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Discrepancies in diagnoses and treatment of type B ankle fractures

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General introduction and outline of this thesis

Chapter 1 General introduction and outline of this thesis

With an incidence in the Netherlands of approximately 35.000 ankle fractures a year[1], these fractures are one of the most common types of fractures diagnosed at the Emergency Department. In young people, most cases are sports-related trauma. In the middle-aged population, ankle fractures are mostly caused by low to moderate-impact trauma. About one third of patients with an ankle fracture is older than 65 years. With the growing number of elderly people, the incidence of low-energy trauma ankle fractures will increase.

The ankle joint consists of the osseous tibia, fibula and talus. These bone structures are stabilized by ligamentous complexes. The stabilization of the joint is laterally formed by the syndesmosis and the talofibular ligaments. On the posterior side, the posterior tibiofibular ligament connects the tibia to the fibula. Medially, the deltoid ligament, also referred to as the medial collateral ligament, is situated. This ligament is a strong, broad ligament that connects the medial malleolus with the talus, calcaneus and navicular bones, forming a delta shape. The ligament consists of two layers: a superficial and a deep layer. The superficial layer consists of the tibiocalcaneal and tibionavicular ligaments. The deep layer consists of the deep posterior tibiotalar ligament and the deep anterior tibiotalar ligament. (Figure 1)

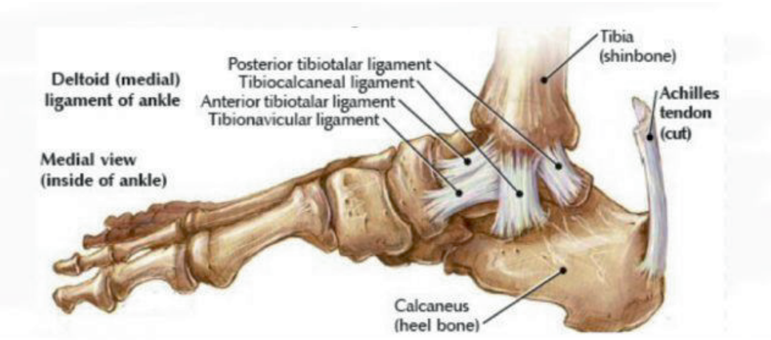


Figure 1. Medial view of the ankle

In the diagnostic process after ankle trauma, a classification facilitates the objective description of the extent of osseous and ligamental injury and subsequently the stability of the joint. For ankle fractures, two main classifications are used. The oldest one, the Weber classification, focuses on the fracture level in relation to the syndesmosis, with a Weber type A fracture located distally from the syndesmosis, a type B fracture being a fracture at the level of the syndesmosis and a Weber C fracture being a fracture proximal from the syndesmosis.[2]

To specify the trauma mechanism that leads to an ankle fracture in detail, describing the rotational mechanism of injury and thereby the possible ligamental injuries, the Lauge Hansen classification is regularly used these days. [3] This classification is developed based on the mechanism of trauma. It determines the position of the foot (supination or pronation) and the direction of the deforming force (abduction, adduction, external rotation).

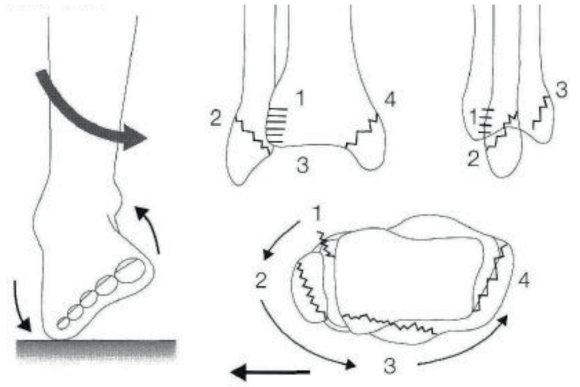
This thesis focuses on the supination external rotation (SER) type fracture according to the Lauge Hansen classification. This is the same type of fracture as the Weber type B fracture according to the Weber classification.

Approximately 70% of all ankle fractures are type B ankle fractures [4] and approximately 60% of these Weber type B fractures are SER type II fractures. The other 40% consist of SER type IV fractures.

The stable SER type II fractures can, in general, safely be treated conservatively when the ankle joint is congruent. [5-7] When the rotational trauma is of higher energy, this can lead to either a medial avulsion fracture (i.e. bimalleolar fracture) or a deltoid ligament disruption. This rotational trauma can be described as follows and is shown in figure 2A. In figure 2B, the different stages of rupture or fracture are shown.

First, a rupture of the anterior-inferior tibiofibular ligament occurs (Figure 2B-1), combined with an oblique fracture of the lateral malleolus (Figure 2B-2). When the rotational force continues, the posterior-inferior tibiofibular ligament will rupture (Figure 2B-3), eventually with either a fracture of the medial malleolus or a rupture of the deltoid ligament. (Figure 2B-4).

Figure 2A. The rotational mechanism of a Supination External Rotation trauma



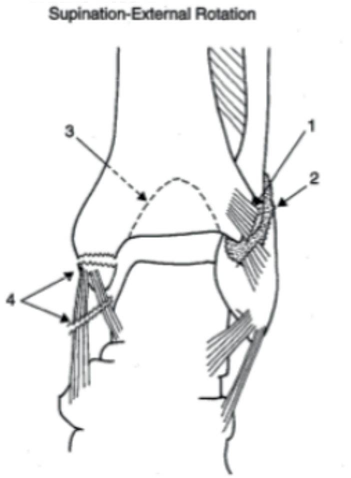


Figure 2B. The different injuries associated with a Supination External Rotation mechanism: 1: rupture of the anterior-inferior tibiofibular ligament, 2: oblique fracture of the lateral malleolus, 3: rupture of the posterior-inferior tibiofibular ligament, 4: either transverse fracture medial malleolus or rupture of the deltoid ligament.

In case of this deltoid ligament rupture, the fracture will be classified as a SER type IV fracture. This type of fracture is instable and generally requires surgical reduction and fixation.

Surgical fixation of type B ankle fractures is in general performed using a fibular plate and screw fixation, after open reduction (ORIF: open reduction and internal fixation). As with any type of surgery, this surgical treatment comes with certain risks. Amongst others, the risks include those of anesthesia-related complications, wound infection, venous thromboembolism, bleeding, nerve injury and need for removal of the osteosynthesis material in case of persistent pain complaints.[8] In addition to these medical risks, surgical treatment is generally associated with higher costs than non-operative treatment strategies. The average costs of non-surgical management of an isolated unstable fibula fracture are US$ 1892, versus US$ 6404 for surgical treatment.[9]

With this in mind, it is of the utmost importance to carefully select only those patients with a confirmed unstable fracture or inacceptable fracture dislocation for surgical treatment. Patients with stable, undisplaced fractures that are being treated surgically, are exposed to unnecessary risks and costs.

On the other hand, when a fracture seems to be a stable SE type II fracture without adequate assessment of the deltoid ligament and is thus treated non-operatively, this patient might develop early posttraumatic osteoarthritis with worse functional outcome.[10] Therefore, the differentiation between stable and unstable type B fracture is crucial in deciding whether to treat surgically or conservatively. Although the medical profession acknowledges this importance, no consensus exists on the best radiologic tool for diagnosing medial injury. Widening of the medial clear space (MCS) on a mortise radiograph (the initial trauma X-ray) can be used to indicate medial injury. However, even in patients with a MCS > 6 mm, the deltoid ligament can still be intact. Thus, using the MCS as indication for deltoid rupture might lead to surgical treatment of stable ankle fractures.[11] Several other diagnostics have been analysed for their ability to diagnose medial disruption and thus ankle instability. The manual stress radiograph, the weightbearing radiograph, the gravity stress radiograph, the ultrasound, the MRI and the CT scan have all been investigated. Still, neither of these has been singled out as the best diagnostic tool.

This thesis deals with the discrepancies in diagnostics and treatment of type B ankle fractures and more specifically focuses on the relevance of the distinction between the SER type II and SER type IV fractures and the clinical implications. How is this distinction currently made? And how should we make the distinction in the future? What radiologic tools are best used for adequately diagnosing medial injury and how should we treat these confirmed isolated type B ankle fractures? This thesis presents results that will help to distinguish between stable and instable ankle fractures and determine their subsequent therapy.

Outline

The inconsistency in management of type B ankle fractures presents an opportunity for improvement. The aim of this thesis is first to describe the current practice in diagnosis and treatment of type B ankle fractures. This is described in part I. The second aim, elaborated on in part II of this thesis, is to identify the most accurate radiologic diagnostics for medial injury in order to formulate a diagnostic pathway as recommendation. This pathway can then lead to the applicable treatment.

Generally, surgical treatment is advised for unstable fractures and conservative treatment for stable fractures. But what is the long-term functional outcome of patients with these fractures? **Chapter 2** compares the functional outcome of patients with fibular fractures after surgical and conservative treatment. Therefore, this chapter can be regarded as a cornerstone of this thesis.

To evaluate the current practice, to identify gaps in existing knowledge and to formulate a consensus in diagnosis and treatment of type B fibular fractures, the results of a survey amongst all trauma and orthopedic surgeons in the Netherlands are described in **chapter 3.** The final chapter of part I of this thesis, **chapter 4,** focuses on the one thing doctors should never forget to think about: the most relevant treatment outcomes according to the patients.

After having established what is most important in the treatment and outcome for both patients and doctors, part two of this thesis then concentrates on how to improve the diagnosis and thus treatment of type B ankle fractures. It starts with **chapter 5,** in which the additional value of the gravity stress radiograph to diagnose medial ligament injury is investigated in comparison with MRI. Based on this study, the gravity stress radiograph has been integrated as part of the ankle fracture diagnostic protocol in the study hospital. **Chapter 6** describes the influence of the integration of the gravity stress view on clinical practice. It provides an answer to the question whether the introduction of the gravity stress radiograph has resulted in less operative treatment. The study described in **Chapter 7** contains an enlargement of the cohort of chapter 6, studying those patients in whom an additional weight-bearing radiograph was performed. Again, the weightbearing radiograph is compared with MRI to evaluate its diagnostic accuracy in determining deltoid ligament rupture.

To pinpoint the remaining gaps in knowledge about type B ankle fractures, a systematic review concerning the different radiologic diagnostics to evaluate medial ligament injury was performed and is described in **chapter 8.** The last chapter of part II, **chapter 9,** investigates the diagnostic value of the fibular fracture diastasis in determining an instable ankle joint. Many surgeons use the measurement of fibular fracture diastasis on the regular mortise view as parameter to diagnose instability. However, no literature has described this measurement as an indicator of instability. As such, the aim of this chapter is to investigate whether a correlation between the fibular diastasis and medial instability can be established.

The studies in this thesis and future study ideas in the field of fibula fractures are discussed in **Chapter 10. Chapter 11** presents an English summary of the thesis. A Dutch summary is provided in **Chapter 12**. The curriculum vitae and list of publications of the author are described in the **Appendices**.

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PART I

Current practice and its outcomes

2

Long-term outcome in operatively and non-operatively treated isolated type B fibula fractures

Van Leeuwen CAT, Hoffman RPC, Hoogendoorn JM.

Injury 2019 Dec;50(12):2318-2323.

Chapter 2 Long-term outcome in operatively and non-operatively treated isolated type B fibula fractures

Abstract

Purpose

Type B fibula fractures are the most common type of ankle fractures. Generally, surgical repair is advised for unstable fractures and non-operative treatment for stable fractures. However, evidence on long-term functional outcome of both treatment regimens is lacking.

Aim of this study is to compare the long-term outcome in function and pain between patients with an isolated type B fibula fracture treated non-operatively and surgically.

Material & methods

In this retrospective cohort study, all consecutive patients aged between 18 and 75 years, treated non-operatively or surgically between January 2008 and December 2015 for a distal fibula fracture at the level of the syndesmosis without an additional medial or posterior fracture and with a medial clear space ≤ 6mm were included. All eligible patients received a questionnaire, composed of the the Olerud-Molander Ankle Score (OMAS), the American Orthopaedic Foot and Ankle Society ankle-hindfoot score (AOFAS), the Euroqol-5D (EQ-5D) for quality of life and the Visual Analogue Scale (VAS) for pain sensation.

Results

With a mean follow-up of 5.3 years, 229 patients were included. For all aspects of the questionnaire, there was no significant difference between non-operative and operative treatment in outcome of function and pain: the EQ-5D score was respectively 0.8 vs. 0.9 (p=0.72), mean VAS score 0.8 vs. 1.3 (p=0.09), OMA score 84 vs. 84 (p=0.98) and for the AOFAS 93 vs. 90 (p=0.28). 33% of the patients who had surgery had revision surgery for implant removal because of persistent pain complaints. In 3% of the surgically treated patients, a wound infection required intravenous antibiotic treatment. In the non-operatively treated cohort, one patient developed a deep venous thrombosis in the fractured leg.

Conclusion

According to results of this study, in adult patients with an isolated distal fibula and medial clear space ≤ 6 mm, without proven instability these fractures can safely be treated non-operatively,

while avoiding risks and costs of surgery and preserving good long-term outcome in terms of pain and function.

Introduction

Ankle fractures are one of the most common fractures encountered in the hospital, representing 10% of all fractures [1]. The most common type is the isolated transsyndesmotic (type B) fibula fracture[1].

In current literature, consensus has been reached that a type B1 fracture, without additional medial or posterior injury and thus stable, can be treated safely non-operatively[3-5]. On the contrary, in case of a distal fibula fracture combined with a medial fracture or deep deltoid ligamentous injury the talus is more likely to lateralise and thereby form an incongruent ankle joint. Anatomical reduction and fixation of the fibula fracture have, in these cases, been found to yield better results[2].

The mortise radiograph is the most commonly used diagnostic tool to differentiate between stable and unstable fractures. In case of a medial clear space (MCS) < 4mm the fracture is considered stable and generally non-operative treatment is advised. According to most studies, a MCS of > 6 mm or a MCS > superior clear space (SCS) + 2 mm is suggestive of a total tear of the deep deltoid ligament (DDL)[5,6]. In healthy patients, these fractures are generally treated surgically. For B-type fractures with a MCS 4-6 mm on the mortise view, additional diagnostics are advised to differentiate between a stable and unstable ankle fracture and thereby choice of treatment. With definite exclusion of medial injury, based on the additional diagnostics, these fractures also may be treated non-operatively[7].

However, a recent national online survey among 182 trauma- and orthopedic surgeons in the Netherlands revealed that surgical management is preferred by 30% of the surgeons in case of MCS > 4 mm or a fibula dislocation > 2mm - even without additional diagnostic information about the medial ligament[8]. However, in a substantial number of radiographs with a MCS widening >4 mm, the DDL is still (partially) intact[9]. Probably, many type B fractures are incorrectly diagnosed as unstable and therefore many patients undergo unnecessary surgery. This surgery is associated with costs and risks. Not only the risks of the anesthesia, but also infection, venous thromboembolism, failure of fixation and the need for revision surgery are risks that the surgeon and patient should be aware of[10].

Moreover, the average costs of surgical and non-surgical management of an isolated unstable lateral malleolar fracture are US$1892 and US$6404, respectively[11].

Mittal et al. recently published that in the short term (one year post operatively), surgery is not superior to non-surgical management for type B1 distal fibula fractures without significant talar shift, which was defined as MCS being at least 2 mm wider than the SCS on a mortise X-ray view of the ankle[5]. To our knowledge, there has been no research yet investigating the long-term outcome of these ankle fractures, thereby comparing surgical treatment with non-operative treatment.

The aim of the current study is to determine the long-term differences in function of the ankle and level of pain in non-operatively and surgically treated patients with an isolated type B fibula fracture. Our hypothesis is that there will be no difference between the operated and non-operatively treated patients in both groups concerning pain and function.

Methods

Study design

This study is a retrospective single-center cohort study performed in the Haaglanden Medical Centre (HMC) in The Hague, a level one trauma center. All consecutive patients aged between 18 and 75 years, treated non-operatively or surgically between January 2008 and December 2015 for an isolated distal fibula fracture at the level of the syndesmosis were included in a database. All trauma radiographs of these patients have been scored. Patients with an isolated type B fibula fracture and MCS ≤ 6 mm were eligible for inclusion. Exclusion criteria were patients with a MCS > 6 mm, a lack of mental capacity, a former fracture of the same ankle, a pre-existent decreased function of the ankle, decreased function of the extremities because of other comorbidities, multi-trauma patients without normal rehabilitation, cognitive impairment, inability to speak Dutch or English. The decision to treat surgically or non-operatively was initially made by the surgeon based on the radiographic diagnostics and his/her judgment of stability of the fracture. Most fractures were evaluated in the outpatient department within one week. Most of the trauma surgeons decided to treat operatively in case of MCS > SCS + 2 mm. Many of our surgeons advised surgery in case of a fibular fracture dislocation >2mm as well, independent of joint incongruency. Written informed consent was obtained from all patients willing to participate.

Standard practice in our center, in case of non-operative treatment contains a two-week period of non-weightbearing in either a cast or orthesis depending on the surgeons' preference, followed by a weightbearing period dependent on pain complaints. Operatively treated patients were recommended a two-week period of a splint and, in case of good wound healing, weightbearing depending on pain complaints after two weeks.

The database included patient characteristics (age, gender, comorbidities), fracture characteristics (AO-classification, fracture side, additional radiographic diagnostics (MRI or gravity test)) and type of treatment (surgery yes/no, type of surgery, non-operative treatment; duration of immobilization). Moreover, complications and re-surgery for removal of material were recorded. Unfortunately, data on percentage of arthrosis was not present.

Radiological parameters

For each isolated distal fibula fracture, the following measurements were achieved from the picture archiving (PACS) based on the mortise view: medial clear space (MCS), the distance between the lateral border of the medial malleolus and the medial border of the talus, at the level of the talar dome; tibio-fibular clear space (TCS) at the level of the epiphyseal scar on the distal part of the tibia; superior clear space (SCS); distal fracture height (distance between the distal tip of the fracture and the talar dome); lateral diastasis (the maximum width of the fracture line). On the lateral view the following measurements were accomplished: posterior diastasis (the maximum width of the fracture line); posterior and anterior fracture height (perpendicular to the level of the talar dome)[12]. Figure 1 and 2 show these measurements.

Figure 1 . Measurements of the mortise radiograph. A: medial clear space, B: superior clear space, C: distal fracture height, D: lateral diastasis

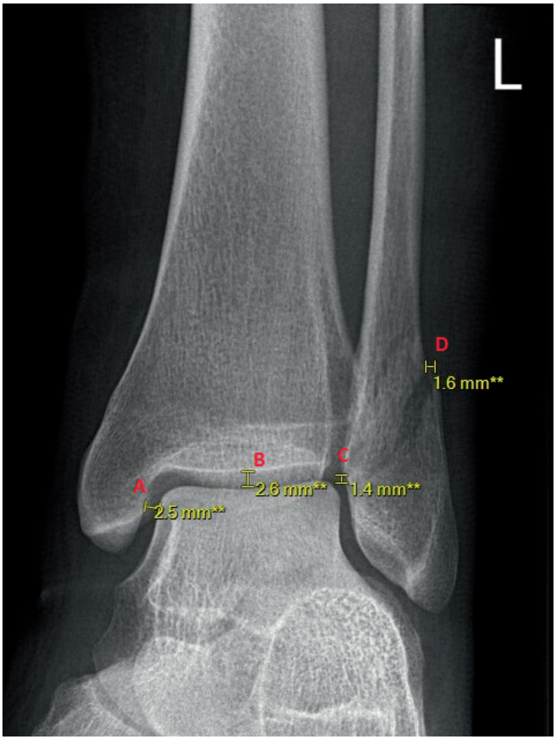
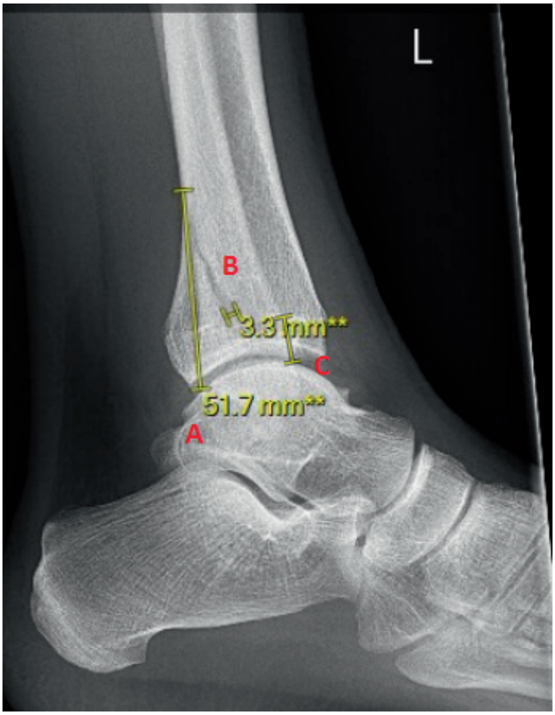


Figure 2. Measurements of the lateral radiograph: A: posterior fracture height, B: posterior diastasis, C: anterior fracture height.



Outcome measurements

Outcome was measured using standard questionnaires, which were sent to all eligible patients. After no response, a second questionnaire was sent. A third notification was made by telephone.

The questionnaire consisted of the Olerud-Molander Ankle Score (OMAS), the American Orthopaedic Foot & Ankle Society (AOFAS), the Euroqol-5D (EQ-5D) for quality of life and the Visual Analog Scale (VAS) for pain sensation. The OMAS[13] is a self-administered patient questionnaire with a score of zero (totally impaired) to 100 (completely unimpaired) and is based on nine different items: pain, stiffness, selling, stair climbing, running, jumping, squatting, supports and work or daily activities. The American Orthopaedic Foot & Ankle Society (AOFAS)[14] scale includes questions on pain, activity and functional limitations, walking distance, balance, difficulties with different terrains, influence on daily live and functioning and ranges from 0 (worst score) to 100 (no complaints at all). The EQ-5D[15] is a standardized instrument developed by the EuroQol group as a measure of health-related quality of life and comprises five dimensions: mobility, selfcare, usual activities, pain/discomfort and anxiety/depression. Secondary endpoints included any complications and removal of the material. A Visual Analog Scale (VAS)[16] ranging 0-10 was used to measure pain.

Statistical analysis

The statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS), version 24. For all different aspects of the questionnaire, statistics were performed to compare the surgically treated group with the non-operatively treated group, using one-way ANOVA to compare these continuous variables between groups. A p-value <0.05 was taken as level of statistical significance.

The study was approved by the regional medical ethical committee: METC Zuidwest Holland study number 17-054.

Results

In total, 229/751 (31%) patients fulfilled the questionnaire after a mean follow-up of 5.3 years. The patient baseline characteristics of the respondents and the non-respondents are shown in table 1. The two cohorts (respondents versus non respondents) had similar baseline characteristics. None of the patients treated non-operatively had to have surgery due to secondary fracture displacement.

Table 1. Baseline characteristics of the responders vs. non-responders

Medial Clear Space (MCS), Superior Clear Space (SCS)

	Responders (n=229)	**Non - responders (n=556)**	**One-way ANOVA**
Mean age (in years)	58.6 (20-95)	47.3 (21-76)	*p= 0.000*
Male (n)	93 (40.6%)	309 (50.6%)	*p=0.114*
Smokers (n)	15 (6.6%)	14 (2.6%)	p=0.000
Diabetes (n)	13 (5.3%	6 (1.1%)	*p=0.039*
Treatment			
Non-operative (n)	131(53.0%)	324 (58.2%)	*p=0.373*

Operative (n)	116 (47.0%)	232 (41.8%)	*p=0.373*
Follow up (in years)	5.3 (1.7-9.0)	5.8 (2.9-9.6)	*p=0.001*
Medial clear space (MCS)	3.3 (1.2-5.8)	3.4 (1.6-5.9)	*p= 0.133*
MCS group (n)			
<4mm	173 (75.5%)	412 (74.1%)	*p=0.795*
4-6mm	56 (24.5%)	144 (25.9%)	*p=0.795*
Superior Clear space (SCS)	3.2 (1.5-4.9)	3.2 (1.8-5.2)	*p=0.754*
Laterale diastasis	1.5 (0.0-7.4)	1.4 (0.0-5.4)	*p=0.364*
Posterior diastasis	1.6 (0.0-8.0)	1.7 (0.0-6.4)	*p=0.438*

Table 2 shows the mean scores of all different aspects of the questionnaire, subdivided into non-operative (n = 130) and operative (n = 99) treated groups. Baseline characteristics did show significant diffrences in age (operative group 56 years vs. non-operative group 61 years, p = 0.02) and MCS (operative group 3.6 mm vs. non-operative group 2.9, p < 0.01).

Table 2. Radiographic and questionnaire results operative vs. non-operative

Medial Clear Space (MCS), Superior Clear Space (SCS), Talofibular Clear Space (TCS), Visual Analogue Scale (VAS), Olerud and Molander Ankle Score (OMAS), American Academy of Orthopaedic Surgeons (AAOS), EuroQol 5D (EQ-5D)

	Operative (n=99)	**Non-operative (n=130)**	**One-way ANOVA**
Patient Characteristics			
Mean age (in years)	56 (25-86)	61 (20-95)	*p=0.022*
Male (n)	34 (34.4%)	59 (45.4%)	*p=0.093*

Smoking (n)	12 (12.1%)	3(2.3%)	*p=0.000*
Diabetes (n)	3 (3.0%)	7 (5.4%)	*p=0.070*
Radiographic results			
Medial clear space (MCS) (in mm)	3.6 (1.4-5.8; σ 1.0)	2.9 (1.2-5.1; σ 0.8)	*p= 0.000*
MCS < 4 mm (n)	60 (60.6%)	113 (86.9%)	*p=0.000*
MCS > SCS (superior clear space) + 2 mm	12 (12.1%)	1 (0.8%)	
Talofibular Clear Space (TCS) (in mm)	3.7 (1.7-6.6; σ 1.1)	3.4 (1.0-7.2; σ 1.1)	*p= 0.43*
Laterale diastasis (in mm)	1.9 (0.0-7.4; σ 1.2)	1.2 (0.0-3.2; σ 0.7)	*p= 0.000*
Posterior diastasis (in mm)	1.9 (0.0-7.6; σ 1.4)	1.2 (0.0-8.0; σ 1.1)	*p= 0.000*
Distal fracture height (in mm)	1.2(-5.8-10.3; σ 2.7)	2.4 (-9.5-34.8; σ 5.0)	*p= 0.046*
Posterior fracture height (in mm)	34.8 (1.4-151.0; σ 20.6)	30.3 (7.4-69.2; σ 10.6)	*p= 0.045*
Anterior fracture Height (in mm)	5.9 (-6.0-34.4; σ 5.7)	6.0 (-4.3-30.1; σ 6.8)	*p= 0.901*
Fracture angle (degrees)	144 (1-172; σ 25)	144 (1-162; σ 19)	*p= 0.983*
Outcome			

Visual Analogue Scale (VAS) for pain	1.3 (0.0-8.00; σ 2.1)	0.8 (0.0-8.0; σ 1.7)	*p= 0.091*
Olerud-Molander Ankle Score (OMAS)	84 (25-100; σ 14)	84 (35-100; σ 14)	*p= 0.988*
American Academy of Orthopaedic Surgeons (AAOS)	90 (0-100; σ 17)	93.0 (0-100; σ 15)	*p= 0,281*
EuroQol 5D (EQ-5D)	0.9 (0.0-6.0; σ 1.5)	0.8 (0.0-6.0; σ 1.4)	*p= 0.720*
Removal of hardware	33 (34.4%)		
Deep infection:	1 (0.4%)	-	
Superficial infection	1 (0.4%)		
Nerve injury	1 (0.4%)	-	
Deep Venous Trombosis	-	1 (1.2%)	

For all aspects of the questionnaire, there was no significant difference between non-operative and operative treatment in outcome of function and pain: the EQ-5D score was respectively 0.8 vs. 0.9 (p=0.72), mean VAS pain score 0.8 vs. 1.3 (p=0.09), OMA score 84 vs. 84 (p=0.98) and for the AOFAS 93 vs. 90 (p=0.28). In 33% of the patients who had surgery, the implants were removed due to persistent complaints of pain. In 3% of the surgically treated patients, a wound infection after ORIF required intravenous antibiotic treatment. In the non-operatively treated group, one patient developed a deep venous thrombosis in the fractured leg. (Table 2)

Divided into subgroups, 173 patients (75.5%) had a MCS < 4 mm and 56 patients (24.5%) a MCS 4-6 mm. In the MCS < 4 mm group, 65.3% of the patients were treated non-operatively, in the MCS 4-6 mm group this percentage was 30.4%. In total, 60/99 (60.6 %) of the patients that were treated surgically, had a MCS < 4 mm.

