On ankle fractures

Emilia Möller Rydberg

Department of Orthopaedics

Institute of Clinical Sciences

Sahlgrenska Academy, University of Gothenburg

UNIVERSITY OF GOTHENBURG

Gothenburg, 2023

Illustrations, including cover, by Pontus Andersson / Pontus Art Production
Layout by Guðni Ólafsson & Adam Werner / GO Grafik

On ankle fractures

emilia.rydberg@vgregion.se

ISBN 978-91-8069-006-5 (PRINT)
ISBN 978-91-8009-999-8 (PDF)
http://hdl.handle.net/2077/74155

Printed in Borås, Sweden, 2023
Printed by Stema Specialtryck AB

“Culture eats strategy for breakfast”

Peter Drucker

ABSTRACT

Ankle fractures range from simple avulsions to complex injuries and the treatment options are numerous. Sweden has no national guidelines regarding the management and treatment of ankle fractures, leaving these choices up to local tradition or individuals' decisions. The overall aim of this thesis is to investigate how ankle fractures are classified, managed and treated and analyse the effect of a structured treatment algorithm (TA). The Swedish Fracture Register (SFR) is the platform for all the included studies.

Paper I describes the epidemiology of all 57,433 ankle fractures registered in the SFR between 2012 and 2022. The results demonstrate that women more often sustain ankle fractures and are older than men at the time of injury. Ankle fractures are most frequently caused by a simple same-level fall. There is a pronounced seasonal variation, with a distinct peak during winter, which is driven by simple same-level falls causing B-type fractures. **Paper II** reveals that the incidence of ankle fractures declined during the first wave of the Covid-19 pandemic. The greatest reduction was seen during the first studied month, March 2020, among women and in the ≥ 70 years age group. This paper also demonstrates that the SFR can be utilised to compare fracture incidences over time. **Paper III** investigates how lateral malleolar fractures at the level of the syndesmosis are classified, managed and treated. One key aspect to which fractures that are safe to treat non-surgically is the stability of the fracture and consequently the ankle joint. Stability is dependent on the integrity of the deltoid ligament. Paper III illuminates the difficulties involved in clinically evaluating the deltoid ligament. The results demonstrate the variability that exists in management and treatment decisions, as 30% of the patients were treated surgically and 70% non-surgically, with no clear relationship to the assessment of stability. **Paper IV** presents the results of a study comparing a group of lateral malleolar ankle fractures at the level of the syndesmosis treated before the introduction of a structured TA with a group managed and treated afterwards. The results show that a TA induced changes in all the studied parameters; reducing the number of radiographic examinations, the number of days immobilised and the proportion of surgical treatment, as well as increasing the number of patients that were allowed full weight-bearing. **Paper V** is a qualitative interview study with physicians registering fractures in the SFR with the objective of extending knowledge

of how a knowledge support system was perceived by users. The results reveal that users appreciate knowledge support, finding that it increases the value for work and the incentive to register fractures during busy working days.

To conclude, ankle fractures predominantly affect women and occur during winter as a result of simple same-level falls. The incidence declined during the Covid-19 pandemic, primarily during the first month, in women and in the $\geq$ 70 years age group. Structured TAs can optimise resource consumption in the management and treatment of ankle fractures. The implementation of a TA for ankle fractures was found to reduce the number of unnecessary surgical procedures and make decisions regarding treatment less dependent on the individual surgeon's discretion. Knowledge support based on a TA incorporated into the SFR provides an appreciated validation of the clinical decisions taken by physicians and was found by the users to increase the value of the care they provided.

SAMMANFATTNING PÅ SVENSKA

En fotledsfraktur är en skada som kan drabba alla, oavsett ålder, och är en av de vanligaste frakturtyperna. En fotledsfraktur kan vara allt från en skada som mest liknar en stukning och går att behandla med en elastisk linda, till en allvarlig skada i behov av upprepade kirurgiska ingrepp, vilket gör att behandlingsvalen är otaliga. I Sverige finns det inga nationella riktlinjer för behandlingen av fotledsfrakturer varför variationen inom landet är stor. Det övergripande målet med den här avhandlingen är att undersöka hur fotledsfrakturer omhändertas och behandlas i Sverige och hur detta påverkas av införandet av strukturerade behandlingsriktlinjer. Alla inkluderade studier baseras på data från Svenska Frakturregistret (SFR).

Den första studien i avhandlingen är en epidemiologisk kartläggning av alla 57,433 fotledsfrakturer som registrerats i SFR under en tioårsperiod, 2012 till 2022. Studien visar att kvinnor oftare drabbas av en fotledsfraktur och är äldre när de skadar sig än män. Den vanligaste skademekanismen är ett fall i samma plan, genom till exempel snubbling eller fall på grund av halka. Studien visar också att det finns en tydlig säsongsvariation i antalet fotledsfrakturer, som ökar markant under vintermånaderna på grund av enkla fall mellan november och mars. Den andra studien visar att antalet fotledsfrakturer minskade under Covid-19-pandemins första våg våren 2020. Den största minskningen sågs från mitten av mars till mitten av april samt i gruppen kvinnor och bland de över 70 år. Den här studien är också ett exempel på hur data från SFR kan användas för att göra snabba jämförelser av hur många frakturer som inträffar under en tidsperiod, nästan i realtid. Fotledsfrakturer kan vara stabila eller instabila, vilket, tillsammans med patientfaktorer, avgör om de ska behandlas kirurgiskt eller icke-kirurgiskt. Hos den vanligaste typen av fotledsfraktur, som utgör nästan en tredjedel av alla fotledsfrakturer, är det avgörande för stabiliteten om det utöver frakturen också finns ledbandsskador. Den tredje studien i avhandlingen undersöker hur den här typen av frakturer har klassificerats, omhändertagits och sedermera behandlats. Studien visar på svårigheterna som föreligger med att avgöra om det finns en ledbandsskada eller inte. Resultaten visar att 70% behandlades icke-kirurgiskt medan 30% opererades och behandlingsvalet verkar inte korrelera med om man funnit misstankar om en ledbandsskada eller inte. Studien ledde fram till att man på Sahlgrenska universitetssjukhuset (SU) tog fram riktlinjer för hur fotledsfrakturer ska behandlas, med målsättning att göra vården säkrare och mer jämlik. Den fjärde studien jämför en grupp patienter med fotledsfraktur som behandlades på SU innan det fanns några riktlinjer med en grupp som behandlats efter att riktlinjerna infördes. Studien undersöker om riktlinjerna påverkat hur patienterna omhändertas och behandlas. Resultaten visar förändringar i alla de studerade parametrarna; det vill säga att en minskad andel patienter opererades, antalet röntgenundersökningar blev färre, antalet vårddygn minskade, gipstiden kortades och fler patienter fick belasta fullt i sitt gips eller sin ortos. Studien visar att en strukturerad riktlinje som styr rekommenderad behandling för fotledsfrakturer kan göra vården mer jämlik och minska antalet onödiga operationer. De framtagna riktlinjerna för behandlingen av fotledsfrakturer användes som underlag för att formulera ett kunskapsstöd som under 2020 kopplades till SFR. Detta innebar att de läkare som registrerar fotledsfrakturer i SFR fick upplysning om rekommenderad behandling för den registrerade frakturtypen i samband med att de gjorde sin registrering. Det sista delarbetet i avhandlingen är en kvalitativ intervjustudie med 20 läkare som registrerat fotledsfrakturer i SFR och träffat på kunskapsstödet, med målsättning att inhämta deras upplevelser. Studien visar att användarna uppskattade att erbjudas kunskapsstöd. De kände sig mer trygga i sina beslut och incitamentet att lägga tid på att registrera frakturer i SFR ökade.

Sammanfattningsvis är en fotledsfraktur en skada som framförallt drabbar kvinnor och inträffar vintertid som följd av ett fall i samma plan. Under Covid-19 pandemin minskade antalet fotledsfrakturer i Sverige, framförallt under den första månaden, bland kvinnor och bland de över 70 år. Handläggningen av patienter med fotledsfrakturer blir mer standardiserad genom införandet av riktlinjer och beslut kring behandling blir mindre baserade på individuella läkares preferenser. Att rätt patienter får rätt vård leder också till en bättre fördelning av vårdens resurser. Att koppla riktlinjer till nationella kvalitetsregister i form av kunskapsstöd uppskattas av läkare och upplevs förbättra den vård man erbjuder patienterna.

LIST OF PAPERS

This thesis is based on the following studies, referred to in the text by their Roman numerals.

I. Rydberg EM, Wennergren D, Stigevall C, Ekelund J, Möller M.

Epidemiology of more than 50,000 ankle fractures in the Swedish Fracture Register during a period of 10 years.

Manuscript.

II. Rydberg EM, Möller M, Ekelund J, Wolf O, Wennergren D.

Does the Covid-19 pandemic affect ankle fracture incidence? Moderate decrease in Sweden.

Acta Orthopaedica. 2021:1-4.

III. Rydberg EM, Zorko T, Sundfeldt M, Möller M, Wennergren D.

Classification and treatment of lateral malleolar fractures - a single-center analysis of 439 ankle fractures using the Swedish Fracture Register.

BMC Musculoskeletal Disorders. 2020 Aug 5;21(1):521.

IV. Rydberg EM, Skoglund J, Brezicka H, Ekelund J, Sundfeldt M, Möller M, Wennergen D.

Fractures of the lateral malleolus – a retrospective before-and-after study of treatment and resource utilization following the implementation of a structured treatment algorithm.

BMC Musculoskeletal Disorders. 2022;23(1).

V. Rydberg EM, Insulan J, Rolfson O, Mohaddes M, Åhlström L.

Knowledge support for ankle fractures in the Swedish Fracture Register - a qualitative study of physicians' experiences.

BMC Health Services Research. 2022;22(1):382.

ADDITIONAL PUBLICATIONS BY THE AUTHOR

I Möller M, Wolf O, Bergdahl C, Mukka S, Rydberg EM, Hailer NP, Ekelund J, Wennergren D.

The Swedish Fracture Register - ten years of experience and 600,000 fractures collected in a National Quality Register.

BMC Musculoskeletal Disorders. 2022;23(1):141.

II Buckley R, Kwek E, Duffy P, Korley R, Puloski S, Buckley A, Martin R, Rydberg EM, Möller E, Schneider P.

Single-Screw Fixation Compared With Double Screw Fixation for Treatment of Medial Malleolar Fractures: A Prospective Randomized Trial.

Journal of Orthopaedic Trauma. 2018;32(11):548-53.

TABLE OF CONTENTS

ABBREVIATIONS

SFR	Swedish Fracture Register
NQR	National Quality Register
ATFL	Anterior tibiofibular ligament
PTFL	Posterior tibiofibular ligament
FTA	Anterior talofibular ligament
CF	Calcaneofibular ligament
OA	Osteoarthritis
PTOA	Post-traumatic ostheoarthritis
CT	Computed tomography
AO	Arbeitsgemeinschaft für Osteosynthesefragen
OTA	Orthopaedic Trauma Association
JOT	Journal of Orthopaedic Trauma
MRI	Magnetic resonance imaging
ORIF	Open reduction internal fixation
TTC	Tibiotalocalcaneal
CCC	Closed contact casting
ROM	Range of motion
SU	Sahlgrenska University Hospital
PIN	Personal Identification Number
NPR	National Patient Register
ICD	International Statistical Classification of Diseases and Related Health Problems
SHPR	Swedish Hip Arthroplasty Register
A&E	Accident and Emergency Department
PROM	Patient-Reported Outcome Measurement
EQ-5D	EuroQol 5 Dimension
SMFA	Short Musculoskeletal Function Assessment
CDSS	Clinical Decision Support System
CDS	Clinical Decision Support
AI	Artificial Intelligence
KSS	Knowledge Support System
EMR	Electronic Medical Record
SUS	System Usability Scale
QCA	Qualitative content analysis
MU	Meaning units
SD	Standard deviation
CI	Confidence intervals
GDPR	General Data Protection Regulation
TA	Treatment algorithm
WHO	World Health Organisation
BMD	Bone mineral density
PHEIC	Public Health Emergency of International Concern
PHA	Public Health Authority
MCS	Medial clear space
RCT	Randomised controlled trial
AOFAS	American Orthopaedic Foot and Ankle Society
BOAST	British Orthopaedic Association Standards for Trauma
NICE	The National Institute for Health and Care Excellence
rRCT	Register-based randomised controlled trial

BRIEF DEFINITIONS

Ankle fracture	Fracture to one or more of the malleoli and/or injuries to the adjacent ligaments stabilising the ankle joint
Isolated ankle fracture	Fracture to one of the malleoli without concomitant injuries to the adjacent ligaments stabilising the ankle joint
Fracture type	Three-digit code according to the AO/OTA classification, e.g. 44B
Fracture group	Four-digit code according to the AO/OTA classification, e.g. 44B2
Fracture subgroup	Five-digit code according to the AO/OTA classification, e.g. 44B2.1
Knowledge support system	Computer-aided system presenting knowledge-based information without connection to patient-related information
Clinical decision support system	Computer-aided systems presenting patient-specific recommendations with the purpose of providing clinicians with decision support
Semi-structured interviews	A qualitative research method utilising a blend of predetermined, closed, and open-ended questions
Completeness	The number of registered events in an NQR compared with official health databases. In this thesis, completeness is the number of fractures registered in the SFR compared with the NPR
Coverage	The number of departments enrolled in an NQR. In this thesis, the number of orthopaedic departments participating in the SFR
Accuracy	The degree to which the result of a measurement, calculation or specification correlates to the correct value. In this thesis accuracy is the agreement between the AO/OTA classification in the SFR and a reference group classification of the same fracture
Poisson distribution	A statistical probability distribution expressing how many times an event is likely to occur within a specified period of time given that the event occurs at a known mean and that the arrival of the event is independent of the event before
Radiographic examinations	In this thesis defined as plain radiographic examinations, MRI, CT scans and ultrasounds
Pre-TA	The time period before the introduction of a structured treatment algorithm (TA) for ankle fractures at SU
Post-TA	The time period after the introduction of a structured treatment algorithm (TA) for ankle fractures at SU

01

INTRODUCTION

The topic of this thesis is ankle fractures. The foundation is a description of ankle fracture epidemiology in Sweden during the past 10 years, using data from the Swedish Fracture Register (SFR). This thesis will then describe the way ankle fractures are classified, treated and managed and discuss the effects of standardising this by implementing structured treatment algorithms.

Treatment algorithms can be incorporated into national quality registers (NQRs) as knowledge support systems. The second part of this thesis will discuss the way in which the management of ankle fractures can be affected by supporting the SFR with up-to-date knowledge, presented to the users upon ankle fracture registration.

This thesis will further describe how the SFR can be used for the almost real-time analysis of changes in fracture incidence over time.

1.1 ANATOMY

The ankle joint, also referred to as the tibiotalar or talocrural articulation, connects the crura, the leg, to the talus, the dome of the foot. The joint consists of the distal part of the tibia and fibula that forms a mortise, a groove, into which the superior part of the talus, the trochlea, fits. The medial malleolus of the tibia and the lateral malleolus of the fibula constitute the walls of the mortise while the roof is formed by the inferior surface of the tibia, the tibia plafond. The posterior segment of the tibia plafond is often referred to as the posterior malleolus. The bony structures of the ankle joint are visualised in Figure 1.

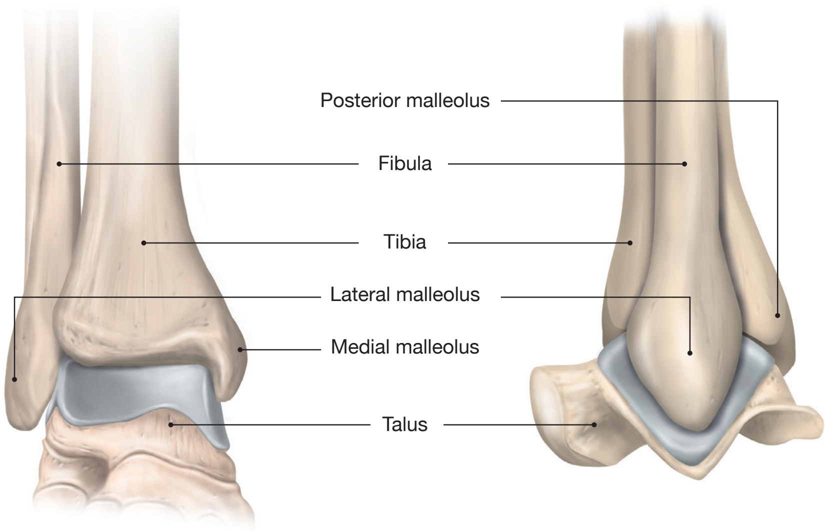


FIGURE 1. The bony structures of the ankle joint.

In order to prevent the tibia and fibula from being forced apart, a complex of ligaments, often referred to as the tibiofibular syndesmosis, is of the greatest importance[1]. This complex consists of three ligaments; the interosseous tibiofibular ligament, the anterior tibiofibular ligament (ATFL) and the posterior tibiofibular ligament (PTFL) (Figure 2). The interosseous tibiofibular ligament is a distal continuation of the interosseous membrane, a network of fibres that connects the tibia and fibula.[2] The interosseous tibiofibular ligament is 2-3 cm long and starts distally just above the fibular notch, or incisura fibularis tibiae, on the tibia, and ends 4-5 cm proximal to the ankle joint.[3] The anterior tibiofibular ligament runs from the lateral part of the distal tibia obliquely to the fibula. The anterior tibiofibular ligament in itself consists of three parts, the middle one of which is the strongest.[2] The posterior tibiofibular ligament is a compact, strong ligament that runs from the posterior aspect of the tibia to the posterior aspect of the fibula and almost forms a labrum over the posterior lateral ridge of the ankle joint. [2, 4]

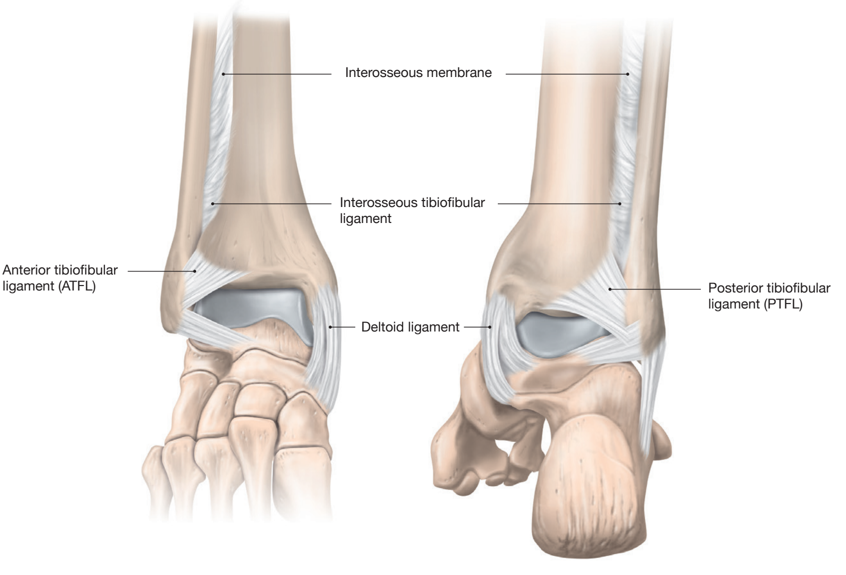


FIGURE 2. Ligaments of the ankle from the anterior (left) and the posterior (right) view.

The stability of the ankle joint is furthermore reinforced by collateral ligaments. The deltoid ligament (or medial collateral ligament) on the medial side is a triangular-shaped, strong structure that fans out from the medial malleolus and has insertion points on the talus, calcaneus and navicular bones.[5, 6] The deltoid ligament is of great importance for stability in the ankle mortise.[6-8] It is further divided into a deep and a superficial part that prevents valgus tilting of the talus and external rotation in the ankle joint, especially in plantarflexion (Figures 3 and 4).[1, 8] The exact functions of the superficial and deep part respectively are described in various ways in the literature. It appears that the superficial part mainly attends to the alignment of the talus to the medial malleolus, whereas the deep part prevents lateral displacement and plantar flexion.[6]

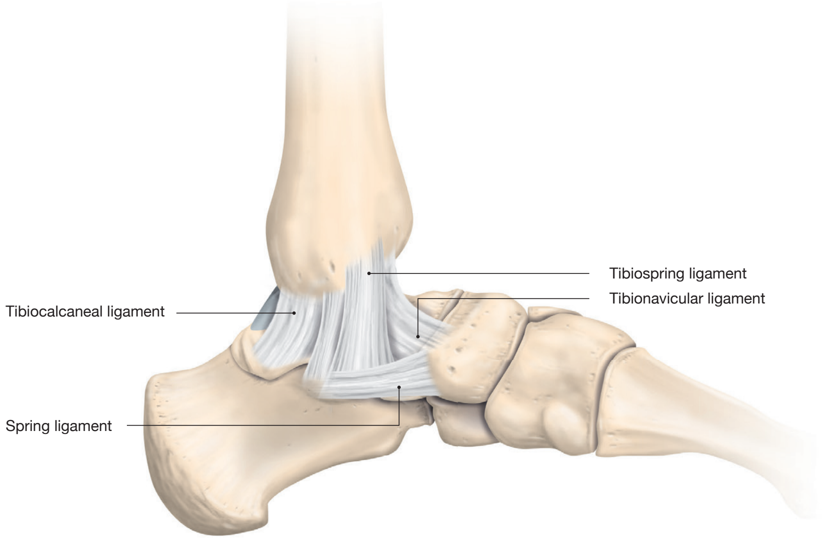


FIGURE 3. The superficial part of the deltoid ligament.

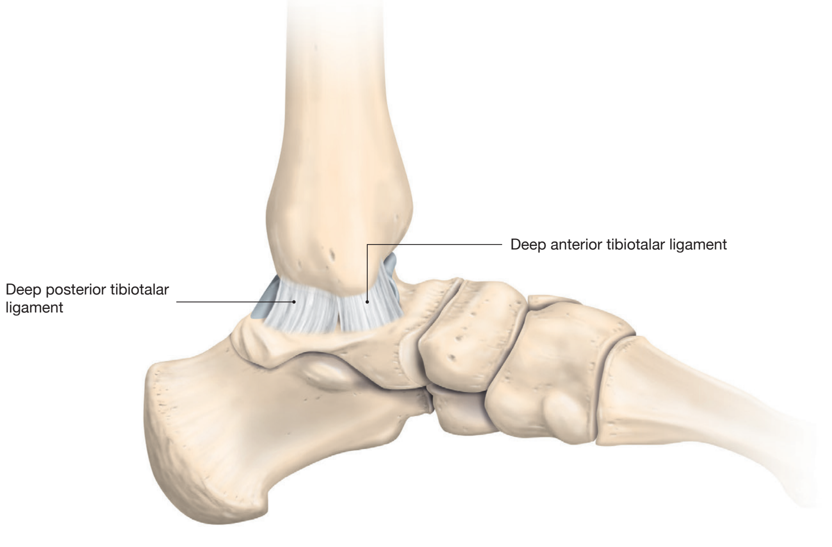


FIGURE 4. The deep part of the deltoid ligament.

On the lateral side the ankle joint is stabilised by three separate ligaments connecting the lateral malleolus to the talus and calcaneus respectively.[1] These ligaments reduce inversion, limit varus stress and hinder rotation.[1, 9] The ligaments connecting the lateral malleolus of the fibula to the talus are the anterior talofibular ligament (FTA) and posterior talofibular ligament (PTFL), while the ligament connecting the lateral malleolus to the calcaneus is the calcaneofibular (CF) ligament, shown in Figure 5.

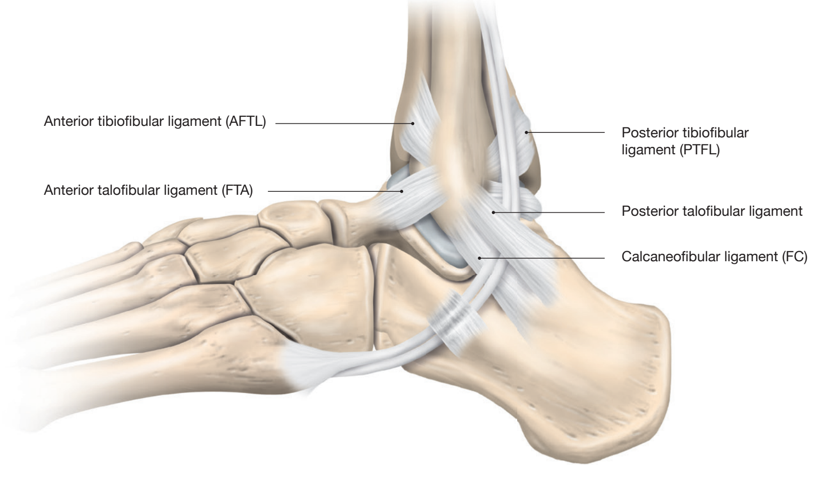


FIGURE 5. Ligaments on the lateral side of the ankle.

The ankle joint ultimately links the lower limb to the foot.[1] Motion in the ankle joint allows the foot to interact with the ground, enabling gait, running and other locomotor activities[1]. The bony segments of the ankle joint, reinforced by the ligamentous structures, makes the joint stable, but with a high degree of motion, mainly plantar- and dorsiflexion.[10] Due to the shape of the talar trochlea, slightly conical with its wider part anteriorly, the ankle joint is most unstable in plantar flexion where some movement of adduction, abduction, inversion and eversion is possible. When the foot is dorsiflexed the wider part of the trochlea enters between the two malleoli and applies a separating force, which tightens their grip and makes the ankle joint more stable.[1, 11]

When standing and walking, the vast majority of the bodyweight is transferred through the tibia to the talus. The fibula is not a weight-bearing bone and it merely functions as an attachment for ligaments and to provide stability to the ankle joint. Depending on the position of the foot, the main force is directed to different aspects of the talus.[11] In walking the stride is divided into two phases, the stance and the swing phase. These phases are constantly repeated and referred to as the gait cycle (Figure 6). In the stance phase, the bony anatomy of the ankle joint with the talus, the medial and lateral malleoli is sufficient to provide stability. In the swing phase, the reinforced stability from soft tissue structures is essential for stability.[1]

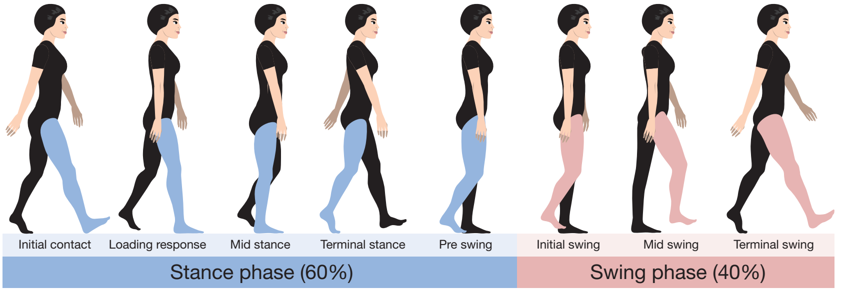


FIGURE 6. The gait cycle.

Despite the weight to which the ankle joint is exposed in all activities with weight-bearing, it is less prone to development of osteoarthritis (OA) than, for example, the hip or knee joints.[12] OA of the knee is eight to nine times as common as OA of the ankle joint and ankle joint OA constitutes only 2-4% of all OA cases.[13] OA of the hip and knee has been the subject of significantly more research than OA of the ankle joint, which explains why the full picture of osteoarthritic development in the ankle joint is still not fully understood. Even though the ankle joint cartilage is thinner than that of the knee or hip, it has a higher resistance towards the development of OA. This is thought to be due to metabolic differences and a higher compressive stiffness in the ankle joint cartilage.[14, 15] The ankle joint also has a smaller area of contact compared with the hip or knee and has a higher degree of stability in motion.[16]

In knee and hip joints only 2-10% of OA is post-traumatic compared with the ankle joint where up to 90% of OA is due to an earlier injury.[17] The most common underlying injury behind post-traumatic osteoarthritis (PTOA) of the ankle joint is a previous malleolar fracture.[14, 15, 18] Severe sprains, persistent ankle instability and pilon-fractures are also prone to the development of PTOA. It is the subject of debate whether the persistent ankle instability, incongruence or the initial cartilage injury is the primary cause of PTOA development.[17, 19]

PTOA of the ankle joint results in pain and dysfunction, with its first degenerative changes within 12-18 months after the injury. The advanced stages of ankle joint OA develop 10-20 years after onset.[13, 15] Patients with PTOA of the ankle joint have a mean age of only around 50 years, making them much younger than other OA patients.[13, 15, 17]

1.2 CLASSIFICATION OF ANKLE FRACTURES

Ankle fractures are defined as injuries involving one or more of the malleoli. This includes fractures to the medial or posterior malleolus of the tibia and/or the lateral malleolus of the fibula, but it also includes injuries to adjacent ligaments. Distal tibia fractures, i.e., pilon fractures, are not ankle (i.e., malleolar) fractures and will not be further discussed in this thesis.

