.Wrist, transf=transf.ilogit, digits=5)
pes.Mixed=predict(pes.logit.Mixed, transf=transf.ilogit, digits=5)
dat.diffvar=data.frame(estimate=c(pes.logit.Hand$b, pes.logit.Wrist$b,
pes.logit.Mixed$b),
                       stderror=c(pes.logit.Hand$se, pes.logit.Wrist$se, pes.logit.Mixed$se),
                       Site=c("Hand", "Wrist", "Mixed"),
                       tau2=round(c(pes.logit.Hand$tau2,
                                    pes.logit.Wrist$tau2,
                                    pes.logit.Mixed$tau2), 3))
subganal.Site=rma(estimate, sei=stderror, data=dat.diffvar,
                  mods=~Site, method="FE")
```

```
pes.logit.Site=rma(estimate, sei=stderror, method="REML", data=dat.diffvar)
pes.Site=predict(pes.logit.Site, transf=transf.ilogit)
print(pes.Hand, digits=6); print(pes.logit.Hand, digits=3)
print(pes.Wrist, digits=6); print(pes.logit.Wrist, digits=3)
print(pes.Mixed, digits=6); print(pes.logit.Mixed, digits=3)
print(subganal.Site, digits=3)
print(pes.Site, digits=6)

subganal.Site=rma(yi, vi, data=ies.logit, mods=~Site, method="DL")
pes.summary=metaprop(cases, total, authoryear, data=dat,
                     sm="PLO",
                     method.tau="DL",
                     method.ci="NAsm",
                     subgroup=Site,
                     tau.common=TRUE,
                     tau.preset=sqrt(subganal.Site$tau2))
forest(pes.summary,
      xlim=c(0,50),
      pscale=100,
      rightcols=FALSE,
      leftcols=c("studlab", "effect", "ci"), leftlabs=c("Study", "Proportion", "95% C.I."),
      xlab="Risk of SSI", smlab="", weight.study="random", squaresize=0.5,
col.square="navy", col.diamond="maroon", col.diamond.lines="maroon",
pooled.totals=TRUE,
      comb.fixed=TRUE,
      fs.hetstat=10,
      print.tau2=TRUE,
      print.Q=TRUE,
      print.pval.Q=TRUE,
      print.I2=TRUE,
      digits=2,
      overall=FALSE, overall.hetstat = FALSE)

## Subgroup analysis 4 - Injury Type

pes.logit.Open=rma(yi, vi, data=ies.logit,
```

```
                subset=Type=="Open",
                method="REML")
pes.logit.Closed=rma(yi, vi, data=ies.logit,
                subset=Type=="Closed",
                method="REML")
pes.logit.Mixed=rma(yi, vi, data=ies.logit,
                subset=Type=="Mixed",
                method="REML")
pes.Open=predict(pes.logit.Open, transf=transf.ilogit, digits=5)
pes.Closed=predict(pes.logit.Closed, transf=transf.ilogit, digits=5)
pes.Mixed=predict(pes.logit.Mixed, transf=transf.ilogit, digits=5)
dat.diffvar=data.frame(estimate=c(pes.logit.Open$b, pes.logit.Closed$b,
pes.logit.Mixed$b),
                stderror=c(pes.logit.Open$se, pes.logit.Closed$se, pes.logit.Mixed$se),
                Type=c("Open", "Closed", "Mixed"),
                tau2=round(c(pes.logit.Open$tau2,
                        pes.logit.Closed$tau2,
                        pes.logit.Mixed$tau2), 3))
subganal.Type=rma(estimate, sei=stderror, data=dat.diffvar,
               mods=~Type, method="FE")
pes.logit.Type=rma(estimate, sei=stderror, method="REML", data=dat.diffvar)
pes.Type=predict(pes.logit.Type, transf=transf.ilogit)
print(pes.Open, digits=6); print(pes.logit.Open, digits=3)
print(pes.Closed, digits=6); print(pes.logit.Closed, digits=3)
print(pes.Mixed, digits=6); print(pes.logit.Mixed, digits=3)
print(subganal.Type, digits=3)
print(pes.Type, digits=6)

subganal.Type=rma(yi, vi, data=ies.logit, mods=~Type, method="DL")
pes.summary=metaprop(cases, total, authoryear, data=dat,
                sm="PLO",
                method.tau="DL",
                method.ci="NAsm",
                subgroup=Type,
                tau.common=TRUE,
```

```
            tau.preset=sqrt(subganal.Type$tau2))
forest(pes.summary,
     xlim=c(0,50),
     pscale=100,
     rightcols=FALSE,
     leftcols=c("studlab", "effect", "ci"), leftlabs=c("Study", "Proportion", "95% C.I."),
     xlab="Risk of SSI", smlab="", weight.study="random", squaresize=0.5,
col.square="navy", col.diamond="maroon", col.diamond.lines="maroon",
pooled.totals=TRUE,
     comb.fixed=TRUE,
     fs.hetstat=10,
     print.tau2=TRUE,
     print.Q=TRUE,
     print.pval.Q=TRUE,
     print.I2=TRUE,
     digits=2,
     overall=FALSE, overall.hetstat = FALSE)

## Subgroup analysis 5 - Intervention

pes.logit.STR=rma(yi, vi, data=ies.logit,
            subset=Intervention=="STR",
            method="REML")
pes.logit.Kwire=rma(yi, vi, data=ies.logit,
              subset=Intervention=="Kwire",
              method="REML")
pes.logit.ORIF=rma(yi, vi, data=ies.logit,
                   subset=Intervention=="ORIF",
                   method="REML")
pes.logit.ExFix=rma(yi, vi, data=ies.logit,
                  subset=Intervention=="ExFix",
                  method="REML")
pes.logit.Mixed=rma(yi, vi, data=ies.logit,
            subset=Intervention=="Mixed",
            method="REML")
pes.STR=predict(pes.logit.STR, transf=transf.ilogit, digits=2)
```

```
pes.Kwire=predict(pes.logit.Kwire, transf=transf.ilogit, digits=2)
pes.ORIF=predict(pes.logit.ORIF, transf=transf.ilogit, digits=2)
pes.ExFix=predict(pes.logit.ExFix, transf=transf.ilogit, digits=2)
pes.Mixed=predict(pes.logit.Mixed, transf=transf.ilogit, digits=2)
dat.diffvar=data.frame(estimate=c(pes.logit.STR$b, pes.logit.Kwire$b, pes.logit.ORIF$b, pes.logit.ExFix$b, pes.logit.Mixed$b),
                       stderror=c(pes.logit.STR$se, pes.logit.Kwire$se, pes.logit.ORIF$se, pes.logit.ExFix$se, pes.logit.Mixed$se),
                       Intervention=c("STR", "Kwire", "ORIF", "ExFix", "Mixed"),
                       tau2=round(c(pes.logit.STR$tau2,
                                    pes.logit.Kwire$tau2,
                                    pes.logit.ORIF$tau2,
                                    pes.logit.ExFix$tau2,
                                    pes.logit.Mixed$tau2), 3))
subganal.Intervention=rma(estimate, sei=stderror, data=dat.diffvar,
                          mods=~Intervention, method="FE")
pes.logit.Intervention=rma(estimate, sei=stderror, method="REML", data=dat.diffvar)
pes.Intervention=predict(pes.logit.Intervention, transf=transf.ilogit)
print(pes.STR, digits=2); print(pes.logit.STR, digits=3)
print(pes.Kwire, digits=2); print(pes.logit.Kwire, digits=3)
print(pes.ORIF, digits=2); print(pes.logit.ORIF, digits=3)
print(pes.ExFix, digits=2); print(pes.logit.ExFix, digits=3)
print(pes.Mixed, digits=2); print(pes.logit.Mixed, digits=3)
print(subganal.Intervention, digits=2)
print(pes.Intervention, digits=2)

subganal.Intervention=rma(yi, vi, data=ies.logit, mods=~Intervention, method="DL")
pes.summary=metaprop(cases, total, authoryear, data=dat,
                     sm="PLO",
                     method.tau="DL",
                     method.ci="NAsm",
                     subgroup=Intervention,
                     tau.common=TRUE,
                     tau.preset=sqrt(subganal.Intervention$tau2))
forest(pes.summary,
     xlim=c(0,50),
```

```
      pscale=100,
      rightcols=FALSE,
      leftcols=c("studlab", "effect", "ci"), leftlabs=c("Study", "Proportion", "95% C.I."),
      xlab="Risk of SSI", smlab="", weight.study="random", squaresize=0.5,
col.square="navy", col.diamond="maroon", col.diamond.lines="maroon",
pooled.totals=TRUE,
      comb.fixed=TRUE,
      fs.hetstat=10,
      print.tau2=TRUE,
      print.Q=TRUE,
      print.pval.Q=TRUE,
      print.I2=TRUE,
      digits=2,
      overall=FALSE, overall.hetstat = FALSE


## Subgroup analysis 6 - Infection Definition


pes.logit.Clinical=rma(yi, vi, data=ies.logit,
                subset=InfectionDefinition=="Clinical",
                method="REML")
pes.logit.Unknown=rma(yi, vi, data=ies.logit,
                 subset=InfectionDefinition=="Unknown",
                 method="REML")
pes.logit.Classification=rma(yi, vi, data=ies.logit,
                 subset=InfectionDefinition=="Classification",
                 method="REML")
pes.Clinical=predict(pes.logit.Clinical, transf=transf.ilogit, digits=5)
pes.Unknown=predict(pes.logit.Unknown, transf=transf.ilogit, digits=5)
pes.Classification=predict(pes.logit.Classification, transf=transf.ilogit, digits=5)
dat.diffvar=data.frame(estimate=c(pes.logit.Clinical$b, pes.logit.Unknown$b,
pes.logit.Classification$b),
                   stderror=c(pes.logit.Clinical$se, pes.logit.Unknown$se,
pes.logit.Classification$se),
                   InfectionDefinition=c("Clinical", "Unknown", "Classification"),
                   tau2=round(c(pes.logit.Clinical$tau2,
                          pes.logit.Unknown$tau2,
```

```
                pes.logit.Classification$tau2), 3))
subganal.InfectionDefinition=rma(estimate, sei=stderror, data=dat.diffvar,
          mods=~InfectionDefinition, method="FE")
pes.logit.InfectionDefinition=rma(estimate, sei=stderror, method="REML",
data=dat.diffvar)
pes.InfectionDefinition=predict(pes.logit.InfectionDefinition, transf=transf.ilogit)
print(pes.Clinical, digits=6); print(pes.logit.Clinical, digits=3)
print(pes.Unknown, digits=6); print(pes.logit.Unknown, digits=3)
print(pes.Classification, digits=6); print(pes.logit.Classification, digits=3)
print(subganal.InfectionDefinition, digits=3)
print(pes.InfectionDefinition, digits=6)


subganal.InfectionDefinition=rma(yi, vi, data=ies.logit, mods=~InfectionDefinition,
method="DL")
pes.summary=metaprop(cases, total, authoryear, data=dat,
          sm="PLO",
          method.tau="DL",
          method.ci="NAsm",
          subgroup=InfectionDefinition,
          tau.common=TRUE,
          tau.preset=sqrt(subganal.InfectionDefinition$tau2))
forest(pes.summary,
     xlim=c(0,50),
     pscale=100,
     rightcols=FALSE,
     leftcols=c("studlab", "effect", "ci"), leftlabs=c("Study", "Proportion", "95% C.I."),
     xlab="Risk of SSI", smlab="", weight.study="random", squaresize=0.5,
col.square="navy", col.diamond="maroon", col.diamond.lines="maroon",
pooled.totals=TRUE,
     comb.fixed=TRUE,
     fs.hetstat=10,
     print.tau2=TRUE,
     print.Q=TRUE,
     print.pval.Q=TRUE,
     print.I2=TRUE,
     digits=2,
```

```
      overall=FALSE, overall.hetstat = FALSE)

## Subgroup analysis 7 - Risk of Bias

pes.logit.Low=rma(yi, vi, data=ies.logit,
                  subset=RoB=="Low",
                  method="REML")
pes.logit.Moderate=rma(yi, vi, data=ies.logit,
                   subset=RoB=="Moderate",
                   method="REML")
pes.logit.High=rma(yi, vi, data=ies.logit,
                   subset=RoB=="High",
                   method="REML")
pes.Low=predict(pes.logit.Low, transf=transf.ilogit, digits=5)
pes.Moderate=predict(pes.logit.Moderate, transf=transf.ilogit, digits=5)
pes.High=predict(pes.logit.High, transf=transf.ilogit, digits=5)
dat.diffvar=data.frame(estimate=c(pes.logit.Low$b, pes.logit.Moderate$b,
pes.logit.High$b),
                     stderror=c(pes.logit.Low$se, pes.logit.Moderate$se, pes.logit.High$se),
                     RoB=c("Low", "Moderate", "High"),
                     tau2=round(c(pes.logit.Low$tau2,
                                  pes.logit.Moderate$tau2,
                                  pes.logit.High$tau2), 3))
subganal.RoB=rma(estimate, sei=stderror, data=dat.diffvar,
                 mods=~RoB, method="FE")
pes.logit.RoB=rma(estimate, sei=stderror, method="REML", data=dat.diffvar)
pes.RoB=predict(pes.logit.RoB, transf=transf.ilogit)
print(pes.Low, digits=6); print(pes.logit.Low, digits=3)
print(pes.Moderate, digits=6); print(pes.logit.Moderate, digits=3)
print(pes.High, digits=6); print(pes.logit.High, digits=3)
print(subganal.RoB, digits=3)
print(pes.RoB, digits=6)

subganal.RoB=rma(yi, vi, data=ies.logit, mods=~RoB, method="DL")
pes.summary=metaprop(cases, total, authoryear, data=dat,
```

```
            sm="PLO",
            method.tau="DL",
            method.ci="NAsm",
            subgroup=RoB,
            tau.common=TRUE,
            tau.preset=sqrt(subganal.RoB$tau2))
forest(pes.summary,
    xlim=c(0,50),
    pscale=100,
    rightcols=FALSE,
    leftcols=c("studlab", "effect", "ci"), leftlabs=c("Study", "Risk of SSI", "95% C.I."),
    xlab="Risk of SSI", smlab="", weight.study="random", squaresize=0.5,
col.square="navy", col.diamond="maroon", col.diamond.lines="maroon",
pooled.totals=TRUE,
    comb.fixed=TRUE,
    fs.hetstat=10,
    print.tau2=TRUE,
    print.Q=TRUE,
    print.pval.Q=TRUE,
    print.I2=TRUE,
    digits=2,
    overall=FALSE, overall.hetstat = FALSE)

#Meta-regression

metareg.moderator=rma(yi, vi, data=ies.logit, mods=~Site)
metareg.moderator=rma(yi, vi, data=ies.logit, mods=~RoB)
metareg.moderator=rma(yi, vi, data=ies.logit, mods=~Intervention)
metareg.moderator=rma(yi, vi, data=ies.logit, mods=~Studytype)
metareg.moderator=rma(yi, vi, data=ies.logit, mods=~Studydesign)
metareg.moderator=rma(yi, vi, data=ies.logit, mods=~InfectionDefinition)

metareg.moderators=rma(yi, vi, data=ies.logit,

mods=~Site+Type+Intervention+RoB+Studytype+InfectionDefinition+Studydesign)
```

```
metareg.moderators$beta <- exp(metareg.moderators$beta)
metareg.moderators$ci.ub <- exp(metareg.moderators$ci.ub)
metareg.moderators$ci.lb <- exp(metareg.moderators$ci.lb)

print(metareg.moderators) #oddsratios

vif(metareg.moderators) #colinearity

(metareg.moderators)

permutest(metareg.moderators) #permutation
print(metareg.moderators)

metareg.moderators=rma(yi, vi, data=ies.logit,
                       mods=~Studydesign)

metareg.moderators$beta <- exp(metareg.moderators$beta)
metareg.moderators$ci.ub <- exp(metareg.moderators$ci.ub)
metareg.moderators$ci.lb <- exp(metareg.moderators$ci.lb)

print(metareg.moderators) #oddsratios

vif(metareg.moderators) #colinearity

(metareg.moderators)

permutest(metareg.moderators) #permutation
print(metareg.moderators)