The baseline characteristics and results of the subgroup with MCS 4-6 mm are shown in table 3. The mean EQ-5D score was in the non-operatively treated cohort 1.06 vs. 1.08 in the surgically treated cohort. (p = 0.96) The mean VAS pain score in this group was respectively 0.50 vs. 1.11 (p=0.19), the OMA score was 83.82 vs. 81.62 (p=0.61) and for the AOFAS score the MCS 4-6 mm cohort scored respectively 92.83 vs. 91.57 (p=0.42) (table 3)

Table 3. Baseline characteristics and questionnaire of the subgroup MCS 4-6 mm.
Visual Analogue Scale (VAS), Olerud-Molander Ankle Score (OMAS), American Academy of Orthopaedic Surgeons (AAOS), EuroQol 5D (EQ-5D)

	Non-operative (n=17)	**Operative (n=39)**	**One-way ANOVA**
Mean age (in years)	60.6 (35-95)	50.2 (25-80)	*p=0.018*
Follow up (in months)	70.5 (31-106)	55.4 (22-102)	*p=0.050*
Male	13 (76.5%)	18 (46.2%)	*p=0.036*
VAS pain	0.5 (0.0-2.0)	1.1 (0.0-7.5)	*p=0.199*
Olerud-Molander Ankle Score (OMAS)	83.8 (55.0-100.0)	81.6 (35.0-100.0)	*p=0.610*
AAOS	94.4 (56.0-100.0)	90.1 (58.0-100.0)	*p=-.299*
EuroQol 5D (EQ-5D)	1.1 (0.0-4.0)	1.1 (0.0-4.0)	*p=0.963*

Table 4 shows results of the subgroup with fibula dislocation > 2 mm. The mean fibula dislocation (being maximum dislocation on lateral or anterior-posterior radiograph) ranged from 0.0-8.0 mm in the non-operatively treated group and from 0.0 to 7.6 mm in the surgically treated group. Of the subgroup with fibula dislocation > 2 mm, 25/93 (26.9%) was treated non-operatively vs. 68/93

(73.1%) surgically. Also within this group, results for VAS (0.6 vs. 1.5, p=0.08), OMAS (82.8 vs. 85.5, p=0.08), AAOS (96.4 vs. 91.0, p=0.11) and EQ-5D (0.33 vs. 0.69, p=0.24) were not significantly different comparing non-operative and surgical treatment.

Table 4. Baseline characteristics and questionnaire of the subgroup fibula dislocation > 2 mm.

Visual Analogue Scale (VAS), Olerud-Molander Ankle Score (OMAS), American Academy of Orthopaedic Surgeons (AAOS), EuroQol 5D (EQ-5D)

	Non-operative (n=25)	**Operative (n=68)**	**One-way ANOVA**
Mean age (in years)	64.4 (24-95)	56.2 (25-86)	*p=0.043*
Follow up (in months)	59.7 (20-106)	29.1 (0-106)	*p=0.428*
Male	14 (56%)	33 (48.5%)	*p=0.528*
VAS pain	0.60 (0.0-6.0)	1.5 (0.0-8.0)	*p=0.080*
Olerud-Molander Ankle Score (OMAS)	82.8 (35-100)	85.5 (35-100)	*p=0.443*
AAOS	96.4 (52-100)	91.00 (0-100)	*p=0.116*
EuroQol 5D (EQ-5D)	0.33 (0-3)	0.69 (0-6)	*p=0.242*

Discussion

One of the most common ankle fractures is the B type, with its fibula fracture at the level of the distal tibio-fibular syndesmosis. This type of injury can be stable (without medial injury) or unstable (with an additional medial fracture or deltoid ligament rupture). Stable fractures can be safely treated nonoperatively. Even despite fibular displacement up to 5mm, this is the treatment of choice leading to excellent function[17-21]. On the contrary, for unstable fractures surgical treatment is advised in healthy patients.

The mortise radiograph is the most commonly used diagnostic tool to differentiate between stable and unstable fractures. However, when using only this radiograph, no information is given about medial ligament injury. In current research, several other radiographic diagnostic tools are being investigated to determine the most sensitive predictive tool in diagnosing medial injury. For example, a recent study showed that the gravity stress test has a sensitivity of 100% and a specificity of 91.7% compared to the reference standard MRI in predicting deep deltoid ligament injury[22].

Other studies found good results with 100% specificity and sensitivity for detecting deltoid rupture with ultrasound[23,24]. However, the numbers in these studies were very small and radiologists with sufficient expertise to perform such ultrasounds are not always present in-hospital. Also, the manual ankle stress radiograph[25] (sensitivity and specificity of respectively 66% and 77% compared to MRI) and weight-bearing radiograph[26-28] were investigated recently. The latter, however, was not compared to MRI or surgical exploration as reference standard.

These different diagnostic tools may be useful to predict medial injury and therefore support the decision-making process in choosing non-operative or surgical treatment based on biomechanical principles. However, it is noticeable that studies comparing the clinical outcome of both treatment regimens are lacking.

The recently published CROSSBAT study showed that in the short-term (12 months post-injury), surgery is not superior to non-operative treatment in isolated distal fibula fractures (type 44-B1 fracture without MCS > 2 mm wider than superior clear space on the mortise view) in terms of ankle function and health-related quality of life. Respectively, the results for the surgically vs. non-operatively treated group in two main questionnaires: the American Academy of Orthopaedic Surgeons Foot and Ankle Outcomes Questionnaire (FAOQ) and the physical component score (PCS) of the SF-12c2 General Health survey, showed results of 43.8 vs. 44.7 (p=0.65) and 47.1 vs. 46.8 (p=0.9).[5]

To our knowledge, the current study is the first to investigate the long-term outcome of these specific type of ankle fractures by comparing the two types of treatment.

This study reveals that in adult patients, aged 18 to 75 years with an isolated type B ankle fracture, surgical management was not superior to non-surgical management in terms of pain, ankle function and health-related quality of life after a mean follow-up of 5.3 years. Furthermore, surgery was associated with complications like wound infections and need for re-surgery to remove the material.

It is known that in case of doubt, many surgeons tend to have a preference for surgical treatment mostly based on the MCS widening, thereby often using a cut-off value of MCS >4 mm.[8] In our study cohort, 70% of the patients presenting with an isolated type B fibula fracture and a MCS between 4-6mm have been operated. However, recent studies showed that using this threshold, many ankle fractures will incorrectly be diagnosed as unstable and have therefore might be fixed unnecessarily. [9,29]

The current study proves that the effectiveness of surgery in stable ankle fractures is not superior to non-operative treatment when comparing long-term outcome. Also, high costs and many risks can be prevented when stable fractures are being treated safely non-operatively. Comparing surgery with non-operative treatment, neither MCS groups (MCS < 4mm and MCS 4-6 mm) had any significant difference in outcome. Moreover, even with fibula dislocation ranging up to 5.4mm, this study revealed good results after non-operative treatment. In the Netherlands, for example, many surgeons treat fractures with fibula dislocation > 2 mm surgically, even without medial widening.[8] According to the current results, this might lead to surgical overtreatment.

A limitation of this study is the lack of a strict treatment protocol that can be used by the trauma surgeon, leading to confounding by allocation. The decision to treat surgically was based on their own judgment of instability and fibular fracture dislocation. Solely based on the MCS, stability of a type b ankle fracture is not possible as rotation and shortening of the fibula cannot exactly be assessed on the X-ray. Thus, patients with stable fractures may have been treated operatively, as well as patients with unstable fractures treated non-operatively.

Moreover, we are aware that this is a retrospective design and a prospective study is needed to confirm our findings. In our center, we are currently performing a prospective trial that compares the weight-bearing and gravity stress radiographs with MRI scan to indicate complete medial ligamentous injury and therefore instability. Results of this study will hopefully confirm the findings of the current retrospective study.

By using a questionnaire, it is inevitable to have some selection bias. Moreover, we faced a very selective response of 33%, the main drawback of this study; even after second and third notifications mails and calls. As shown in table 1, this responsive cohort is, however, representative for the total study population. However, although these patients characteristics are representative, they may not be representative for outcome.

Strength of this study is the patient reported outcome. The objective data, derived from the database and the radiographs, combined with the patient's own appraisal of outcome is the most optimal outcome measurement. With a mean follow-up of 5.3 years we were able to compare the outcome of treatments not only during the recent rehabilitation process but also years after.

As a consequence of this current study we changed our protocol and started to perform gravity and weight-bearing radiographs on a regular basis. Making use of Holmes' flowchart[7], we regularly perform a gravity stress radiograph at the Emergency Department in case of type B fibula fractures without a medial fracture and decide for surgical treatment in case of a MCS > 6 mm. When the MCS is < 6 mm, a plaster of paris is applied. Within a week after injury a weight bearing radiograph is performed and if no widening of the MCS is shown on this radiograph, we definitively decide to treat non-operatively. In doing so, the number of patients that is selected for operative treatment could be significantly lowered with good clinical outcome. We hope that other surgeons do realize that when in doubt about the stability of an isolated type B ankle fracture, further diagnostics should be performed. Without proven instability, these injuries can be treated safely non-operatively; without risks and costs of surgery, and with good long-term outcome in terms of pain and function.

All authors declare that they have no conflict of interest.

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3

The diagnosis and treatment of isolated type B fibular fractures: Results of a nationwide survey

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Chapter 3 The diagnosis and treatment of isolated type B fibular fractures: Results of a nationwide survey.

Abstract

Introduction

In isolated Weber B fractures (type B fibular fractures), ruling out instability is critical for safe conservative treatment. In fractures without evident medial injury, additional diagnostics like MRI scan or gravity stress test should be done to differentiate between a stable and unstable fracture. The aim of the current study is to gain more insight in current practice and treatment of type B fractures by Dutch trauma- and orthopaedic surgeons.

Materials & Methods

In December 2017 and January 2018, 559 trauma surgeons were invited by email to join an online survey. This survey consisted of questions regarding diagnostics and treatment of isolated distal fibula fractures. Also, respondents were asked to state their preferred treatment of eight separate cases.

Results

In total, 161 surgeons participated, covering 68 different hospitals in the Netherlands. Of them, 32.0% treat more than 30 ankle fractures a year. Based on regular mortise radiographs, 13.6% of the respondents chose surgical treatment in case of a medial clear space (MCS) > 4mm, 33.8% in case of a MCS > 6mm and 45.5% in case of a MCS > 4mm in addition to the MCS ≥ superior clear space + 1mm. Moreover, 18.2% make use of additional diagnostics (43.9% repeat mortise view after a week, 16.6% weight bearing radiograph, 8.6% gravity stress view, 7.9% exorotation radiograph, 6.5% MRI scan, 0.7% ultrasound, 16.8% other) and 8% establishes their decision not based on the mortise radiograph. Fibular dislocation of ≥ 2mm was used as an indication for surgical treatment by 69%. Of them, 56% decides to treat surgically in these cases, even with proven medial stability.

Conclusion

Many surgeons treat type B fibular fractures with a MCS > 4mm at mortise view surgically, even without proven medial injury. Rarely, additional diagnostics as MRI or gravity stress test are performed in cases with a MCS 4-6mm. Consequently many stable ankle fractures are treated operatively unnecessarily.

Introduction

Treatment of B-type ankle fractures, with its fibular fracture at the level of the syndesmosis, depends on stability of the ankle joint. Fractures without medial injury (Lauge-Hansen supination-exorotation (SER) type 2 injury) are considered stable and therefore conservative treatment is recommended.[1-5] In case of an additional medial fracture or a rupture of the deep deltoid ligament (SER type 4 injury), the fracture is considered unstable and generally operative treatment is recommended.[6] Therefore the accurate diagnosis of medial injury, is of great clinical importance.

Lateral and mortise X-ray views of the ankle are generally performed if an ankle fracture is suspected. A fracture of the medial malleolus is usually clearly visible, however medial ligamentous injury can be more difficult to diagnose. Generally, the medial clear space (MCS) is used to diagnose deep deltoid ligamentous injury. However, the cut-off value for a widened MCS has been subject to debate.[7-8] In many hospitals, B-type fibular fractures with a MCS > 4mm are treated operatively, despite a lack of evidence supporting this treatment.[9, 10] Consequently, this might lead to surgical overtreatment of stable fractures. Therefore, the recently published Dutch guideline 'Ankle fractures' only advises operative treatment in case of a medial fracture or MCS > 6mm. In cases of uncertain medial integrity additional diagnostics like the weight bearing radiograph[11,12,13], ultrasound[14,15]or MRI[16,17]should be considered to exclude instability. If no instability is proven, the guideline advises conservative treatment. [5]

The aim of this study is to examine the current use of diagnostics tools and treatment of B-type fractures among Dutch trauma surgeons. Additionally we evaluated whether this current common practice is in concordance with the Dutch guideline 'Ankle fractures'.

Materials & Methods

Study design

For this cross-sectional study, an online Dutch survey was developed. Its questions were partly derived from recent literature. The survey was sent to 559 trauma surgeons, Orthopedic surgeons and residents from both specialties in 68 different Dutch hospitals (contrary to most other countries in the Netherlands both trauma surgeons and Orthopedic surgeons treat musculoskeletal trauma). The survey consisted of 4 personal demographic questions, 6 diagnostic related questions, 5 treatment related questions, 16 example cases and 3 questions about awareness of current guidelines. The cases provide patient characteristics and fracture radiographs, asking the surgeon to decide treatment. Moreover, additional diagnostics that were used were included in a following question, asking whether these additional examinations influence their treatment decision. All questions included in the survey are shown in table 1. In the survey, for some questions it was possible to agree with multiple answers, resulting in a total response of more than 100%. The radiographs of the example cases are shown in the Appendix.

Table 1. online survey, translated from Dutch to English

1.	Number of years of work experience, including (prior) education		
	a.	0-5	6,2%
	b.	6-10	16,2%
	c.	11-15	35,8%
	d.	16 years or more	41,9%
2.	What is your medical speciality		
	a.	Trauma surgeon	40,5%
	b.	Orthopaedic surgeon	50,0%
	c.	General surgery resident	0,6%
	d.	Orhopaedic surgery resident	9,0%
3.	In which hospital are you currently employed?		
		68 different hospitals	
4.	How many ankle fractures do you treat approximately in one year?		
	a.	0-10	17.4%
	b.	11-20	32.6%
	c.	21-30	18.0%
	d.	30 or more	32.0%

5.	What MCS cut-value is an indication for surgery for you in a healthy middle aged patient? (multiple answers possible)	
a.	MCS > 4mm	13.6%
b.	MCS > 4mm and MCS > superior clear space (SCS) + 1mm	45.5%
c.	MCS > 6mm	15.6%
d.	MCS > 6mm; conduct additional diagnostics between MCS 4-6mm	13.6%
e.	MCS > 6mm; conduct additional diagnostics b	4.6%
f.	Otherwise (open field)	22.7%
6.	In case you have chosen to conduct additional diagnostics, which one do you use? (multiple answers possible)	
a.	Repeat the mortise view after 1 week (in cast)	43.9%
b.	Gravity stress view	8.6%
c.	Weight bearing view (without cast)	16.6%
d.	Exorotation test	7.9%
e.	MRI	6.5%
f.	Ultrasound	0.7%
g.	Does not apply	19.4%
h.	Other diagnostic (open field)	20.9%
7.	Does fibula dislocation play a role for you in your decision to treat conservatively or surgically?	
a.	Yes	90.9%
b.	No	9.1%
8.	What value of the anterior-posterior fibula dislocation do you accept in treating conservatively?	
a.	2mm	53.7%
b.	3mm	20.6%
c.	4mm	6.6%
d.	Does not apply	0.00%

3

	e.	Otherwise (open field)	19.1%
9.	What value of the lateral fibula dislocation do you accept at the regular mortise view?		
	a.	2mm	69.1%
	b.	3mm	11.8%
	c.	4mm	4.4%
	d.	Otherwise (open field)	14.7%
10.	Do you prefer surgery when the fibula dislocation is your maximum value (question 8-9) in combination with a congruent anke joint?		
	a.	Yes	56.0%
	b.	No	44.0%
11.	How do you conservatively treat stable Weber B fractures in healthy patients?		
	a.	Cast	85.1%
	b.	Brace	1.4%
	c.	Walker	6.1%
	d.	Otherwise (open field)	7.4%
12.	How many weeks do you tell the patient to wear the cast, the brace or the walker?		
		Mean 5 weeks	
13.	After how many weeks do you allow the patient to walk (weight bearing)?		
		Mean 3 weeks	
14.	How do you start this weight bearing programme from the start?		
	a.	A constructive scheme in 4-6 weeks	27.7%
	b.	Direct guided by pain	68.2%
	c.	Otherwise	4.1%
15.	How do you treat an isolated Weber B fracture post surgery?		

a	Cast for 2 weeks; followed by non weight bearing mobilization in case of normal wound healing	26.4%
b.	Cast for 2 weeks; followed by walking cast in case of normal wound healing	23.0%
c.	Cast for 2 weeks; followed by direct weight bearing mobilization, without cast	3.4%

Questions 16-31 case example questions

Data were collected using SurveyMonkey (http://www.surveymonkey.com): an online data collection program.

Analysis

All data gathered from the online database were stated as frequencies and percentages.

Results

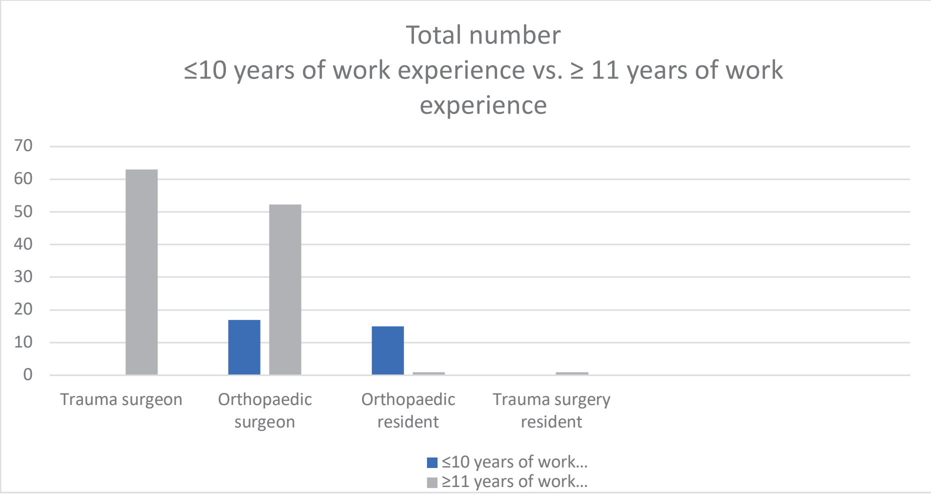
Surgeon characteristics

In total 178 (161 surgeons; 17 residents) recipients from 68 different hospitals returned the questionnaire (response rate 32%). Of these 77.1% had more than 10 years of experience treating ankle fractures. This differentiation is shown in graph 1. The majority (82.6%) treated more than 10 ankle fractures a year, of whom 32.0% treated more than 30 ankle fractures a year.

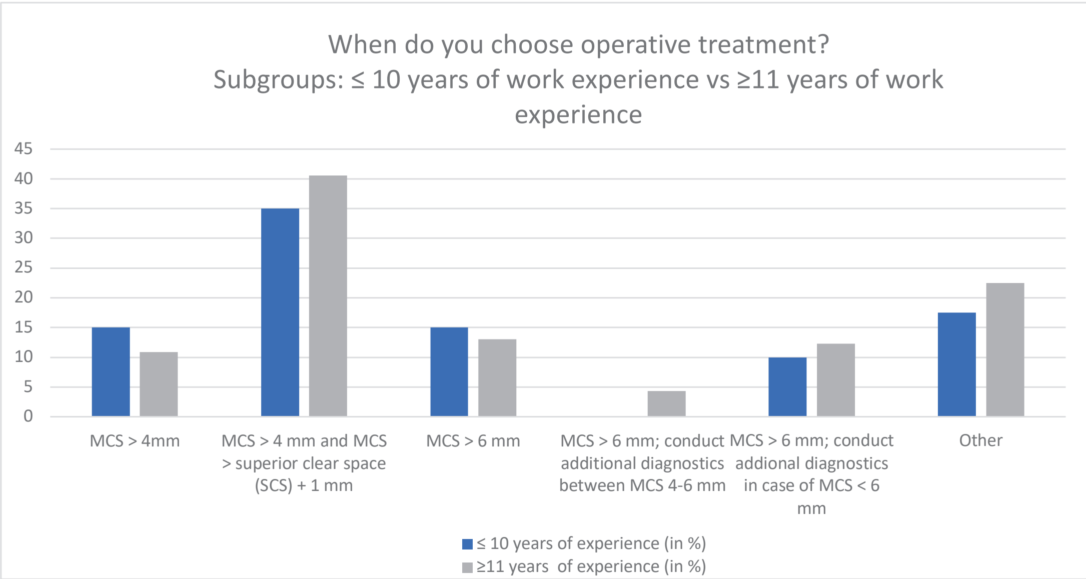
Treatment characteristics

Of the surgeons, 13.6% stated to treat ankle fractures with MCS > 4mm at regular mortise radiographs surgically, and 33.8% in case of a MCS > 6mm without any additional information about medial ligamentous injury (question 5). Almost half (45.5%) chose surgery in case of MCS > 4mm and MCS ≥ superior clear space (SCS) + 1mm. Moreover, 18% made use of additional diagnostics (43.8% repeat the mortise view (in cast) after one week, 15.9% CT scan, 16.6% weight bearing view, 8.6% gravity stress view, 7.9% exorotation radiograph, 6.5% MRI scan, 0.7% ultrasound) and 8% established their decision not based on the mortise radiograph. Table 1 shows all results. In graph 2, a subdivision based on years of experience is made between surgeons, comparing their criteria to treat surgically.

Graph 1. Total number of surgeons subdivided into years of experience



Graph 2. Criteria used for operative treatment; subdivided into years of experience.



A total of 90.9% of the surgeons declared fibular displacement critical in determining treatment. Regardless of medial injury, more than half of the surgeons (53.7%) allow a maximum of 2 mm lateral displacement with conservative treatment. On the lateral radiograph over 2 mm of fibular displacement led to surgical treatment by 69.1% of the surgeons, while 20.6% allow 3 mm and 6.6% allow 4 mm displacement. 14.7% do not use displacement on the lateral radiograph as a critical measurement in their treatment decision.

Furthermore, conservative treatment differs between the respondents. A stable B-type fracture in a healthy adult is treated with a cast (mean duration of 5 weeks) by 85.1% of the surgeons, with a walker by 6.0% and with a brace by 1.4%. The remaining 7.5% vary treatment depending on patients' characteristics and preference; often starting off with a cast for three weeks followed by a brace for a few more weeks.

Surgical after-treatment consists of direct non-weightbearing mobilization of the ankle (29.1%); non-weightbearing plaster for two weeks, followed by non-weightbearing mobilization (26.4%) or non-weightbearing plaster for two weeks, followed by a walking cast (23.0%). Unprotected weightbearing after two weeks in a non-weightbearing plaster is allowed by 3.4% of the surgeons; while 3.4% allow direct postoperative weightbearing without any form of immobilization.

It is noticeable that 58.4% of the surgeons was acquainted with the Dutch guideline 'Ankle fractures'. In 30.6% of the surgeons, the guideline did influence their diagnosis and treatment.

To illustrate, 56.9% of the respondents would treat the ankle fracture in case 1 of the Appendix surgically; 25.3% nonoperative; while the remaining 17.8% would use additional diagnostics. With the additional information of the gravity stress view in the next question 54.8% would treat surgically while 45.2% of the surgeons choose nonoperative treatment.

Opinions on surgical versus nonsurgical treatment of case 3 is divided in 43.7% versus 35.9% respectively, with the other 20.4% using additional diagnostics. Adding the weightbearing radiographs, 79.6% would treat conservatively.

Discussion

The aim of this study was to assess the variation in current use of diagnostics and management of type B fibular fractures among surgeons in the Netherlands.

Of the survey respondents, 13.6% stated to treat ankle fractures with MCS > 4mm at regular mortise radiographs surgically, and 33.8% in case of a MCS > 6mm without any additional information about medial ligamentous injury. Moreover, 18% made use of additional diagnostics (43.8% repeat the mortise view (in cast) after one week, 15.9% CT scan, 16.6% weight bearing view, 8.6% gravity stress view, 7.9% exorotation radiograph, 6.5% MRI scan, 0.7% ultrasound) and 8% established their decision not based on the mortise radiograph

A total of 90.9% of the surgeons declared fibular displacement critical in determining treatment and 58.4% of the surgeons was acquainted with the Dutch guideline 'Ankle fractures'.

In general, stable fractures can safely be treated conservatively, while for unstable fractures surgical treatment is advised. Therefore, it is important to differentiate accurately between stable and unstable ankle fractures. In stable fractures, functional outcome after surgical stabilization is not superior to nonsurgical treatment. Moreover, surgery is associated with significant costs and possible complications.[2, 9,18,19]

To evaluate stability of ankle fractures additional diagnostics like ultrasound, MRI scan or loaded stress test can be used. The MRI scan has met most requirements to distinguish between a stable and unstable ankle fracture, with a proven sensitivity of 80% and a specificity of 100% with surgical exploration as a reference.[16,17] Disadvantages are its high costs and limited availability.

Two studies reported 100% specificity and sensitivity for detecting a rupture of the deep deltoid ligament with ultrasound.[14,15]However, the number of patients in these studies was very small. Disadvantage is the fact that it is an operator-dependent examination.