Ankle fractures occur when a loaded foot is exposed to a deforming force, usually rotational or sideways, under supination (or occasionally pronation). The occurrence of an ankle fracture and the type of fracture depend on the force directed at the ankle, as well as inherent factors and mechanical properties of the skeleton like osteoporosis or earlier fractures to the bones of the ankle.[20]

Fractures in general are classified according to various classification systems in order to create a language that ensures that standardised information is transmitted. The purpose of fracture classification is further to understand the fracture and its prognosis and to plan for the most suitable treatment. Many fractures in other locations can be classified directly from a plain radiograph or computed tomography (CT). To classify ankle fractures, however, information about concomitant injuries to the ligaments around the ankle joint is also needed to understand the nature of the fracture and classify it correctly.

A number of classification systems for ankle fractures have been introduced; Lauge-Hansen, Danis Weber and AO/OTA (Arbeitsgemeinschaft für Osteosynthesefragen/ Orthopaedic Trauma Association) are the most commonly used.[21-24]

The Lauge-Hansen classification system considers the injury mechanism and the position of the foot at the time of injury. It is made up of two-word descriptions, where the first word describes the deforming force hitting the ankle and the second word describes the position of the foot at the time of the injury (Figure 7). The Lauge-Hansen classification system is excellent for describing the resulting fracture patterns caused by the deforming forces. However, the reliability and reproducibility of the classification system have been questioned.[25, 26] The Lauge-Hansen classification system cannot be used as an exact description but as a tool for understanding the most likely fracture patterns that occur as a result of specified injury mechanisms.

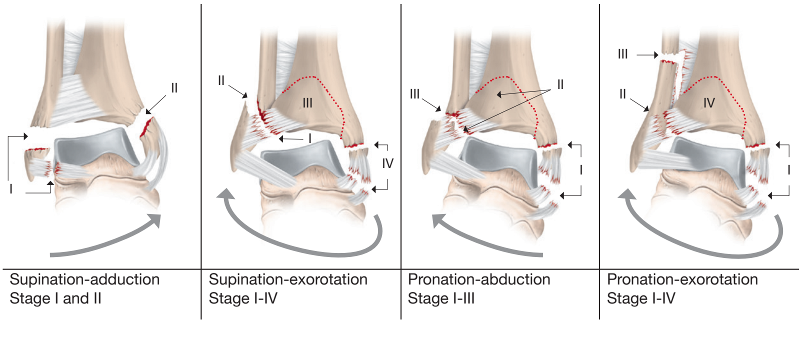


FIGURE 7. The Lauge-Hansen classification of ankle fractures.

The Danis-Weber classification on the other hand, describes the fracture by the distance of the lateral malleolus fracture to the distal tibiofibular syndesmosis (Figure 8). According to Danis-Weber, A fractures are situated below the syndesmosis, and are always regarded as stable, as they do not affect the stability of the ankle joint. Danis-Weber B fractures occur at the level of the syndesmosis and can be either stable or unstable. C fractures, above the syndesmosis, according to Danis-Weber, are always regarded as unstable.

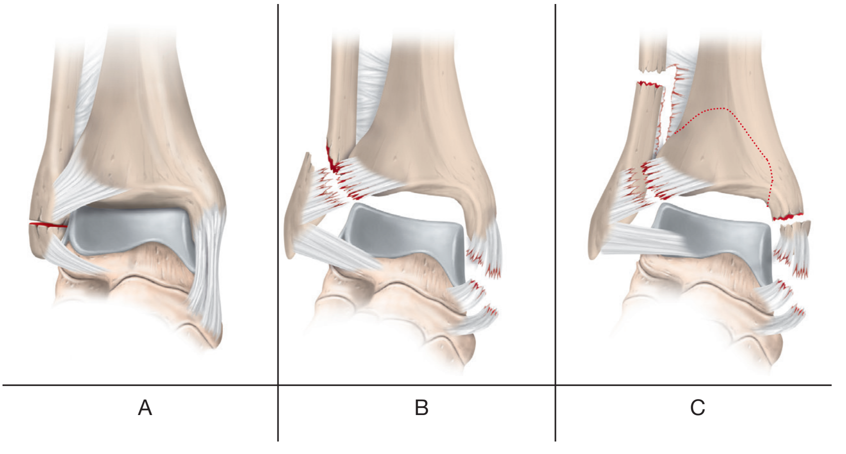


FIGURE 8. The Danis-Weber classification of ankle fractures.

The AO/OTA classification system can be seen as a further development of the Danis-Weber classification, combined with the understanding of the injury mechanism by Lauge-Hansen. One of the founding fathers of the AO Foundation in 1958, and the person responsible for the first AO classification, was Maurice E Müller. The AO foundation identified a need for a classification system for all types of fractures that would help the surgeon to understand the morphology of the fracture and plan for the most suitable treatment. They began their work by identifying common features shared by all types of fracture, diaphyseal as well as fractures to the metaphyses and epiphyses. They concluded that a classification system is useful only if it can help the surgeon understand the severity of the fracture and decide on the most suitable treatment plan. This work resulted in "The comprehensive classification of fractures of long bones" by Müller and the AO Foundation. The first English version of this classification was published in 1990.[22] In 1996, the AO Foundation, together with the Orthopaedic Trauma Association (OTA), published a further developed version of the classification system as a compendium to the Journal of Othopaedic Trauma (JOT).[27] They used the principles of Müller and colleagues and coded the remaining bones with the aim of creating one system for classifying all types of fracture instead of different systems for different fracture locations. In 2007, the AO/OTA revised the classification and also included the paediatric classification system[23]. A second revision was undertaken in 2018 and the AO/OTA has stated that the classification system will be continually revised every ten years.[24]

The full AO/OTA 2018 classification system for ankle fractures has 27 different subgroups to choose between when classifying an ankle fracture. In the SFR, the 2007 version of the AO/OTA classification system is used and the classification system has been limited to include only the group level for C fractures and merging some of the subgroups in the A and B groups. As such, the AO/OTA classification system used in the SFR has 14 possible subgroups for ankle fracture classification and also a "not able to classify" option (Figure 9). The accuracy of ankle fracture classifications in the SFR has been studied and has been shown to be accurate and valid.[28]

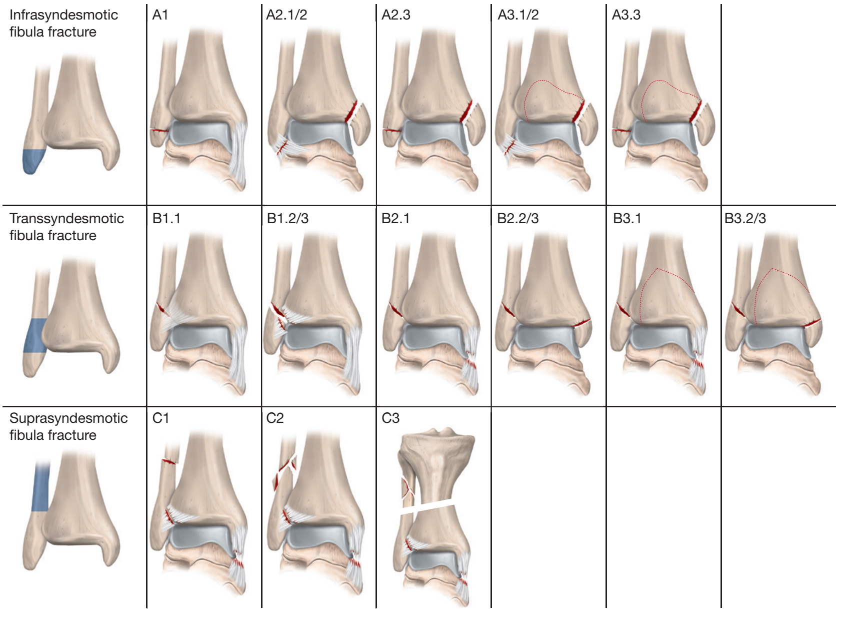


FIGURE 9. The AO/OTA classification of ankle fractures used in the SFR.

When classifying fractures according to the AO/OTA classification system, it is necessary to start by identifying the bone involved. This is the basis of the five-digit alphanumerical structure, or code, created (Figure 10). For malleolar (ankle) fractures, the identifying bone is the tibia, numbered 4. It is then necessary to identify the end of the bone at which the fracture is located, for ankle fractures in the most distal end of the tibia, giving it number 4, as the numbering goes from proximal to distal. So, AO/OTA 44 is the starting code for all types of malleolar fractures. After this, the fractures are given a letter-code, A, B or C, thereby resembling the coding by Danis-Weber. The letter code is the fracture type according to AO/OTA. A-type ankle fractures are infrasyndesmotic, B fractures transsyndesmotic and C fractures are suprasyndesmotic.

When the fracture has been given a type (A, B or C), it can be further classified into a group. For type A and B fractures group 1 means that the fibular fracture is isolated, group 2 means that there is also a medial injury (fracture or ligament injury) and group 3 means that there is also a posterior fracture. For C-type fractures, group 1 means a simple fibular fracture, group 2 a wedge and group 3 a proximal fibular fracture.

The final step in the classification of malleolar fractures is to identify the subgroup. The subgroup basically differs if the injuries on which the grouping of the fracture was based on were ligamentous, avulsions or fractures.

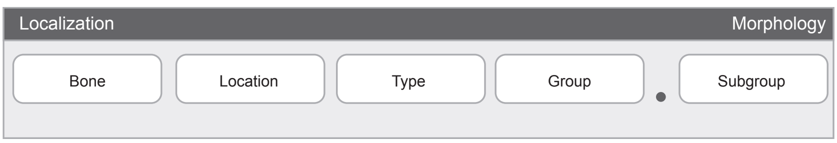


FIGURE 10. The AO/OTA alphanumeric structure.

To conclude, when classifying an ankle fracture according to the AO/OTA classification system, it is necessary to decide on the level of the fibular fracture (Type), the number of involved malleoli (Group) and the nature of the medial injury or the fragmentation of the fibular fracture (depending on the fracture group) (Subgroup). One of the difficulties involved in classifying ankle fractures according to the AO/OTA classification system, especially the transsyndesmotic type B fractures, is the matter of identifying whether a ligamentous injury is present and then correctly classify the given fracture and adjacent ligamentous injuries. As ligamentous injuries, to the deltoid ligament, for example, are not visible on plain radiographs, a clinical examination or other kind of evaluation has to be performed in order to classify the fracture.

As the AO/OTA classification considers both fractures and ligamentous injuries, the fracture group, and subgroup, describe the injury as stable or unstable. This information is essential for the decision regarding further management and treatment.

1.3 STABILITY IN AO/OTA B-TYPE ANKLE FRACTURES

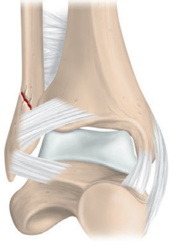
Among ankle fractures, the most debated in terms of stability and, ultimately, the most suitable treatment method is probably the transsyndesmotic fracture, or AO/OTA type B fracture. On a plain radiographic examination, an isolated, and stable, B1 fracture will appear similar to an unstable B2 fracture with a ruptured deltoid ligament (B2.1) (given that the ankle joint is still congruent). The type B fracture is also the most common ankle fracture, alone constituting more than 50% of all ankle fractures. This thesis will focus primarily on B-type fractures in groups 1 and 2 (Figure 11).

The ankle mortise is by definition stable in an isolated malleolar fracture or ligamentous injury as the other side of the ankle joint is unaffected and suppresses any dislocating forces. A bimalleolar fracture, on the other hand, is by definition unstable, as the stabilising malleolus or ligament on both sides of the ankle mortise are injured. If a patient presents with an isolated fibular fracture and no signs indicating a medial ligament injury, the decision for non-surgical treatment is easy. If a patient presents with a lateral malleolar fracture and a medial malleolar fracture, the decision for surgical treatment is not controversial. The clinically difficult situation occurs when a patient presents with a lateral malleolar fracture, medial tenderness and no obvious talar shift on radiographic examination.[29] The ligamentous stability of the ankle joint in ankle fractures is dependent on the integrity of the deltoid ligament on the medial side, as well as the syndesmosis. How best to evaluate the two remains a topic for debate.

As demonstrated in Figure 11, AO/OTA B-type fractures are all located at the level of the syndesmosis. AO/OTA B1 fractures are isolated fibular fractures. This means that there should be no fracture, or ligament injury, on the medial side of the ankle joint. AO/OTA B2 fractures are fibular fractures with a concurrent medial injury. The injury can be either a medial malleolar fracture or a ruptured deltoid ligament. AO/OTA B3 fractures are fibular fractures, with a medial injury (fracture or ligament) and a concurrent fracture to the posterior rim (or posterior malleolus) of the tibia.

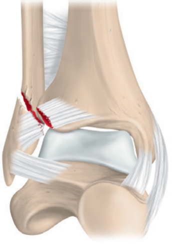
Transsyndesmotic isolated fibula fracture

44B1.1



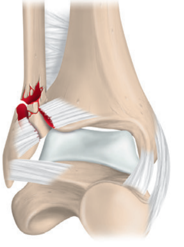
Simple fibula fracture

44B1.2



With a rupture of the anterior syndesmosis

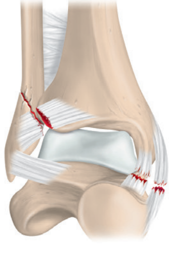
44B1.3



Wedge or multifragmentary fibula fracture

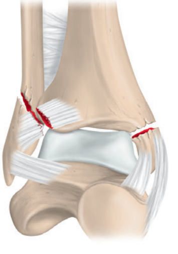
Transsyndesmotic fibula fracture with a medial injury

44B2.1



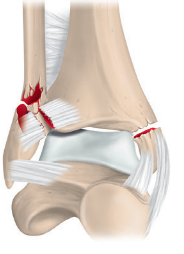
With a rupture of the deltoid ligament and the anterior syndesmosis

44B2.2



With a medial malleolus fracture and a rupture of the anterior syndesmosis

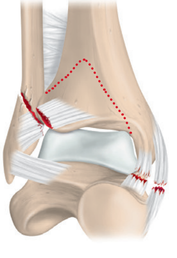
44B2.3



Wedge or multifragmentary fibula fracture with medial injury (deltoid ligament or malleolar fracture)

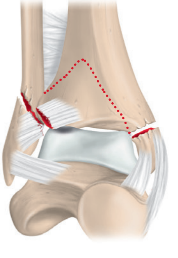
Transsyndesmotic fibula fracture with a medial injury (ligamentous or fracture) and a fracture to the posterior malleolus

44B3.1



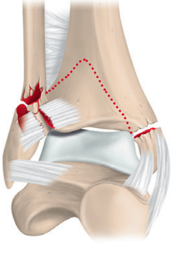
Simple fibula fracture with a deltoid ligament rupture and a posterior malleolar fracture

44B3.2



Simple fibula fracture with a medial and posterior malleolar fracture

44B3.3



Wedge or multifragmentary fibular fracture with a fracture of the medial malleolus and a fracture of the posterior malleolus

FIGURE 11. AO/OTA B-type fractures.

The question of how best to determine whether or not an associated injury to the deltoid ligament is present in a patient with a lateral malleolar fracture remains unresolved. Medial tenderness, ecchymosis and swelling are regarded by many as unreliable predictors of a ligament injury.[30-33] It has been argued that magnetic resonance imaging (MRI) is the best non-invasive method of evaluating the deltoid ligament, but it has the disadvantage of high costs and often low availability.[30, 34] Ultrasonography has also been advocated by some as a method with high sensitivity when diagnosing deltoid ligament injuries.[35] A manual stress test with measurements of the medial clear space is presented in some studies as the method of choice,[29, 30, 36] whereas, in others, it is presented as unreliable and associated with the risk of generating false positive results, exposing stable fractures to the risks of surgery.[37-40]

Another advocated method of evaluating the deltoid ligament integrity is the gravity stress radiograph, not to be confused with the manual stress test. For the gravity stress radiographic examination, the patient lies down with the ankle hanging free from external support, with the medial side facing up while plain radiographs are taken.[29] Michelson et al argue that a talar shift greater than 2 mm or a talar tilt greater than 10° occur in gravity stress radiographs only when the deltoid ligament is completely torn and the ankle is unstable.[29] In their cadaveric study the gravity stress radiographic examination was found to have 100% sensitivity and specificity for total deltoid ligament disruption.[29]

Studies have demonstrated several benefits of the gravity stress test compared with the manual stress test. Schock et al compared the gravity stress test and the manual stress test on patients and found that the gravity stress test was reliable and less uncomfortable for the patient.[41] They found that the manual stress test generated a much higher degree of experienced pain when compared with the gravity stress test: the manual stress test generated a mean VAS-score of 6.1, whereas the gravity stress test only generated a VAS-score of 3.5. Cadaver studies have shown that the manual stress test appears to be less predictive than the gravity stress when it comes to deltoid ligament injury and more sensitive to the way the foot is held, with regard to dorsiflexion and external rotation. Manual stress tests have also been shown to require a greater increase in the medial clear space for the diagnosis of deltoid ligament injury than the stress gravity test.[42] Another benefit of the stress gravity test over the manual stress test is that gravity, applying the dislocation force in the gravity stress test, is consistent and not examiner dependent, which explains why the examination can be performed without a specifically trained examiner. Despite the benefits of the gravity stress radiographs, other studies have found it to be unspecific and to allocate too many patients to surgical treatment.[40, 43, 44]

Since they were introduced, weight-bearing radiographs, taken seven to ten days after the injury, have been presented as an easy and reliable method to exclude the need for surgical treatment in ankle fractures.[40, 43, 44]

To conclude, despite numerous efforts to determine the best way to evaluate the integrity of the deltoid ligament in malleolar fractures, the best method is still the subject of debate. Despite the evident shortcomings of medial swelling, ecchymosis and tenderness as predictors of deltoid ligament injury, they are still frequently the discriminators of suspected injury used in clinical practice, as other methods are associated with high costs, low availability or reliance on specifically trained examiners.

1.4 EPIDEMIOLOGY

Studies have shown that the incidence of ankle fractures is increasing and that the epidemiology is changing.[45-51] With an ageing population, the incidence of ankle fractures among the elderly is increasing and women are more commonly affected than men.[46, 48, 50, 51] Recent studies report an incidence of 169-179 /100,000 inhabitants and year.[49, 50] In Sweden, ankle fractures are the third most common fracture according to a recent study from the SFR. [52]

Most ankle fractures are low-energy injuries caused by tripping, slipping or stumbling. A few previous studies have demonstrated a seasonal variation with an increasing number of ankle fractures during the winter months and during exceptionally cold winters, probably due to slipping on snow and ice.[46, 49, 50] The frequency of open ankle fractures is between 1.6 and 3%.[45, 48, 52]

It has long been known that the most common ankle fracture type is located at the trans-syndesmotic level, the B fracture, a group that constitute between 52% and 66% of all fractures.[45, 49, 50] The focus of this thesis is primarily the transsyndesmotic type B1 and B2 fractures, which are by far the most common ankle fractures. Type B1 and B2 fractures together alone constitute around 50% of all ankle fractures.[45, 50]

Despite being one of the most common fractures, surprisingly little has been written on the epidemiology of ankle fractures based on large patient material. Most previous studies are either based on smaller material or only include hospitalised patients. Comprehensive studies including all types of ankle fractures, based on large patient material, are needed to obtain a full, up-to-date picture of the ankle fracture epidemiology.

1.5 TREATMENT

Ankle fractures can be treated either surgically or non-surgically. Non-surgical treatment ranges from an elastic bandage to braces or plasters (Figure 12). By far the most common surgical treatment method is open reduction and internal fixation (ORIF) with plates and screws to achieve stable fixation. In some hospitals in Sweden, a technique with surgical adaptation with staples, pins and cerclages is also used.[53] In situations with compromised soft tissues and fracture dislocations of the ankle joint or large fracture displacements, a period of external fixation is often needed to stabilise the fracture and allow soft-tissue recovery before ORIF can be performed (Figure 13).

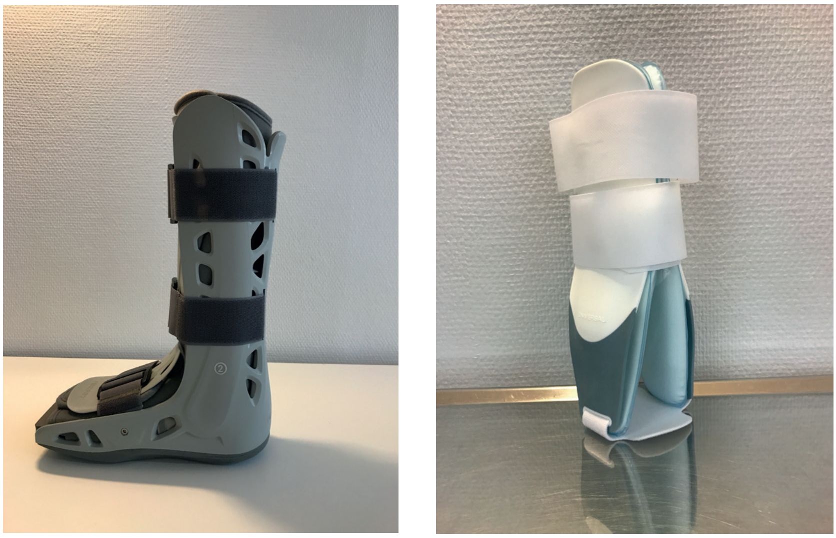


FIGURE 12. Example of braces for treatment of ankle fractures. Left: Walker orthosis, Right: Stirrup orthosis.

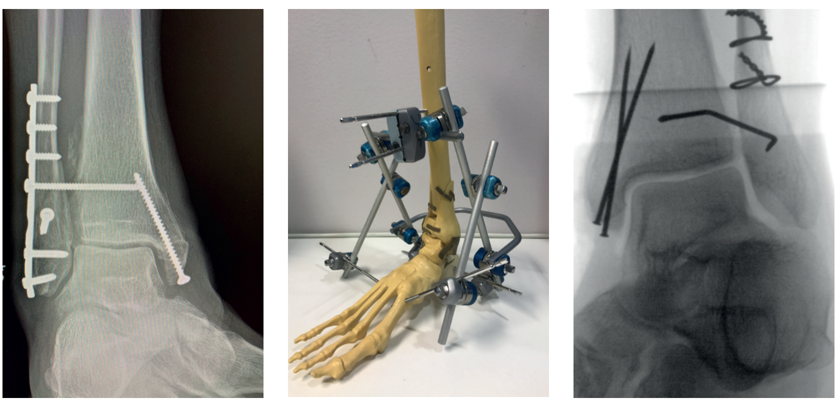


FIGURE 13. Example of surgical treatment methods for ankle fracrtures.
Left: ORIF, Centre: External fixation, Right: Surgical adaptation

Despite the number of papers published on the subject of ankle fracture treatment, a Cochrane systematical review in 2012 concluded that "there is currently insufficient evidence to conclude whether surgical or conservative treatment produces superior long-term outcomes for ankle fractures in adults".[54] This is probably due to the heterogeneity of ankle fractures that range from simple avulsions to trimalleolar displaced fractures. Interestingly, a more recent review from 2019 by Larsen et al. reports that both stable and unstable (after satisfactory closed reduction in a cast) ankle fractures can be treated non-surgically or surgically with equal short-term results.[55]

Unimalleolar (isolated lateral) ankle fractures of types A and B are traditionally considered stable and safe to treat non-surgically.[40] Type C-fractures, as well as bi- and trimalleolar A and B fractures, on the other hand, are regarded as unstable and suitable for surgical treatment. It still remains unclear whether or not the potentially unstable B-type fractures are safe to treat non-surgically. Studies have shown that they only displace in about 2% of the cases and many advocate a more conservative treatment regimen for these fractures than was historically the case.[40] There is a wide agreement not to expose patients to the potential risks of surgery for a fracture that can just as well be safely treated non-surgically, but the question of which fractures this involves is still the subject of debate.[40]

In addition to the nature of the fracture, it is important to consider the patient characteristics and co-morbidities when choosing the optimal treatment method.[55] Even though the fracture would be best treated surgically, the patient might not be suitable for surgical treatment. For elderly patients and those with diabetes or peripheral vascular disease, the evidence supports non-surgical treatment as far as possible to reduce the risks of infection and wound- and/or fracture-healing complications.[56-58]

A more recent development is the use of hind foot/tibotalocalcaneal (TTC) nails or closed contact casting (CCC) to treat unstable ankle fractures in the elderly.[59, 60] The TTC nailing has the advantage of allowing immediate postoperative weight-bearing and minimal surgical trauma.[61] CCC allows unstable ankle fractures in patients not suitable for surgical treatment to be treated non-surgically, with a reasonable success rate.[62, 63] However, most studies of these two methods are case reports, so larger studies and studies with long-term follow-up are still lacking.

There are many different postoperative rehabilitation regimens or traditions for ankle fractures. Traditionally, ankle fracture patients have been postoperatively immobilised in a cast and kept non-weight-bearing for six weeks, due to the risk of displacement. In Central Europe traditional AO teaching focused on early range of motion exercises but kept the patients non-weight-bearing. In Sweden, early weight-bearing has been more accepted but in combination with immobilisation in a plaster. During the past ten years, studies have shown a significantly better outcome for patients that are allowed to weight-bear early and are allowed early range of motion. For surgically treated patients, early weight-bearing has been shown to result in improved ankle range of motion (ROM), a shorter time to full weight-bearing, an early return to previous work and an earlier return to pre-injury activities.[64-67]

1.6 TREATMENT ALGORITHMS

One way of aiding clinicians in making evidence-based decisions in health care is by introducing structured guidelines or treatment algorithms.[68] This was found to be successful by both Wykes et al. and Jain et al., who implemented evidence-based guidelines for ankle fracture treatment.[69, 70] They showed that the number of radiographs, days immobilised and days without permitted weight-bearing were reduced significantly, saving both economical resources and patient discomfort, without increasing complications.[69] A similar effect was shown regarding hip fractures at a large teaching hospital in Denmark by Palm et al., who implemented a structured treatment algorithm (the Hvidovre algorithm).[71] The number of re-operations and consequently the number of in-patient day were reduced significantly.[71] Regarding ankle fractures, no national and, to our knowledge few local guidelines exist in Sweden, leaving the decision regarding the choice of treatment, follow-up and weight-bearing restrictions largely at the surgeon's discretion.

1.6.1 Treatment algorithm for ankle fractures at SU

At Sahlgrenska University Hospital (SU; Göteborg/Mölndal), alike many other hospitals, no structured treatment algorithm had been in place for ankle fractures up to 2017. In 2011, there was a notion in the department that too many stable ankle fractures were treated surgically, fractures that could potentially be treated non-surgically, and that there was a variation with regard to postoperative management and weight-bearing restrictions. Because of this, an epidemiological mapping of ankle fractures treated at SU was performed in 2012-2014. This mapping confirmed the hypothesis and showed that there was a large variation within the department with regard to the choice of treatment, planned follow-up and weight-bearing restrictions. This led up to the formation of a structured treatment algorithm at SU for all ankle fractures.

The aim of introducing a structured treatment algorithm for ankle fracture management was to clarify the indications for surgical treatment. It was thought that this would reduce the number of unnecessary operations and subsequent complications of surgery and optimise resource utilisation.

The treatment algorithm was formulated by one specialist consultant and two senior orthopaedic consultants at SU. It was a compilation of tradition, recent up-to-date research and expert opinions. When finalised, the treatment algorithm was revised by one orthopaedic specialist and two senior orthopaedic consultants and a professor in orthopaedics at SU, as well as a professor in orthopaedics from Karolinska University Hospital. The work began in 2015 and the treatment algorithm for the management of ankle fractures was introduced in clinical practice at SU in September 2017 after a period of thorough implementation. The treatment algorithm was implemented through e-mails and information at multiple meetings at the department and was posted on the hospital intranet. In addition to this, the treatment algorithm was printed as posters and pocket-size cards that were distributed to all the doctors at the department. The treatment algorithm was considered to be fully implemented on 1 September 2017.