#Funnel plot

funnel(pes.logit, yaxis="sei")
regtest(pes.logit, model="rma", predictor="sei")
```

# 10.4 Appendix 4. References to all included studies in SRMA

| Study | Reference | Citation |
|---|---|---|
| Abouelela 2020 | 1 | Abouelela A, Mubark I, Hassan M, Howells M, Ashwood N, Kitsis C. Mid-Term Outcomes of Unstable Complex Proximal Interphalangeal Joint Fracture Management Using the Ligamentotaxor® Device: A Case Series of 33 Cases. Cureus. 2020 Sep;12(9):e10519. |
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# 10.5 Appendix 5. Characteristics of included RCTs

| Author Year | Site | Type | Intervention | Study Type | Study Design | Infection Definition | Risk of Bias | SSI | Total |
|---|---|---|---|---|---|---|---|---|---|
| Grossman 1981 | Hand | Open | STR | Prospective | RCT | Unknown | Moderate | 3 | 265 |
| Peacock 1988 | Hand | Mixed | Mixed | Prospective | RCT | Classification | High | 1 | 87 |
| Horton 2003 | Hand | Closed | K-wire | Prospective | RCT | Clinical | High | 6 | 15 |
| Werber 2003 | Wrist | Closed | Ex-Fix | Prospective | RCT | Clinical | Moderate | 6 | 50 |
| Hargreaves 2004 | Wrist | Closed | K-wire | Prospective | RCT | Classification | High | 12 | 56 |
| Azzopardi 2005 | Wrist | Closed | K-wire | Prospective | RCT | Clinical | High | 1 | 30 |
| Whittaker 2005 | Mixed | Open | STR | Prospective | RCT | Classification | Moderate | 17 | 157 |
| Egol 2006 | Wrist | Mixed | Ex-Fix | Prospective | RCT | Classification | High | 21 | 118 |
| Rafique 2006 | Hand | Open | K-wire | Prospective | RCT | Clinical | High | 12 | 60 |
| Zettl 2009 | Wrist | Closed | ORIF | Prospective | RCT | Clinical | HIgh | 1 | 120 |
| Aydin 2010 | Hand | Mixed | Mixed | Prospective | RCT | Classification | High | 24 | 818 |
| Foldhazy 2010 | Wrist | Closed | Mixed | Prospective | RCT | Clinical | High | 4 | 22 |
| Hove 2010 | Wrist | Closed | Ex-Fix | Prospective | RCT | Clinical | Moderate | 19 | 70 |
| Kivi 2011 | Wrist | Closed | K-wire | Prospective | RCT | Clinical | High | 15 | 99 |
| Berwald 2014 | Hand | Open | STR | Prospective | RCT | Clinical | High | 1 | 73 |
| Costa 2014 | Wrist | Closed | Mixed | Prospective | RCT | Classification | Low | 32 | 461 |
| Chung 2019 | Wrist | Closed | Mixed | Prospective | RCT | Clinical | Moderate | 30 | 183 |
| Dias 2020 | Wrist | Closed | K-wire | Prospective | RCT | Classification | Low | 2 | 203 |
| Lawson 2021 | Wrist | Closed | ORIF | Prospective | RCT | Clinical | Low | 0 | 80 |
| Maradei-Pereira 2021 | Wrist | Closed | K-wire | Prospective | RCT | Classification | Moderate | 14 | 220 |
| Mishra 2021 | Wrist | Closed | Mixed | Prospective | RCT | Unknown | High | 3 | 62 |
| Noor 2021 | Hand | Closed | Mixed | Prospective | RCT | Unknown | High | 7 | 56 |
| Costa 2022 | Wrist | Closed | K-wire | Prospective | RCT | Classification | Low | 4 | 245 |

STR = soft tissue reconstruction, Ex-Fix = external fixation, ORIF = open reduction internal fixation, RCT = randomised control trial

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Khan 2022 | Hand | Mixed | K-wire | Prospective | RCT | Classification | High | 21 | 122 |
| Lee 2022 | Mixed | Open | STR | Prospective | RCT | Clinical | High | 2 | 25 |
| Lundqvist 2022 | Wrist | Closed | ORIF | Prospective | RCT | Clinical | High | 3 | 147 |
| Supichyangur 2022 | Hand | Closed | Mixed | Prospective | RCT | Clinical | High | 1 | 23 |

# 10.6 Appendix 6. Characteristics of included cohort studies

| Author Year | Site | Type | Intervention | Study Type | Study Design | Infection Definition | Risk of Bias | SSI | Total |
|---|---|---|---|---|---|---|---|---|---|
| Suprock 1990 | Hand | Open | Mixed | Prospective | Cohort | Clinical | High | 8 | 91 |
| Platt 1995 | Hand | Open | Mixed | Prospective | Cohort | Clinical | Moderate | 13 | 124 |
| Shetty 1997 | Hand | Open | STR | Retrospective | Cohort | Clinical | High | 0 | 102 |
| Stone 1998 | Hand | Open | STR | Retrospective | Cohort | Clinical | High | 3 | 140 |
| Goslings 1999 | Wrist | Mixed | Ex-Fix | Prospective | Cohort | Clinical | Low | 9 | 39 |
| Joosten 1999 | Wrist | Mixed | Ex-Fix | Prospective | Cohort | Clinical | High | 20 | 174 |
| Lassner 2001 | Hand | Mixed | STR | Retrospective | Cohort | Unknown | Moderate | 3 | 48 |
| Lallemand 2002 | Hand | Mixed | ORIF | Retrospective | Cohort | Unknown | High | 1 | 43 |
| Yim 2004 | Hand | Open | STR | Retrospective | Cohort | Clinical | Low | 2 | 26 |
| Al-Qattan 2005 | Hand | Mixed | STR | Retrospective | Cohort | Clinical | Moderate | 0 | 73 |
| Ahmad 2006 | Hand | Mixed | Mixed | Retrospective | Cohort | Clinical | High | 1 | 38 |
| Benson 2006 | Hand | Open | Mixed | Retrospective | Cohort | Clinical | Moderate | 7 | 34 |
| Fu 2006 | Wrist | Mixed | Ex-Fix | Prospective | Cohort | Clinical | Low | 1 | 98 |
| Kurzen 2006 | Hand | Mixed | ORIF | Retrospective | Cohort | Clinical | Moderate | 3 | 54 |
| McCallister 2006 | Hand | Closed | STR | Prospective | Cohort | Clinical | Low | 2 | 26 |
| Ochman 2006 | Wrist | Closed | Ex-Fix | Retrospective | Cohort | Unknown | High | 7 | 67 |
| Zhou 2008 | Hand | Closed | Mixed | Retrospective | Cohort | Clinical | High | 3 | 72 |
| Egol 2010 | Wrist | Mixed | Mixed | Retrospective | Cohort | Unknown | High | 0 | 44 |
| Gereli 2010 | Wrist | Mixed | Mixed | Retrospective | Cohort | Clinical | High | 3 | 30 |
| Lattman 2011 | Wrist | Closed | Mixed | Prospective | Cohort | Unknown | High | 1 | 245 |
| Nygaard 2011 | Hand | Mixed | Mixed | Retrospective | Cohort | Clinical | High | 24 | 51 |
| Al-Qattan 2012 | Hand | Open | Mixed | Retrospective | Cohort | Clinical | Moderate | 2 | 36 |
| Faruqui 2012 | Hand | Closed | K-wire | Retrospective | Cohort | Clinical | High | 1 | 50 |
| Mehdinasab 2012 | Hand | Open | STR | Prospective | Cohort | Unknown | High | 0 | 32 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Ghosh 2013 | Hand | Open | K-wire | Prospective | Cohort | Clinical | High | 4 | 30 |
| Kim 2013 | Wrist | Mixed | ORIF | Retrospective | Cohort | Clinical | Moderate | 3 | 60 |
| Frueh 2014 | Hand | Open | STR | Retrospective | Cohort | Clinical | High | 1 | 191 |
| Lutz 2014 | Wrist | Mixed | K-wire | Prospective | Cohort | Unknown | Moderate | 16 | 129 |
| Weinand 2014 | Hand | Open | STR | Retrospective | Cohort | Clinical | Moderate | 67 | 401 |
| Lauder 2015 | Wrist | Mixed | ORIF | Prospective | Cohort | Unknown | High | 0 | 18 |
| Miao 2015 | Hand | Closed | Ex-Fix | Prospective | Cohort | Unknown | High | 6 | 41 |
| Teunis 2015 | Wrist | Closed | ORIF | Retrospective | Cohort | Clinical | Low | 11 | 1511 |
| Van Leeuwen 2016 | Mixed | Open | K-wire | Retrospective | Cohort | Clinical | Low | 85 | 1213 |
| Basat 2017 | Hand | Open | Mixed | Retrospective | Cohort | Clinical | Moderate | 9 | 61 |
| Donnally 2017 | Mixed | Mixed | Mixed | Retrospective | Cohort | Clinical | High | 6 | 41 |
| Jose 2017 | Wrist | Closed | ORIF | Prospective | Cohort | Clinical | High | 1 | 53 |
| Ridley 2017 | Mixed | Open | K-wire | Retrospective | Cohort | Clinical | Low | 99 | 695 |
| Nguyen 2018 | Hand | Open | STR | Retrospective | Cohort | Clinical | High | 0 | 30 |
| Terndrup 2018 | Hand | Closed | K-wire | Retrospective | Cohort | Clinical | Low | 21 | 444 |
| Truntzer 2018 | Wrist | Closed | ORIF | Retrospective | Cohort | Clinical | Low | 154 | 7890 |
| Lutsky 2019 | Mixed | Mixed | K-wire | Prospective | Cohort | Classification | Low | 17 | 141 |
| Minhas 2019 | Hand | Mixed | Mixed | Retrospective | Cohort | Clinical | Low | 31 | 3506 |
| Ornelli 2019 | Hand | Mixed | STR | Retrospective | Cohort | Unknown | High | 0 | 12 |
| Saied 2019 | Hand | Closed | K-wire | Prospective | Cohort | Clinical | High | 2 | 61 |
| Tareen 2019 | Wrist | Open | Mixed | Retrospective | Cohort | Clinical | High | 14 | 92 |
| Davies 2020 | Hand | Open | Mixed | Prospective | Cohort | Clinical | Low | 41 | 983 |
| Henry 2020 | Wrist | Open | ORIF | Retrospective | Cohort | Unknown | High | 0 | 24 |
| Lee 2020 | Wrist | Mixed | ORIF | Retrospective | Cohort | Clinical | Low | 85 | 1921 |
| Liu Y 2020 | Wrist | Mixed | Ex-Fix | Retrospective | Cohort | Unknown | High | 15 | 207 |
| Al-Shahwanii 2021 | Wrist | Closed | Mixed | Prospective | Cohort | Clinical | High | 5 | 26 |
| Baldwin 2021 | Mixed | Mixed | Mixed | Retrospective | Cohort | Classification | Low | 20 | 556 |

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|---|---|---|---|---|---|---|---|---|---|
| Baumgartner 2021 | Hand | Closed | ORIF | Retrospective | Cohort | Clinical | Moderate | 0 | 79 |
| Bennur 2021 | Wrist | Closed | Mixed | Prospective | Cohort | Clinical | High | 6 | 80 |
| Chul-Ho 2021 | Hand | Closed | K-wire | Retrospective | Cohort | Unknown | Moderate | 1 | 25 |
| Feldman 2021 | Hand | Mixed | Mixed | Retrospective | Cohort | Clinical | Moderate | 7 | 107 |
| Galivanche 2021 | Wrist | Mixed | ORIF | Retrospective | Cohort | Clinical | Low | 383 | 16990 |
| Gumussuyu 2021 | Hand | Closed | K-wire | Retrospective | Cohort | Clinical | Moderate | 1 | 21 |
| Johnson 2021 | Mixed | Open | Mixed | Retrospective | Cohort | Clinical | High | 2 | 89 |
| Jokhio 2021 | Wrist | Closed | ORIF | Prospective | Cohort | Clinical | High | 1 | 200 |
| Langridge 2021 | Hand | Closed | Mixed | Retrospective | Cohort | Clinical | Moderate | 3 | 49 |
| Levy 2021 | Mixed | Mixed | K-wire | Retrospective | Cohort | Clinical | Moderate | 0 | 90 |
| Liu 2021 | Hand | Open | STR | Retrospective | Cohort | Clinical | Moderate | 5 | 24 |
| Liu Q 2021 | Hand | Open | STR | Retrospective | Cohort | Unknown | High | 5 | 24 |
| Meaike 2021 | Wrist | Closed | ORIF | Retrospective | Cohort | Unknown | High | 0 | 115 |
| Raza 2021 | Wrist | Closed | K-wire | Retrospective | Cohort | Unknown | High | 5 | 50 |
| Shakoor 2021 | Hand | Closed | ORIF | Prospective | Cohort | Unknown | High | 3 | 16 |
| Sim 2021 | Mixed | Open | Mixed | Retrospective | Cohort | Clinical | Moderate | 3 | 232 |
| Starr 2021 | Hand | Open | Mixed | Retrospective | Cohort | Clinical | Low | 2 | 27 |
| Thakur 2021 | Wrist | Closed | ORIF | Prospective | Cohort | Unknown | High | 0 | 21 |
| Wang 2021 | Hand | Mixed | STR | Retrospective | Cohort | Unknown | Moderate | 0 | 6 |
| Wang 2021 | Wrist | Open | STR | Retrospective | Cohort | Clinical | High | 0 | 11 |
| Wei 2021 | Wrist | Mixed | Mixed | Retrospective | Cohort | Classification | Moderate | 57 | 39275 |
| Ahmad 2022 | Wrist | Closed | Mixed | Retrospective | Cohort | Clinical | Moderate | 6 | 190 |
| Constantine 2022 | Wrist | Mixed | Mixed | Retrospective | Cohort | Clinical | Moderate | 781 | 87169 |
| Hery 2022 | Hand | Open | Mixed | Prospective | Cohort | Classification | Moderate | 5 | 405 |
| Kadhum 2022 | Mixed | Open | STR | Retrospective | Cohort | Clinical | High | 7 | 151 |
| Li 2022 | Hand | Mixed | Mixed | Retrospective | Cohort | Clinical | High | 1 | 70 |
| Mahmood 2022 | Wrist | Closed | ORIF | Retrospective | Cohort | Clinical | Moderate | 456 | 132650 |

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|---|---|---|---|---|---|---|---|---|---|
| Michael 2022 | Wrist | Mixed | Ex-Fix | Prospective | Cohort | Clinical | Moderate | 3 | 32 |
| Rao 2022 | Hand | Open | STR | Retrospective | Cohort | Clinical | Moderate | 0 | 78 |
| Skochdopole 2022 | Wrist | Closed | ORIF | Retrospective | Cohort | Unknown | Moderate | 13 | 5894 |

# 10.7 Appendix 7. Characteristics of included case-control studies

| Author Year | Site | Type | Intervention | Study Type | Study Design | Infection Definition | Risk of Bias | SSI | Total |
|---|---|---|---|---|---|---|---|---|---|
| Bednar 2004 | Wrist | Closed | Ex-Fix | Retrospective | Case control | Clinical | High | 2 | 12 |
| Dwyer 2017 | Wrist | Closed | Mixed | Retrospective | Case control | Unknown | High | 6 | 25 |

# 10.8 Appendix 8. Characteristics of included case series

| Author Year | Site | Type | Intervention | Study Type | Study Design | Infection Definition | Risk of Bias | SSI | Total |
|---|---|---|---|---|---|---|---|---|---|
| Conolly 1973 | Hand | Mixed | Mixed | Retrospective | Case series | Clinical | High | 18 | 260 |
| Marshall 1978 | Hand | Open | STR | Retrospective | Case series | Unknown | High | 0 | 7 |
| Grundberg 1981 | Hand | Mixed | ORIF | Retrospective | Case series | Unknown | High | 0 | 21 |
| Adkison 1982 | Wrist | Mixed | Mixed | Retrospective | Case series | Clinical | High | 1 | 54 |
| Smith 1988 | Wrist | Closed | ORIF | Retrospective | Case series | Clinical | Moderate | 0 | 16 |
| Swanson 1991 | Hand | Closed | Mixed | Retrospective | Case series | Clinical | Moderate | 7 | 117 |
| Botte 1992 | Mixed | Closed | K-wire | Retrospective | Case series | Clinical | Moderate | 10 | 137 |
| Duncan 1993 | Hand | Closed | Mixed | Retrospective | Case series | Clinical | Moderate | 6 | 75 |
| Eglseder 1993 | Wrist | Mixed | Ex-Fix | Retrospective | Case series | Clinical | High | 0 | 19 |
| Starker 1995 | Hand | Open | K-wire | Prospective | Case series | Clinical | High | 0 | 68 |
| Hove 1997 | Wrist | Closed | Ex-Fix | Retrospective | Case series | Unknown | High | 1 | 29 |
| Lopes 1997 | Wrist | Closed | ORIF | Retrospective | Case series | Unknown | High | 1 | 19 |
| Ring 1997 | Wrist | Closed | ORIF | Prospective | Case series | Clinical | Moderate | 0 | 22 |
| Page 1998 | Hand | Open | ORIF | Retrospective | Case series | Clinical | Moderate | 3 | 82 |
| Bauze 1999 | Hand | Closed | ORIF | Retrospective | Case series | Clinical | Moderate | 2 | 10 |
| Ignacio 1999 | Wrist | Mixed | Ex-Fix | Prospective | Case series | Unknown | High | 5 | 25 |
| Stahl 2001 | Mixed | Open | K-wire | Retrospective | Case series | Clinical | Moderate | 13 | 236 |
| Bhat 2002 | Hand | Open | K-wire | Retrospective | Case series | Clinical | High | 11 | 120 |
| Akmaz 2003 | Wrist | Mixed | Ex-Fix | Retrospective | Case series | Clinical | High | 4 | 25 |
| Lee 2003 | Wrist | Closed | ORIF | Retrospective | Case series | Clinical | Moderate | 1 | 22 |
| Anderson 2004 | Wrist | Mixed | Ex-Fix | Retrospective | Case series | Clinical | Moderate | 9 | 24 |
| Gradl 2005 | Wrist | Closed | Ex-Fix | Prospective | Case series | Clinical | Low | 3 | 25 |
| Kömürcü 2005 | Wrist | Mixed | Ex-Fix | Retrospective | Case series | Clinical | Moderate | 4 | 24 |
| Bach 2006 | Hand | Open | ORIF | Retrospective | Case series | Clinical | Moderate | 0 | 10 |

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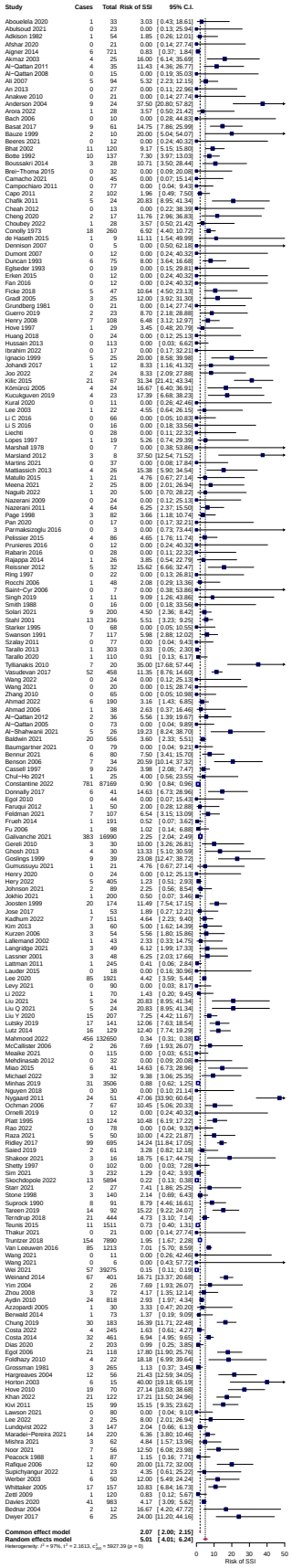
|---|---|---|---|---|---|---|---|---|---|
| Rocchi 2006 | Hand | Closed | K-wire | Retrospective | Case series | Clinical | Moderate | 1 | 48 |
| Saint-Cyr 2006 | Hand | Open | ORIF | Retrospective | Case series | Clinical | Moderate | 0 | 7 |
| Ali 2007 | Hand | Mixed | Mixed | Prospective | Case series | Clinical | High | 5 | 94 |
| Dennison 2007 | Wrist | Closed | ORIF | Retrospective | Case series | Clinical | Moderate | 0 | 5 |
| Dumont 2007 | Hand | Closed | ORIF | Retrospective | Case series | Clinical | High | 0 | 12 |
| Al-Qattan 2008 | Hand | Closed | ORIF | Prospective | Case series | Clinical | Moderate | 0 | 15 |
| Henry 2008 | Hand | Mixed | STR | Retrospective | Case series | Clinical | Moderate | 7 | 108 |
| Nazerani 2009 | Hand | Open | STR | Retrospective | Case series | Unknown | Moderate | 0 | 24 |
| Anakwe 2010 | Wrist | Closed | ORIF | Prospective | Case series | Clinical | Moderate | 0 | 21 |
| Tyllianakis 2010 | Wrist | Open | Ex-Fix | Retrospective | Case series | Clinical | Moderate | 7 | 20 |
| Zhang 2010 | Hand | Closed | K-wire | Prospective | Case series | Clinical | Low | 0 | 65 |
| Al-Qattan 2011 | Hand | Closed | K-wire | Retrospective | Case series | Clinical | Low | 4 | 35 |
| Campochiaro 2011 | Wrist | Closed | Mixed | Retrospective | Case series | Clinical | Moderate | 0 | 77 |
| Capo 2011 | Hand | Open | Mixed | Retrospective | Case series | Clinical | Moderate | 2 | 102 |
| Chafik 2011 | Hand | Closed | K-wire | Prospective | Case series | Clinical | High | 5 | 24 |
| Nazerani 2011 | Hand | Mixed | STR | Retrospective | Case series | Unknown | High | 4 | 64 |
| Szalay 2011 | Hand | Closed | ORIF | Retrospective | Case series | Clinical | Low | 0 | 77 |
| Cheah 2012 | Hand | Closed | ORIF | Retrospective | Case series | Clinical | Moderate | 0 | 13 |
| Marsland 2012 | Hand | Closed | Ex-Fix | Retrospective | Case series | Clinical | High | 3 | 8 |
| Reissner 2012 | Hand | Closed | K-wire | Retrospective | Case series | Clinical | Low | 5 | 32 |
| An 2013 | Hand | Closed | K-wire | Retrospective | Case series | Clinical | High | 0 | 27 |
| Hussain 2013 | Hand | Open | STR | Retrospective | Case series | Unknown | High | 0 | 113 |
| Mattiassich 2013 | Hand | Closed | K-wire | Retrospective | Case series | Unknown | Moderate | 4 | 26 |
| Tarallo 2013 | Wrist | Closed | ORIF | Retrospective | Case series | Clinical | Moderate | 1 | 303 |
| Aigner 2014 | Wrist | Mixed | Mixed | Retrospective | Case series | Clinical | Moderate | 6 | 721 |
| Boussakri 2014 | Hand | Closed | K-wire | Retrospective | Case series | Clinical | High | 3 | 28 |
| Rajappa 2014 | Mixed | Open | STR | Prospective | Case series | Clinical | Moderate | 1 | 26 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Brei-Thoma 2015 | Hand | Closed | ORIF | Retrospective | Case series | Clinical | Moderate | 0 | 32 |
| de Haseth 2015 | Hand | Closed | K-wire | Retrospective | Case series | Clinical | Moderate | 1 | 9 |
| Erken 2015 | Hand | Open | STR | Retrospective | Case series | Unknown | Moderate | 0 | 12 |
| Kilic 2015 | Hand | Open | STR | Retrospective | Case series | Clinical | High | 21 | 67 |
| Matullo 2015 | Wrist | Mixed | ORIF | Retrospective | Case series | Unknown | Moderate | 1 | 21 |
| Pelissier 2015 | Hand | Closed | K-wire | Retrospective | Case series | Clinical | Moderate | 4 | 86 |
| Fan 2016 | Wrist | Mixed | ORIF | Retrospective | Case series | Unknown | High | 0 | 12 |
| Li C 2016 | Hand | Closed | ORIF | Prospective | Case series | Unknown | Low | 0 | 66 |
| Li S 2016 | Hand | Mixed | K-wire | Retrospective | Case series | Unknown | Moderate | 0 | 16 |
| Parmaksizoglu 2016 | Hand | Open | STR | Retrospective | Case series | Clinical | Moderate | 0 | 3 |
| Prunieres 2016 | Hand | Open | K-wire | Prospective | Case series | Clinical | High | 0 | 12 |
| Rabarin 2016 | Hand | Open | STR | Retrospective | Case series | Clinical | Moderate | 0 | 28 |
| Johandi 2017 | Wrist | Mixed | STR | Retrospective | Case series | Unknown | Moderate | 1 | 12 |
| Vasudevan 2017 | Wrist | Closed | K-wire | Retrospective | Case series | Clinical | Moderate | 52 | 458 |
| Ficke 2018 | Wrist | Mixed | ORIF | Retrospective | Case series | Clinical | Moderate | 5 | 47 |
| Huang 2018 | Wrist | Mixed | ORIF | Retrospective | Case series | Unknown | Low | 0 | 24 |
| Guerro 2019 | Hand | Mixed | ORIF | Retrospective | Case series | Clinical | Low | 2 | 23 |
| Kucukguven 2019 | Hand | Open | STR | Prospective | Case series | Unknown | Low | 4 | 23 |
| Singh 2019 | Hand | Closed | ORIF | Retrospective | Case series | Clinical | Moderate | 1 | 11 |
| Abouelela 2020 | Hand | Closed | K-wire | Retrospective | Case series | Clinical | Moderate | 1 | 33 |
| Afshar 2020 | Hand | Closed | ORIF | Prospective | Case series | Clinical | Low | 0 | 21 |
| Cheng 2020 | Wrist | Closed | K-wire | Retrospective | Case series | Clinical | Low | 2 | 17 |
| Kural 2020 | Hand | Closed | Mixed | Retrospective | Case series | Clinical | High | 0 | 11 |
| Pan 2020 | Hand | Open | STR | Prospective | Case series | Clinical | High | 0 | 17 |
| Tarallo 2020 | Wrist | Closed | ORIF | Retrospective | Case series | Clinical | Low | 1 | 110 |
| Abulsoud 2021 | Hand | Closed | K-wire | Prospective | Case series | Unknown | Moderate | 0 | 23 |
| Beeres 2021 | Wrist | Mixed | ORIF | Retrospective | Case series | Clinical | High | 0 | 12 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Camacho 2021 | Hand | Mixed | ORIF | Retrospective | Case series | Unknown | High | 0 | 45 |
| Martins 2021 | Hand | Open | STR | Retrospective | Case series | Unknown | High | 0 | 37 |
| Meena 2021 | Wrist | Mixed | ORIF | Retrospective | Case series | Clinical | High | 2 | 25 |
| Solari 2021 | Hand | Closed | K-wire | Retrospective | Case series | Clinical | Low | 9 | 200 |
| Wang 2021 | Hand | Closed | K-wire | Retrospective | Case series | Unknown | Low | 0 | 20 |
| Wang 2021 | Hand | Closed | K-wire | Retrospective | Case series | Unknown | High | 0 | 20 |
| Arora 2022 | Wrist | Closed | ORIF | Retrospective | Case series | Clinical | Moderate | 1 | 28 |
| Choubey 2022 | Wrist | Closed | ORIF | Prospective | Case series | Clinical | Moderate | 1 | 28 |
| Ibrahim 2022 | Mixed | Open | Mixed | Retrospective | Case series | Clinical | High | 0 | 17 |
| Joo 2022 | Wrist | Open | ORIF | Retrospective | Case series | Clinical | High | 2 | 24 |
| Liechti 2022 | Wrist | Closed | ORIF | Prospective | Case series | Clinical | Low | 0 | 28 |
| Naguib 2022 | Hand | Closed | Ex-Fix | Prospective | Case series | Clinical | Low | 1 | 20 |
| Wang 2022 | Hand | Open | STR | Retrospective | Case series | Clinical | Moderate | 0 | 24 |

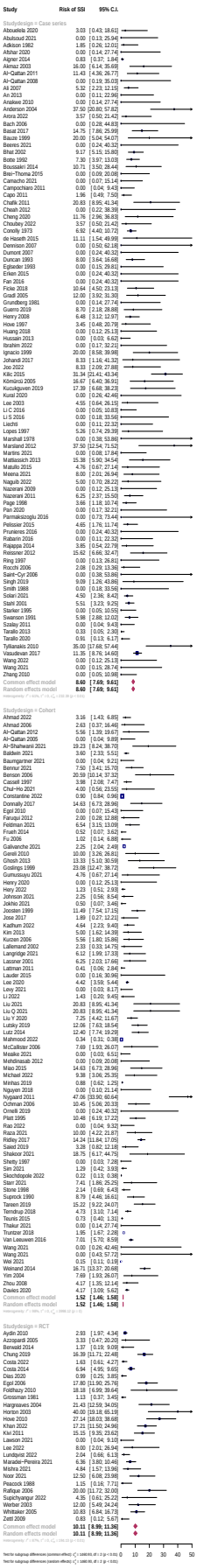
# 10.9 Appendix 9. Meta-analysis of all included studies

*Please zoom to 350% for detail*



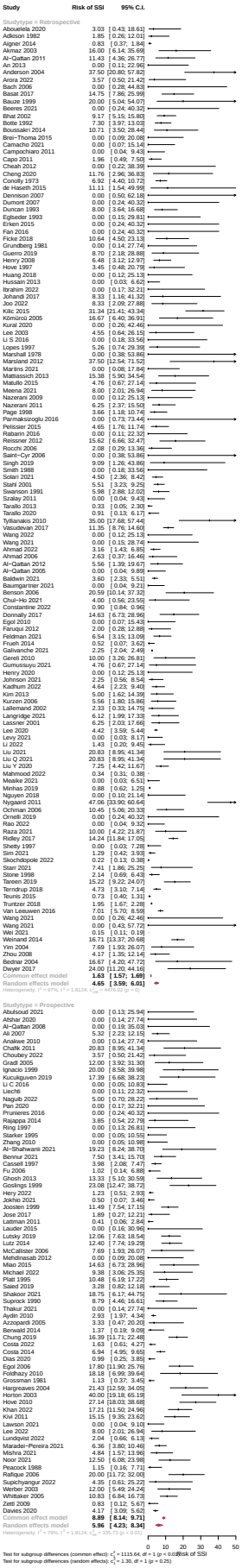
# 10.10 Appendix 10. Meta-analysis: subgroup analysis by study design

*Please zoom to 350% for detail*



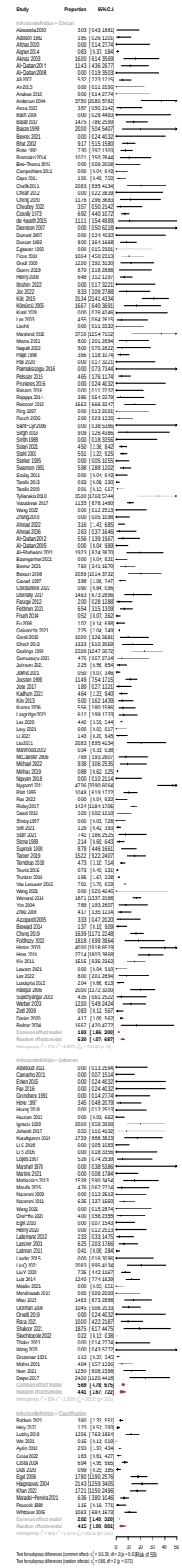
# 10.11 Appendix 11. Meta-analysis: subgroup analysis by study type

*Please zoom to 350% for detail*



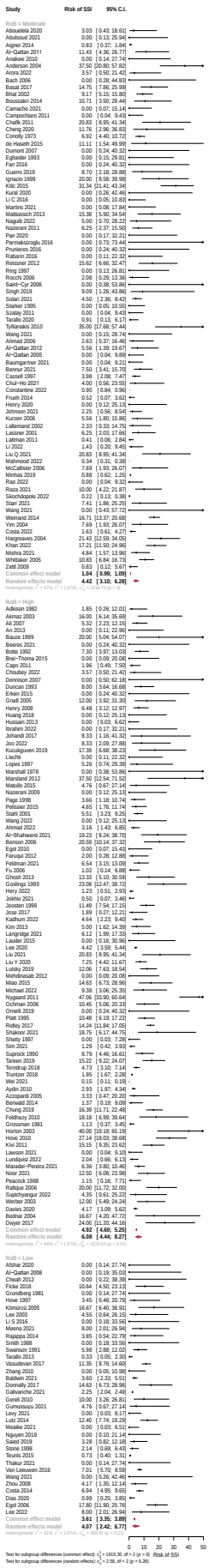
# 10.12 Appendix 12. Meta-analysis: subgroup analysis by infection definition

*Please zoom to 350% for detail*



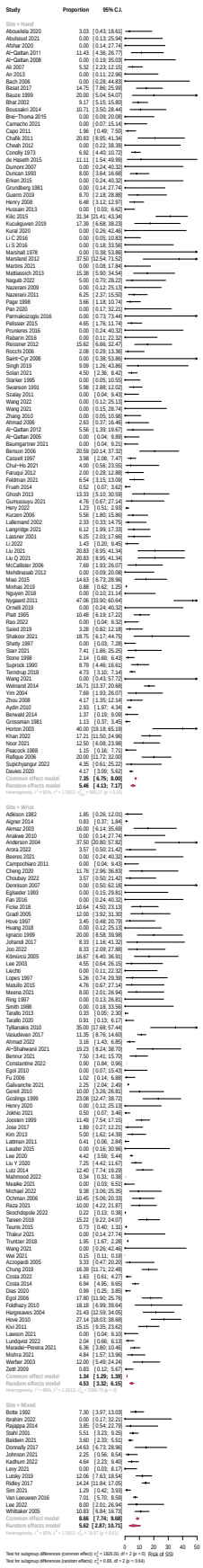
# 10.13 Appendix 13. Meta-analysis: subgroup analysis by risk of bias

*Please zoom to 350% for detail*



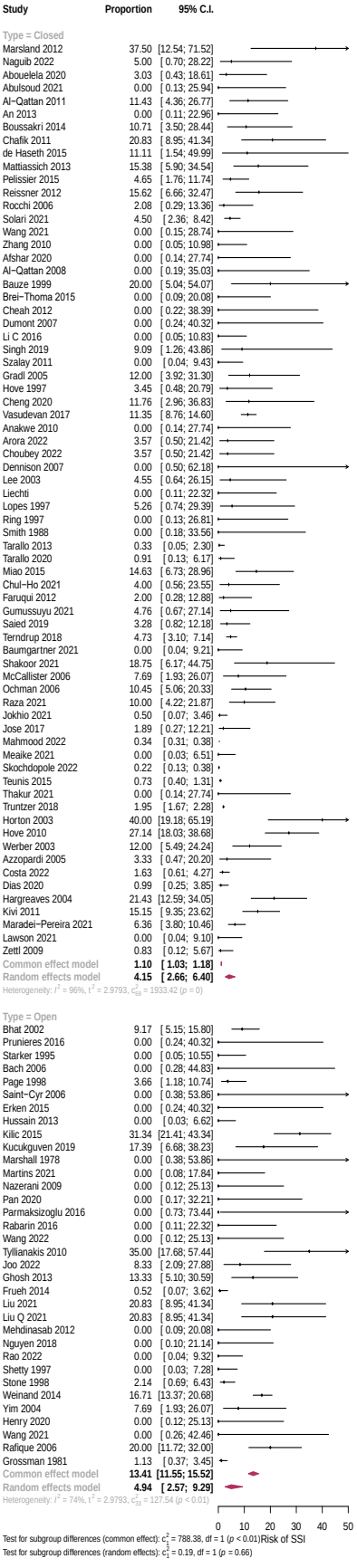
# 10.14 Appendix 14. Meta-analysis: subgroup analysis by injury site

*Please zoom to 350% for detail*



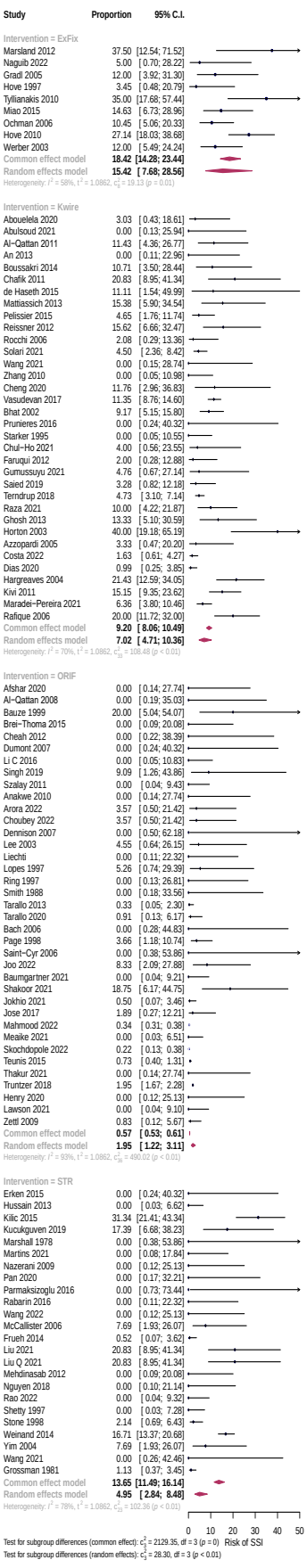
# 10.15 Appendix 15. Meta-analysis: subgroup analysis by injury type

*Please zoom to 350% for detail*



# 10.16 Appendix 16. Meta-analysis: subgroup analysis by intervention

*Please zoom to 350% for detail*



# 10.17 Appendix 17. Meta-regression output

```
> #Meta-regression
>
> metareg.moderator=rma(yi, vi, data=ies.logit, mods=~Site)
Warning message:
Studies with NAs omitted from model fitting.
> metareg.moderator=rma(yi, vi, data=ies.logit, mods=~RoB)
Warning message:
Studies with NAs omitted from model fitting.
> metareg.moderator=rma(yi, vi, data=ies.logit, mods=~Intervention)
Warning message:
Studies with NAs omitted from model fitting.
> metareg.moderator=rma(yi, vi, data=ies.logit, mods=~Studytype)
Warning message:
Studies with NAs omitted from model fitting.
> metareg.moderator=rma(yi, vi, data=ies.logit, mods=~Studydesign)
Warning message:
Studies with NAs omitted from model fitting.
> metareg.moderator=rma(yi, vi, data=ies.logit, mods=~InfectionDefinition)
Warning message:
Studies with NAs omitted from model fitting.
>
> metareg.moderators=rma(yi, vi, data=ies.logit,
+
mods=~Site+Type+Intervention+RoB+Studytype+InfectionDefinition+Studydesign)
Warning message:
Studies with NAs omitted from model fitting.
>
> metareg.moderators=rma(yi, vi, data=ies.logit,
+                    mods=~Studydesign)
Warning message:
Studies with NAs omitted from model fitting.
>
```

```
> metareg.moderators$beta <- exp(metareg.moderators$beta)
> metareg.moderators$ci.ub <- exp(metareg.moderators$ci.ub)
> metareg.moderators$ci.lb <- exp(metareg.moderators$ci.lb)
>
> print(metareg.moderators) #oddsratios

Mixed-Effects Model (k = 146; tau^2 estimator: REML)

tau^2 (estimated amount of residual heterogeneity):     1.1878 (SE = 0.1767)
tau (square root of estimated tau^2 value):             1.0899
I^2 (residual heterogeneity / unaccounted variability): 95.48%
H^2 (unaccounted variability / sampling variability):   22.12
R^2 (amount of heterogeneity accounted for):            5.51%

Test for Residual Heterogeneity:
QE(df = 142) = 4357.1378, p-val < .0001

Test of Moderators (coefficients 2:4):
QM(df = 3) = 9.0521, p-val = 0.0286

Model Results:

                    estimate      se     zval    pval   ci.lb   ci.ub
intrcpt                0.2582  0.8873  -1.5257  0.1271  0.0454  1.4701
StudydesignCase series 0.3396  0.9047  -1.1937  0.2326  0.0577  2.0002
StudydesignCohort      0.1929  0.8997  -1.8292  0.0674  0.0331  1.1248  .
StudydesignRCT         0.3039  0.9186  -1.2966  0.1948  0.0502  1.8392

---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

>
> vif(metareg.moderators) #colinearity

StudydesignCase series  StudydesignCohort  StudydesignRCT
```

```
          17.5006          19.4010        12.1914

>
> (metareg.moderators)

Mixed-Effects Model (k = 146; tau^2 estimator: REML)

tau^2 (estimated amount of residual heterogeneity):     1.1878 (SE = 0.1767)
tau (square root of estimated tau^2 value):             1.0899
I^2 (residual heterogeneity / unaccounted variability): 95.48%
H^2 (unaccounted variability / sampling variability):   22.12
R^2 (amount of heterogeneity accounted for):            5.51%

Test for Residual Heterogeneity:
QE(df = 142) = 4357.1378, p-val < .0001

Test of Moderators (coefficients 2:4):
QM(df = 3) = 9.0521, p-val = 0.0286

Model Results:

                    estimate      se     zval    pval   ci.lb   ci.ub
intrcpt                0.2582  0.8873  -1.5257  0.1271  0.0454  1.4701
StudydesignCase series 0.3396  0.9047  -1.1937  0.2326  0.0577  2.0002
StudydesignCohort      0.1929  0.8997  -1.8292  0.0674  0.0331  1.1248  .
StudydesignRCT         0.3039  0.9186  -1.2966  0.1948  0.0502  1.8392

---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

>
> permutest(metareg.moderators) #permutation
Running 1000 iterations for an approximate permutation test.
  |==================================================| 100%
elapsed=38s
```

Test of Moderators (coefficients 2:4):[1]
QM(df = 3) = 9.0521, p-val = 0.0340

Model Results:

| | estimate | se | zval | pval[1] | ci.lb | ci.ub | |
|---|---|---|---|---|---|---|---|
| intrcpt | 0.2582 | 0.8873 | -1.5257 | 0.9790 | 0.0454 | 1.4701 | |
| StudydesignCase series | 0.3396 | 0.9047 | -1.1937 | 0.2010 | 0.0577 | 2.0002 | |
| StudydesignCohort | 0.1929 | 0.8997 | -1.8292 | 0.0550 | 0.0331 | 1.1248 | . |
| StudydesignRCT | 0.3039 | 0.9186 | -1.2966 | 0.1700 | 0.0502 | 1.8392 | |

---
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

1) p-values based on permutation testing

> print(metareg.moderators)

Mixed-Effects Model (k = 146; tau^2 estimator: REML)

tau^2 (estimated amount of residual heterogeneity): 1.1878 (SE = 0.1767)
tau (square root of estimated tau^2 value): 1.0899
I^2 (residual heterogeneity / unaccounted variability): 95.48%
H^2 (unaccounted variability / sampling variability): 22.12
R^2 (amount of heterogeneity accounted for): 5.51%

Test for Residual Heterogeneity:
QE(df = 142) = 4357.1378, p-val < .0001

Test of Moderators (coefficients 2:4):
QM(df = 3) = 9.0521, p-val = 0.0286

Model Results:

```
                    estimate      se     zval    pval   ci.lb   ci.ub
intrcpt                0.2582  0.8873  -1.5257  0.1271  0.0454  1.4701
StudydesignCase series    0.3396  0.9047  -1.1937  0.2326  0.0577  2.0002
StudydesignCohort         0.1929  0.8997  -1.8292  0.0674  0.0331  1.1248  .
StudydesignRCT            0.3039  0.9186  -1.2966  0.1948  0.0502  1.8392

---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

> metareg.moderator=rma(yi, vi, data=ies.logit, mods=~Site)
Warning message:
Studies with NAs omitted from model fitting.
> metareg.moderator=rma(yi, vi, data=ies.logit, mods=~RoB)
Warning message:
Studies with NAs omitted from model fitting.
> metareg.moderator=rma(yi, vi, data=ies.logit, mods=~Intervention)
Warning message:
Studies with NAs omitted from model fitting.
> metareg.moderator=rma(yi, vi, data=ies.logit, mods=~Studytype)
Warning message:
Studies with NAs omitted from model fitting.
> metareg.moderator=rma(yi, vi, data=ies.logit, mods=~Studydesign)
Warning message:
Studies with NAs omitted from model fitting.
> metareg.moderator=rma(yi, vi, data=ies.logit, mods=~InfectionDefinition)
Warning message:
Studies with NAs omitted from model fitting.
> metareg.moderators=rma(yi, vi, data=ies.logit,
+
mods=~Site+Type+Intervention+RoB+Studytype+InfectionDefinition+Studydesign)
Warning message:
Studies with NAs omitted from model fitting.
> metareg.moderators$beta <- exp(metareg.moderators$beta)
> metareg.moderators$ci.ub <- exp(metareg.moderators$ci.ub)
> metareg.moderators$ci.lb <- exp(metareg.moderators$ci.lb)
```

```
>
> print(metareg.moderators) #oddsratios

Mixed-Effects Model (k = 146; tau^2 estimator: REML)

tau^2 (estimated amount of residual heterogeneity):     0.9027 (SE = 0.1489)
tau (square root of estimated tau^2 value):             0.9501
I^2 (residual heterogeneity / unaccounted variability): 89.49%
H^2 (unaccounted variability / sampling variability):   9.51
R^2 (amount of heterogeneity accounted for):            28.19%

Test for Residual Heterogeneity:
QE(df = 129) = 1289.4455, p-val < .0001

Test of Moderators (coefficients 2:17):
QM(df = 16) = 55.7220, p-val < .0001

Model Results:

                          estimate      se     zval    pval   ci.lb   ci.ub
intrcpt                     0.4016  0.9812  -0.9297  0.3525  0.0587  2.7479
SiteMixed                   0.8499  0.3549  -0.4582  0.6468  0.4240  1.7039
SiteWrist                   0.6754  0.2434  -1.6126  0.1068  0.4192  1.0882
TypeMixed                   1.3707  0.2493   1.2651  0.2058  0.8410  2.2341
TypeOpen                    1.4903  0.2919   1.3666  0.1717  0.8410  2.6409
InterventionKwire           0.5709  0.3654  -1.5341  0.1250  0.2789  1.1684
InterventionMixed           0.3172  0.3345  -3.4327  0.0006  0.1647  0.6110  ***
InterventionORIF            0.1942  0.3504  -4.6767  <.0001  0.0977  0.3860  ***
InterventionSTR             0.3481  0.4377  -2.4105  0.0159  0.1476  0.8210    *
RoBLow                      0.9715  0.2770  -0.1045  0.9167  0.5645  1.6718
RoBModerate                 0.7999  0.2229  -1.0017  0.3165  0.5168  1.2381
StudytypeRetrospective      0.8312  0.2583  -0.7157  0.4742  0.5010  1.3790
InfectionDefinitionClinical 2.1890  0.3647   2.1481  0.0317  1.0710  4.4741    *
InfectionDefinitionUnknown  2.2493  0.4276   1.8958  0.0580  0.9729  5.1999    .
StudydesignCase series      0.3059  0.8657  -1.3685  0.1712  0.0561  1.6687
```

StudydesignCohort 0.1870 0.8579 -1.9546 0.0506 0.0348 1.0046 .
StudydesignRCT 0.3385 0.9044 -1.1978 0.2310 0.0575 1.9923

---
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

>
> vif(metareg.moderators) #colinearity

SiteMixed SiteWrist TypeMixed TypeOpen InterventionKwire InterventionMixed InterventionORIF InterventionSTR RoBLow RoBModerate StudytypeRetrospective InfectionDefinitionClinical InfectionDefinitionUnknown StudydesignCase series StudydesignCohort StudydesignRCT
1.3480 1.7483 1.5671 1.9617 2.9807 2.8728 2.0623 2.6545 1.2685 1.3417 1.8834 3.1246 2.8795 19.7996 21.9811 14.7955

>
> (metareg.moderators)

Mixed-Effects Model (k = 146; tau^2 estimator: REML)

tau^2 (estimated amount of residual heterogeneity): 0.9027 (SE = 0.1489)
tau (square root of estimated tau^2 value): 0.9501
I^2 (residual heterogeneity / unaccounted variability): 89.49%
H^2 (unaccounted variability / sampling variability): 9.51
R^2 (amount of heterogeneity accounted for): 28.19%

Test for Residual Heterogeneity:
QE(df = 129) = 1289.4455, p-val < .0001

Test of Moderators (coefficients 2:17):
QM(df = 16) = 55.7220, p-val < .0001

Model Results:

estimate se zval pval ci.lb ci.ub

```
intrcpt                  0.4016  0.9812  -0.9297  0.3525  0.0587  2.7479
SiteMixed                0.8499  0.3549  -0.4582  0.6468  0.4240  1.7039
SiteWrist                0.6754  0.2434  -1.6126  0.1068  0.4192  1.0882
TypeMixed                1.3707  0.2493   1.2651  0.2058  0.8410  2.2341
TypeOpen                 1.4903  0.2919   1.3666  0.1717  0.8410  2.6409
InterventionKwire        0.5709  0.3654  -1.5341  0.1250  0.2789  1.1684
InterventionMixed        0.3172  0.3345  -3.4327  0.0006  0.1647  0.6110  ***
InterventionORIF         0.1942  0.3504  -4.6767  <.0001  0.0977  0.3860  ***
InterventionSTR          0.3481  0.4377  -2.4105  0.0159  0.1476  0.8210    *
RoBLow                   0.9715  0.2770  -0.1045  0.9167  0.5645  1.6718
RoBModerate              0.7999  0.2229  -1.0017  0.3165  0.5168  1.2381
StudytypeRetrospective   0.8312  0.2583  -0.7157  0.4742  0.5010  1.3790
InfectionDefinitionClinical  2.1890  0.3647   2.1481  0.0317  1.0710  4.4741    *
InfectionDefinitionUnknown   2.2493  0.4276   1.8958  0.0580  0.9729  5.1999    .
StudydesignCase series   0.3059  0.8657  -1.3685  0.1712  0.0561  1.6687
StudydesignCohort        0.1870  0.8579  -1.9546  0.0506  0.0348  1.0046    .
StudydesignRCT           0.3385  0.9044  -1.1978  0.2310  0.0575  1.9923

---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

>
> permutest(metareg.moderators) #permutation
Running 1000 iterations for an approximate permutation test.
  |==============================================| 100%
elapsed=48s

Test of Moderators (coefficients 2:17):[1]
QM(df = 16) = 55.7220, p-val = 0.0010

Model Results:

                    estimate      se     zval    pval[1]   ci.lb   ci.ub
intrcpt                0.4016  0.9812  -0.9297  0.9610   0.0587  2.7479
SiteMixed              0.8499  0.3549  -0.4582  0.6350   0.4240  1.7039
```