Another radiographic tool is the manual stress radiograph in which the tibia is internally rotated to obtain a mortise view. This is followed by manual dorsiflexion and external rotation of the foot.[20] McConnel et al. studied the stress radiograph and found a significant difference in MCS from 3.63 mm in stable fractures vs. 5.69 mm in instable fractures ($p<0.0001$).[21]

Compared with the gravity stress radiograph the manual stress radiograph was equivalent in determining deltoid injury (mean MCS were 5.21 and 5.00 mm ($p=0.69$) on the manual and gravity stress radiographs, respectively). Disadvantages include the fact that the amount of force applied is not standardized and that it is considered a painful examination.[22]

During the gravity stress test the patient lies down horizontally with the medial side of the ankle up. The ankle and foot are free of any external support. The MCS widens if a complete deltoid rupture is present. Gill[22] and Schock[23] compared the external rotation test with the gravity stress radiograph. The MCS did not differ significantly between the gravity stress test and the external rotation test in these studies. The gravity stress test was, however, experienced less painful than the external rotation test. Another recently published study showed that compared to MRI, the gravity stress radiograph (with a threshold of MCS $\geq$ 6 mm) has a sensitivity of 100 and specificity of 91.7 in detecting deep deltoid rupture.[24]

Another diagnostic option is the weightbearing stress test. Within ten days after the initial trauma a barefoot weightbearing mortise radiograph is made to judge the MCS. Weber et al. found that in 90% of their cohort the fracture was considered stable based on the weightbearing radiograph and showed a mean AOFAS ankle-hindfoot score of 96.1 (range 86-100) with a mean follow-up of 5.2 years after conservative treatment.[11] Hoshino et al. investigated the weightbearing radiograph as well and demonstrated a mean AOFAS score of 92 at final follow-up (at 12 months)of conservatively treated patients[12] Hastie et al. studied the treatment of undisplaced malleolar fractures of uncertain stability in functional braces using weightbearing radiographs to judge stability. They found a risk of displacement of 0% thus providing support for the use of weightbearing radiographs to guide treatment of undisplaced ankle fractures.[13] Holmes et al. concluded that weightbearing radiographs are predictive of stability in Weber B ankle fractures. Their cohort was treated nonsurgically in case of a normal mortise relationship on weightbearing radiographs in addition to MCS $<$ 7 mm on gravity stress radiographs and showed a mean AOFAS of 92.3 and no MCS widening on subsequent weightbearing radiographs at 1 year follow-up. [25] One disadvantage of this radiograph is that because of the height of the x-ray tube, it is in some hospitals practically not possible to perform this radiograph without the patient standing on a little step. This can be a difficult exercise especially in elderly patients with a recent fracture.

Our results show that almost half of the respondents treat ankle fractures with MCS $>$ 4mm or MCS $>$ SCS + 1mm surgically without information on the integrity of the deltoid ligament. Recent literature has shown that in a fibular fracture with MCS $>$ 6mm, the deltoid ligament is still intact in 9%.[26] This percentage will increase with MCS 4-6mm. Surgical treatment might cause complications[18]and is costly. In the Netherlands a conservatively treated ankle fracture costs approximately 400 euros, compared to 3500 euros for surgical treatment; this amount lies between American and English costs [27,28]

In the cohort of this study, only a fifth of the surgeons perform one of the additional diagnostic tests in case of MCS 4-6mm. Of them, 43.9% repeat the mortise view one week after trauma, followed by the weight bearing test (16.6%) and the gravity stress test (8.6%). Only 6.5% of the surgeons make use of the MRI scan as additional tool.

Of the respondents, 90.9% do use fibular displacement as a critical determinant in the decision-making process. Of them 53.7% treat surgically with more than 2 mm lateral fibular displacement even if there is no high suspicion of medial injury. However, in isolated distal fibular fractures, the degree of fibular displacement is not directly associated with tibiotalar incongruity and ankle instability.[29-31] Hence, it has been proven that stable ankle fractures can safely be treated non-operatively with fibular displacement up to 5 mm.[32-36]
It is, thus, very noticeable that, without support for this in literature, 90.9% of the surgeons do use fibular displacement as a determinant in their treatment decision.

When treating ankle fractures nonoperatively, the majority of the surgeons choose cast as primary choice of treatment and only a very small percentage makes use of a brace. Known disadvantages of casting are joint stiffness, muscle wasting, lack of comfort, risk of thromboembolism and skin problems.[37,38]Compared to a cast, a brace or elastic support have proven to be more comfortable options for treating stable type B ankle fractures.[39,40,41]
We are aware that our study has several limitations. Despite many reminder emails, the response rate is still quite low (32%). Next to the low response rate, this study represents only a national cohort. However, to our knowledge, the Dutch standard of care is not substantially different from care in other high-developed countries and therefore we expect these results to be representative internationally.

Also, the guideline was published online in July 2017. The survey was sent to the surgeons in December of 2017. This relative short interval might have led to the guideline not being implemented in local hospitals yet as evidenced by the fact that just over half of the respondents was acquainted with the guideline. It would be interesting to repeat this study in a few years.

This is the first study to investigate the current use of additional diagnostics in excluding medial instability in a subset of ankle fractures. This nationwide survey investigates the treatment of a common fracture. In our country, with a high standard of care, surgeons do not make use of the latest insights in diagnostics and treatment. They make limited use of the guideline based on these insights.

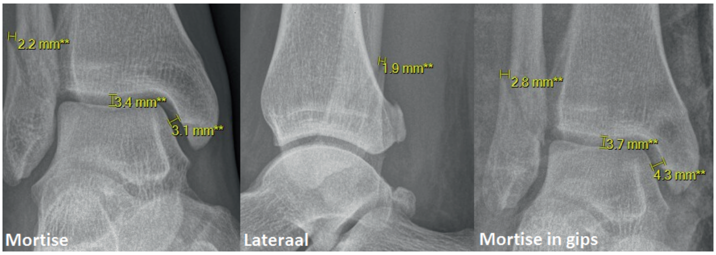
Conclusion

This study demonstrates the lack of uniform diagnostic and treatment strategies for type B ankle fractures. Despite the recent availability of a national guideline, common practice of Dutch surgeons has not changed accordingly. This leads to surgical overtreatment of stable type B ankle fractures with associated complications and costs.

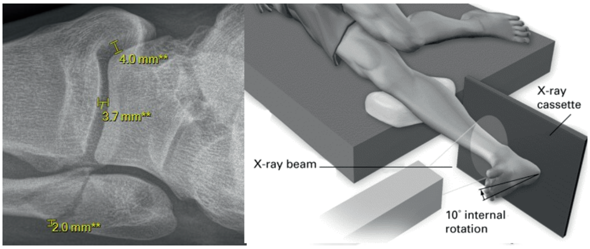
Appendix

Cases example questions

Case 1



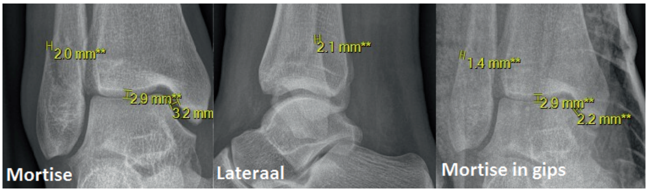
16.	How would you treat this ankle fracture of a 20 years old healthy man?	
a.	Operative	56.9%
b.	Conservative	25.3%
c.	The additional diagnostics chosen in question 6	17.8%



17. How would you treat this fracture with the additional information of this gravity stress view?

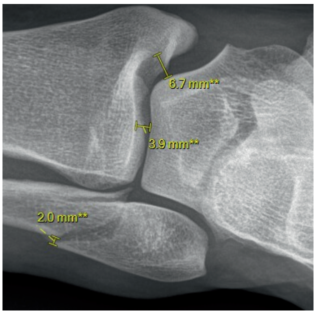
a.	Conservative	45.2%
b.	Operative	54.8%

Case 2



18. How would you treat this ankle fracture of a 26 years old healthy woman?

a.	Operative	49.0%
b.	Conservative	30.8%
c.	The additional diagnostics chosen in question 6	20.3%

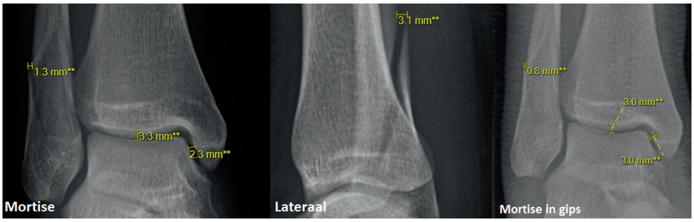


19. How would you treat this fracture with the additional information of this gravity stress view?

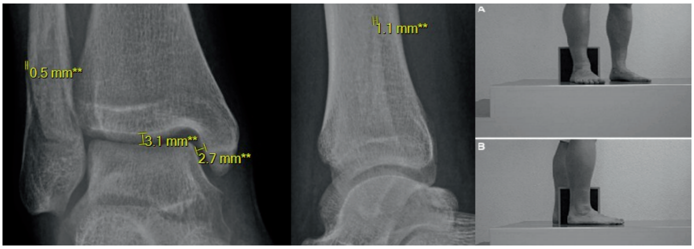
a.	Conservative	8.5%

b.	Operative	88.6%
c.	Otherwise	2.8%

Case 3

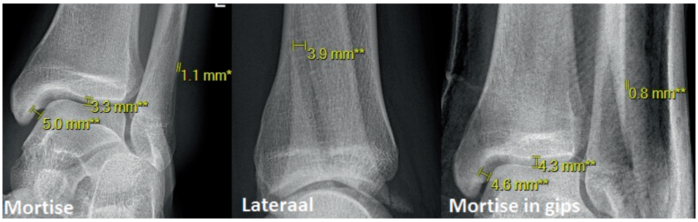


20.	How would you treat this ankle fracture of a 23 years old healthy woman?		
	a.	Operative	43.7%
	b.	Conservative	35.9%
	c.	The additional diagnostics chosen in question 6	20.4%



21.	How would you treat this fracture with the additional information of this weight-bearing view?		
	a.	Conservative	79.6%
	b.	Operative	20.4%

Case 4

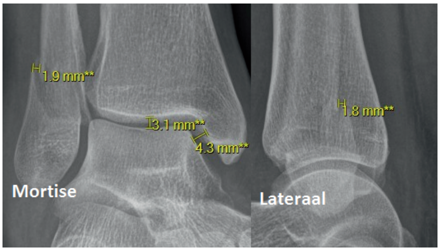


20.	How would you treat this ankle fracture of a 23 years old healthy woman?		
	a.	Operative	83.2%

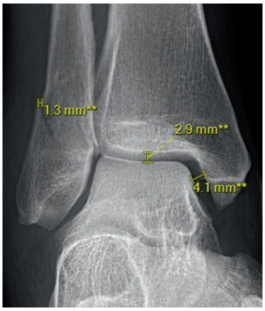
b.	Conservative	4.9%
c.	The additional diagnostics chosen in question 6	11.9%

23.	How would you treat this fracture with the additional information of this weight-bearing view?	
a.	Conservative	0.7%
b.	Operative	99.3%

Cases 5

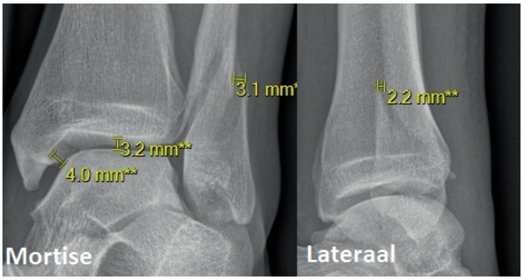


24.	How would you treat this ankle fracture of a 56 years old healthy man?	
a.	Operative	70.6%
b.	Conservative	9.1%
c.	The additional diagnostics chosen in question 6	20.3%

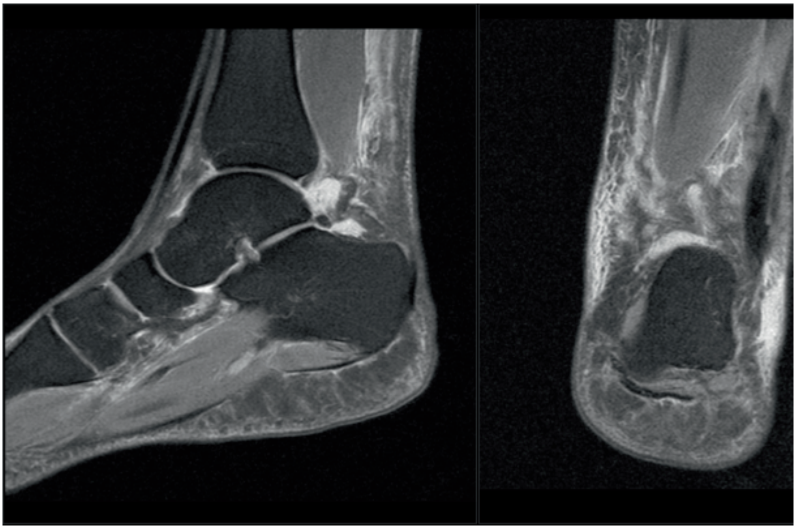


25.	How would you treat this fracture with the additional information of this weight-bearing view?	
a.	Conservative	39.4%
b.	Operative	60.6%

Case 6

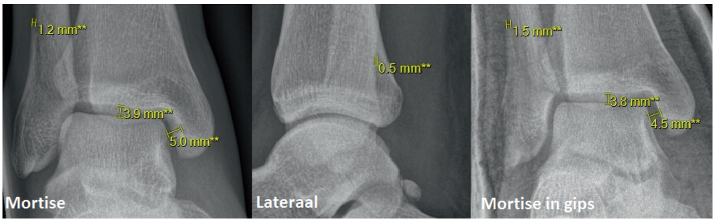


26.	How would you treat this ankle fracture of a 45 years old healthy woman?	
a.	Operative	87.2%
b.	Conservative	3.6%
c.	The additional diagnostics chosen in question 6	9.2%

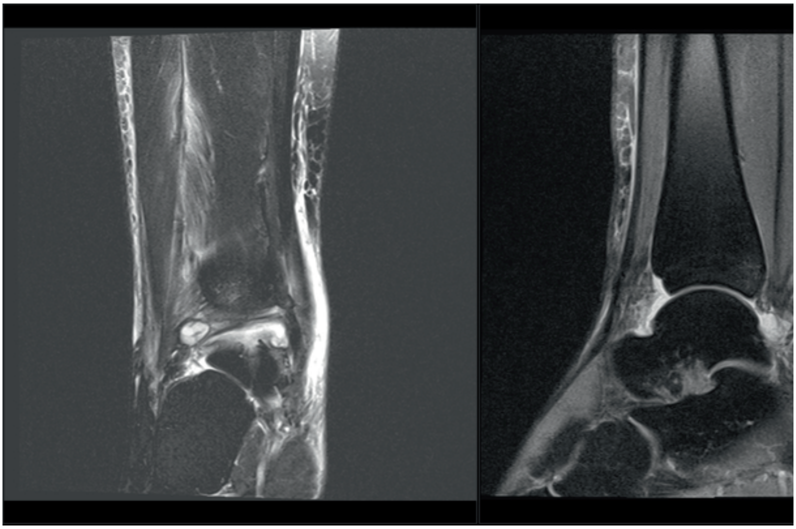


27	An MRI was made within a week, showing a fracture of the distal fibula, with the medial malleolus and malleolus tertius intact with a rupture of the deep ligament deltoid. How would you treat this fracture after having seen the additional MRI scan?	
a.	Conservative	12.1%
b.	Operative	87.9%

Case 7

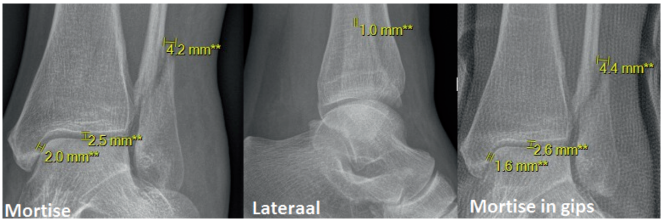


28.	How would you treat this ankle fracture of a 35 years old healthy man?	
a.	Operative	25.00%
b.	Conservative	47.8%
c.	The additional diagnostics chosen in question 6	27.2%

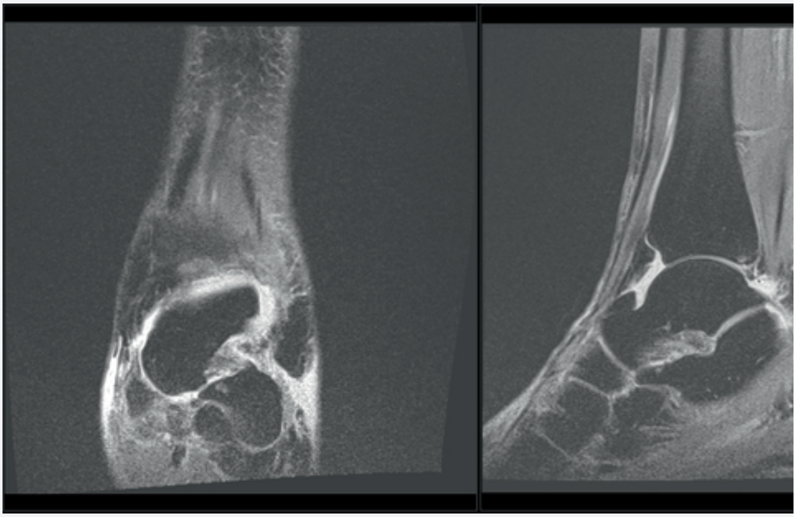


29	An MRI was made within a week, showing a fracture of the distal fibula, with the medial malleolus and malleolus tertius intact without a rupture of the deep ligament deltoid. How would you treat this fracture after having seen the additional MRI scan?	
a.	Conservative	82.6%
b.	Operative	17.4%

Case 8



30	How would you treat this ankle fracture of a 45 years old healthy man?	
a.	Operative	74.5%
b.	Conservative	13.9%
c.	The additional diagnostics chosen in question 6	11.7%



31	An MRI was made within a week, showing a fracture of the distal fibula with the medial malleolus and malleolus tertius intact without rupture of the deep ligament deltoid. How would you treat this fracture after having seen the additional MRI scan?	
a.	Conservative	32.4%
b.	Operative	67.7%

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4

Outcomes of treatment of foot and ankle fractures: which are important to the patient?

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Chapter 4. Outcomes of treatment of foot and ankle fractures: which are important to the patient?

Abstract

Background

Fractures of the ankle and foot are common and may be associated with long-term disabilities. Previous studies have examined function as an important patient-reported outcome, but little is known about patient expectations and satisfaction after their treatment. Aim of this study was to assess which outcomes are important to patients with an ankle or calcaneus fracture, and to assess which background and fracture characteristics might be associated with these outcomes.

Methods

A cross-sectional survey among 335 patients (response rate: 58%, n = 194) treated for a Weber B/C or calcaneus fracture, was performed. Patients were asked to identify and rank five treatment outcomes (out of 22 outcomes) that were the most important to them. The weighted importance of each outcome was calculated and averaged on group level. Stepwise multivariable regression analyses were performed to assess patient characteristics that are associated with patients' preferences for the most important outcomes.

Results

"Self-sufficiency" was reported most frequently (in 50/194; 25.8%) as the most important outcome, followed by "walking" and "complete recovery". The top five of most important outcomes differed somewhat between patient subgroups. The weighted importance of the outcomes was associated with various patient characteristics.

Conclusions

Self-sufficiency, walking and complete recovery are generally valued most by patients with an ankle or calcaneal fracture. The surgeon should be aware of this in order to manage any preoperative discrepancies between surgeons' and patients' expectations. Furthermore, evaluation of care should become more focussed on the outcome parameters that matter to the patient.

Introduction

Ankle fractures comprise 9% of all fractures, affecting mainly young men and older women. [1] The calcaneal fracture is less common (1-2% of all fractures).

Both ankle and calcaneal fractures are invalidating injuries. Nonoperative as well as operative treatment of these fractures are followed by long-term rehabilitation and potential disability when performing daily activities. [2,3] While functional outcomes are increasingly monitored using patient-reported outcome measures (PROMs), other outcomes that are relevant to the patient are still overlooked. During the rehabilitation process, patients experience physical and psychological problems such as pain, reduced muscle power, anxiety, frustration and even depression. They face, often unexpectedly, problems with recreational and leisure activities in their daily social life.[4,5] To be able to manage patients' expectations, it is important for the clinician to be aware of the most important problems that patients experience during their recovery.

The success of any medical intervention is often based on measurement of technical parameters.[6,7,8] However, other outcomes may be relevant for clinical decision making or for the evaluation of the outcome of fracture care, depending on the perspective that is taken.[9]From a socio-economical perspective, the trade-off between costs and benefits plays a prominent role.[10] From a clinical perspective, the focus is mainly on an optimal recovery and the prevention of complications. From the perspective of the patient, other outcomes may be important, such as quick return to work, the ultimate functional or cosmetic result or to be free from pain as soon as possible.

Little is known about what patients consider as relevant outcomes after fracture treatment [11] and if these preferences are related to specific patient or fracture characteristics.[9]

The aim of this study was to assess which outcomes are important to patients with a Weber B/C or calcaneus fracture, and to assess what factors are associated with these outcomes.

Study design and participants

The present cross-sectional study was conducted at two level one trauma centres in the Netherlands: the Leiden University Medical Centre (LUMC) in Leiden and the Haaglanden Medical Centre (HMC) in The Hague. The study was for both hospitals approved by the institutional medical ethics review board of the LUMC (protocol no. P16.138). All patients participating in each phase of the study provided written informed consent.

Questionnaire development

In October 2016, one author (TvdG)) performed semi-structured interviews with eight patients who had sustained an ankle or foot fracture between July 2015 and September 2016, to identify the important outcomes for patients with these types of fractures. Purposive sampling was applied to select patients with contrasting views from the above described population, taking into account the following characteristics of patients during the sampling process: gender (male/female), age (20-74 years), follow-up duration since fracture (8 weeks-1 year), type of fracture (Weber B/C or calcaneus) and work (student, paid work, retired). The eight interviews were audiotaped and word for word transcribed. They were analysed using open coding by two independent authors (TvdG, PK). In the last two interviews no new information was obtained, so that data saturation was considered to be reached and no more interviews were held. A total of 22 outcomes relevant to the patients were identified during the interviews.

The questionnaire was developed based on the results of the interviews, and consisted of three parts. The first part focused on the characteristics of the patient: age, gender, comorbidities, educational level (low: no education, lower education and preparatory education; middle: secondary education and intermediate education; high: senior general secondary and pre-university education, university), support at home (no: living alone and living alone with child(ren); yes: living with partner, living with partner and child(ren) and living with others) and social participation (yes: being a student, having paid work or voluntary work; no: unemployed, disabled or retired).

The second part included questions about the characteristics of the fracture (fracture type, treatment, affected side) and the number of sport hours per week before the fracture took place. A visual analogue scale (VAS) was included to score the current pain level experienced in rest and in movement on a scale from 0 (no pain) to 10 (worst pain imaginable). Furthermore, patients were asked to report their use of pain medication related to pain due to the fracture.

The third part consisted of two questions covering the 22 identified relevant outcomes. In the first question, patients were asked to select the five out of 22 outcomes that were most important to them. In the second question, they were asked to rank these selected five outcomes from most (1) to least (5) important.

Survey

The questionnaire was sent to a consecutive cohort selected from the trauma registries of the two participating trauma centres. Patients aged ≥ 18 years and diagnosed with a Weber B/C or calcaneus fracture in the period July 2015 till September 2016 were eligible for inclusion (n=338). One reminder was sent after two weeks to the patients who had not responded. Patients who had not responded to the first reminder were contacted by phone after two weeks.

Analysis

All received questionnaires were included in the analysis. The questionnaires were filled in almost completely, with no more than 2% of the answers missing in total. Participant characteristics and outcomes were reported using descriptive statistics. To calculate the weighted importance of every outcome in the "top five" for each patient, we assigned a score of 1 to the outcome that was reported as most important by the patient; a score of 0.8 to the outcome in second place; a score of 0.6 to the outcome in third place; 0.4 to the outcome in fourth place and, a score of 0.2 to fifth, least important outcome. The outcomes not listed in the top 5 were assigned a score of 0. To identify the expected outcomes for the total group of patients, the average score for each outcome in the questionnaire was calculated. For specific subgroups a sub-analysis was performed: Weber B/C fractures or calcaneus fracture; age <70 or age ≥ 70 years; social participation yes or no; conservative treatment or operative treatment; male or female. Stepwise multi-variable linear regression analyses were performed to assess which background and fracture characteristics were associated with the patient reported outcomes. Potential factors of influence included patient (gender, age, comorbidity, sport, educational level, societal participation and support at home) and fracture (pain during rest, type of fracture and type of treatment) characteristics, as well as the length of follow-up since fracture (time between date of filling in the questionnaire and date of the trauma). Pain in motion was not included due to the high correlation with pain in rest.

The questionnaire were analysed using IBM SPSS Statistics for Windows, version 23.0. The level of statistical significance was set at $p < 0.05$.

Results

Of the 338 recruited patients, two patients had died and one patient had difficulties with walking for a different reason. As a result, they were excluded. 194 of the remaining 335 (58%) patients completed the questionnaire. The reason for non-response was not verified. In the non-respondent group, 77/141 patients (54,6%) were male and the mean age was 41.7 years.

In the respondent group, 104/194 patients (53.6%) were male and the mean age was 51.6 years. Mean followup time since fracture of these patients was 272,5 days (SD 109). 116/170 (68,6%) of the patients with a Weber B/C fracture were operated, while in the calcaneus fracture group only 5/24 (20,8%) were treated surgically. Mean pain scores in motion, either loaded or unloaded, in patients with a Weber B/C and in those with a calcaneus fracture were respectively 2.3 and 3.7. Patient characteristics of all included patients are presented in Table 1.

Table 1. Patient characteristics of the responding group, by fracture type.

Patient characteristic	Weber B/C fracture n=170	Calcaneus fracture n=24	Total n=194
Gender, n (%)			
Male	89 (52.4)	15 (62.5)	104 (53.6)
Female	81 (47.6)	9 (37.7)	90 (46.4)
Age (years), mean (SD)	51.6 (17.4)	50.9 (15.4)	51.5 (17.2)
Comorbidity, n (%)			
Yes	58 (34.1)	9 (37.5)	67 (34.5)
No	112 (65.9)	15 (62.5)	127 (65.5)
Weekly hours of sport, mean (SD)	3.4 (4.0)	3.5 (3.8)	3.4 (3.9)
Educational level, n (%)			
Low	32 (18.9)	5 (20.8)	37 (19.2)
Middle	49 (29.0)	10 (41.7)	59 (30.6)
High	88 (52.1)	9 (37.5)	97 (50.3)
Societal participation, n (%)			
Yes	111 (65.7)	11 (47.8)	123 (64.1)
No	58 (34.3)	12 (52.2)	67 (35.9)
Support at home, n (%)			
Yes	117 (68.8)	16 (66.7)	133 (68.6)
No	53 (31.2)	8 (33.3)	61 (31.4)
Pain score, mean (SD)			
In rest	1.3 (1.8)	1.8 (2.3)	1.4 (1.9)
In motion	2.3 (2.3)	3.7 (2.7)	2.5 (2.4)

Pain medication, n (%)			
Yes	26 (15.3)	4 (16.7)	30 (15.5)
No	144 (84.7)	20 (83.3)	164 (84.5)
Treatment, n (%)			
Operative	116 (68.6)	5 (20.8)	121 (62.7)
Conservative	53 (31.4)	19 (79.2)	72 (37.3)
Length of followup since fracture (days), mean (SD)	273.9 (106.8)	261.6 (126.8)	272.5 (109.0)
Hospital, n (%)			
University hospital	44 (25.9)	13 (54.2)	57 (29.4)
Non-university teaching hospital	126 (74.1)	11 (45.8)	137 (70.6)

4

Table 2 shows the 22 outcomes listed in the questionnaire, with the mean weighted scores for importance per outcome for the total group and separately for the patients with an ankle or calcaneus fracture. 'Self-sufficiency' was reported most frequently (by 50/194 patients, 25,8%) as the most important outcome (with mean weighted score for importance of 0.44), followed by "walking" and "complete recovery" (mean score 0.28), "being independent of other people" (mean score 0.24) and "self-reliance outside of the house" (mean 0.21). For patients with calcaneus fracture, the top five was similar, although the ranking was different. In the ankle fracture group, sport (mean score 0.20) was listed in the top five instead of self-reliance outside the house.