The treatment algorithm is extensive and discusses the following topics:

- Instructions for a physical examination in patients with a suspected ankle fracture
- Indications for a radiographic examination in patients with a suspected ankle fracture
- Instructions on the classification of ankle fractures according to the AO/OTA classification system
- Choice of treatment for the individual fracture groups and subgroups
- Methods of surgical treatment
- In which cases weight-bearing restrictions are justified
- Plan for follow-up

1.7 NATIONAL REGISTERS

Sweden has a long history of national registration of its population, dating back to the parochial registers in the mid-16th century. The now existing Swedish registers in health care can be divided into two categories; national public authority registers, that are administered by the National Board of Health and Welfare, and National Quality Registers (NQRs) that are run by the profession.

As of 1 January 1947, Sweden has had a unique personal identity number (PIN) system. The PIN is a ten-digit number used in Sweden to identify individuals. The PIN system enables the registration of individuals in registers, both authority run and NQRs, and enables registers to link data between different NQRs and to healthcare databases. A specific patient can be followed, even when treated at different hospitals or at out-patient clinics.

One of the authority-run registers is the National Patient Register (NPR).[72] Since the 1960s, the NPR has been collecting statistics on diseases and surgical procedures in Sweden. Data are submitted to the NPR continuously and automatically by healthcare providers. The NPR uses the PIN to collect data on patient age and gender and also to gather information from medical records and administrative systems. One of the pieces of information recorded in the NPR is the ICD-10 codes (International Statistical Classification of Diseases and Related Health Problems – 10th revision) from medical records. The ICD-10 codes are specific codes that diseases and medical conditions are given in the medical records when the patient is discharged from hospital or at any out-patient visit.

NATIONAL QUALITY REGISTERS

The first Swedish quality register was an orthopaedic register started by Dr Göran Bauer in Lund in 1975, the Swedish knee arthroplasty register, soon followed by the Swedish hip arthroplasty register (SHPR) founded by Dr Peter Herberts in 1979.[73, 74] Dr Bauer was inspired by a Dr Armony Codman (1869-1940), a surgeon at Harvard, USA, and founder of the American college of surgeons.[75] Dr Codman was a pioneer in what we now call evidence-based medicine. He made a lifelong effort to following up his patients and recording the end result of their care. Disappointed by the lack of follow-up of outcome, Dr Codman started his own hospital in 1911, called "The end result hospital". There he recorded all the errors and the outcome of the care they provided and recorded this in annual reports that were sent out to hospitals throughout the country, challenging them to do the same. Unfortunately, Dr Codman's efforts to link care, errors and "end results" and report them with the aim of improving healthcare brought him mostly poverty, censure and enemies. It took almost another century before Dr Codman's "End result idea" was fully accepted and results and outcomes from hospitals were reported openly through NQRs.

Since the start of NQRs in Sweden in the 1970s, multiple registers have evolved. Today, Sweden has more than one hundred national quality registers run by the profession that report on the quality and results of the care provided.[76] The early orthopaedic registers have had a large impact, both nationally and internationally, on the treatment of orthopaedic patients.[77]

1.7.1 The Swedish Fracture Register

The Swedish Fracture Register (SFR) is a national quality register that was founded by orthopaedic surgeons at SU (Göteborg/Mölndal) in 2011. The SFR prospectively collects data on all types of fractures treated by orthopaedic surgeons.[78] Both non-surgically treated and surgically treated fractures are registered.

When it was founded, the SFR only collected data on tibia and humeral fractures at SU, but it has gradually evolved into its present form. Since 2015, the SFR has included information on all types of fractures (except skull and ribs that are traditionally not treated by orthopaedic surgeons). Ankle fractures have been registered in the SFR since April 2012. The participation of orthopaedic departments in the SFR is voluntary, but, as of 1 January 2021, the SFR has had 100% coverage, comprising all the orthopaedic departments in Sweden.[79]

The SFR utilises a web-based platform where the classification of fractures and related information on the injury is entered by the treating physician at patient presentation in the Accident & Emergency Department (A&E) at the time of the injury. Since the registration is made by the treating orthopaedic surgeon or physician, the act of registration has been designed to be as efficient and non-disruptive as possible.

Fractures are registered in the SFR and classified according to the AO/OTA classification system. When registered, the ICD-10 code for ankle fracture is also automatically recorded. Several studies have been conducted showing the substantial accuracy and high reliability of fracture classification according to AO/OTA in the SFR for a number of injury locations, including ankle fractures.[28, 80, 81]

The SFR is crosschecked every year with the NPR, for ICD-10 codes. The number of fractures registered in the SFR, i.e., the completeness of the SFR, is thereby analysed. A recent study from the SFR on the completeness of humeral fracture registrations in the

SFR concludes that the NPR has a completeness of 97% but grossly overestimates the number of fractures with an accuracy of only 70%.[82] The SFR, on the other hand, has an acceptable completeness (88%) but a perfect (100%) accuracy and "constitutes a complete, accurate and efficient source of information".[82] Completeness figures for the latest available year (2021) shows a completeness for lower leg and ankle fractures nationally of 68%, with many departments reaching over 90% completeness.[83]

In line with most other registers, the main outcome in the SFR is re-operations, for surgically treated patients, and late surgeries (e.g., osteotomy after malunion), for non-surgically treated patients. The other main outcome variables are mortality and patient-reported outcome measurements (PROMs), using the EQ-5D and SMFA, at day zero and after one year.[84, 85]

DATA ENTRY IN THE SFR

Data are entered in the SFR by the attending physician at the time of diagnosis. This is usually done by junior doctors or resident orthopaedic surgeons at the A&E. Should the patient be allocated to non-surgical treatment, the same physician will continue entering data on treatment. Should the patient, on the other hand, be allocated to surgical treatment, the orthopaedic surgeon performing the operation will register data on the treatment method after the surgery is performed. As a result, multiple physicians can be involved in registering different sections of a fracture registration on the same patient.

The process of entering data into the SFR is a web-based, three-step procedure also described in detail by Wennergren at al.[78]

STEP 1 – The injury

The first step in the data entry process for each patient starts with the injury date and the registration of the injury mechanism behind the fracture, i.e. the reason for the fracture (Figure 14). This panel also includes questions on whether the injury was high or low energy.

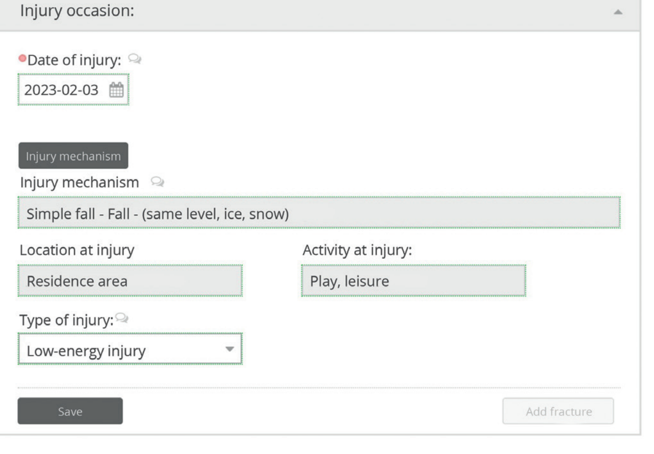


FIGURE 14. Registration of the injury occasion in the SFR.

Injury mechanism

In the SFR, there are 476 possible injury mechanisms to choose between. In order to make this data manageable for research the injury mechanisms were grouped into six categories by Bergdahl et al. and Wennergren et al. in previous studies.[86, 87]

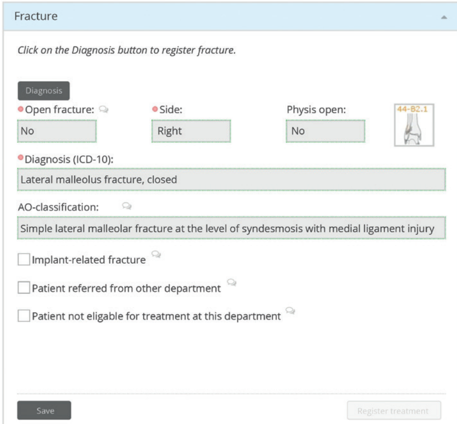
The six categories defined by Bergdahl et al:

1. Simple fall
    a. A fall from standing height
2. Fall from a height
    a. A fall down from a higher level, e.g. from a ladder or down a staircase
3. Unspecified fall
    a. A fall that was not further classified than this in the SFR, meaning it could be either a simple fall or a fall from any height
4. Traffic
    a. All accidents involving any kind of vehicle, motorcycle, bicycle etc.
5. Miscellaneous
    a. Fractures with a mechanism of injury that did not fit the other categories, such as sports injuries, fractures sustained in fights or injuries caused by machines
6. Non-traumatic
    a. Includes pathological fractures, spontaneous fractures and stress fractures

STEP 2 – The fracture

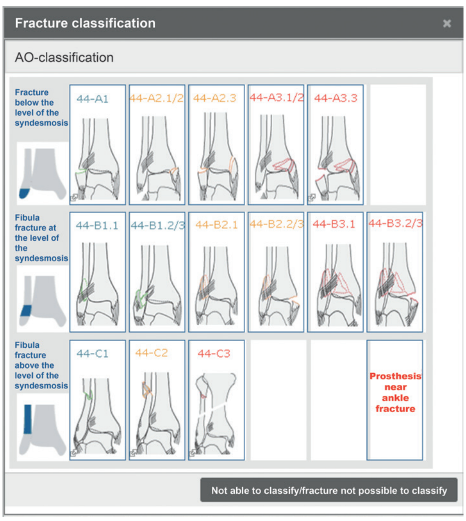
The second part of the data entry process in the SFR is related to the fracture (Figure 15a-c). Here information on the side (right or left) and whether or not the fracture is open is recorded. Open fractures are further classified according to the Gustilo-Anderson classification.[88] In this panel, the AO/OTA classification of the fracture is also made. When classification according to the AO/OTA system is made, the fracture automatically also receives the corresponding ICD-10 code.

Ankle fractures are classified in the SFR using the simplified AO/OTA-classification system described above, with 14 possible fractures to choose between.



a)

b)



c)

FIGURE 15. Registration and classification of ankle fractures in the SFR. a) The fracture registration panel. b) Selection of the injured bone and the side of the body. c) Classification according to AO/OTA with pictures and explanations.

STEP 3 – The treatment

The final step in the data entry process deals with the treatment of the fracture. This part is filled out by the same physician who entered information under Steps 1 and 2 if the patient is allocated to non-surgical treatment, or by the operating surgeon if the patient is allocated to surgical treatment. In this panel, the date of treatment is entered (for non-surgical treatment, the day of initiation of treatment), the type of treatment and the experience level of the responsible surgeon (Figure 16). For treatment method, either non-surgical or surgical treatment is chosen and, for surgical treatment, there are then a variety of different choices of surgical approaches and fixation methods or type of implants used. If further surgeries are performed, this step with treatment registration, can be repeated, and a new treatment panel is then opened and linked to the same fracture.

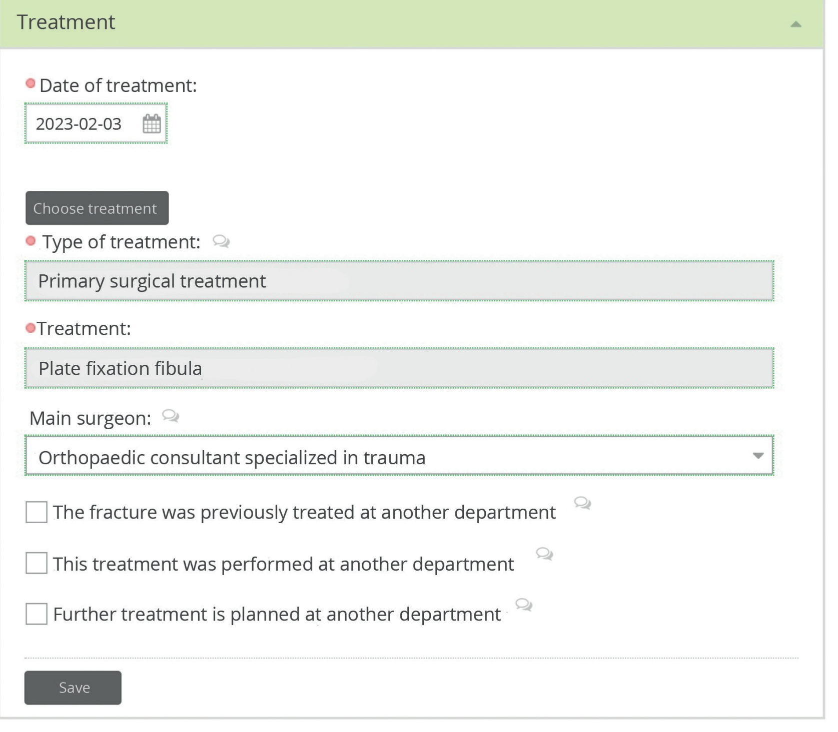


FIGURE 16. The panel for registration of treatment in the SFR.

1.8 KNOWLEDGE AND DECISION SUPPORT SYSTEMS

The complex information environment in healthcare constitutes a challenge for physicians attempting to make informed decisions, as the amount of information to be processed is constantly increasing. There are numerous examples of ways in which these challenges might be mitigated using computer-aided systems. The first attempts to recruit computers to aid in diagnosis and treatment decisions were made almost 50 years ago.[89, 90]

Sweden was early in adopting this, outlining ideas for early computerised decision support systems (CDSS).[91] Despite this, there are still only a few clinical decision support systems in use in Sweden and fewer than expected internationally.[92]

Clinical decision support systems (CDSS) are systems designed to provide physicians with clinical decision support (CDS), i.e. assistance in clinical decision-making by providing patient-specific recommendations. There are two types of CDSS, knowledge based and non-knowledge based. Knowledge-based systems combine data from the knowledge base with patient data to alert the physician to interactions of drugs, for example. Non-knowledge based CDSS, on the other hand, uses artificial intelligence (AI) to find patterns in data and use the patterns to alert the physician.

Another kind of computer-aided support in clinical decision-making is knowledge bases or knowledge support systems (KSS). These systems provide knowledge, but does not, unlike the CDSS, have a link to electronic medical records (EMR) or patient-specific data. KSSs do not give patient-specific recommendations or aid in decision-making but merely presents the clinician with knowledge already present in other sources but packaged in the KSS to be easily available to the user.

1.8.1 Knowledge support system in the SFR

In 2020, a knowledge support system (KSS) was introduced in the SFR. The KSS is linked to the registration of ankle fractures. When an ankle fracture is registered in the SFR, the KSS appears and provides the user with knowledge support. The aim of the KSS was to improve the care of patients with ankle fractures by spreading knowledge through the SFR. Another aim was to increase the incentive to register fractures in the SFR for the individual physician and to broaden the use of the SFR.

The KSS was launched as a pilot project for a time period of three months at four departments registering data in the SFR: SU (Göteborg/Mölndal), Karlstad, Gävle and Falun. The physicians at these orthopaedic departments were exposed to the KSS when registering any of the following eight different groups and subgroups of ankle fractures: AT/OTA 44-A1, B1.1, B1.2/3, A2.1/2, A2.3, B2.1, B2.2/3, C3.

The above listed eight fracture groups/subgroups (out of the 14 available in the AO/OTA classification of ankle fractures in the SFR) were chosen for the pilot project, as they were assessed as those in which the general understanding of the classification was poorest or their treatment was the subject of debate.

Since 1 October 2020, the KSS for ankle fractures in the SFR has been available to all participating departments and, since December 2021, it has been active for all AO/OTA groups and subgroups of ankle fractures.

The KSS was designed as a three-step model following the steps in the data-entering process performed by the physician in the SFR, described above.

THE KSS FOR ANKLE FRACTURES IN THE SFR

STEP 1 – Confirmation of classification

During the process of registering an ankle fracture in the SFR, at the stage when the fracture classification according to AO/OTA is saved in the system, the first part of the KSS appears (Figure 17). The purpose of this first text box is to confirm that the fracture was correctly classified according to the AO/OTA-classification system and that attention was focused on possible concomitant ligamentous injuries. Once the user clicks "OK", the box disappears and the user can either continue the registration or go back and change the AO/OTA classification chosen.

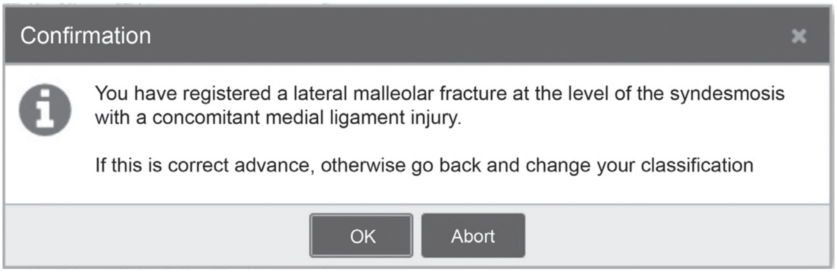


FIGURE 17. Confirmation of correct classification, step one in the KSS for ankle fractures in the SFR.

STEP 2 – Consensus information

When the full panel of registration of an ankle fracture in the SFR is saved, the next text box in the KSS appears (Figure 18). This text box presents information on the recommended treatment method for the classified fracture group or subgroup. This box also presents data from the SFR on how this fracture group/subgroup has been treated over the past year at the individual department and in the country as a whole.

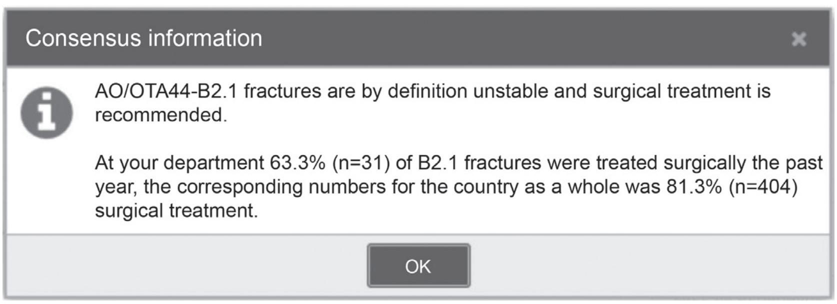


FIGURE 18. Consensus information, step two in the KSS for ankle fractures in the SFR.

STEP 3 – Consensus or deviation

The last stage of the KSS appears when the treatment panel for fracture registration is saved. This text box again presents the same information as presented in Step 2 (to ensure all the involved users receive the same information, as different steps in the registration process can be made by different users). This step also presents the user with a question on whether or not the treatment recommended in the KSS was chosen and, if not, why not (Figure 19).

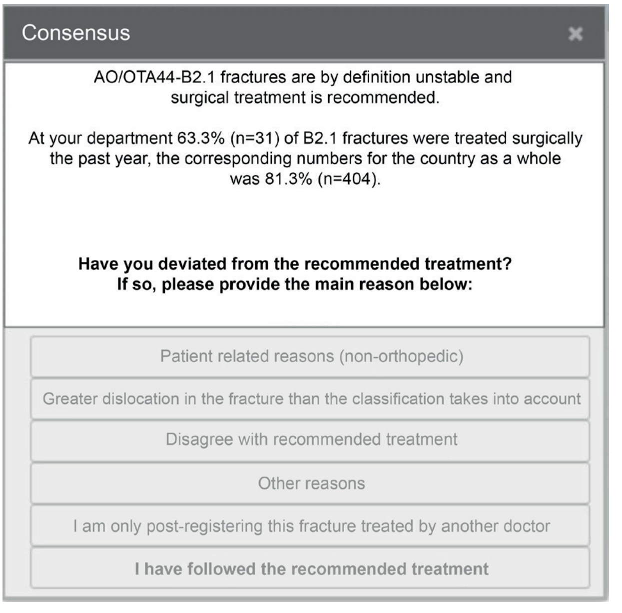


FIGURE 19. Consensus information (repeated) and a question regarding adherence to the recommended treatment, the final step of the KSS for ankle fractures in the SFR.

PILOT PROJECT

During the development of the KSS in the autumn and winter of 2019, contact was made with the heads of four orthopaedic departments (SU, Karlstad, Gävle and Falun) asking about interest in participating in a pilot project testing the KSS for three months. All four departments agreed to participate in the project. On 18 December 2019, an e-mail was sent out to all the doctors at these departments giving detailed information on the KSS and the project. On 25 February 2020, the KSS was launched in the SFR for the participating departments. The KSS was active for three months, 25 February to 25 May 2020.

Evaluation

At the end of the pilot project, the KSS was evaluated using data from the SFR and a survey of all the active users of the SFR at the participating departments. Data were extracted from the SFR on the number of users that had come in contact with the KSS (i.e. had registered an ankle fracture during the three-month period) and the number of ankle fractures that had been registered during the time period. Data were also retrieved regarding the answers to the question raised in the last step of the KSS, relating to the reason for deviating from the recommended treatment.

Data from the SFR

Data from the SFR showed that 98 unique users (SU:46, Falun:19, Gävle: 18, Karlstad:15) came in contact with the KSS, making a total of 200 ankle fracture registrations. Answers to the question on whether or not the recommended treatment was chosen demonstrate that:

- 74% chose to follow the recommended treatment
- 9% were late registrations (where the registering physician was not the one responsible for the patient)
- 8% deviated because of patient-related factors
- 5% deviated for "other causes"
- 2% deviated because the dislocation in the fracture was greater than the classification system takes into account
- 2% did not agree with the recommended treatment

Survey

A survey was sent out to all the active users of the SFR at the four included departments. All the active users in the SFR are not registering physicians, but this could not be selected for due to preserving anonymity and, as a result, the survey was sent out to all registered active users. A total of 482 surveys were sent out (SU 244, Falun 79, Karlstad 89, Gävle 70) and 145 replies were received. In addition to the answers listed below, the questions in the survey had an answer option "I have not encountered the new feature in the SFR". Answers were removed in the analysis, if the respondent had given this answer to one or more of the questions.

The survey contained the following questions:

1. For how long have you been working in an orthopaedic department?
   (0-1 yrs., 2-5 yrs., 6-10 yrs., 11-15 yrs., 16 yrs. or longer)
2. Do you think the new feature giving feedback regarding treatment when registering a fracture was useful for you in your clinical setting?
   (Yes, No, Don't know)
3. Did the feature add to your workload?
   (Yes, No, Don't know)
4. Would you like to see similar features for other types of fracture in the register?
   (Yes, No, Don't know)

Question one obtained a large variety in terms of the experiences of working in an orthopaedic department with 17-25% in each of the categories. Question two, which addressed whether the respondents had found the KSS useful in the clinical setting, showed that 51% of respondents found the KSS useful in their clinical setting. 70% did not find that the KSS had increased their workload and 61% of the respondents would like to see similar features for other types of fracture in the SFR.

The survey also included a validated method for assessing the usability of software applications, the system usability scale (SUS).[93] The SUS includes 10 standardised questions and was analysed separately from the other survey questions. The SUS generates a score value which ranges from 0-100, where 100 is the maximum attainable score. The mean SUS score in the survey was 76.6 (SD16.8) and the median score was 78.8 (range 42.5-100).

Statistical analysis has shown that a score of 68 is the mean value for the SUS when it comes to web-based applications. Studies have sought to correlate SUS scores with a verdict from the users to better represent the "grade" to which a certain SUS score would correlate to.[94] Using the suggested interpretation model for the SUS score, this would correspond for the KSS in the SFR to a useability of in-between "Good" and "Excellent".

1.9 QUALITATIVE RESEARCH

While the first four papers in this thesis are based on quantitative research, the fifth paper is a qualitative study. Qualitative research methodologies traditionally aim to generate hypotheses rather than, like quantitative research, testing them.[95] Where quantitative research is hypothesis testing, aimed at collecting and analysing numerical data, the research questions addressed by qualitative research are often open-ended and exploratory.[95] As theories and research literature on the studied phenomenon in Paper V, clinicians' experiences of being presented with knowledge support through an NQR, were limited, a qualitative research methodology was chosen.

Many of the qualitative research methodologies were developed in psychology, sociology and anthropology around the beginning of the 20th century. They aim to investigate subjective experiences and develop new theories, hypotheses and insights in topics that have not been fully understood.[95] Numerous qualitative research methodologies exists, each suitable for different studied phenomena, groups or situations. Qualitative content analysis (QCA) is one, perhaps the most commonly used, qualitative research methodology, and the one used in Paper V.

Traditionally, content analysis was considered to be either quantitative, positivistic, or qualitative, hermeneutic.[96] Quantitative content analysis strove to find the real truth, counting frequencies and proportions, whereas qualitative content analysis was more interpretative. Since then, the method has evolved and is now considered to offer opportunities both to analyse manifest content, close to the text, and to make more latent, interpretative content analysis.[97]

QCA can have an approach that is either inductive or deductive. With an inductive approach the data analysis is based on searching for patterns, similarities and differences in the text, with no assumption of what you might find. With a deductive approach, on the other hand, you have an idea from theory before you start the analysis.

The purpose of QCA is to illuminate certain peoples' experiences of something or to explore the feelings, thoughts and opinions of the persons studied. When using QCA to analyse written texts (for example, transcribed interviews) the emphasis can be placed on both the manifest and the latent content of the text. The manifest content is the visible, obvious content, the words written or spoken. The latent content is an interpretation of the underlying meaning of the text.

An overview of the important concepts of QCA and a template for the analysis process was presented by Graneheim and Lundman in 2004.[96] When using QCA for the analysis of written material, the first step is to decide on the unit of analysis, i.e. the material to be analysed, usually whole interviews. From the unit of analysis, meaning units are selected. Meaning units are parts of the text, sentences or paragraphs, that relate to the same topic. The meaning units are then condensed, meaning that they are shortened but still preserve the core meaning. After this each condensed meaning unit is labelled with a code. The codes are then grouped into categories. Here, it is important that no data fall outside the categories created and that no data can fit into more than one category. It is also possible to divide the categories into sub-categories. The final, optional, step is the creation of themes. Themes deal with the latent content and links the underlaying meaning together.

When assessing the quality of qualitative, as well as quantitative, studies, the concept of trustworthiness is central.[98] For quantitative research, trustworthiness is evaluated with regard to validity, reliability and generalisation. Basically, the same concepts are used for qualitative research but under different labels. What quantitative researchers think of as validity is referred to in qualitative research as credibility, reliability is referred to as dependability and generalisation as transferability. Credibility deals with how well data and analyses address the intended focus. The credibility of a qualitative study is increased by selecting interviewees with a variety of experiences, gender and age but also by presenting in tables and text how the data analysis was performed. Dependability deals with what changes during the study period. For example, if the data collection period is very long, dependability gets lower, as there is a risk of inconsistency in the data collection, or, on the other hand, if all the interviews for a study are is conducted by the same interviewer, this strengthens the dependability of the study. Transferability shows how well the findings can be transferred to another context or setting.

1.10 RATIONALE OF THIS THESIS

The incidence of ankle fractures is increasing. Ankle fractures are now the third most common type of fracture. In spite of this, updated epidemiological studies of larger materials is lacking and little is known about the epidemiology of the individual ankle fracture types and groups. A comprehensive epidemiological study of ankle fractures is needed.

As the Covid-19 pandemic hit the world in the spring of 2020, the general notion was – where did all the fractures go? As data from the SFR can be extracted almost in real time, it was an obvious source to find out if the sensation of fewer ankle fractures was in fact real by relating the incidence in 2020 to the preceding years.

As no national guidelines on the management of ankle fractures are available in Sweden, the choice of treatment, postoperative rehabilitation regimen and follow-up is largely left to the individual surgeon's discretion. To make the management of ankle fractures more consistent and evidence based, the way they are managed has to be mapped and evaluated.

Structured treatment algorithms have been shown to improve the care provided. However, to our knowledge, few studies have been conducted comparing a group of ankle fracture patients treated before the introduction of a structured treatment algorithm with a similar group after a treatment algorithm has been introduced.

Being provided with knowledge and decision support has been shown to be appreciated by healthcare professionals. When knowledge support is introduced in an NQR, the possible benefits are numerous. However, more information is needed on how orthopaedic surgeons experience being presented with knowledge support while registering fractures in the SFR. By involving the users of an NQR, the registers can evolve and be of greater use to both patients and professionals.