```
SiteWrist                  0.6754  0.2434  -1.6126  0.1010   0.4192  1.0882
TypeMixed                  1.3707  0.2493   1.2651  0.2050   0.8410  2.2341
TypeOpen                   1.4903  0.2919   1.3666  0.1850   0.8410  2.6409
InterventionKwire          0.5709  0.3654  -1.5341  0.1270   0.2789  1.1684
InterventionMixed          0.3172  0.3345  -3.4327  0.0040   0.1647  0.6110   **
InterventionORIF           0.1942  0.3504  -4.6767  0.0010   0.0977  0.3860  ***
InterventionSTR            0.3481  0.4377  -2.4105  0.0240   0.1476  0.8210    *
RoBLow                     0.9715  0.2770  -0.1045  0.9260   0.5645  1.6718
RoBModerate                0.7999  0.2229  -1.0017  0.3290   0.5168  1.2381
StudytypeRetrospective     0.8312  0.2583  -0.7157  0.4870   0.5010  1.3790
InfectionDefinitionClinical  2.1890  0.3647   2.1481  0.0280   1.0710  4.4741    *
InfectionDefinitionUnknown   2.2493  0.4276   1.8958  0.0520   0.9729  5.1999    .
StudydesignCase series     0.3059  0.8657  -1.3685  0.1510   0.0561  1.6687
StudydesignCohort          0.1870  0.8579  -1.9546  0.0520   0.0348  1.0046    .
StudydesignRCT             0.3385  0.9044  -1.1978  0.2170   0.0575  1.9923

---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

1) p-values based on permutation testing

> print(metareg.moderators)

Mixed-Effects Model (k = 146; tau^2 estimator: REML)

tau^2 (estimated amount of residual heterogeneity):     0.9027 (SE = 0.1489)
tau (square root of estimated tau^2 value):             0.9501
I^2 (residual heterogeneity / unaccounted variability): 89.49%
H^2 (unaccounted variability / sampling variability):   9.51
R^2 (amount of heterogeneity accounted for):            28.19%