Table 2. The 22 identified patient-reported outcomes, ranked by the patients based on importance

	Weighted importance (top-five ranking)		
Outcomes	Total group (n=194)	Weber B/C (n=170)	Calcaneus (n=24)
A. Self-sufficiency (showering, going to the toilet, cooking)	0.44 (1)	0.44 (1)	0.43 (2)
B. Walking	0.28 (2)	0.25 (3)	0.47 (1)
C. Complete recovery	0.28 (3)	0.27 (2)	0.33 (3)
D. Being independent of other people	0.24 (4)	0.24 (4)	0.21 (5)
E. Self-reliance outside the house (shopping, going for a walk, going on vacation)	0.21 (5)	0.20	0.30 (4)
F. Sport	0.19	0.20 (5)	0.11

G. Performing household chores (vacuuming, washing, cleaning)	0.18	0.19	0.10
H. Driving	0.15	0.15	0.15
I. Going to work	0.14	0.14	0.11
J. Having no pain or irritating feeling in the ankle or foot	0.09	0.10	0.07
K. Having no fear of falling	0.09	0.10	0.02
L. Sleeping well at night	0.08	0.08	0.06
M. Knowing what to expect of my recovery	0.07	0.05	0.18
N. Bicycling	0.07	0.07	0.07
O. Having no additional complains (backache, neck pain or pain in the other leg)	0.06	0.06	0.08
P. Having a stable weight	0.06	0.06	0.03
Q. Posing no burden for others	0.06	0.06	0.04
R. Having social interaction, seeing family and friends	0.05	0.06	0.00
S. Staying physically fit	0.05	0.05	0.03
T. Not being physically tired	0.04	0.04	0.03
U. Exercise hobbies	0.03	0.03	0.04
V. Having no fear of undertaking activities	0.03	0.03	0.02

Table 3 shows that the top five outcomes relevant to the patient varied only slightly between patient subgroups. Again, the outcome 'self-sufficiency' was the most important outcome for each subgroup except for the calcaneus fracture group; walking was the most important outcome for these patients. In the group of responders without societal participation, 'performing household chores' was listed in third place (mean score 0.27). And for the male responders 'driving' and 'sport' were important and ranked equally in fourth place (mean score 0.21).

Table 3. Weighted scores for importance of the outcomes reported by all patients and by subgroups.

	N	1st place	2nd place	3rd place	4th place	5th place
Total Group	194	A (0.44)	B (0.28)	C (0.28)	D (0.24)	E (0.21)
Fracture: Weber B/C	170	A (0.44)	C (0.27)	B (0.25)	D (0.24)	F (0.20)
Fracture: calcaneus	24	B (0.47)	A (0.43)	C (0.33)	E (0.30)	D (0.21)
Age < 70	162	A (0.42)	C (0.30)	B (0.28)	D (0.24)	F (0.21)
Age ≥ 70	32	A (0.57)	B (0.28)	D (0.25)	E (0.23)	G (0.22)
Societal participation: yes	123	A (0.40)	C (0.33)	B (0.26)	D (0.26)	F (0.24)
Societal participation: no	69	A (0.50)	B (0.32)	G (0.27)	E (0.22)	D (0.21)
Treatment: conservative	72	A (0.49)	B (0.32)	E (0.25)	C (0.24)	D (0.22)
Treatment: operative	121	A (0.41)	C (0.29)	B (0.25)	D (0.25)	F (0.21)
Gender: male	104	A (0.45)	B (0.28)	C (0.28)	H/F (0.21)	E (0.20)
Gender: female	90	A (0.43)	D (0.31)	C (0.27)	B (0.27)	E (0.22)

A= Self-sufficiency; B=Walking; C=Complete recovery; D=Being independent of other people; E=Self-reliance outside the house; F=Sport; G=Performing household chores; H=Driving.

4

The results of the multivariable analyses are shown in table 4. Patients who exercised more regularly, ranked the outcome self-sufficiency as less important (regression coefficient B=-0.016, p=0.04). Patients participating in society considered the complete recovery outcome more important than patients who did not participate in society (B=0.140, p=0.03). Being independent of other people was considered more important by female patients (B=0.157, p = 0.003), and less important by patients with a longer follow-up (B=-0.001, p=0.02) and patients with higher pain scores in rest (B=-0.029, p=0.03). Patients with support at home ranked self-reliance outside as less important (B=-0.101, p=0.03). Sport was ranked as less important by older patients (B=-0.003, p=0.03) whereas patients who exercised more regularly ranked the outcome sport as more important (B=0.021, p<0.0001).

Table 4. Patient and fracture characteristics, related to the level of importance, that patients assign to outcomes after foot and ankle fractures, expressed as linear regression coefficient (beta) and corresponding 95% confidence interval (CI).

Outcome	Characteristic	Beta	95% CI	*p value*
A. Self-sufficiency				
	Sport (hours)	-0.016	-0.032;-0.001	0.037
B. Walking				
	Calcaneus vs Weber B/C	-0.253	-0.422;-0.083	0.004
C. Complete recovery				
	Societal participation	0.140	0.017;0.264	0.026
D. Independent of other people				
	Female gender	0.157	0.055;0.259	0.003
	Length of followup since fracture	-0.001	-0.001;-0.0002	0.015
	Pain in rest	-0.029	-0.056;-0.002	0.033
E. Self-reliance outside				
	Support at home	-0.101	-0.192;-0.010	0.030
F. Sport				
	Sport (hours)	0.021	0.011;0.032	<0.0001
	Age (years)	-0.003	-0.005;-0.0004	0.025

Discussion

This study reveals the outcome parameters after treatment for patients with a Weber B/C or calcaneus fracture that are important to patients. It also addresses factors that may be of influence on the importance that patients assign to those outcomes. Most of the outcomes reported as important by patients reflect aspects of the self-reliance of the patient. The other important outcomes for patients, “walking”, “complete recovery” and “sport”, reflect aspects of physical functionality. Between subgroups of patients there were some differences regarding the top five of most important outcomes. For instance, male responders scored the outcome “driving” as important. However, the outcome “self-sufficiency” still was the most important outcome in most subgroups. Patient characteristics, like age or gender, have little impact on the ranking of outcomes by patients so that almost the same outcomes are important for all patient subgroups. For the most important outcomes there were factors associated with the level of importance.

This study demonstrates that "self-sufficiency" is more important to patients, whereas the clinical perspective is focused on an optimal recovery and the prevention of complications. One other study [3] has also investigated outcomes important to patients with ankle fractures. This study, however, had a list of seven patient-reported outcomes, like "complete functioning", having no pain", "complete mobility of my ankle", "having no complications" and "time till recovery", from which patients chose their top three of most important outcomes. The current study had a list of twenty-two outcomes, conducted by the patients themselves, from which patients chose their own top five. With more (self-conducted) options for the patient to choose from, the outcome will be more extensive and possibly more reliable.

"Self-sufficiency" was the most important outcome in our study, whereas the study of the Dutch Patient Federation [12] found "optimal functioning" as most important outcome. Outcomes including "complete recovery" were listed in the top three of this study. In the study of the Dutch Patient Federation the mean follow-up time since fracture was between two and three years, which may be of influence for the outcome "optimal functioning" on the first place. Furthermore, our study population - with 194 completed questionnaires - is much larger than the 97 respondents who participated in the previous study. The current study gives more detailed information on the most important outcomes for patients and reveals new information of factors influencing these preferences of patients.

This study has some limitations. First, the number of patients with a calcaneus fracture was small, which made it difficult to evaluate whether the outcomes for the patients with a calcaneus fracture differed from those with an ankle fracture. However, the rehabilitation process of Weber B/C and calcaneus patients is roughly the same [1,4,12] which renders it less likely that relevant differences in outcomes between these fracture groups do exist. Second, the use of a paper-based questionnaire may have induced response bias. Elderly people are more likely to take the trouble to post the questionnaire in a mailbox because they generally have more time than younger people. Indeed, the mean age of patients who filled out the questionnaire (51.6 years) was higher than the mean age of patients who did not respond (41.7 years). Furthermore, patients who experience more pain and discomfort may be more likely to respond, which may also have induced response bias.

A strength of this study is that the outcomes used in the questionnaire were identified during interviews with patients who were diagnosed with a Weber B/C or calcaneus fracture, and who differed in follow-up duration since fracture, age, gender and type of work. This ensures that the list of outcomes in the questionnaire was not based on the beliefs of the researchers, but based on the opinion of patients themselves. Consequently, a rather complete set of outcomes covering various aspects of both physical and mental well being were included in the questionnaire. Another strength of this study is the high response rate (58%), which enables us to draw firm conclusions. Furthermore, this study is one of the first that investigated the importance of treatment outcomes in patients with a Weber B/C or calcaneus fracture, and the first study that gives insight in possible factors influencing outcomes that are perceived as important by patients.

Understanding what is important for patients can be helpful in daily practice. For instance, clinicians can improve the self-reliance of their patients by discussing the limitations that patients are to expect during their recovery and by giving advice and information about aids that may help them to be less dependent on others in and around the house, especially during the early period of recovery and immobilization. The chosen outcomes are dependent of various factors (gender, age, hours of exercise) and therefore it remains important to realise that every patient is different and that the clinician must take into account the individual patient's preferences.

In conclusion, this study revealed that there are two groups of important outcomes as indicated by the patients with a Weber B/C or calcaneus fracture: "self-reliance" and "complete recovery". Furthermore, this study identified multiple patient related factors, like sport activities, female sex, type of fracture and support at home, that influence the level of relevance of the outcomes. The surgeon should be aware of these phenomena in order to manage any preoperative discrepancies between surgeons' and patients' expectations. Furthermore, evaluation of care should be focused on the outcome parameters that matter to the individual patient.

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PART II

The search for new diagnostics

5

The additional value of gravity stress radiographs in predicting deep deltoid ligament integrity in supination external rotation ankle fractures

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Chapter 5 The additional value of gravity stress radiographs in predicting deep deltoid ligament integrity in supination external rotation ankle fractures

Abstract

Objectives

Goal of this study was to investigate whether a gravity stress radiograph is beneficial in determining instability in Supination-External rotation (SER)-type ankle fractures without a medial fracture.

Methods

39 patients with a SER-type ankle fracture without a medial or posterior fracture and medial clear space (MCS)$<$6mm at regular mortise view were included. A gravity stress radiograph and Magnetic Resonance imaging (MRI)-scan were made. The MCS measurements of the regular and gravity stress radiographs were compared with the MRI findings (set as reference standard) to determine the sensitivity, specificity, and positive (PPV) and negative (NPV) predictive values as indication for a complete deltoid ligament rupture.

Results

Mean MCS at regular mortise views was 3.11 (range: 1.73-5.93) mm, compared to 4.54 (range: 2.33-10.40) mm at gravity stress radiographs. With MCS$\geq$4mm as threshold for predicting a complete rupture at regular ankle mortise views the sensitivity was 66.7, specificity 91.7, PPV 40.0 and NPV 97.0. Gravity stress radiographs with MCS$\geq$6mm as threshold led to a sensitivity of 100, specificity 91.7, PPV 50.0 and NPV 100.

Conclusion

Gravity stress radiographs have more discriminative ability for diagnosing SER-type fractures with or without a complete deltoid ligament tear than regular ankle mortise views.

Introduction

Supination-external rotation (Lauge-Hansen SER) Weber B-type ankle fractures are among the most common injuries seen at the Emergency Department. [1] The decision whether to operate or treat conservatively is principally based on the stability of the ankle. The syndesmosis of the ankle, the tibiofibular ligaments and interosseous membrane, are stabilisers of the ankle. However, the deep deltoid ligament (DDL) is, together with the medial malleolus, the main stabiliser of the ankle joint during axial load. [2] Fibular fractures without medial injury are considered stable and most surgeons advocate conservative treatment, because nonoperative treatments have good clinical outcomes. [3-5] On the other hand, a bimalleolar or a bimalleolar equivalent fracture, i.e. a fibular fracture with additional deep deltoid ligament rupture, will be unstable due to the incompetent lateral and medial restraints of the ankle and requires operative treatment. [1,6]

Accurate exclusion of medial injury in a SER ankle injury with an isolated lateral malleolus fracture is of great clinical importance, because this information confirms the choice of safe conservative management.

Widening of the medial clear space (MCS) at a mortise X-ray view is used to predict and indicate a DDL rupture. However, the latter might lead to surgical overtreatment of stable ankle fractures. [7]

According to several authors, magnetic resonance imaging (MRI) is considered the reference standard for detecting DDL rupture. [8-10] However, recognized disadvantages of MRI are its availability and costs. An alternative tool for MRI is the gravity stress radiograph. In this examination, a radiograph is performed anteroposteriorly with the leg horizontal (medial side up) without ankle support. A complete deltoid rupture in the absence of a talar shift on the conventional mortise view may thus be detected by manifest widening of the MCS on this additional radiograph. To our knowledge, so far no research has reported the diagnostic accuracy of the gravity stress radiograph compared with the results of MRI. [3,11-13]

The purpose of the current study is to examine the additional diagnostic value of the gravity stress radiograph in determining deltoid ligament disruption in ankle fractures. The sensitivity and specificity of this test will be compared with findings on MRI, which is used as the reference standard.

Patients & Methods

All patients, aged between 18 and 70 years, who were admitted to the Emergency Department of our centre between May 2014 and November 2015 and diagnosed with a supination-external rotation (SER) Weber B-type fibular fracture (unimalleolar) were informed and received an information guide about the study. Patients with a widening of the MCS ≥ 6mm on conventional mortise view were excluded from the study and received operative treatment according to the local protocol. Also, patients with any contraindication to undergo MRI, mentally incompetent patients or patients with no mastery of our national language were excluded from the study. After informed consent to participate in the study, MRI protocol of the ankle and a gravity stress radiograph (by an instructed radiology technician) were made within one week of the initial injury. All patients were treated with a cast in the period in between. The decision whether to operate or treat conservatively was made by the attending surgeon. The follow-up of all patients took place with predefined intervals.

The gravity stress radiograph was performed with the patient in the lateral decubitus position with the injured ankle dependent off the end of the table. Directly after having positioned the patient, the radiograph can be made by the technician. To approach a standard radiological mortise view an internal rotation of the tibia of approximately 10° was required. Figure 1 illustrates acquisition of a gravity stress radiograph. (fig 1) There was no need for local anaesthetic agents in any of the patients undergoing this examination.

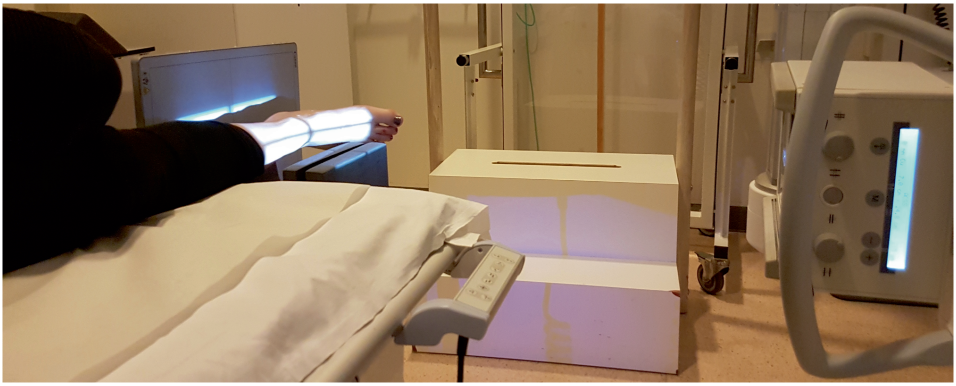


Figure 1. The optimal positioning to obtain a gravity view. The leg was positioned horizontally with the medial side up. The ankle and foot were free of any external support.

Magnetic resonance imaging was performed on two clinical 1,5-Tesla magnetic resonance units (Magnetom Avanto and Magnetom Symphony, Siemens Healthcare, Erlangen, Germany).
The patients were examined in the supine position with the injured extremity placed in an extremity coil in a neutral position without a cast.
The performed MRI protocol consisted of 3-4 mm-thick three-plane proton-density weighted turbo spin-echo fat suppressed images, 3-4 mm-thick sagittal and transaxial T1-weighted spin-echo images and 3 mm-thick coronal T2-weighted turbo spin-echo fat suppressed images. (table 1)

	PD TSE fs sag	**PD TSE fs cor**	**PD TSE fs tra**	**T1W SE sag**	**T1W SE tra**	**T2W TSE fs cor**
Voxel (mm)	0.5x0.5x3	0,4x0,4x3	0,4x0,4x4	0,7x0,5x3	0,8x0,4x4	0,5x0,3x3
Slices (mm)	22x distance 20%	27x distance 25%	27x distance 20%	22x distance 20%	26x distance 20%	28x distance 20%
FOV (mm)	160	140	140	160	140	140
FOV phase	100	100	100	100	100	100
TR (msec)	2380	2920	2990	504	583	2530
TE (msec)	33	33	33	14	14	70
NSA	2	2	2	1	1	2
phase enc	AP	RL	AP	AP	AP	RL
turbofacto r	7	7	7	1	1	15

Table 1. Ankle MRI protocol at 1,5 T.
Note: Protocols are performed at 1,5-Tesla magnetic resonance units (Magnetom Avanto and Magnetom Symphony, Siemens Healthcare, Erlangen, Germany). FOV= field of view, FS = fat saturation, NSA = number of signals acquired, PD = proton density-weighted, TE = echo time, TR = repetition time, TSE = Turbo spin-echo.

The MCS was measured as a horizontal line drawn from the medial talar surface at the level of the talar dome to the lateral surface of the medial malleolus (figure 2). It was measured by using a digital calibrated ruler in Zillion PACS Viewer by Rogan, Delft. The cut-off value for widening of the MCS for the conventional mortise view was ≥4mm, and 5 and 6mm for the gravity stress radiograph. The superior clear space (SCS) was measured as the vertical distance of the lateral tibiotalar articulation.

Figure 2. The medial clear space was measured as a perpendicular
line from the medial talar surface to the lateral surface of the medial malleolus

The DDL was optimally interpretable on the coronal proton-density images and was graded as intact, oedematous, partially torn or completely torn. The intact DDL was isointense with continuous fibres with a striated appearance. In case of an oedematous ligament there was a T2 hyperintense signal intensity with an intact striated appearance. The partially torn ligament showed an irregular contour and partially disrupted fibres with a T2 hyperintense signal intensity caused by oedema. The complete torn ligament (all 4 parts) showed a complete discontinuity of the fibres and a T2 hyperintense signal intensity due to a full thickness defect of the DDL.

The MCS was measured independently on both the regular mortise view and the gravity stress radiograph by 2 trauma surgeons and a musculoskeletal radiologist, who were unaware of the clinical findings. The mean results were compared with the results of the MRI, which were retrospectively and scored by consensus interpretation (by a trained musculoskeletal radiologist with over four years experience and a resident in his fifth year) with particular attention to the

integrity of the deep deltoid ligament. According to the general classification, the integrity of the deep deltoid ligament on MRI was categorized as: normal, intact but presence of oedema, partial rupture, and total rupture. [14]
With an expected specificity of the gravity stress radiograph of 0.9, a statistical power analysis showed that a size of 33 patients would be able to detect a significant difference between the two types of radiographs.

Using cross-tabs, the sensitivity, specificity, negative predictive value and positive predictive value of both the regular mortise and gravity stress mortise views were calculated. Statistical analyses were performed using Statistical Package for the Social Sciences (SPSS), version 24.0.

Approval of the regional Medical Ethical Committee was obtained for this study.

Results
A total of 39 patients fulfilled the inclusion and exclusion criteria for this study. The mean MCS on the regular mortise view was 3.11 ± 0.84 mm (1.73-5.93), while on the gravity stress radiograph the mean MCS widening was 4.54 ± 1.56 mm (2.33-10.40). The sample represented normal distribution.
Classifying the MCS into groups, the conventional mortise view showed a MCS widening of ≤3mm in 21 patients (53.8%), a widening in between 3-3.5mm in 7 patients (17.9%), a widening of 3.5-4mm in 6 patients (15.4%) and a widening of ≥4mm in 5 patients (12.8%).
The gravity stress radiograph group was divided in 28 patients (72%) with a MCS widening of ≤5mm, 6 patients (15.4%) with a MCS widening of between 5-6mm and 5 patients (12.8%) with a MCS widening of ≥6mm.
According to MRI, made within one week after initial trauma, in 20 patients (51.3%) the deltoid ligament was valued normal, in 12 patients (33.3%) there was oedema, 4 patients (7.7%) had a partially ruptured ligament and in 3 patients (7.7%) the ligament was completely ruptured. Moreover, the different ligaments of the syndesmosis, the anterior inferior tibiofibular ligament (AITFL) and the posterior inferior tibiofibular ligament (PITFL) and a fracture of the posterior malleolus were also analysed. In all but one patient, the AITFL was completely ruptured. These results are shown in table 2.

Table 2 Results of the MRI analyses

Patient	Regular mortise			Gravity mortise	MRI				Surgery	
	MCS	SCS	Fibular disloca-tion	MCS	AITFL	PITFL	Posterior fracture	Deltoid ligament	Yes/no	Surgery type
1	1.7	2.6	2.3	2.3	3	1	No	1	No	
2	2.0	2.9	1.6	2.8	3	3	No	1	No	
3	2.1	2.2	0	3.3	1	1	Yes	1	No	
4	2.2	2.4	0	2.8	3	1	Yes	1	No	
5	2.2	2.5	4.2	3.4	3	1	No	1	No	
6	2.4	2.6	1.4	3.6	3	1	No	1	No	
7	2.4	3.4	4	3.6	3	1	No	1	No	
8	2.5	3.9	1.2	3.6	3	1	No	2	No	
9	2.5	2.5	1	4.0	3	1	No	1	No	
10	2.5	3.0	1.3	5.1	3	1	No	1	No	
11	2.5	2.9	0	2.6	3	2	Yes	2	No	
12	2.5	3.4	1.9	5.5	3	3	Yes	1	No	
13	2.6	3.1	2.2	5.0	3	1	No	1	No	
14	2.6	3.5	1.9	4.6	3	1	No	1	No	
15	2.6	3.7	2.3	4.0	3	1	No	1	No	
16	2.7	3.2	2.2	3.4	3	3	No	1	No	
17	2.7	3.5	0.7	4.4	3	1	Yes	1	No	
18	2.8	2.8	1.3	3.2	3	1	No	1	No	
19	2.9	2.8	0	4.0	3	1	Yes	1	No	
20	3.0	3.3	1.5	2.8	3	1	No	1	Yes	lag screw with neutralisation plate
21	3.0	3.1	2.4	4.5	3	1	Yes	2	No	
22	3.1	3.2	1.5	4.3	3	2	No	1	No	
23	3.1	3.4	0	4.7	3	1	Yes	1	No	
24	3.1	3.0	3.2	6.3	3	3	Yes	1	Yes	lag screw with neutralisation plate
25	3.2	3.1	0	3.3	3	1	Yes	1	No	
26	3.2	2.8	1	4.7	3	2	No	1	No	
27	3.4	3.3	2.7	5.3	3	1	Yes	1	Yes	neutralisation plate
28	3.4	3.4	0	4.3	3	1	No	1	No	
29	3.6	3.4	2	6.0	3	1	No	3	Yes	lag screw with neutralisation plate
30	3.7	3.6	1.2	4.7	3	1	No	1	No	
31	3.7	3.4	1.7	5.7	3	3	No	1	Yes	2 lagscrews
32	3.8	2.7	2	4.0	3	1	No	1	No	
33	3.8	3.1	2	4.2	3	1	No	1	No	
34	3.9	3.6	0	4.4	3	1	No	1	No	
35	4.1	4.3	0	10.4	3	3	Yes	2	Yes	neutralisation plate
36	4.4	3.4	5	7.2	3	1	No	3	Yes	lag screw with neutralisation plate
37	4.7	4.4	3.8	7.0	3	1	No	1	Yes	lag screw with neutralisation plate
38	5.1	3.1	1.3	5.9	3	1	Yes	1	No	
39	5.9	3.8	3.8	7.1	3	1	No	1	Yes	lag screw with neutralisation plate

Ligament scoring: 1: intact; 2: partial rupture; 3: complete rupture

MCS medial clear space, *AITFL* anterior inferior tibiofibular ligament, *PITFL* posterior inferior tibiofibular ligament

An absolute MCS positive cut-off value of ≥4mm on the conventional mortise X-ray was 66.7% sensitive and 91.7% specific for the diagnosis of a deep deltoid ligament disruption, corresponding to a positive and negative predictive value of respectively 40% and 97%.

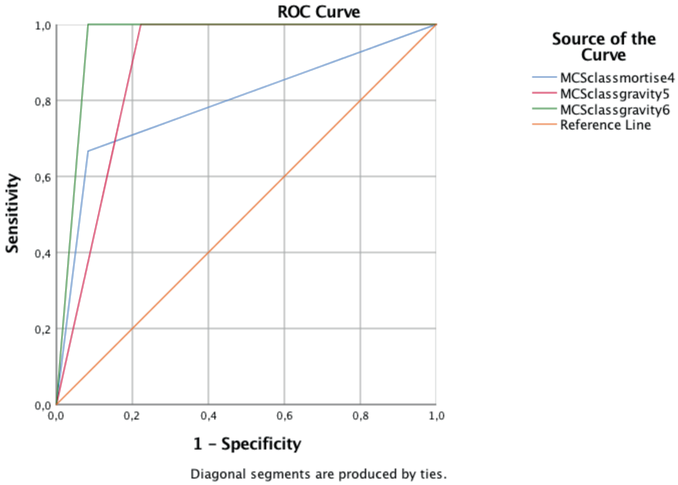
An alternative measurement technique, using a 4-mm absolute MCS-positive cut-off value, with the MCS value being 1mm greater than the superior clear space (SCS), was 73% sensitive and 46% specific for the diagnosis of a deep deltoid ligament tear. [15]

The gravity view was 100% sensitive, 91.7% specific, 50% positive predictive, and 100% negative predictive with MCS≥6mm as cut-off value. These results are shown in table 3.

Receiver operating characteristics (ROC) curves with area under the curves (AUC) are shown in figure 3.