02

AIMS

The overall aim of this thesis is to analyse how ankle fractures are classified, managed and treated and to analyse the effects of a well-implemented treatment algorithm on the same. A further aim of the thesis is to describe the way in which a national quality register can be used to produce greater benefits for both patients and users of the register. The specific aim of each study is presented below.

- To describe the epidemiology of ankle fractures in Sweden during the past ten years using data from the SFR. The objective is to present the epidemiology of all ankle fractures, as well as the epidemiology for each ankle fracture group, according to the AO/OTA classification **(Paper I)**
- To analyse the incidence of ankle fractures during the Covid-19 pandemic and compare it with the preceding three years. This study further aims to study if the SFR can be utilised to compare fracture incidence over years in real time **(Paper II)**
- To describe how lateral malleolar fractures were managed, classified and treated over a two-year period at SU. This study also describes the epidemiology of all ankle fractures at SU over the same time period **(Paper III)**
- To evaluate the effects of a structured treatment algorithm on the classification, management and treatment of ankle fractures. The aim of this study is to compare a group of ankle fractures managed before the introduction of a structured treatment algorithm with a group managed after the introduction **(Paper IV)**
- To qualitatively evaluate the users' experiences of being presented with knowledge support in the SFR while registering ankle fractures **(Paper V)**

03

MATERIAL AND METHODS

All the papers in this thesis originate from data from the Swedish Fracture Register (SFR). Papers I and II are observational register studies. Papers III and IV combines data from the SFR with data from electronic medical records. In Paper V, a new function with knowledge support in the SFR is evaluated qualitatively.

Firstly, the material used for each paper is described. The aspects of data from the SFR, the basis of all the included papers, are then presented. Secondly, the methodological aspects of each individual study are introduced. For each paper, the specific methodologies can also be found in the attached papers and manuscripts.

3.1 MATERIALS

The material for all the included papers is presented in Table 1 below.

Paper I

Paper I comprises all the ankle fractures in individuals aged 16 years and older registered in the SFR at all the participating orthopaedic departments in Sweden from 1 April 2012 to 31 March 2022. Data were retrieved from the SFR according to all ICD-10 codes for ankle fractures (S82.40, S82.41, S82.50, S82.51, S82.60, S82.61, S82.80 and S82.81). Patients were selected on ICD-10 code (not AO/OTA classification) in order not to miss fractures classified as “not able to classify” at the AO/OTA classification panel upon fracture registration.

Paper II

For Paper II, a sample of orthopaedic departments with a history of high completeness in their registrations in the SFR were selected. The orthopaedic departments at the hospitals in Varberg, Uddevalla/Trollhättan, Sahlgrenska University Hospital (SU), Borås, Falun, Gävle and Östersund all had a completeness in their registrations of 70% or more in 2016-2018 and were therefore included in the study.[99, 100] The same departments also have a history of rapid fracture entry in the register (registering a substantial number of fractures within 30 days of the injury) which was important for this study, as the time between the studied time period and the retrieval of data from the SFR was fairly short.[101]

Data on all ankle fractures (AO/OTA-44) were extracted from the SFR, in individuals aged 16 years and older, registered by the seven departments listed above for the time period of 15 March to 15 June 2020, as well as for the same period (15 March to 15 June) in the preceding three years (2017-2019).

Paper III

Paper III comprises all ankle fractures (AO/OTA-44), in individuals aged 16 years or older, registered in the SFR at SU between 1 April 2012 and 31 March 2014.

All patients were included in an epidemiological mapping. For fractures classified as AO/OTA44-B1 a further review of medical records and radiographs was also conducted. For this analysis of B1 fractures, patients that were initially treated or followed up at other hospitals or patients for whom medical records could not be found or could not be accessed were excluded.

Paper IV

To a great extent, Paper IV is like Paper III, but it compares two cohorts of patients from different time periods. Paper IV comprises all ankle fractures (AO/OTA44), in individuals aged 16 years and older, registered in the SFR at SU from 1 September 2017 to 31 August 2019, as well as from 1 April 2012 to 31 March 2014 (the cohort from Paper III).

All the patients were included in an epidemiological mapping. For fractures classified as AO/OTA44-B1, a further review of medical records and radiographs was also conducted. For this analysis the following patients were excluded:

- Initially treated or followed up at another hospital
- Medical record not found or could not be accessed
- First visit to A&E > 7 days after injury

Paper V

In Paper V, the knowledge support system (KSS) for ankle fractures in the SFR is described and evaluated qualitatively. The KSS was tested for three months as a pilot project at four of the orthopaedic departments registering fractures in the SFR (SU, Karlstad, Gävle and Falun). Twenty semi-structured interviews were then conducted with physicians at these departments who had come into contact with the KSS. Five interviewees were selected from each of the four departments. As a result, the material for Paper V is 20 orthopaedic surgeons/physicians.

TABLE 1. The material used for the studies behind the included papers.

Paper	Cohort	Patient selection	Department
Paper I	Fractures registered as ICD-10: S82.40, S82.41, S82.50, S82.51, S82.60, S82.61, S82.80, S82.81	≥16 yrs at injury 1 April 2012 to 31 March 2022	All departments participating in the SFR
Paper II	Fractures registered as AO/OTA-44	≥16 yrs at injury 15 March to 15 June 2017, 2018, 2019 and 2020	The orthopaedic departments in Varberg, Uddevalla/Trollhättan, Sahlgrenska University Hospital (SU), Borås, Falun, Gävle and Östersund
Paper III	Fractures registered as AO/OTA-44	≥16 yrs at injury 1 April 2012 to 31 March 2014	SU
Paper IV	Fractures registered as AO/OTA-44	≥16 yrs at injury 1 September 2017 to 31 August 2019 and 1 April 2012 to 31 March 2014	SU
Paper V	Physicians registering fractures in the SFR	Five interviewees from each of the four departments	SU, Karlstad, Gävle and Falun

3.2 THE SWEDISH FRACTURE REGISTER

3.2.1 Inclusion and exclusion criteria

The SFR collects data on patients of all ages with fractures diagnosed and treated at the affiliated departments. The SFR has only three exclusion criteria: the first is if the patient does not have a permanent Swedish PIN, the second is if the fracture is sustained outside Sweden and the third is if the fracture type is not traditionally treated by orthopaedic surgeons.

Exclusion criteria for registration in the SFR:

1. The patient does not have a Swedish PIN
    a. Patient registration in the SFR is based on the patient's ten-digit Swedish PIN. The SFR has a real-time connection to the Swedish Tax Agency population register, making it impossible to include a patient without a Swedish PIN.
2. The fracture is not sustained in Sweden
    a. Registration requires a fracture diagnosed on radiographs (plain radiographs, CT scan, MRI or other radiographic modalities). Fractures sustained abroad are not included.
3. The fracture type is not treated by orthopaedic surgeons
    a. The SFR is an orthopaedic quality register and it therefore only includes fractures treated by orthopaedic surgeons, e.g., skull and rib fractures are not included.

Registration in the SFR is non-compulsory and patients have the right to decline or withdraw registration at any time.

In contrast to many other national quality registers that collect data on only surgically treated patients, the SFR collects data on fractures treated either surgically or non-surgically, patients admitted to hospital and those merely treated as out-patients.

3.2.2 DATA FROM THE SFR

For Papers I-IV, data were retrieved from the SFR. For all these papers, the following parameters were used for analysis:

1. Age at the time of injury
2. Sex (male or female)
3. Injury date
4. Injury mechanism
5. Injury type (high- or low-energy)
6. Fracture classification according to the AO/OTA classification system
7. Open or closed fracture
8. Affected side (left or right)

For injury mechanisms, the same six categories defined by Bergdahl et al. and explained in detail in the introduction section of this thesis were used.[86, 87]

Fracture classification was analysed by AO/OTA classification type, group and subgroup for Papers II, III and IV and limited to group level for Paper I.

Treatment was analysed in Papers III and IV and grouped as surgical, non-surgical or conversion of treatment from non-surgical to surgical at an early stage. For Paper II, treatment was only analysed as surgical or non-surgical.

3.2.3 Calculation of incidence

Paper II describes the incidence of ankle fractures during the first three months of the Covid-19 pandemic in Sweden (15 March to 15 June 2020) at a number of selected departments and compares it with the preceding three years.

From the observed number of ankle fractures during the studied periods, the monthly rate of ankle fractures was calculated. These incidence rates were compared, assuming the population size was similar during the time period 2017-2020 and that the number of fractures had a Poisson distribution. There is a slight continuous increase in population size over the years, which explains why this assumption was thought to lead to conservative estimates of a decrease in incidence rates from 2017-2019 to 2020. Data for the observed period in 2020 were compared with the mean for the corresponding periods in the preceding three years (2017-2019). Comparisons were made with the mean of three years in order to achieve as a robust comparison as possible with limited variability for years without a pandemic. The preceding three years were chosen due to their proximity in time, in order to minimize changes in other parameters influencing the results.

Comparisons of incidence rates were made for the total number of fractures during the observed time period (the full three-month period) as well as for three 30-day periods (15 March-14 April, 15 April-14 May and 15 May-15 June) respectively. Subgroup analyses included sex and age groups.

3.3 DATA FROM ELECTRONIC MEDICAL RECORDS

For all patients registered with an AO/OTA44-B1 fracture in Papers III and IV, electronic medical records (EMR) and radiographs were reviewed, in addition to the observational data from the SFR.

From the medical records, the following variables were studied:

- Signs of medial ligament injuries found at the initial physical examination
    - From EMR, it was noted whether the examining physician had reported findings of medial ecchymosis, swelling or tenderness or had reported the absence of the same. It was also noted if no comment relating to the status of the medial structures was to be found in the EMR.
- Instructions regarding weight-bearing restrictions
    - Weight-bearing instructions were documented as full, partial or no weight-bearing allowed.
- Immobilization period
    - This was calculated as the time period from cast or orthosis application to the removal of the same for non-surgically treated patients. For surgically treated patients, the time period was calculated from the date of the surgery to cast or orthosis removal at the out-patient clinic. For some patients, the orthosis was to be removed at home and for these patients the time period was calculated to the day instructed to terminate immobilisation documented in the EMR.
- The number of outpatient visits
- The number of days hospitalised
- The number of radiographic examinations performed
    - All performed radiographic examinations of the affected ankle were counted, including plain radiographs, CT scans and MRI.

From the EMRs, it was also noted whether stability tests had been performed and whether there were any significant concomitant injuries. Radiographs were reviewed in cases in which the treatment deviated from standard care to make sure the fracture classification in the SFR was correct. The EMRs of the patients that had initially been assigned to non-surgical treatment but for whom treatment had been changed to surgical at an early stage were closely studied to understand why the treatment strategy had been changed.

3.4 COMPARATIVE BEFORE AND AFTER STUDY

Paper IV presents an uncontrolled, observational before-and-after study. Before-and-after studies can be controlled, meaning that two groups are studied before and after the introduction of an intervention, but only one of the groups is exposed to the intervention.[102] In Paper IV, one group was studied before the introduction of a structured treatment algorithm and a similar group was studied after the introduction, making the study uncontrolled.

The structured treatment algorithm was considered fully implemented at SU on 1 September 2017. Paper IV compares a group of AO/OTA44B1 fractures registered at SU between 1 September 2017 and 31 August 2019 with the group of AO/OTA44B1 fractures from Paper III, registered at SU between 1 April 2012 and 31 March 2014.

In order to be able to evaluate the effect of the structured treatment algorithm, all patients seeking care for their ankle fracture more than seven days after the injury were excluded from the study, as the treatment algorithm was assessed as not being applicable that long time after the trauma. This was done both in the group of fractures from the time period of 2012-2014 and in the group of fractures from 2017-2019.

For the 2012-2014 group, a new dataset was retrieved from the SFR. This dataset included 515 AO/OTA44-B1 fractures, an additional three fractures compared with the original dataset (due to late registrations made between the data retrieval in 2015 and 2020). From these, the initial 73 exclusions were made (medical record not found or could not be accessed, initial examination or follow-up not conducted at SU) and an additional 31 patients were excluded due to not seeking medical care within seven days from the injury. This resulted in a total of 410 ankle fractures from the time period 2012-2014 that were included in the before-and-after study (Figure 20).

The same exclusion criteria were used for the group of patients registered between 1 September 2017 and 31 August 2019. From this group, 36 exclusions were made.

The explanation for the exceedingly large number of exclusions from the 2012-2014 group compared with the 2017-2019 group is that, in 2012-2014 all fractures were registered in the SFR at SU when an orthopaedic surgeon at SU was contacted by a colleague from another hospital with questions regarding a patient with an ankle fracture. As a result, a significant number of ankle fractures registered in the SFR at SU in the early days of the SFR were never treated at SU and it was not possible to review their medical records.

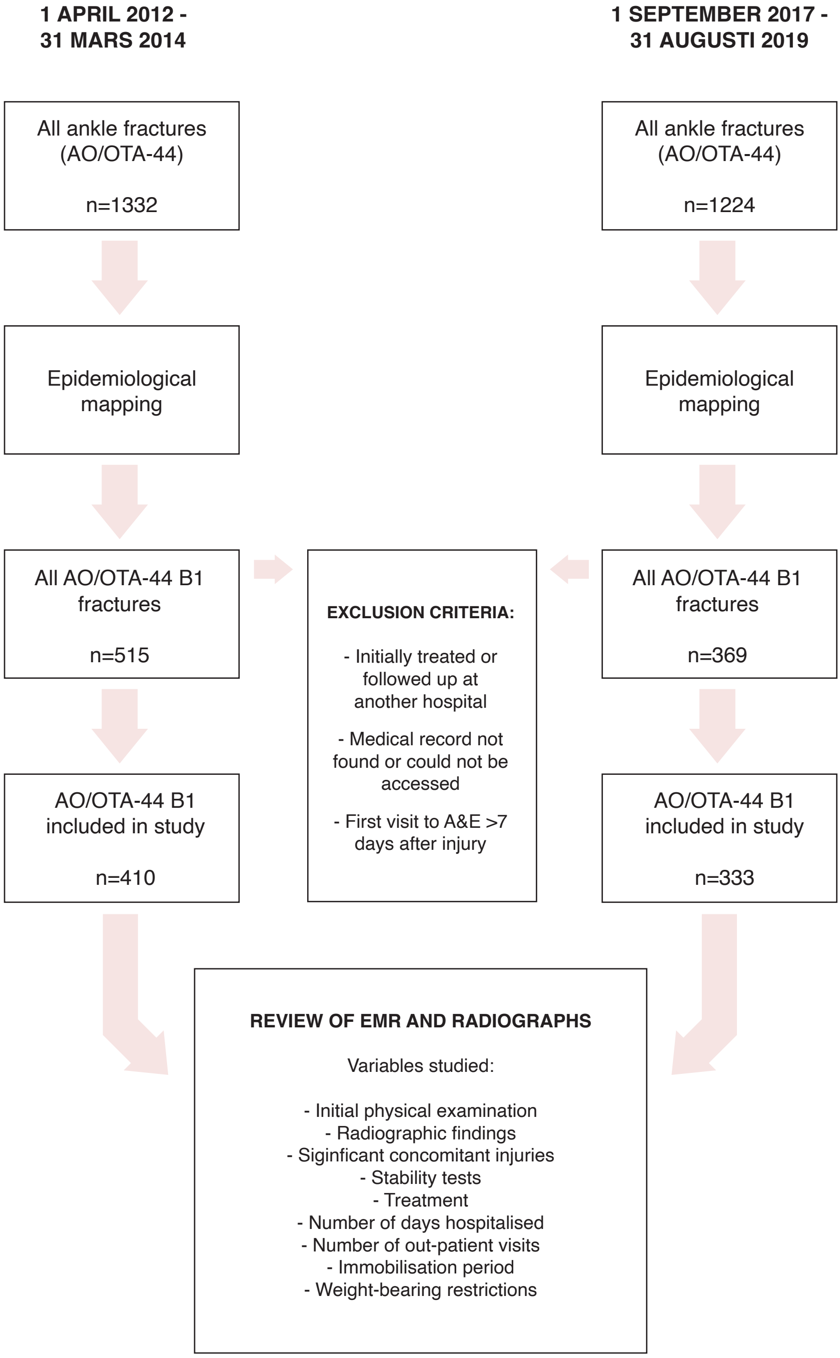


FIGURE 20. Flow chart of how the study was conducted.

3.5 SEMI-STRUCTURED INTERVIEWS

To capture the users' experiences of the KSS for ankle fractures in the SFR, it was evaluated using a qualitative method with semi-structured interviews. Twenty semi-structured interviews were conducted with physicians that had come into contact with the KSS.

Selection of interviewees

On 28 April 2020, the heads of the departments that were included in the pilot project testing the KSS were contacted inquiring participants for the interviews. A range of different ages, sex and experience working in an orthopaedic department were desired, in order to attempt to capture different perspectives. Twenty interviewees were recruited, five from each of the four participating departments.

Data collection

The interviews were conducted in Swedish, in person or via the digital Zoom network. All the interviews were recorded and conducted by the same interviewer. All the interviews started with demographic questions about age, work experience and gender. An initial open question on experiences of the KSS was then asked. An interview guide with eight predetermined questions was thereafter used (translated here to English with the aim of conserving the original meaning):

1. How did you experience getting feedback regarding treatment from the SFR?
2. What has the KSS added to your daily work?
3. Describe an example of a case in which the KSS influenced your classification of an ankle fracture.
4. Describe an example of a case in which the KSS influenced your choice of treatment of an ankle fracture.
5. If you could change anything about the KSS, what would you change?
6. Do you have any idea for a feature you would like to see in SFR, in an ideal world?
7. What advice would you give to those working on developing SFR?
8. Describe whether the KSS induced any reactions or other emotional response from you or others.

The recorded interviews were then transcribed using the TranskriberaMera online service.[103] The transcribed interviews were read through by the interviewer and two other researchers and corrected for missing words and transcription errors.

Data analysis

The interviews were analysed using conventional qualitative content analysis with an inductive approach, looking for similarities and differences in the interviews. The Nvivo

12 software, developed for qualitative analysis, was used to aid the data analysis. First, the twenty interviews were read through by three individual researchers to get a sense of the whole. Parts containing meaningful information were then identified as meaning units (MU). The MUs were then condensed into short descriptive sentences which were labelled with a code. The codes were compared based on differences and similarities and grouped into sub-categories (Table 2). The sub-categories were then grouped into main categories which were then combined into themes.

TABLE 2. Example of how the data analysis was conducted.

Meaning unit (MU)	Condensed MU	Code	Sub-category	Category
"What does the literature actually say and what do you do because you simply do things?"	What the literature says and what you do	Positive reactions to the function	Positive thoughts about the function	Experiences

3.6 STATISTICAL METHODS

In Paper I, data were presented using descriptive statistics. For categorical data, the results were presented as counts and proportions (%) and, for continuous data, as the mean (SD) and median (range).

In Paper II, descriptive statistics are presented as the mean (SD), median (range) and proportions. Differences in fracture incidences between the studied periods were obtained by assuming that the number of fractures follow a Poisson distribution and estimating the incidence with the calculated number of fractures per time unit. 95% confidence intervals (CI) for differences in fracture incidence were used.

In Paper III, descriptive statistical analyses were presented as counts, proportions (%) and the mean (range).

For Paper IV, demographic data were presented descriptively. Continuous variables were presented as the mean (SD) and median (range) and categorical data were presented as frequencies and percentages. Statistical tests were performed comparing demographic data between the group before the introduction of the treatment algorithm and the group after the introduction of the treatment algorithm. These tests were performed using an independent samples t-test and Fisher's exact test. The distribution of fractures according to the AO/OTA classification was compared between the groups using a chi-square test. To evaluate the effect of the treatment algorithm outcome variables were compared between the groups using Fisher's exact test and the Mann-Whitney U test.

For Paper V, demographic data regarding sex, age, position, range of experience and affiliated hospital of the interviewees were grouped and presented descriptively.

3.7 ETHICS

The SFR functions in accordance with the Swedish Patient Data Act and the General Data Protection Regulation (GDPR).[104] According to Swedish legislation national quality registers do not require signed consent from the individual patient upon registration. All patients have the right to withdraw their participation in the register at registration or at any time point later (opt-out system). For the ethical applications in this thesis, the invasion of the individual patient's privacy has been weighed against the value of the research performed. We found that the invasion caused was well out-weighed by the benefits of the performed studies.

Paper V combines data from the SFR with qualitative research on clinicians registering fractures in the SFR. For this study the integrity of the clinicians interviewed was considered ethically prior to the study. Detailed information on the study and an informed consent form were sent out to all the interviewees before the interview. In the interviews, the interviewees' names were replaced by an ID number and all possible respect was paid to guaranteeing the integrity of the person interviewed. All publication of what was said in the interviews was done anonymously.

Papers I and II were approved by the Regional Ethical Review Board in Gothenburg, Sweden (reference number 758-17). An additional application for amendment was approved by the Swedish Ethical Review Authority (reference number 2020-02783).

Paper III and IV were approved by the Regional Ethical Review Board in Gothenburg, Sweden (reference number 1011-15).

Paper V was approved by the Swedish Ethical Review Authority (reference number 2020-00867).

04

RESULTS

4.1 PAPER I

Epidemiology of more than 50,000 ankle fractures in the Swedish Fracture Register during a period of 10 years

During the first ten years of registering ankle fractures in the SFR (2012-2022), 57,433 fractures, in 56,439 patients, were registered. When analysed according to AO/OTA type 24% were classified as type A, 64% as type B and 12% as type C (Figure 21). Within each type, fractures in group 1 (i.e. A1, B1 and C1) were most common.

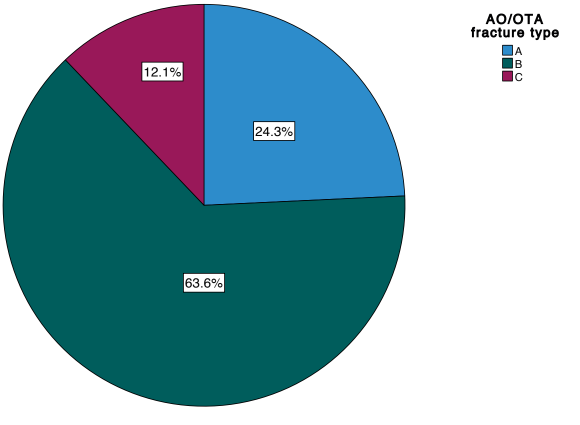


FIGURE 21. Distribution between AO/OTA44 fracture types. Data shown for 1 April 2012 to 31 March 2022. Fractures that were classified as “not able to classify” and pediatric fractures are not included.

The mean age at the time of the ankle fracture was 55 years (range 16-107) and 61% of the fractures involved women. The affected men had a mean age of eight years lower than the women (men: 50 years, women: 58 years). Women were more commonly affected in all AO/OTA fracture groups except the C3 group where 62% of the fractures occurred in men.

Overall, the frequency of open fractures in the study was 1.8%. Open fractures were most common between the ages of 60-70 years. Over the age of 50, open fractures were more common in women, while, in the age groups between 20 and 50, men were more commonly affected by open ankle fractures (Figure 22).

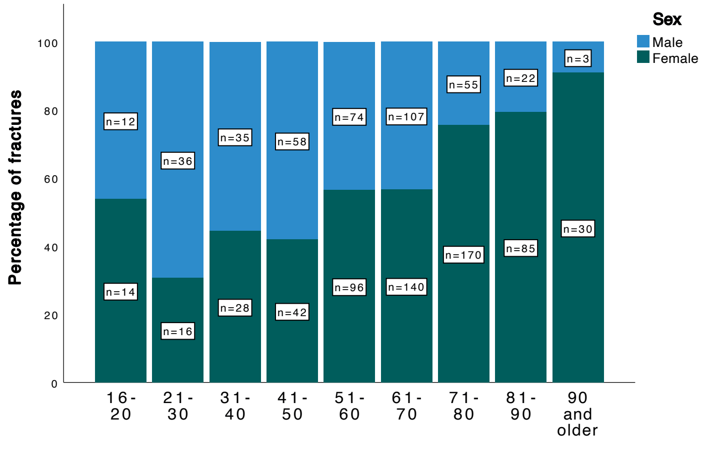


FIGURE 22. The distribution of open ankle fractures per sex and age group.
Data shown for 1 April 2012 to 31 March 2022. Fractures that were classified as "not able to classify" and pediatric fractures are not included

A simple fall was the underlying injury mechanism behind 66% of the ankle fractures in the study and the most common injury mechanism in all individual fracture groups. A peak in the number of ankle fractures during the Swedish winter months, between November and March, was found (Figure 23). The results further show that this was caused by an increase in simple falls causing B-type fractures.

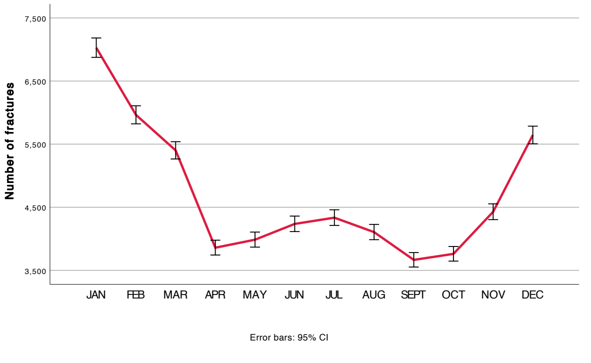


FIGURE 23. The seasonal variation in the number of ankle fractures.
Data shown for all AO/OTA44 ankle fracture types between 1 April 2012 and 31 March 2022. Fractures that were classified as "not able to classify" and paediatric fractures are not included

Additional results

Primary treatment was analysed as either surgical, non-surgical or surgical treatment after the early failure of non-surgical treatment. Over the full ten-year study period, 48.2% (n=26,645) of all patients with ankle fractures were treated surgically and 51.7% (n=28,566) non-surgically (Figure 24). In 22 patients (0.04%), non-surgical treatment was converted at an early stage to surgical due to the failure of non-surgical treatment.

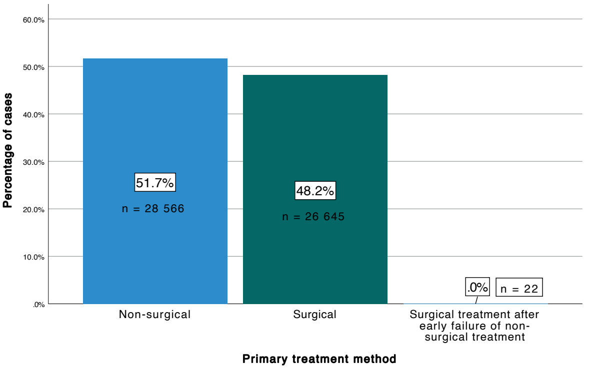


FIGURE 24. Distribution of primary treatment method for all AO/OTA types of ankle fracture. Fractures classified as pediatric fractures are not included.

To evaluate whether any shifts in the primary chosen treatment had occurred over time, the first five years of the study period were compared with the last five years. An almost identical distribution was found between the two periods, where 48.7% were treated surgically during the first five years, compared to 48.0% during the last five years (Figure 25).

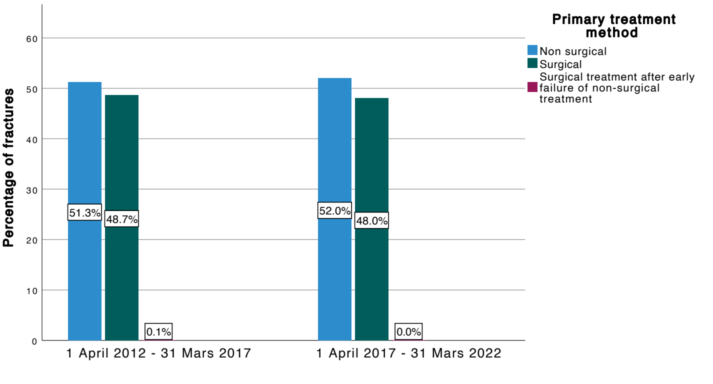


FIGURE 25. Change in the distribution of primary treatment method for all AO/OTA types of ankle fracture during the first five years of the study period compared with the last five years.
Fractures classified as paediatric fractures are not included.