Test for Residual Heterogeneity:
QE(df = 129) = 1289.4455, p-val < .0001

Test of Moderators (coefficients 2:17):
```

QM(df = 16) = 55.7220, p-val < .0001

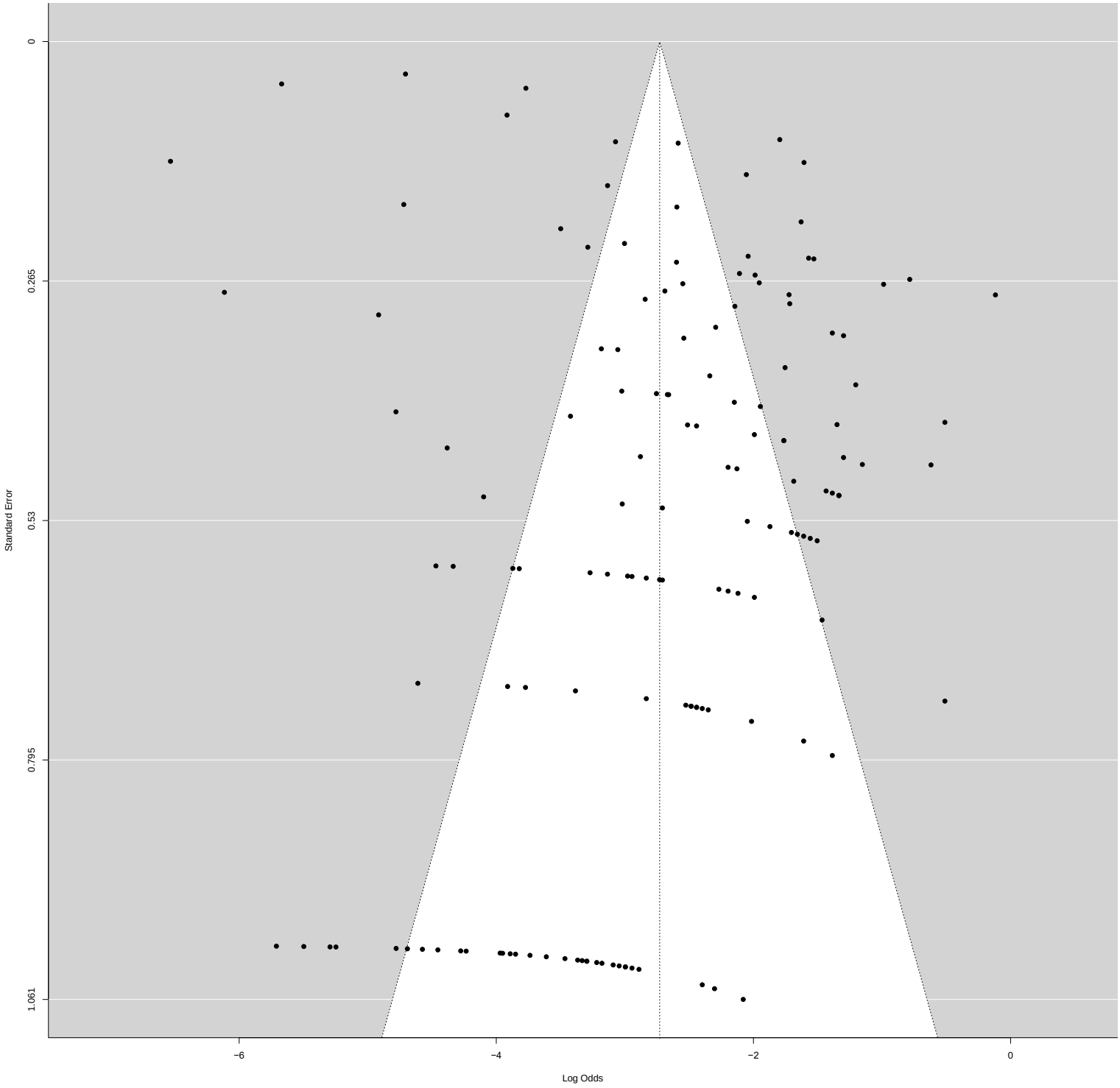
Model Results:

| | estimate | se | zval | pval | ci.lb | ci.ub | |
|---|---|---|---|---|---|---|---|
| intrcpt | 0.4016 | 0.9812 | -0.9297 | 0.3525 | 0.0587 | 2.7479 | |
| SiteMixed | 0.8499 | 0.3549 | -0.4582 | 0.6468 | 0.4240 | 1.7039 | |
| SiteWrist | 0.6754 | 0.2434 | -1.6126 | 0.1068 | 0.4192 | 1.0882 | |
| TypeMixed | 1.3707 | 0.2493 | 1.2651 | 0.2058 | 0.8410 | 2.2341 | |
| TypeOpen | 1.4903 | 0.2919 | 1.3666 | 0.1717 | 0.8410 | 2.6409 | |
| InterventionKwire | 0.5709 | 0.3654 | -1.5341 | 0.1250 | 0.2789 | 1.1684 | |
| InterventionMixed | 0.3172 | 0.3345 | -3.4327 | 0.0006 | 0.1647 | 0.6110 | *** |
| InterventionORIF | 0.1942 | 0.3504 | -4.6767 | <.0001 | 0.0977 | 0.3860 | *** |
| InterventionSTR | 0.3481 | 0.4377 | -2.4105 | 0.0159 | 0.1476 | 0.8210 | * |
| RoBLow | 0.9715 | 0.2770 | -0.1045 | 0.9167 | 0.5645 | 1.6718 | |
| RoBModerate | 0.7999 | 0.2229 | -1.0017 | 0.3165 | 0.5168 | 1.2381 | |
| StudytypeRetrospective | 0.8312 | 0.2583 | -0.7157 | 0.4742 | 0.5010 | 1.3790 | |
| InfectionDefinitionClinical | 2.1890 | 0.3647 | 2.1481 | 0.0317 | 1.0710 | 4.4741 | * |
| InfectionDefinitionUnknown | 2.2493 | 0.4276 | 1.8958 | 0.0580 | 0.9729 | 5.1999 | . |
| StudydesignCase series | 0.3059 | 0.8657 | -1.3685 | 0.1712 | 0.0561 | 1.6687 | |
| StudydesignCohort | 0.1870 | 0.8579 | -1.9546 | 0.0506 | 0.0348 | 1.0046 | . |
| StudydesignRCT | 0.3385 | 0.9044 | -1.1978 | 0.2310 | 0.0575 | 1.9923 | |

---

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

# 10.18 Appendix 18. Meta-analysis: funnel plot



# 10.19 Appendix 19. Read codes: hand trauma cohort

| Concept | Concept name |
|---|---|
| 4051298 | Traumatic amputation, through wrist |
| 45500683 | Closed traumatic dislocation other carpal joint |
| 45424151 | Open division wrist ligament NOS |
| 45493795 | Other symptoms in proximal interphalangeal joint of finger |
| 4062229 | Closed injury, common digital nerve |
| 45427435 | Traumatic amputation, through wrist |
| 45430913 | [X]Traumatic amputation of two or more fingers alone (complete)(partial) |
| 45490815 | Injury of unspecified blood vessel at wrist and hand level |
| 45494225 | Closed injury, common digital nerve |
| 45480885 | Other closed traumatic dislocation of wrist |
| 45471090 | [X]Crushing injury of other and unspecified parts of wrist and hand |
| 4062230 | Open injury, common digital nerve |
| 45430775 | Traumatic amputation of arm and hand NOS |
| 4050550 | Open injury, digital artery |
| 45510771 | Injury of unspecified muscle and tendon at wrist and hand level |
| 45497490 | Injury of extensor muscle and tendon of other finger(s) at forearm level |
| 45514134 | Open injury, digital artery |
| 45520775 | Open injury, common digital nerve |
| 45474180 | Open division finger ligament NOS |
| 4052992 | Degloving injury hand, dorsum |
| 45447334 | Closed injury, digital vein |
| 4050380 | Degloving injury, finger, multiple |
| 45454027 | Superficial injury of wrist NOS, infected |
| 45480886 | Closed traumatic subluxation of the wrist, unspecified |
| 45430772 | Degloving injury hand, dorsum |
| 4055589 | Closed injury of digital vein |
| 45460696 | Degloving injury, finger, multiple |
| 45457343 | Hand dislocation NOS |
| 45484141 | Open fracture of middle or proximal phalanx or phalanges, unspecified part |

| | |
|---|---|
| 45424148 | Complete tear ligament finger NOS |
| 45510760 | Open injury, digital nerve, multiple |
| 45427369 | Open traumatic dislocation of finger, unspecified |
| 45464143 | Complete tear wrist or hand NOS |
| 4059101 | Open injury, digital nerve, multiple |
| 45497539 | [X]Injury of unspecified nerve at wrist and hand level |
| 45504140 | Injury of flexor muscle and tendon of other finger(s) at forearm level |
| 45437313 | Open fracture lunate |
| 45427430 | Partial division flexor tendon wrist |
| 45490798 | Partial division flexor tendon hand |
| 4051154 | Partial division flexor tendon wrist |
| 45487471 | Open fracture trapezium |
| 442765 | Open fracture of trapezium of wrist |
| 45443931 | Open fracture finger middle phalanx, base |
| 73616 | Open fracture of lunate bone of wrist |
| 45430734 | Closed traumatic dislocation of wrist not otherwise specified |
| 4015489 | Open fracture finger middle phalanx, base |
| 4050229 | Partial division flexor tendon hand |
| 45500812 | Closed injury, digital nerve in finger |
| 4057344 | Contusion wrist, volar |
| 45440757 | Closed crush injury wrist, dorsum |
| 4057019 | Closed injury, digital nerve in finger |
| 45424191 | Traumatic amputation of wrist and hand, level unspecified |
| 45444015 | Complete division, both flexor tendons |
| 4051898 | Closed crush injury wrist, dorsum |
| 4052670 | Contusion wrist, dorsum |
| 45424222 | Contusion wrist, volar |
| 45470997 | Contusion wrist, dorsum |
| 45490803 | Traumatic amputation, finger, through proximal interphalangeal joint |
| 45474140 | Open multiple fractures of hand bones |
| 434184 | Multiple open fractures of hand bones |
| 4014518 | Rupture wrist flexors |

| | |
|---|---|
| 45460663 | Rupture wrist flexors |
| 4002799 | Dislocation of tendon, wrist or hand |
| 4053126 | Traumatic amputation, finger, through proximal interphalangeal joint |
| 45470921 | Complete tear wrist ligament NOS |
| 45470657 | Dislocation of tendon, wrist or hand |
| 4012304 | Open fracture finger middle phalanx, shaft |
| 45490814 | Digital blood vessel injury |
| 194209 | Digital blood vessel injury |
| 45514155 | Open crush injury hand, palm |
| 45477496 | Closed fracture finger middle phalanx, multiple |
| 4010532 | Closed fracture finger middle phalanx, multiple |
| 45424109 | Open fracture finger middle phalanx, shaft |
| 45453969 | Complete tear wrist ligament |
| 4059551 | Open crush injury hand, palm |
| 45500668 | Open fracture finger distal phalanx, shaft |
| 4056297 | Traumatic amputation fingertip, type 2 |
| 4009450 | Open fracture finger metacarpal base |
| 45490804 | Traumatic amputation finger tip, type 2 (pulp and nail loss) |
| 4015965 | Open fracture finger distal phalanx, shaft |
| 45443929 | Open fracture finger metacarpal base |
| 4009594 | Closed fracture finger distal phalanx, multiple |
| 4057478 | Closed crush injury hand, palm |
| 45464107 | Closed fracture finger distal phalanx, multiple |
| 45470882 | Open fracture finger metacarpal head |
| 45514126 | Traumatic amputation, finger, through distal interphalangeal joint |
| 45430819 | Closed crush injury hand, palm |
| 4009451 | Open fracture finger metacarpal head |
| 79957 | Traumatic amputation of finger with complication |
| 4051294 | Traumatic amputation, finger, through distal interphalangeal joint |
| 4009597 | Open fracture finger proximal phalanx, shaft |
| 4050387 | Traumatic amputation fingertip, type 1 |
| 45427433 | Traumatic amputation of finger with complication |

| | |
|---|---|
| 45517398 | Open fracture finger proximal phalanx, shaft |
| 45470966 | Traumatic amputation finger tip, type 1 (pulp only involved) |
| 4050222 | Complete division flexor tendon wrist |
| 45460637 | Closed traumatic subluxation of the wrist |
| 45487543 | Complete division flexor tendon wrist |
| 45514045 | Open fracture triquetral |
| 45494158 | Degloving injury, finger unspecified |
| 76838 | Open fracture of triquetral bone of wrist |
| 45523986 | Open wound of fingernail |
| 45510640 | Open division wrist ligament |
| 4059434 | Open crush injury hand, dorsum |
| 45470925 | Rupture wrist extensors |
| 45474333 | [X]Contusion of other parts of wrist and hand |
| 4014383 | Open division wrist ligament |
| 4016828 | Rupture wrist extensors |
| 45474249 | Open crush injury hand, dorsum |
| 45500701 | Open fracture dislocation wrist |
| 4015062 | Open fracture dislocation wrist |
| 438004 | Open fracture of hamate bone of wrist |
| 45524109 | [X]Sprain and strain of other and unspecified parts of wrist and hand |
| 45477490 | Open fracture hamate |
| 4012728 | Closed traumatic subluxation of wrist |
| 45447237 | Wrist fracture - open |
| 4019055 | Complete tear of wrist ligament |
| 45454026 | Splinter of wrist, without major open wound |
| 4058223 | Splinter of wrist, without major open wound |
| 45430754 | Open division finger ligament |
| 45440653 | Closed traumatic dislocation of wrist |
| 45490797 | Complete division flexor tendon hand |
| 45447242 | Open fracture finger proximal phalanx, base |
| 4015487 | Open fracture finger proximal phalanx, base |
| 4002798 | Subluxation of tendon, wrist or hand |

| | |
|---|---|
| 45520411 | Subluxation of tendon, wrist or hand |
| 45494157 | Open wound of finger or thumb with complication |
| 4012429 | Open fracture finger distal phalanx, base |
| 4014387 | Open division finger ligament |
| 4344504 | Rupture of tendon of wrist and hand |
| 45520688 | Rupture tendon hand or wrist NOS |
| 45464108 | Open fracture finger distal phalanx, base |
| 45430717 | Closed fracture finger proximal phalanx, multiple |
| 45447327 | Traumatic amputation of arm and hand |
| 4009461 | Closed fracture finger proximal phalanx, multiple |
| 45507408 | Other elbow, forearm and wrist injuries |
| 45523913 | Closed fracture finger middle phalanx, neck |
| 45494071 | Multiple fractures of hand bones NOS |
| 4010531 | Closed fracture finger middle phalanx, neck |
| 4056162 | Complete division flexor tendon hand |
| 45514063 | Carpal dislocation NOS |
| 4015483 | Closed fracture finger middle phalanx, head |
| 45453919 | Closed fracture finger middle phalanx, head |
| 45484216 | Traumatic amputation of finger without mention of complication |
| 4084891 | Self-mutilation of hands |
| 45448017 | Self-mutilation of hands |
| 45440681 | Complete tear, wrist or hand |
| 45490838 | Splinter of hand, without major open wound or mention of infection |
| 4015361 | Open fracture finger metacarpal neck |
| 4052209 | Injury of ulnar artery at wrist and hand level |
| 45510720 | Open crush injury, finger, multiple |
| 45427351 | Open fracture finger metacarpal neck |
| 4018968 | Sprain finger, proximal interphalangeal joint, radial collateral ligament |
| 4057479 | Open crush injury, finger, multiple |
| 443231 | Traumatic amputation of arm and hand |
| 45514092 | Complete tear ligament finger |
| 45497429 | Injury of ulnar artery at wrist and hand level |

| | |
|---|---|
| 45450628 | Sprain finger, proximal interphalangeal joint, radial collateral ligament |
| 45503981 | Closed fracture finger metacarpal, multiple |
| 4010387 | Closed fracture finger metacarpal, multiple |
| 4019054 | Complete tear of ligament of wrist and/or hand |
| 4018628 | Complete tear of ligament of finger |
| 45487541 | Open wound of wrist, dorsal |
| 4050220 | Open wound of wrist, dorsal |
| 434193 | Closed traumatic dislocation of distal radioulnar joint of wrist |
| 45464117 | Closed traumatic dislocation distal radio-ulnar joint |
| 45447321 | Open wound of lower arm, NOS |
| 4050234 | Mallet finger with open tendon injury |
| 45504060 | Mallet finger with open tendon injury |
| 72481 | Open wound of wrist with complication |
| 45504059 | Open wound of wrist with complication |
| 45430718 | Closed fracture finger distal phalanx, shaft |
| 4010533 | Closed fracture finger distal phalanx, shaft |
| 45504198 | [X]Fracture of other and unspecified parts of wrist and hand |
| 45510719 | Closed crush injury hand, dorsum |
| 4054859 | Injury of radial nerve at wrist and hand level |
| 45494224 | Injury of radial nerve at wrist and hand level |
| 4057477 | Closed crush injury hand, dorsum |
| 45420934 | Rupture tendon of finger NOS |
| 45474204 | Complete division extensor tendon hand |
| 4051282 | Complete division extensor tendon hand |
| 45490796 | Multiple open wounds of wrist and hand |
| 4191822 | Multiple open wounds of wrist and hand |
| 434773 | Closed multiple fractures of hand bones |
| 45440639 | Closed multiple fractures of hand bones |
| 45484144 | Open fracture of one or more phalanges of hand NOS |
| 45484136 | Hand fracture - carpal bone |
| 45497331 | Open fracture of distal phalanx or phalanges, unspecified part |
| 45450593 | Open fracture of the scaphoid |

| | |
|---|---|
| 77124 | Open fracture of scaphoid bone of wrist |
| 4059100 | Open injury, digital nerve in finger |
| 45520676 | Sprain tendon wrist or hand |
| 45427504 | Open injury, digital nerve in finger |
| 45490729 | Multiple fractures of metacarpal bones |
| 4009460 | Closed fracture finger proximal phalanx, neck |
| 45484140 | Closed fracture finger proximal phalanx, neck |
| 45427349 | Closed fracture trapezoid |
| 436551 | Closed fracture of trapezoidal bone of wrist |
| 45514086 | Sprain wrist flexors |
| 36683549 | Strain of wrist flexor tendon |
| 45420957 | Open wound of wrist, volar |
| 4052981 | Open wound of wrist, volar |
| 45517469 | Partial division extensor tendon hand |
| 4050228 | Partial division extensor tendon hand |
| 4059553 | Closed crush injury, finger, multiple |
| 45477513 | Closed traumatic dislocation of wrist, unspecified |
| 45517508 | Closed crush injury, finger, multiple |
| 45510602 | Open fracture finger distal phalanx, tuft |
| 4015491 | Open fracture finger distal phalanx, tuft |
| 45470999 | Crush injury, wrist and hand NOS |
| 36683548 | Strain of wrist extensor tendon |
| 45500710 | Sprain wrist extensors |
| 45457313 | Closed fracture finger middle phalanx, shaft |
| 4009592 | Closed fracture finger middle phalanx, shaft |
| 4054857 | Injury of ulnar nerve at wrist and hand level |
| 45450743 | Injury of ulnar nerve at wrist and hand level |
| 4015878 | Closed fracture finger proximal phalanx, head |
| 45457312 | Closed fracture finger proximal phalanx, head |
| 73906 | Open wound of wrist with tendon involvement |
| 45514123 | Open wound of wrist with tendon involvement |
| 4050232 | Open wound, finger, multiple |

| | |
|---|---|
| 45440709 | Open wound, finger, multiple |
| 45474205 | Degloving injury hand |
| 437406 | Closed traumatic dislocation of joint of wrist |
| 4052990 | Degloving injury of hand |
| 45464119 | Dislocation of wrist NOS |
| 4018225 | Closed fracture subluxation of the wrist |
| 45460649 | Closed fracture-subluxation of the wrist |
| 45437515 | [X]Injuries to the wrist and hand |
| 45460624 | Open fracture of phalanx or phalanges, unspecified |
| 45500667 | Closed fracture finger distal phalanx, mallet |
| 4010535 | Closed fracture finger distal phalanx, mallet |
| 45460626 | Open fracture finger middle phalanx |
| 73042 | Open fracture finger middle phalanx |
| 45477574 | Open wound of finger with tendon injury |
| 45487478 | Multiple fractures of hand bones |
| 443114 | Open fracture finger proximal phalanx |
| 45503984 | Closed fracture finger proximal phalanx, shaft |
| 45440638 | Open fracture finger proximal phalanx |
| 4010530 | Closed fracture finger proximal phalanx, shaft |
| 4015873 | Open fracture finger metacarpal |
| 45487476 | Open fracture finger metacarpal |
| 4292073 | Multiple fractures of hand bones |
| 80854 | Closed fracture of capitate bone of wrist |
| 45510597 | Closed fracture capitate |
| 45430770 | Open wound of elbow, forearm and wrist NOS |
| 45464214 | Superficial injury of hand NOS, infected |
| 4010534 | Closed fracture finger distal phalanx, tuft |
| 45520709 | Open wound of lower arm without mention of complication |
| 45497329 | Closed fracture finger distal phalanx, tuft |
| 4010527 | Closed fracture of sesamoid bone of hand |
| 45437315 | Closed fracture sesamoid bone of hand |
| 45444014 | Open wound of hand with tendon involvement |

| | |
|---|---|
| 4056161 | Open wound of hand with tendon involvement |
| 45504061 | Degloving injury, finger |
| 4003136 | Hand and wrist flexor tendon rupture |
| 45473900 | Hand and wrist flexor tendon rupture |
| 78274 | Closed fracture of pisiform bone of wrist |
| 45517396 | Closed fracture pisiform |
| 4052998 | Degloving injury of finger |
| 45504133 | Injury of unspecified nerve at wrist and hand level |
| 37110530 | Injury of nerve at hand level |
| 45477627 | Injury of digital nerve of thumb |
| 4062231 | Injury of digital nerve of thumb |
| 45464185 | Traumatic amputation of finger NOS |
| 45490728 | Closed fracture lunate |
| 75375 | Closed fracture of lunate bone of wrist |
| 45467574 | Contusion, finger NOS |
| 45464181 | Open wound of finger or thumb with tendon involvement |
| 4052524 | Abrasion of finger |
| 45510699 | Abrasion, finger |
| 45427354 | Closed fracture of one or more phalanges of hand NOS |
| 45484139 | Closed fracture of middle or proximal phalanx or phalanges, unspecified part |
| 45484217 | Traumatic amputation, finger tip |
| 4096480 | Traumatic amputation of fingertip |
| 45434010 | Hand fracture - metacarpal bone |
| 441977 | Closed traumatic dislocation of carpometacarpal joint of wrist |
| 45460635 | Closed traumatic dislocation carpometacarpal joint |
| 45484248 | Contusion, wrist and hand NOS |
| 45440708 | Open wound of hand, dorsum |
| 4052989 | Open wound of hand, dorsum |
| 45501029 | Slashed wrists self inflicted |
| 45444086 | Tendon injury to hand NOS |
| 45514062 | Dislocation or subluxation of wrist |
| 45450627 | Hand sprain NOS |

| | |
|---|---|
| 4009593 | Closed fracture finger distal phalanx, base |
| 45487477 | Closed fracture finger distal phalanx, base |
| 4054986 | Open crush injury, finger |
| 45484256 | Open crush injury, finger |
| 45477535 | Closed fracture dislocation of wrist |
| 4018221 | Closed fracture dislocation of wrist |
| 45487563 | Superficial injury of finger NOS, infected |
| 45490813 | Injury of radial artery at wrist and hand level |
| 4050547 | Injury of radial artery at wrist and hand level |
| 4168061 | Open wound of finger with tendon injury |
| 45440676 | Finger sprain |
| 45470883 | Closed fracture of distal phalanx or phalanges, unspecified part |
| 45470963 | Open wound fingernail |
| 45424142 | Sprain tendon of finger |
| 36683537 | Strain of finger tendon |
| 45514046 | Closed fracture finger metacarpal head |
| 4015355 | Closed fracture finger metacarpal head |
| 45447358 | Crush injury wrist or hand |
| 4003135 | Hand and wrist extensor tendon rupture |
| 45477253 | Hand and wrist extensor tendon rupture |
| 4053836 | Open wound of fingernail |
| 4016263 | Dislocation or subluxation of wrist |
| 45447346 | Multiple superficial injuries of wrist and hand |
| 4051597 | Multiple superficial injuries of wrist and hand |
| 45427432 | Open wound of finger or thumb without mention of complication |
| 45424139 | Hand sprain unspecified |
| 45447241 | Open fracture of one or more phalanges of hand |
| 4058513 | Crush injury wrist and/or hand |
| 433886 | Closed fracture of trapezium bone of wrist |
| 45480875 | Closed fracture trapezium |
| 45450664 | Open wound of finger with damage to nail |
| 44789002 | Open wound of finger with damage to nail |

| | |
|---|---|
| 79167 | Open fracture of distal phalanx of finger |
| 45427355 | Open fracture finger distal phalanx |
| 133646 | Injury of digital nerve |
| 45450746 | Digital nerve injury |
| 45464147 | Mallet finger with closed tendon injury |
| 4016831 | Mallet finger with closed tendon injury |
| 45427476 | Closed crush injury, finger |
| 4051900 | Closed crush injury, finger |
| 45460638 | Closed traumatic dislocation of finger not otherwise specified |
| 4050226 | Open wound of hand, palm |
| 45434092 | Open wound of hand, palm |
| 45420958 | Open wound of hand, excluding fingers, NOS |
| 4144188 | Cutting own wrists |
| 45441449 | Cutting own wrists |
| 45420893 | Closed fracture finger middle phalanx, base |
| 4015879 | Closed fracture finger middle phalanx, base |
| 45477495 | Closed fracture of phalanx or phalanges, unspecified |
| 76542 | Open fracture of one or more phalanges of hand |
| 437123 | Closed fracture of hamate bone of wrist |
| 45477489 | Closed fracture hamate |
| 37116302 | Superficial injury of elbow, forearm and wrist |
| 45437427 | Superficial injury of elbow, forearm and wrist |
| 45480909 | Wrist and hand sprain NOS |
| 4019244 | Rupture tendon forearm or wrist |
| 45440685 | Rupture tendon forearm or wrist |
| 4309673 | Hyperextension injury of finger |
| 45474177 | Hyperextension injury of finger |
| 4050227 | Open wound of hand with complication |
| 45500740 | Open wound of hand with complication |
| 45434059 | Rupture tendon of finger |
| 45480876 | Closed fracture finger metacarpal base |
| 4010386 | Closed fracture finger metacarpal base |

| | |
|---|---|
| 4019248 | Rupture of tendon of finger |
| 4129405 | Open wound of hand |
| 45430771 | Open wound of hand without mention of complication |
| 45434090 | Open wound of elbow, forearm and wrist |
| 45434024 | Dislocation of finger or thumb not otherwise specified |
| 45457308 | Wrist fracture - closed |
| 4009459 | Closed fracture finger proximal phalanx, base |
| 45497328 | Closed fracture finger proximal phalanx, base |
| 4154164 | Fingernail injury |
| 45434170 | Other fingernail injuries |
| 74768 | Closed fracture of triquetral bone of wrist |
| 45487469 | Closed fracture triquetral |
| 45504139 | Other finger injuries NOS |
| 80223 | Closed fracture finger middle phalanx |
| 45517397 | Closed fracture finger middle phalanx |
| 45474250 | Trapped finger |
| 45494068 | Closed fracture finger metacarpal |
| 4015871 | Closed fracture finger metacarpal |
| 45420984 | Superficial injury of hand, excluding fingers |
| 45514152 | Contusion, finger |
| 4055866 | Superficial injury of hand, excluding fingers |
| 45440671 | Fracture-dislocation/subluxation finger/thumb |
| 4138281 | Fracture subluxation of finger |
| 4138275 | Fracture dislocation of wrist joint |
| 45437347 | Fracture-dislocation or subluxation of wrist |
| 45484138 | Closed fracture of one or more phalanges of hand |
| 4052671 | Contusion, fingernail |
| 45467573 | Contusion, fingernail (includes subungual haematoma) |
| 45441015 | Self inflicted lacerations to wrist |
| 45467460 | Closed fracture finger distal phalanx |
| 4297304 | Closed fracture of distal phalanx of finger |
| 45487474 | Closed fracture finger metacarpal neck |

| | |
|---|---|
| 4015354 | Closed fracture finger metacarpal neck |
| 45424110 | Multiple fractures of fingers |
| 4297437 | Fracture of multiple sites of phalanges of hand |
| 4319560 | Self inflicted lacerations to wrist |
| 45510677 | Traumatic amputation of finger(s) |
| 4086197 | Superficial injury of hand |
| 45510698 | Superficial injury of hand NOS, without mention of infection |
| 45460656 | Tendon injury - hand |
| 4319151 | Traumatic amputation of finger |
| 45450690 | Superficial injury of wrist NOS |
| 4164346 | Superficial injury of wrist |
| 45434023 | Closed traumatic dislocation of finger, unspecified |
| 45424221 | Contusion wrist or hand |
| 4134947 | Tendon injury - hand |
| 81186 | Contusion of wrist |
| 45420992 | Contusion, wrist |
| 4052668 | Contusion wrist or hand |
| 72465 | Closed fracture of one or more phalanges of hand |
| 45510600 | Closed fracture finger proximal phalanx |
| 45457420 | Crush injury, wrist |
| 75114 | Crushing injury of wrist |
| 443115 | Closed fracture finger proximal phalanx |
| 438268 | Closed traumatic dislocation of joint of finger |
| 45453937 | Dislocation or subluxation of finger or thumb |
| 45500769 | Superficial of injury finger(s) |
| 74211 | Superficial injury of finger without infection |
| 45427462 | Superficial injury of finger NOS, without mention of infection |
| 45460729 | Foreign body in hand |
| 4058346 | Foreign body in hand |
| 4166906 | Superficial injury of finger |
| 37311123 | Dislocation of digit of hand |
| 45434093 | Open wound, finger |

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|---|---|
| 45497489 | Finger injury |
| 45497455 | Contusion, finger, unspecified |
| 45447320 | Open wound of wrist, unspecified |
| 45507383 | Crush injury, hand, excluding fingers |
| 4057476 | Crush injury, hand, excluding fingers |
| 45450626 | Hand sprain |
| 4170462 | Foreign body - finger |
| 45424213 | Foreign body - finger |
| 4052669 | Contusion, hand, excluding finger |
| 45520741 | Contusion, hand, excluding finger |
| 73045 | Sprain of hand |
| 4054062 | Open wound of wrist |
| 45497334 | Fracture of bone of hand |
| 4071876 | Fracture of hand |
| 45514084 | Sprain of wrist and hand |
| 45464313 | [X]Unspecified injury of wrist and hand |
| 73649 | Contusion of finger |
| 81169 | Superficial foreign body of finger without major open wound AND without infection |
| 45464215 | Splinter of finger, without major open wound or mention of infection |
| 4018956 | Sprain of wrist and/or hand |
| 45464257 | Unspecified injury of hand |
| 45450596 | Fracture of one or more phalanges of hand NOS |
| 45500665 | Closed fracture of the scaphoid |
| 80552 | Closed fracture of scaphoid bone of wrist |
| 45490765 | Sprain finger |
| 4134309 | Sprain of ligament of finger |
| 45517399 | Fracture of other finger |
| 45443714 | Mallet finger |
| 77647 | Mallet finger |
| 45487472 | Fracture at wrist and hand level |
| 4015350 | Fracture at wrist and/or hand level |
| 45494195 | Crush injury, finger(s) |

| | |
|---|---|
| 45427353 | Fracture of one or more phalanges of hand |
| 45454070 | Unspecified injury of wrist |
| 45520711 | Open wound of finger(s) NOS |
| 75406 | Crushing injury of finger |
| 4137945 | Fracture of scaphoid bone of wrist |
| 45507274 | Fracture of scaphoid |
| 45460780 | Other finger injuries |
| 45480948 | Open wound of hand, excluding finger(s) |
| 4056160 | Open wound of hand, excluding finger(s) |
| 4226282 | Fracture of phalanx of hand |
| 45447323 | Open wound of finger(s) or thumb |
| 45510599 | Finger fracture |
| 4057580 | Fracture of phalanx of finger |
| 4054063 | Open wound of finger |
| 45481020 | Other hand injury, excluding finger |
| 45447392 | Other wrist injuries |
| 45471043 | Other finger injuries, unspecified |
| 80004 | Injury of hand |
| 444129 | Injury of wrist |
| 81454 | Injury of finger |

# 10.20 Appendix 20. Read codes: hand trauma surgery cohort

| Concept | Concept name |
|---|---|
| 45505860 | Amputation of finger NEC |
| 4297321 | Amputation of finger, except thumb |
| 4263590 | Amputation of hand |
| 4078561 | Amputation of phalanx of finger |
| 45522551 | Amputation of phalanx of finger |
| 45445831 | Closed (or no) reduction of fracture and external fixation |
| 45522495 | Closed (or no) reduction of fracture and internal fixation |
| 45472707 | Closed reduction # arm |
| 4321394 | Closed reduction of dislocation of finger |
| 45522527 | Closed reduction of dislocation of finger |
| 4088717 | Closed reduction of dislocation of wrist |
| 45419494 | Closed reduction of dislocation of wrist |
| 45509329 | Closed reduction of fracture |
| 4313275 | Closed reduction of fracture |
| 4160364 | Closed reduction of fracture and external fixation |
| 45509189 | Closed reduction of fracture dislocation of joint and internal fixation of joint |
| 4106591 | Closed reduction of fracture dislocation of joint and internal fixation of joint |
| 45425937 | Closed reduction of fracture of finger |
| 4079111 | Closed reduction of fracture of finger |
| 45462593 | Closed reduction of fracture of radius and or ulna |
| 4079114 | Closed reduction of fracture of radius and/or ulna |
| 4075918 | Closed reduction of fracture of small bone and fixation using screw |
| 45472704 | Closed reduction of fracture of small bone and fixation using screw |
| 45515961 | Closed reduction of fracture of thumb |
| 4079112 | Closed reduction of fracture of thumb |
| 45502542 | Closed reduction of fracture of upper limb |
| 4146119 | Closed reduction of fracture of upper limb |
| 4076443 | Closed reduction of fracture of wrist |
| 45455815 | Closed reduction of fracture of wrist |
| 4188615 | Closed reduction of fracture with internal fixation |
| 4074406 | Complex reconstruction operations on hand and foot |
| 45452449 | Complex reconstruction operations on hand and foot |
| 45509175 | Debridement of open fracture |
| 4101851 | Debridement of open fracture |
| 4229905 | Exploration of tendon |
| 45476006 | Exploration of tendon NEC |
| 4078271 | Finger operation |
| 45439228 | Finger operation |
| 4173316 | Fixation of tendon |

| | |
|---|---|
| 45524661 | Follow-up care involving plastic surgery |
| 45459205 | Hand operation |
| 4003065 | Hand reconstruction |
| 45522492 | K wiring of fracture |
| 4343908 | Ligament reconstruction |
| 45429298 | Manipulation of fracture of bone NEC |
| 4308659 | Manipulation of wrist joint |
| 45492651 | Manipulation of wrist joint |
| 45505852 | Manipulation of wrist joint under anaesthetic |
| 45498859 | Microsurgical graft to peripheral nerve NEC |
| 45455463 | Microsurgical repair of peripheral nerve |
| 4066794 | Microsurgical repair of peripheral nerve |
| 45498861 | Microsurgical repair of peripheral nerve NOS |
| 4313570 | Open reduction of fracture |
| 4083670 | Open reduction of fracture dislocation of joint |
| 45512580 | Open reduction of fracture dislocation of joint and fixation of joint, unspecified |
| 4071354 | Open reduction of fracture with internal fixation |
| 45489340 | Open surgical fracture of bone |
| 4313023 | Operation on tendon |
| 4308878 | Operation on tendon sheath |
| 4010247 | Operative procedure on hand |
| 45476054 | Other closed reduction of fracture of bone |
| 45486006 | Other closed reduction of fracture of bone NOS |
| 45505811 | Other complex reconstruction of hand |
| 45439185 | Other complex reconstruction of hand NOS |
| 45419486 | Other interposition reconstruction of joint |
| 45476009 | Other operation on tendon NOS |
| 45429252 | Other operations on sheath of tendon |
| 45522457 | Other operations on tendon |
| 45419466 | Other primary open reduction of fracture of bone |
| 45465955 | Other primary open reduction of fracture of bone NOS |
| 45489371 | Other reconstruction of joint |
| 45519238 | Other reconstruction of ligament |
| 45442561 | Other specified amputation of hand |
| 45439157 | Other specified operation on tendon |
| 45459154 | Other specified primary open reduction of fracture of bone and intramedullary fixation |
| 45452416 | Other specified primary repair of tendon |
| 45465986 | Other specified reconstruction of ligament |
| 45465918 | Plastic repair of tendon |
| 4071370 | Plastic repair of tendon |
| 45429249 | Plastic repair of tendon NOS |
| 4042311 | Plastic repair procedure |

| | |
|---|---|
| 45425938 | Primary closed reduction of fracture alone |
| 45489346 | Primary closed reduction of fracture and internal fixation with screw(s) |
| 4076321 | Primary closed reduction of fracture and internal fixation with screw(s) |
| 45479386 | Primary closed reduction of fracture and internal fixation with wire |
| 45462587 | Primary closed reduction of fracture and other internal fixation |
| 45432554 | Primary closed reduction of fracture and skeletal traction NEC |
| 45482672 | Primary closed reduction of fracture and wire fixation |
| 4076317 | Primary closed reduction of fracture and wire fixation |
| 45442520 | Primary external fixation of fracture |
| 4077773 | Primary external fixation of fracture |
| 45482337 | Primary microsurgical repair of peripheral nerve NEC |
| 45515951 | Primary open reduction of fracture alone |
| 45505823 | Primary open reduction of fracture and cast immobilisation |
| 4077482 | Primary open reduction of fracture and cast immobilization |
| 45486001 | Primary open reduction of fracture and external fixation |
| 4076193 | Primary open reduction of fracture and external fixation |
| 4078965 | Primary open reduction of fracture and internal fixation with K-wire |
| 45425934 | Primary open reduction of fracture and internal fixation with K-wire |
| 4182345 | Primary open reduction of fracture and internal fixation with plate |
| 45472703 | Primary open reduction of fracture and internal fixation with plate NEC |
| 45495884 | Primary open reduction of fracture and internal fixation with screw(s) |
| 4078967 | Primary open reduction of fracture and internal fixation with screw(s) |
| 4075782 | Primary open reduction of fracture and internal fixation with tension band wiring |
| 45495883 | Primary open reduction of fracture and internal fixation with tension band wiring |
| 45492617 | Primary open reduction of fracture and intramedullary nail fixation |
| 45455809 | Primary open reduction of fracture and other internal(extramedullary) fixation |
| 4116617 | Primary open reduction of fracture dislocation |
| 4077794 | Primary open reduction of fracture dislocation and fixation with plate(s) |
| 45492640 | Primary open reduction of fracture dislocation and fixation with plate(s) |
| 4106584 | Primary open reduction of fracture dislocation and wire fixation |
| 45522525 | Primary open reduction of fracture dislocation and wire fixation |
| 45479407 | Primary open reduction of fracture dislocation of joint and combined internal and external fixation |
| 45462615 | Primary open reduction of fracture dislocation of joint NEC |
| 4324896 | Primary open reduction of fracture dislocation of joint with combined internal and external fixation |
| 45492618 | Primary open reduction of fracture of bone and external fixation |
| 45519206 | Primary open reduction of fracture of bone and extramedullary fixation |
| 4075780 | Primary open reduction of fracture of bone and extramedullary fixation |
| 45435920 | Primary open reduction of fracture of bone and extramedullary fixation NOS |
| 45472700 | Primary open reduction of fracture of bone and intramedullary fixation |
| 4074392 | Primary open reduction of fracture of bone and intramedullary fixation |
| 45445826 | Primary open reduction of fracture of bone and intramedullary fixation NOS |
| 45509163 | Primary open reduction of fracture of long bone and complex extramedullary fixation NEC |

| | |
|---|---|
| 45479384 | Primary open reduction of fracture of long bone and fixation using rigid nail NEC |
| 4078961 | Primary open reduction of fracture of small bone and fixation using screw |
| 45425933 | Primary open reduction of fracture of small bone and fixation using screw |
| 45449059 | Primary plastic repair tendon |
| 4071371 | Primary plastic repair tendon |
| 45442476 | Primary repair of tendon |
| 4071373 | Primary repair of tendon |
| 45515905 | Primary repair of tendon NOS |
| 45442477 | Primary repair of tendon using graft |
| 4072044 | Primary repair of tendon using graft |
| 45425892 | Primary repair of tendon using tendon transfer procedure |
| 4071374 | Primary repair of tendon using tendon transfer procedure |
| 45449060 | Primary simple repair of tendon |
| 4072045 | Primary simple repair of tendon |
| 45495888 | Primary wire fixation of fracture |
| 4077626 | Primary wire fixation of fracture |
| 4118094 | Reattachment of finger |
| 4321095 | Reconstruction of joint |
| 45422706 | Reconstruction of ligament NOS |
| 45452466 | Remanipulation of fracture of bone NEC |
| 4311041 | Repair of artery |
| 45492471 | Repair of other artery |
| 45512403 | Repair of other artery NOS |
| 45478249 | Repair of scarred tissue |
| 4121003 | Repair of single tendon |
| 45449158 | Replantation of finger NEC |
| 45509165 | Secondary open reduction of fracture of bone and intramedullary fixation however further qualified |
| 4300388 | Surgical manipulation of wrist joint |
| 45469381 | Suture of tendon |
| 45432505 | Tendon operations |
| 45452419 | Tendon operations NOS |
| 4072035 | Tendon transfer to extensor tendon of hand |
| 45429246 | Tendon transfer to extensor tendon of hand |
| 45425890 | Tenodesis |
| 45486045 | Terminalisation of finger |
| 4106037 | Terminalization of finger |

# 10.21 Appendix 21. HES APC whole dataset ICD-10 and OPCS-4.9 code list

| **OPCS Bone and Joint** | | | |
|---|---|---|---|
| **1st code** | **2nd code** | **1st code procedure** | **2nd code anatomy** |
| W26 | Z83 | Closed reduction | hand joints |
| W26 | Z73 | Closed reduction | hand bones |
| W26 | Z82 | Closed reduction | wrist joints |
| W26 | Z72 | Closed reduction | carpal bones |
| W26 | Z70 | Closed reduction | radius |
| W26 | Z71 | Closed reduction | ulna |
| W26 | Z81.5 | Closed reduction | Elbow joint |
| W26 | Z81.6 | Closed reduction | Superior radioulnar joint |
| W26 | Z81.7 | Closed reduction | Inferior radioulnar joint |
| W26 | Z69.5 | Closed reduction | Lateral condyle of humerus |
| W26 | Z69.6 | Closed reduction | Medial epicondyle of humerus |
| W26 | Z69.7 | Closed reduction | Lower end of humerus NEC |
| W26 | Z89.3 | Closed reduction | Forearm NEC |
| W26 | Z89.4 | Closed reduction | Hand NEC |
| W26 | Z89.5 | Closed reduction | Thumb NEC |
| W26 | Z89.6 | Closed reduction | Finger NEC |
| W26 | Z89.8 | Closed reduction | Multiple digits of hand NEC |
| W19 | Z73 | Primary intramedullary ORIF (extra articular) | hand bones |