	Sensitivity(%)	Specificity(%)	PPV	NPV
Conventional Mortise View: MCS≥ 4 mm	66,7	91,7	40	97
Conventional Mortise View: MCS≥ 4 mm and ≥1mm SCS	33,3	93,9	33,3	93,9
Gravity stress radiograph: MCS≥ 5 mm	100	72,2	23,1	100
Gravity stress radiograph: MCS≥ 6 mm	100	91,7	50	100

Table 3. Summary of predictive accuracy for different radiographs MCS values. Abbreviations: MCS, medial clear space; SCS, superior clear space; PPV, positive predictive value; NPV, negative predictive value



Area Under the Curve

Test Result Variable(s)	Area
MCSclassmortise4	,792
MCSclassgravity5	,889
MCSclassgravity6	,958

Figure 3. Receiver operating characteristics curves (ROC) with area under the curves (AUC) for the different cut-off values: MCS ≥ 4mm on mortise view, MCS ≥ 5mm on gravity view, MCS ≥ 6 mm on gravity view.

The mean dislocation of the fibula fracture on conventional mortise view (measured as the maximum dislocation on either the lateral or anterior-posterior radiograph) was 1.66 mm (0-5.0), in 15 patients there was a dislocation of ≥ 2 mm. The mean dislocation of the fibula on the gravity stress view was 2.09 mm (0-5.5), with a dislocation of ≥ 2 mm in 18 patients.

Discussion

One of the most common ankle fractures is the supination-external rotation type injury. The Lauge-Hansen classification, first described in 1954, is based on the position and subsequently the movements of the foot as a result of its deforming force. [16] This type of injury can be stable (SE-type II without DDL rupture) or unstable (SE-type IV with medial fracture or DDL rupture). In stable ankle fractures non-operative treatment is the treatment of choice leading to excellent function in a high percentage of cases, even despite fibular displacement up to 5mm. [3,5,17-21]

The most important goal is the ability to select patients with a stable ankle fracture in order to safely treat them non-operatively. To be able to evaluate the integrity of the DDL, and thereby choice of optimal treatment, it is necessary and important to have an accurate diagnostic tool.
Currently, no consensus exists on the best test for diagnosing a DDL rupture, and thus identification of an unstable ankle. Recent studies show that the predictive value of physical examination to distinguish between stable or unstable fractures is not sufficient. Therefore, an additional diagnostic tool is necessary. [8,15,22] The mortise radiograph is the most commonly used tool nowadays. According to most studies, a MCS width of ≥ 4mm on radiograph suggests a total tear of the DDL. [23] However, in 7.7% of the patients with a MCS widening of ≥6mm the DDL is still (partially) intact and in patients with a MCS widening of <6mm this percentage is even higher. [24] Consequently, this MCS cut-off value of ≥4mm might lead to surgical overtreatment of stable ankle fractures.
This is also reported by Murphy et al. [25], who identified patient-specific factors that produce differences in MCS measurements. This study calls into question the widespread use of an MCS measurement of 4 or 5mm as the threshold in determining surgical versus nonsurgical treatment of Weber B fractures. Particularly men and people of tall stature are at risk for a false-positive diagnosis of DDL rupture. They concluded that a threshold value for MCS of 4 or 5 mm will lead to operative invention for some patients with SER-II fractures who could have been reliably treated nonoperatively.

The gold standard for identifying a DDL rupture is a (open or arthroscopic) surgical exploration of the ankle. It is obviously not ethical nor desirable to perform this invasive procedure in all patients presenting with a SER-type fracture with an intact medial malleolus. Magnetic resonance imaging (MRI) has met most requirements to make an adequate distinction between a stable and unstable ankle. [9] The posterior part of the DDL, the posterior deep tibiotalar ligament (PDTL), is the most contributing part of the ligament for the stability of the ankle and is perceptible in most of the patients with the use of MRI. [26] Frequent utilization of this method, however, has two main disadvantages. First of all, it is not feasible to perform MRI in all patients with an ankle fracture. Due to limitations in availability, MRI may not be used for this purpose in some centers or regions. Moreover, the MRI scan is a rather expensive tool to use in this context.

Research has been done to find alternative radiographic tools as reliable predictor for ligament injury. Ultrasound is one of the examinations being investigated, while being a safe and portable tool to use in the Emergency Department. Two studies found good results with 100% specificity and sensitivity for detecting DDL rupture. [27, 28] However, the numbers of patients in these studies were very small. Furthermore, radiologists with sufficient expertise to perform these ultrasounds are not always present in-hospital.

Another radiographic method is the manual stress radiograph in which the tibia is internally rotated to obtain a mortise view, followed by manual dorsiflexion and external rotation of the foot. [13] This is considered a painful method for patients and is not usually done without the use of anaesthetics.

Schottel et al. [29] investigated 52 patients with ankle fractures and compared MRI results with the results of this manual stress ankle radiograph. They found a sensitivity and specificity of 66% and 77% respectively in diagnosing a complete rupture of the DDL.

Koval et al. [30] also studied the predictive value of this stress ankle test radiograph in detecting DDL rupture compared to MRI and concluded that the ankle stress test can indeed be used to prevent MRI in all patients with MCS widening on standard mortise radiograph. They found that 90% of the patients with a positive manual stress test, i.e. MCS widening of ≥4mm, had evidence of only a partially torn DDL on MRI. Disadvantages of this type of radiograph are the degree of ankle joint flexion influencing the results [31] and the amount of force needed to perform the radiograph is not standardised. [23]

Another type of stress radiograph is the weight-bearing radiograph that was investigated and reported by several authors. [32-35] Fractures of the lateral malleolus that were classified stable, according to the weight-bearing radiograph, were being treated conservatively. This resulted in radiographic - and clinical union without dislocation and a good functional outcome in all patients. The accuracy of this test, however, has not yet been thoroughly investigated in comparison with surgical exploration or MRI. Moreover, a cadaveric study by Stewart found no widening of the MCS during axial load spiral fibula fractures with rupture of DDL. [36] Therefore, this radiograph might underestimate the degree of instability.

An alternative method of detecting DDL rupture to discuss, investigated in the current study, concerns the gravity stress radiograph. For this radiograph, the patient lies down horizontally with the medial side of the ankle up, with the ankle and foot free of any external support. In theory, the medial clear space only widens in presence of a distal fibular fracture in combination with a complete deltoid rupture, and no shift will occur in lack of a complete deltoid rupture, thereby confirming stability. Figure 3 shows a normal congruent ankle joint at the standard mortise view with an equally normal gravity stress radiograph with no MCS widening. On the contrary, figure 4 shows a standard mortise view with no abnormalities, but a gravity stress radiograph with significant widening of the MCS and thus clear instability.

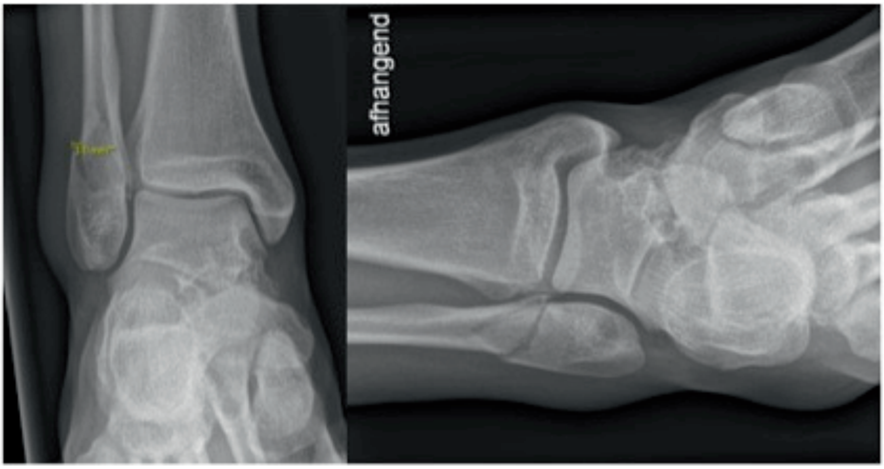


Figure 3. Conventional mortise view and a gravity stress view, both with no widening of MCS.

Figure 4 No widening of MCS on the conventional mortise view. Clear MCS widening on the gravity stress view.

Michelson et al. were the first to investigate this type of radiograph and found a promising specificity and sensitivity of 100% to detect a DDL rupture. However, this was a cadaveric study with only eight lower extremities. [11]

Talar shift occurred only when the DDL, and not only the superficial part, was ruptured. Instability seen on this simple radiographic method was considered a useful indication for surgery in patients

with an ankle fracture without talar displacement on standard mortise view. They concluded that the gravity stress radiograph can be regarded as a simple method, in which there is no need to put extra force on the patients' already painful ankle. Therefore, this could be an alternative practical diagnostic tool to be used in the Emergency Department. However, they did not compare their results with a reference standard.
Gill [13] and Schock [12] did compare results of the external rotation test and the gravity stress radiograph and both did not find significant differences in measurements of the MCS. The gravity stress view was experienced less painful than the external rotation test, with a Visual Analogue Scale (VAS) score [37] of respectively 3.4 vs. 6.1. They concluded that this examination can be used as the initial diagnostic screening examination for the detection of occult medial ligamentous injuries in SER fractures of the ankle.

To our knowledge, this present study is the first clinical study that prospectively compares the gravity stress radiograph with MRI findings. We found that the gravity stress radiograph with MCS≥6mm as cut-off value has a 100% sensitivity and 91.7 specificity compared to the MRI, with a negative predictive value of 100%. These results are worse with MCS≥5mm as cut-off value. This confirms the conclusions of Holmes et al, who stated that traditional threshold values of 4 mm or 5 mm for MCS on gravity stress radiographs may overestimate instability in these injuries because the average MCS on such radiographs in their population was 4.42mm. In their clinic, patients were excluded and planned for surgery if the MCS was >7mm, 2mm greater than the SCS, or 2mm greater than the contralateral MCS. Even patients with an MCS between 5.0 and 6.0mm on initial gravity stress had no MCS widening during follow-up and good clinical outcomes. Despite this high average measurement, all patients in their study group were treated nonsurgically and went on to fracture union without MCS widening. [35]
Recently, Gougoulias and Sakellariou [38] published an overview of the different types of radiograph and confirm our statement concerning the importance of the integrity of the deep deltoid ligament in identifying stability of the ankle. They propose a further division in ligamentous SER-type IV fractures, potentially unstable, with a ruptured anterior tibiotalar ligament (ATTL), but an intact posterior tibiotalar ligament (PTTL). They recommend that these fractures, with even a 50% ruptured deep deltoid ligament, could be treated safely with immobilisation in a cast. Further prospective research is needed to clarify this issue further.

In addition to the beneficial results, this study also has some limitations. It has been reported that MRI is not a 100% accurate predictor of ligament disruption. [39,40] As written above, the gold standard is a surgical (open or arthroscopic) exploration of the ankle. Still, MRI has been found to be highly sensitive and specific for diagnosing traumatic ligament injury and is currently the best available non-invasive comparative radiographic test. [8-10]

Furthermore, theoretically a complete joint dislocation during the gravity stress test could lead to nerve palsy or compartment syndrome. In our centre, however, we have experienced no such complications yet and there has been no description in the literature concerning these problems either.

Moreover, the number of totally ruptured DDL's in this patient cohort is quite limited. This is due to the choice we made to exclude patients with a MCS widening of ≥6mm on the convential mortise view, because they were immediately planned for operative treatment.

In conclusion, gravity stress radiographs have additional value in detecting a complete rupture of the DDL in addition to the conventional mortise view. It can be regarded as a safe, fast, and beneficial method to make an accurate distinction between stable and unstable isolated Weber B ankle fractures without using MRI.

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6

The Value of Additional Gravity Stress Radiographs for Decision Making in the Treatment of Isolated Type B Distal Fibular Fractures

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Chapter 6 The Value of Additional Gravity Stress Radiographs for Decision Making in the Treatment of Isolated Type B Distal Fibular Fractures

Abstract

Background

Prior to treatment decisions concerning isolated Weber type B ankle fractures, assessment of the stability of the ankle joint is mandatory. The gravity stress (GS) radiograph is a radiographic tool to determine stability. We hypothesized that this additional GS radiograph would lead to fewer operative treatments by applying the criteria of operative treatment when MCS > SCS + 2mm on the GS radiograph, compared with the non-stress mortise view criteria of advising operative treatment in case of MCS > SCS + 1mm.

Patients and Methods

This retrospective comparative cohort study analyzed 343 patients aged between 18 and 70 years with an isolated Weber type B ankle fracture diagnosed at the Emergency Department between January 2014 and December 2019. The cohort was divided in two groups based on whether or not an additional GS radiograph was performed. Group I consisted of 151 patients in whom a regular mortise and lateral radiograph were performed. Group II comprised 192 patients, with an additional GS radiograph. Primary outcome was type of treatment (conservative vs operative). Secondary outcomes were patient-reported functional outcomes and pain.

Results

Baseline characteristics of both groups did not differ. In group I, surgery was performed in 60 patients (39.7%) compared to 108 patients (56.3%) in group II (p=0.002). In the operatively treated patients, the mean medial clear space (MCS) on regular mortise view was significantly smaller in patients in whom an additional GS radiograph was performed compared to patients without an additional GS radiograph (4.1 mm vs. 5.2 mm, p<0.001). Mean OMAS and mean VAS for pain did not differ significantly between groups I and II.

Conclusions

Contrary to what was hypothesized, the introduction of an additional gravity stress radiograph, by which operative treatment was indicated if the MCS was wider than the superior clear space + 2mm, did not result in reduced operative treatment of Weber type B ankle fractures.

Introduction

In Weber type B ankle fractures, it is important to determine stability and congruency of the ankle joint.[31] The current consensus is that stable fractures with no dislocation can safely be treated conservatively. In the case of an incongruent ankle joint with proven instability, operative treatment is needed. During axial load, the deep deltoid ligament (DDL) is together with the medial malleolus the main stabilizer of the ankle joint. [9] In type B ankle fractures, instability occurs in case of a bimalleolar fracture or a bimalleolar equivalent fracture, i.e. a fibular fracture with additional deep deltoid ligament rupture. The latter type of fracture will be unstable due to the incompetent lateral and medial restraints of the ankle. In type B distal fibular fractures without an additional medial or posterior malleolar fracture it is thus important to exclude a DDL rupture.

Measuring the Medial Clear Space (MCS) width on a conventional mortise view radiograph of the ankle is one common method to determine stability. Although widely used, the MCS value on mortise view of ankle is a static diagnostic tool and use of the standard MCS cut-off value (taking into account the natural width of MCS on mortise) to indicate instability may lead to surgical overtreatment.[12] Therefore, alternative radiographic tools for judgment of congruency and stability have been studied.[5, 14, 17, 23, 26, 27, 33]

The gold standard for determining DDL condition is open surgical exploration. However, this is obviously not feasible nor ethical to perform in all patients. Magnetic Resonance Imaging (MRI) is considered a non-invasive gold standard for determining DDL rupture.[4] However, performing and assessing an MRI is limited due to costs and MRI (and radiologist) availability. An additional disadvantage of this tool is the static nature of the examination.

The ultrasound has also been assessed as a tool to predict ligament integrity. Henari was the first to evaluate the ultrasound in determining deltoid rupture. He found a 100% sensitivity and specificity of the ultrasound, however they only included 12 patients. Moreover, those 12 patients already had an indication for surgery at the moment that the ultrasound was performed.[11] Rosa et al. compared the ultrasound with GS radiograph in 81 patients. Sensitivity of ultrasound was 100%, specificity was 90% compared to GS radiograph.[24]

Another examination is the weightbearing radiograph, that was investigated and reported by several authors.[10, 13, 27, 33] However, the weightbearing test has not yet been compared with MRI or surgical exploration. Moreover, Stewart et al. found no widening of the MCS during axial load in a cadaveric cohort with rupture of DDL, suggesting underestimation of the degree of instability using the weightbearing radiograph.[29]

In 2017, Marzo et al. were the first to investigate the weightbearing CT scan, in comparison with the GS radiograph. Mean MCS on weightbearing CT scan (1.41 mm) was significantly less than that on standard radiographs (3.28 mm) and GS radiographs (5.82 mm). However, a relation between the weightbearing CT scan and patient outcome has not been studied.[16] The weightbearing CT scan might thus underestimate instability.

The radiographic tool of this study is the GS radiograph, for which the patient is placed on the affected side with the medial side of the ankle facing upwards (figure 1). The gravity stress is thought to simulate traction on the deltoid ligaments. Therefore, when deep the deltoid ligament is ruptured, gravity will cause the talus to translate to the lateral side of the foot and thus show widening of the MCS as a sign of instability of the ankle joint. The idea of the GS radiograph is that significant medial widening only can occur in case of a complete rupture. The goal of the radiograph is to prevent surgical overtreatment solely based on natural widening of MCS on a misinterpreted conventional mortise radiograph. In 2014, the GS radiograph was introduced in our hospital. Since then, the GS radiograph is used in isolated type B fibular fractures, depending on the preference and opinion of the attending physician. Surgical treatment was advised when on GS radiograph the MCS was wider than SCS + 2mm.

Figure 1. Performance of an anteroposterior (AP) view of the gravity stress radiograph

The aim of this study was to determine the clinical influence of the GS radiograph in a retrospective comparative cohort study comparing type of treatment in two groups (with and without additional GS radiograph) of patients with isolated Weber B fractures. We hypothesized that performing the additional GS radiographs, with a higher cut-off value than used for the mortise view, would lead to fewer primary operative treatments. In addition, patient-reported functional outcome, pain and general quality of life were determined as secondary outcome parameters.

Materials and Methods

Data of all patients, aged 18-70 years, presenting at the Emergency Department of a level-1 trauma center from January 2014 up to December 2019 with an isolated Weber type B distal fibula fracture, were retrospectively collected. Patients presenting with multitrauma, bi- or trimalleolar fractures or a previous fracture of the affected ankle in their medical history were excluded. Another reason for exclusion was participation in a former trial of our hospital, which was performed between May 2014 and November 2015. All 90 patients with an isolated type B distal fibular fracture that were included in this study underwent an additional MRI-scan of the ankle, which findings influenced the treatment decision. [31]
All eligible patients were asked to provide written informed consent for use of their medical data and received questionnaires by mail. Approval of the regional Medical Ethics Committee was obtained (protocol number N20.096).

In 2014, the GS radiograph was introduced in our hospital. In daily practice, the attending trauma surgeon decided whether or not to perform an additional GS radiograph for patients with an isolated type B fibula fracture. For a patient presenting at the Emergency Department preliminary treatment consists of immobilization of the injured joint in a plaster cast. The decision for definite treatment, operative or conservative, was made by the attending trauma surgeon based on the available diagnostic information. In our institution, operative treatment was advised if the regular mortise view showed a MCS> Superior Clear Space (SCS)+1mm and/or a lateral or posterior dislocation of the fibular fracture >2mm or if the additional GS radiograph showed on the anteroposterior (AP) view a MCS>SCS+2mm. Patients with an indication for surgery based on these radiographs were planned for open reduction and internal fixation within one week. All other patients were seen at the outpatient clinic after one week to repeat the radiograph and change to a soft cast or brace. Weightbearing was allowed depending on the radiograph results and pain, starting 2 to 4 weeks after initial trauma. In all patients, mortise and lateral radiographs were performed after six weeks, to ascertain fracture healing and exclude secondary dislocation.

The MCS, SCS, and lateral and posterior diastasis were measured on the radiographs using a digitally calibrated ruler in Zillion PACS Viewer by Rogan, Delft. Figure 2A illustrates the measurements on a regular mortise view radiograph, figure 2B illustrates a lateral ankle radiograph. The MCS was measured on the mortise and on GS radiographs in AP view by drawing a line perpendicular to the medial surface of the talus to the lateral surface of the medial malleolus. The SCS was measured on the mortise radiograph by measuring the tibiotalar distance in the middle of the tibiotalar articulation. The lateral and posterior fibular diastasis were measured on the mortise and lateral radiographs by drawing a line perpendicular to the fracture line or, if this was not possible, by measuring displacement in a horizontal plane[21]. For the radiographs after 6 weeks the largest of both diastases, either lateral or posterior, was used for analysis.

Figure 2a. Regular mortise view radiograph with measurements of medial clear space (A), superior clear space (B) and fibular lateral diastasis (C); mm** = millimeter

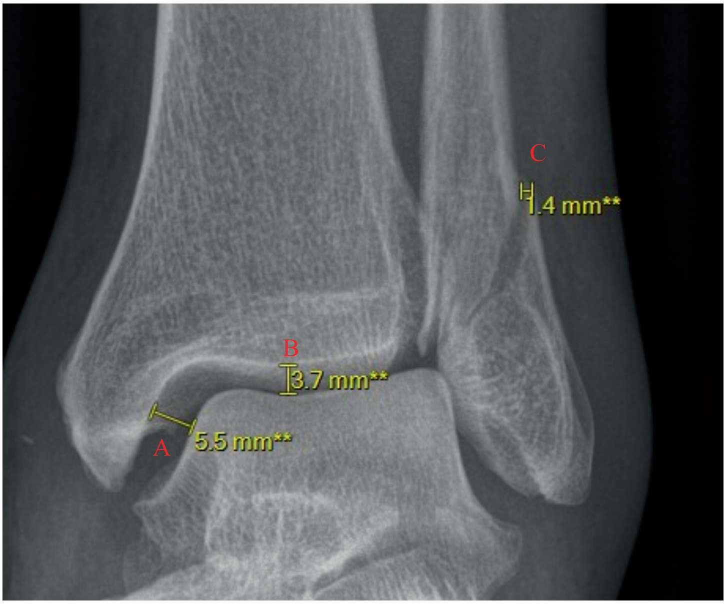


Figure 2b. Lateral view radiograph with measurements of fibular posterior diastasis; mm** = millimeter

Primary outcome was type of fracture treatment, operative or conservative. Information regarding treatment and follow-up was collected from the electronic medical records.

Secondary outcomes were patient-reported functional outcome and pain. Included patients were asked by mail to fill out a questionnaire combining the Olerud-Molander Ankle Score (OMAS) and a Visual Analogue Scale (VAS) for pain at rest and in motion. The OMAS is a validated functional outcome questionnaire leading to a score ranging from 0 to 100, with 0 being the worst possible outcome and 100 the best (without decline in functionality).[6, 18, 22] The VAS for pain ranged from 0 (no pain) to 10 (worst pain imaginable).[3] After a period of 3 weeks, all patients that did not respond to the questionnaire were contacted by phone. Complications were also collected from the medical records. Removal of osteosynthesis material for reasons of pain or infection, additional surgery due to non-union or cases of pneumonia or thrombosis following surgery were registered as complications.[8] Moreover, wound infections were assessed according to CDC Guidelines of Surgical Site Infection (SSI).[8] Secondary dislocation was defined as MCS widening >1mm or increased dislocation of the fibular fracture of >1mm compared to the injury radiograph (in case of conservative treatment) or compared to the postoperative radiograph (in case of operative treatment). Mentally incompetent patients and patients unable to speak or read either English or the national language were excluded from completing the questionnaires.

Statistical analyses were performed using IBM Statistical Package for the Social Sciences (SPSS) version 26.0. Baseline characteristics and outcome parameters were compared between patient groups. Mean values were compared using unpaired t-tests and percentages were compared using Chi-squared tests.

Results

A total of 343 patients were included (figure 3) and divided into group I (regular mortise and lateral radiograph, n=151) and group II (regular mortise, lateral radiograph and additional GS view, n=192). The baseline characteristics of both groups are presented in table 1. Demographic characteristics of both groups did not differ significantly (results not shown). Mean age and male to female ratio did not differ significantly between both groups. The mean posterior diastasis in the fibular fracture was 2.4 mm (range 0.0-15) and 2.0 mm (0.0-10.9) for groups I and II respectively (p=0.01). On the initial injury radiographs mean MCS, SCS and fibular fracture lateral diastasis showed no significant differences. In group II, the mean MCS on the GS radiograph was 5.7 mm (2.0-23.5).

Table 1. Baseline characteristics

Parameter	Group 1: Regular Mortise (n=151)	Group 2: Regular Mortise and Gravity Stress (n=192)	Significance (*P* Value)
Age, y, mean (range)	45.6 (21-69)	43.7 (19-68)	.19
Gender (% male)	49.7	46.4	.54
Follow-up, mo, mean (range)	46 (10-82)	46 (10-82)	
Regular mortise, mm, mean (range)			
Medial clear space	4.0 (1.1-11.9)	3.8 (0.9-8.1)	.11
Superior clear space	3.3 (1.6-5.2)	3.4 (1.8-5.5)	.12
Fibula lateral diastasis	1.8 (0.0-8.1)	1.7 (0.0-6.4)	.60
Fibula posterior diastasis	2.4 (0.0-15.0)	2.0 (0.0-10.9)	**.01**
Gravity stress medial clear space, mm, mean (range)		5.7 (2.0-23.5)	
Radiograph on mortise after 1 or 6 wk, mm, mean (range)			
Medial clear space	3.3 (1.0-6.2)	3.2 (1.0-6.5)	.65
Fibular fracture diastasis	1.1 (0.0-7.9)	0.8 (0.0-5.5)	.06

Figure 3: Flow Diagram of included and excluded patients with reason for exclusion

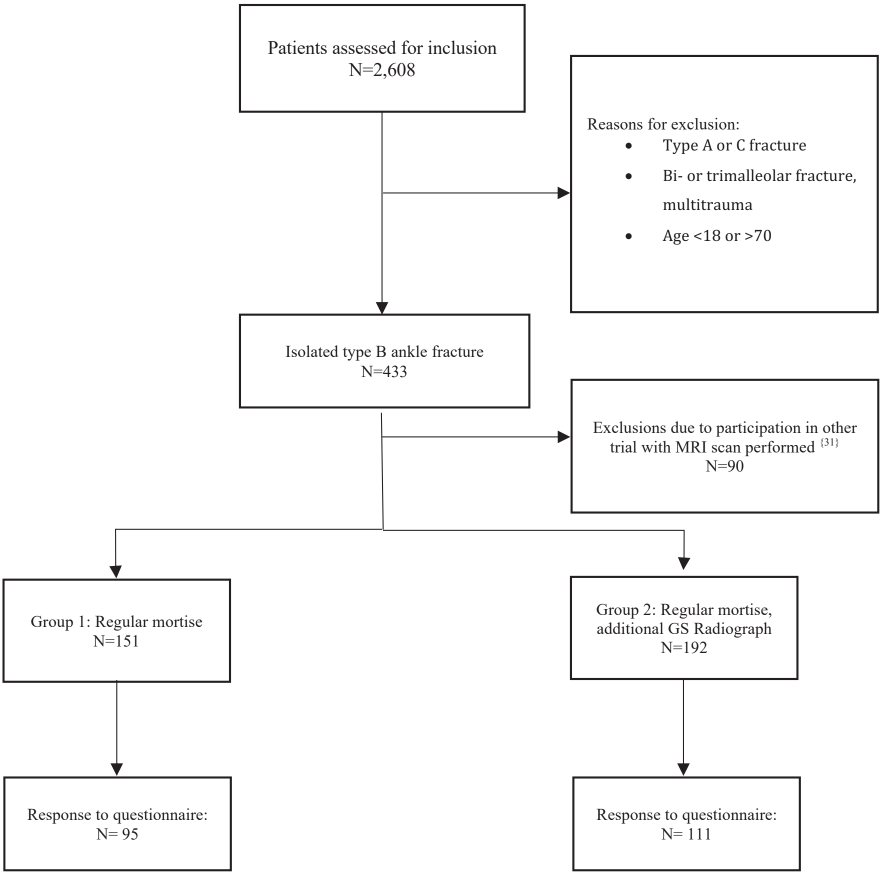


Table 2 shows the percentage of patients who were treated operatively in group I (n=60/151, 39.7%) and group II (n=108/192, 56.3% in group II) (p=0.002).