4.2 PAPER II

**Does the Covid-19 pandemic affect ankle fracture incidence?
Moderate decrease in Sweden**

During the first wave of the Covid-19 pandemic in Sweden, between 15 March and 15 June 2020, a mean of 139 patients with ankle fractures per month (monthly rate) were registered in the SFR at the studied departments. During the observed months in 2017-2019, the monthly rate was 161 ankle fractures/month. This statistically significant decrease corresponds to a reduction of 14% for the three-month period in 2020 compared with the corresponding months in 2017-2019. When analysed month per month, the greatest reduction in the number of fractures was seen during the first studied month, 15 March to 14 April, with a reduction of 26% (Table 3).

TABLE 3. The monthly rates in the number of ankle fractures in 2020 compared with 2017-2019.

	Monthly rates		
	2017-2019	**2020**	**Change (%) compared with 2017-2019**
Total time period	161	139	-14
15 March-14 April	174	129	-26
15 April-15 May	144	144	0
16 May-15 June	164	144	-12

A subgroup analysis of sex and for age groups revealed a reduction in the number of ankle fractures in women of 16% for the full three-month period, while the corresponding reduction for males was 10%. In the age group of 70 years or older, almost 30% fewer ankle fractures were seen in 2020 compared with 2017-2019 (Table 4).

TABLE 4. The monthly rates in the number of ankle fractures in 2020 compared with 2017-2019 grouped by sex and for age groups.

	Monthly rates		
	2017-2019	2020	Change (%) compared with 2017-2019
Sex			
Male	64	58	-10
Female	97	81	-16
Age group			
<30	28	23	-19
30–49	34	36	7
50–69	58	51	-12
≥70	41	29	-29

When subgroup analyses for sex and age groups were performed for the individual 30-day periods, the monthly rate for ankle fractures demonstrated the greatest reduction in the first studied month for females (-31%) and the same month in the age group of 70 years or older (-36%). In the age group of 30-49 years, an increase in the number of fractures of 43% was demonstrated in the second studied month (Table 5).

TABLE 5. The change (%) in the monthly rate of ankle fractures in 2020 compared with 2017-2019, sub grouped for sex and by age group.

	Time period		
	15 March–14 April	15 April–15 May	16 May–15 June
Sex			
Male	-18	5	-13
Female	-31	-3	-12
Age group			
<30	-19	-23	-15
30–49	-20	43	4
50–69	-24	2	-12
≥70	-36	-21	-26

4.3 PAPER III

Classification and treatment of lateral malleolar fractures - a single-center analysis of 439 ankle fractures using the Swedish Fracture Register

Between 1 April 2012 and 31 March 2014, 1,332 ankle fractures, in 1,328 patients, were registered in the SFR at SU. There was a slight predominance of women who had sustained 58% of the fractures. The mean age at the time of injury was 55 years and women were a mean of 10 years older than the men at the time of injury (mean age men: 47 yrs., mean age women 57 yrs.). High-energy trauma was the underlying cause of 7% of the ankle fractures in the study and 2% were open fractures.

When analysed by fracture type, 63% of the fractures were trans-syndesmotic B-type fractures, 27% were infra-syndesmotic A-type fractures and 11% were C-type fractures. For fracture groups, a majority of women were affected in all fracture groups except A3 and C3 where men significantly outnumbered the women (A3 65% men, C3 76% men). The highest frequency of open fractures was found in the C2 group, whereas the most cases of high-energy injuries were found in the A2 group (Table 6).

Of the 1,332 ankle fractures, 512 were classified as AO/OTA44-B1 fractures upon registration in the SFR. Of these, 439 were both initially treated and followed up at SU and were included in the detailed study of management and treatment. Among the B1 fractures, 309 (70%) were treated non-surgically. Medial tenderness was analysed as an indicator of deltoid ligament injury, something that, according to the AO/OTA classification system for ankle fractures, should not be present in a B1 fracture. The results show that medial tenderness was found in 24% of the non-surgically treated patients and in 48% of the surgically treated patients. Of all non-surgically treated patients, five (1%) were converted to surgical treatment at an early stage, of which the majority (3) had no signs of medial tenderness at the first clinical examination. In two of the converted cases, a slight lateralisation of talus at the one-week radiographical follow-up was documented, whereas, in the other three cases no clear indication for a change in treatment plan was to be found. Another two of the non-surgically treated patients were surgically treated at a later stage due to non-union (Figure 26).

At this time, all non-surgically treated B1 fractures were followed up at one week with a radiographic examination. This follow-up visit changed the treatment plan to surgical in five (1%) of the non-surgically treated patients in the study, regardless of the presence or not of medial tenderness at first presentation. One of these patients had documented medial tenderness at the first clinical examination.

TABLE 6. Demographics of patients registered with ankle fractures at Sahlgrenska University Hospital between 1 April 2012 and 31 March 2014.

		A n=354 (27%)			**B n=838 (63%)**			**C n=140 (11%)**		
		A1 n=225 (64%)	A2 n=109 (31%)	A3 n=20 (6%))	B1 n=512 (61%)	B2 n=158 (19%)	B3 n=168 (20%)	C1 n=58 (41%)	C2 n=36 (26%)	C3 n=46 (33%)
Sex	Male n (%)	80 (36)	47 (43)	13 (65)	245 (48)	56 (35)	51 (30)	24 (41)	9 (25)	35 (76)
	Female n (%)	145 (64)	62 (57)	7 (35)	267 (52)	102 (65)	117 (70)	34 (59)	27 (75)	11 (24)
Mean age	Total years (range)	50.4 (16-93)	51.8 (16-96)	48 (20-95)	51.8 (16-98)	58.4 (18-98)	58.4 (17-94)	47.9 (16-97)	51.9 (18-90)	46.8 (17-86)
	Male years (range)	41.8 (16-88)	47.4 (16-96)	42.6 (21-95)	47.7 (16-90)	53.6 (18-95)	52.7 (17-86)	40.8 (17-82)	37.9 (21-61)	45.7 (17-86)
	Female years (range)	55.2 (16-93)	55.2 (16-91)	57.9 (20-95)	55.6 (16-98)	60.9 (19-98)	60.9 (22-94)	52.9 (16-97)	56.6 (18-90)	50.5 (24-81)
Fracture	Open n (%)	1 (0.4)	4 (3.7)	0 (0)	6 (1.2)	2 (1.3)	4 (2.4)	0 (0)	3 (8.3)	2 (4.3)
	High energy[1] n (%)	7 (3.1)	21 (19.2)	1 (5)	17 (3.3)	8 (5.1)	8 (4.8)	4 (6.9)	5 (13.9)	5 (10.9)
	Low energy[1] n (%)	213 (94.7)	84 (77.1)	18 (90)	488 (95.3)	150 (95)	157 (93.5)	52 (89.7)	31 (86.1)	41 (89.1)

[1]In some cases, information on high or low energy is missing and, as a result, the total is not 100%.

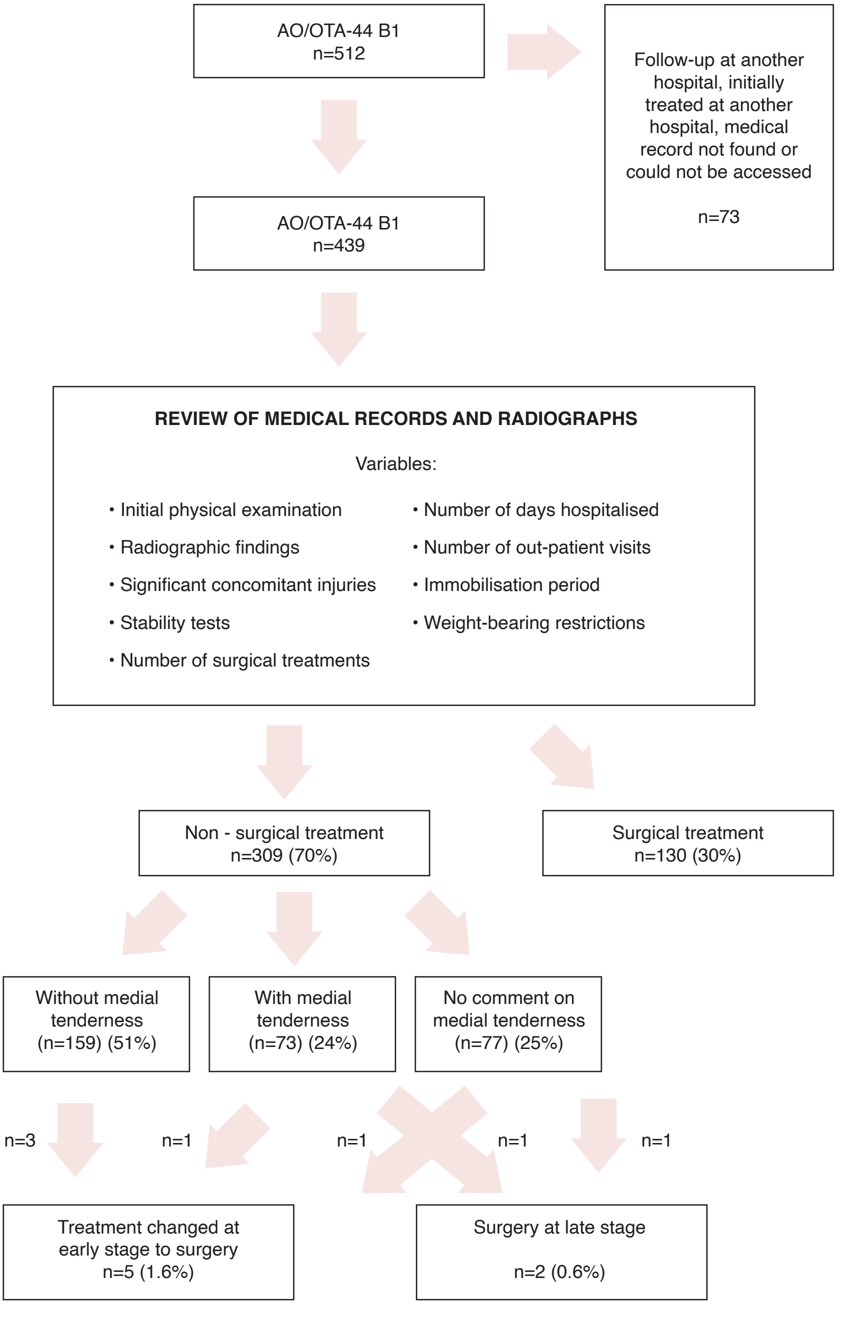


FIGURE 26. Flow chart of how the detailed study of AO/OTA 44B1 fractures was conducted and how the fractures that were initially assigned to non-surgical treatment were treated with regard to findings of medial tenderness.

4.4 PAPER IV

Fractures of the lateral malleolus – a retrospective before-and-after study of treatment and resource utilization following the implementation of a structured treatment algorithm

Paper III resulted in the development of a structured treatment algorithm (TA) for the management, classification and treatment of ankle fractures at SU. The aim of Paper IV was to evaluate the effects of the TA. This was done by comparing the group of AO/OTA-B1 fractures from Paper III with a similar group of B1 fractures treated after the introduction of the TA.

The group of AO/OTA-B1 fractures managed before the introduction of a TA, in 2012-2014, the pre-TA group, consisted of 410 fractures (after exclusions, see methods section). In Paper IV, this group was compared with another group of AO/OTA-B1 fractures registered in the SFR at SU during a two-year period after the introduction of a TA, the post-TA group. This group consisted of 333 fractures (after exclusions, see method section). Between the two groups, no clinically important differences in demographics were seen (Table 7).

TABLE 7. Demographics of AO/OTA44-B1 fractures registered in the SFR at SU before (pre-TA) and after (post-TA) the introduction of the structured treatment algorithm. P-values provided for the differences between the pre-TA and the post-TA group.

	Pre-TA (n=410)	Post-TA (n=333)	p-value
Mean age			0.735*
Total, years (SD)	52 (19)	53 (19)	
Male,years(SD)	48 (20)	52 (20)	
Female, years (SD)	56 (18)	53 (19)	
Sex			0.207**
Male, n (%)	189 (46)	138 (41)	
Female, n (%)	221 (54)	195 (59)	
Open fractures, n (%)	6 (1.5)	0 (0)	0.036**
High energy, n (%)	14 (3.4)	9 (2.7)	0.673**

* Independent samples t-test
**Fisher's exact test

The two groups were analysed regarding whether or not the finding, or absence, of medial tenderness at the first clinical presentation was documented in the medical records (yes/no) and to identify the number of patients who were deemed to have medial tenderness, ecchymosis or swelling. The results showed that the number of patients in whom medial tenderness was commented on in the medical records increased between the pre-TA and the post-TA groups, from 80% to 87%, and the number of patients in whom medial tenderness was found diminished from 49% to 33%. In both the group with and the group without medial tenderness, the proportion treated non-surgically increased post-TA (Table 8).

TABLE 8. Treatment related to findings of medial tenderness at the first clinical examination.

	Pre-TA n (%)	Post-TA n (%)	p-value*
Medial tenderness commented on	328 (80)	288 (87)	0.024
Medial tenderness present	161 (49)	95 (33)	<0.001
No medial tenderness found			
Non-surgical treatment	144 (86)	181 (94)	0.020
Medial tenderness found			
Non-surgical treatment	76 (47)	79 (83)	<0.001

*Fisher's exact test

Regarding treatment, the following parameters were studied; choice of treatment method, weight-bearing restrictions and immobilisation period. A significant change was seen in all parameters post-TA. The surgical treatment of AO/OTA-B1 fractures was reduced from 32% to 10%, the number of patients allowed full weight-bearing increased from 41% to 84% and the time immobilised reduced from 45 to 42 days post-TA (Table 9). In two of the non-surgically treated patients in the post-TA group and five in the pre-TA group, treatment was changed to surgical at an early stage.

TABLE 9. Parameters regarding the treatment of AO/OTA44-B1 fractures before (pre-TA) and after (post-TA) the introduction of a structured treatment algorithm.

	Pre-TA (n=410)	Post-TA (n=333)	p-value
Surgically treated, n (%)	130 (32)	34 (10)	<0.001*
Full weight-bearing allowed, n (%)	166 (41)	278 (84)	<0.001*
Partial weight-bearing allowed, n (%)	181 (44)	22 (6.6)	<0.001*
Immobilisation time, days			
Median (range)	43 (14-108)	42.0 (0-95)	<0.001**
Mean (SD)	45 (8.99)	41.87 (10)	

* Fisher's exact test
** Mann-Whitney U test

4.5 PAPER V

Knowledge support for ankle fractures in the Swedish Fracture Register – a qualitative study of physicians' experiences

Paper V qualitatively investigated the experiences of a group of physicians presented with knowledge support while registering ankle fractures in the SFR through semi-structured interviews. The mean age of the interviewees was 36.9 years (median age 37.5, range: 24-55 years). Thirteen of the participants were men and seven were women. There were three junior doctors, two interns, five resident orthopaedic surgeons, seven specialists in orthopaedic surgery and three consultant orthopaedic surgeons. The semi-structured interviews were analysed using qualitative content analysis. The analysis resulted in the identification of four main themes and each of the themes consisted of two categories (Figure 27).

The theme "Enhancing the quality control of the decisions made" consisted of the categories "Validation" and "Action", which related to the impact of the KSS on the decisions made by the physician. The statements in these categories demonstrate a notion that the KSS improved the decisions that were taken and spurred extra consideration by providing a reminder of the recommended treatment.

The theme "Being afraid of losing control" contained the categories "The physician" and "The patient". This theme dealt with concepts of the KSS hindering the physicians' potential to think for themselves, as well as notions regarding the bluntness of the KSS with regard to patient-related factors like age and comorbidities.

The third theme, "Acknowledging the benefits associated with a KSS", contained the categories "Suggestions" and "Experiences". This theme related to the experiences of coming in contact with the KSS where the perception was that the KSS enhanced the quality of care provided. This theme also contained suggestions for the further development of the KSS and other computer-aided systems in healthcare.

The final theme, "Managing the organizational obstacles in healthcare", consisted of the categories "Implementation" and "Organisation" and dealt with the experiences of lack of information within the department regarding the introduction of the KSS. This theme also contained thoughts on the strategic flow surrounding the management of fracture patients and the registration of fractures in the SFR.

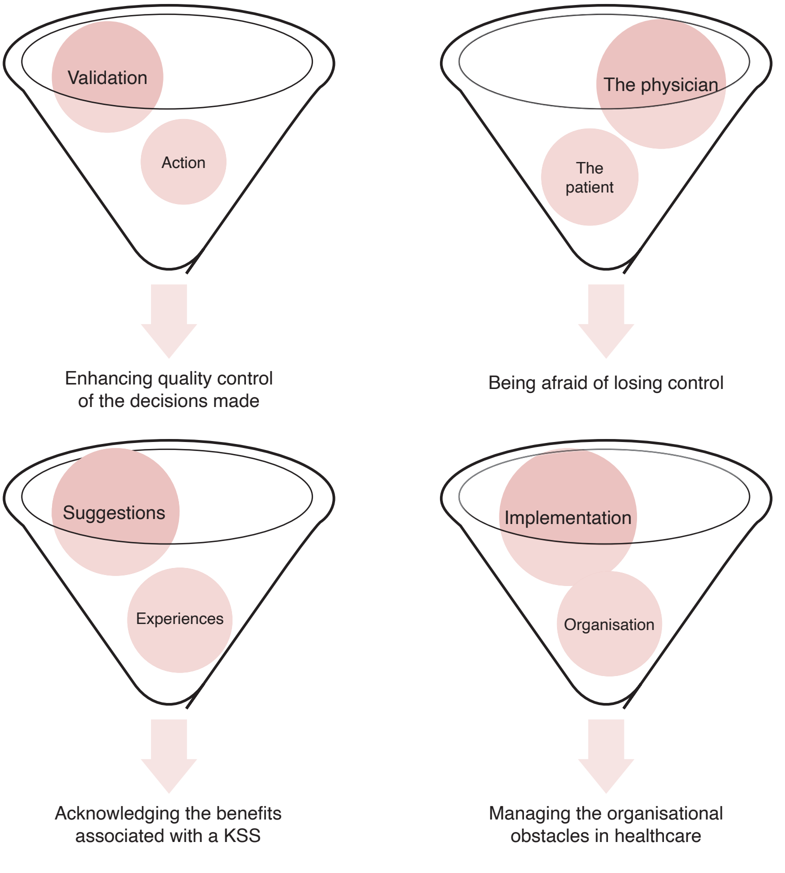


FIGURE 27. The resulting categories and themes relating to experiences of the KSS in the SFR.

This study supports previous findings that physicians appreciate being provided with knowledge support. The KSS was found to both increase the value of work and enhance the initiative to register ankle fractures in the SFR. The KSS was found to validate the clinical decisions taken and the interviewees experienced that the KSS improved care. Some fear of being overly reliant on a template was noted.

05

DISCUSSION

5.1 EPIDEMIOLOGY OF ANKLE FRACTURES

5.1.1 EPIDEMIOLOGY AND INCIDENCE

Epidemiological studies expand our understanding of the underlying causes, patterns and distribution of injuries and fractures between subgroups. A research team led by Professor Charles Court-Brown in Scotland have been performing epidemiological mappings of numerous different fractures since the 1990s, studies regarded as the basis of epidemiological research in trauma orthopaedics. These studies have been the foundation of many subsequent studies. Today, the SFR offers a unique opportunity to further expand, and update, our knowledge of fracture epidemiology. The growing number of epidemiological studies originating from the SFR demonstrate the value, and amount, of information available for large-scale epidemiological studies.[86, 87, 105-107] To our knowledge, **Paper I**, is the largest and most detailed study of the epidemiology of ankle fractures ever conducted. It is based on material compromising more than 55,000 ankle fractures collected prospectively in the SFR and classified by orthopaedic surgeons according to the AO/OTA classification system. The study spans over a ten-year period between 2012 and 2022. **Papers II**, **III** and **IV** are also epidemiological mappings of ankle fractures but with different specific aims and research questions. However, the epidemiological findings in these papers support the findings in Paper I but on smaller, geographically limited material.

The main findings in **Paper I** are that women are more frequently affected by ankle fractures and are older at the time of injury than men. The study further demonstrates a distinct seasonal variation in the number of ankle fractures, with a peak during the Swedish winter months between November and March. The increasing number of ankle fractures in wintertime is driven by an increase in simple same-level falls causing B-type fractures.

For the past thirty years, studies of ankle fracture epidemiology have indicated that the incidence is increasing.[45, 46, 48, 49, 108] Recent studies report an incidence of between 69 and 179 fractures/100,000 person-years (Table 9). Looking at those numbers, it is obvious that incidence is a measurement that is sensitive to the way it is calculated. The variation is probably caused by the variability in material and methods used for the studies. Most previous epidemiological studies have either included only hospitalised or surgically treated patients or reported on small-scale material.[46, 48, 109] Studies based on hospitalised or surgically treated ankle fracture patients demonstrate incidence rates around 70 fractures/100,000 person-years, compared with studies including both hospitalised and patients treated as out-patients, who demonstrate incidence rates around 170/100,000 person-years. To our knowledge, only one previous study has included both hospitalised patients and patients treated as out-patients and it is based on a material larger than a few hundred patients. That study, by Elsoe et al. from 2018, is based on 9,767 patients treated for ankle fractures at Aalborg University Hospital between 2005 and 2014.[49] Elsoe et al. report an incidence of 169/100,000 person-years, which is in line with the findings of studies that reports incidence for fractures in all locations of the extremities. A study by Beerekamp et al. from 2017 reports an incidence for ankle fractures of 158/100,000 person-years in 2012. Bergh et al. report a slightly lower incidence, 127/100,000 person-years, in a study from 2020 based on data from the SFR. Table 10 presents an overview of the incidence rates for ankle fractures presented in previous studies.

TABLE 10. Overview of results relating to ankle fracture incidence rates.

Author	Year	Country	Material	Incidence (/100,000 person-years)	Incidence, men (/100,000 person-years)	Incidence, women (/100,000 person-years)
Court-Brown	1998	UK	1500		132	112
Elsoe	2018	Denmark	9767	169	157	180
Juto	2018	Sweden	1756	179		
Kannus*	2002	Finland	369 (year 1970) 1545 (year 2000)		38 (year 1970) 114 (year 2000)	66 (year 1970) 174 (year 2000)
Thur*	2012	Sweden	91 410	71	63	79
Happonen*	2022	Finland	118 929	69		
Beerekamp**	2017	Netherlands		113 (year 2004) 158 (year 2012)		
Bergh**	2020	Sweden		127	100	153

* Hospitalised patients only
**Based on all extremity fractures, only incidence for ankle fractures displayed in table

Regardless of the absolute value of incidence, previous studies all report that the greatest increase in incidence is seen in the group comprising elderly women.[45, 47, 110, 111] Kannus et al. reported a dramatic increase in the incidence of ankle fractures in women over 60 years or age between 1970 and year 2000 and anticipated a continuous threefold increase until 2030.[46] Thur et al. reported a slightly lower increase, with an annual increase in the incidence of ankle fractures in women over 60 years of age of 1%.[48] Due to the difficulty involved in calculating and reporting incidence rates in a comparable manner, **Paper I** does not include calculations of incidence. **Paper I** includes all the ankle fractures registered in the SFR since 2012, from all the affiliated orthopaedic departments. The number of affiliated departments in the SFR has gradually increased to its present level, with coverage of 100%.[112] As a result, calculations of incidence would have been very cumbersome as the catchment area gradually increased. However, **Paper I** confirms the finding the ankle fractures are most common amongst older women. Overall, the frequency of ankle fractures, in both sexes, was shown to be highest between the ages of 50 and 70. Over 60% of all ankle fractures occur in women and women account for the highest number of fractures between the age of 50 and 80 years.

Paper I further demonstrates that simple same-level falls is the single most common injury mechanism behind ankle fractures, underlying 66% of all ankle fractures. This has been shown before, but the size of the material in Paper I, including more than 55,000 ankle fractures, is unprecedented. When looking in more detail into the simple falls, 64% of the patients sustaining an ankle fracture due to a simple fall were women.

Fragility, or osteoporotic, fractures are defined as fractures resulting from a mechanism of injury or a mechanical force that would not normally result in a fracture.[113] The World Health Organisation (WHO) has defined these low-energy traumas, as forces equivalent to a fall from standing height or less. Another definition of osteoporotic, fragility, fractures is that they are associated with low bone mineral density (BMD) and that they increase over the age of 50.[114] The question of whether ankle fractures should be regarded as fragility, or osteoporosis-related, fractures remains the subject of debate. A systematic review by So et al. from 2020 reported a significant association between ankle fractures in the elderly and a reduction in femoral neck BMD.[115] These findings are supported by another systematic review from 2020 showing bone microarchitectural changes in ankle fractures, like other fragility fracture types.[116] A study by Biver et al. from 2015 further demonstrates that women with ankle fractures have lower BMD and trabecular bone alternations.[117] However, a recent study by Hjelle et al. failed to show an association between ankle fractures and osteoporosis and a study by Guggenbuhl et al. argues that ankle fractures should not be regarded as directly related to osteoporosis but as a predictor of osteoporotic fractures at other sites.[118, 119] Despite the continuous debate on whether or not ankle fractures are to be regarded as fragility fractures, most previous studies agree with the statement that an ankle fracture is an indicator of poor bone quality and might be a predictor of future fracture risk.[116, 119-121]

According to the findings in **Paper I**, men demonstrate the highest number of ankle fractures before the age of 40. This in is line with the findings of Singer at al. who report that, at the age of 35, men run a 2.9 higher risk of a fracture than women, whereas, at the age of 60, women run a 2.3 times higher fracture risk than men.[122] In all age groups, men were more frequently injured by high-energy trauma than women. The injury mechanism with the highest proportion of men, 75%, was the group of miscellaneous injuries. This group includes fractures sustained in sports injuries and in fights. To conclude, ankle fractures affect both sexes and all age groups but men and women sustain their ankle fractures at different ages and are injured by different trauma mechanisms.

Only a few previous studies have reported on ankle fracture epidemiology including detailed fracture classification.[45, 50] Regarding the distribution between AO/OTA fracture types, Court-Brown reported that 38% were type A fractures, 52% type B and 10% type C. Results from both Juto et al. and from **Papers I, III** and **IV** in this thesis support the finding that C-type fractures account for around one in ten ankle fractures. Paper I, with by far the largest material and therefore probably the results closest to the truth in this matter, reports a slightly higher proportion, with 12% C-fractures. All the above-mentioned studies agree that B-type fractures constitute the largest group, according to **Papers I, III** and **IV**, constituting 63% of all ankle fractures. A-type fractures were found by Court-Brown to constitute 38% of all ankle fractures, but a slightly smaller number were found by both Juto et al. and in **Papers I, III** and **IV**, between 20% and 27%. One of the reasons for this might be that minimal avulsions of the tip of the fibula are regarded as distortions and are not registered in the SFR, possibly slightly reducing the proportion of A fractures in studies based on data from the SFR compared with other studies.

Previous studies have demonstrated that the isolated medial malleolar fracture, AO/OTA44 A2.1, should not to be regarded as an osteoporotic fracture.[45, 50] In fact, it is the subgroup of ankle fractures that is most related to high-energy trauma, sports and traffic accidents. According to Court-Brown, the same pattern is seen for all A2 fractures, but it is most pronounced for the A2.1 fracture subgroup. These findings are confirmed in both **Paper I** and **Paper III** in this thesis, where the A2 fractures are the group with the highest frequency of high-energy trauma (Paper I: 13.4%, Paper III: 19%).

To conclude, the incidence of ankle fractures is increasing and the largest increase can be seen in the group of elderly women. In **Paper I**, the frequency of ankle fractures in women was already found to increase after the age of 50. With an ageing population and, simultaneously, a population that remains more active for longer in life, this increase in the incidence of fractures is unlikely to decline. Studies of the incidence of fractures in general, and ankle fractures in particular, point out that measures must be taken to enable the health care system to cope with the challenges of an ageing population with an increasing incidence of fractures.[46, 49, 51, 123, 124] In order for healthcare to cope with this increasing burden of fractures, both preventive measures and adjustments to the manner in which we manage these patients must be undertaken, e.g. through structured treatment algorithms.