| W19 | Z72 | Primary intramedullary ORIF (extra articular) | carpal bones |
| W19 | Z70 | Primary intramedullary ORIF (extra articular) | radius |
| W19 | Z71 | Primary intramedullary ORIF (extra articular) | ulna |
| W19 | Z89.3 | Primary intramedullary ORIF (extra articular) | Forearm NEC |
| W19 | Z89.4 | Primary intramedullary ORIF (extra articular) | Hand NEC |
| W19 | Z89.5 | Primary intramedullary ORIF (extra articular) | Thumb NEC |
| W19 | Z89.6 | Primary intramedullary ORIF (extra articular) | Finger NEC |
| W19 | Z89.8 | Primary intramedullary ORIF (extra articular) | Multiple digits of hand NEC |

| | | | |
|---|---|---|---|
| W20 | Z73 | Primary extramedullary ORIF (extra articular) | hand bones |
| W20 | Z72 | Primary extramedullary ORIF (extra articular) | carpal bones |
| W20 | Z70 | Primary extramedullary ORIF (extra articular) | radius |
| W20 | Z71 | Primary extramedullary ORIF (extra articular) | ulna |
| W20 | Z89.3 | Primary extramedullary ORIF (extra articular) | Forearm NEC |
| W20 | Z89.4 | Primary extramedullary ORIF (extra articular) | Hand NEC |
| W20 | Z89.5 | Primary extramedullary ORIF (extra articular) | Thumb NEC |
| W20 | Z89.6 | Primary extramedullary ORIF (extra articular) | Finger NEC |
| W20 | Z89.8 | Primary extramedullary ORIF (extra articular) | Multiple digits of hand NEC |
| W21 | Z83 | Primary ORIF for intra articular | hand joints |
| W21 | Z73 | Primary ORIF for intra articular | hand bones |
| W21 | Z82 | Primary ORIF for intra articular | wrist joints |
| W21 | Z72 | Primary ORIF for intra articular | carpal bones |
| W21 | Z70 | Primary ORIF for intra articular | radius |
| W21 | Z71 | Primary ORIF for intra articular | ulna |
| W21 | Z89.3 | Primary ORIF for intra articular | Forearm NEC |
| W21 | Z89.4 | Primary ORIF for intra articular | Hand NEC |
| W21 | Z89.5 | Primary ORIF for intra articular | Thumb NEC |
| W21 | Z89.6 | Primary ORIF for intra articular | Finger NEC |
| W21 | Z89.8 | Primary ORIF for intra articular | Multiple digits of hand NEC |
| W21 | Z69.5 | Primary ORIF for intra articular | Lateral condyle of humerus |
| W21 | Z69.6 | Primary ORIF for intra articular | Medial epicondyle of humerus |
| W21 | Z69.7 | Primary ORIF for intra articular | Lower end of humerus NEC |
| W23 | Z83 | secondary ORIF (all fractures) | hand joints |
| W23 | Z73 | secondary ORIF (all fractures) | hand bones |
| W23 | Z82 | secondary ORIF (all fractures) | wrist joints |
| W23 | Z72 | secondary ORIF (all fractures) | carpal bones |
| W23 | Z70 | secondary ORIF (all fractures) | radius |
| W23 | Z71 | secondary ORIF (all fractures) | ulna |
| W23 | Z89.3 | secondary ORIF (all fractures) | Forearm NEC |
| W23 | Z89.4 | secondary ORIF (all fractures) | Hand NEC |

| | | | |
|---|---|---|---|
| W23 | Z89.5 | secondary ORIF (all fractures) | Thumb NEC |
| W23 | Z89.6 | secondary ORIF (all fractures) | Finger NEC |
| W23 | Z89.8 | secondary ORIF (all fractures) | Multiple digits of hand NEC |
| W23 | Z69.5 | secondary ORIF (all fractures) | Lateral condyle of humerus |
| W23 | Z69.6 | secondary ORIF (all fractures) | Medial epicondyle of humerus |
| W23 | Z69.7 | secondary ORIF (all fractures) | Lower end of humerus NEC |
| W24 | Z83 | closed reduction with external fixation | hand joints |
| W24 | Z73 | closed reduction with external fixation | hand bones |
| W24 | Z82 | closed reduction with external fixation | wrist joints |
| W24 | Z72 | closed reduction with external fixation | carpal bones |
| W24 | Z70 | closed reduction with external fixation | radius |
| W24 | Z71 | closed reduction with external fixation | ulna |
| W24 | Z89.3 | closed reduction with external fixation | Forearm NEC |
| W24 | Z89.4 | closed reduction with external fixation | Hand NEC |
| W24 | Z89.5 | closed reduction with external fixation | Thumb NEC |
| W24 | Z89.6 | closed reduction with external fixation | Finger NEC |
| W24 | Z89.8 | closed reduction with external fixation | Multiple digits of hand NEC |
| W24 | Z69.5 | closed reduction with external fixation | Lateral condyle of humerus |
| W24 | Z69.6 | closed reduction with external fixation | Medial epicondyle of humerus |
| W24 | Z69.7 | closed reduction with external fixation | Lower end of humerus NEC |
| W25 | Z83 | closed reduction and external fixation | hand joints |
| W25 | Z73 | closed reduction and external fixation | hand bones |
| W25 | Z82 | closed reduction and external fixation | wrist joints |
| W25 | Z72 | closed reduction and external fixation | carpal bones |
| W25 | Z70 | closed reduction and external fixation | radius |
| W25 | Z71 | closed reduction and external fixation | ulna |
| W25 | Z89.3 | closed reduction and external fixation | Forearm NEC |
| W25 | Z89.4 | closed reduction and external fixation | Hand NEC |
| W25 | Z89.5 | closed reduction and external fixation | Thumb NEC |
| W25 | Z89.6 | closed reduction and external fixation | Finger NEC |
| W25 | Z89.8 | closed reduction and external fixation | Multiple digits of hand NEC |

| | | | |
|---|---|---|---|
| W25 | Z69.5 | closed reduction and external fixation | Lateral condyle of humerus |
| W25 | Z69.6 | closed reduction and external fixation | Medial epicondyle of humerus |
| W25 | Z69.7 | closed reduction and external fixation | Lower end of humerus NEC |
| W26 | Z83 | other closed reduction of fracture of bone | hand joints |
| W26 | Z73 | other closed reduction of fracture of bone | hand bones |
| W26 | Z82 | other closed reduction of fracture of bone | wrist joints |
| W26 | Z72 | other closed reduction of fracture of bone | carpal bones |
| W26 | Z70 | other closed reduction of fracture of bone | radius |
| W26 | Z71 | other closed reduction of fracture of bone | ulna |
| W26 | Z89.3 | other closed reduction of fracture of bone | Forearm NEC |
| W26 | Z89.4 | other closed reduction of fracture of bone | Hand NEC |
| W26 | Z89.5 | other closed reduction of fracture of bone | Thumb NEC |
| W26 | Z89.6 | other closed reduction of fracture of bone | Finger NEC |
| W26 | Z89.8 | other closed reduction of fracture of bone | Multiple digits of hand NEC |
| W26 | Z69.5 | other closed reduction of fracture of bone | Lateral condyle of humerus |
| W26 | Z69.6 | other closed reduction of fracture of bone | Medial epicondyle of humerus |
| W26 | Z69.7 | other closed reduction of fracture of bone | Lower end of humerus NEC |
| O17 | Z83 | secondary closed reduction and internal fixation | hand joints |
| O17 | Z73 | secondary closed reduction and internal fixation | hand bones |
| O17 | Z82 | secondary closed reduction and internal fixation | wrist joints |
| O17 | Z72 | secondary closed reduction and internal fixation | carpal bones |
| O17 | Z70 | secondary closed reduction and internal fixation | radius |
| O17 | Z71 | secondary closed reduction and internal fixation | ulna |
| O17 | Z89.3 | secondary closed reduction and internal fixation | Forearm NEC |
| O17 | Z89.4 | secondary closed reduction and internal fixation | Hand NEC |
| O17 | Z89.5 | secondary closed reduction and internal fixation | Thumb NEC |
| O17 | Z89.6 | secondary closed reduction and internal fixation | Finger NEC |
| O17 | Z89.8 | secondary closed reduction and internal fixation | Multiple digits of hand NEC |
| O17 | Z69.5 | secondary closed reduction and internal fixation | Lateral condyle of humerus |
| O17 | Z69.6 | secondary closed reduction and internal fixation | Medial epicondyle of humerus |

| | | | |
|---|---|---|---|
| O17 | Z69.7 | secondary closed reduction and internal fixation | Lower end of humerus NEC |
| W65 | Z83 | primary open reduction of traumatic joint dislocation | hand joints |
| W65 | Z82 | primary open reduction of traumatic joint dislocation | wrist joints |
| W65 | Z81.5 | primary open reduction of traumatic joint dislocation | Elbow joint |
| W65 | Z81.6 | primary open reduction of traumatic joint dislocation | Superior radioulnar joint |
| W65 | Z81.7 | primary open reduction of traumatic joint dislocation | Inferior radioulnar joint |
| W65 | Z89.3 | primary open reduction of traumatic joint dislocation | Forearm NEC |
| W65 | Z89.4 | primary open reduction of traumatic joint dislocation | Hand NEC |
| W65 | Z89.5 | primary open reduction of traumatic joint dislocation | Thumb NEC |
| W65 | Z89.6 | primary open reduction of traumatic joint dislocation | Finger NEC |
| W65 | Z89.8 | primary open reduction of traumatic joint dislocation | Multiple digits of hand NEC |
| W66 | Z83 | primary closed closed reduction joint dislocation | hand joints |
| W66 | Z82 | primary closed closed reduction joint dislocation | wrist joints |
| W66 | Z81.5 | primary closed closed reduction joint dislocation | Elbow joint |
| W66 | Z81.6 | primary closed closed reduction joint dislocation | Superior radioulnar joint |
| W66 | Z81.7 | primary closed closed reduction joint dislocation | Inferior radioulnar joint |
| W66 | Z89.3 | primary closed closed reduction joint dislocation | Forearm NEC |
| W66 | Z89.4 | primary closed closed reduction joint dislocation | Hand NEC |
| W66 | Z89.5 | primary closed closed reduction joint dislocation | Thumb NEC |
| W66 | Z89.6 | primary closed closed reduction joint dislocation | Finger NEC |
| W66 | Z89.8 | primary closed closed reduction joint dislocation | Multiple digits of hand NEC |
| O21.1 | Z69.7 | Primary total prosthetic replacement of elbow joint using cement | Lower end of humerus NEC |
| O21.8 | z69.7 | Other specified total prosthetic replacement of elbow joint using cement | Lower end of humerus NEC |
| O21.9 | z69.7 | Unspecified total prosthetic replacement of elbow joint using cement | Lower end of humerus NEC |
| O22.1 | Z69.7 | Primary total prosthetic replacement of elbow joint not using cement | Lower end of humerus NEC |
| O22.8 | Z69.7 | Other specified total prosthetic replacement of elbow joint not using cement | Lower end of humerus NEC |
| O22.9 | Z69.7 | Unspecified total prosthetic replacement of elbow joint not using cement | Lower end of humerus NEC |
| O23.1 | Z69.7 | Primary total prosthetic replacement of elbow joint NEC | Lower end of humerus NEC |
| O23.8 | Z69.7 | Other specified total prosthetic replacement of elbow joint | Lower end of humerus NEC |
| O23.9 | Z69.7 | Unspecified total prosthetic replacement of elbow joint | Lower end of humerus NEC |

| | | | |
|---|---|---|---|
| O24.1 | Z70 | Primary prosthetic replacement of head of radius using cement | radius fracture |
| O24.8 | Z70 | Other specified prosthetic replacement of head of radius using cement | radius fracture |
| O24.9 | Z70 | Unspecified prosthetic replacement of head of radius using cement | radius fracture |
| O25.1 | Z70 | Primary prosthetic replacement of head of radius not using cement | radius fracture |
| O25.8 | Z70 | Other specified prosthetic replacement of head of radius not using cement | radius fracture |
| O25.9 | Z70 | Unspecified prosthetic replacement of head of radius not using cement | radius fracture |
| O26.1 | Z70 | Primary prosthetic replacement of head of radius NEC | radius fracture |
| O26.8 | Z70 | Other specified other prosthetic replacement of head of radius | radius fracture |
| O26.9 | Z70 | Unspecified other prosthetic replacement of head of radius | radius fracture |
| O174 | | remanipulation of fracture of short bone & fixation using screw | |
| O175 | | remanipulation of fracture of fragment of bone & fixation using screw | |
| O176 | | remanipulation of fracture of bone using plate | |
| O27 | | other stabilising operations on joint | |
| W01 | | complex reconstruction of thumb | |
| W02 | | Other complex reconstruction of hand | |
| W178 | | Other specified reconstruction of bone | |
| W179 | | Unspecified other reconstruction of bone | |
| W18 | | Drainage of bone | |
| W22 | | Other primary ORIF | |
| W28 | | Other ORIF | |
| W332 | | Debridement open fracture of bone | |
| W333 | | Suture of periosteum | |
| W336 | | Debridement of bone NEC | |
| W337 | | Lavage of bone | |
| W338 | | Other specified other open operations on bone | |
| W339 | | Unspecified other open operations on bone | |
| W74 | | Other reconstruction of ligament | |
| W75 | | Other open repair of ligament | |
| W77 | | Stabilising operations on joint | |
| W80 | | Debridement and irrigation of joint | |

| | | | |
|---|---|---|---|
| W81 | | Other operations on joint | |
| W91 | | Other manipulation of joint | |
| W92 | | Other operations on joint | |
| **OPCS Soft-tissue** | | | |
| **1st code** | **2nd code** | **1st code procedure** | **2nd code anatomy** |
| T67 | Z89.3 | primary repair of tendon | Forearm NEC |
| T67 | Z89.4 | primary repair of tendon | Hand NEC |
| T67 | Z89.5 | primary repair of tendon | Thumb NEC |
| T67 | Z89.6 | primary repair of tendon | Finger NEC |
| T67 | Z89.7 | primary repair of tendon | Multiple digits of hand NEC |
| T67 | Z89.8 | primary repair of tendon | Specified arm region NEC |
| T67 | Z89.9 | primary repair of tendon | Arm NEC |
| T67 | Z56.3 | primary repair of tendon | Flexor digitorum superficialis |
| T67 | Z56.4 | primary repair of tendon | Flexor digitorum profundus |
| T67 | Z55.1 | primary repair of tendon | Flexor muscle of forearm |
| T67 | Z55.2 | primary repair of tendon | Extensor muscle of forearm |
| T67 | Z55.5 | primary repair of tendon | Palmaris longus |
| T67 | Z55.8 | primary repair of tendon | Specified muscle of forearm NEC |
| T67 | Z55.9 | primary repair of tendon | Muscle of forearm NEC |
| T67 | Z56.7 | primary repair of tendon | Extensor muscle of hand |
| T67 | Z56.1 | primary repair of tendon | Flexor pollicis longus |
| T67 | Z56.8 | primary repair of tendon | Specified muscle of hand NEC |
| T67 | Z56.9 | primary repair of tendon | Muscle of hand NEC |
| A62 | Z09.7 | microsurgical repair of nerve | Digital nerve of finger |
| A62 | Z09.2 | microsurgical repair of nerve | Median nerve |
| A62 | Z09.3 | microsurgical repair of nerve | Radial nerve |
| A62 | Z09.4 | microsurgical repair of nerve | Ulna nerve |
| A62 | Z09.8 | microsurgical repair of nerve | Specified peripheral nerve of arm NEC |
| A62 | Z09.9 | microsurgical repair of nerve | Peripheral nerve of arm NEC |
| A62 | Z89.3 | microsurgical repair of nerve | Forearm NEC |

| | | | |
|---|---|---|---|
| A62 | Z89.4 | microsurgical repair of nerve | Hand NEC |
| A62 | Z89.5 | microsurgical repair of nerve | Thumb NEC |
| A62 | Z89.6 | microsurgical repair of nerve | Finger NEC |
| A62 | Z89.7 | microsurgical repair of nerve | Multiple digits of hand NEC |
| A62 | Z89.8 | microsurgical repair of nerve | Specified arm region NEC |
| A62 | Z89.9 | microsurgical repair of nerve | Arm NEC |
| A63 | Z09.7 | graft to peripheral nerve | Digital nerve of finger |
| A63 | Z09.2 | graft to peripheral nerve | Median nerve |
| A63 | Z09.3 | graft to peripheral nerve | Radial nerve |
| A63 | Z09.4 | graft to peripheral nerve | Ulna nerve |
| A63 | Z09.8 | graft to peripheral nerve | Specified peripheral nerve of arm NEC |
| A63 | Z09.9 | graft to peripheral nerve | Peripheral nerve of arm NEC |
| A63 | Z89.3 | graft to peripheral nerve | Forearm NEC |
| A63 | Z89.4 | graft to peripheral nerve | Hand NEC |
| A63 | Z89.5 | graft to peripheral nerve | Thumb NEC |
| A63 | Z89.6 | graft to peripheral nerve | Finger NEC |
| A63 | Z89.7 | graft to peripheral nerve | Multiple digits of hand NEC |
| A63 | Z89.8 | graft to peripheral nerve | Specified arm region NEC |
| A63 | Z89.9 | graft to peripheral nerve | Arm NEC |
| A64 | Z09.7 | other repair of peripheral nerve | Digital nerve of finger |
| A64 | Z09.2 | other repair of peripheral nerve | Median nerve |
| A64 | Z09.3 | other repair of peripheral nerve | Radial nerve |
| A64 | Z09.4 | other repair of peripheral nerve | Ulna nerve |
| A64 | Z09.8 | other repair of peripheral nerve | Specified peripheral nerve of arm NEC |
| A64 | Z09.9 | other repair of peripheral nerve | Peripheral nerve of arm NEC |
| A64 | Z89.3 | other repair of peripheral nerve | Forearm NEC |
| A64 | Z89.4 | other repair of peripheral nerve | Hand NEC |
| A64 | Z89.5 | other repair of peripheral nerve | Thumb NEC |
| A64 | Z89.6 | other repair of peripheral nerve | Finger NEC |
| A64 | Z89.7 | other repair of peripheral nerve | Multiple digits of hand NEC |
| A64 | Z89.8 | other repair of peripheral nerve | Specified arm region NEC |

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|---|---|---|---|
| A64 | Z89.9 | other repair of peripheral nerve | Arm NEC |
| X01 | | replantations of upper limb | |
| X07 | | amputations of arm (above hand and wrist) | |
| X08 | | amputations of hand | |

**ICD codes**

| Code | Condition |
|---|---|
| S66.0 | Injury of long flexor muscle and tendon of thumb at wrist and hand level |
| S66.1 | Injury of flexor muscle and tendon of other finger at wrist and hand level |
| S66.2 | Injury of extensor muscle and tendon of thumb at wrist and hand level |
| S66.3 | Injury of extensor muscle and tendon of other finger at wrist and hand level |
| S66.4 | Injury of intrinsic muscle and tendon of thumb at wrist and hand level |
| S66.5 | Injury of intrinsic muscle and tendon of other finger at wrist and hand level |
| S66.6 | Injury of multiple flexor muscles and tendons at wrist and hand level |
| S66.7 | Injury of multiple extensor muscles and tendons at wrist and hand level |
| S66.8 | Injury of other muscles and tendons at wrist and hand level |
| S66.9 | Injury of unspecified muscle and tendon at wrist and hand level |
| S64.0 | Injury of ulnar nerve at wrist and hand level |
| S64.1 | Injury of median nerve at wrist and hand level |
| S64.2 | Injury of radial nerve at wrist and hand level |
| S64.3 | Injury of digital nerve of thumb |
| S64.4 | Injury of digital nerve of other finger |
| S64.7 | Injury of multiple nerves at wrist and hand level |
| S64.8 | Injury of other nerves at wrist and hand level |
| S64.9 | Injury of unspecified nerve at wrist and hand level |
| S65.0 | Injury of ulnar artery at wrist and hand level |
| S65.1 | Injury of radial artery at wrist and hand level |
| S65.2 | Injury of superficial palmar arch |
| S65.3 | Injury of deep palmar arch |
| S65.4 | Injury of blood vessel(s) of thumb |

| | |
|---|---|
| S65.5 | Injury of blood vessel(s) of other finger |
| S65.7 | Injury of multiple blood vessels at wrist and hand level |
| S65.8 | Injury of other blood vessels at wrist and hand level |
| S65.9 | Injury of unspecified blood vessel at wrist and hand level |
| S67.0 | Crushing injury of thumb and other finger(s) |
| S67.8 | Crushing injury of other and unspecified parts of wrist and hand |
| S68.0 | Traumatic amputation of thumb (complete)(partial) |
| S68.1 | Traumatic amputation of other single finger (complete)(partial) |
| S68.2 | Traumatic amputation of two or more fingers alone (complete)(partial) |
| S68.3 | Combined traumatic amputation of (part of) finger(s) with other parts of wrist and hand |
| S68.4 | Traumatic amputation of hand at wrist level |
| S68.8 | Traumatic amputation of other parts of wrist and hand |
| S68.9 | Traumatic amputation of wrist and hand, level unspecified |
| S69.7 | Multiple injuries of wrist and hand |
| | Injuries classifiable to more than one of the categories S60-S68 |
| S69.8 | Other specified injuries of wrist and hand |
| S69.9 | Unspecified injury of wrist and hand |
| S60 | Superficial injury of wrist and hand |
| S60.0 | Contusion of finger(s) without damage to nail |
| | Contusion of finger(s) NOS |
| | Excludes: |
| S60.1 | Contusion of finger(s) with damage to nail |
| S60.2 | Contusion of other parts of wrist and hand |
| S60.7 | Multiple superficial injuries of wrist and hand |
| S60.8 | Other superficial injuries of wrist and hand |
| S60.9 | Superficial injury of wrist and hand, unspecified |
| S61 | Open wound of wrist and hand |
| | Excludes: |
| S61.0 | Open wound of finger(s) without damage to nail |
| | Open wound of finger(s) NOS |
| | Excludes: |

| | |
|---|---|
| S61.1 | Open wound of finger(s) with damage to nail |
| S61.7 | Multiple open wounds of wrist and hand |
| S61.8 | Open wound of other parts of wrist and hand |
| S61.9 | Open wound of wrist and hand part, part unspecified |
| S62.0 | Fracture of navicular [scaphoid] bone of hand |
| S62.1 | Fracture of other carpal bone(s) |
| | Capitate [os magnum] |
| | Hamate [unciform] |
| | Lunate [semilunar] |
| | Pisiform |
| | Trapezium [greater multangular] |
| | Trapezoid [lesser multangular] |
| | Triquetrum [cuneiform of carpus] |
| S62.2 | Fracture of first metacarpal bone |
| | Bennett's fracture |
| S62.3 | Fracture of other metacarpal bone |
| S62.4 | Multiple fractures of metacarpal bones |
| S62.5 | Fracture of thumb |
| S62.6 | Fracture of other finger |
| S62.7 | Multiple fractures of fingers |
| S62.8 | Fracture of other and unspecified parts of wrist and hand |
| | |
| S63 | Dislocation, sprain and strain of joints and ligaments at wrist and hand level |
| S63.0 | Dislocation of wrist |
| | Carpal (bone) |
| | Carpometacarpal (joint) |
| | Metacarpal (bone), proximal end |
| | Midcarpal (joint) |
| | Radiocarpal (joint) |
| | Radioulnar (joint), distal |
| | Radius, distal end |

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|---|---|
| | Ulna, distal end |
| S63.1 | Dislocation of finger |
| | Interphalangeal (joint), hand |
| | Metacarpal (bone), distal end |
| | Metacarpophalangeal (joint) |
| | Phalanx, hand |
| | Thumb |
| S63.2 | Multiple dislocations of fingers |
| S63.3 | Traumatic rupture of ligament of wrist and carpus |
| | Collateral, wrist |
| | Radiocarpal (ligament) |
| | Ulnocarpal (palmar) |
| S63.4 | Traumatic rupture of ligament of finger at metacarpophalangeal and interphalangeal joint(s) |
| | Collateral |
| | Palmar |
| | Volar plate |
| S63.5 | Sprain and strain of wrist |
| | Carpal (joint) |
| | Radiocarpal (joint) (ligament) |
| S63.6 | Sprain and strain of finger(s) |
| | Interphalangeal (joint), hand |
| | Metacarpophalangeal (joint) |
| | Phalanx, hand |
| | Thumb |
| S63.7 | Sprain and strain of other and unspecified parts of hand |
| S42.4 | Fracture of lower end of humerus |
| S52.2 | Fracture of shaft of ulna |
| S52.4 | Fracture of shafts of both ulna and radius |
| S52.5 | Fracture of lower end of radius |
| S52.6 | Fracture of lower end of both ulna and radius |
| S52.7 | Multiple fractures of forearm |

| | |
|---|---|
| S52.8 | Fracture of other parts of forearm |
| S52.9 | Fracture of forearm unspecified |
| S53 | Dislocation, sprain and strain of joints and ligaments of elbow |
| S53.0 | Dislocation of radial head |
| S53.1 | Dislocation of elbow, unspecified |
| S53.2 | Traumatic rupture of radial collateral ligament |
| S53.3 | Traumatic rupture of ulnar collateral ligament |
| S53.4 | Sprain and strain of elbow |
| S54 | Injury of nerves at forearm level |
| S54.0 | Injury of ulnar nerve at forearm level |
| S54.1 | Injury of median nerve at forearm level |
| S54.2 | Injury of radial nerve at forearm level |
| S54.3 | Injury of cutaneous sensory nerve at forearm level |
| S54.7 | Injury of multiple nerves at forearm level |
| S54.8 | Injury of other nerves at forearm level |
| S54.9 | Injury of unspecified nerve at forearm level |
| S55 | Injury of blood vessels at forearm level |
| S55.0 | Injury of ulnar artery at forearm level |
| S55.1 | Injury of radial artery at forearm level |
| S55.2 | Injury of vein at forearm level |
| S55.7 | Injury of multiple blood vessels at forearm level |
| S55.8 | Injury of other blood vessels at forearm level |
| S55.9 | Injury of unspecified blood vessel at forearm level |
| S56 | Injury of muscle and tendon at forearm level |
| S56.0 | Injury of flexor muscle and tendon of thumb at forearm level |
| S56.1 | Injury of long flexor muscle and tendon of other finger(s) at forearm level |
| S56.2 | Injury of other flexor muscle and tendon at forearm level |
| S56.3 | Injury of extensor or abductor muscles and tendons of thumb at forearm level |
| S56.4 | Injury of extensor muscle and tendon of other finger(s) at forearm level |
| S56.5 | Injury of other extensor muscle and tendon at forearm level |

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|---|---|
| S56.7 | Injury of multiple muscles and tendons at forearm level |
| S56.8 | Injury of other and unspecified muscles and tendons at forearm level |
| S58 | Traumatic amputation of forearm |
| S58.0 | Traumatic amputation at elbow level |
| S58.1 | Traumatic amputation at level between elbow and wrist |
| S58.9 | Traumatic amputation of forearm, level unspecified |
| S59 | Other and unspecified injuries of forearm |
| S59.7 | Multiple injuries of forearm |
| S59.8 | Other specified injuries of forearm |
| S59.9 | Unspecified injury of forearm |
| M001 | STAPHYLOCOCCAL ARTHRITIS SHOULDER |
| M002 | STAPHYLOCOCCAL ARTHRITIS UPPER ARM |
| M0013 | PNEUMOCOCCAL ARTHRITIS FOREARM |
| M0014 | PNEUMOCOCCAL ARTHRITIS HAND |
| M0021 | OTHER STREPTOCOCCAL ARTHRITIS SHOULDER |
| M0022 | OTHER STREPTOCOCCAL ARTHRITIS UPPER ARM |
| M0023 | OTHER STREPTOCOCCAL ARTHRITIS FOREARM |
| M0024 | OTHER STREPTOCOCCAL ARTHRITIS HAND |
| M009 | PYOGENIC ARTHRITIS UNSPECIFIED |
| M0092 | PYOGENIC ARTHRITIS UPPER ARM |
| M0093 | PYOGENIC ARTHRITIS FOREARM |
| M0094 | PYOGENIC ARTHRITIS HAND |
| M6500 | ABSCESS OF TENDON SHEATH SHOULDER |
| M6502 | ABSCESS OF TENDON SHEATH UPPER ARM |
| M6503 | ABSCESS OF TENDON SHEATH FOREARM |
| M6504 | ABSCESS OF TENDON SHEATH HAND |
| M6509 | ABSCESS OF TENDON SHEATH UNSPECIFIED |
| M6510 | INFECTIVE TENOSYNOVITIS MULTIPLE SITES |
| M6512 | INFECTIVE TENOSYNOVITIS UPPER ARM |
| M6513 | INFECTIVE TENOSYNOVITIS FOREARM |
| M6514 | INFECTIVE TENOSYNOVITIS HAND |
| M6519 | INFECTIVE TENOSYNOVITIS UNSPECFIED |

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|---|---|
| M8611 | OTHER ACUTE OSTEOMYELITIS SHOULDER |
| M8612 | OTHER ACUTE OSTEOMYELITIS UPPER ARM |
| M8613 | OTHER ACUTE OSTEOMYELITIS FOREARM |
| M8614 | OTHER ACUTE OSTEOMYELITIS HAND |
| M8621 | SUBACUTE OSTEOMYELITIS SHOULDER |
| M8622 | SUBACUTE OSTEOMYELITIS UPPER ARM |
| M8623 | SUBACUTE OSTEOMYELITIS FOREARM |
| M8624 | SUBACUTE OSTEOMYELITIS HAND |
| M8691 | OSTEOMYELITIS UNSPECIFIED SHOULDER |
| M8692 | OSTEOMYELITIS UNSPECIFIED UPPER ARM |
| M8693 | OSTEOMYELITIS UNSPECIFIED FOREARM |
| M8694 | OSTEOMYELITIS UNSPECIFIED HAND |
| S41 | UPPER LIMB INJURIES |
| S42 | UPPER LIMB INJURIES |
| S44 | UPPER LIMB INJURIES |
| S45 | UPPER LIMB INJURIES |
| S46 | UPPER LIMB INJURIES |
| S47 | UPPER LIMB INJURIES |
| S48 | UPPER LIMB INJURIES |
| S49 | UPPER LIMB INJURIES |
| S50 | UPPER LIMB INJURIES |
| S51 | UPPER LIMB INJURIES |
| S52 | UPPER LIMB INJURIES |
| S53 | UPPER LIMB INJURIES |
| S54 | UPPER LIMB INJURIES |
| S55 | UPPER LIMB INJURIES |
| S56 | UPPER LIMB INJURIES |
| S57 | UPPER LIMB INJURIES |
| S58 | UPPER LIMB INJURIES |
| S59 | UPPER LIMB INJURIES |
| S60 | UPPER LIMB INJURIES |
| S61 | UPPER LIMB INJURIES |

| | |
|---|---|
| S62 | UPPER LIMB INJURIES |
| S63 | UPPER LIMB INJURIES |
| S64 | UPPER LIMB INJURIES |
| S65 | UPPER LIMB INJURIES |
| S66 | UPPER LIMB INJURIES |
| S67 | UPPER LIMB INJURIES |
| S68 | UPPER LIMB INJURIES |
| S69 | UPPER LIMB INJURIES |
| T10 | FRACTURE UPPER LIMB US |
| T11 | OTHER INJURIES UPPER LIMB US |
| W53 | RAT BITE |
| W54 | DOG BITE |
| W55 | OTHER MAMMAL BITE |
| X78 | DSH SHARP OBJECT |
| X79 | DSH BLUNT OBJECT |

## 10.22 Appendix 22. HES APC outcomes and timepoints

| **Complications** | **30 days** | **90 days** | **2 years** |
|---|---|---|---|
| Systemic complications | ✓ | ✓ | ✗ |
| Surgical site infection | ✓ | ✓ | ✗ |
| Wound dehiscence | ✓ | ✓ | ✗ |
| Osteomyelitis | ✓ | ✓ | ✗ |
| Septic arthritis | ✓ | ✓ | ✗ |
| Nerve injury | ✓ | ✓ | ✗ |
| Vascular injury | ✓ | ✓ | ✗ |
| Re-manipulation | ✓ | ✓ | ✗ |
| Rupture | ✓ | ✓ | ✗ |
| Removal of metalwork | ✓ | ✓ | ✓ |
| Tenolysis | ✓ | ✓ | ✓ |

# 10.23 Appendix 23. HES APC outcome codes

| | | ICD10 | |
|---|---|---|---|
| | | ICD10 Code | ICD10 Code Name |
| Systemic complications | Any of: | I60X or I61X or I62X or I63X or I64X | Stroke (excluding mini-stroke) |
| | | J12X or J13X or J14X or J15X or J16X or J18x J20X or J22 or J86X or J440 or J851 or J690 | Lower respiratory tract infection (LRTI): (pneumonia, aspiration pneumonia, lung abscess w |
| | | I21X or I22X | Acute myocardial infarction (AMI) |
| | | I26X | Pulmonary embolism (PE) |
| | | N300 or N308 or N309 or N390 or N10 | Urinary tract infection (UTI) |
| | | N170 or N171 or N172 or N178 or N179 or N990 | Acute renal failure (ARF) |
| | | Extracted from the Office for National Statistics (ONS) mortality data | Death |

| | | OPCS Procedure | | | OPCS Anatomical | | | ICD10 | |
|---|---|---|---|---|---|---|---|---|---|
| | | OPCS Code | OPCS Code Name | | OPCS Code | OPCS Code Name | | ICD10 Code | ICD10 Code Name |
| Surgical Site Infection (req debridement) | Any of: | T963 | Debridement of soft tissue NEC | AND and of: | Z894 | Hand NEC | AND any of: | T814 | Infection following a procedure NEC |
| | | T964 | Evacuation of seroma from soft tissue | | Z895 | Thumb NEC | | L024 | Cutaneous abscess of limb |
| | | T968 | Other specified other operations on soft tissue | | Z896 | Finger NEC | | L025 | Cutaneous abscess of hand |
| | | T969 | Unspecified other operations on soft tissue | | Z897 | Multiple digits of hand NEC | | | |
| | | | | | Z898 | Specified area of arm region NEC | | | |
| | | | | | Z502 | Skin of hand | | | |
| | | | | | Z503 | Skin of finger | | | |
| Wound dehiscence (req closure) | Any of: | S604 | Refashioning of scar | AND any of: | Z894 | Hand NEC | AND | T813 | Disruption of operation wound NEC |
| | | S422 | Delayed primary suture of skin NEC | | Z895 | Thumb NEC | | | |
| | | S424 | Secondary suture of skin NEC | | Z896 | Finger NEC | | | |
| | | S424 | Resuture of skin NEC | | Z897 | Multiple digits of hand NEC | | | |
| | | | | | Z898 | Specified area of arm region NEC | | | |
| | | | | | Z502 | Skin of hand | | | |
| | | | | | Z503 | Skin of finger | | | |
| Osteomyelitis | Any of: | W336 | Debridement of bone NEC | AND any of: | Z89.6 | Finger | AND | M8613 | Other acute osteomyelitis forearm |
| | | W337 | Lavage of bone | | Z89.4 | Hand | | M8614 | Other acute osteomyelitis hand |
| | | W338 | Other specified other open operations on bone | | Z89.8 | Multiple digits of hand | | M8623 | Subacute osteomyelitis forearm |
| | | W339 | Unspecified other open operations on bone | | Z89.5 | Thumb | | M8624 | Subacute osteomyelitis hand |
| | | W181 | Fenestration of cortex of bone | | Z73.1 | First metacarpal | | M8693 | Osteomyelitis unspecified forearm |
| | | W182 | Saucerisation of bone | | Z73.2 | Metacarpal | | M8694 | Osteomyelitis unspecified hand |
| | | W183 | Sequeestrectomy of bone | | Z73.3 | Phalanx of thumb | | T846 | Infection and inflammatory reaction due to internal fixation device (any site) |
| | | W184 | Decompression of fourage of bone | | Z73.4 | Phalanx of finger | | T847 | Infection and inflammatory reaction due to other internal orthopaedic devices, implants an |
| | | W185 | Insertion of drainage system into bone | | Z73.8 | Specified bone of hand NEC | | | |
| | | W188 | Other specified drainage of bone | | Z73.9 | Bone of hand NEC | | | |
| | | W189 | Unspecified drainage of bone | | | | | | |
| Septic arthritis | Any of: | W801 | Open debridement and irrigation of joint | AND any of: | Z83.1 | MCPJ thumb | AND any of: | M003 | Staphylococcal arthritis forearm |
| | | W802 | Open debridement of joint NEC | | Z83.2 | MCPJ finger | | M004 | Staphylococcal arthritis hand |
| | | W803 | Open irrigation of joint NEC | | Z83.3 | IPJ thumb | | M0013 | Pneumococcal arthritis forearm |
| | | W808 | Open specified debridement and irrigation of joint | | Z83.4 | PIPJ finger | | M0014 | Pneumococcal arthritis hand |
| | | W809 | Unspecified debridement and irrigation of joint | | Z83.5 | DIPJ finger | | M0023 | Other streptococcal arthritis forearm |
| | | W813 | Drainage of joint NEC | | Z83.6 | IPJ finger NEC | | M0024 | Other streptococcal arthritis hand |
| | | W814 | Incision of joint NEC | | Z83.8 | Specified joint of finger NEC | | M0093 | Pyogenic arthritis forearm |
| | | | | | Z83.9 | Joint of finger NEC | | M0094 | Pyogenic arthritis hand |
| | | | | | | | | T845 | Infection and inflammatory reaction due to internal joint prosthesis |
| | | | | | | | | T846 | Infection and inflammatory reaction due to iinternal fixation device (any site) |
| | | | | | | | | T847 | Infection and inflammatory reaction due to other internal orthopaedic devices, implants an |
| Nerve injury (req repair) | Any of: | A641 | Primary approximation of peripheral nerve | AND any of: | Z894 | Hand NEC | AND | T812 | Accidental puncture and laceration during a procedure NEC |
| | | A642 | Primary repair of peripheral nerve NEC | | Z895 | Thumb NEC | | | |
| | | A643 | Secondary repair of peripheral nerve and mobilisation of peripheral nerve | | Z896 | Finger NEC | | | |
| | | A644 | Secondary repair of peripheral nerve NEC | | Z897 | Multiple digits of hand NEC | | | |
| | | A648 | Other specified other repair of peripheral nerve | | Z898 | Specified area of arm region NEC | | | |
| | | A649 | Unspecified other repair of peripheral nerve | | Z092 | Median nerve | | | |
| | | A621 | Primary microsurgical graft to peripheral nerve | | Z093 | Radial nerve | | | |
| | | A622 | Secondary microsurgical graft to peripheral nerve | | Z094 | Ulna nerve | | | |
| | | A623 | Microsurgical graft to peripheral nerve NEC | | Z095 | Posterior interosseous nerve | | | |
| | | A624 | Primary microsurgical repair of peripheral nerve NEC | | Z096 | Anterioer interossesous nerve | | | |
| | | A625 | Secondary microsurgical repair of peripheral nerve NEC | | Z097 | Digital nerve of finger | | | |
| | | A626 | Microsurgical graft to multiple peripheral nerves NEC | | | | | | |
| | | A627 | Microsurgical repair of multiple peripheral nerves NEC | | | | | | |
| | | A628 | Other specified microsurgical repair of peripheral nerve | | | | | | |
| | | A629 | Unspecified microsurgical repair of peripheral nerve | | | | | | |
| | | A631 | Primary graft to peripheral nerve NEC | | | | | | |
| | | A632 | Secondary graft to peripheral nerve NEC | | | | | | |
| | | A638 | Other specified other graft to peripheral nerve | | | | | | |
| | | A639 | Unspecified other graft to peripheral nerve | | | | | | |
| Vascular injury (req repair) | Any of: | L684 | Repair of artery using vein graft NEC | AND any of: | Z894 | Hand NEC | AND any of: | T810 | Haemorrhage or haematoma complicating a procedure NEC |
| | | L688 | Other specified repair of artery | | Z895 | Thumb NEC | | T812 | Accidental puncture and laceration during a procedure NEC |
| | | L689 | Unspecified repair of artery | | Z896 | Finger NEC | | | |
| | | L981 | Microvascular vessel anastomosis | | Z897 | Multiple digits of hand NEC | | | |
| | | L984 | Anastomosis of vessel using microvascular anastomotic device | | Z898 | Specified area of arm region NEC | | | |
| | | L985 | Revision of microvascular anatomosis | | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | L988 | Other specified operations on microvascular vessel | | | | | | |
| | | L989 | Unspecified operations on microvascular vessel | | | | | | |

| | | OPCS Procedure | | | OPCS Anatomical | | | ICD10 | |
|---|---|---|---|---|---|---|---|---|---|
| | | OPCS Code | OPCS Code Name | | OPCS Code | OPCS Code Name | | ICD10 Code | ICD10 Code Name |
| Remanipulation | Any of: | O172 | Remanipulation of fracture of long bone and rigid internal fixation NEC | AND any of: | Z89.6 | Finger | AND any of: | T840 | Mechanical complication of internal joint prosthesis |
| | | O173 | Remanipulation of fracture of long bone and flexible internal fixation HFQ | | Z89.4 | Hand | | T841 | Mechanical complication of internal fixation device of bones of limb |
| | | O174 | Remanipulation of fracture of short bone and fixation using screw | | Z89.8 | Multiple digits of hand | | T843 | Mechanical complication of other bone devices, implants and grafts |
| | | O175 | Remanipulation of fragment of bone and fixation using screw | | Z89.5 | Thumb | | T844 | Mechanical complication of other internal orthopaedic devices, implants and grafts |
| | | O176 | Remanipulation of fracture of bone and fixation using plate | | Z73.1 | First metacarpal | | | |
| | | O178 | Other specified secondary closed reduction of fracture of bone and internal fixation | | Z73.2 | Metacarpal | | | |
| | | O179 | Unspecified secondary closed reduction of fracture of bone and internal fixation | | Z73.3 | Phalanx of thumb | | | |
| | | | | | Z73.4 | Phalanx of finger | | | |
| | | | | | Z73.8 | Specified bone of hand NEC | | | |
| | | | | | Z73.9 | Bone of hand NEC | | | |
| | | | | | Z83.1 | MCPJ thumb | | | |
| | | | | | Z83.2 | MCPJ finger | | | |
| | | | | | Z83.3 | IPJ thumb | | | |
| | | | | | Z83.4 | PIPJ finger | | | |
| | | | | | Z83.5 | DIPJ finger | | | |