In group I, 66% (99/151) and in group II 67% (128/192) of the treatment decisions were according to the protocol.

Parameter	Group 1: Regular Mortise (n=151)	Group 2: Regular Mortise and Gravity Stress (n=192)	Significance (*P* Value)
Surgery (%)	39.7	56.3	**.002**
MCS for operatively treated patients, mm, mean (range)	5.2 (1.1-11.9)	4.0 (1.8-8.1)	**<.001**
Surgery			
Time in cast, wk, mean (range)	2.4 (0-6)	2.4 (0-6)	.92
Time before weightbearing, wk, mean (range)	4.8 (1-6)	4.8 (0-6)	.98
Conservative treatment			
Percentage in cast (%) vs brace	90.1	94.0	.43
Time in cast, wk, mean (range)	5.2 (0-8)	5.6 (2-8)	.07
Time before weightbearing, wk, mean (range)	3.2 (0-7)	3.6 (0-8)	.19

Abbreviation: MCS, medial clear space.

Table 2. Treatment Outcome

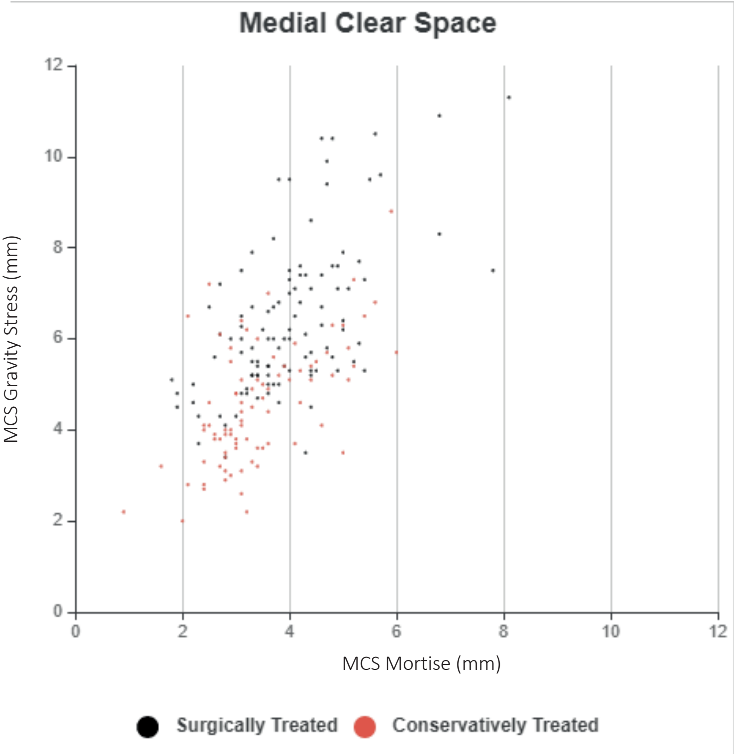
In the operatively treated patients of group I and II, mean MCS on regular mortise radiograph was 5.2 mm (1.1-11.9) and 4.0 mm (1.8-8.1) respectively ($p<0.001$).

Figure 4 shows the correlation between the mortise MCS and GS radiograph. MCS in the operatively treated group and the conservatively treated group. The MCS on the GS radiograph was higher in operatively treated patients. Mean MCS on mortise was 4.5mm in the operatively treated group, mean MCS on GS radiograph was 6,6mm. In the conservatively treated patients, mean MCS on mortise was 3.3 mm and on GS radiograph the mean MCS was 4.6 mm.

6

In the operatively treated patients, the mean time in cast (2.4 weeks) and mean time until weightbearing (4.8 weeks) were similar for both groups. In group I, 82/91 conservatively treated patients were treated with a cast (90.1%) and in group II, 79/84 conservatively treated patients were treated with a cast (94.0%, p=0.43). All other patients in both groups were treated with a brace.

Figure 4. Correlation between Medial Clear Space (MCS) on Mortise radiograph and Medial Clear Space (MCS) on Gravity Stress Radiograph in the surgically and conservatively treated groups



Complications occurred in both groups. For operatively treated patients, in group I, osteosynthesis material was removed in 18 patients (30%) due to persistent pain complaints and two patients suffered from a superficial incisional surgical site infection (SSI) (3.3%). In group II, again focusing on the operatively treated patients, removal of osteosynthesis material occurred 18 times (16.7%), in 15.9% due to pain complaints and in 0.8% due to a deep incisional SSI. In the patient with a deep incisional SSI, the removal of osteosynthesis material took place 6 months after the primary surgery. In the other patients in whom osteosynthesis material was removed because of pain, the mean time between surgery and removal was 13 months. Furthermore, in group II, two patients underwent additional debridement and ORIF surgery due to non-union after 3 months (1.9%), one patient suffered from pneumonia (0.9%) following treatment and one patient suffered from deep venous thrombosis (0.9%). Secondary dislocation did not occur in both groups.

The questionnaires were completed by 205 patients (59.7%). Eight percent of the patients were excluded from filling out the questionnaire because they did not speak English or the national language. In group I, 94 patients responded (62%) and in group II, 111 patients responded (57%). Of them, in group I 40% was treated surgically and in group II 65.8% was treated surgically. Mean follow-up time of the respondents in both groups was 46 months (10-82 months). Scores for functional outcome and pain are presented in table 3 and did not differ between the groups. Functional outcome and pain score did not differ significantly between the patients treated surgically and those treated conservatively.

Table 3. Functional outcomes

Parameter	Group 1: Regular Mortise, Mean (Range) (n=95)	Group 2: Regular Mortise and Gravity Stress, Mean (Range) (n=111)	Significance (*P* Value)
OMAS score	82.1 (5-100)	85.3 (10-100)	.32
Follow-up time, mo	46 (10-82)	46 (10-82)	
Score on visual analog scale			
VAS score for pain at rest	1.2 (0-10)	1.0 (0-8)	.42
VAS score for pain in motion	1.7 (0-10)	1.4 (0-10)	.35
VAS score for general health	7.4 (0-10)	7.7 (2-10)	.25

Abbreviations: OMAS, Olerud-Molander Ankle Score; VAS, visual analog scale.

Discussion

We performed a retrospective study to determine the clinical influence of an additional GS radiograph in patients with isolated Weber B fractures, hypothesizing that this would lead to less operative treatments with a higher cut-off value to indicate surgical treatment: MCS > SCS + 2mm. In this study, two cohorts (patients with and without performance of GS radiograph) were compared for multiple outcomes. In the patients without GS radiograph, surgery was performed in 39.7% compared to 56.3% of the patients with GS radiograph. In the operatively treated patients, the mean medial clear space (MCS) on regular mortise view was significantly smaller in patients in whom an additional GS radiograph was performed. The mean functional outcome did not differ significantly between the two groups.

Determination of a DDL rupture, and thereby instability, is an important factor in choosing type of treatment in type B ankle fractures.[2, 30] The best radiographic tool for accurately excluding

DDL rupture has been subject of debate and surgeons use different methods and standards for determining unstable ankle fractures.[32]

A common method to distinguish between stable and unstable fractures is by measuring the MCS widening on the mortise view radiograph of the ankle. The cut-off value that is used by most surgeons to indicate instability is MCS > 4 mm.[32] However, in 7.7% of fractures with MCS > 6 mm the DDL was proven to be intact.[31] Theoretically, the percentage of fractures with MCS 4-6 mm but an intact DDL will be even higher. This presumably leads to surgical overtreatment of stable fractures when using the cut-off value MCS > 4 mm for surgical treatment. This potentially incorrect cut-off value may induce the burden of unnecessary surgical treatment itself, apart from the generic risks that come with surgical interventions (anesthesiologic risks, wound infection, deep venous thrombosis (DVT) and reoperation for removal of osteosynthesis material).[20] Also, the costs are substantially higher compared to conservative treatment.[28] To prevent unnecessary surgical procedures by making an accurate distinction between stable and unstable fractures, performing an additional radiographic tool for judgment of congruency and stability is advised.[5, 14, 17, 23, 26, 27, 33] However, a recent survey among orthopaedic trauma surgeons in the Netherlands showed that only 18.2% of them make use of such alternative diagnostics additional to a regular mortise view.[32]

Michelson et al. were the first to describe the GS radiograph; they found a specificity and sensitivity of 100% to detect DDL rupture when using talar shift as indicator of a rupture. However, they did not compare their results with MRI or other reference standard and their study included only eight cadaveric extremities.[19] Another study, from LeBa et al., compared the GS radiograph with manual external rotation stress radiograph, for the injured and contralateral ankle. They concluded that the GS radiograph showed a significant increase in MCS compared with manual stress widening (1.85 vs. 1.35 mm, $p=0.017$).[15] Another comparison between the manual and gravity stress radiograph was made by Gill et al. They used the MCS cut-off value of ≥ 4 mm and MCS > SCS + 1mm for a fracture in order to be classified as unstable.[7] They found a mean MCS on GS radiograph of 4.26 mm in stable fractures, compared to 5.0 mm in unstable fractures ($p<0.05$). This same comparison and cut-off value were used by Schock et al., who found a significant difference of mean MCS on GS radiograph (6.09 mm) compared to MCS on manual stress test (5.81 mm).[25] Ashraf et al. explored the need for a higher MCS cut-off value to indicate DDL rupture and examined cadaveric extremities with GS radiographs. With a cut-off value of

MCS > 5 mm to indicate DDL rupture, the PPV was 80%. Using a cut-off value of 6 mm, the PPV improved to 100%.[1]

A recent study compared the GS radiograph with results of the MRI and found a sensitivity of 100, specificity of 91.7 for the GS radiograph to determine DDL rupture using MCS cut-off value ≥ 6mm.[31] However, the number of DDL ruptures of their cohort of 39 patients was limited.

Despite our assumption that the GS view with cut-off value MCS > SCS + 2mm would help narrow down the indication for operative treatment of these fractures, the results of our cohort show that in similar patients with comparable radiographic fracture characteristics and dislocation, significantly more patients were treated operatively in the group of patients that had an additional GS radiograph performed. The question is what do these results imply? Does the GS radiograph incorrectly diagnose unstable ankle fractures, leading to surgical overtreatment? Are the cut-off values insufficient? Also, may we safely conclude that the GS has no additional value in the diagnostic work-up of isolated Weber B ankle fractures? Did the implementation of the GS radiograph improve the functional outcome?

One factor that might lead to an incorrect interpretation of instability on the GS radiograph is the natural widening of the MCS when performing a GS radiograph. This might be explained by subtle plantarflexion of the foot when performing the GS radiograph. One of our former trials, that has recently been expanded with new data, shows that in stable type B ankle fractures (without rupture on MRI scan), the GS radiograph has a physiological MCS widening of 1.2 mm more than the regular mortise view.[31] Pitakveerakul et al. described that even in non-fractured ankles, there is a significantly wider MCS on GS radiograph than on mortise view.[23] They studied normative radiographic data for GS radiographs in 120 healthy patients without fracture. They found a mean MCS of 3.19mm on GS radiograph vs a mean MCS of 3.01 mm on mortise view ($p=0.02$). They concluded that the surgeon should be aware of an unstable ankle in case of MCS > 4 mm on GS view.

Murphy et al. studied the variability in MCS of the normal unfractured ankle and concluded that use of a single threshold value for MCS as an operative indicator might produce false-positive diagnoses of deltoid incompetence.[21]

Taking into account this natural widening of MCS on GS radiograph, a higher cut-off value for GS radiograph is required in order to be able to determine ankle instability. Further research is needed to repeat this study in a prospective manner, in order to benchmark the correct cut-off point for acceptable MCS on the GS radiograph.

Our current protocol, advising operative treatment when MCS > SCS + 2mm on the GS radiograph, should be revised and a higher cut-off value is needed. Our results show an average mortise MCS widening of 1.2mm in stable type B fractures and an average mortise MCS widening of 2mm in operatively treated fractures.

Consequently, the cut-off value for diagnosing unstable ankle fractures on GS radiograph should be approximately 2mm higher than the cut-off value for the mortise view. These calculated cut-off values were unknown at the time of the current study, and the attending surgeon made his decision to treat operatively based on the 'old' cut-off values.

The functional outcome between group I and group II did not differ. Moreover, no trend existed towards a better functional outcome after performance of the GS radiograph. It is thus questionable whether implementation of the protocol in its current form is preferable.

A randomized controlled trial is required including all isolated type B ankle fractures, to obtain a definite answer to our questions about the values of additional WB or GS radiographs. Both treatment strategies (surgically or conservatively) and results of treatment in terms of functional outcome should be evaluated as outcome measures.

We advise to make use of a higher cut-off value on GS radiograph to decide for surgical treatment, at least 2 mm higher than the mortise cut-off value. Our belief based on the results of this study is that the GS radiograph might have additional value in determining medial injury, but only when making use of a correct cut-off value. Nowadays, the cut-off values being used internationally lead to surgical overtreatment when making use of the GS, in contrast to its goal.

This study is, to our knowledge, the first study to evaluate the performance of a large number of performed GS radiographs. This cohort has given us the opportunity to assess the value of the GS radiograph and moreover, to evaluate the related functional outcome after treatment.

This study has also some limitations. All limitations inherent to the retrospective design of this study apply. Patient data were used from a period of 5 years, the differences in follow-up will affect the perceived outcome scores. Furthermore, since its introduction, the GS radiograph has only been performed in approximately half of the patients presenting with a distal fibula fracture. This means that the implementation of the GS radiograph in the current protocol has not been fully achieved. The attending surgeon decided whether or not to perform a GS radiograph, which might have led to incomplete interpretation of the results. In one-third of the patients, the attending surgeon did not follow the protocol with the advised cut-off values.

In conclusion, both groups were comparable on all radiographic fracture characteristics and had the same clinical performance outcomes. However, a significantly higher number of performed surgeries was found in the group with an additional GS radiograph. This shows that, in contrast to its initial goal of preventing surgical overtreatment, the introduction of the GS radiograph did not result in reduced operative treatment of type B ankle fractures. Further research is needed to determine the correct cut-off value but our results suggest that it should be at least 2mm higher than the MCS cut-off value used for mortise view.

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The additional value of weight-bearing and gravity stress ankle radiographs in determining stability of isolated type B ankle fractures

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Chapter 7 The additional value of weight-bearing and gravity stress ankle radiographs in determining stability of isolated type B ankle fractures

Abstract

Goal

The aim of this study is to investigate whether weight-bearing and gravity stress radiographs have additional value in predicting concomitant deep deltoid ligamentous (DDL) injury in case of isolated Weber type B fibular fractures. This may help to make the clinically relevant distinction between unstable fractures and fractures that can be treated conservatively.

Methods

In this prospective cohort study, 90 patients with an isolated type B ankle fracture, without a medial or posterior fracture, and a medial clear space (MCS) < 6 mm on the regular mortise (RM) view. In all patients, an additional gravity stress (GS) view and an MRI scan were performed. Furthermore, in 51 patients, an additional weight-bearing (WB) radiograph was performed. The MCS and superior clear space (SCS) measurements of these radiographs were compared with MRI findings to measure sensitivity and specificity in excluding deep deltoid ligament (DDL) rupture.

Results

The mean MCS on the RM view was 3.32 mm (1.73-5.93) compared to 4.75 mm (2.33-10.40) on the GS view and 3.18 mm (1.93-6.9) on the WB radiograph. MRI showed a high-grade or complete deltoid ligament tear in 25 (28%) patients. Using an MCS cut-off value of ≥ SCS + 2mm, the RM view showed 0% sensitivity and 97% specificity in diagnosing a DDL rupture. Both the GS view (with MCS ≥ SCS + 3mm as cut-off value) and the WB radiograph (with cut-off value MCS ≥ SCS + 2mm) showed 6% sensitivity and 100% specificity.

Conclusion

The gravity stress and weight-bearing radiograph can accurately exclude DDL injury. They might have extra value in addition to the conventional mortise view in assessing the stability of isolated type B ankle fractures. This helps in deciding whether patients should be selected for operative or safe conservative treatment.

Introduction

According to the Lauge-Hansen classification [1], supination-external rotation type IV ankle fractures constitute two-thirds of the ankle fractures seen at the Emergency Department (ED). [2] In isolated type B fibular fractures without a medial or posterior fragment, the assessment of stability is fundamentally important in deciding what treatment strategy should be followed. The main stabilizer of the ankle during axial load is the medial malleolus with the deep deltoid ligament (DDL). [3] Isolated distal fibular fractures with an additional rupture of this DDL (supination external rotation IV (SER IV) equivalent ankle fractures) are considered unstable and require operative treatment. [4-7] Stable lateral malleolus fractures with a congruent ankle joint (SER II) are commonly treated conservatively with good outcomes. [7-10] Therefore, an accurate assessment of the ankle joint and the exclusion of medial ligamentous injury is required.

In current practice, a medial clear space (MCS) of ≥6mm at the conventional mortise is generally considered to be part of an unstable injury with a direct need for operative treatment. [11] A national survey in The Netherlands showed that many (orthopaedic) trauma surgeons consider a MCS >4mm and/or a MCS > superior clear space (SCS) + 1 or 2mm at a regular mortise (RM) X-ray view a marker for potential DDL rupture. [12] In figure 1 a mortise radiograph with an example of these measurements is shown.

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However, in a significant amount of fractures with a MCS ≥ 6 mm, the DDL is shown to be (partially) intact and, therefore, stable without requiring surgical fixation. [13] In fractures with MCS widening of 4-6mm, this percentage is presumably even higher. The cut-off value of MCS>4mm might thus lead to surgical overtreatment.

Therefore, the Dutch guideline on ankle fractures advises to use additional diagnostics in order to exclude or confirm medial injury in case of an isolated type B fibular fracture with a MCS < 6mm. [11] According to the literature, the reference standard for detecting a DDL rupture is the magnetic resonance imaging (MRI) scan. [14-16] However, the costs are high and the availability of this diagnostic tool is restricted.

The gravity stress (GS) radiograph and the weight-bearing (WB) radiograph are alternative diagnostic tools. The GS radiograph is performed in anteroposterior direction with the leg lying horizontally with its medial side up and without support of the foot (Figure 1).

Figure 1. Gravity stress view. The leg was positioned horizontally with medial side up. Ankle and foot are free of external support.

Theoretically, a rupture of the DDL will cause widening of the MCS as gravity will make the talus slide downwards laterally. The WB radiograph is made while the patient is full weight-bearing on both feet. In case of a rupture of the DDL, there will be lateral displacement and external rotation of the talus. Widening of the MCS might then indicate instability.

In one of our previous studies, we found that the GS view with a cut-off value of MCS ≥ 6mm has a sensitivity of 100% and a specificity of 91.7% in predicting DDL injury in 39 patients with a SER-type ankle fracture without a medial or posterior fracture and a MCS<6mm with MRI as reference standard. [17] To our knowledge, no research has yet been conducted reporting the accuracy of the weight-bearing radiograph in predicting DDL injury. [18-21]

The purpose of the current study is to examine the additional diagnostic value of the GS and WB radiographs in predicting concomitant deep deltoid ligamentous injury in isolated Weber type B fibular fractures, compared with MRI.

Patients and methods

The study group consisted of two separate cohorts of which the data were pooled (figure 2). In both cohorts, all consecutive patients aged between 18 and 70 years admitted to the ED of our hospital due to an isolated Weber type B fibular fracture with MCS<6mm at regular mortise (RM) view were eligible for participation. Patients with a MCS ≥ 6 mm were excluded, because these injuries were considered unstable with a clear indication for operative treatment. Patients with a bi-malleolar fracture (i.e. medial malleolus fracture of posterior malleolus fracture) no mastery of the national language, mentally disabled patients, and patients with a contra-indication to undergo an MRI scan were excluded. All eligible patients received written information about the study and were asked to provide informed consent.

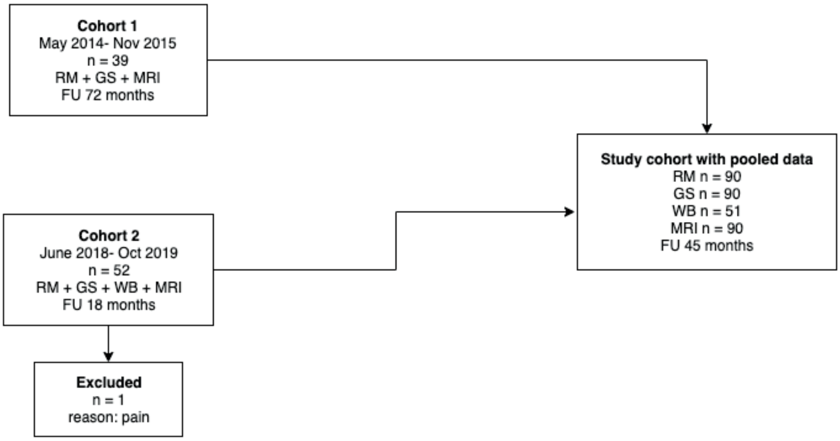

Figure 2. Flow chart of the combined two cohorts. RM = regular mortise, GS = gravity stress, WB = weightbearing

The patients in the first cohort were included between May 2014 and November 2015. These patients had an additional GS radiograph taken at the ED. Within one week, an MRI scan was made. A previous study on this cohort has been published. [17] The patients in the second cohort were included between June 2018 and October 2019. After inclusion, a GS radiograph was taken at the ED and additionally a WB radiograph (after removal of the cast) and MRI scan were made within one week.

Outcome measures were the sensitivity and specificity of the RM, GS and WB radiographs, based on MCS widenings (with different cut-off values) compared with observed partial or high grade DDL rupture on MRI (as reference standard). Based on previous studies [11,12] we assumed that an MCS cut-off value of > 4 mm might overestimate instability, therefore we decided to make use of higher cut-off values when using the additional radiographs than the ones used nationwide in daily practice. Bearing in mind that the gravity stress widens naturally for about 1mm at least, we added 1mm to the current cut-off values. [17]

For the GS radiograph, we calculated outcomes with cut-off values MCS > 6mm, MCS > SCS + 2mm and MCS > SCS + 3mm.

For the WB radiograph, we calculated outcomes with cut-off values MCS > 4 mm, MCS > SCS + 1mm, MCS > SCS + 2mm

Both the medial clear space (MCS) and the superior clear space (SCS) were measured on the radiographs using a digital calibrated ruler in Zillion PACS Viewer by Rogan, Delft. The MCS was measured drawing a line perpendicular to the medial talar surface at the level of the talar dome to the lateral surface of the medial malleolus. The SCS was measured as the vertical distance of the lateral tibiotalar articulation. An example of these measurements is shown in Figure 3. On the RM, GS and WB view, the lateral and posterior dislocation of the fibula fracture was measured and the largest value of these two was included in the data. No anesthetics were required for making the GS radiograph and the WB radiograph. However, one patient in this cohort was too afraid to fully load the foot of the fractured ankle for the WB radiograph and was, therefore, excluded.

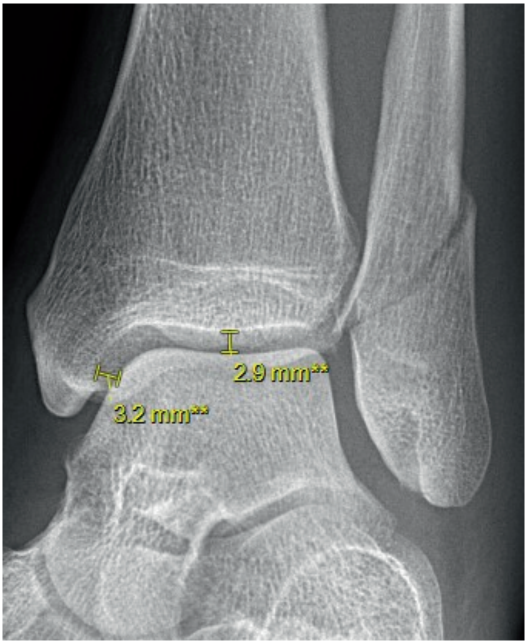

Figure 3. Regular mortise radiograph with a Medial Clear Space (MCS) of 3.2mm and Superior Clear Space (SCS) of 2.9mm are shown.

MRI was performed on 1.5-T magnetic resonance units (Magnetom Avanto and Magnetom Symphony, Siemens Healthcare, Erlangen, Germany). The MRI protocol consisted of 3 mm-thick sagittal, coronal and transverse proton-density weighted turbo spin-echo fat suppressed images (TE=32ms, 31ms and 31ms, matrix=320, 448, and 448, respectively) and T1-weighted spin-echo 3 mm-thick sagittal, coronal and transverse images (TE=15ms, 15ms and 11ms, matrix=384, 384, 448, respectively). The field of view was 150 mm.

On MRI, the DDL (anterior and posterior tibiotalar ligament), tibiospring and tibiocalcaneal ligament, and the flexor retinaculum were assessed. Associated injuries such as medial malleolar fractures, distal avulsion fractures, osteochondral injuries of the talus, syndesmosis injuries and tibialis posterior abnormalities were not assessed. The DDL was graded as intact, edematous, low grade tear or high grade tear. [22] An intact DDL was isointense with continuous fibers with a striated appearance. An edematous ligament was determined by a T2 hyperintense signal intensity with an intact striated appearance. This was also seen in the low grade tear ruptured ligaments. However, they also showed an irregular contour and partially disrupted fibers. High grade rupture was defined as complete discontinuity of the fibers. Isolated type B fracture were considered stable (SE2) in case of an intact or edematous DDL and unstable (SE4) in case of a low or high grade DDL tear on MRI.

Measurements on the mortise view, GS radiograph, and WB radiograph were performed independently by one trauma surgeon, one surgical resident and two musculoskeletal radiologists who were unaware of the clinical findings. These results were compared with the MRI results, which were scored by the two musculoskeletal radiologists. In case of disagreement, consensus was reached between the radiologists after discussion.

The decision to treat non-operatively or to plan surgery was made by the attending surgeon based on the available diagnostics. Surgical stabilization was advised for all patients who sustained an unstable ankle fracture.

The statistical analyses were performed using Statistical Package for the Social Sciences (SPSS), version 24.0. For different cut-off values for MCS, the sensitivity, specificity, negative predictive value (NPV) and positive predictive value (PPV) of the GS and WB radiographs were calculated for predicting partial or complete rupture of DLL on MRI. Receiver Operating Characteristic (ROC) curves with their corresponding Area Under the Curve (AUC) were calculated for the different radiologic diagnostics and their different cut-off values for MCS and MCS-SCS.

Approval of the Regional Medical Ethics Committee was obtained. (study number 17-134).

Results

Cohort 1 consisted of 39 patients and cohort 2 consisted of 51 patients. All 90 patients had a RM radiograph, a GS radiograph and an MRI scan made. In the 51 patients of the second cohort, a WB radiograph was also made. In *table 1,* the baseline characteristics of the combined patient population are shown. Detailed results of the radiographs of all individual patients are shown in the Appendix.