As the most common injury mechanism behind an ankle fracture is a simple same-level fall, measures must also be undertaken to prevent falls, especially in the elderly. With an increasing age, the risk of falls increases and the consequences of falls are aggravated. As the simple falls have been shown to increase dramatically during the Swedish winter months, attention must focus on limiting slippery conditions and removing snow. The findings in **Paper I**, supported by the findings in previous studies, indicate that age-related skeletal fragility might be a risk factor for ankle fractures. Including ankle fractures in the traditionally regarded osteoporotic fracture types and making women aged > 50 years who have sustained an ankle fracture the subject of osteoporosis screening, might help to reduce the number of subsequent fractures.

5.1.2 THE COVID-19 PANDEMIC

On 30 January 2020, the WHO declared the outbreak of the novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) causing coronavirus disease 2019 (COVID-19) a Public Health Emergency of International Concern (PHEIC). The spread had begun in December 2019 in the city of Wuhan, in the People's Republic of China, with the first reported death in China on 11 January 2020.[125] On 11 March 2020, the WHO declared the disease a pandemic and, since then, ath the time of writing, the pandemic has spread to 228 countries and territories, with a total of over 600 million infected people and 6.5 million deaths.[126]

Sweden had its first confirmed case of Covid-19 on 31 January 2020 and the pandemic reached most European countries by February 2020. On 24 February, Swedish citizens who had visited selected countries (Italy, Iran, South Korea or China) were requested to be attentive to symptoms of Covid-19 and, on the 26 February, the Swedish Public Health Authority (PHA) held its first press conference, something that was then repeated daily throughout the pandemic.

Many countries imposed strict regulations on their citizens during the Covid-19 pandemic, establishing quarantines and lockdowns. Sweden implemented a less restrictive strategy, based mostly on recommendations regarding individual responsibility from the Swedish PHA. On the 17 March, high-schools and universities were urged to go into online teaching and, on 19 March, the Swedish PHA recommended that the public should avoid all unnecessary travels. On 27 March, the Swedish Public Health Authority imposed a restriction on all public gatherings from 500 to 50 people, one of the few hard restrictions imposed in Sweden during the Covid-19 pandemic.

Paper II investigated the number of ankle fractures in Sweden during the first wave of the Covid-19 pandemic, between 15 March and 15 June 2020. By mid- March, the pandemic was a fact in Sweden and the 15 March was the earliest possible date to obtain three months of data from the SFR and still get the data out before the summer of 2020. The results showed that there was a decline of 14% in the incidence of ankle fractures during this period compared with the same time period in the three preceding years. In the age group of patients over 70 years, a reduction of almost one third, 29%, was seen. This was interpreted as people over the age of 70 years exercising the greatest compliance with the recommendations on social distancing, limiting of social activities and avoiding high-risk activities to limit the burden on hospitals due to accidents. The strictest recommendations in Sweden were directed at this age group, making this interpretation plausible. A study from the USA confirms the findings of a lower incidence of ankle fractures during the Covid-19 pandemic in 2020 and they also found the greatest decrease amongst women.[127] However, they found a decrease of only 4% when comparing incidence rates between July to December 2020 with the same time period in 2019. Most other studies of fracture incidences during the Covid-19 pandemic have only compared the incidences during the pandemic with one other preceding year, something that might affect the differences seen in the decrease levels reported. Several studies have found that that the Covid-19 pandemic had a great impact on all aspects of trauma care in 2020.[128-130] The findings in **Paper II** of a larger decline in the incidence of ankle fractures is further supported by Haskel et al., who found that the volume of ankle fractures decreased by 76.5% between 22 March and 30 April 2020 compared with 2019.[131] The same study also demonstrates that the incidence of hip fractures remained unchanged during the same time period. This further supports the assumption that the reduced activity in society was the main reason for the reduction in ankle fractures, as the majority of ankle fractures are sustained due to a simple fall and during activities outside, whereas hip fractures predominantly occur inside the homes of the elderly. In Sweden, the PHA declared on 24 March that sport and working out are good for the health and should therefore be continued, but people above the age of 70 years were urged not to participate in group activities indoors.

Paper II exemplifies how the SFR can be utilised to make comparisons of fracture incidence over years, due to its construction almost real time. Due to data being entered in the SFR by physicians at the time of injury, and by the responsible surgeon at the time of the surgery, there is little delay in the data entry process in the SFR compared with other registers, making studies like this possible to conduct.

5.1.3 STRENGTHS, LIMITATIONS AND METHODOLOGICAL CONSIDERATIONS

Epidemiological studies often report on the incidence of medical conditions or injuries. However, as discussed, incidence is a measurement that must be compared between studies with caution. As mentioned above, **Paper I** does not include calculations of incidence due to the SFR's gradual expansion in coverage. The lack of incidence calculations can be seen as a limitation to Paper I, as the findings are more difficult to compare with the findings in previous studies. On the other hand, not restricting the study to one defined catchment area is a strength, as patients in Sweden are free to seek medical care for acute conditions at all hospitals, thereby possibly reporting with fractures outside their own catchment area. In the author's opinion, the findings in Study I can still be of great value, as they demonstrate the proportion of fractures in subgroups of sex, age and during the various months of the year, for example. These findings are easily comparable to other previous studies, despite the use of different reporting units.

Thanks to the SFR, large-scale epidemiological studies of fractures are possible to conduct. These studies have high reliability due to the coverage and completeness of the SFR.[82] In 2021, the overall completeness of lower leg and ankle fractures in the SFR was 68%, with many departments reaching over 90%.[83] As the SFR has evolved, since its inception in 2011, the coverage and completeness hve gradually increased. Epidemiological studies from the SFR are based on prospectively collected data, in contrast to most previous epidemiological studies that are retrospective. The major strength of Paper I is the fact that it includes almost 60,000 prospectively collected ankle fractures, making it, to our knowledge, the largest epidemiological study of ankle fractures. Another strength of Paper I is that, in contrast to most other epidemiological studies, it includes a detailed classification of the included fractures, according to the AO/OTA classification system. As the fractures are classified in the SFR by the registering physician, these data are available for all registered fractures and make it possible to study the epidemiology of groups and sub-groups of ankle fractures in material larger than ever previously presented.

Another strength of **Paper I** is that the studied time period is so long. A study time of ten years limits the risk of variations in epidemiological parameters that may be present for single years. This strength also applies to **Paper II**, where the studied time period in 2020 is compared with the mean of the preceding three years. The fact that a comparison is made with the mean of three years is a strength as, in the same manner as in Paper I, it limits the risk of variations seen for single years. The fact that the comparative years were the closest preceding years is another strength, as other factors with an impact on the studied variables are less likely to have changed in such a short timeframe. The material for **Paper II** was ankle fracture registrations from seven different departments. Compared with other studies of fracture incidences during the Covid-19 pandemic, this is a strength as most other studies were single centre. The fact that registrations from seven different departments were used makes the results more trustworthy in terms of generalisation.

One limitation to **Paper I** is the short time that elapsed between the studied time period and data retrieval from the SFR. The seven studied departments were chosen due to their history of rapid fracture registration entry in the SFR, registering a large number of fractures within 30 days. Nevertheless, some ankle fractures might have been registered in the SFR after data retrieval and are therefore missing from the study. Another limitation to **Paper II** is that the pandemic was not over by the end of the study period in June 2020. It would have been interesting to conduct a long-term follow-up to see whether the decline in ankle fracture incidence subsided later during the pandemic or whether a rebound effect was seen, with an increasing number of fractures as the restrictions eased, an objective for a future study.

5.2 ASSESSMENT OF ANKLE FRACTURES

5.2.1 CLASSIFICATION

The three most common classification systems for ankle fractures are the Lauge-Hansen, the Danis-Weber and the AO/OTA classification systems (Figures 7-9 in the introduction section). All three have advantages, but they also have shortcomings. The Lauge-Hansen system has been repeatedly shown to be difficult to reproduce, but it can be of great value when it comes to understanding the injury mechanisms behind ankle fractures.[26, 132] The Danis-Weber system is easy to use, as it only evaluates the level of the fibular fracture, but is as such it has been criticised for being overly simplified.[133] On the other hand, the AO/OTA classification system has been criticised for being overly complex, with its up to 27 different subgroups of fractures to classify between, but, on the other hand, it has the advantage of providing a detailed classification that predicts future outcome.[132] In the SFR, ankle fractures are classified according to the AO/OTA classification system. A study from 2016 by Juto et al. of the accuracy of ankle fracture classifications in the SFR, comparing classifications in the SFR with a group of experts, concluded that the classification of ankle fractures in the SFR is accurate and valid.[28] However, Juto et al. identified some difficulties in classifying ankle fractures correctly.

It appears that one difficulty in classifying ankle fractures, according to Juto et al., is discriminating between B2 and B3 fractures. The study further shows that A1 fractures are difficult to distinguish from B fractures and C1 fractures appear to be mistaken for C2 fractures.[28] The study by Juto et al., like other studies of the accuracy of ankle fracture classifications, was performed using only radiographic images. This might be the explanation for the finding of few misclassifications between B1 and B2 fractures, as they look similar on plain radiographs and further assessment requires additional information on clinical findings indicating ligament injury. The clinical experience is that the greatest difficulties in classifying ankle fractures appears to be found between B1 and B2 fractures.

In **Paper III**, the medical records of all patients with ankle fractures classified in the SFR as AO/OTA44-B1 were reviewed in terms of the findings of medial tenderness, ecchymosis and swelling on the first clinical examination. According to the AO/OTA classification system, B1 fractures are isolated lateral malleolar fractures, and should therefore not have any indication of deltoid ligament injury. From the medical records, it was noted whether or not medial tenderness, ecchymosis or swelling was present, as indicators of deltoid ligament injury. **Paper III** revealed that, of the non-surgically treated patients, classified as having B1 fractures, 24% had findings of medial tenderness. Of the patients allocated to surgical treatment, 48% had medial tenderness. These findings indicate that 24% of the 309 non-surgically treated patients and 48% of the 130 surgically treated patients were possibly misclassified and should in fact have been classified as B2 fractures, if the tenderness that was found was interpreted as a deltoid ligament tear. In contrast to the findings of Juto et al., evaluating the accuracy of the AO/OTA classification from radiographic images, the findings in **Paper III** indicate that B1 fractures are difficult to discriminate from B2 fractures, with up to 31% (137 of 439 fractures) possible misclassifications.

Paper IV demonstrates that, after the introduction of a structured algorithm for ankle fracture management, the number of patients classified as having an AO/OTA44-B1 fracture and the concurrent finding of medial tenderness fell from 49% to 33%. If one third within a fracture group is still misclassified it is problematic. However, due to the limitation of medial tenderness as an indicator of complete deltoid ligament injury, all these should probably not be classified as B2 fractures either. Nevertheless, one third is still probably closer to the truth, and supports the value of introducing a treatment algorithm containing detailed information about the AO/OTA classification of ankle fractures. An overall increase in the number of fractures classified as B2 and a decrease in the number of fractures classified as B1 after the introduction of the treatment algorithm further indicates that more fractures are classified correctly after the introduction. However, the medical records of the patients classified as B2 were not reviewed and this must therefore be interpreted with caution.

The use of artificial intelligence (AI) in healthcare is increasing. The idea that AI could be utilised to aid in fracture classification is a tempting thought. A study by Olczak from 2021 evaluates the use of machine learning in the classification of ankle fractures according to the AO/OTA classification system.[134] They concluded that the studied network was good at classifying ankle fractures but failed for some subgroups.[134] For B2.1 fractures, the network only deemed the fractures as B2.1 based on incongruity of the ankle joint, as no clinical information about the patient was taken into account. Given the discussion above, this is problematic. In the author's opinion, AI will not be able fully to classify ankle fractures, especially not the B-type fractures that constitute over 60% of all ankle fractures. At least not as long as AI classifies from radiographic images alone, as the B-type fractures have to be evaluated clinically, or by some other modality such as MRI or stress tests, to discriminate between the different groups and subgroups. In contrast to the speculations by Berg in 2017, that AI might be able to link machine learning data to outcome and completely skip the need for traditional classification systems, we do not believe that the physician, or the classification systems, can be replaced in terms of ankle fracture assessment.[135] AI can function as a great help and aid in the review of radiographic images, but for obvious reasons it cannot replace the clinical examination.

5.2.2 STABILITY

One central concept in ankle fracture assessment is the stability of the ankle joint. The stability of the ankle joint in ankle fractures is dependent on the fracture, the integrity of the deltoid ligament on the medial side and the syndesmosis between the tibia and the fibula. As discussed, the AO/OTA classification of ankle fractures considers both malleolar fractures and ligamentous injuries. As a result, the fracture group, and subgroup, in the AO/OTA classification describes whether the injury is stable or unstable. Historically, a great deal of emphasis has been placed on the syndesmotic ligament and its integrity in ankle fractures. However, according to biomechanical studies, in ankle fractures with intact medial structures (malleolus and deltoid ligament), the integrity of the syndesmosis is of inferior importance for the stability, healing and outcomes.[8, 29] According to these studies, the deltoid ligament should be the structure in focus when determining stability in ankle fractures.

The deltoid ligament consists of a superficial and a deep part. According to biomechanical studies, lateral malleolar ankle fractures with a concurrent partial deltoid ligament tear does not result in abnormal motion of the ankle joint according.[1, 6, 8, 29] A complete deltoid ligament injury, on the other hand, makes the ankle joint unstable in lateral malleolar fractures and needs to be identified in order to select the right patients for surgical treatment. The most reliable and efficient method for evaluating the deltoid ligament integrity remains unidentified. Considering the amount of research in this matter, additional methods are probably not needed and a full consensus on this matter might never be achieved. Many studies advocate the use of gravity stress radiographs, while others favour weight-bearing radiographs or manual stress tests.[30-33, 41, 44, 136] In the author's opinion, gravity stress radiographs are the most promising method for evaluating the deltoid ligament. Weight-bearing radiographs at one week may nonetheless have a place in the evaluation of stability in certain fracture types.

Paper III and **Paper IV** utilise findings of medial tenderness, ecchymosis and swelling, as they were the indicators of deltoid ligament injury used in clinical practice at the time of the studies. These are also the indicators recommended by the American Academy of Orthopaedic Surgeons.[32] However, numerous studies have questioned the reliability of medial tenderness, ecchymosis and swelling as predictors of deltoid ligament tear and discriminators between ankle fractures in need of surgery and those stable and safe to treat non-surgically.[31-33] The findings regarding medial tenderness in **Paper III** demonstrate the difficulties involved in determining the integrity of the deltoid ligament, in terms of both correct classification, as discussed above, and consequently as an indicator of ankle joint instability.

Clinical studies by Gregersen et al. support the findings in the above-mentioned biomechanical studies that partial deltoid ligament injuries do not compromise ankle joint stability. Gregersen et al. allocated ankle fractures of type SER-IVa (lateral malleolar fractures with a partial deltoid ligament tear) with an initial medial clear space (MCS) of less than 7 mm to non-surgical treatment with a one-week follow-up with weight-bearing radiographs. They found that only 1.4% were displaced and required surgery at a later stage.[137] A further study by the same research group then allocated bimalleolar ankle fractures that were stable on weight-bearing radiographs to non-surgical treatment and found that they healed with a congruent ankle joint. The included fractures all had a medial malleolar fracture of the anterior colliculus, leaving the posterior tibiotalar ligament (the posterior part of the deep deltoid ligament) intact, resulting in their conclusion that even bimalleolar fractures with an intact posterior part of the deep deltoid ligament are safe to treat non-surgically if congruent on weight-bearing radiographs.

It can be concluded that there is a general agreement that AO/OTA44-B1 fractures are to be treated non-surgically. Given the findings of Gregersen et al., perhaps even AO/OTA B2 ankle fractures with an initial congruent ankle joint on weight-bearing radiographs should be allocated to non-surgical treatment? To a great extent, this would override the whole debate on deltoid ligament integrity. These findings are supported by the findings in **Paper III** and **Paper IV** where the results show that, of the patients treated non-surgically, despite being found to have medial tenderness, ecchymosis and swelling, in only 1% and 0.6% of the cases respectively was the treatment plan was changed to surgical at an early stage after radiographic follow-up. The statement that potentially unstable ankle fractures can be treated non-surgically is further supported by the findings of Fox et al., who found that 2% displaced and were converted to surgical treatment with excellent results and they concluded that weight-bearing radiographs at one week are the best predictor of union in anatomical alignment.[138] Considering the difficulties involved in clinically evaluating the deltoid ligament, the findings that even bimalleolar fractures which remain congruent on weight-bearing radiographs might be possible to treat non-surgically is an intriguing thought. However, further studies of more extensive material and with a longer follow-up are needed before any firm conclusions can be drawn.

5.3 TREATMENT OF ANKLE FRACTURES

5.3.1 MANAGEMENT AND TREATMENT

The goal for ankle fracture treatment is to restore the ankle joint to normal alignment and enable good range of motion once the fracture has healed. Depending on the nature of the fracture, this can be accomplished by non-surgical or surgical treatment. As discussed above, unimalleolar ankle fractures, i.e. isolated fractures on the medial, lateral or posterior malleolus, do not affect ankle joint stability and are regarded as safe to treat non-surgically. Bi- and tri-malleolar ankle fractures, i.e. fractures or ligamentous injuries to two or more of the malleoli, can affect ankle joint stability and the most suitable treatment method for these fractures is the subject of debate.

During the past ten years, multiple efforts have been made in systematic reviews to conclude whether or not ankle fractures in adults should be treated surgically or non-surgically.[54, 55, 139, 140] Not surprisingly, it has not been possible to reach a conclusion. As ankle fractures are such a heterogenous group of injuries, it is not possible to generalise one conclusion regarding treatment applicable to all types, groups and subgroups of fractures. Larsen et al. found comparable results for surgical and non-surgical treatment for non-displaced stable ankle fractures.[55] Both Elgayar et al. and later Javed et al. concluded that surgical treatment resulted in a lower risk of non-union, mal-union and loss of reduction but a higher risk of infection and the need for further surgeries.[139, 140] Javed et al. concluded that the short term outcomes were similar for the surgical and non-surgical treatment of displaced or unstable ankle fractures.[140] However, when looking at the studies included in the systematic review by Javed et al., in the largest study, contributing more than 50% of the participants, 26% of the non-surgically treated unstable ankle fractures experienced early failure and were converted to internal fixation.[60]

Mittal et al. reported that the surgical treatment of AO/OTA44-B1 fractures is associated with an increase in adverse events and is not superior to non-surgical treatment at a 12-month follow-up in terms of PROMs.[141] These findings are supported by the findings of van Leeuwen et al. who followed B1 fractures for a mean of 5.4 years and found that they can be safely treated non-surgically.[142] These findings are in line with the findings in **Paper III** which demonstrates that only five non-surgically treated B1 fractures out of 309 (1.5%) had a changed treatment plan at an early stage. The early failure rate of 1.5% in **Paper III** is an overestimation, as the review of medical records for these patients revealed no clear indication of a change in treatment plan (no displacement of fracture or dislocation in the ankle joint) in three of the five cases. The findings in **Paper III** further demonstrate that, of the included lateral malleolar fractures with medial tenderness treated non-surgically, early failure was seen in only 1% of the cases. **Paper IV** further confirms these findings, showing that, in the group of B1 fractures treated non-surgically after the introduction of the treatment algorithm, only 0.6% were converted to surgical treatment at an early stage due to a slight displacement of the fracture at a one-week follow-up.

In addition to the stability of the ankle joint, the determining aspect behind the choice of treatment strategy for ankle fractures is factors relating to the patient, such as age and comorbidities. The treatment of ankle fractures in the elderly and the frail should focus on obtaining and maintaining reduction until fracture union, allowing early mobilisation, with the least invasive method possible.[62] Diabetes with complications, vascular disease and age over 75 years have been shown to be risk factors for wound complications and infections in surgically treated ankle fractures.[57] For these patients, the risk of ORIF should be carefully weighed up against the benefits of less invasive treatment methods. The recently most advocated less invasive surgical treatment methods for patients with unstable ankle fractures and advanced age or comorbidities are fibular nailing or tibiotalocalcaneal (TTC) nailing. The fibular nail has been shown by its advocates to be more cost effective, provide a good outcome both radiologically and functionally and result in fewer complications than ORIF with plates and screws.[143-145] The same benefits of being a minimally invasive procedure and still providing a higher degree of stability, suitable for carefully selected patients with unstable fractures and high risks of complications, are underlined for the TTC. It has been argued that TTC is a safe and effective method for the fixation of unstable ankle fractures in frail patients.[59, 61, 146] In order to limit the risks involved in a surgical procedure completely, a non-surgical method for the treatment of unstable ankle fractures in the elderly has been proposed by orthopaedic surgeons from the UK, called Closed Contact Casting (CCC).[60] According to their findings, CCC results in an equivalent functional outcome at six months compared with internal fixation, but the patients require careful monitoring to ensure that reduction is maintained in the cast and, as mentioned above, over a quarter of the patients were converted to internal fixation due to early failure.[60, 62, 63] However, a long-term follow-up and larger studies of both CCC and TTC are needed in order fully to evaluate the safety and efficacy of these treatment methods.

The risk of displacement has been the rationale behind the traditional teaching of non-weight-bearing and plaster immobilisation for surgically treated ankle fractures. However, since 2013, at least three large RCTs and two systematic reviews have established that surgically treated unstable ankle fractures should be allowed early weight-bearing, as this improves functional outcome, accelerates return to work and activities and is not associated with increased complication rates.[64-67, 147] In most studies, early weight-bearing is defined as full weight-bearing after two to three weeks, whereas late weight-bearing is defined as full weight-bearing permitted at six weeks. An RCT by Seeing et al. was terminated at an early stage, due to the great advantages seen in the early and unprotected weight-bearing group compared with a group permitted protected weight-bearing and another group assigned to protected non-weight-bearing.[147] The most recent systematic review by Smeeing et al. concludes that active exercises and early weight-bearing both accelerate return to work and daily activities compared with immobilisation or late weight-bearing. They further concluded that the combination of immediate weight-bearing and active exercises might be a safe option, but more RCTs are ongoing in this area and the conclusions await.[148] Previous research on the effects of early mobilisation after the surgical fixation of unstable ankle fractures found the same benefits as described above, but also found an increased risk of wound complications and infections in the patients allowed early range of motion. These findings have not been confirmed by the more recent studies mentioned above.[149-151] Regarding early weight-bearing and immobilisation for non-surgically treated ankle fractures, previous studies have been difficult to find. However, since allocation to non-surgical treatment is usually based on a assessment of the fracture and the ankle joint as stable, non-surgically treated patients should be even more suitable for early full weight-bearing and a short immobilisation period.

The results of **Paper III** show that the average number of days immobilised in a cast or orthosis at SU in 2012-2014 was 46 days (6.6 weeks) for the surgically treated patients and 79% had some kind of weight-bearing restriction. For non-surgically treated patients, 50% had some kind of weight-bearing restriction and they were immobilized on average for 43 days (6.1 weeks) in a cast or orthosis. In other words, ankle fractures at SU in 2012-2014 were subject to late weight-bearing and a long immobilisation period. These findings, and the results of the above-mentioned studies, led up to the formation of the structured treatment algorithm for ankle fractures that was implemented at the department in 2017. The treatment algorithm recommended full weight-bearing for all ankle fractures except for the subgroup of B3 fractures and for all C fractures that were recommended an initial three weeks of partial weight-bearing before full weight-bearing was allowed. Surgically treated patients were recommended three weeks of immobilization, followed by three weeks in a stable orthosis (Figure 12 in the introduction section) with free ROM exercises permitted at three weeks. Non-surgically treated patients with stable fractures were recommended a stable orthosis (Stirrup orthosis for A1 fractures, Figure 12) and allowed free ROM exercises immediately. These recommendations were not applicable to the old and frail patients discussed above.

The effects of the treatment algorithm are described in Paper IV. The results in Paper IV include patients with B1 fractures treated both surgically and non-surgically. The results in **Paper IV** demonstrate that, after the introduction of the treatment algorithm, 84% of B1 fractures were instructed to fully weight-bear and only 7% were restricted to partial weight-bearing. Before the introduction of the treatment algorithm, the corresponding numbers were that 41% of B1 fractures were allowed full weight-bearing and 44% were instructed to partially weight-bear. **Paper IV** further demonstrates that the number of days that patients with B1 fractures were immobilised declined from a mean of 45 days before the introduction of the treatment algorithm to 42 days after it.

To conclude, as ankle fractures range from simple avulsions to complex displaced fractures, it will never be possible to determine whether surgical or non-surgical treatment is the best treatment method for everyone. In contrast, future research must continue to strive to find the most suitable treatment method for the individual fracture groups and subgroups. Given the present state of research in the field, it is justifiable to conclude that isolated, unimalleolar ankle fractures are best treated non-surgically. Most recent research also indicates that it is safe to treat bimalleolar ankle fractures that maintain alignment on weight-bearing radiographs non-surgically. Unstable bi- and trimalleolar ankle fractures should be subject to surgical treatment, if patient factors permit. In elderly and frail patients, the goal is to maintain fracture reduction until union using the least invasive method possible.

5.3.2 TREATMENT ALGORITHMS

In 2015, a survey was administered among the members of the American Orthopaedic Foot & Ankle Society (AOFAS) and Orthopaedic Trauma Association (OTA).[152] The survey sought to investigate how long American orthopaedic surgeons would instruct ankle fracture patients to non-weight-bear after ORIF of an ankle fracture. This study revealed a significant variation in the length of the recommended period, ranging from 4.9 (±3.1) weeks in young patients to 7.6 (±6.0) weeks in older patients with comorbidities.[152] The authors identified a need for the development of strategies to guide orthopaedic surgeons on the patients in whom it is safe to allow early-weight-bearing. The findings of this study are in line with the findings in **Paper III**, which demonstrate large intradepartmental variations in terms of the management of ankle fractures that existed at SU before the introduction of a treatment algorithm.

Studies from the UK by Wykes et al. and Jain et al. demonstrate that guidelines for ankle fracture management can improve the quality of treatment and result in savings of healthcare resources.[69, 70] Jain et al. demonstrated that, before the introduction of a treatment protocol for stable ankle fractures, 60% were treated in a brace, compared with 91% when the treatment protocol was implemented. Jain et al. further demonstrated a reduction in the number of follow-up visits and radiographic examinations for ankle fractures with a treatment protocol in place. By standardising practice, the cost per ankle fracture patient in their study was reduced by 58%. **Paper IV** demonstrates statistically significant reductions in the number of radiographic examinations performed, as well as the number of days hospitalised. The number of outpatient visits was reduced, but this was was not found to be statistically significant. One of the largest costs for ankle fractures is surgical treatment. In **Paper IV**, the surgical treatment of B1 fractures was found to be reduced from 32% to 10% after the introduction of the treatment algorithm. For all types of ankle fractures, surgical treatment was reduced from 48% before the treatment algorithm was implemented, to 41% after. No calculation of the financial savings after the introduction of the treatment algorithm for ankle fractures at SU was performed, but it is evident that large savings were made, enabling the relocation of resources.

A study by Palm et al. of the effects of a treatment algorithm for hip fracture patients reports that the algorithm included recommendations for all types of fractures in the heterogeneous group that hip fractures constitute. As such, the algorithm included recommendations for fracture types where no level-one evidence was present. The demonstrated improvement in outcomes was found to support the overall recommendations. The treatment algorithm for ankle fractures studied in **Paper IV** was a compilation of research evidence, experience and expert opinion. Only the B1 fractures were studied in detail, but the epidemiological mapping of all ankle fractures demonstrates a statistically significant reduction in surgical treatment for the whole group of ankle fractures, as well as for almost half of the individual AO/OTA fracture groups. This indicates that a general discussion of the indications for the surgical treatment of ankle fractures, and an awareness throughout the department of these questions lead to a more restrained approach regarding surgical treatment for all ankle fractures.

The studies by Wykes et al. and Jain et al. point to the importance of the thorough, and repeated, implementation of guidelines to achieve adherence within the department.[69, 70] As described in the introduction section of this thesis, the structured treatment algorithm for ankle fracture management at SU was thoroughly implemented at meetings, through written material and pocket-sized cards. Since the writing of **Paper IV**, the treatment algorithm was revised in 2020, after which a new round of implementation was conducted. The demonstrated effect on all the studied outcome variables in **Paper IV** is probably largely due to the amount of work that was, and is, put into the implementation of, and adherence to, the algorithm.