| | | | | | Z83.6 | IPJ finger NEC | | | |
| | | | | | Z83.8 | Specified joint of finger NEC | | | |
| | | | | | Z83.9 | Joint of finger NEC | | | |

| | | OPCS Procedure | | | OPCS Anatomical | | | ICD10 | |
|---|---|---|---|---|---|---|---|---|---|
| | | OPCS Code | OPCS Code Name | | OPCS Code | OPCS Code Name | | ICD10 Code | ICD10 Code Name |
| Removal of metalwork | Any of: | S442 | Removal of metal from skin NEC | AND any of: | Z89.6 | Finger | AND | Z470 | Follow-up care involving removal of fracture plate and other internal fixation device |
| | | S448 | Other specified removal of removal of other inorganic substance from skin | | Z89.4 | Hand | | | |
| | | S449 | Unspecified removal of other inorganic substance from skin | | Z89.8 | Multiple digits of hand | | | |
| | | W283 | | | Z89.5 | Thumb | | | |
| | | w293 | | | Z73.1 | First metacarpal | | | |
| | | w303 | | | Z73.2 | Metacarpal | | | |
| | | | | | Z73.3 | Phalanx of thumb | | | |
| | | | | | Z73.4 | Phalanx of finger | | | |
| | | | | | Z73.8 | Specified bone of hand NEC | | | |
| | | | | | Z73.9 | Bone of hand NEC | | | |
| | | | | | Z83.1 | MCPJ thumb | | | |
| | | | | | Z83.2 | MCPJ finger | | | |
| | | | | | Z83.3 | IPJ thumb | | | |
| | | | | | Z83.4 | PIPJ finger | | | |
| | | | | | Z83.5 | DIPJ finger | | | |
| | | | | | Z83.6 | IPJ finger NEC | | | |
| | | | | | Z83.8 | Specified joint of finger NEC | | | |
| | | | | | Z83.9 | Joint of finger NEC | | | |

| | | OPCS Procedure | | | OPCS Anatomical | | | ICD10 | |
|---|---|---|---|---|---|---|---|---|---|
| | | OPCS Code | OPCS Code Name | | OPCS Code | OPCS Code Name | | ICD10 Code | ICD10 Code Name |
| Tenolysis | Any of: | T69 | Primary tenolysis | AND any of: | Z89.6 | Finger | NA | NA | |
| | | T69.1 | Revision of tenolysis | | Z89.4 | Hand | | | |
| | | T69.8 | Other specificied freeing of tendon | | Z89.8 | Multiple digits of hand | | | |
| | | T69.9 | Unspecified freeing of tendon | | Z89.5 | Thumb | | | |
| | | | | | Z56.3 | Flexor digitorum superficialis | | | |
| | | | | | Z56.4 | Flexor digitorum profundus | | | |
| | | | | | Z55.1 | Flexor muscle of forearm | | | |
| | | | | | Z55.5 | Palmaris longus | | | |
| | | | | | Z561 | Flexor pollicis longus | | | |
| | | | | | Z568 | Specified muscle of hand NEC | | | |
| | | | | | Z569 | Muscle of hand NEC | | | |
| | | | | | Z567 | Extensor muscle of hand | | | |
| | | | | | Z552 | Extensor muscle of forearm | | | |

# 10.24 Appendix 24. HES APC missing data table

| | Hand fracture fixation | | | Flexor tendon repair | | | Extensor tendon repair | | | Digital nerve injury | | | Wrist nerve injury | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Category** | *n* | *Missing (%)* | *Complete (%)* | *n* | *Missing (%)* | *Complete (%)* | *n* | *Missing (%)* | *Complete (%)* | *n* | *Missing (%)* | *Complete (%)* | *n* | *Missing (%)* | *Complete (%)* |
| Sex | 143357 | 0 | 100 | 91239 | 0 | 100 | 26316 | 0 | 100 | 19835 | 0 | 100 | 20103 | 0 | 100 |
| Age | 143235 | 0.09 | 99.91 | 91113 | 0.14 | 99.86 | 26281 | 0.13 | 99.87 | 19812 | 0.12 | 99.88 | 20082 | 0.1 | 99.9 |
| IMD | 141400 | 1.37 | 98.63 | 88998 | 2.46 | 97.54 | 25909 | 1.55 | 98.45 | 19302 | 2.69 | 97.31 | 19556 | 2.72 | 97.28 |
| Ethnicity | 143357 | 0 | 100 | 91239 | 0 | 100 | 26316 | 0 | 100 | 19835 | 0 | 100 | 20103 | 0 | 100 |
| Charlson Index | 143357 | 0 | 100 | 91239 | 0 | 100 | 26316 | 0 | 100 | 19835 | 0 | 100 | 20103 | 0 | 100 |

# 10.25 Appendix 25. HAWAII Participant Information Sheet



## Hand and Wrist Trauma: Antimicrobial Sutures and Infection (HAWAII) Feasibility Study

Chief Investigator: Mr Justin Wormald

## PATIENT INFORMATION SHEET

**Background information**

We would like to invite you to take part in a research study investigating whether two treatments for hand and wrist injuries can be compared. Before you decide to participate in the study we would like you to understand why the research is being done and what it would involve for you. Someone from our team will go through the information sheet with you and answer any questions you have.

You have injured your hand or wrist and need an operation to repair it. This operation will involve the use of surgical stitches, known as sutures. These sutures are used to repair the skin, which may have been damaged during the injury, or may need to be opened to get to the injured part of your hand or wrist. There are two different types of suture to repair the skin and injured parts of the hand and wrist. One type of suture is coated in a substance that may help reduce infection, known as 'antimicrobial' sutures. The other type is the standard type of suture that does not have an antimicrobial coating, but is the same in every other way, known as 'standard sutures'. Both sutures are used across the NHS for patients undergoing surgery, although antimicrobial sutures are more commonly used in other types of operations, like bowel surgery.

**What is the purpose of this study?**

This is a small study that will help us to plan a larger study to compare these two types of sutures. In this preliminary study, we will work out the best way to collect the information that we need for our research, and check that there are enough patients who are able and willing to take part in the study. The larger trial will tell us if there is any difference in the risk of infection between these sutures

**Why have I been invited?**

You have been invited because your doctors have looked at your injury and decided that an operation will give you the best result. The operation that you need will require some sutures to repair your hand and wrist. This has made you eligible to be part of this research project. Three hospitals in England will be taking part in this small-scale study and we hope to recruit 116 patients with a similar injury to yours.



<<<TO BE PRINTED ON LOCAL HEADED PAPER>>>

**Do I have to take part?**

No, it is entirely your decision whether you choose to take part or not. Throughout the study you are still free to withdraw at any time and without giving a reason. A decision to withdraw or a decision not to take part will not affect the standard of care you receive. However, we will not be able to remove the data we have already collected prior to your decision to withdraw.

**What will happen if I decide to take part?**

If you decide you would like to be involved in the research study you will be asked to complete a consent form. We will then ask you some basic questions such as your age, your email address, mobile phone number.

After signing the consent form, we will ask you to fill out two questionnaires before you have surgery. The first 'before injury' questionnaire will ask you about how well you were able to perform certain day-to-day tasks and how you were feeling before your injury occurred. The second 'after injury' questionnaire will ask you about how well you are able to perform certain day-to-day tasks and how you are feeling now that you are injured. The questionnaires will take approximately 20 minutes to complete.

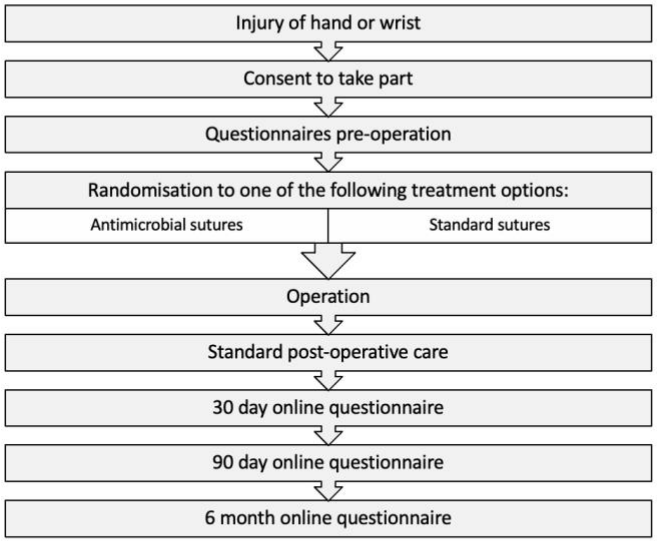
A researcher will then enter your details into a computer. A computer program will then allocate you to one of the treatment groups; either 'standard sutures' or 'antimicrobial sutures' during the repair of your injury. This is important because this way, we can test the different treatments fairly and nobody can influence the allocation of the treatments. Your doctor or the researcher will not be able to affect which treatment you get and you will not be able to choose. You will have the same chance of receiving either treatment, but we are not able to tell you which of the two treatments you will receive. This is done so that your treatment will not influence the answers to your questions.

You will be followed up according to the usual treatment plan of your hospital, in the same way as patients not taking part in this study. The only additional commitment the research team would ask of you would be to fill out questionnaires when we first see you, and on three occasions during your recovery, as described below.

When you leave the hospital, your doctor may arrange to see you at regular intervals for routine check-ups. The research team will follow how your recovery progresses over the next 6 months. We propose to do this in two ways. Firstly the research team will obtain relevant information from your hospital, to see how you are getting on. Secondly, the research team will ask you to fill out a further questionnaire at 30 days, 90 days and 6 months after your surgery. The questions will be very similar to those asked at the start of the study so that we can monitor your recovery. The questionnaires will be sent to you via email or SMS (depending on your preference), with a link to an online questionnaire with the questions on it. With your

permission, we will also let your GP know that you are taking part in this study, may contact them to confirm your details and may ask them for additional information on whether you had any complications during your treatment.

The flow-chart below shows a schedule of the activities/assessments of the study:




We will occasionally send you an email or mobile text message to inform you a questionnaire is due. We will then send two reminder messages at 48 hourly intervals after the initial message. If we have not received your questionnaire results 7 days after the initial message, we will telephone you to check you are not having problems completing the questionnaire.

**What is the difference between the treatment methods?**

The operation process will be exactly the same as it normally would be for both groups, other than the use of either antimicrobial or standard suture material. Antimicrobial sutures are the same as standard sutures in every way, apart from their coating. Their coating is made of a layer of Triclosan, which is a commonly used antimicrobial substance. It has no effect on human cells, but is toxic to bacteria and other germs. The amount of Triclosan that is used to coat the sutures is extremely small in comparison to the amounts used in commercial and





environmental products. Antimicrobial sutures dissolve in the same way as standard sutures and are the same in appearance and feel. Sutures that do not dissolve (non-absorbable sutures) are not antimicrobial sutures and so will not be tested in this study.

**What are the possible disadvantages and risks of taking part?**

The risks associated with this study are predominantly the risks associated with the anaesthetic and surgical procedure. Participants in both groups will undergo the usual surgical management of their injury and will potentially be at risk from any/all of the complications that are associated with the operation. These will be discussed between you and your doctor before surgery. There are no additional risks in either the antimicrobial suture group or the standard suture group. Although mild allergy can occur with Triclosan, there have been no reports of any adverse reaction with antimicrobial sutures in the last 13 years.

**What are the possible benefits of taking part?**

There is no specific advantage to you in taking part in this study. However, the information we get from this study will help us to improve treatment for future patients with similar injuries. It will also provide valuable information on best use of resources within the NHS.

**What if new information becomes available?**

Sometimes during the course of a research project, new information becomes available about the treatment that is being studied. If this happens, the research team will tell you about it and discuss with you whether you want to continue in the study. If you decide to withdraw, we will encourage you to discuss your continued care with your doctor. If you decide to continue in the study you will be asked sign an updated consent form.

**Will my taking part in the study be kept confidential?**

Yes. We will only use your personal details such as name and contact details where this is absolutely necessary to send you information or obtain updates from your hospital. We will assign you a unique study code which we will use on all our paperwork, instead of your name or other personal identifiers.

Responsible members of the University of Oxford and the relevant NHS Trust(s) may be given access to data for monitoring and/or audit of the study to ensure that the research is complying with applicable regulations.

**What will happen to my data?**

Data protection regulation requires that we state the legal basis for processing information about you. In the case of research, this is 'a task in the public interest.' The University of Oxford

is the data controller and is responsible for looking after your information and using it properly.

We will be using information from you and your medical records in order to undertake this study and will use the minimum personally-identifiable information possible. A copy of your consent form and information we have collected about your health related to this study will be held on an online secure database called REDCap. We will keep identifiable information about you for 6 months after the study has finished. This excludes any research documents with personal data, just as consent forms, which will be held securely at the University of Oxford for 3 years after the end of the study.

Your data from the questionnaires will also be available to your local research team at the hospital where you will have consented for the study, in this way they will have full oversight of the data in relation to your study participation. Your personal data will only be used as we explain it in this information sheet.

The local NHS trust will use your name and NHS number to oversee the quality of the study and to send copies of sections of your medical notes that are relevant to this study to the study office at the University of Oxford. A copy of your consent form will be kept in your secure medical notes. The Trust will keep identifiable information about you from this study in keeping with local policy for retention of medical notes.

Data protection regulation provides you with control over your personal data and how it is used. When you agree to your information being used in research, however, some of those rights may be limited in order for the research to be reliable and accurate. Further information about your rights with respect to your personal data is available at:

https://compliance.admin.ox.ac.uk/individual-rights.

The lawful basis for the processing of your personal data is governed by the UK General Data Protection Regulation (GDPR) & Data Protection Act (DPA) 2018 Articles 6 & 9. The University of Oxford will not transfer your personal data to any third countries or international organisations.

If you are concerned about how your personal data is being used, please contact the Chief Investigator/study team at: hawaii@ndorms.ox.ac.uk

**What will happen to the results of the research study?**

This research study is expected to last 2 years. We will publish the findings of the study at the end of the study in medical journals and at medical conferences. The study will form part of the Chief Investigator's (Justin Wormald) PhD, known as a DPhil at the University of Oxford.



UNIVERSITY OF OXFORD <<<TO BE PRINTED ON LOCAL HEADED PAPER>>> Hand and Wrist Trauma: Antimicrobial Sutures and Infection HAWAII

Anonymised research data may be made available, upon request, to other researchers at the end of the study

You will not be identified in any reports or publications. A lay summary of the results will be made available on the study website (URL XXXXXX).

**Who is organising and funding the study?**

This study is part of an NIHR Doctoral Research Fellowship and is being led by Justin Wormald (Chief Investigator) at the University of Oxford. It is coordinated by Oxford Trauma, a part of the Nuffield Department of Orthopaedics, Rheumatology and Musculoskeletal Sciences (NDORMS) at the University of Oxford. This study is funded by the National Institute for Health Research (NIHR) Doctoral Research Fellowship (NIHR301793), the British Association of Plastic, Reconstructive and Aesthetic Surgery (BAPRAS) Pump Priming Grant and the Royal College of Surgeons One-Year Research Fellowship.

**Who has reviewed this study?**

All research in the NHS is looked at by an independent group of people, called a Research Ethics Committee, to protect participants' interests. This study has been reviewed and given favourable opinion by South Central - Oxford C Research Ethics Committee.

**What if there is a problem?**

The University of Oxford is the Sponsor for the study and has appropriate insurance in place in the unlikely event that you suffer any harm as a direct consequence of your participation in this study. NHS indemnity covers any other clinical treatment with which you are provided.

If you wish to discuss about any aspect of the way in which you have been approached or treated during the course of this study, you should contact Professor Matt Costa who is the overall lead of this study on 01865 223114 or you may contact the University of Oxford Research Governance, Ethics & Assurance (RGEA) office on 01865 616480 or email the director of RGEA at ctrg@admin.ox.ac.uk.

The Patient Advice Liaison Service (PALS) is a confidential NHS service that can provide you with independent advice and support for any complaints or queries you may have regarding the care you receive as an NHS patient. PALS can give general advice, however they will not be able to give specific information regarding this study. If you wish to contact the PALS team, please contact <insert relevant NHS Site phone number and email from the PALS website>

If, at any time, you would like further information about this research project you may contact the Study Manager of this research study by telephoning **+44 (0) 1865 223101**. Or you can contact your local research lead <<insert name of local researcher>> telephone number <<insert telephone number>>.

# 10.26 Appendix 26. HAWAII Consent Form

**<<<TO BE PRINTED ON LOCAL HEADED PAPER>>>**

**Screening ID:**_____

**HAWAII Study ID:**_____

Consent Form

| | |
|---|---|
| 1. I confirm that I have read and understood the HAWAII Patient Information Sheet [version, date]. I have had the opportunity to consider the information, ask questions and have had these questions answered to my satisfaction. | ☐ Check box if you agree |
| 2. I understand that participation is voluntary and I am free to withdraw from the study at any time, without giving a reason and without my medical care and legal rights being affected. | ☐ Check box if you agree |
| 3. I agree to complete study questionnaires. | ☐ Check box if you agree |
| 4. I understand that relevant sections of my medical notes and data collected during the study may be looked at by individuals from the research team, regulatory authorities, the University of Oxford and from participating NHS organisations, where this is relevant to my participation in this study. I give permission for these individuals to have access to my medical records. | ☐ Check box if you agree |
| 5. I understand that copies of my completed questionnaires will be sent to the research team at the hospital where I consented to the research. | ☐ Check box if you agree |
| 6. I understand that the research team will store my identifiable details in order to contact me during the study period regarding this study. Identifiable details will be available only to the research team and stored securely. | ☐ Check box if you agree |
| 7. I agree that my General Practitioner can be informed of my participation where this is relevant to my taking part in the study, and may be contacted in order to provide information about my health status. | ☐ Check box if you agree |
| | |
| | |
| 9. I agree to take part in the above study. | ☐ Check box if you agree |
| Full name of patient | |
| Signature of patient | |
| Date of consent | |
| **Research Team** | |
| Name of person taking consent | |
| Signature of person taking consent | |
| Date of consent | |
| Valid Consent – hidden field | |
| Version | @READONLY |
| [PIS Version Used – hidden field] | |

One copy to be kept securely in REDCAP, one copy to be sent to the participant and one copy to be kept in the participant's medical notes

## 10.27 Appendix 27. HAWAII Case Report Forms

The post-injury PEM, PROMIS UE and EQ5D are the same as those deployed at follow-up so are not included here.

## 10.27.1 HAWAII CRF: Baseline hospital

### Section 1. Presentation

**A. Date of birth: DD/MM/YYYY**

**B. Sex: Male/Female/Other/ Prefer not to say**

**C. Date of injury: DD/MM/YYYY**

**D. Date of presentation to hand trauma service: DD/MM/YYYY**

**E. Referral pathway:**

- Emergency department: Within NHS trust
- Emergency department: Outside NHS trust (regional referral)
- Urgent care centre: Within NHS trust
- Urgent care centre: Outside NHS trust (regional referral)
- General practitioner
- Other speciality: Orthopaedic surgery
- Other speciality: General surgery
- Other speciality: Other

### Section 2. Injury details

**A. Injury site** (*Choose <u>one</u> only*):
- Right
- Left
- Bilateral

**B. Dominant hand** (*Choose <u>one</u> only*):
- Yes
- No

**C. Anatomical location of injury** (*Choose <u>one</u> only*):
- Hand (injury distal to and including CMCJ)
- Wrist (injury proximal to CMCJ)
- Hand and wrist (injuries distal to and proximal to CMCJ)

**D. Injured structures** (*Choose all that apply*):
- Skin
- Tendon
- Nerve
- Artery
- Muscle
- Ligament
- Joint
- Bone

**E. Injury type** (*Choose one only*):
- Open (full-thickness skin injury)
- Closed (skin intact)

**F. If open, injury contamination:**
- Contaminated (all open, fresh, accidental wounds)
- Dirty (old traumatic wounds, environmental contamination)

## Section 3. Initial management

Please answer the following questions that relate to management performed prior to presentation to hand trauma service.

**A. Was first aid given during initial management?**
- Yes
- No
- Unknown

**B. If yes, first aid details:**(*Tick all that apply*)
- Wound irrigation
- Tetanus vaccine
- Protective sterile dressing
- Elevation
- Splint/cast
- Other
- Unknown

**C. During initial management, were prophylactic antibiotics given?**
- Yes
- No
- Unknown

**D. If yes, please give prophylactic antibiotics details:** (*Tick one only*)
- Co-amoxiclav (give duration)
- Flucloxacillin (give duration)

- Clindamycin (give duration)
- Other (give duration)
- Unknown

**E. Was a wound swab performed by the initial management team?**

- Yes
- No
- Unknown

**Section 4. Hand trauma team management**

**A. Was first aid performed by the hand trauma team during assessment?**

- Yes
- No
- Unknown

**B. If yes, provide details:**(*Tick all that apply)*

- Wound irrigation
- Tetanus vaccine
- Protective sterile dressing
- Elevation
- Splint/cast
- Other
- Unknown

**C. Were prophylactic antibiotics prescribed by the hand trauma team?** *(No need to answer if you answered yes to antibiotics prescribed in initial management)*

- Yes
- No
- Unknown

**D. If yes, which prophylactic antibiotic was prescribed:** (*Tick <u>one only</u> and please give the prescription duration)*

- Co-amoxiclav - Duration:_____ days
- Flucloxacillin - Duration: _____ days
- Clindamycin - Duration: _____ days
- Other - Duration: _____ days
- Unknown

**F. If open injury, has a wound swab been performed by the hand trauma team?**

- Yes
- No
- Previously performed

**G. If yes, are the wound swab results available?**

- Yes – positive
- Yes – negative

- No
- Unknown

**H. What is the organism?** *(free text)*

**I. Has the patient been admitted to hospital following hand trauma team assessment?**
- Date of admission: ___/___/_____ (DD/MM/YYYY)

## Section 4. Operative management plan

**A. Decision to manage operatively made by:** (*Choose one only*):
- Foundation doctor
- Core trainee / senior house officer
- Registrar
- Consultant/ associate specialist
- Advanced nurse practitioner
- Other
- Unknown

**B. Date decision to operate made:** ___/___/_____ (DD/MM/YYYY)

**C. Planned date for operation:** ___/___/_____ (DD/MM/YYYY)

**D. Type of operation planned** (*Choose all that apply*):
- Wound debridement and washout
- Joint washout
- Repair of nerve(s)
- Repair of artery(s)
- Repair of tendon(s)
- Repair of muscle
- Repair of ligament(s)
- Repair of joint capsule/ volar plate
- Manipulation under anaesthesia
- Open reduction and internal fixation (ORIF) of fracture
- Open reduction and external fixation of fracture
- Open reduction and K-wire of fracture

## 10.27.2 HAWAII CRF: Baseline participant

### Section 1. General Information

**A. Are you a regular smoker?**
- a. Yes
  - i. If yes, how many cigarettes do you usually smoke per day?
  - ii. For how many years have you smoked?
- b. No
- c. Unknown

**B. Do you have diabetes?**
- a. Yes
  - i. If yes, do you have type 1 or type 2 diabetes?
  - ii. Do you use insulin for your diabetes?
- b. No
- c. Unknown

**C. Do you have any medical conditions or take any medication that reduces your immune system?**
- a. Yes
- b. No
- c. Unknown

**D. What is your BMI?**
- a. Height (cm):
- b. Weight (kg):

**E. How did you injure your hand/wrist?**
- a. At work - occupational injury
- b. At home – domestic accident
- c. Fall
- d. Sport
- e. Altercation
- f. Other
- g. Unknown

**F. What is your current employment status?**

a. Employee
b. Worker
c. Self-employed
d. Independent contractor
e. Free lance
f. Apprentice
g. Zero hours contract
h. Unemployed
i. Retired
j. Other
k. Unknown

**G. What is your residential status?**

a. Own home
b. Sheltered housing
c. Residential care
d. Nursing care
e. Other
f. Unknown

## Section 2. Before your injury

Please answer these questions as if you **HAD NOT** injured your hand/wrist

### Part 1. Hand function before your injury (PEM)

**The FEELING in my hand is now:**

*1 2 3 4 5 6 7*

*Normal* *Abnormal*

**When my hand is cold and/or damp, the PAIN is now:**

*1 2 3 4 5 6 7*

*Non-existent* *Unbearable*

**Most of the time, the PAIN in my hand is now:**

*1 2 3 4 5 6 7*

*Non-existent Unbearable*

**When I try to USE my hand for fiddly things, it is now:**

1 *2 3 4 5 6 7*

*Skilful Clumsy*

**Generally, when I MOVE my hand it is:**

*1 2 3 4 5 6 7*

*Flexible Stiff*

**The GRIP in my hand is now:**

*1 2 3 4 5 6 7*

*Strong Weak*

**For everyday ACTIVITIES, my hand is now:**

1 2 3 4 5 6 7

*No problem Useless*

**For WORK, my hand is now:**

*1 2 3 4 5 6 7*

*No problem Useless*

**When I look at the appearance of my hand now, I feel:**

*1 2 3 4 5 6 7*

*Unconcerned* *Embarrassed and self-conscious*

**Generally, when I think about my hand I feel:**

*1 2 3 4 5 6 7*

*Unconcerned* *Very upset*

**Part 2. Hand function before your injury (PROMIS UE CAT)**

**Delivered as a computer adaptive test. Full list of items below:**

## PROMIS Upper Extremity – Computer Adaptive Test

| | Without any difficulty | With a little difficulty | With some difficulty | With much difficulty | Unable to do |
|---|---|---|---|---|---|
| Are you able to carry a heavy object (over 10 pounds /5 kg)? | 5 | 4 | 3 | 2 | 1 |
| Are you able to dress yourself, including tying shoelaces and buttoning your clothes? | 5 | 4 | 3 | 2 | 1 |
| Are you able to reach into a high cupboard? | 5 | 4 | 3 | 2 | 1 |
| Are you able to use a hammer to pound a nail? | 5 | 4 | 3 | 2 | 1 |
| Are you able to cut your food using eating utensils? | 5 | 4 | 3 | 2 | 1 |
| Are you able to open a can with a hand can opener? | 5 | 4 | 3 | 2 | 1 |
| Are you able to pull heavy objects (10 pounds/ 5 kg) towards yourself? | 5 | 4 | 3 | 2 | 1 |
| Are you able to wash your back? | 5 | 4 | 3 | 2 | 1 |
| Are you able to open and close a zipper | 5 | 4 | 3 | 2 | 1 |
| Are you able to put on and take off a coat or jacket? | 5 | 4 | 3 | 2 | 1 |
| Are you able to dry your back with a towel? | 5 | 4 | 3 | 2 | 1 |
| Are you able to turn a key in a lock? | 5 | 4 | 3 | 2 | 1 |
| Are you able to write with a pen or pencil? | 5 | 4 | 3 | 2 | 1 |
| Are you able to put on a shirt or blouse? | 5 | 4 | 3 | 2 | 1 |
| Are you able to peel fruit? | 5 | 4 | 3 | 2 | 1 |
| Are you able to brush your teeth? | 5 | 4 | 3 | 2 | 1 |
| Are you able to button your shirt? | 5 | 4 | 3 | 2 | 1 |
| Are you able to wash dishes, pots, and utensils by hand while standing at a sink? | 5 | 4 | 3 | 2 | 1 |
| Are you able to carry a shopping bag or briefcase? | 5 | 4 | 3 | 2 | 1 |
| Are you able to change the bulb in a table lamp? | 5 | 4 | 3 | 2 | 1 |
| Are you able to press with your index finger (for example ringing a doorbell)? | 5 | 4 | 3 | 2 | 1 |

| | | | | | |
|---|---|---|---|---|---|
| Are you able to shave your face or apply makeup? | 5 | 4 | 3 | 2 | 1 |
| Are you able to squeeze a new tube of toothpaste? | 5 | 4 | 3 | 2 | 1 |
| Are you able to cut a piece of paper with scissors? | 5 | 4 | 3 | 2 | 1 |
| Are you able to pick up coins from a tabletop? | 5 | 4 | 3 | 2 | 1 |
| Are you able to hold a plate full of food? | 5 | 4 | 3 | 2 | 1 |
| Are you able to pour liquid from a bottle into a glass? | 5 | 4 | 3 | 2 | 1 |
| Are you able to push open a door after turning the knob? | 5 | 4 | 3 | 2 | 1 |
| Are you able to shampoo your hair? | 5 | 4 | 3 | 2 | 1 |
| Are you able to tie a knot or a bow? | 5 | 4 | 3 | 2 | 1 |
| Are you able to lift 10 pounds (5 kg) above your shoulder? | 5 | 4 | 3 | 2 | 1 |
| Are you able to open a new milk carton? | 5 | 4 | 3 | 2 | 1 |
| Are you able to open car doors? | 5 | 4 | 3 | 2 | 1 |
| Are you able to remove something from your back pocket? | 5 | 4 | 3 | 2 | 1 |
| Are you able to change a light bulb overhead? | 5 | 4 | 3 | 2 | 1 |
| Are you able to put on a pullover sweater? | 5 | 4 | 3 | 2 | 1 |
| Are you able to turn faucets on and off? | 5 | 4 | 3 | 2 | 1 |
| Are you able to reach and get down a 5-pound (2 kg) object from above your head? | 5 | 4 | 3 | 2 | 1 |
| Are you able to trim your fingernails? | 5 | 4 | 3 | 2 | 1 |
| Are you able to lift one pound (0.5 kg) to shoulder level without bending your elbow? | 5 | 4 | 3 | 2 | 1 |
| Are you able to use your hands, such as for turning faucets, using kitchen gadgets, or sewing? | 5 | 4 | 3 | 2 | 1 |
| Are you able to water a house plant? | 5 | 4 | 3 | 2 | 1 |
| Are you able to lift a heavy painting or picture to hang on your wall above eye-level? | 5 | 4 | 3 | 2 | 1 |
| Are you able to pass a 20-pound (10 kg) turkey or ham to other people at the table? | 5 | 4 | 3 | 2 | 1 |
| Are you able to continuously swing a baseball bat or tennis racket back and forth for 5 minutes? | 5 | 4 | 3 | 2 | 1 |
| | **Not at all** | **Very little** | **Somewhat** | **Quite a lot** | **Cannot do** |

| | | | | | |
|---|---|---|---|---|---|
| Does your health now limit you in opening a previously opened jar? | 5 | 4 | 3 | 2 | 1 |

**Part 3. Quality of life (EQ-5D-5L)**

Under each heading, please tick the ONE box that best describes your health BEFORE YOUR INJURY.

MOBILITY

I have no problems in walking about ❑

I have slight problems in walking about ❑

I have moderate problems in walking about ❑

I have severe problems in walking about ❑

I am unable to walk about ❑

SELF-CARE

I have no problems washing or dressing myself ❑

I have slight problems washing or dressing myself ❑

I have moderate problems washing or dressing myself ❑

I have severe problems washing or dressing myself ❑

I am unable to wash or dress myself ❑

**USUAL ACTIVITIES** (e.g. work, study, housework, family or leisure activities)

I have no problems doing my usual activities ❑

I have slight problems doing my usual activities ❑

I have moderate problems doing my usual activities ❑

I have severe problems doing my usual activities ❑

I am unable to do my usual activities ❑

PAIN/DISCOMFORT

I have no pain or discomfort ❑

I have slight pain or discomfort ❑

I have moderate pain or discomfort ❑

I have severe pain or discomfort ❑

I have extreme pain or discomfort ❑

ANXIETY/DEPRESSION

I am not anxious or depressed ❑

I am slightly anxious or depressed ❑

I am moderately anxious or depressed ❑

I am severely anxious or depressed ❑

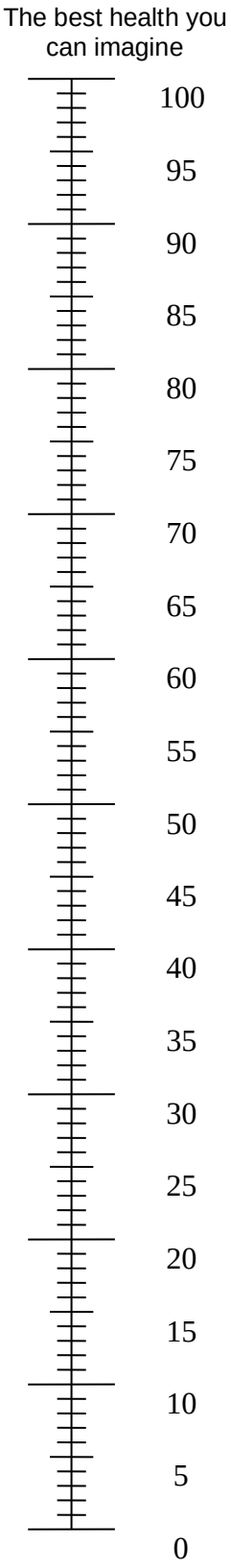
I am extremely anxious or depressed ❑

We would like to know how good or bad your health was BEFORE YOUR INJURY.

- This scale is numbered from 0 to 100.
- 100 means the best health you can imagine.

  0 means the worst health you can imagine.
- Mark an X on the scale to indicate how your health is BEFORE YOUR INJURY.
- Now, please write the number you marked on the scale in the box below.

YOUR HEALTH TODAY [ ]



## Section 3. After your injury

Please answer these questions based on how you are today.

### Part A. Hand function after your injury (PEM)

**The FEELING in my hand is now:**

*1 2 3 4 5 6 7*

*Normal* *Abnormal*

**When my hand is cold and/or damp, the PAIN is now:**

*1 2 3 4 5 6 7*

*Non-existent* *Unbearable*

**Most of the time, the PAIN in my hand is now:**

*1 2 3 4 5 6 7*

*Non-existent* *Unbearable*

**When I try to USE my hand for fiddly things, it is now:**

1 *2 3 4 5 6 7*

*Skilful* *Clumsy*

**Generally, when I MOVE my hand it is:**

*1 2 3 4 5 6 7*

*Flexible* *Stiff*

**The GRIP in my hand is now:**

*1 2 3 4 5 6 7*

*Strong* *Weak*

**For everyday ACTIVITIES, my hand is now:**

1 2 3 4 5 6 7

*No problem* *Useless*

**For WORK, my hand is now:**

*1 2 3 4 5 6 7*

*No problem* *Useless*

**When I look at the appearance of my hand now, I feel:**

*1 2 3 4 5 6 7*

*Unconcerned* *Embarrassed and self-conscious*

**Generally, when I think about my hand I feel:**

*1 2 3 4 5 6 7*

*Unconcerned* *Very upset*

**Part B. Hand function after your injury (PROMIS UE CAT)**

**Delivered as a computer adaptive test. Full list of items below:**

## PROMIS Upper Extremity – Computer Adaptive Test

| | Without any difficulty | With a little difficulty | With some difficulty | With much difficulty | Unable to do |
|---|---|---|---|---|---|
| Are you able to carry a heavy object (over 10 pounds /5 kg)? | 5 | 4 | 3 | 2 | 1 |
| Are you able to dress yourself, including tying shoelaces and buttoning your clothes? | 5 | 4 | 3 | 2 | 1 |
| Are you able to reach into a high cupboard? | 5 | 4 | 3 | 2 | 1 |
| Are you able to use a hammer to pound a nail? | 5 | 4 | 3 | 2 | 1 |
| Are you able to cut your food using eating utensils? | 5 | 4 | 3 | 2 | 1 |
| Are you able to open a can with a hand can opener? | 5 | 4 | 3 | 2 | 1 |
| Are you able to pull heavy objects (10 pounds/ 5 kg) towards yourself? | 5 | 4 | 3 | 2 | 1 |
| Are you able to wash your back? | 5 | 4 | 3 | 2 | 1 |
| Are you able to open and close a zipper | 5 | 4 | 3 | 2 | 1 |
| Are you able to put on and take off a coat or jacket? | 5 | 4 | 3 | 2 | 1 |
| Are you able to dry your back with a towel? | 5 | 4 | 3 | 2 | 1 |
| Are you able to turn a key in a lock? | 5 | 4 | 3 | 2 | 1 |
| Are you able to write with a pen or pencil? | 5 | 4 | 3 | 2 | 1 |
| Are you able to put on a shirt or blouse? | 5 | 4 | 3 | 2 | 1 |
| Are you able to peel fruit? | 5 | 4 | 3 | 2 | 1 |
| Are you able to brush your teeth? | 5 | 4 | 3 | 2 | 1 |
| Are you able to button your shirt? | 5 | 4 | 3 | 2 | 1 |
| Are you able to wash dishes, pots, and utensils by hand while standing at a sink? | 5 | 4 | 3 | 2 | 1 |
| Are you able to carry a shopping bag or briefcase? | 5 | 4 | 3 | 2 | 1 |
| Are you able to change the bulb in a table lamp? | 5 | 4 | 3 | 2 | 1 |
| Are you able to press with your index finger (for example ringing a doorbell)? | 5 | 4 | 3 | 2 | 1 |

| | | | | | |
|---|---|---|---|---|---|
| Are you able to shave your face or apply makeup? | 5 | 4 | 3 | 2 | 1 |
| Are you able to squeeze a new tube of toothpaste? | 5 | 4 | 3 | 2 | 1 |
| Are you able to cut a piece of paper with scissors? | 5 | 4 | 3 | 2 | 1 |
| Are you able to pick up coins from a tabletop? | 5 | 4 | 3 | 2 | 1 |
| Are you able to hold a plate full of food? | 5 | 4 | 3 | 2 | 1 |
| Are you able to pour liquid from a bottle into a glass? | 5 | 4 | 3 | 2 | 1 |
| Are you able to push open a door after turning the knob? | 5 | 4 | 3 | 2 | 1 |
| Are you able to shampoo your hair? | 5 | 4 | 3 | 2 | 1 |
| Are you able to tie a knot or a bow? | 5 | 4 | 3 | 2 | 1 |
| Are you able to lift 10 pounds (5 kg) above your shoulder? | 5 | 4 | 3 | 2 | 1 |
| Are you able to open a new milk carton? | 5 | 4 | 3 | 2 | 1 |
| Are you able to open car doors? | 5 | 4 | 3 | 2 | 1 |
| Are you able to remove something from your back pocket? | 5 | 4 | 3 | 2 | 1 |
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| Are you able to put on a pullover sweater? | 5 | 4 | 3 | 2 | 1 |
| Are you able to turn faucets on and off? | 5 | 4 | 3 | 2 | 1 |
| Are you able to reach and get down a 5-pound (2 kg) object from above your head? | 5 | 4 | 3 | 2 | 1 |