	Total (n = 90)
Mean age (years)	41 (19-76)
RM mean MCS in mm (range)	3.3 (2-5.9)
GS mean MCS in mm (range)	4.8 (2.3-10.4)
WB mean MCS in mm (range)	3.2 (2-6.9)
Fibula dislocation RM in mm (range)	1.5 (0-5)
RM mean SCS in mm (range)	3.3 (0-4.4)
MRI 0 = intact, n (%)	43 (47.8)
MRI 1 = edema and/or low-grade partial rupture n (%)	22 (24.4)
MRI 2 = high-grade partial rupture, n (%)	21 (23.3)
MRI 3 = complete rupture, n (%)	4 (4.4)

Table 1. Baseline characteristics

24 of the 90 performed MRI scans showed a partial (n=20) or complete (n=4) rupture of the DDL. For both cohorts combined, the mean MCS on the RM view was 3.3 mm (range 1.7-5.9) and the mean superior clear space (SCS) was 3.3 mm. The mean fibula dislocation on RM view was 1.5 mm (0.1-4.2). On the GS radiograph, the mean MCS was 4.8 mm (2.3-10.4) and the mean fibula dislocation was 1.7 mm (0.1-4). Finally, on the WB radiograph, the mean MCS was 3.2 (1.9-6.9) and the mean fibula dislocation was 1.3 mm (0.1-2.9). The mean MCS on mortise radiograph in stable fractures was 3.2mm (1.7-5.9) compared to 4.4 mm (2.3-7.1) on GS radiograph.

The sensitivity, specificity, negative predictive value (NPV) and positive predictive value (PPV) of the different tests with used cut-off values are shown in *table 2*. For both cohorts together, the MCS cut-off value of ≥ SCS + 2mm on the RM view showed 0% sensitivity and 97% specificity for diagnosing a partial or complete rupture of the DDL, corresponding with a positive and negative predictive value of 0% and 72% respectively.

The GS view was 6% sensitive, 100% specific, 100% positive predictive and 70% negative predictive with MCS ≥ SCS + 3mm as cut-off value. The WB view with a cut off value MCS ≥ SCS + 2mm also showed a sensitivity of 6%, a specificity of 100%, a PPV of 100% and a NPV of 70%.

	Cut-off value	Sensitivity	Specificity	PPV	NPV
Conventional mortise (n=90)	**MCS ≥ 4 mm**	36%	95%	75%	80%
	MCS > SCS + 1mm	12%	94%	43%	75%
	MCS ≥ SCS + 2mm	0%	97%	0%	72%
Gravity (n=90)	**MCS ≥ 6 mm**	36%	94%	69%	79%
	MCS > SCS + 2mm	8%	97%	50%	73%
	MCS ≥ SCS + 3mm	6%	100%	100%	70%
Weight-bearing (n=51)	**MCS ≥ 4 mm**	11%	97%	75%	67%
	MCS > SCS + 1 mm	6%	97%	50%	65%
	MCS ≥ SCS + 2mm	6%	100%	100%	70%

Table 2. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) for different tests with different cut-off values in determining a **high-grade partial or complete** rupture of the deep deltoid ligament (DDL).

The Receiver Operating Characteristics (ROC) curves of the RM, GS and WB radiographs are presented in Figure 4. The overall ability of the GS radiograph to diagnose DLL based on the MCS was acceptable (AUC 0.77, 95% confidence interval 0.65-0.88), whereas this was low for the RM and WB radiographs (AUC<0.70). The AUC results are shown in *table 3*.

Table 3. The **Area Under the receiver operating characteristic Curve (AUC**) of the different radiologic tests with their 95% Confidence Interval (CI).

Radiologic test	**AUC**	**CI (95%)**
MCS mortise	0.65	0.52-0.78
MCS-SCS mortise	0.56	0.42-0.69
MCS gravity stress	0.75	0.64-0.87
MCS-SCS gravity stress	0.66	0.53-0.79
MCS weightbearing	0.58	0.40-0.75
MCS-SCS weightbearing	0.51	0.34-0.67

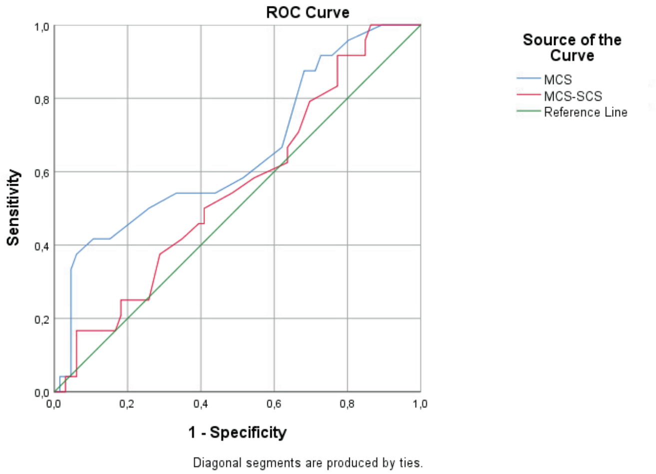

Figure 4a. Receiver Operating Characteristic (ROC) curves and corresponding Area Under the Curve (AUC) for predicting deep deltoid ligamentous injury on MRI based on the mortise view with Medial Clear Space (MCS) and Medial Clear Space minus Superior Clear Space (MCS-SCS) as criteria.

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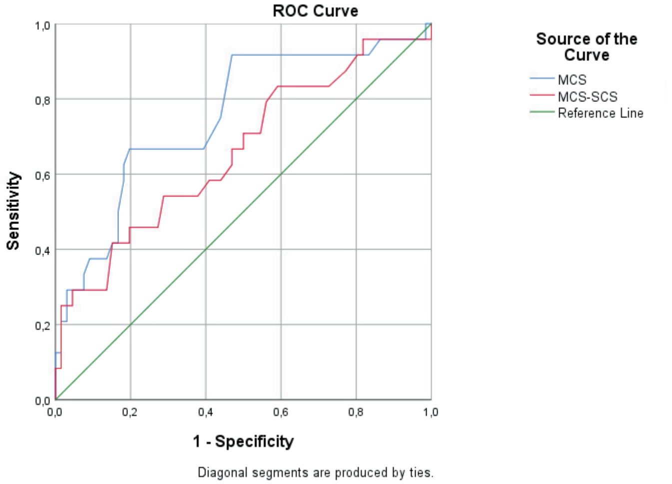

Figure 4b. Receiver Operating Characteristic (ROC) curves and corresponding Area Under the Curve (AUC) for predicting deep deltoid ligamentous injury on MRI based on the

gravity stress view with Medial Clear Space (MCS) and Medial Clear Space minus Superior Clear Space (MCS-SCS) as criteria.

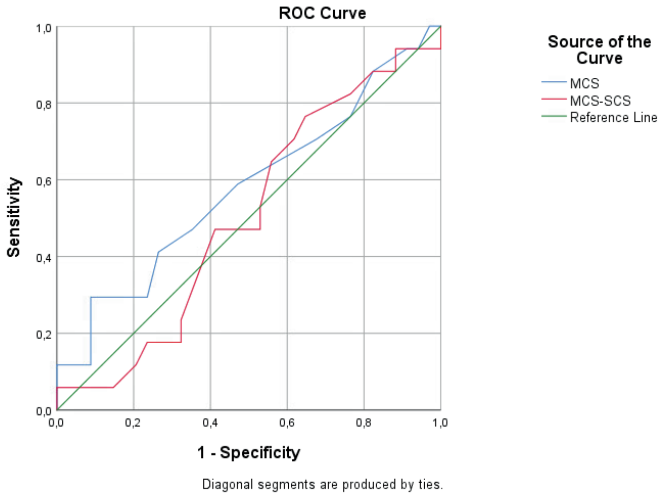

Figure 4c. Receiver Operating Characteristic (ROC) curves and corresponding Area Under the Curve (AUC) for predicting deep deltoid ligamentous injury on MRI based on the weightbearing view with Medial Clear Space (MCS) and Medial Clear Space minus Superior Clear Space (MCS-SCS) as criteria.

Discussion

The most important goal in the radiologic evaluation of Weber type B ankle fractures is to make an accurate distinction between fractures with or without DDL rupture. The isolated type B fracture without DDL rupture is stable and can safely be treated conservatively with good functional outcomes. [8,10,24-28]

To be able to differentiate between stable and unstable fractures, an accurate diagnostic tool is necessary. Currently, there is no consensus on the best diagnostic tool for diagnosing a deep deltoid rupture. Open surgical exploration is the gold standard for identifying a medial rupture. However, it is obviously not desirable nor ethical to perform surgery in all patients with a type B ankle fracture. Till now, with sufficient presentation of the posterior part of the DDL (the posterior deep tibiotalar ligament), the MRI scan has met most requirements in determining a medial ligament rupture. [15,29] Due to its high costs and limited availability, however, it is not feasible to use MRI for this purpose in every center. Moreover, it is a static and not a dynamic diagnostic tool. Thus, studies have been performed to find alternative radiographic diagnostic tools with the ability to predict DDL rupture and stability of the fracture.

Nowadays, the mortise radiograph is the most commonly used tool for this purpose. However, it has been shown that MCS widening on the mortise radiograph depends on patient-specific factors and that a MCS cut-off value of 4 or 5 mm will lead to surgical treatment in some patients with type B fractures who could safely have been treated without an operation. [30] Moreover, to achieve a correct mortise view, the positioning of the patient is crucial. Without adequate positioning and adequate dorsiflexion, the MCS might incorrectly be wider. Therefore, it is quite important that the radiology laborant knows exactly how to perform this type of radiograph.

Another radiographic discongruency that is used to assess instability is the comparison between the MCS and the SCS. A cut-off value of MCS ≥ SCS + 2mm to indicate instability is commonly used. [12,21]

In the current study, we found a very high specificity of both GS and WB radiographs. With cut-off value MCS ≥ SCS + 2 mm, the WB radiograph was 100% specific in excluding medial injury, with a sensitivity of 6%. With this same cut-off value, the RM has a specificity of 97% and a sensitivity of 0%. The GS has a sensitivity of 6% and specificity of 100% with cut-off value MCS ≥ SCS + 3mm.

Based on these results we would advise to make use of the GS radiograph in case of MCS 4-6 mm on mortise radiograph. When MCS is < SCS + 3mm on GS radiograph, the advice would be to perform the WB radiograph. Figure 5 illustrates this advice for the work-up process in a flowchart.

Figure 5. Flow-chart for the work-up process of the different radiologic tests and cut-off values.

Previous studies on the additional value of the GS have been published. In one recent prospective study, the authors concluded that the GS radiograph, also compared with MRI, has a high sensitivity of 100% with cut-off value of MCS > 6 mm in detecting deltoid ligament rupture. [17]

However, the other study concluded that the GS radiograph has higher MCS values compared to the mortise and WB radiograph, and may therefore lead to surgical overtreatment when using these same cut-off values of 4 or 5 mm. In this cohort, patients with MCS between 5 and 6 mm on initial GS radiographs showed no MCS widening during follow-up and had good clinical functional outcomes with conservative treatment. [21]

In the current study, the very low sensitivity is presumably due to the small number of ruptures in the second cohort and makes this value less significant.

The other diagnostic tool investigated in the current study, the WB radiograph, has, to our knowledge, not yet been compared with MRI or surgical exploration. Previous studies found good clinical outcomes in conservatively treated patients with no widening of MCS on the WB radiograph. [20,21,32,33] Stewart et al. performed a cadaveric study in which they found no MCS widening during axial load in patients with a rupture of the DDL, hereby suggesting underestimation of the degree of instability when using the WB radiograph. [34] The main advantage of the WB radiograph is the fact that in case of no medial widening, the fracture is proven stable while weight-bearing. These patients can safely start weight-bearing shortly after sustaining the fracture.

Seidel et al. compared the GS radiograph with the WB radiograph in a prospective cohort study. They concluded that the WB radiograph is a reliable method to evaluate functional stability in isolated lateral malleolar fractures, allowing successful conservative treatment, while the GS radiograph indicates a high number of presumed instabilities. The presumed instability appeared to be of no clinical relevance. [31] This finding corresponds with our results that the GS radiograph tends to have higher mean MCS values even in patients with no proven medial injury on MRI. This might lead to surgical overtreatment when using the same cut-off values of 4 or 5 mm. As proven in this cohort, even in confirmed stable fractures (without rupture on MRI), the MCS widens on GS at least 1mm compared to MCS on RM. This emphasizes the need for a different MCS cut-off value when using the GS view, taking into account this natural widening of 1mm. For future studies, a comparison with MCS of the not-fractured ankle is advised.

In light of our results and conclusions, the main limitation of this study is the small number of complete ruptured DDLs. In only 4 patients, complete ruptured DDL's were seen. Of these 4 patients, in only one a WB radiograph was obtained. This makes the calculated value of the sensitivity and specificity of the WB radiograph for only a complete rupture less significant. In 21 patients, a partial rupture was seen. Similar to the study by Schottel et al, these injuries were also considered as supination external rotation IV (SER IV) equivalent ankle fractures. [35]

To avoid unnecessary costs and delay in operative treatment, patients with MCS widening > 6 mm on mortise radiograph were not included in this study and were immediately scheduled for surgery. Unfortunately, this has led to a very small number of completely ruptured DDLs as diagnosed by MRI in the current study. To better determine the accuracy of all tests, it is necessary to conduct a larger, prospective study including more patients with ruptured DDLs. This study should consider including all patients with MCS > 6 mm regardless of their clear indication for surgical treatment.

Another limitation is that the degree of weight-bearing during the performance of the WB radiograph was not measured objectively. Even with no mention of pain, it is questionable how much weight the patients put on their broken ankle. For an adequate evaluation of the value of this radiograph as a diagnostic tool, it is necessary to check on full weight-bearing during the taking of the WB radiograph.

MRI scanning results were used as a reference standard in this study. Although this is currently the best available radiographic test, this tool is not a 100% predictor of ligament disruption. [36,37] Advantage of MRI scan is the possibility of further assessment of additional injuries (medial malleolar fractures, distal avulsion fractures, osteochondral injuries of the talus, syndesmosis injuries and tibialis posterior abnormalities). In this study, the focus was on DDL rupture and for this reason the additional injuries were not assessed.

Given the need to distinguish between stable and unstable fractures, which can best be detected during loading and movement, the static character of the diagnostic tool MRI scan is a disadvantage. As stated by Nortunen et al., a quantitative test (for example, the WB radiograph) would be more suitable for the assessment of the stability than a qualitative examination such as MRI. [37]

In conclusion, despite their low sensitivity, the gravity stress and weight-bearing radiographs might have additional value in excluding deep deltoid ligament rupture. When taking into account the natural MCS widening on gravity stress, the gravity stress radiograph with MCS > SCS + 3mm and weight-bearing radiograph with MCS > SCS + 2mm may both exclude deep deltoid rupture with a specificity of 100%. Therefore, we suggest the optional use of these additional radiographs in case of MCS 4-6 mm on mortise radiograph as an additional help in exclusion of a rupture of the deep deltoid ligament.

All authors declare that they do not have any conflict of interest.

Patient		Mortise			Gravity	Weight-bearing
	MRI medial	MCS (mm)	SCS (mm)	Fib. disloc. (mm)	MCS (mm)	MCS (mm)
				AP		
1	1	3,2	2,8	1,6	4,9	3,2
2	0	3,1	2,7	2,5	4,1	3
3	1	3,6	3,7	0,8	5	3,1
4	1	3,2	2,9	1,8	4,2	3
5	2	2,8	3,5	2,3	4,5	2,7
6	1	3,6	3,8	1,7	3,8	3,3
7	1	3,6	3,7	1	5,6	3,9
8	0	3,2	3,2	1,6	4,6	2,9
9	2	4	3	0,1	3,4	2,9
10	0	2,5	2,6	1,5	4,7	2,5
11	1	3,4	3,1	1,8	4,8	2,7
12	1	3,1	3,2	1,3	3,8	3
13	2	3,7	3,4	1,3	5,1	3,3
14	0	3,7	3,1	1,7	4,3	3,1
15	0	3,7	3,5	0,8	4,4	3,5
16	0	3	2,8	0,8	6,1	3,2
17	2	3,2	3,9	2	6,8	3,6
18	0	3,1	3,7	0,5	4,7	3,2
19	0	3,4	3	1,6	3,3	2,6
20	0	3,6	2,9	1,5	4,3	3
21	2	3,1	2,8	2	5,2	3,2
22	0	3,1	2,4	2,5	3,2	2
23	0	3,6	3,2	1,3	4,2	2,9
24	0	4	3,1	3,3	4,9	3,5
25	0	3,7	4	1,4	4,7	3,5
26	0	3,5	3,2	2,3	4,7	3
27	0	3	3,2	1,8	3,8	2,7
28	2	4,3	4,4	0,1	6,3	3,7
29	0	2,5	3,4	1,1	4,9	2,8
30	2	3,9	3	1	6,1	3
31	0	3,7	2,9	1,5	4,4	3
32	0	5	3,8	2,1	5,7	4,1
33	0	3,1	2,9	0,8	4,6	2,9
34	1	3,8	4,1	1	5,7	3,8
35	2	3	3,3	1,1	5,9	3
36	0	3	3,7	2,2	4,5	2,7
37	*2*	*5,8*	*4*	*2,1*	*7,7*	*6,9*
38	2	3,7	3,4	0,1	5,3	3,3

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39	0	3,9	3,7	3	6,6	3,4
40	2	4,1	3,6	2,1	5,6	4,6
41	2	3,9	3,4	0,8	4,6	3,1
42	2	4,2	3,2	2,2	5,4	2,5
43	0	3,4	3,3	1,2	6,1	3,1
44	2	3	3	1,6	4,5	2,8
45	3	4,2	4,1	1,3	5,3	3,7
46	0	3,7	3,2	1,2	4,4	3,1
47	1	2,9	3,4	0,1	4,2	2,8
48	2	2,6	2,8	1	4,5	3,1
49	1	3,4	3,1	1,3	4,5	3,4
50	2	3	3,2	0,1	4,6	3
51	2	3	3,4	1,4	5,4	2,8
52	0	1,7	2,6	2,3	2,3	
53	1	2,0	2,9	1,6	2,8	
54	0	2,1	2,2	0	3,3	
55	0	2,2	2,4	0	2,8	
56	0	2,2	2,5	4,2	3,4	
57	0	2,4	2,6	1,4	3,6	
58	1	2,4	3,4	4	3,6	
59	0	2,5	3,9	1,2	3,6	
60	0	2,5	2,5	1	4,0	
61	1	2,5	3,0	1,3	5,1	
62	2	2,5	2,9	0	2,6	
63	0	2,5	3,4	1,9	5,5	
64	0	2,6	3,1	2,2	5,0	
65	0	2,6	3,5	1,9	4,6	
66	1	2,6	3,7	2,3	4,0	
67	1	2,7	3,2	2,2	3,4	
68	1	2,7	3,5	0,7	4,4	
69	0	2,8	2,8	1,3	3,2	
70	0	2,9	2,8	0	4,0	
71	*1*	*3,0*	*3,3*	*1,5*	*2,8*	
72	2	3,0	3,1	2,4	4,5	
73	1	3,1	3,2	1,5	4,3	
74	1	3,1	3,4	0	4,7	
75	*2*	*3,1*	*3,0*	*3,2*	*6,3*	
76	0	3,2	3,1	0	3,3	
77	0	3,2	2,8	1	4,7	
78	*0*	*3,4*	*3,3*	*2,7*	*5,3*	
79	0	3,4	3,4	0	4,3	
80	*3*	*3,6*	*3,4*	*2*	*6,0*	
81	0	3,7	3,6	1,2	4,7	

82	*1*	*3,7*	*3,4*	*1,7*	*5,7*	
83	0	3,8	2,7	2	4,0	
84	0	3,8	3,1	2	4,2	
85	0	3,9	3,6	0	4,4	
86	*3*	*4,1*	*4,3*	*0*	*10,4*	
87	*3*	*4,4*	*3,4*	*5*	*7,2*	
88	*2*	*4,7*	*4,4*	*3,8*	*7,0*	
89	1	5,1	3,1	1,3	5,9	
90	*1*	*5,9*	*3,8*	*3,8*	*7,1*	

Appendix - Baseline characteristics and medial clear space (MCS), superior clear space (SCS), fibula dislocation of the cohort with mortise, gravity and weight-bearing radiograph. MRI score: 0: normal, 1: edema or low-grade partial rupture, 2: high-grade partial rupture, 3: complete rupture)

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8

The value of radiologic diagnostics in evaluating deltoid integrity in isolated type B ankle fractures: a systematic review of the literature

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Arch Orthop Trauma Surg. 2021 Mar 10.

Chapter 8 The value of radiologic diagnostics in evaluating deltoid integrity in isolated type B ankle fractures: a systematic review of the literature.

Abstract

Introduction

Excluding deep deltoid ligament (DDL) rupture in isolated type B ankle fractures is crucial in the decision-making process for surgical or conservative treatment. There is no consensus about the most accurate radiologic diagnostic test to determine medial injury. The aim of this study is to systematically review the literature concerning radiologic diagnostics that evaluate medial injury in adult patients with isolated type B ankle fractures.

Methods

The electronic databases PubMed, Embase, Web of Science, COCHRANE Library and Emcare were searched to identify studies published from January 1990 to December 2020 concerning sensitivity and specificity of diagnostic tests that evaluate medial injury in patients with an isolated type B ankle fracture. For inclusion comparison to a reference test was required to provide results in terms of sensitivity, specificity, and preferably positive predictive value and negative predictive value

Results

This review included 8 studies. Ultrasound showed the highest sensitivity of 100% and a specificity between 90-100% for detecting DDL rupture. Gravity stress radiographs showed a sensitivity of 71-100% and a specificity between 88 and 92%. The mortise, external rotation stress test and MRI had lower sensitivity and specificity values, between 65% and 88%.

Conclusion

The most accurate and available methods for diagnosing deltoid integrity seem to be the ultrasound and the GS radiograph. Further research is needed to confirm the results of this review.

Introduction

The type B ankle fracture, or Lauge-Hansen Supination External Rotation fracture (SER- type fractures), is one of the most frequently seen fractures at the Emergency Department.[1]
The decision to treat this fracture surgically or conservatively is merely based on the stability of the ankle. During axial load, the deep deltoid ligament (DDL) is the main stabilizer of the ankle. [2,3] In case of a bimalleolar fracture, or a unimalleolar fracture with DDL rupture, the fracture is considered unstable.
The current consensus is that unstable ankle fractures do require surgical treatment. [1,4] The diagnosis of DDL rupture is therefore crucial in the decision-making process. Stable fractures need to be identified in order to safely treat these fractures conservatively, if the amount of dislocation is limited and acceptable. Different types of radiographs (mortise, external rotation stress, gravity stress, weight-bearing radiograph), the ultrasound and the MRI scan have been investigated in order to find the best diagnostic tool to ascertain DDL integrity. However, to date, there is no evidence-based consensus on how to best evaluate deltoid ligament integrity.

Therefore, in this study, the literature was reviewed to evaluate the value of the clinically available radiologic diagnostics for the assessment of the deltoid ligament integrity in SER ankle fractures, in order to formulate recommendations for treatment strategies.

Materials and methods

This review was performed according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) for Diagnostic Test Accuracy guidelines.[5]

Search strategy

Clinical studies concerning the diagnostic value of radiographic tests to determine medial injury of the ankle in adult patients with an isolated distal fibular fracture were eligible for this systematic review. We searched MEDLINE with PubMed, Embase, Web of Science, COCHRANE Library and Emcare in the period of January 1990 to December 2020. The search strategy for PubMed is presented in table 1. Only full text articles in the English language were included. Abstracts from meetings, case reports and cadaveric studies were excluded.

Table 1. Search strategy for PubMed

(("weber b ankle fracture"[tw] OR "weber b ankle fractures"[tw] OR "weber b fracture"[tw] OR "weber b fractures"[tw] OR "weber b ankle"[tw] OR "type b ankle fracture"[tw] OR "type b ankle fractures"[tw] OR "type b ankle"[tw] OR "B ankle fracture"[tw] OR "B ankle fractures"[tw] OR "Lateral Malleolus Fractures"[tw] OR "Lateral Malleolus Fracture"[tw] OR "Lateral Malleolar Fractures"[tw] OR "Lateral Malleolar Fracture"[tw] OR "unimalleolar fracture"[tw] OR "unimalleolar fractures"[tw] OR (("Ankle Fractures"[Mesh] OR "ankle fracture"[tw] OR "ankle fractures"[tw] OR "fractured ankle"[tw] OR "fractured ankles"[tw] OR (("ankle"[tw] OR "ankles"[tw] OR ankle*[tw] OR malleolar*[tw]) AND ("fracture"[tw] OR "fractures"[tw] OR fractur*[tw]))) AND ("Weber B"[tw] OR weber b*[tw] OR weberb*[tw] OR "type B"[tw] OR "type-B1"[tw] OR "type-B2"[tw] OR "type-B3"[tw] OR "type-B4"[tw] OR "type-B5"[tw] OR "typeB"[tw] OR ("B"[tw] AND ("type"[tw] OR "weber"[tw])) OR "B1"[tw] OR "B2"[tw] OR "B3"[tw] OR "B4"[tw] OR "B5"[tw] OR "B 1"[tw] OR "B 2"[tw] OR "B 3"[tw] OR "B 4"[tw] OR "B 5"[tw] OR "44B"[tw] OR "44 B"[tw] OR "Lateral Malleolus"[tw] OR "Lateral Malleolar"[tw] OR "unimalleolar"[tw] OR "SER"[tw] OR "supination external rotation"[tw]))) AND ("diagnosis"[Subheading] OR "diagnosis"[tw] OR diagnos*[tw] OR "Diagnosis"[mesh] OR radiogra*[tw] OR "MRI"[tw] OR "magnetic resonance"[tw] OR mr imag*[tw] OR computer tomogr*[tw] OR computed tomogr*[tw] OR computer assisted tomogr*[tw] OR computed assisted tomogr*[tw] OR ultraso*[tw] OR sonogra*[tw] OR diagnostic imag*[tw]) NOT (("Case Reports"[ptyp] OR "case report"[ti] OR "case reports"[ti] OR "editorial"[ptyp] OR "comment"[ptyp] OR "editorial"[ti]) NOT ("Review"[ptyp] OR "review"[ti] OR "Clinical Study"[ptyp] OR "trial"[ti] OR "RCT"[ti])) AND english[la] NOT (("Infant"[mesh] OR "Child"[mesh] OR "Adolescent"[mesh] OR "child"[ti] OR "children"[ti] OR infant*[ti] OR adolescen*[ti]) NOT ("Adult"[mesh] OR "adult"[ti] OR "adults"[ti])) NOT ("avulsion"[ti] OR "Fractures, Avulsion"[Majr]))

Study selection

Two reviewers (CvL, JH) independently reviewed the title and abstract of the identified studies to select relevant articles for full-text review. From the full text, two reviewers (CvL, JH) independently selected articles eligible for inclusion using the same inclusion criteria. Disagreement was resolved by consensus. To be selected, the paper needed to describe a comparison between two radiographic tests, with the judgement of medial integrity of the ankle joint as outcome measure in adult patients with an isolated distal fibula fracture. To include a study, a reference test was required with results in terms of sensitivity, specificity, and preferably positive predictive value and negative predictive value. Regarding the radiologic tests, papers evaluating the mortise radiograph, manual external rotation stress test, gravity stress radiograph, weightbearing radiograph, MRI and ultrasound were included. Articles that described bi- or trimalleolar fractures or multi-traumatized patients were excluded. Articles of which the full-text publication could not be retrieved were excluded too. The reference lists of selected studies were screened for other potential studies meeting the criteria.