Since the above-mentioned studies by Wykes et al. and Jain et al., the British Orthopaedic Association Standards for Trauma (BOASTs) has published standards for the management of ankle fractures, based partly on the recommendations in the guidelines developed by the National Institute for Health and Care Excellence (NICE).[153] A national UK audit from 2019 demonstrates that 81% of the non-surgically treated patients were, in accordance with the NICE guidelines, instructed to early weight-bear.[154] For surgically treated patients, however, only 21% were instructed to weight-bear at an early stage. The authors describe that NICE was not able to identify any RCT evaluating weight-bearing in non-surgically treated ankle fractures in adults. The lack of other evidence resulted in the recommendation that unimalleolar ankle fractures were to be allowed full immediate weight-bearing.[154] For surgically treated patients, the authors request a large RCT to determine the most suitable strategy for postoperative weight-bearing. Considering the number of RCTs and systematic reviews produced on this subject during the past few years, this is somewhat surprising.[65-67, 147] In order to evaluate the results in larger materials, possibly a register-based study would be more comprehensive.

As demonstrated in **Paper IV**, healthcare resources can be saved, or relocated, by the introduction of a structured treatment algorithm that entails fewer unnecessary surgical procedures, reduces the number of days hospitalised and limits the number of radiographic examinations. National guidelines for the management and treatment of ankle fractures are available in the UK but, to our knowledge, not in other countries. Sweden has no national guidelines regarding ankle fracture management, but, considering the number of requests to use the treatment algorithm originating from SU, a great demand for national guidelines is evident.

5.3.3 STRENGTHS, LIMITATIONS AND METHODOLOGICAL CONSIDERATIONS

The primary strength in **Paper III** and **Paper IV** is the thorough review of the medical records of patients with ankle fractures in these studies. For **Paper IV**, almost 750 medical records of prospectively collected patients with AO/OTA-B1 fractures were thoroughly reviewed for a number of parameters. Both **Paper III** and **Paper IV** are based on material from the SFR, supplemented by data from medical records. One strength of all the studies based on material from the SFR is that they include both hospitalised patients and those treated as out-patients. Register-based studies also have the benefits of including all the available patients, as they do not exclude patients based on exclusion criteria, which RCTs do. Studies of non-surgically treated ankle fractures patients with a review of medical records for 309 (**Paper III**) and 579 (**Paper IV**) patients respectively are unique.

One of the parameters studied from the electronic medical records (EMRs) in **Paper III** and **Paper IV** were findings of medial tenderness, ecchymosis and swelling at the first clinical examination. These parameters have been shown to be difficult to assess. This was also demonstrated in the studies, in the numerous different ways in which findings, or their absence, of these parameters were described. One limitation to the studies is the size of the orthopedic department at SU, with many different physicians, of varying experience, involved in the first examination of the studied patients. To mitigate this limitation, the review of EMRs was performed by two researches in Paper III by three in Paper IV, thereby enabling unclear formulations to be jointly discussed and categorised.

The main limitation to both **Paper III** and **Paper IV** is the lack of a long-term follow-up. Both studies have been limited to a short-term follow-up, usually around six weeks. Regarding the patients registered in the SFR as having sustained a B1 fracture in **Paper III**, 70% were treated non-surgically. Of these, at least 24% had findings of medial tenderness at the first presentation (for another 25%, no documentation on this could be found in the medical records, why 24% is probably an underestimation). For these patients, who had potentially sustained a B2.1 fracture and were treated non-surgically, a long-term follow-up is needed. **Paper III** demonstrated that non-surgical treatment was only converted to surgical treatment at an early stage in 1% of the cases, but, as a long-term follow-up is lacking, it is unclear whether more patients underwent surgery at a later stage or suffered other types of complications, such as non- or mal-union or the development of post-traumatic osteoarthritis (PTOA). **Paper IV** demonstrates a reduction in the number of surgical treatments for B1 fractures from 32% to 10%. However, the lack of a long-term follow-up in this study in terms of reoperations, late surgeries and postoperative complications is a clear objective for future studies.

Another limitation to **Paper III** and **Paper IV** is that the outcome measurements do not include PROMs. It can be speculated, with the support of previous studies, that the shorter immobilisation period, fewer follow-up visits and the reduced number of days hospitalised are probably appreciated by the patients, and reflected in the way they perceive their health, but this has not been investigated in the studies in this thesis.[155]

Paper IV is a before-and-after study comparing a group of B1 fractures treated before the introduction of a structured treatment algorithm with a similar group of patients treated after the introduction of a treatment algorithm. The study found changes in all the studied parameters after the introduction of the treatment algorithm. However, it cannot be said with certainty that the treatment algorithm was the cause of these changes, as other factors that might have changed over the period were not studied. In spite of this, it is difficult to think of other factors that could have coincided with the introduction of the treatment algorithm and affected the results to the demonstrated extent as, to our knowledge, no other major factors changed at the department during the study period.

5.4 KNOWLEDGE SUPPORT SYSTEMS

5.4.1 KNOWLEDGE AND DECISION SUPPORT

The first clinical records of patients were introduced at the large teaching hospitals in the USA back in the 19th century.[156] However, it was not until the mid-20th century that medical records were used for direct patient care. The first computed systems were introduced in large hospitals around the same time but the first electronic medical records of patients were not in place until some time in the 1980/90s. Early studies concluded that humans are less effective than computers in analysing large volumes of information and that computers might help clinicians and be of practical value.[89]

With the introduction of computers and electronic medical records (EMRs) in healthcare, the information available for clinicians to process increased rapidly. Studies from the end of the 20th century and beginning of the 21st century acknowledge the rate of errors in medical care and place a great deal of hope in the introduction of clinical decision support systems (CDSSs) to improve the quality of care.[91, 157] Since then, numerous studies have acknowledged the benefits of CDSSs.[158-160]

Roshanov et al. identified factors that determine whether a CDSS is effective or ineffective with regard to improving the care process and the patient outcomes.[161] The three major factors for a successful system according to the authors were that information was presented to both patients and clinicians, that clinicians had to present a reason for overriding the advice and that the systems were developed together with the users and evaluated by the developers. In our opinion, these success factors can also be applied to knowledge support systems (KSSs) because of the similarities between the modalities in these areas. The KSS for ankle fractures evaluated in **Paper V** includes a step in which the user is obliged to provide a reason for deviating from the recommended treatment, recognising one of the three success factors from the above-mentioned study by Roshanoiv et al. In addition, the KSS in the SFR was developed in close contact with users of the SFR and closely evaluated, both quantitatively and, as demonstrated in **Paper V**, qualitatively.

As CDSSs and KSSs are becoming increasingly common in healthcare, reports on alert fatigue and desensitisation have started to appear. Studies have shown that up to 96% of alerts are overridden by clinicians.[162] However, Ancker et al. demonstrated that there was no evidence of desensitisation in a study of over 100 clinicians. Alert fatigue seen was found with repeated alerts for the same patient or in complex patients where repeated reminders were shown. The KSS for ankle fractures evaluated in **Paper V** might be subject to some alert fatigue if one clinician performs the full registration and is exposed to the KSS multiple times for the same patient. However, for surgically treated patients, this is usually not the case and the alerts given by the KSS are likely to be accepted by the users. The fact that no desensitisation was seen is important, as the KSS in the SFR is shown every time a user registers an ankle fracture, but, given the findings of Ancker et al., this should not lead to desensitisation.

5.4.2 KNOWLEDGE SUPPORT SYSTEMS IN ORTHOPAEDICS

The knowledge support system for ankle fractures in the SFR that is evaluated in **Paper V** aims to provide the user with established up-to-date knowledge on the recommended treatment, as well as statistical data on how the fracture has been treated historically. The KSS in the SFR does not provide guidance on how to treat individual patients but provides easy access to already available information. The information is already available to the user and is not specific to the SFR or the patients registered in the SFR. Studies of the effects of introducing knowledge support systems are hard to find. Knowledge support systems provide knowledge, but does not, in contrast to the CDSSs, have a link to EMRs or patient-specific data. KSSs do not give patient-specific recommendations or aid in decision-making but merely present the clinician with knowledge already present in other sources but packaged in the KSS to be easily available to the user.

The implementation of guidelines in orthopaedic surgery is important and needs to be up to date with the way in which knowledge is transmitted and the way in which decisions are to be made.[163] A systematic review from 2008 points out that the best way to implement guidelines is through multiple implementation strategies, i.e. education, reminders and audits.[164] The KSS evaluated in **Paper V** was implemented through e-mails and information at multiple meetings at the department and was posted on the hospital intranet. In addition to this, the treatment algorithm was printed as posters and pocket-size cards that were distributed to all the doctors at the department.

5.4.3 THE USERS' EXPERIENCE

An increasing number of qualitative studies of the surgical disciplines in healthcare have started to emerge. Qualitative studies are valuable, as they shed light on the experiences, of patients or physicians, in ways that quantitative studies are unable to do.

Paper V demonstrates that the KSS was appreciated by the users of the SFR. The interviewees found that the KSS improved the value of the care provided. The users did not find that the KSS increased their workload. The study further demonstrated a fear amongst the users of being overly reliant on a template. A qualitative interview study by Ford et al. from 2021, discussing a hypothetical CDSS, confirms the findings in **Paper V** to a large extent.[165] They found that the interviewees wanted CDSSs to be up to date with the information presented, easily assessable and technically well integrated.

They also demonstrated that there was a fear amongst the interviewees of losing their autonomy and feeling that the CDSSs de-professionalised them. This study also pointed to the great importance of implementing and informing about CDSSs before they are introduced to the users; otherwise there was a risk that the users only learned how to disenable them and not to use the presented information in the best way.

5.4.4 STRENGTHS, LIMITATIONS AND METHODOLOGICAL CONSIDERATIONS

Most qualitative studies in orthopaedics focus on the experiences of patients, but recently more qualitative studies have started focusing on the experiences of the physicians. In 2020, a study was published on the experiences of orthopaedic surgeons dealing with periprosthetic joint infections.[166] To our knowledge, no previous study has been conducted on the way physicians experience being presented with a KSS through an NQR. As a result, one strength of **Paper V** is that it provides an insight into a phenomenon that has not previously been studied. Hopefully, more papers will follow in order to understand the barriers to and facilitators for implementing guidelines and KSSs or CDSSs in orthopaedic surgery.

One limitation to **Paper V** is that the data collection coincided with the Covid-19 pandemic. This resulted in fewer ankle fractures (as demonstrated in Paper II) which in turn lead to fewer exposures to the KSS. The Covid-19 pandemic also restricted travelling and face-to-face meetings, which explains why most of the interviews for **Paper V** had to be conducted via the Zoom digital network, instead of, as planned, in person. Conducting interviews via a digital network could mean that some parts of communication are harder for the interviewer to perceive. The only interviews that were conducted in person were the ones at SU, as the researcher responsible for the study worked there. The fact that the responsible researcher worked at one of the studied departments, contributing 25% of the interviewees to the study, is also a limitation to **Paper V**. The same person was also the person responsible for the development of the KSS in the SFR. This was known at the department and might have influenced the results of the study. However, when analysed, neither the quantitative nor the qualitative evaluation reflected any positive bias towards the physicians working at SU.

One final limitation to **Paper V** is that the interviewees were recruited from the departments through volunteering. This might have selected interviewees that had either positive or negative thoughts on the KSS that they were willing to share. This limitation was mitigated through a large sample size of twenty interviewees.

06

CONCLUSIONS

- Age-related skeletal fragility may be a risk factor for ankle fractures, as six of ten fractures occur in women, who have a higher mean age at the time of injury compared with men. A pronounced seasonal variation in B-type ankle fractures is caused by simple same-level falls during the Swedish winter months. Men are more often injured in high-energy trauma and more often suffer severe open injuries. **(Paper I)**
- During the first wave of the Covid-19 pandemic in the spring of 2020, the incidence of ankle fractures declined. The greatest reduction was seen during the first studied month, among women and in the age group of over 70 years. The strictest recommendations on keeping social distance and limiting activities were directed at this age group and this is possibly one of the explanations. The SFR provides a readily available source for comparing fracture incidences over time, almost in real time. **(Paper II)**
- The isolated transsyndesmotic lateral malleolar fracture with no injury to the deltoid ligament (AO/OTA44-B1) is the most common ankle fracture. Medial tenderness as a discriminator between stable and unstable B-type fractures is a method with great limitations. In the absence of guidelines, there is a lack of consensus on how to classify and subsequently treat B fractures. There is no need to follow up B1 fractures with a radiographic examination at one week. **(Paper III)**
- A well-implemented treatment algorithm can provide standardisation to the management and treatment of ankle fractures. Decisions that are less dependent on the individual surgeons' preferences can significantly reduce the number of unnecessary surgical procedures for stable ankle fractures. A structured treatment algorithm can reduce the number of radiographic examinations, the number of surgically treated stable fractures and the number of days immobilised and increase the number of patients that are allowed to fully weight-bear. **(Paper IV)**
- Being provided with knowledge support while registering ankle fractures is appreciated by the users of the SFR. A knowledge support system (KSS) is perceived by users as increasing the value for work and enhancing the initiative to register fractures during busy working days. The users experience that the care they provide is improved by the KSS and that the KSS supplies an appreciated validation of the clinical decisions that are taken. **(Paper V)**

07

FUTURE PERSPECTIVES

As a result of the SFR, doors have opened to enable the straightforward conduct of high-quality fracture research. With a full coverage since 2020 and a gradually increasing completeness, the SFR is becoming exceedingly valuable for orthopaedic research. Paper I present the results of a large-scale epidemiological mapping of ankle fractures. However, at the start of the study period in 2012, the coverage and completeness of the SFR were limited. Full coverage by the SFR opens the door to future epidemiological studies. By coupling data from the SFR to data from the NPR, conducting an whole population study might be possible in the not-too-distant future. This would produce trustworthy incidence numbers and also make it possible to draw safe conclusions on the unusual subgroups of ankle fractures for which material is still scarce.

The SFR can only be further developed as a source of information by testing what the extracted data can be used for. Paper II demonstrates how the incidence of fractures can be compared over time using the SFR. Hopefully, the methodology can inspire to future studies when a change in the incidence of a certain fracture type is suspected. Thanks to the arrangement of fracture registrations in the SFR, data can be rapidly retrieved and studies like this have a swift impact on clinical practice. Both Paper I and Paper II contain data on the injury mechanisms behind ankle fractures. The injury mechanisms behind fractures in general still constitute an area in which further research is needed. Future studies could attempt to turn the usual research question around and study the fractures resulting from different injury mechanisms. With this knowledge, more measures could be undertaken to make sure fractures are avoided to a greater extent and recommendations are directed at different subgroups.

The treatment algorithm evaluated in Paper IV was shown to reduce the number of surgical treatments for stable B1 fractures from 32% to 10%. As discussed, the lack of a long-term follow-up in that study is a limitation. Further studies are planned with a longer follow-up of re-operations, late surgeries and postoperative complications in the two cohorts of patients from Paper IV. If data on patient-reported outcome measurements (PROMs) are added to the clinical outcomes, strong conclusions can be drawn regarding the benefit of reducing surgical treatments for lateral malleolar fractures. A long-term follow up can be achieved by comparing data from the SFR with data from the NPR in order to capture all re-operations, as well as late surgeries, such as arthrodesis for PTOA of the ankle. Paper IV further demonstrates that the number of patients permitted full weight-bearing increased dramatically, from 41% to 84%, after the introduction of the treatment algorithm. The number of days immobilised was also reduced. A reduced immobilisation period and immediate full weight-bearing can be assumed to reduce the number of venous thromboembolic events (VTE) which can be investigated in future studies.

One key piece of knowledge regarding outcome after ankle fractures is provided by the patients. The collection of PROMs has been in place in the SFR for more than ten years and the amount of information is abundant. Future research should focus on expectations relating to the results after fracture treatment correlated to the actual reported result one year later. Future research should also focus on the correlation between socio-economic factors and their contribution to the end result after fracture care.

In recent years, several national multicentre, register-based, randomised controlled trials (rRCT) have been initiated in the SFR.[167, 168] The on-going discussion on weight-bearing restrictions and the need for the immobilisation of ankle fractures could perhaps be resolved by initiating an rRCT. A modification to the treatment registration for ankle fractures in the SFR to include information on immobilisation period and weight-bearing restrictions can also be made and followed up in a large observational study. In this way, a large-scale mapping of practice in Sweden could be easily undertaken. This could then be followed by an rRCT investigating the results of different regimens.

The data in the SFR are dependent on the continuous data entry by orthopaedic surgeons across the country. To maintain this work, the SFR needs to constantly evolve and be further developed. The best way to further develop the SFR is by co-operation with the users, testing the ways in which the use of the SFR can be extended. Paper V evaluates a new modality introduced to the SFR with the aim of broadening the use of the SFR and increasing the quality of care for ankle fracture patients. As demonstrated in Paper V, the initiative to register fractures in the SFR was enhanced by the introduction of the KSS and similar initiatives to develop the SFR will definitely make the register even more appreciated by the users and help to further increase its completeness. One recent example is the link from the SFR to the national guidelines for the treatment of distal radius fractures. With the anticipated introduction of national guidelines for ankle fracture management and treatment, the KSS needs to be revised and further developed. Ideally, national guidelines for ankle fracture treatment could be incorporated into the SFR as a CDSS.

08

ACKNOWLEDGEMENTS

With the words from my theme song for the writing of this book, I can conclude that it has been: ten percent luck, twenty percent skill, fifteen percent concentrated power of will, five percent pleasure and fifty percent pain.

It would not have been possible to write the included papers and this thesis without the help of many. I am so grateful and especially want to thank:

Michael Möller, my dad, my friend, my colleague and creator of the SFR. You have always believed in me to make my own decisions, guided me when times were tough and made me feel loved. Unfortunately, I don't always listen to your wise advice, for example, when you told me five years ago not to start writing my thesis. Now it's done and it could not have been done without your endless support.

David Wennergren, my supervisor and friend. Thank you for your endless patience, your wisdom and support. You, and your thesis, have been my two hopes to cling to during this process. You always remind me of where focus should be placed and, in the unlikely event that you are not able to answer my questions, the answer is to be found in your thesis. I look forward to continuing the work we've started and hope for many future inspiring projects together.

Ola Rolfson, my co-supervisor, Head of the Department of Orthopaedics at the Sahlgrenska Academy, my colleague and my friend. You were my tutor as a resident and my main supervisor for the major part of this journey. Thank you for guiding me through the work on this thesis and thank you for the many good talks over the years. To be continued.

Mikael Sundfeldt, my co-supervisor, colleague and friend. Thank you for your clinical insights in the writing of this thesis and for your short but to-the-point comments on my writing.

Anna Rubenson, head of the trauma section of the Department of Orthopaedics, colleague and friend. Thank you for letting me in on your team and for letting me out to write this thesis. I'm looking forward to the future at the trauma section.

Anna Nilsdotter, Head of the Department of Orthopaedics at Sahlgrenska University Hospital. Thank you for giving me the opportunity to combine research with clinical work.

Richard Buckley, co-author and first supervisor. Thank you for the inspiration and the early insights into the fact that all patients go missing as soon as you start recruiting for an RCT. It was a pleasure working with you and I hope we will continue to stay in contact.

Jan Ekelund, co-author and statistician. Thank you for your endless patience. You are three standard deviations above the mean. I will never fully understand anything you say, but you almost make me feel that I do.

Olof Wolf, my co-author and friend. Thank you for the input along this journey and I look forward to future exciting projects together.

Maziar Mohaddes, co-author and colleague. Thank you for the inspiring work on the KSS and the qualitative parts of this thesis. I look forward to more projects outside the box with you.

Linda Åhlström, co-author. Thank you for the supervision during the writing of Paper V.

Jaque Riad and **Aina Danielsson**, my initial supervisors. Thank you for getting me started on this journey.

Madelene Albrektsson and **Caroline Stigevall**, my dear colleagues and partners in this crime of PhD work. Thank you for the support and the fun along the way.

Jeanette Kliger, language reviewer. Thank you for always being available and for making this book much more enjoyable to read.

Pontus Andersson, illustrator responsible for all the illustrations in this thesis. Thank you for your great drawings and your swift replies over the years.

Jesper Hallsten, my college and friend. Thank you for your enthusiasm for gait analysis. You have brightened up the writing of this thesis with your sarcastic comments along the way.

Barbro Rydberg, my dearly loved mother and friend. Thank you for constantly being there for me and for my children. Thank you for the love and the guidance in life. And thank you for keeping orthopaedics at arm's length from all dinner conversations.

Olivia and **Elias**, my wonderful children. Without you, this book would have undoubtedly been finished two years earlier, been twice as long and be more thoroughly read through. Thank you for constantly reminding me of what is really important in life. Together, we make things possible. I love you more than words can express.

You, who just came into my life. Despite the endless writing you have made me not just endure, but actually enjoy, these past few months. You are beyond expectation.

And last, but, in reality, foremost, thanks to **all the orthopaedic surgeons** across the country for entering data in the SFR and making studies like the ones in this thesis feasible.

09

REFERENCES

1. Brockett CL, Chapman GJ. Biomechanics of the ankle. Orthop Trauma. 2016;30(3):232-8.

2. Bartonicek J. Anatomy of the tibiofibular syndesmosis and its clinical relevance. Surg Radiol Anat. 2003;25(5-6):379-86.

3. Fojtik P, Kostlivy K, Bartonicek J, Nanka O. The fibular notch: an anatomical study. Surg Radiol Anat. 2020;42(10):1161-6.

4. Ebraheim NA, Taser F, Shafiq Q, Yeasting RA. Anatomical evaluation and clinical importance of the tibiofibular syndesmosis ligaments. Surg Radiol Anat. 2006;28(2):142-9.

5. Boss AP, Hintermann B. Anatomical study of the medial ankle ligament complex. Foot Ankle Int. 2002;23(6):547-53.

6. Savage-Elliott I, Murawski CD, Smyth NA, Golano P, Kennedy JG. The deltoid ligament: an in-depth review of anatomy, function, and treatment strategies. Knee Surg Sports Traumatol Arthrosc. 2013;21(6):1316-27.

7. Curtis MJ, Michelson JD, Urquhart MW, Byank RP, Jinnah RH. Tibiotalar contact and fibular malunion in ankle fractures. A cadaver study. Acta Orthop Scand. 1992;63(3):326-9.

8. Michelson JD, Waldman B. An axially loaded model of the ankle after pronation external rotation injury. Clin Orthop Relat Res. 1996(328):285-93.

9. Procter P, Paul JP. Ankle joint biomechanics. J Biomech. 1982;15(9):627-34.

10. Sarrafian SK. Biomechanics of the subtalar joint complex. Clin Orthop Relat Res. 1993(290):17-26.

11. Calhoun JH, Li F, Ledbetter BR, Viegas SF. A comprehensive study of pressure distribution in the ankle joint with inversion and eversion. Foot Ankle Int. 1994;15(3):125-33.

12. Richmond SA, Fukuchi RK, Ezzat A, Schneider K, Schneider G, Emery CA. Are joint injury, sport activity, physical activity, obesity, or occupational activities predictors for osteoarthritis? A systematic review. J Orthop Sports Phys Ther. 2013;43(8):515-B19.

13. Herrera-Perez M, Valderrabano V, Godoy-Santos AL, de Cesar Netto C, Gonzalez-Martin D, Tejero S. Ankle osteoarthritis: comprehensive review and treatment algorithm proposal. EFORT Open Rev. 2022;7(7):448-59.

14. Valderrabano V, Horisberger M, Russell I, Dougall H, Hintermann B. Etiology of ankle osteoarthritis. Clin Orthop Relat Res. 2009;467(7):1800-6.

15. Saltzman CL, Salamon ML, Blanchard GM, Huff T, Hayes A, Buckwalter JA, et al. Epidemiology of ankle arthritis: report of a consecutive series of 639 patients from a tertiary orthopaedic center. Iowa Orthop J. 2005;25:44-6.

16. Weatherall JM, Mroczek K, McLaurin T, Ding B, Tejwani N. Post-traumatic ankle arthritis. Bull Hosp Jt Dis (2013). 2013;71(1):104-12.

17. Delco ML, Kennedy JG, Bonassar LJ, Fortier LA. Post-traumatic osteoarthritis of the ankle: A distinct clinical entity requiring new research approaches. J Orthop Res. 2017;35(3):440-53.

18. Adams SB, Leimer EM, Setton LA, Bell RD, Easley ME, Huebner JL, et al. Inflammatory Microenvironment Persists After Bone Healing in Intra-articular Ankle Fractures. Foot Ankle Int. 2017;38(5):479-84.

19. McKinley TO, Rudert MJ, Koos DC, Brown TD. Incongruity versus instability in the etiology of posttraumatic arthritis. Clin Orthop Relat Res. 2004(423):44-51.

20. Morgan EF, Unnikrisnan GU, Hussein AI. Bone Mechanical Properties in Healthy and Diseased States. Annual Review of Biomedical Engineering. 2018;20(1):119-43.

21. Lauge-Hansen N. Fractures of the ankle. II. Combined experimental-surgical and experimental-roentgenologic investigations. Arch Surg. 1950;60(5):957-85.

22. Müller. Maurice E, Nazarian. Serge, Koch. Peter, Schatzker. Joseph. The Comprehensive Classification of Fractures of Long Bones: Springer Verlag; 1990.

23. Marsh JL, Slongo TF, Agel J, Broderick JS, Creevey W, DeCoster TA, et al. Fracture and dislocation classification compendium - 2007: Orthopaedic Trauma Association classification, database and outcomes committee. J Orthop Trauma. 2007;21(10 Suppl):S1-S133.

24. Meinberg EG, Agel J, Roberts CS, Karam MD, Kellam JF. Fracture and Dislocation Classification Compendium-2018. J Orthop Trauma. 2018;32 Suppl 1:S1-s170.

25. Michelson J, Solocoff D, Waldman B, Kendell K, Ahn U. Ankle fractures. The Lauge-Hansen classification revisited. Clin Orthop Relat Res. 1997(345):198-205.

26. Kwon JY, Gitajn IL, Walton P, Miller TJ, Appleton P, Rodriguez EK. A cadaver study revisiting the original methodology of Lauge-Hansen and a commentary on modern usage. J Bone Joint Surg Am. 2015;97(7):604-9.

27. Fracture and dislocation compendium. Orthopaedic Trauma Association Committee for Coding and Classification. J Orthop Trauma. 1996;10 Suppl 1:v-ix, 1-154.

28. Juto H, Moller M, Wennergren D, Edin K, Apelqvist I, Morberg P. Substantial accuracy of fracture classification in the Swedish Fracture Register: Evaluation of AO/OTA-classification in 152 ankle fractures. Injury. 2016;47(11):2579-83.

29. Michelson JD, Varner KE, Checcone M. Diagnosing Deltoid Injury in Ankle Fractures: The Gravity Stress View. Clinical Orthopaedics and Related Research®. 2001;387:178-82.

30. Motley DPMFTA, Carpenter DPMFB, Clements DPMFJR, Moxley DPMK, Garrett DPMFA. Evaluation of the Deltoid Complex in Supination External Rotation Ankle Fractures. The Foot and Ankle Online Journal. 2010.

31. McConnell T, Creevy W, Tornetta P, 3rd. Stress examination of supination external rotation-type fibular fractures. J Bone Joint Surg Am. 2004;86(10):2171-8.

32. DeAngelis NA, Eskander MS, French BG. Does medial tenderness predict deep deltoid ligament incompetence in supination-external rotation type ankle fractures? J Orthop Trauma. 2007;21(4):244-7.

33. Egol KA, Amirtharajah M, Tejwani NC, Capla EL, Koval KJ. Ankle stress test for predicting the need for surgical fixation of isolated fibular fractures. J Bone Joint Surg Am. 2004;86(11):2393-8.

34. Park YH, Yoon MA, Choi WS, Choi GW, Hong SJ, Kim HJ. The predictive value of MRI in the syndesmotic instability of ankle fracture. Skeletal Radiol. 2018;47(4):533-40.

35. Henari S, Banks LN, Radovanovic I, Queally J, Morris S. Ultrasonography as a diagnostic tool in assessing deltoid ligament injury in supination external rotation fractures of the ankle. Orthopedics. 2011;34(10):e639-43.

36. van den Bekerom MP, Mutsaerts EL, van Dijk CN. Evaluation of the integrity of the deltoid ligament in supination external rotation ankle fractures: a systematic review of the literature. Arch Orthop Trauma Surg. 2009;129(2):227-35.