| Are you able to trim your fingernails? | 5 | 4 | 3 | 2 | 1 |
| Are you able to lift one pound (0.5 kg) to shoulder level without bending your elbow? | 5 | 4 | 3 | 2 | 1 |
| Are you able to use your hands, such as for turning faucets, using kitchen gadgets, or sewing? | 5 | 4 | 3 | 2 | 1 |
| Are you able to water a house plant? | 5 | 4 | 3 | 2 | 1 |
| Are you able to lift a heavy painting or picture to hang on your wall above eye-level? | 5 | 4 | 3 | 2 | 1 |
| Are you able to pass a 20-pound (10 kg) turkey or ham to other people at the table? | 5 | 4 | 3 | 2 | 1 |
| Are you able to continuously swing a baseball bat or tennis racket back and forth for 5 minutes? | 5 | 4 | 3 | 2 | 1 |
| | **Not at all** | **Very little** | **Somewhat** | **Quite a lot** | **Cannot do** |

| | | | | | |
|---|---|---|---|---|---|
| Does your health now limit you in opening a previously opened jar? | 5 | 4 | 3 | 2 | 1 |

**Part C. Quality of life (EQ-5D-5L)**

Under each heading, please tick the ONE box that best describes your health AFTER YOUR INJURY.

MOBILITY

I have no problems in walking about ❑

I have slight problems in walking about ❑

I have moderate problems in walking about ❑

I have severe problems in walking about ❑

I am unable to walk about ❑

SELF-CARE

I have no problems washing or dressing myself ❑

I have slight problems washing or dressing myself ❑

I have moderate problems washing or dressing myself ❑

I have severe problems washing or dressing myself ❑

I am unable to wash or dress myself ❑

**USUAL ACTIVITIES** (e.g. work, study, housework, family or leisure activities)

I have no problems doing my usual activities ❑

I have slight problems doing my usual activities ❑

I have moderate problems doing my usual activities ❑

I have severe problems doing my usual activities ❑

I am unable to do my usual activities ❑

PAIN/DISCOMFORT

I have no pain or discomfort ❑

I have slight pain or discomfort ❑

I have moderate pain or discomfort ❑

I have severe pain or discomfort ❑

I have extreme pain or discomfort ❑

ANXIETY/DEPRESSION

I am not anxious or depressed ❑

I am slightly anxious or depressed ❑

I am moderately anxious or depressed ❑

I am severely anxious or depressed ❑

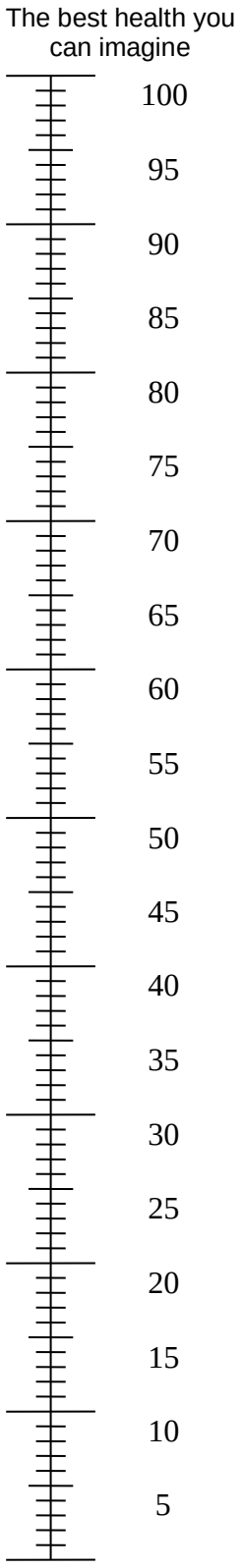
I am extremely anxious or depressed ❑

We would like to know how good or bad your health was AFTER YOUR INJURY.

- This scale is numbered from 0 to 100.
- 100 means the best health you can imagine.

  0 means the worst health you can imagine.
- Mark an X on the scale to indicate how your health is AFTER YOUR INJURY.
- Now, please write the number you marked on the scale in the box below.

YOUR HEALTH TODAY ☐



## 10.27.3 HAWAII CRF: Operation hospital

### Section 1. Clinical Details

**A. Date and time of operation:** (DD/MM/YYYY) _____

**B. Grade of lead surgeon:**

- Consultant
- Registrar
- Core surgical trainee/ SHO
- Advanced nurse practitioner
- Foundation doctor

**C. Grade of surgical assistant:**

- Consultant
- Registrar
- Core surgical trainee/ SHO
- Advanced nurse practitioner
- Foundation doctor
- No assistant

### Section 2. Peri-operative details

**A. Operating room setting:**

- Main operating theatre (including CEPOD, Day Surgery theatre)
- Minor operating room
- Trauma clinic/ outpatient room
- Emergency Department room

**B. Anaesthetic:**

- General
- Local (including WALANT)
- Other

**C. Surgical preparation fluid:**
- Alcoholic betadine
- Alcoholic chlorhexidine
- Aqueous betadine
- Aqueous chlorhexidine
- Other

**D. Sterile field preparation:**
- Full sterile draping
- Aperture drape
- None
- Other

**E. Induction antibiotics given?**
- Yes
- No
- Unknown
    i. If yes:
        - Co-amoxiclav
        - Flucloxacillin
        - Clindamycin
        - Other

## Section 3. Operative management

**J. Was a wound swab performed?**
- Yes
- No
- Unknown

**K. Was wound debridement performed?**
- Yes
- No
- Unknown

**L. Was wound washout performed?**
- Yes
- No
- Unknown
    i. If yes:
        1. <1L
        2. 1-3L
        3. 3L+
        4. Unknown

**M. Operation performed:** *tick all that apply*

- Wound debridement and washout
- Joint washout
- Repair of nerve(s)
- Repair of artery(s)
- Repair of tendon(s)
- Repair of muscle
- Repair of ligament(s)
- Repair of joint capsule/ volar plate
- Manipulation under anaesthesia
- Open reduction and internal fixation (ORIF) of fracture
- Open reduction and external fixation of fracture
- Open reduction and K-wire of fracture

**E1. Were sutures used for repair of tendon, nerve, vessel or other structures?**

- Yes
- No
- Unknown

**If Yes:**

- Antimicrobial
- Standard

**E1a. If these sutures were not the type allocated to this participant at randomisation, why were the allocated sutures not used?**

- Sutures not in stock/on shelf
- Sutures not available in size/ gauge required

**E2. What type of sutures were used?** *(Tick all that apply)*

- Braided absorbable: Gauge_____ Number of packs: _____
- Monofilament absorbable: Gauge_____ Number of packs: _____
- Non-absorbable: Gauge_____ Number of packs: _____
- Unknown

**F1. Were sutures used for skin closure?**

- Yes
- No
- Unknown

**If Yes:**

- Antimicrobial
- Standard sutures

**F1a. If these sutures were not the type allocated to this participant at randomisation, why were the allocated sutures not used?**

- Sutures not in stock/on shelf
- Sutures not available in size/ gauge required

**F2. What type of sutures were used?** *(Tick all that apply)*

- Braided absorbable: Gauge_____ Number of packs: _____
- Monofilament absorbable: Gauge_____ Number of packs: _____
- Non-absorbable: Gauge_____ Number of packs: _____
- Unknown

## Section 4. Post-operative management

**E. Was dressing applied?**

- Yes
- No
- Unknown

**If Yes, which type of dressing was applied?** (*Choose <u>one only</u>*)

- Standard non-adherent dressing
  - Name of contact layer dressing applied: _____
- Antimicrobial non-adherent dressing
  - Name of contact layer dressing applied: _____
- Other

**F. Was a splint applied?**

- Yes
- No
- Unknown

**If Yes, what type of splint was applied?**

- Plaster-of-Paris cast
- Thermoplastic cast
- Bulky bandage
- Finger splint (e.g. Zimmer splint)
- Other
- Unknown

**G. Was there post-operative elevation?**

- Yes
- No
- Unknown

**If yes, what type of elevation was used?**

- High-arm sling/ Bradford sling
- Not-specified

**H. Were post-operative antibiotics prescribed?**

- Yes
- No – already prescribed pre-operatively
- No – not indicated

**I. If yes, give post-operative antibiotics details:** (*Choose <u>one only</u>)*

- Co-amoxiclav – Duration _____days
- Flucloxacillin - Duration _____days
- Clindamycin – Duration _____days?
- Other – Duration _____days?
- Unknown

**N. Post-operative destination:** (*Choose <u>one only</u>)*

- Patient's usual place of residence
- Inpatient ward
- Other (free text)
- Unknown

**O. Follow-up plan:** (*Choose <u>one only</u>)*

- Review by clinical team within 1 week

- Review by clinical team between 1-2 weeks
- Review by clinical team between 2+ weeks
- Referral to hand therapy for follow-up and rehabilitation
- GP review in 1-2 weeks
- No follow-up required
- Other (free text)
- Unknown

## 10.27.4 HAWAII CRF: Bluebelle Wound Healing Questionnaire

# *WOUND HEALING QUESTIONNAIRE*

We are interested in knowing how your wound(s) have healed since you left hospital after having surgery. Please complete this short questionnaire yourself. It is fine to ask someone else to write the answers for you or help answer some of the questions, for example if you have not been able to see your wound(s).

If you have more than one wound, please answer the questions **thinking about just one wound** — either your main wound or another wound if there have been any concerns about how it has been healing. We would like you to think about the wounds on your skin rather than any wounds that may be inside your body.

The following questions ask about how your wound has healed and wound care **since you left hospital after having surgery**. It includes some problems that may occur with wound healing. Please note these are only possibilities and do not occur for many people. The words in brackets are the medical terminology. Next to each question, please tick the box that is most relevant to your experience.

| Since you left hospital after having surgery…. | | Not at all | A little | Quite a bit | A lot |
|---|---|---|---|---|---|
| **1.** | Was there redness spreading away from the wound? (erythema/cellulitis) | ☐ | ☐ | ☐ | ☐ |
| **2.** | Was the area around the wound warmer than the surrounding skin? | ☐ | ☐ | ☐ | ☐ |
| **3.** | Has any part of the wound leaked clear fluid? (serous exudate) | ☐ | ☐ | ☐ | ☐ |
| **4.** | Has any part of the wound leaked blood-stained fluid? (haemoserous exudate) | ☐ | ☐ | ☐ | ☐ |
| **5.** | Has any part of the wound leaked thick and yellow/green fluid? (pus/purulent exudate) | ☐ | ☐ | ☐ | ☐ |
| **6a.** | Have the edges of any part of the wound separated/gaped open on their own accord? (spontaneous dehiscence) | ☐ | ☐ | ☐ | ☐ |
| | Please answer the next question only if you have said the edges of the wound separated/gaped open: | | | | |
| | **6b.** Did the deeper tissue also separate? | ☐ | ☐ | ☐ | ☐ |
| **7.** | Has the area around the wound become swollen? | ☐ | ☐ | ☐ | ☐ |
| **8.** | Has the wound been smelly? | ☐ | ☐ | ☐ | ☐ |

| | | | | | |
|---|---|---|---|---|---|
| **9.** | Has the wound been painful to touch? | ☐ | ☐ | ☐ | ☐ |
| **10.** | Have you had, or felt like you have had, a raised temperature or fever? (fever >38°C) | ☐ | ☐ | ☐ | ☐ |

Please check that you have ticked one box for each question where required, before moving onto the next page.

| Since you left hospital after having surgery…. | | **Yes** | **No** |
|---|---|---|---|
| **11.** | Have you sought advice because of a problem with your wound, other than at a planned follow-up appointment? | ☐ | ☐ |
| **12.** | Has anything been put on the skin to cover the wound? (dressing) | ☐ | ☐ |
| **13.** | Have you been back into hospital for treatment of a problem with your wound? | ☐ | ☐ |
| **14.** | Have you been given antibiotics for a problem with your wound? | ☐ | ☐ |
| **15.** | Have the edges of your wound been deliberately separated by a doctor or nurse? | ☐ | ☐ |
| **16.** | Has your wound been scraped or cut to remove any unwanted tissue? (debridement of wound) | ☐ | ☐ |
| **17.** | Has your wound been drained? (drainage of pus / abscess) | ☐ | ☐ |

**18.** Have you had an operation under general anaesthetic for treatment of a problem with your wound? ☐ ☐

---

Please check that you have ticked one box for each question on this page.

Thank you for completing the questionnaire.

## 10.27.5 HAWAII CRF: Employment questionnaire

### Employment

**H. What is your current employment status?**

a. Working paid – full time
b. Working paid – part time
    i. %FTE
c. Working unpaid
d. Not working

**B. Since your injury, did you have to take any time off work due to your hand injury?**

Yes
Duration: _____days

No – no time off
No – not working

**C. Since your injury, did you have to change your work due to your hand injury?**

Yes
No – no change
No – not working

# 10.28 Appendix 28. SPIRIT Checklist: HAWAII protocol

SPIRIT 2013 Checklist: Recommended items to address in a clinical trial protocol and related documents*

| Section/item | Item No | Description | Addressed on page number |
|---|---|---|---|
| **Administrative information** | | | |
| Title | 1 | Descriptive title identifying the study design, population, interventions, and, if applicable, trial acronym | Title page |
| Trial registration | 2a | Trial identifier and registry name. If not yet registered, name of intended registry | Title page |
| | 2b | All items from the World Health Organization Trial Registration Data Set | NA |
| Protocol version | 3 | Date and version identifier | Title page |
| Funding | 4 | Sources and types of financial, material, and other support | Title page |
| Roles and responsibilities | 5a | Names, affiliations, and roles of protocol contributors | Title page |
| | 5b | Name and contact information for the trial sponsor | Full protocol |
| | 5c | Role of study sponsor and funders, if any, in study design; collection, management, analysis, and interpretation of data; writing of the report; and the decision to submit the report for publication, including whether they will have ultimate authority over any of these activities | Full protocol |
| | 5d | Composition, roles, and responsibilities of the coordinating centre, steering committee, endpoint adjudication committee, data management team, and other individuals or groups overseeing the trial, if applicable (see Item 21a for data monitoring committee) | Full protocol |

| | | | |
|---|---|---|---|
| **Introduction** | | | |
| Background and rationale | 6a | Description of research question and justification for undertaking the trial, including summary of relevant studies (published and unpublished) examining benefits and harms for each intervention | 3-4 |
| | 6b | Explanation for choice of comparators | 3-4 |
| Objectives | 7 | Specific objectives or hypotheses | 5 |
| Trial design | 8 | Description of trial design including type of trial (eg, parallel group, crossover, factorial, single group), allocation ratio, and framework (eg, superiority, equivalence, noninferiority, exploratory) | 6 |
| **Methods: Participants, interventions, and outcomes** | | | |
| Study setting | 9 | Description of study settings (eg, community clinic, academic hospital) and list of countries where data will be collected. Reference to where list of study sites can be obtained | 6 |
| Eligibility criteria | 10 | Inclusion and exclusion criteria for participants. If applicable, eligibility criteria for study centres and individuals who will perform the interventions (eg, surgeons, psychotherapists) | 7 |
| Interventions | 11a | Interventions for each group with sufficient detail to allow replication, including how and when they will be administered | 10 |
| | 11b | Criteria for discontinuing or modifying allocated interventions for a given trial participant (eg, drug dose change in response to harms, participant request, or improving/worsening disease) | NA |
| | 11c | Strategies to improve adherence to intervention protocols, and any procedures for monitoring adherence (eg, drug tablet return, laboratory tests) | 11 |
| | 11d | Relevant concomitant care and interventions that are permitted or prohibited during the trial | 10-11 |

| | | | |
|---|---|---|---|
| Outcomes | 12 | Primary, secondary, and other outcomes, including the specific measurement variable (eg, systolic blood pressure), analysis metric (eg, change from baseline, final value, time to event), method of aggregation (eg, median, proportion), and time point for each outcome. Explanation of the clinical relevance of chosen efficacy and harm outcomes is strongly recommended | 12 |
| Participant timeline | 13 | Time schedule of enrolment, interventions (including any run-ins and washouts), assessments, and visits for participants. A schematic diagram is highly recommended (see Figure) | 11, Appendix 1 |
| Sample size | 14 | Estimated number of participants needed to achieve study objectives and how it was determined, including clinical and statistical assumptions supporting any sample size calculations | 13 |
| Recruitment | 15 | Strategies for achieving adequate participant enrolment to reach target sample size | 7 |
| **Methods: Assignment of interventions (for controlled trials)** | | | |
| Allocation: | | | |
| Sequence generation | 16a | Method of generating the allocation sequence (eg, computer-generated random numbers), and list of any factors for stratification. To reduce predictability of a random sequence, details of any planned restriction (eg, blocking) should be provided in a separate document that is unavailable to those who enrol participants or assign interventions | 6 |
| Allocation concealment mechanism | 16b | Mechanism of implementing the allocation sequence (eg, central telephone; sequentially numbered, opaque, sealed envelopes), describing any steps to conceal the sequence until interventions are assigned | 6 |
| Implementation | 16c | Who will generate the allocation sequence, who will enrol participants, and who will assign participants to interventions | 6 |
| Blinding (masking) | 17a | Who will be blinded after assignment to interventions (eg, trial participants, care providers, outcome assessors, data analysts), and how | 10 |
| | 17b | If blinded, circumstances under which unblinding is permissible, and procedure for revealing a participant's allocated intervention during the trial | 10 |

| | | | |
|---|---|---|---|
| **Methods: Data collection, management, and analysis** | | | |
| Data collection methods | 18a | Plans for assessment and collection of outcome, baseline, and other trial data, including any related processes to promote data quality (eg, duplicate measurements, training of assessors) and a description of study instruments (eg, questionnaires, laboratory tests) along with their reliability and validity, if known. Reference to where data collection forms can be found, if not in the protocol | 12 |
| | 18b | Plans to promote participant retention and complete follow-up, including list of any outcome data to be collected for participants who discontinue or deviate from intervention protocols | 11 |
| Data management | 19 | Plans for data entry, coding, security, and storage, including any related processes to promote data quality (eg, double data entry; range checks for data values). Reference to where details of data management procedures can be found, if not in the protocol | Full protocol |
| Statistical methods | 20a | Statistical methods for analysing primary and secondary outcomes. Reference to where other details of the statistical analysis plan can be found, if not in the protocol | 14 |
| | 20b | Methods for any additional analyses (eg, subgroup and adjusted analyses) | 14 |
| | 20c | Definition of analysis population relating to protocol non-adherence (eg, as randomised analysis), and any statistical methods to handle missing data (eg, multiple imputation) | 14 |
| **Methods: Monitoring** | | | |
| Data monitoring | 21a | Composition of data monitoring committee (DMC); summary of its role and reporting structure; statement of whether it is independent from the sponsor and competing interests; and reference to where further details about its charter can be found, if not in the protocol. Alternatively, an explanation of why a DMC is not needed | NA |
| | 21b | Description of any interim analyses and stopping guidelines, including who will have access to these interim results and make the final decision to terminate the trial | NA |

| | | | |
|---|---|---|---|
| Harms | 22 | Plans for collecting, assessing, reporting, and managing solicited and spontaneously reported adverse events and other unintended effects of trial interventions or trial conduct | Full protocol |
| Auditing | 23 | Frequency and procedures for auditing trial conduct, if any, and whether the process will be independent from investigators and the sponsor | Full protocol |
| **Ethics and dissemination** | | | |
| Research ethics approval | 24 | Plans for seeking research ethics committee/institutional review board (REC/IRB) approval | 7 |
| Protocol amendments | 25 | Plans for communicating important protocol modifications (eg, changes to eligibility criteria, outcomes, analyses) to relevant parties (eg, investigators, REC/IRBs, trial participants, trial registries, journals, regulators) | Full protocol |
| Consent or assent | 26a | Who will obtain informed consent or assent from potential trial participants or authorised surrogates, and how (see Item 32) | 8 |
| | 26b | Additional consent provisions for collection and use of participant data and biological specimens in ancillary studies, if applicable | NA |
| Confidentiality | 27 | How personal information about potential and enrolled participants will be collected, shared, and maintained in order to protect confidentiality before, during, and after the trial | Full protocol |
| Declaration of interests | 28 | Financial and other competing interests for principal investigators for the overall trial and each study site | Full protocol |
| Access to data | 29 | Statement of who will have access to the final trial dataset, and disclosure of contractual agreements that limit such access for investigators | Full protocol |
| Ancillary and post-trial care | 30 | Provisions, if any, for ancillary and post-trial care, and for compensation to those who suffer harm from trial participation | Full protocol |
| Dissemination policy | 31a | Plans for investigators and sponsor to communicate trial results to participants, healthcare professionals, the public, and other relevant groups (eg, via publication, reporting in results databases, or other data sharing arrangements), including any publication restrictions | Full protocol |
| | 31b | Authorship eligibility guidelines and any intended use of professional writers | Full protocol |
| | 31c | Plans, if any, for granting public access to the full protocol, participant-level dataset, and statistical code | Full protocol |

| | | | |
|---|---|---|---|
| **Appendices** | | | |
| Informed consent materials | 32 | Model consent form and other related documentation given to participants and authorised surrogates | On request |
| Biological specimens | 33 | Plans for collection, laboratory evaluation, and storage of biological specimens for genetic or molecular analysis in the current trial and for future use in ancillary studies, if applicable | NA |

# 10.29 Appendix 29. CONSORT Checklist: HAWAII Feasibility Study

CONSORT checklist of information to include when reporting a pilot trial*

| Section/topic and item No | Standard checklist item | Extension for pilot trials | Page No where item is reported |
|---|---|---|---|
| **Title and abstract** | | | |
| 1a | Identification as a randomised trial in the title | Identification as a pilot or feasibility randomised trial in the title | 133 |
| 1b | Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts) | Structured summary of pilot trial design, methods, results, and conclusions (for specific guidance see CONSORT abstract extension for pilot trials) | 134 |
| **Introduction** | | | |
| Background and objectives: | | | |
| 2a | Scientific background and explanation of rationale | Scientific background and explanation of rationale for future definitive trial, and reasons for randomised pilot trial | 136 |
| 2b | Specific objectives or hypotheses | Specific objectives or research questions for pilot trial | 137 |
| **Methods** | | | |
| Trial design: | | | |
| 3a | Description of trial design (such as parallel, factorial) including allocation ratio | Description of pilot trial design (such as parallel, factorial) including allocation ratio | 138 |
| 3b | Important changes to methods after trial commencement (such as eligibility criteria), with reasons | Important changes to methods after pilot trial commencement (such as eligibility criteria), with reasons | NA |
| Participants: | | | |
| 4a | Eligibility criteria for participants | | 139 |
| 4b | Settings and locations where the data were collected | | 139 |
| 4c | | How participants were identified and consented | 139 |
| Interventions: | | | |
| 5 | The interventions for each group with sufficient details to allow replication, including how and when they were actually administered | | 140 |
| Outcomes: | | | |
| 6a | Completely defined prespecified primary and secondary outcome measures, including how and when they were assessed | Completely defined prespecified assessments or measurements to address each pilot trial objective specified in 2b, including how and when they were assessed | 141 |
| 6b | Any changes to trial outcomes after the trial commenced, with reasons | Any changes to pilot trial assessments or measurements after the pilot trial commenced, with reasons | NA |
| 6c | | If applicable, prespecified criteria used to judge whether, or how, to proceed with future definitive trial | NA |

| | | | |
|---|---|---|---|
| Sample size: | | | |
| 7a | How sample size was determined | Rationale for numbers in the pilot trial | 143 |
| 7b | When applicable, explanation of any interim analyses and stopping guidelines | | |
| Randomisation: | | | |
| Sequence generation: | | | |
| 8a | Method used to generate the random allocation sequence | | 141 |
| 8b | Type of randomisation; details of any restriction (such as blocking and block size) | Type of randomisation(s); details of any restriction (such as blocking and block size) | 141 |
| Allocation concealment mechanism: | | | |
| 9 | Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned | | 141 |
| Implementation: | | | |
| 10 | Who generated the random allocation sequence, enrolled participants, and assigned participants to interventions | | 141 |
| Blinding: | | | |
| 11a | If done, who was blinded after assignment to interventions (eg, participants, care providers, those assessing outcomes) and how | | 141 |
| 11b | If relevant, description of the similarity of interventions | | NA |
| Analytical methods: | | | |
| 12a | Statistical methods used to compare groups for primary and secondary outcomes | Methods used to address each pilot trial objective whether qualitative or quantitative | 144 |
| 12b | Methods for additional analyses, such as subgroup analyses and adjusted analyses | Not applicable | 144 |
| **Results** | | | |
| Participant flow (a diagram is strongly recommended): | | | |
| 13a | For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome | For each group, the numbers of participants who were approached and/or assessed for eligibility, randomly assigned, received intended treatment, and were assessed for each objective | 145 |
| 13b | For each group, losses and exclusions after randomisation, together with reasons | | 145 |
| Recruitment: | | | |

| | | | |
|---|---|---|---|
| 14a | Dates defining the periods of recruitment and follow-up | | 146 |
| 14b | Why the trial ended or was stopped | Why the pilot trial ended or was stopped | |
| Baseline data: | | | |
| 15 | A table showing baseline demographic and clinical characteristics for each group | | 148-151 |
| Numbers analysed: | | | |
| 16 | For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups | For each objective, number of participants (denominator) included in each analysis. If relevant, these numbers should be by randomised group | 148-151 |
| Outcomes and estimation: | | | |
| 17a | For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval) | For each objective, results including expressions of uncertainty (such as 95% confidence interval) for any estimates. If relevant, these results should be by randomised group | 152 |
| 17b | For binary outcomes, presentation of both absolute and relative effect sizes is recommended | Not applicable | NA |
| Ancillary analyses: | | | |
| 18 | Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing prespecified from exploratory | Results of any other analyses performed that could be used to inform the future definitive trial | 155 |
| Harms: | | | |
| 19 | All important harms or unintended effects in each group (for specific guidance see CONSORT for harms) | | 156 |
| 19a | | If relevant, other important unintended consequences | |
| **Discussion** | | | |
| Limitations: | | | |
| 20 | Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses | Pilot trial limitations, addressing sources of potential bias and remaining uncertainty about feasibility | 160 - 164 |
| Generalisability: | | | |
| 21 | Generalisability (external validity, applicability) of the trial findings | Generalisability (applicability) of pilot trial methods and findings to future definitive trial and other studies | 160 - 164 |
| Interpretation: | | | |
| 22 | Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence | Interpretation consistent with pilot trial objectives and findings, balancing potential benefits and harms, and considering other relevant evidence | 160 - 164 |
| 22a | | Implications for progression from pilot to future definitive trial, including any proposed amendments | |
| **Other information** | | | |

| | | | |
|---|---|---|---|
| Registration: | | | |
| 23 | Registration number and name of trial registry | Registration number for pilot trial and name of trial registry | 135 |
| Protocol: | | | |
| 24 | Where the full trial protocol can be accessed, if available | Where the pilot trial protocol can be accessed, if available | 135 |
| Funding: | | | |
| 25 | Sources of funding and other support (such as supply of drugs), role of funders | | 135 |
| 26 | | Ethical approval or approval by research review committee, confirmed with reference number | 135 |

*Here a pilot trial means any randomised study conducted in preparation for a future definitive RCT, where the main objective of the pilot trial is to assess feasibility.

# 10.30 Appendix 30. Trainee collaborator agreement

NDORMS **HAWAII Collaborator Agreement** HAWAII

This information sheet details the agreement between Oxford Trauma and HAWAII Collaborators

- Oxford Trauma recognises the NIHR Associate PI (aPI) scheme and values the role trainees can have in research.
- Oxford Trauma seeks to involve Associate PIs and other trainees &/or consultants in all studies where possible.
- Oxford Trauma commits alongside site staff and R&D depts to provide evidence for trainees &/or consultants of their participation in studies as part of CPD.
- Oxford Trauma recognises the International Committee of Medical Journal Editors requirements for authorship[1] and the statement from the National Research Collaborative & the Association of Surgeons in Training.[2]
- Oxford Trauma intends to name individuals, within the constraints of house styles set by Journals, who can demonstrate these criteria as collaborators on submitted manuscripts. Collaborators will only be acknowledged in the main clinical paper, and the NIHR monograph unless otherwise stated.

The criteria for determining an individual's collaborator status are:

1. **Acquisition of data and local site coordination:**

| Activity | Points | Evidence/ suggestions |
|---|---|---|
| Set-up | Up to 3 | • Site Feasibility Questionnaire<br>• Site Activation Checklists<br>• SIV Attendance Logs |
| Screening | 1 | REDCap username on CRF |
| Consent | 1 | REDCap username on CRF and name on consent form |
| Confirming eligibility and randomisation | 1 | RRAMP username on CRF |
| Operative data collection | 1 | REDCap username on CRF |
| Complications form completion | 1 | REDCap username on CRF |

***5 points and above – certificate and PubMed citable collaborator***

AND

2. **Final approval of the version to be submitted.**

AND

3. **Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.**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NDORMS **HAWAII Collaborator Agreement** HAWAII

**Calculating points**

- It is the responsibility of the collaborator to contact the trial team and provide evidence of the activities laid out above
- Total points will be calculated at the end of the study by the central study team in Oxford based on this evidence
- We strongly discourage having some members of site staff transcribing trial activities into REDCap, as this will not reflect and acknowledge the contribution of the team.
- If this will be an issue, sites will need to track their own points for those undertaking trial activities but not completing direct data entry.
- Points can travel with clinicians as they go on rotation to different NEON sites.
- As well as being a deviation, no points will be awarded for staff completing activities without being on the delegation log.

**References**

1. ICMJE | Recommendations | Defining the Role of Authors and Contributors [Internet]. [cited 2019 Sep 15]. Available from: http://www.icmje.org/recommendations/browse/roles-and-responsibilities/defining-the-role-of-authors-and-contributors.html
2. National Research Collaborative & Association of Surgeons in Training Collaborative Consensus Group. Recognising contributions to work in research collaboratives: Guidelines for standardising reporting of authorship in collaborative research. Int J Surg. 2018 Apr;52:355–60.


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# 10.31 Appendix 31. Publications, presentations and prizes

## 10.31.1 Publications

### 10.31.1.1 Research papers

- **Wormald JCR**, Baldwin AJ, Nadama H, Shaw A, Wade RG, Prieto-Alhambra D, Cook J, Rodrigues JN, Costa ML. Surgical site infection following surgery for hand trauma A systematic review and meta-analysis. Accepted *25th June 2023*, Journal of Hand Surgery European Volume. ***(Chapter 2)***
- **Wormald JC**, Rodrigues JN, Cook JA, Prieto-Alhambra D, Costa ML, HAWAII Collaborative. Hand and Wrist Trauma: Antimicrobials and Infection (HAWAII) a protocol for a multicentre, feasibility study of antimicrobial sutures in hand and wrist trauma surgery. Bone & Joint Open. 2022 Jul 1;3(7):529-35 ***(Chapter 5)***
- **Wormald JCR**, Rodrigues JN, Bheekharry R, Riley N, Tucker S, Furniss D, Dunlop R, Jones R, Appelbe D, Herbert K, Prieto-Alhambra D, Cook JA, and Costa ML, on behalf of the HAWAII Collaborative. The Hand And Wrist: Antimicrobials and Infection (HAWAII) Trial: A feasibility study of antimicrobial sutures in hand trauma surgery. In submission, British Journal of Surgery *(24th June 2023)* ***(Chapter 6)***
- **Wormald JCR**, Claireaux HA, Baldwin AJ, Chan JK-K, Rodrigues JN, Cook JA, Prieto-Alhambra D, Clarke MJ, Costa ML. Antimicrobial sutures for the prevention of surgical site infection. Cochrane Database of Systematic Reviews 2022, Issue 6. Art. No.: CD014719. DOI: 10.1002/14651858.CD014719.
- Shaw AV, Holmes DG, Rodrigues JN, Lane JC, Gardiner MD, **Wormald JC**. Outcome measurement in adult flexor tendon injury: A systematic review. J Plast Reconstr Aesthet Surg. 2022 Apr;75(4):1455-1466. doi: 10.1016/j.bjps.2021.08.033.

- Peck LJ, Rodrigues JN, **Wormald JCR**. Research in hand surgery: types of study design. J Hand Surg Eur Vol. 2023 Jul 17:17531934231186941. doi: 10.1177/17531934231186941

10.31.1.2 National guidelines

- Hand surgery: Guidelines for operating outside of main theatres May 2022. British Society for Surgery of the Hand (BSSH) and the Getting It Right First Time (GIRFT) national guideline. Available at https://www.bssh.ac.uk/_userfiles/pages/files/professionals/girft/girft-operating_outside_theatres.pdf
- National Institute for Health and Care Excellence (NICE). Plus Sutures for preventing surgical site infection: Medical technologies guidance [MTG59] Published: 28 June 2021. Available from https://www.nice.org.uk/guidance/MTG59/chapter/1-Recommendations

## 10.31.2 Presentations

- Antibiotics in hand surgery. J Wormald, J Totty. BSSH Autumn Scientific Meeting, 12-14th October 2022, Winchester, UK
- Surgical site infection following surgery for hand trauma: a systematic review and meta-analysis. J Wormald, A Shaw, A Baldwin, H Nadama, J Rodrigues, J Cook, D Prieto-Alhambra, M Costa. Stoke Mandeville Symposium – Ganga Prize Competition, 14th December 2021
- Epidemiology of acute flexor tendon injury and an analysis of severe adverse outcomes – a study of 101,559 patients in England and Wales. J Wormald, J Lane, M Ng, J Mawhinney, D Furniss. BSSH Autumn Scientific Meeting, 9-10th September 2021, Oxford, UK
- Surgical site infection following surgery for hand trauma: a systematic review and meta-analysis. J Wormald, A Shaw, A Baldwin, H Nadama, J Rodrigues, J Cook, D Prieto-Alhambra, M Costa. BSSH Autumn Scientific Meeting, 9-10th September 2021, Oxford, UK

### 10.31.3 Prizes

- BOASTiC Dragon's Den Prize – Winner, September 2022 Awarded by the BOASTiC Course Panel
- Rosetrees Essay Prize 2021 – Runner Up, May 2022 Awarded by the Royal College of Surgeons
- BSSH Best Poster Presentation, September 2021 Awarded by the British Society for Surgery of the Hand (BSSH)
- Botnar Research Centre Student Symposium 2021 Presentation Prize, June 2021 Awarded by NDORMS Head of Department

## 10.32 Appendix 32. Research tasks and collaborations

| | **Task** | **Performed by** |
|---|---|---|
| **Chapter 2 - SRMA** | Protocol development | JCRW |
| | Literature search | JCRW |
| | Abstract screening | JCRW, AS, AB, HN |
| | Data extraction | JCRW, AS, AB, HN |
| | Risk of bias | JCRW, AS, AB, HN |
| | Data analysis | JCRW |
| **Chapter 3 - CPRD** | Protocol development | JCRW |
| | Data cleaning | JCRW, MS |
| | Data extraction | JCRW, MS |
| | Data analysis | JCRW |
| **Chapter 4 - HES** | Protocol development | JCRW |
| | Data cleaning | MN |
| | Data extraction | JCRW, MN |
| | Data analysis | JCRW |