37. Murphy JM, Kadakia AR, Irwin TA. Variability in radiographic medial clear space measurement of the normal weight-bearing ankle. Foot Ankle Int. 2012;33(11):956-63.

38. Schuberth JM, Collman DR, Rush SM, Ford LA. Deltoid ligament integrity in lateral malleolar fractures: a comparative analysis of arthroscopic and radiographic assessments. J Foot Ankle Surg. 2004;43(1):20-9.

39. Pakarinen HJ, Flinkkil TE, Ohtonen PP, Ristiniemi JY. Stability criteria for nonoperative ankle fracture management. Foot & ankle international. 2011;32(2):141-7.

40. Gougoulias N, Sakellariou A. When is a simple fracture of the lateral malleolus not so simple? how to assess stability, which ones to fix and the role of the deltoid ligament. Bone Joint J. 2017;99-b(7):851-5.

41. Schock HJ, Pinzur M, Manion L, Stover M. The use of gravity or manual-stress radiographs in the assessment of supination-external rotation fractures of the ankle. J Bone Joint Surg Br. 2007;89(8):1055-9.

42. Park SS, Kubiak EN, Egol KA, Kummer F, Koval KJ. Stress radiographs after ankle fracture: the effect of ankle position and deltoid ligament status on medial clear space measurements. J Orthop Trauma. 2006;20(1):11-8.

43. Dawe EJ, Shafafy R, Quayle J, Gougoulias N, Wee A, Sakellariou A. The effect of different methods of stability assessment on fixation rate and complications in supination external rotation (SER) 2/4 ankle fractures. Foot Ankle Surg. 2015;21(2):86-90.

44. Weber M, Burmeister H, Flueckiger G, Krause FG. The use of weightbearing radiographs to assess the stability of supination-external rotation fractures of the ankle. Arch Orthop Trauma Surg. 2010;130(5):693-8.

45. Court-Brown CM, McBirnie J, Wilson G. Adult ankle fractures--an increasing problem? Acta Orthop Scand. 1998;69(1):43-7.

46. Kannus P, Palvanen M, Niemi S, Parkkari J, Järvinen M. Increasing number and incidence of low-trauma ankle fractures in elderly people: Finnish statistics during 1970-2000 and projections for the future. Bone. 2002;31(3):430-3.

47. Bengner U, Johnell O, Redlund-Johnell I. Epidemiology of ankle fracture 1950 and 1980. Increasing incidence in elderly women. Acta Orthop Scand. 1986;57(1):35-7.

48. Thur CK, Edgren G, Jansson KA, Wretenberg P. Epidemiology of adult ankle fractures in Sweden between 1987 and 2004: a population-based study of 91,410 Swedish inpatients. Acta Orthop. 2012;83(3):276-81.

49. Elsoe R, Ostgaard SE, Larsen P. Population-based epidemiology of 9767 ankle fractures. Foot Ankle Surg. 2018;24(1):34-9.

50. Juto H, Nilsson H, Morberg P. Epidemiology of Adult Ankle Fractures: 1756 cases identified in Norrbotten County during 2009-2013 and classified according to AO/OTA. BMC Musculoskelet Disord. 2018;19(1):441.

51. Hemmann P, Friederich M, Korner D, Klopfer T, Bahrs C. Changing epidemiology of lower extremity fractures in adults over a 15-year period - a National Hospital Discharge Registry study. BMC Musculoskelet Disord. 2021;22(1):456.

52. Bergh C, Wennergren D, Moller M, Brisby H. Fracture incidence in adults in relation to age and gender: A study of 27,169 fractures in the Swedish Fracture Register in a well-defined catchment area. PLoS One. 2020;15(12):e0244291.

53. Berggren SS, Tiderius CJ. The Cedell method (cerclage wire and staple) leads to less reoperations than the AO method: a retrospective comparative study of 347 lateral ankle fractures. Acta Orthop. 2015;86(3):384-7.

54. Donken CC, Al-Khateeb H, Verhofstad MH, van Laarhoven CJ. Surgical versus conservative interventions for treating ankle fractures in adults. Cochrane Database Syst Rev. 2012(8):CD008470.

55. Larsen P, Rathleff MS, Elsoe R. Surgical versus conservative treatment for ankle fractures in adults - A systematic review and meta-analysis of the benefits and harms. Foot Ankle Surg. 2019;25(4):409-17.

56. Sanders DW, Tieszer C, Corbett B, Canadian Orthopedic Trauma S. Operative versus nonoperative treatment of unstable lateral malleolar fractures: a randomized multicenter trial. J Orthop Trauma. 2012;26(3):129-34.

57. SooHoo NF, Krenek L, Eagan MJ, Gurbani B, Ko CY, Zingmond DS. Complication rates following open reduction and internal fixation of ankle fractures. J Bone Joint Surg Am. 2009;91(5):1042-9.

58. Miller AG, Margules A, Raikin SM. Risk factors for wound complications after ankle fracture surgery. J Bone Joint Surg Am. 2012;94(22):2047-52.

59. Lu V, Tennyson M, Zhou A, Patel R, Fortune MD, Thahir A, et al. Retrograde tibiotalocalcaneal nailing for the treatment of acute ankle fractures in the elderly: a systematic review and meta-analysis. EFORT Open Rev. 2022;7(9):628-43.

60. Willett K, Keene DJ, Mistry D, Nam J, Tutton E, Handley R, et al. Close Contact Casting vs Surgery for Initial Treatment of Unstable Ankle Fractures in Older Adults: A Randomized Clinical Trial. JAMA. 2016;316(14):1455-63.

61. Georgiannos D, Lampridis V, Bisbinas I. Fragility fractures of the ankle in the elderly: Open reduction and internal fixation versus tibio-talo-calcaneal nailing: Short-term results of a prospective randomized-controlled study. Injury. 2017;48(2):519-24.

62. Keene DJ, Lamb SE, Mistry D, Tutton E, Lall R, Handley R, et al. Three-Year Follow-up of a Trial of Close Contact Casting vs Surgery for Initial Treatment of Unstable Ankle Fractures in Older Adults. Jama. 2018;319(12):1274-6.

63. Keene DJ, Willett K. Implications of the Ankle Injury Management (AIM) trial: close contact casting or surgery for older adults with an unstable ankle fracture? Bone Joint J. 2019;101-b(12):1472-5.

64. Park JY, Kim BS, Kim YM, Cho JH, Choi YR, Kim HN. Early Weightbearing Versus Nonweightbearing After Operative Treatment of an Ankle Fracture: A Multicenter, Noninferiority, Randomized Controlled Trial. Am J Sports Med. 2021;49(10):2689-96.

65. Black JD, Bhavikatti M, Al-Hadithy N, Hakmi A, Kitson J. Early weight-bearing in operatively fixed ankle fractures: a systematic review. Foot (Edinb). 2013;23(2-3):78-85.

66. Dehghan N, McKee MD, Jenkinson RJ, Schemitsch EH, Stas V, Nauth A, et al. Early Weightbearing and Range of Motion Versus Non-Weightbearing and Immobilization After Open Reduction and Internal Fixation of Unstable Ankle Fractures: A Randomized Controlled Trial. J Orthop Trauma. 2016;30(7):345-52.

67. Smeeing DP, Houwert RM, Briet JP, Kelder JC, Segers MJ, Verleisdonk EJ, et al. Weight-bearing and mobilization in the postoperative care of ankle fractures: a systematic review and meta-analysis of randomized controlled trials and cohort studies. PLoS One. 2015;10(2):e0118320.

68. Kwan JL, Lo L, Ferguson J, Goldberg H, Diaz-Martinez JP, Tomlinson G, et al. Computerised clinical decision support systems and absolute improvements in care: meta-analysis of controlled clinical trials. Bmj. 2020;370:m3216.

69. Wykes PR, Eccles K, Thennavan B, Barrie JL. Improvement in the treatment of stable ankle fractures: an audit based approach. Injury. 2004;35(8):799-804.

70. Jain N, Symes T, Doorgakant A, Dawson M. Clinical audit of the management of stable ankle fractures. Ann R Coll Surg Engl. 2008;90(6):483-7.

71. Palm H, Krasheninnikoff M, Holck K, Lemser T, Foss NB, Jacobsen S, et al. A new algorithm for hip fracture surgery. Reoperation rate reduced from 18 % to 12 % in 2,000 consecutive patients followed for 1 year. Acta Orthop. 2012;83(1):26-30.

72. National Patient Register (NPR) https://www.socialstyrelsen.se/en/statistics-and-data/registers/national-patient-register/. Accessed 7 October 2022.

73. Knutson K, Robertsson O. The Swedish Knee Arthroplasty Register (www.knee.se). Acta Orthop. 2010;81(1):5-7.

74. Karrholm J. The Swedish Hip Arthroplasty Register (www.shpr.se). Acta Orthop. 2010;81(1):3-4.

75. Neuhauser D. Ernest Amory Codman MD. Qual Saf Health Care. 2002;11(1):104-5.

76. Emilsson L, Lindahl B, Koster M, Lambe M, Ludvigsson JF. Review of 103 Swedish Healthcare Quality Registries. J Intern Med. 2015;277(1):94-136.

77. Herberts P, Malchau H. Long-term registration has improved the quality of hip replacement: a review of the Swedish THR Register comparing 160,000 cases. Acta Orthop Scand. 2000;71(2):111-21.

78. Wennergren D, Ekholm C, Sandelin A, Moller M. The Swedish fracture register: 103,000 fractures registered. BMC Musculoskelet Disord. 2015;16:338.

79. Swedish Fracture Register. Annual report 2021. 2022.

80. Wennergren D, Ekholm C, Sundfeldt M, Karlsson J, Bhandari M, Moller M. High reliability in classification of tibia fractures in the Swedish Fracture Register. Injury. 2016;47(2):478-82.

81. Knutsson SB, Wennergren D, Bojan A, Ekelund J, Moller M. Femoral fracture classification in the Swedish Fracture Register - a validity study. BMC Musculoskelet Disord. 2019;20(1):197.

82. Bergdahl C, Nilsson F, Wennergren D, Ekholm C, Moller M. Completeness in the Swedish Fracture Register and the Swedish National Patient Register: An Assessment of Humeral Fracture Registrations. Clin Epidemiol. 2021;13:325-33.

83. The Swedish Fracture Register. https://sfr.registercentrum.se/. Accessed 7 October 2022.

84. Rabin R, de Charro F. EQ-5D: a measure of health status from the EuroQol Group. Ann Med. 2001;33(5):337-43.

85. Swiontkowski MF, Engelberg R, Martin DP, Agel J. Short musculoskeletal function assessment questionnaire: validity, reliability, and responsiveness. J Bone Joint Surg Am. 1999;81(9):1245-60.

86. Bergdahl C, Ekholm C, Wennergren D, Nilsson F, Moller M. Epidemiology and patho-anatomical pattern of 2,011 humeral fractures: data from the Swedish Fracture Register. BMC Musculoskelet Disord. 2016;17:159.

87. Wennergren D, Bergdahl C, Ekelund J, Juto H, Sundfeldt M, Moller M. Epidemiology and incidence of tibia fractures in the Swedish Fracture Register. Injury. 2018;49(11):2068-74.

88. Gustilo RB, Mendoza RM, Williams DN. Problems in the management of type III (severe) open fractures: a new classification of type III open fractures. J Trauma. 1984;24(8):742-6.

89. de Dombal FT, Leaper DJ, Staniland JR, McCann AP, Horrocks JC. Computer-aided diagnosis of acute abdominal pain. Br Med J. 1972;2(5804):9-13.

90. Wraith SM, Aikins JS, Buchanan BG, Clancey WJ, Davis R, Fagan LM, et al. Computerized consultation system for selection of antimicrobial therapy. Am J Hosp Pharm. 1976;33(12):1304-8.

91. Timpka T. Knowledge-based decision support for general practitioners: an integrated design. Comput Methods Programs Biomed. 1987;25(1):49-60.

92. Berner ES. What can be done to increase the use of diagnostic decision support systems? Diagnosis (Berl). 2014;1(1):119-23.

93. Brooke J. SUS: A quick and dirty usability scale. Teoksessa PW Jordan, B. Thomas, BA Weerdmeester & IL McClelland (toim.) Usability Evaluation in Industry. London: Taylor & Francis; 1996.

94. Bangor A, Kortum PT, Miller JT. An Empirical Evaluation of the System Usability Scale. International Journal of Human-Computer Interaction. 2008;24(6):574-94.

95. Burck C. Comparing qualitative research methodologies for systemic research: the use of grounded theory, discourse analysis and narrative analysis. Journal of Family Therapy. 2005;27(3):237-62.

96. Graneheim UH, Lundman B. Qualitative content analysis in nursing research: concepts, procedures and measures to achieve trustworthiness. Nurse Educ Today. 2004;24(2):105-12.

97. Graneheim UH, Lindgren BM, Lundman B. Methodological challenges in qualitative content analysis: A discussion paper. Nurse Educ Today. 2017;56:29-34.

98. Elo S, Kääriäinen M, Kanste O, Pölkki T, Utriainen K, Kyngäs H. Qualitative Content Analysis. SAGE Open. 2014;4(1).

99. Swedish Fracture Register. Annual Report 2017. 2018.

100. Swedish Fracture Register. Annual Report 2018. 2019.

101. Swedish Fracture Register. Annual Report 2019. 2020.

102. P S. Before and after study designs. BMJ. 2014;2014;349:g5074.

103. Transkriberamera. https://www.transkriberamera.se/. Accessed 25 October 2022.

104. SFS 2008:355 Patient Data Act (Swe). Sect. Chapter 7 (2008).

105. Kihlstrom C, Moller M, Lonn K, Wolf O. Clavicle fractures: epidemiology, classification and treatment of 2 422 fractures in the Swedish Fracture Register; an observational study. BMC Musculoskelet Disord. 2017;18(1):82.

106. Mattisson L, Bojan A, Enocson A. Epidemiology, treatment and mortality of trochanteric and subtrochanteric hip fractures: data from the Swedish fracture register. BMC Musculoskelet Disord. 2018;19(1):369.

107. Rundgren J, Bojan A, Mellstrand Navarro C, Enocson A. Epidemiology, classification, treatment and mortality of distal radius fractures in adults: an observational study of 23,394 fractures from the national Swedish fracture register. BMC Musculoskelet Disord. 2020;21(1):88.

108. Beerekamp MSH, de Muinck Keizer RJO, Schep NWL, Ubbink DT, Panneman MJM, Goslings JC. Epidemiology of extremity fractures in the Netherlands. Injury. 2017;48(7):1355-62.

109. Happonen V, Kroger H, Kuismin M, Sund R. Ankle fractures in Finland: 118,929 operatively treated between 1987 and 2019. Acta Orthop. 2022;93:327-33.

110. Daly PJ, Fitzgerald RH, Jr., Melton LJ, Ilstrup DM. Epidemiology of ankle fractures in Rochester, Minnesota. Acta Orthop Scand. 1987;58(5):539-44.

111. Jensen SL, Andresen BK, Mencke S, Nielsen PT. Epidemiology of ankle fractures. A prospective population-based study of 212 cases in Aalborg, Denmark. Acta Orthop Scand. 1998;69(1):48-50.

112. Moller M, Wolf O, Bergdahl C, Mukka S, Rydberg EM, Hailer NP, et al. The Swedish Fracture Register - ten years of experience and 600,000 fractures collected in a National Quality Register. BMC Musculoskelet Disord. 2022;23(1):141.

113. National Institute for Health and Care Excellence: Guidelines. Osteoporosis: assessing the risk of fragility fracture. London: National Institute for Health and Care Excellence (NICE) Copyright © NICE 2019.; 2017.

114. Kanis JA, Oden A, Johnell O, Jonsson B, de Laet C, Dawson A. The burden of osteoporotic fractures: a method for setting intervention thresholds. Osteoporos Int. 2001;12(5):417-27.

115. So E, Rushing CJ, Simon JE, Goss DA, Jr., Prissel MA, Berlet GC. Association Between Bone Mineral Density and Elderly Ankle Fractures: A Systematic Review and Meta-Analysis. J Foot Ankle Surg. 2020;59(5):1049-57.

116. Therdyothin A, Phiphopthatsanee N, Wajanavisit W, Woratanarat P, Laohajaroensombat S, Tawonsawatruk T. Is ankle fracture related to low bone mineral density and subsequent fracture? A systematic review. Osteoporos Sarcopenia. 2020;6(3):151-9.

117. Biver E, Durosier C, Chevalley T, Herrmann FR, Ferrari S, Rizzoli R. Prior ankle fractures in postmenopausal women are associated with low areal bone mineral density and bone microstructure alterations. Osteoporos Int. 2015;26(8):2147-55.

118. Hjelle AM, Apalset EM, Gjertsen JE, Nilsen RM, Lober A, Tell GS, et al. Associations of overweight, obesity and osteoporosis with ankle fractures. BMC Musculoskelet Disord. 2021;22(1):723.

119. Guggenbuhl P, Meadeb J, Chales G. Osteoporotic fractures of the proximal humerus, pelvis, and ankle: epidemiology and diagnosis. Joint Bone Spine. 2005;72(5):372-5.

120. Warner SJ, Gausden EB, Levack AE, Lorich DG. Supination External Rotational Ankle Fracture Injury Pattern Correlation With Regional Bone Density. Foot Ankle Int. 2019;40(4):384-9.

121. Stone KL, Seeley DG, Lui LY, Cauley JA, Ensrud K, Browner WS, et al. BMD at multiple sites and risk of fracture of multiple types: long-term results from the Study of Osteoporotic Fractures. J Bone Miner Res. 2003;18(11):1947-54.

122. Singer BR, McLauchlan GJ, Robinson CM, Christie J. Epidemiology of fractures in 15,000 adults: the influence of age and gender. J Bone Joint Surg Br. 1998;80(2):243-8.

123. Somersalo A, Paloneva J, Kautiainen H, Lonnroos E, Heinanen M, Kiviranta I. Incidence of fractures requiring inpatient care. Acta Orthop. 2014;85(5):525-30.

124. Lambers K, Ootes D, Ring D. Incidence of patients with lower extremity injuries presenting to US emergency departments by anatomic region, disease category, and age. Clin Orthop Relat Res. 2012;470(1):284-90.

125. Zhu N, Zhang D, Wang W, Li X, Yang B, Song J, et al. A Novel Coronavirus from Patients with Pneumonia in China, 2019. N Engl J Med. 2020;382(8):727-33.

126. Worldometers. 2022 https://www.worldometers.info/coronavirus/. Accessed 11 November 2022.

127. Mo K, Gupta A, Singh P, Malan S, McDaniel C, Thompson JM, et al. Emergency Department Visits for Ankle Fractures Through COVID-19: An Analysis of the National Electronic Injury Surveillance System. Foot Ankle Orthop. 2022;7(3):24730114221119188.

128. Benazzo F, Rossi SMP, Maniscalco P, Moretti B, Vaienti E, Ruggieri P, et al. The orthopaedic and traumatology scenario during Covid-19 outbreak in Italy: chronicles of a silent war. Int Orthop. 2020;44(8):1453-9.

129. Park C, Sugand K, Nathwani D, Bhattacharya R, Sarraf KM. Impact of the COVID-19 pandemic on orthopedic trauma workload in a London level 1 trauma center: the “golden month”. Acta Orthop. 2020;91(5):556-61.

130. Sugand K, Park C, Morgan C, Dyke R, Aframian A, Hulme A, et al. Impact of the COVID-19 pandemic on paediatric orthopaedic trauma workload in central London: a multi-centre longitudinal observational study over the “golden weeks”. Acta Orthop. 2020;91(6):633-8.

131. Haskel JD, Lin CC, Kaplan DJ, Dankert JF, Merkow D, Crespo A, et al. Hip Fracture Volume Does Not Change at a New York City Level 1 Trauma Center During a Period of Social Distancing. Geriatric Orthopaedic Surgery & Rehabilitation. 2020;11.

132. Tartaglione JP, Rosenbaum AJ, Abousayed M, DiPreta JA. Classifications in Brief: Lauge-Hansen Classification of Ankle Fractures. Clin Orthop Relat Res. 2015;473(10):3323-8.

133. Fonseca LLD, Nunes IG, Nogueira RR, Martins GEV, Mesencio AC, Kobata SI. Reproducibility of the Lauge-Hansen, Danis-Weber, and AO classifications for ankle fractures. Rev Bras Ortop. 2018;53(1):101-6.

134. Olczak J, Emilson F, Razavian A, Antonsson T, Stark A, Gordon M. Ankle fracture classification using deep learning: automating detailed AO Foundation/Orthopedic Trauma Association (AO/OTA) 2018 malleolar fracture identification reaches a high degree of correct classification. Acta Orthop. 2021;92(1):102-8.

135. Berg HE. Will intelligent machine learning revolutionize orthopedic imaging? Acta Orthop. 2017;88(6):577.

136. Nortunen S, Lepojärvi S, Savola O, Niinimäki J, Ohtonen P, Flinkkilä T, et al. Stability assessment of the ankle mortise in supination-external rotation-type ankle fractures: lack of additional diagnostic value of MRI. J Bone Joint Surg Am. 2014;96(22):1855-62.

137. Gregersen MG, Molund M. Weightbearing Radiographs Reliably Predict Normal Ankle Congruence in Weber B/SER2 and 4a Fractures: A Prospective Case-Control Study. Foot Ankle Int. 2021;42(9):1097-105.

138. Fox A, Wykes P, Eccles K, Barrie J. Five years of ankle fractures grouped by stability. Injury. 2005;36(7):836-41.

139. Elgayar L, Arnall F, Barrie J. A Systematic Review Investigating the Effectiveness of Surgical Versus Conservative Management of Unstable Ankle Fractures in Adults. J Foot Ankle Surg. 2019;58(5):933-7.

140. Javed OA, Javed QA, Ukoumunne OC, Di Mascio L. Surgical versus conservative management of ankle fractures in adults: A systematic review and meta-analysis. Foot Ankle Surg. 2020;26(7):723-35.

141. Mittal R, Harris IA, Adie S, Naylor JM, Group CS. Surgery for Type B Ankle Fracture Treatment: a Combined Randomised and Observational Study (CROSSBAT). BMJ Open. 2017;7(3):e013298.

142. van Leeuwen CAT, Hoffman RPC, Hoogendoorn JM. Long-term outcome in operatively and non-operatively treated isolated type B fibula fractures. Injury. 2019;50(12):2318-23.

143. Ashman BD, Kong C, Wing KJ, Penner MJ, Bugler KE, White TO, et al. Fluoroscopy-guided reduction and fibular nail fixation to manage unstable ankle fractures in patients with diabetes: a retrospective cohort study. Bone Joint J. 2016;98-b(9):1197-201.

144. Bugler KE, Watson CD, Hardie AR, Appleton P, McQueen MM, Court-Brown CM, et al. The treatment of unstable fractures of the ankle using the Acumed fibular nail: development of a technique. J Bone Joint Surg Br. 2012;94(8):1107-12.

145. White TO, Bugler KE, Appleton P, Will E, McQueen MM, Court-Brown CM. A prospective randomised controlled trial of the fibular nail versus standard open reduction and internal fixation for fixation of ankle fractures in elderly patients. Bone Joint J. 2016;98-b(9):1248-52.

146. Cinats DJ, Kooner S, Johal H. Acute Hindfoot Nailing for Ankle Fractures: A Systematic Review of Indications and Outcomes. J Orthop Trauma. 2021;35(11):584-90.

147. Smeeing DPJ, Houwert RM, Briet JP, Groenwold RHH, Lansink KWW, Leenen LPH, et al. Weight-bearing or non-weight-bearing after surgical treatment of ankle fractures: a multicenter randomized controlled trial. Eur J Trauma Emerg Surg. 2020;46(1):121-30.

148. Khojaly R, Mac Niocaill R, Shahab M, Nagle M, Taylor C, Rowan FE, et al. Is postoperative non-weight-bearing necessary? INWN Study protocol for a pragmatic randomised multicentre trial of operatively treated ankle fracture. Trials. 2021;22(1):369.

149. Lehtonen H, Järvinen TL, Honkonen S, Nyman M, Vihtonen K, Järvinen M. Use of a cast compared with a functional ankle brace after operative treatment of an ankle fracture. A prospective, randomized study. J Bone Joint Surg Am. 2003;85(2):205-11.

150. Thomas G, Whalley H, Modi C. Early mobilization of operatively fixed ankle fractures: a systematic review. Foot Ankle Int. 2009;30(7):666-74.

151. Vioreanu M, Dudeney S, Hurson B, Kelly E, O'Rourke K, Quinlan W. Early mobilization in a removable cast compared with immobilization in a cast after operative treatment of ankle fractures: a prospective randomized study. Foot Ankle Int. 2007;28(1):13-9.

152. Swart E, Bezhani H, Greisberg J, Vosseller JT. How long should patients be kept non-weight bearing after ankle fracture fixation? A survey of OTA and AOFAS members. Injury. 2015;46(6):1127-30.

153. Kyriacou H, Mostafa A, Davies BM, Khan WS. Principles and guidelines in the management of ankle fractures in adults. J Perioper Pract. 2021;31(11):427-34.

154. Collaborative B. Weight-bearing in ankle fractures: An audit of UK practice. Foot (Edinb). 2019;39:28-36.

155. McPhail SM, Dunstan J, Canning J, Haines TP. Life impact of ankle fractures: qualitative analysis of patient and clinician experiences. BMC Musculoskelet Disord. 2012;13:224.

156. Gillum RF. From papyrus to the electronic tablet: a brief history of the clinical medical record with lessons for the digital age. Am J Med. 2013;126(10):853-7.

157. Bates DW, Cohen M, Leape LL, Overhage JM, Shabot MM, Sheridan T. Reducing the frequency of errors in medicine using information technology. J Am Med Inform Assoc. 2001;8(4):299-308.

158. Bonis PA, Pickens GT, Rind DM, Foster DA. Association of a clinical knowledge support system with improved patient safety, reduced complications and shorter length of stay among Medicare beneficiaries in acute care hospitals in the United States. Int J Med Inform. 2008;77(11):745-53.

159. Scott GP, Shah P, Wyatt JC, Makubate B, Cross FW. Making electronic prescribing alerts more effective: scenario-based experimental study in junior doctors. J Am Med Inform Assoc. 2011;18(6):789-98.

160. Carroll AE, Bauer NS, Dugan TM, Anand V, Saha C, Downs SM. Use of a Computerized Decision Aid for ADHD Diagnosis: A Randomized Controlled Trial. Pediatrics. 2013;132(3):e623-e9.

161. Roshanov PS, Fernandes N, Wilczynski JM, Hemens BJ, You JJ, Handler SM, et al. Features of effective computerised clinical decision support systems: meta-regression of 162 randomised trials. BMJ. 2013;346:f657.

162. van der Sijs H, Aarts J, Vulto A, Berg M. Overriding of drug safety alerts in computerized physician order entry. J Am Med Inform Assoc. 2006;13(2):138-47.

163. Grove A, Clarke A, Currie G. How are evidence and knowledge used in orthopaedic decision-making? Three comparative case studies of different approaches to implementation of clinical guidance in practice. Implement Sci. 2018;13(1):75.

164. Francke AL, Smit MC, de Veer AJ, Mistiaen P. Factors influencing the implementation of clinical guidelines for health care professionals: a systematic meta-review. BMC Med Inform Decis Mak. 2008;8:38.

165. Ford E, Edelman N, Somers L, Shrewsbury D, Lopez Levy M, van Marwijk H, et al. Barriers and facilitators to the adoption of electronic clinical decision support systems: a qualitative interview study with UK general practitioners. BMC Med Inform Decis Mak. 2021;21(1):193.

166. Svensson K, Rolfson O, Mohaddes M, Malchau H, Erichsen Andersson A. Reflecting on and managing the emotional impact of prosthetic joint infections on orthopaedic surgeons-a qualitative study. Bone Joint J. 2020;102-b(6):736-43.

167. Wolf O, Sjoholm P, Hailer NP, Moller M, Mukka S. Study protocol: HipSTHeR - a register-based randomised controlled trial - hip screws or (total) hip replacement for undisplaced femoral neck fractures in older patients. BMC Geriatr. 2020;20(1):19.

168. Wolf O, Mukka S, Notini M, Moller M, Hailer NP, Duality G. Study protocol: The DUALITY trial-a register-based, randomized controlled trial to investigate dual mobility cups in hip fracture patients. Acta Orthop. 2020;91(5):506-13.