| **Chapter 5/6 - HAWAII** | Protocol development | JCRW, SW |
| | Ethics approval | JCRW, SW |
| | Study set up | JCRW, SW, JA |
| | Programming | JCRW, DA |
| | Data collection | JCRW |
| | Data analysis | JCRW |

AS – Abigail Shaw, AB – Alexander Baldwin, HN – Hayat Nadama, MS – Marti Sabate, MN – Michael Ng, SW – Stephanie Wallis, JA – Juul Achten, DA – Duncan Applebe

## 10.33 Appendix 32. Curriculum Vitae

# Curriculum Vitae

### Mr. Justin C R Wormald MBBS PGDip(Oxon) MRes MRCS

**Bio**

I am a Plastic Surgery SpR and currently a full-time DPhil Candidate in Musculoskeletal Sciences at NDORMS, University of Oxford. My research focuses on understanding and preventing surgical site infection following surgery for hand and wrist injuries. Prior to starting his DPhil, I completed an NIHR Academic Clinical Fellowship in Plastic and Reconstructive Surgery at NDORMS, University of Oxford and Buckinghamshire Healthcare NHS Trust. My undergraduate training took place at the University of East Anglia, where I attained my MB/BS and Master of Health Research (MRes) with distinction. I undertook my foundation years and core surgical training in London at St. Mary's Hospital, Chelsea and Westminster Hospital, the Royal Free Hospital and Great Ormond Street Hospital.

I have published 90 peer-reviewed papers and have received major research awards from the NIHR, RCS, BSSH and BAPRAS. I am the Trainee Lead for the Reconstructive Surgery Trials Network and an Associate Surgical Specialty Lead for Plastic and Hand Surgery for the Royal College of Surgeons of England. My main clinical interests are in trauma and reconstruction, with a focus on hand and upper limb trauma. My research interests are closely tied to this, focusing on clinical trials in trauma and reconstructive surgery, outcome measurement and evidence synthesis.

**Honorary Rosetrees Trust Research Fellow – 2023-2024**
*Rosetrees Trust and Royal College of Surgeons of England (RCSEng)*

**NIHR Doctoral Research Fellow – 2022-2023**
National Institute for Health Research

**Honorary British Society of Surgery for the Hand Research Fellow – 2021-2022**
*British Society of Surgery for the Hand (BSSH)*

**Royal College of Surgeons/ Blond McIndoe Research Fellow – 2020-2021**
*Blond McIndoe Research Foundation*

**Postgraduate Diploma in Health Research (Merit) – January 2021**
*University of Oxford*

**NIHR Academic Clinical Fellow in Plastic Surgery – 2017-2020**
*National Institute of Health Research (NIHR)*

**Associate Surgical Specialty Lead for Plastic Surgery – 2019-2023**
*Royal College of Surgeons of England (RCSEng)*

**Bachelor of Medicine and Bachelor of Surgery (MB/BS) with Distinction – July 2013**
*Norwich Medical School at the University of East Anglia (UEA)*

**Master of Health Research (MRes) with Distinction – July 2012**
*Norwich Medical School at the University of East Anglia (UEA)*

## Career Progression

**NIHR Doctoral Research Fellowship and DPhil in Musculoskeletal Sciences – 2020 – 2023**
Nuffield Department of Orthopaedics, Rheumatology and Musculoskeletal Sciences
University of Oxford

**PGDip Health Research – 2018 – 2020**
Nuffield Department of Orthopaedics, Rheumatology and Musculoskeletal Sciences
University of Oxford

**NIHR Academic Clinical Fellowship – ST3-ST5 Plastic Surgery**
**Thames Valley and Oxford University, UK (2017 – 2020)**
Buckinghamshire Healthcare NHS Trust October 2017-present

**Core Surgical Training (CT2)**
**Royal Free London and Great Ormond Street Hospital NHS Trusts, London Deanery, UK (2016-2017)**

Plastic Surgery – Royal Free Hospital October 2016 – April 2017

Orthopaedic Surgery – Great Ormond Street Hospital April 2017 – October 2017

**Core Surgical Training (CT1)**
**Chelsea & Westminster Hospital NHS Foundation Trust, London Deanery, UK (2015-2016)**

Plastic Surgery October 2015 – February 2016
Emergency General Surgery February 2016 – May 2016
Paediatric Surgery June 2016 – October 2016

**Foundation Year 2 (FY2)**
**St. Mary's Hospital, Imperial Hospitals Trust, London (2014-2015)**

Accident and Emergency Medicine August 2014 – February 2015
Vascular and General Surgery February 2015 – August 2015

**Foundation Year 1 (FY1)**
**Central Middlesex and Northwick Park Hospitals, North West London Hospitals Trust, London (2013-2014)**

Cardiology August 2013 – December 2013
Community Medicine December 2013 – April 2014
Care of the Elderly April 2014 – August 2014

**Bachelor of Medicine/ Bachelor of Surgery (MBBS) and Master of Health Research (MRes)**
**Norwich Medical School at the University of East Anglia, Norwich (2007-2013)**

MBBS Graduated with Distinction August 2007 – July 2013
Intercalated Master of Health Research (MRes) August 2011 – July 2012

[Elective term (10 weeks): Accident & Emergency, Georgetown Hospital, Guyana (4 weeks)**;** Plastic & Reconstructive Surgery at Tupua Tamasese Meaole Hospital, Samoa (6 weeks)]

## Research Grants

**NIHR Health Technology Assessment – Flexor Repair and Rehabillitation (FLARE)** April 2022

Co-applicant on successful grant application for £1,348,006.00 to fund an RCT

**NIHR Doctoral Research Fellowship** June 2021

£324,424.00 awarded to fund DPhil and doctoral research programme

**FESSH Clinical Research Grant** January 2021

£8,753.05 awarded by FESSH to develop EMCAT PROMs in hand surgery

**BAPRAS Pump Priming Grant 2020**
December 2020

£19,446.30 awarded by BAPRAS to the to fund feasibility study in hand trauma

**British Society of Surgery for the Hand Pump Priming 2020 Grant**
November 2020

£9656 pump priming for development of EMCAT PROMs in hand surgery

**AOUK&I R&PD Major Research Grant 2020** October 2020

£9,000 research grant for development of EMCAT PROMs in hand trauma

**British Society of Surgery for the Hand Research Fellowship**
September 2020

£50,000 research grant for DPhil studies in upper limb trauma and infection

**Royal College of Surgeons/ Blond McIndoe Research Fellowship** July 2020

£69,372 research grant for DPhil studies in upper limb trauma and infection

**University of Oxford Medical Sciences Graduate School Scholarship** June 2020

£85,965 research grant for DPhil tuition fees and research costs

**NIHR Health Technology Assessment – Repair of Adult Digital Nerve (NEON)** April 2019

Co-applicant on successful grant application for £1,155,466.25 to fund an RCT

**BAPRAS Pump Priming Grant 2016**
November 2016

£20,000 awarded by BAPRAS to the WIRE Steering Committee to fund feasibility study in hand trauma

**CW Plus Charitable Grant**
September 2016

£25,000 awarded by CW Plus Charity to develop in-house facemask service for burns patients at Chelsea and Westminster Burns Unit

**Palace of Westminster All Parties Ladies Committee Charitable Grant** February 2016

£9425 awarded by to purchase Cellutome Epidermal Grafting System for burns patients at Chelsea and Westminster Burns Unit

**INSPIRE UK Grant for Undergraduate Research at Norwich Medical School** October 2012

£15,000 awarded from INSPIRE (UK-wide undergraduate research initiative)
Awarded by the Academy of Medical Sciences and the Wellcome Trust, UK

**BAPRAS Student Bursary for Intercalated Degree 2012** February 2012
£500 awarded by BAPRAS, UK

**Jean Shanks Foundation Grant for Intercalated Degree 2011-2012**
September 2011

£9,000 awarded by the Jean Shanks Foundation, UK

**Total: £2,834,589.60**

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**Prizes**

**Botnar Research Centre Student Symposium 2021 Best Presentation Prize** May

2023

Awarded by NDORMS Head of Department

**BOASTiC Dragon's Den Prize – Winner**
September 2022

Awarded by the BOASTiC Course Panel

**Rosetrees Essay Prize 2021 – Runner Up** May 2022

Awarded by the Royal College of Surgeons

**BSSH Best Poster Presentation**
September 2021

Awarded by the British Society for Surgery of the Hand (BSSH)

**Botnar Research Centre Student Symposium 2021 Presentation Prize** June 2021

Awarded by NDORMS Head of Department

**Reconstructive Surgery Trials Network (RSTN) Prize** June 2019

Awarded by the RSTN Committee as senior author

**Reconstructive Surgery Trials Network (RSTN) Prize** June 2016

Awarded by the RSTN Committee as junior author

**Best Review Paper 2015 – Regenerative Medicine in Otorhinolaryngology** March 2016

Awarded by Journal of Laryngology and Otology

**Adrian Tanner Poster Prize 2015 – Runner Up** June 2015

Awarded by the Surgery Section President's Day, Royal Society of Medicine

**PLASTA Prize 2014** February 2014

Awarded by The Plastic Surgery Trainees Association (PLASTA)

**Jenny Lind Medal for Paediatrics 2012** March 2013

Awarded by Norfolk and Norwich University Hospital, UK

**Arthritis Research Campaign Prize in Rheumatology** October 2008

Awarded by the Arthritis Research Campaign, UK

## Research Publications

### Peer-reviewed publications (94)

1. **Wormald JCR**, Baldwin AJ, Nadama H, Shaw A, Wade RG, Prieto-Alhambra D, Cook J, Rodrigues JN, Costa ML. Surgical site infection following surgery for hand trauma A systematic review and meta-analysis. Accepted *25th June 2023*, J Hand Surg Eur Vol. 2023.

2. Peck LJ, Rodrigues JN, **Wormald JCR**. Research in hand surgery: types of study design. J Hand Surg Eur Vol. 2023 Jul 17:17531934231186941. doi: 10.1177/1753193423118694

3. Hardie C, Wade RG, **Wormald JCR**, et al. Surgical excision methods for skin cancer involving the nail unit: a systematic review. *Authorea.* June 06, 2023.

4. Dickson K, Mantelakis A, Reed AJM, Izadi D, Wade RG, **Wormald J**, Furniss D. The management of partial extensor tendon lacerations of the hand and forearm: A systematic review. J Plast Reconstr Aesthet Surg. 2023 Jun 9;85:34-43. doi: 10.1016/j.bjps.2023.06.004. Epub ahead of print. PMID: 37454548.

5. Shaw AV, Holmes D, Jansen V, Fowler C, **Wormald JC**, Wade RG, Taha R, Reay E, Gardiner MD. RSTN COVID Hand: Hand Trauma in the United Kingdom and Europe during the COVID-19 Pandemic. Journal of Plastic, Reconstructive & Aesthetic Surgery. 2023 Apr 23

6. **National Institute for Health and Care Research Global Health Research Unit on Global Surgery.** Reducing the environmental impact of surgery on a global scale: systematic review and co-prioritization with healthcare workers in 132 countries. Br J Surg. 2023 Jun 12;110(7):804-817

7. Dakin HA, Nguyen TTA, Dritsaki M, Greig AVH, Stokes JR, Cook JA, Beard DJ, Davies L, Gardiner MD, Jain A; **NINJA Collaborative**. Cost-effectiveness of Replacing Versus Discarding the Nail in Children with Nail Bed Injury. Br J Surg. 2023 Apr 18

8. Jain A, Greig AVH, Jones A, Cooper C, Davies L, Greshon A, Fletcher H, Sierakowski A, Dritsaki M, Nguyen TTA, Png ME, Stokes JR, Dakin H, Cook JA, Beard DJ, Gardiner MD; **NINJA Collaborative**. Effectiveness of nail bed repair in children with or without replacing the fingernail: NINJA multicentre randomized clinical trial. Br J Surg. 2023 Mar 22

9. Harrison C, Trickett R, **Wormald J**, Dobbs T, Lis P, Popov V, Beard D, Rodrigues J. Remote symptom monitoring with Ecological Momentary Computerized Adaptive Testing (EMCAT): a platform for frequent, low-burden and personalized patient-reported outcome measures. JMIR Preprints. 10/03/2023:47179

10. **Wormald JC,** Rodrigues JN, Cook JA, Prieto-Alhambra D, Costa ML, HAWAII Collaborative. Hand and Wrist Trauma: Antimicrobials and Infection (HAWAII) a protocol for a multicentre, feasibility study of antimicrobial sutures in hand and wrist trauma surgery. Bone & Joint Open. 2022 Jul 1;3(7):529-35

11. **Wormald JCR**, Claireaux HA, Baldwin AJ, Chan JK-K, Rodrigues JN, Cook JA, Prieto-Alhambra

D, Clarke MJ, Costa ML. Antimicrobial sutures for the prevention of surgical site infection. Cochrane Database of Systematic Reviews 2022, Issue 6. Art. No.: CD014719. DOI: 10.1002/14651858.CD014719. Accessed 07 July 2022.

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**Published Abstracts (11)**

1. Geary E, Gorman P, Blake K, **Wormald J**, Dolan R. TOxin for Treating Raynaud's Conditions in Hands (The TORCh Study): A Systematic Review. Irish Journal of Medical Science. 2022 Dec 1; 191:S233-S233

2. Kamran R, Rodrigues J, Dobbs T, **Wormald J**, Trickett R, Harrison C. Using Artificial Intelligence to Improve Outcome Measurement in Thumb-Base Osteoarthritis. Plastic and Reconstructive Surgery–Global Open. 2022 Oct 1;10(10S):41-2.

3. Yoshimura R, Phillips G, **Wormald J**, Collins D. P59 How COVID-19 influenced UK Burns Services: a national multicentred audit. British Journal of Surgery Open 2021. Volume 5, Issue Supplement 1

4. Site-specific patient-reported outcome measures for hand conditions: a systematic review of their development and psychometric properties. **J Wormald**, L Geoghegan, K Sierakowski, A Price, M Peters, A Jain, J Rodrigues. Quality of Life 2018 27, pp. S179–S180

5. A Systematic Review: Autologous Fibrin Glue in Soft Tissue Wound Closure. R Miller, **J Wormald**, R Wade, D Collins. British Journal of Surgery 105: 43-43. Mar 2018

6. Buried versus exposed Kirschener wires following fixation of metacarpal and phalangeal fractures: a national clinician and patient survey. **JC Wormald**, S Gardiner, JN Rodrigues, T Pezas, H Lloyd-Hughes, F Issa, A Jain, MD Gardiner. British Journal of Surgery 105: 43-43. Mar 2018

7. MediPack: Refining the Plastic Surgery Ward Round. C Brewster, **J Wormald**, T Goodwin, D Butler. International Journal of Surgery 2017, Volume 47, S67

8. The Use of an Abdominoplasty Advancement Flap to Aid Closure of Large Pelvico-Perineal Defects. M Little, **J Wormald**, M Singh, B Ayres, M Soldin. International Journal of Surgery 2017, Volume 47, S67

9. Treatment of Severe Hidradenitis Suppurativa of the Axilla: Thoracodorsal Artery Perforator (TDAP) Flap versus Split Skin Graft. **J Wormald**, A Balzano, J Clibbon, A Figus. International Journal of Surgery 2014; 12: S13-S117

10. Long-Term Quality of Life After Oesophagectomy for Cancer - Comparison of Cervical Versus Mediastinal Anastomoses. JM Bennett, **JC Wormald**, M Van Leuven, M Lewis. Gastroenterology 2013; 144 (5) S-1062

11. A combined analgaesic/anaesthetic intervention: Evaluating its effectiveness for the reduction of post-operative pain after breast cancer surgery. **JC Wormald**, A Figus, W Notcutt, J Pereira. British Journal of Surgery 2013; 100 (S4): 2–49

**Book Chapter (2)**

1. Tendon Disorders of the Hand and Wrist: IFSSH/FESSH Instructional Course Book 2022: Chapter 1, Epidemiology. Lane JCE, **Wormald JCR**, Ng M, Furniss D. Germany: Thieme, 2022.

2. Minimally invasive techniques for Facial Rejuvenation: Hyaluronic Acid for Facial Rejvenation. Figus A, **Wormald JCR**, Wade RG, Bistoni G. OMICS Group eBooks. 2014

## International and National Presentations

**All presentations (76)**

*International (29)*

1. Trainee Collaborative Research in Hand Surgery. Invited Speaker. **J Wormald**. Irish Hand Society Meeting, 9th March 2023, Dublin, Ireland

2. Geary E, Gorman P, Blake K, **Wormald J**, Dolan R. TOxin for Treating Raynaud's Conditions in Hands (The TORCh Study): A Systematic Review and Pilot Study. Irish Hand Society Meeting, 9th March 2023, Dublin, Ireland

3. Plate Fixation Versus Flexible Intramedullary Nails For Management Of Closed Femoral Shaft Fractures In The Paediatric Population: A Systematic Review And Meta-Analysis Of The Adverse Outcomes**.** A Singh**,** D Eastwood, W Bierrum, **J Wormald**, G Firth. EFORT Congress, 22 June - 24 June 2022, Lisbon, Portugal

4. How to get into research: tips from a PhD student. Invited Speaker. **J Wormald**. IFSSH, IFSHT & FESSH Combined Congress 2022, 6-10 June 2022 | ExCeL, London, UK

5. Chlorhexidine versus Povidone-Iodine Skin Antisepsis Prior to Upper Limb Surgery (CIPHUR): An International Multicentre Prospective Cohort Study. RG Wade, Grainne Bourke, **JCR Wormald**, JP Totty, GMS Stanley, A Lewandowski, SS Rakhra, MD Gardiner and The CIPHUR Collaborative. IFSSH, IFSHT & FESSH Combined Congress 2022, 6-10 June 2022 | ExCeL, London, UK

6. Computerised adaptive testing of the Patient Evaluation Measure questionnaire is accurate in thumb-base osteoarthritis from as few as 1–4 questions. R Kamran, JN Rodrigue, T Dobbs, **J Wormald**, R Trickett, C Harrison. IFSSH, IFSHT & FESSH Combined Congress 2022, 6-10 June 2022 | ExCeL, London, UK

7. A systematic review of the management of partial extensor tendon apparatus lacerations. K Dickson, A Mantelakis, A Reed, D Izadi, RG Wade, **J Wormald** and D Furniss. IFSSH, IFSHT & FESSH Combined Congress 2022, 6-10 June 2022 | ExCeL, London, UK

8. Outcome measurement in adult flexor tendon injury. Shaw A, Holmes D, Rodrigues J, Lane J, Gardiner M, **Wormald J**. IFSSH, IFSHT & FESSH Combined Congress 2022, 6-10 June 2022 | ExCeL, London, UK

9. Geary E, Gorman P, Blake K, **Wormald J**, Dolan R. TOxin for Treating Raynaud's Conditions in Hands (The TORCh Study): A Systematic Review. IFSSH, IFSHT & FESSH Combined Congress 2022, 6-10 June 2022 | ExCeL, London, UK

10. A systematic review of outcome measurement in adult flexor tendon injury. Shaw A, Holmes D, Rodrigues J, Lane J, Gardiner M, **Wormald J.** Federation of European Societies for Surgery of the Hand 2021. 16-19TH June 2021 (virtual)

11. RSTN Covid Burns: a collaborative, national, multi-centre, mixed methods analysis of the impact of COVID-19 on Burns Care in the UK. Yoshimura R, Philips G, **Wormald J**, Collins D. ISBI 2021. 14th-17th June 2021. (virtual)

12. Modified scoring for the Patient Evaluation Measure achieves previously unmatched validity in hand trauma. CJ Harrison, R Trickett, N Gape, C Gibbons, L Geoghegan, **J Wormald**, J Rodrigues. BSSH Spring Scientific Meeting, 21st April 2021, Exeter, UK

13. How COVID-19 influenced UK Burns Services: a national multi-centred audit. Yoshimura R, Philips G, Wormald J, Collins D. NRCM 2020. (virtual) 19th November-10th December 2020.

14. The Relationship Between Early Post-operative Infection and Long-term Functional Outcome in Dupuytren's Disease. **J Wormald**, T Davis, W Zhang, B Scammell, P Russell, S Fullilove, D Davidson, I Chakrabarti, J Rodrigues. BSSH Autumn Scientific Meeting, 31th October 2019, Dublin, Ireland

15. Free functional muscle transfer for upper limb paralysis: a systematic review - Claireaux HA, Reed AJM, **Wormald J**, Chan J, Shirley R. BSSH Autumn Scientific Meeting, 31th October 2019, Dublin, Ireland

16. Identifying factors associated with toxic shock syndrome in paediatric burns patients. M Marks, A Shaw, J Ross, I Jones, **J Wormald**, A Kearns, LSP Moore, D Collins. European Burns Association, September 2019, Finland (oral)

17. A Systematic Review and Meta-Analysis of Adverse Outcomes Following Buried Versus Un-Buried K-Wires For Paediatric Lateral Condyle Elbow Fractures. C Park, **J Wormald**, D Eastwood. 20th EFORT Congress, 5th June 2019, Lisbon, Portugal

18. A systematic review of the adverse outcomes following conservative versus surgical management of open fractures in the paediatric population. A Singh, W Bierrum, **J Wormald**, D Eastwood. 38th Annual Meeting of European Paediatric Orthopaedic Society (EPOS), 3-6th April 2019, Tel Aviv, Israel

19. Site-specific patient-reported outcome measures for hand conditions: a systematic review of their development and psychometric properties. **J Wormald**, L Geoghegan, K Sierakowski, A Price, M Peters, A Jain, J Rodrigues. ISOQOL 2018 Annual Conference, 27th October 2018, Dublin, Ireland

20. The developing nature and role of research in hand surgery - A Trainee Perspective. **J Wormald.** Dutch National Plastic Surgery Conference, 24th May 2018, Amsterdam, Netherlands

21. Development of a National Burn Care Audit System. Dunne JA, **Wormald JC**, Collins D. BAPRAS/FAPRAS Summer Meeting 2017, 15-17th June 2016, Helsinki, Finland

22. Does burying K-wires influence infection rate following fixation of upper limb fractures? A systematic review and meta-analysis. **J Wormald**, MD Gardiner, H Lloyd-Hughes, S Gardiner, A Jain. International Federation of Societies for Surgery of the Hand (IFSSH) & International Federation of Societies for Hand Therapy Congress 2016, 24th-28th October 2016, Hilton, Buenos Aires, Argentina

23. Finger Necrosis – A Hoarder's Tale. CY Park, **J Wormald,** A Mohan, G Smith. International Federation of Societies for Surgery of the Hand (IFSSH) & International Federation of Societies for Hand Therapy Congress 2016, 24th-28th October 2016, Hilton, Buenos Aires, Argentina

24. Clinical Experience with Biological and Biosynthetic Skin Substitutes: A Survey of United Kingdom and Australasian Burns Units. **J Wormald,** J Dunne, Murray A, Rawlins J. International Society for Burn Injuries (ISBI) 2016 Congress, 29th August – 1st September 2016, Hyatt Regency Hotel, Miami, USA

25. Biosynthetic Skin Substitutes for Large Burns: A Review. **J Wormald**, JA Dunne, Murray A, Rawlins J. International Society for Burn Injuries (ISBI) 2016 Congress, 29th August – 1st September 2016, Hyatt Regency Hotel, Miami, USA

26. Results of a multi-centre audit to improve doctors' awareness of DVLA guidelines. M Maruthappu, M Sykes, B Green, T Soomro, ND Gollop, RA Watson, **JCR Wormald,** M Park, J Diviney, A Taylor, J Shalhoub, KYB Ng. Prague European Days of Internal Medicine (PEDIM), 18-20th September 2014, Prague, Czech Republic

27. Results of a multi-centre audit to improve doctors' awareness of DVLA guidelines. M Maruthappu, M Sykes, B Green, T Soomro, ND Gollop, RA Watson, **JCR Wormald,** M Park, J Diviney, A Taylor, J Shalhoub, KYB Ng. 3rd World Congress of Clinical Safety, International Association of risk management in Medicine, 10-12th September 2014, Madrid, Spain

28. Long-term Quality of Life after Oesophagectomy for Cancer – Comparison of Cervical versus Intra-Thoracic Anastomosis. **JC Wormald,** JMH Bennett, M Van Leuvan, MPN Lewis. Digestive Diseases Week (DDW), May 18-21st 2013, Orlando Convention Centre, Orlando, Florida, USA

29. Adverse Outcomes in Unilateral versus Bilateral DIEP Flap Breast Reconstruction: A Systematic Review and Meta-Analysis. A Figus, **J Wormald,** R Wade. European Association of Plastic, Reconstructive and Aesthetic Surgeons (EURAPS) 24th Annual Meeting, 23-25th May 2013, Antalaya, Turkey

*National (47)*

1. Antibiotics in hand surgery. **J Wormald**, J Totty. BSSH Autumn Scientific Meeting, 12-14th October 2022, Winchester, UK

2. PEMCAT Trauma: further refinements of the PEM for a hand trauma population. **J Wormald**, R Kamran, J Rodrigues, N Gape, T Dobbs, R Trickett, C Harrison. BSSH Autumn Scientific Meeting, 12-14th October 2022, Winchester, UK

3. Surgical site infection following surgery for hand trauma: a systematic review and meta-analysis. **J Wormald**, A Shaw, A Baldwin, H Nadama, J Rodrigues, J Cook, D Prieto-Alhambra, M Costa. Stoke Mandeville Symposium – Ganga Prize Competition, 14th December 2021 (Virtual)

4. Epidemiology of acute flexor tendon injury and an analysis of severe adverse outcomes – a study of 101,559 patients in England and Wales. **J Wormald**, J Lane, M Ng, J Mawhinney, D Furniss. BSSH Autumn Scientific Meeting, 9-10th September 2021, Oxford, UK

5. Surgical site infection following surgery for hand trauma: a systematic review and meta-analysis. **J Wormald**, A Shaw, A Baldwin, H Nadama, J Rodrigues, J Cook, D Prieto-Alhambra, M Costa. BSSH Autumn Scientific Meeting, 9-10th September 2021, Oxford, UK

6. Psychometric properties of the PEM hand PROM in traumatic and elective conditions. **J Wormald**, R Trickett, N Gape, C Gibbons, C Jerosch-Herold, E Gibbons, A Price, R Poulter, J Rodrigues. PROMS UK National Conference, 14th June 2019, Leeds, UK

7. Classical test theory and item response theory validity of the PEM in hand trauma differs from its validity in Dupuytren's disease. **J Wormald**, R Trickett, C Jerosch-Herold, E Gibbons, A Price, R Poulter, C Gibbons, J Rodrigues. BSSH Spring Scientific Meeting, 24th April 2019, Swansea, UK

8. OxScar Plastic Surgery and the RSTN. **J Wormald**. OxScar Spring Meeting, 11th April 2019, Oxford, UK

9. A systematic review of the adverse outcomes following conservative versus surgical management of open fractures in the paediatric population. A Singh, W Bierrum, **J Wormald**, D Eastwood. President's Day (Orthopaedics Section) 7th December 2018, Royal Society of Medicine, London UK (oral)

10. Site-specific patient-reported outcome measures for hand conditions: a systematic review of their development and psychometric properties. **J Wormald**, L Geoghegan, K Sierakowski, A Price, M Peters, A Jain, J Rodrigues. BSSH Autumn Scientific Meeting, 11th October 2018, London, UK

11. Documentation of Non-Accidental Injury and Interaction with Social Care in Paediatric Patients Referred to Plastic Surgery. **J Wormald**, S Sandhu, S Gahunia, C Harrison. 5th National Quality Improvement Conference, 7th July 2018, Stoke Mandeville Hospital, Aylesbury, UK (poster)

12. Site-specific patient-reported outcome measures for hand conditions: a systematic review of their development and psychometric properties, and implications for hand surgery research. **JCR Wormald**, L Geoghegan, K Sierakowski, A Price, M Peters, A Jain, JN Rodrigues. PROMs Conference 2018, 20th June 2018, University of Birmingham, UK (poster)

13. The developing nature and role of research in hand surgery - A Trainee Perspective. **J Wormald.** Buckinghamshire Hand Symposium, 16th May 2018, Stoke Mandeville Hospital,

Aylesbury, UK (oral)

14. A critical review of melanoma self-screening tools on YouTube – a missed opportunity? B Smeeton, **J Wormald,** A Plonczak, D Butler, S Hamilton. ASiT Conference, 6th-8th April 2018, Edinburgh, Scotland (poster)

15. Buried versus exposed Kirschener wires following fixation of metacarpal and phalangeal fractures: a national clinician and patient survey. **Wormald JC,** Gardiner S, Rodrigues JN, Pezas T, Lloyd-Hughes H, Issa F, Jain A, Gardiner MD. Society for Academic and Research Surgery (SARS) Annual General Meeting, January 10-11th 2018, University of Nottingham, UK (oral)

16. A Systematic Review: Autologous Fibrin Glue in Soft Tissue Wound Closure. R Miller, **J Wormald,** R Wade, D Collins. Society for Academic and Research Surgery (SARS) Annual General Meeting, January 10-11th 2018, University of Nottingham, UK (oral)

17. Key steps for success in systematic review. **JC Wormald** (invited speaker). BAPRAS Winter Scientific Meeting 29th November 2017, Park Plaza Victoria, London, UK (oral)

18. Surgical Intervention for Chronic Migraine Headache – A Systematic review. **JC Wormald,** J Luck, B Athwal, T Muehlberger, A Mosahebi. BAPRAS Winter Scientific Meeting 29th November 2017, Park Plaza Victoria, London, UK (oral)

19. Anatomical Concepts and Biomechanics of the Trapezium and First Carpo-Metacarpal Joint. **JC Wormald**, L Geoghegan, RZ Adami, JN Rodrigues. BSSH Autumn Scientific Meeting, 9-10th November 2017, Assembly Rooms, Edinburgh (Poster)

20. Central slip extensor tendon injuries: a systematic review of treatments. L Geoghegan, JC Wormald, RZ Adami, A Khajuria, JN Rodrigues. BSSH Autumn Scientific Meeting, 9-10th November 2017, Assembly Rooms, Edinburgh (Poster)

21. The WIRE: National Survey Results. The WIRE Steering Group - **J Wormald**, S Gardiner, H Lloyd-Hughes, MD Gardiner, JN Rodrigues, T Pezas, F Issa, A Jain. Reconstructive Surgery Trials Network (RSTN) Trials Day, 2nd June 2017, Royal College of Surgeons of England, London, UK (poster)

22. Burns to the lower extremity: comparison of outcomes in diabetic patients vs. non-diabetic patients. **Wormald JC**, Dunne J, Allan A, Jones I, Atkins J. British Burns Association: Annual Meeting 2017, 3-5th May 2017, Royal College of Surgeons of England, London, UK (poster)

23. Development of a National Burn Care Audit System. Dunne JA, **Wormald JC**, Collins D. British Burns Association: Annual Meeting 2017, 3-5th May 2017, Royal College of Surgeons of England, London, UK (poster)

24. Peri-operative Blood Loss and Transfusion in Craniosynostosis Surgery: A Single Centre Experience. **Wormald JC**, Park CY, Miranda B, Ong J, Eccles S. CFSGBI Craniofacial Conference 2017, 5-7th April 2017, SAGE Gateshead, Newcastle, UK (oral)

25. The use of an abdominoplasty advancement flap to aid closure of large pelvicoperineal defects. Little M, Singh M **Wormald JC**, Watkins N, Ayres B, Soldin M. ASiT Conference, 31st March -2nd April 2017, Bournemouth, UK (poster)

26. A One-Year Snapshot of Trauma Mortality at a London Major Trauma Centre. Little M, **Wormald JC**, Osborne M, Lawton G. ASiT Conference, 31st March -2nd April 2017, Bournemouth, UK (poster)

27. Plastic Surgery MediPack. Brewster C, **Wormald JC**, Butler D, Horwitz M. ASiT Conference, 31st March -2nd April 2017, Bournemouth, UK (poster)

28. RSTN Wire Trial National clinical practice survey and National patient survey results. The WIRE Steering Group - **J Wormald**, S Gardiner, H Lloyd-Hughes, MD Gardiner, JN Rodrigues, T Pezas, F Issa, A Jain. BSSH/BAHT Autumn Scientific Meeting 2016, 13th & 14th October 2016, Mercure Cardiff Holland House Hotel, Cardiff, UK (poster)

29. VivostatTM and ReCellTM for Adult Burn Split-thickness Skin Grafting: A Randomised Controlled Clinical Trial. **J Wormald**, D Collins, Z Alaqaf, Jones I, Atkins J. Reconstructive Surgery Trials Network (RSTN) Trials Day, 18th June 2016, Royal College of Surgeons of England, London, UK (oral)

30. CellutomeTM Epidermal Harvesting System and ReCellTM for Vitiligo: A Randomised Controlled Clinical Trial. D Collins, **J Wormald**, I Jones, T Metcalfe, S Riaz. Reconstructive Surgery Trials Network (RSTN) Trials Day, 18th June 2016, Royal College of Surgeons of England, London UK (poster)

31. WIRE Trial – to bury or not bury K wires following fracture fixation. The WIRE Steering Group - S Gardiner, **J Wormald**, H Lloyd-Hughes, MD Gardiner, A Jain**.** Reconstructive Surgery Trials Network (RSTN) Trials Day, 18th June 2016, Royal College of Surgeons of England, London UK (oral)

32. Preliminary results from the WIRE Trial Survey. The WIRE Steering Group - S Gardiner, **J Wormald**, H Lloyd-Hughes, MD Gardiner, A Jain**.** Reconstructive Surgery Trials Network (RSTN) Trials Day, 18th June 2016, Royal College of Surgeons of England, London UK (poster)

33. Finger Necrosis: A Hoarder's Tale. CY Park, **J Wormald**, A Mohan, G Smith. Adrian Tanner Competition, President's Day (Surgery Section) 3rd June 2016, Royal Society of Medicine, London UK (oral)

34. Regenerative Medicine in Otorhinolaryngology. **J Wormald**, JM Fishman, S Juniat, MA Birchall. Journal of Laryngology and Otology Study Day, 5th May 2016, Wellcome Collection, London, UK (oral)

35. Does burying K-wires influence infection rate following fixation of upper limb fractures? A systematic review. **J Wormald**, MD Gardiner, H Lloyd-Hughes, S Gardiner, A Jain. British

Society for Surgery of the Hand (BSSH) Scientific Spring Meeting, 28th April 2016, RCS London, UK (oral)

36. The WIRE Project – buried versus non-buried K-wires and infection rate following fixation of hand fractures - systematic review and national survey of practice. The WIRE Trial Steering Committee - **J Wormald**, MD Gardiner, H Lloyd-Hughes, S Gardiner. British Society for Surgery of the Hand (BSSH) Scientific Spring Meeting, 28th April 2016, RCS London, UK (poster)

37. Junior-led Optimisation Of External Hand Trauma Referrals: Ensuring Radiographic Images Are Received And Reviewed. A Mehdi, CY Park, **J Wormald**, G McArthur. Clinical Leadership Forum, 3rd National NHS Leadership Meeting, 16th April 2016, Hammersmith Hospital, London, UK (poster)

38. Novel teaching programme improves prescribing confidence in final year medical students. K Gananandan, L Elliot, S Field, **J Wormald**. International Associated for Medical Education (AMEE) Conference 2015, 5-9th September 2015, Scottish Exhibition and Conference Centre, Glasgow, Scotland (poster)

39. Audiovestibular disease leading to falls in the elderly: a neglected risk factor? K Ramdoo, **J Wormald**, E Chua, T Tatla. 5th British Academic Conference in Otolaryngology (BACO), 8th July 2015, BT Convention Centre, Liverpool, UK (poster)

40. Aorto-oesophageal fistula: the MDT approach. **J Wormald**, S Dindyal, R Thomas, CJ Peters, K Sritharan. Adrian Tanner Competition, President's Day (Surgery Section) 4th June 2015, Royal Society of Medicine, London UK (oral)

41. Aorto-oesophageal fistula: the MDT approach. **J Wormald**, S Dindyal, R Thomas, CJ Peters, K Sritharan. Adrian Tanner Competition, President's Day (Surgery Section) 4th June 2015, Royal Society of Medicine, London UK (poster)

42. Awareness of melanoma in junior doctors, nurses and the general public: a comparative study. S Field, **J Wormald**, A Carter, G Fishman. 6th Annual DermSchool, British Association of Dermatologists (BAD), 30th June 2014, Scottish Exhibition and Conference Centre (SECC), Glasgow, Scotland

43. Treatment of Severe Hidradenitis Suppurativa of the Axilla: Thoracodorsal Artery Perforator (TDAP) Flap versus Split Skin Graft. **J Wormald**, A Balzano, J Clibbon, A Figus. ASiT Conference, 28-30th March 2014, Belfast Waterfront Conference Centre, Northern Ireland, UK (poster)

44. A combined analgaesic/anaesthetic intervention: Evaluating its effectiveness for the reduction of post-operative pain after breast cancer surgery. **JC Wormald,** A Figus, W Notcutt, J Pereira. Society for Academic and Research Surgery (SARS) Annual General Meeting, January 8-9th 2013, Royal Society of Medicine, London, UK (oral)

45. Long-term Quality of Life after Oesophagectomy for Cancer – Comparison of Cervical versus

Intra-Thoracic Anastomosis. JMH Bennett, **JC Wormald**, M Van Leuvan, MPN Lewis**.** Digestive Disorders Federation (DDF), 17-20 June 2012, Arena and Convention Centre, Liverpool, UK (poster)

46. A combined analgaesic/anaesthetic intervention: Evaluating its effectiveness for the reduction of post-operative pain after breast cancer surgery **JC Wormald,** A Figus, W Notcutt, J Pereira. 4th National Undergraduate Medical Student Research Conference, 13th October 2012, University of Leicester (oral)

47. Traumatic stapes footplate fracture with likely perilymph leak from a rare mechanism of injury. **J Wormald**, S Jing, J Hanif**.** 2nd Foundation ENT Conference, 4th March 2012, Royal College of Surgeons of England, London, UK (poster)

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## Editorial and Peer Review

### Editorial Roles

Associate Editor of the Journal of Hand Therapy: 2021-present

### Peer Reviewer Roles

British Medical Journal: 2021-present
Cochrane Systematic Reviews: 2023-present
British Journal of Surgery: 2016-present
Bone and Joint Journal: 2023-present
Journal of Plastic, Reconstructive and Aesthetic Surgery: 2018-present

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## Teaching and Medical Education

### University Roles

- Clinical Teaching Associate – St. John's College, University of Oxford: October 2021-present
- Interviewer for undergraduate medicine – St. John's College, University of Oxford: December 2021
- Anatomy Demonstrator: October 2016 – October 2017, University College London Medical School

### Teaching Training

- Teaching skills for doctors: Small group teaching – May 2014
- Royal Society of Medicine, London

### National Teaching

- RSM Crash Course in Plastic Surgery: invited lecturer – getting to grips with hand trauma – 2021 to present

- Royal College of Surgeons – Surgical Skills Competition – Research in Surgery, 2017, Tutor

- eLPRAS Teaching Module Author : Monitoring the Burns Patient Following Surgery

- Undergraduate Plastic, Reconstructive and Aesthetic Surgery (UPRAS) November 2016 - Tutor
  Taught surgical skills to undergraduates and foundation doctors

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**Leadership Roles**

RSTN Trainee Lead 2021-present
Reconstructive Surgery Trials Network (RSTN)

Associate Surgical Specialty Lead for Plastic Surgery 2019-present
Royal College of Surgeons (RCS)

RSTN Trainee Network Lead 2018-present
Reconstructive Surgery Trials Network (RSTN)

PLASTA BSSH Representative 2019-present
Plastic Surgery Trainees Association (PLASTA)

PLASTA Research Representative 2018-2019
Plastic Surgery Trainees Association (PLASTA)

The WIRE Trial – Steering Committee 2015-present
Reconstructive Surgery Trials Network

RSM OSCE Courses and Events Committee 2015-present
Royal Society of Medicine

Foundation Doctor Representative 2013-2014
North West London Hospitals Trust

Founder and President 2012-2013
Norwich Academic Training for Undergraduates in Research (NATURE)

INSPIRE representative 2012-2013
Norwich Medical School

Orchestra Leader 2004-2006

Highgate School

Captain of the Fencing Team 2004-2005
Highgate School

Signed:

Justin Wormald
26th July 2023