Data extraction

Of the included studies, the following data were extracted: author, publication date, and study characteristics (design, number of included patients, age, radiologic diagnostics used, radiologic measurements). Outcome parameters were sensitivity, specificity, positive predictive value, negative predictive value and medial clear space (MCS) comparisons between two radiographic tests (with p-value). The study results were not summarized by means of meta-analysis, because different reference tests were used per index test in the selected studies.

Assessment of methodological quality

Methodological quality (risk of bias and applicability) of the studies was assessed according to the QUADAS-2 tool [6]. This tool includes four aspects of the risk of bias (patient selection, index test, reference standard, flow and timing) and three aspects of the applicability concerns (patient selection, index test, reference standard).

Results

In total, 921 articles were found with the search. The main reason for exclusion of 823 studies was that the diagnostic tests in the study did not evaluate medial integrity of the ankle joint. Seventy-one of the remaining 98 studies evaluated a different outcome parameter and 11 studies investigated a non-eligible study population. Eight studies did not use a reference test, nor were sensitivity, specificity, positive predictive value or negative predictive value assessed. After the screening procedure and full-text assessment as shown in figure 1, eight studies were selected for this review. Of those, seven were prospective cohort studies and one a retrospective cohort study. No randomized-controlled trials were found. Two studies investigated the value of ultrasound [7,8], two of gravity stress (GS) radiographs [9-10], one of the MRI scan [11], one of the mortise radiograph [12], and two of external rotation stress radiographs [13-14]. An overview of these studies is shown in table 2. The main results of all studies are summarized in table 3.

Table 2. Included studies

Study (*year of publication),* study design	**Patients *(n)***	**Comparison**
Henari (2011), prospective cohort	12	Ultrasonography vs. mortise radiographs vs. arthrographic findings
Rosa (2020), prospective cohort	81	Ultrasonography vs. gravity stress radiograph
Van Leeuwen (2018), prospective cohort	39	Gravity stress radiograph vs. mortise vs. MRI
Jeong (2018), prospective cohort	37	Gravity stress radiograph vs. MRI vs. external rotation test
Park (2018), retrospective cohort	74	MRI vs. intraoperative stress test
Schuberth (2004), prospective cohort	40	Mortise radiographs vs. direct arthroscopic visualization
Warner (2018), prospective cohort	79	Nonstress and stress radiographs vs MRI
Schottel (2015), prospective cohort	52	Stress radiographs vs MRI

Table 3. Included studies with the results per index- and reference test

Index test	**Study**	**Sensitivity**	**Specificity**	**PPV**	**PNV**	**Reference test**
Mortise	Van Leeuwen	66,7%	91,7%	40%	97%	MRI
Mortise	Henari	57,1%	60%			Arthrogram
Mortise	Schuberth		46,4%			Arthroscopic visualization
External rotation stress test	Schottel	65,8%	76,5%			MRI
External rotation stress test	Warner	87%	13%			Intra-operative visualization
Gravity stress radiograph	Van Leeuwen	100%	91,7%	50%	100%	MRI
Gravity stress radiograph	Jeong	71%	88%			External rotation stress test
Ultrasound	Rosa	100%	90%	97%	100%	Gravity Stress Radiograph
Ultrasound	Henari	100%	100%			Arthrogram
MRI	Jeong	43%	94%			External rotation stress test
MRI	Park	74%	78%	54%		Intraoperative stress test
MRI	Warner	82%	100%			Intra-operative visualization

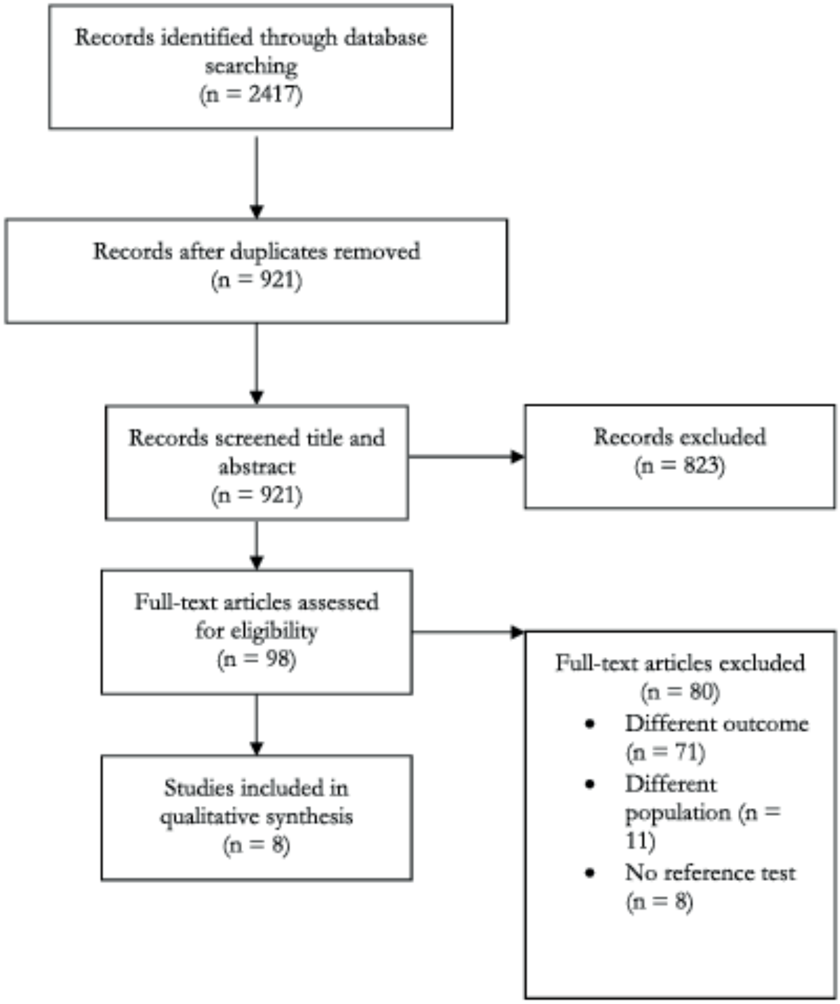

Figure 1. Flowchart diagram of included publications

Henari et al [7] found a sensitivity of 100% and a specificity of 100% for the ultrasonography in diagnosing medial injury in 12 patients with an ankle fracture with indication for surgical fixation based on the mortise radiographs. The ankle arthrogram was used as reference test. The mortise radiographs of the same patients, with MCS > 4 mm or MCS > SCS + 1mm as cut-off value, were 57.1% sensitive and 60% specific in diagnosing DDL rupture, again compared with the findings on arthrogram.

Rosa et al [8] investigated the ultrasound and used the gravity stress (GS) radiograph as reference test in 81 patients with a non-displaced fibula fracture on mortise radiographs. When comparing the ultrasonography with the reference GS radiograph in diagnosing a DDL rupture, a sensitivity of 100% for the ultrasonography was found, a specificity of 90%, a positive predictive value of 97% and a negative predictive value of 100%.

In 2018, Van Leeuwen et al. [10] investigated the value of the GS radiograph compared to MRI for the diagnosis of a DDL rupture. With MCS ≧ 6 mm as threshold value for indicating a DDL rupture, the GS radiograph had a sensitivity of 100%, a specificity of 91.7%, a positive predictive value of 50% and a negative predictive value of 100% compared to the reference MRI. Also compared to MRI results, the mortise view with MCS > 4 mm as cut-off value for indicating a DDL rupture had a sensitivity of 66.7%, a specificity of 91,7%, a positive predictive value of 40% and a negative predictive value of 97%.
Jeong et al.[9] used the external rotation stress test as reference to evaluate the value of the GS radiograph and MRI. They found a sensitivity of 71% and a specificity of 88% for the GS radiograph and a sensitivity of 43% and a specificity of 94% for MRI in diagnosing deltoid rupture. To evaluate the value of the MRI scan, Park et al [11] compared the preoperative MRI findings with results of an intraoperative stress test. They found a sensitivity of 74%, a specificity of 78% and a positive predictive value of 54% and a negative predictive value of 90% for the MRI scan.

Schuberth et al. [12] compared the mortise radiograph with direct arthroscopic visualization in a prospective study. The MCS was measured on injury mortise radiographs of 40 patients who underwent open reduction and internal fixation. Direct arthroscopic visualization was used to evaluate the DDL under manual stress before fracture reduction. The mean MCS in patients with DDL rupture was 6.6 mm (standard deviation 2.4 mm) and in patients without DDL rupture it was 4.0 mm (standard deviation 1.0 mm) (p=0.002). With a cut-off value of MCS ≧ 4 mm, the false positive rate of the mortise radiograph was 53.6%. With the cut-off value of MCS ≧ 5mm, this false positive rate diminished to 26.9%. And finally, with a cut-off value of MCS ≧ 6mm the false positive rate for deltoid rupture was 7.7%.

Warner et al. [13] compared the external rotation stress radiograph and MRI results and used intraoperative direct visualization as reference standard for DDL rupture. In fractures with MCS < 5 mm on mortise radiograph, the stress test was much less sensitive than MRI (46% vs. 79%) in diagnosing DDL rupture. A on mortise view showing a MCS > 5 mm was a strong predictor of DDL rupture (95% sensitivity).

In 2015, Schottel et al. [14] included 52 patients with a supination external rotation injury and performed MCS measurements for external rotation stress tests in order to diagnose DDL tears. A preoperative MRI scan was obtained for all patients as a reference. Results showed that the stress radiograph, with different MCS cut-off values, the highest sensitivity and specificity for a MCS cut-off value > 5 mm, of 65.8% and 76.5% respectively.

Methodological quality analysis

Results of the methodological quality analysis are shown in table 4. For most studies, risk of bias in patient selection and index test was low. In case of risk of bias, this bias was in most studies based on their patient selection. No concerns about applicability were deemed to be present.

Table 4. Methodological quality assessments of the studies. ☺ = low risk, ☹ = high risk, ? = unclear

Study		**Risk of Bias**				**Applicability concerns**	
	Patient selection	**Index test**	**Reference Standard**	**Flow and Timing**	**Patient Selection**	**Index Test**	**Reference Standard**
Henari	☹	☹	☺	☺	☺	☺	☺
Rosa	☺	☺	☹	☺	☺	☺	?
Van Leeuwen	☺	☺	☹	☺	☺	☺	☺
Jeong	☺	☺	☹	☺	☺	☺	☹
Park	☺	☺	☺	☺	☺	☺	☺
Schuberth	☹	☺	☺	☺	☺	☺	☺
Schottel	☺	☺	☹	☺	☺	☺	☺
Warner	☹	☺	☺	☺	☺	☺	☺

Discussion

This review was conducted in order to find the most accurate radiologic diagnostic tool for diagnosing DDL rupture in type B distal fibular fracture. Results were diverse. Although different reference tests were used, ultrasound irrefutably shows the best results with a sensitivity of 100% and a specificity between 90-100%. The gravity stress radiograph also showed good results in excluding DDL rupture, with a sensitivity between 71% and 100% and specificity between 88 and 92%. The mortise, external rotation stress test and MRI have lower sensitivity and specificity with values between 65% and 88%.

The **mortise radiograph**, the initial injury radiograph of ankles with an isolated distal fibular fracture, is the most commonly used radiograph in ankle fractures. [15-16] When the deep deltoid ligament is ruptured additional to the fibula fracture, this allows lateral translation of the talus to lateral. Thus, measurement of the MCS on mortise views may indicate medial injury. However, which cut-off value for MCS indicates a DDL rupture? No consensus exists to that point. According to several studies, a MCS of ≧ 4 mm on the mortise radiograph would suggest a DDL rupture. [15-19] However, in 7.7% of the patients with an MCS widening of ≧ 6 mm, the DDL is still intact. In patients with MCS < 6 mm, this percentage is even higher. [20]
These findings are confirmed by Warner et al., who compared the mortise radiograph with intraoperative direct visualization and found a 95% sensitivity of the mortise view with MCS ≧ 5 mm. [13] However, Schubert et al [12], who also used surgical exploration as gold standard, found a false positive rate of 53.6% of the mortise radiograph with MCS cut-off value of ≧ 4 mm. This difference in outcome demonstrates the unreliable character of the mortise radiograph (especially with a low cut-off value of MCS > 4 mm) in diagnosing DDL rupture. Therefore, when surgeons use the MCS cut-off value of ≧ 4 mm to indicate unstable fractures and decide to treat surgically, this will lead to surgical overtreatment of stable ankle fractures. Murphy et al [21] did also question the widespread use of an MCS measurement of 4 to 5 mm as cut-off value in determining the need for surgical treatment of type B ankle fractures. Overall, multiple studies have concluded that the mortise radiograph alone may not give sufficient information about medial injury to determine the treatment strategy. [12,15]

8

The results of the **ultrasound** are quite promising. Studies with small numbers of patients found good results for the accuracy of the ultrasound, with a 100% specificity and sensitivity for detecting DDL rupture. [7,16] However, the ultrasound was performed in patients who already had an indication for surgical treatment based on the mortise radiograph. The results must therefore be interpreted in the light of this selection bias. Also, Rosa et al.[8] compared the ultrasound results with the gravity stress as reference standard, which is not a golden standard itself.

Nevertheless, based on the overall results, the ultrasound appears to be an accurate tool, in experienced hands. Still ultrasound is not commonly used for the diagnosis of DDL rupture. The practical disadvantages (the required presence of an experienced radiologist, the technical availability) probably make this tool not the diagnostic method of first choice at the moment. [8,16] Also, the unfamiliarity with the scanning technique for the diverse ligaments may pose a burden. However, based on the study results and its high accuracy, it might be worth it to train more radiologists to perform these ultrasounds of the medial ankle in order to exclude DDL rupture.

The **gravity stress radiograph** showed a specificity and sensitivity of 100% in detecting DDL rupture in a cadaveric study by Michelson et al. [22] This study was performed with only eight cadaveric lower extremities. They compared their results of the gravity stress radiograph with soft tissue dissection and thereby exposition of the deltoid ligament. Gill and Schock [17,18] compared the results of the gravity stress radiographs with those of the external rotation test as a reference. They did not find significant differences between these two tests in the values of the MCS. Van Leeuwen et al. [10] found that the gravity stress radiograph with a cut-off value of MCS ≥ 6 mm has a 100% sensitivity and a 91.7% specificity compared to MRI for detecting DDL. The use of a cut-off value of MCS ≥ 5 mm weakened their results. Moreover, the use of MRI scan as reference standard is controversial.[11] Holmes et al. [23] similarly concluded that cut-off values of 4 or 5 mm on gravity stress radiographs may over-estimate instability. The average MCS value in their healthy population was already 4.42mm. Based on these results and taking into account the natural widening of the MCS in gravity stress radiograph, we suggest to use values of MCS > 7 mm and/or MCS > SCS + 3 mm to indicate instability with high sensitivity and specificity.

Magnetic Resonance Imaging (MRI) has also been suggested to be an accurate tool, according to some studies that use it as a gold standard to diagnose ligamentous injury. [24-26] However, for assessment of the deltoid ligament the MRI has never been confirmed as gold standard. Nevertheless, in many studies and in this review as well, it is found to be used as the reference standard.

In this review, however, when the MRI as tested as index modality, a moderate sensitivity of 74-79% [13] and specificity of 78% to diagnose DDL rupture with MRI was found when using intra-operative exploration as reference. [11] Other studies also failed to demonstrate an association between MRI findings and results of an intraoperative stress test that confirmed syndesmotic instability. [27-29] Based on the studies found in literature, the use of MRI as reference standard is questionable. Moreover, MRI is an expensive tool and, like the ultrasound, not always available in every center. This makes the MRI scan less suitable as primary choice for detecting deltoid injury.

Lastly, when the tibia is internally rotated, followed by manual dorsiflexion and external rotation of the foot, an **external rotation stress radiograph (ERSR)** can be performed. [17] In most patients, anesthetics have to be used to make this performance less painful for the patient. Overall, ERSR shows low to moderate sensitivity and very low specificity. [13-14].
A disadvantage of the external rotation stress test is that the amount of force needed to perform the radiograph is not standardized. [30] Moreover, the degree of ankle joint flexion influences the results. [31] Overall, ERSR showed low to moderate sensitivity and very low specificity. The dependence on the force and flexion degree may be part of the explanation for these low values. The combination of pain, the unstandardizable procedure, and the low specificity and sensitivity make us conclude that the external rotation stress test should be dismissed as a radiographic tool for diagnosing DDL injury.

The **weightbearing (WB)** radiograph has been investigated with good clinical outcomes in conservatively treated patients with no widening of MCS on the weightbearing radiograph. [23, 32-39] However, these studies did not compare the WB radiograph with a reference standard and were therefore not included in this review. Van Leeuwen et al. [38] found a specificity of 100% on the weightbearing radiograph with MCS > SCS + 2mm as cut-off value. This confirms the need for a specific threshold when making use of a particular radiographic tool. A disadvantage of the WB radiograph is that the amount of weightbearing is not measured. However, most patients are able to perform the radiograph without pain. [38]

Limitations to this review include the risk of selection bias in some studies. These studies included patients that already had an indication for surgery, which presents a bias by indication. [7,16]. The major limitation of this review is the use of different and, in some studies, unsuitable reference tests. This renders comparison of results difficult, since estimates of test accuracy are based on the assumption that the reference standard is 100% sensitive and 100% specific. In the study of van Leeuwen et al., the GS test is compared with MRI test as reference standard. [10] Other studies have shown, however, that MRI scan is far from 100% sensitive itself. [27-29,39].
Logically, the only real gold standard is intra-operative assessment of the deltoid ligament, which is unfortunately ethically an unfeasible standard.

Finally, the studies used different cut-off values for the MCS to define instability. This makes a fair comparison between the radiologic tests unavoidably difficult.

To conclude, based on the results of this review, primarily the ultrasound and secondarily the GS radiograph seem to present the most accurate evaluation of the deltoid ligament in type B ankle fractures. We advise to make use of these additional diagnostics in the decision-making process of treatment choice for type B ankle fractures. Further research is needed to confirm the promising results of the ultrasound in diagnosing DDL rupture.

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9

Fibular displacement does not predict instability in type B ankle fractures

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Chapter 9 Fibular displacement does not predict instability in type B ankle fractures

Abstract

Introduction
Despite the wide prevalence of ankle fractures, no consensus exists on the most accurate radiologic diagnostic tool to indicate medial ligament injury in isolated type B distal fibular fractures. Aim of this study was to evaluate the value of the fibular fracture displacement in predicting medial clear space widening on the gravity stress radiographs, as a parameter of fracture instability.

Methods
This retrospective cohort study included 192 patients with an isolated type B fibular fracture, for which a regular mortise and gravity stress radiograph was made in our hospital between January 2014 and December 2019. On the regular mortise and lateral radiographs, the medial clear space (MCS), superior clear space (SCS), anteroposterior and lateral fibular displacement were measured. On the gravity stress radiograph, the MCS and SCS were measured. Instability was defined as MCS $\geq$ SCS + 3.0 mm on the gravity stress radiograph. A Receiver Operating Characteristic (ROC) curve was constructed to evaluate the predictive value of the fibular displacement.

Results
Of the 192 included patients, 55 (29%) patients had instable ankle fractures. In predicting instability, fibular displacement demonstrated an Area Under the Curve (AUC) of 0.68 (95% confidence interval 0.60-0.77) and a correlation coefficient of 0.41 with MCS.

Conclusion
Fibular displacement on regular mortise view is a poor predictor of instability in type B fibular fractures. It should not be advised to use the fracture displacement as parameter for medial injury and thus for operative treatment.

Introduction

Three-quarters of all ankle fractures presented at the Emergency Department are type B ankle fractures [1]. Stable (unimalleolar) type B ankle fractures can safely be treated conservatively in many cases. Unstable type B fibular fractures (bimalleolar, trimalleolar or unimalleolar with deep medial deltoid ligament injury), on the other hand, by definition need surgical treatment to reach good functional outcomes [2]. Because of its great clinical impact on choice of treatment, accurate determination of instability is therefore important.
In case of a stable ankle type B fracture, without medial widening, solitary fracture displacement of the fibula is not an indication for operative treatment. [3]

The stability of the ankle is mainly based on the integrity of the Deep Deltoid Ligament (DDL) [2]. Currently, no consensus exists on the best radiographic tool to evaluate rupture of this medial ligament. A recent survey in the Netherlands demonstrated the diversity in current clinical practice.[4] Different radiographic diagnostics have been studied with varying results concerning quality and reliability: The ultrasound, magnetic resonance imaging (MRI), gravity stress radiographs, weightbearing and manual stress radiographs of the ankle have all been evaluated, in addition to the longstanding practice of performing a mortise view of the ankle. [5]
The gravity stress radiograph presented good results for diagnosing medial injury in a previous study, with a sensitivity of 100% and specificity of 91.7. [6]
Next to the MCS widening on mortise or gravity stress radiograph, many surgeons do make use of the fibular displacement (anterior-posteriorly or laterally) on the initial ankle trauma radiographs to assess stability and to decide whether or not to choose for operative treatment. In the Netherlands, 90.9% of trauma and orthopedic surgeons declare fibula displacement critical in determining treatment. [4] A fibular displacement of more than 2mm is commonly described as cut-off value for operative treatment. Although fibular displacement is easy to measure on initial radiographs, the cut-off value of 2mm is not based on published studies. There is hardly any literature on the correlation between the fibular displacement and medial injury, nor what cut-off value for fibular displacement would indicate instability.
Therefore, the aim of this study is to investigate the accuracy of fibular displacement in predicting MCS widening on the gravity stress radiograph and thus determining deltoid rupture of unstable type B fibular fractures.

Patients and Methods

This retrospective cohort study included all patients, aged 18 - 70 years, with an isolated type B fibular fracture, for which a regular mortise and gravity stress radiograph was made in our hospital (Haaglanden Medical Center in The Hague) between January 2014 and December 2019. Patients presenting with multitrauma, bimalleolar or trimalleolar fractures, or a former fracture of the same ankle were excluded. The process of inclusion is shown in figure 1.

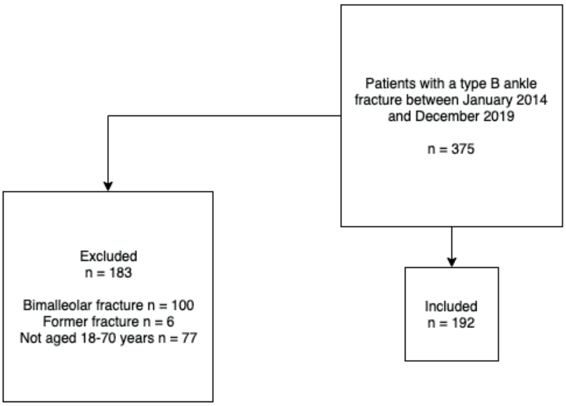

Figure 1. Flow-chart of included and excluded patients with reason for exclusion.

In our hospital, the gravity stress radiograph has been part of the diagnostic protocol for the treatment of isolated type B ankle fractures since 2014. [6] In patients with a type B ankle fracture and MCS > 6mm at the regular mortise view, operative treatment is planned because these injuries are considered unstable. In patients with MCS ≤ 6mm, an additional gravity stress radiograph is performed.

In this study, three parameters were determined: medial clear space (MCS), superior clear space (SCS) and fibular displacement (FD). On the regular mortise and lateral radiographs two of the authors, a surgical resident and an instructed medical student, measured these parameters.

(CvL,RvD). In case of discrepancy, the mean value was used. The MCS and lateral fracture displacement were measured on the mortise radiograph. The MCS was measured as a horizontal line from the lateral surface of the medial malleolus at the level of the talar dome to the medial border of the talus. [7] The SCS was measured from the center of the talar upper border straight to the tibia. [8] Posterior fracture displacement was measured on the lateral radiograph. On the gravity stress radiograph, the MCS and SCS were also measured. An example of these measurements is shown in figure 2. FD was defined as the largest of the posterior and lateral fracture displacement. The interobserver reliability of the variables MCS and SCS was proven to be high in former studies with intraclass correlation coefficients of 0.75 to 0.96. [7,9]

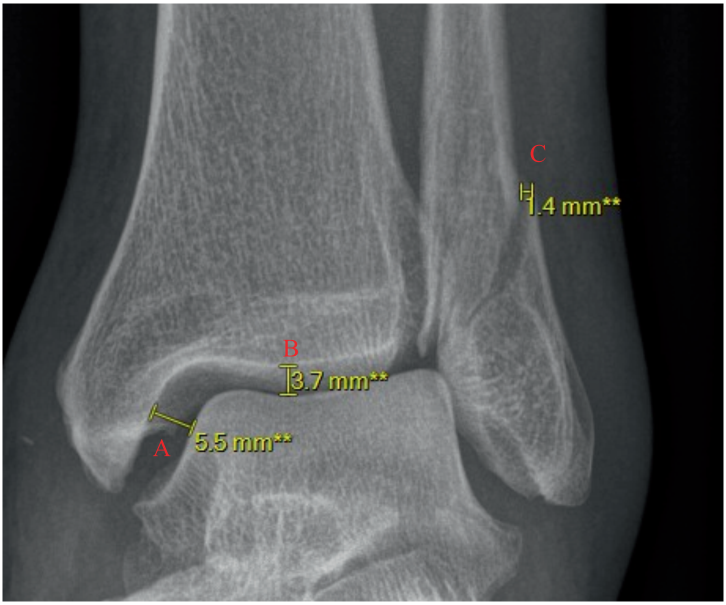

Figure 2a. Regular mortise view radiograph with measurements of medial clear space (A), superior clear space (B) and fibular lateral diastasis (C); mm** = millimeter

Figure 2b. Lateral view radiograph with measurements of fibular posterior diastasis; mm** = millimeter

Instability was defined as MCS ≥ SCS + 3.0 mm on the gravity stress radiograph. This cut-off value of MCS ≥ SCS+ 3.0 mm on the gravity stress radiograph was found to have an adequate value in determining a (partial or complete) rupture of the DDL in a previous study [10]

The patients were divided in groups with and without instability of the ankle based on their MCS and SCS values. Normal distribution of data was assessed prior to statistical testing. The radiographic characteristics of groups with and without instability were compared using the independent samples T-test (table 1). The association between the FD and the MCS on the gravity stress radiograph was calculated with a Pearson correlation coefficient. A Receiver Operating Characteristic curve (ROC curve) was constructed to assess the diagnostic value of FD and the area under the curve (AUC) with the corresponding 95% confidence interval (CI) was calculated. All statistical analyses were performed using IBM Statistical Package for the Social Sciences (SPSS) version 26.0.

Results

In total, 192 patients were included. The number of patients with ankle instability defined by MCS ≥ SCS + 3.0mm on the gravity stress radiograph was 55/192 (28.6%).

Patients with MCS < SCS + 3mm on the gravity stress radiograph were named group I, patients with MCS ≥ SCS +3mm, were classified as group II. Table 1 shows the radiographic characteristics of these two groups. The mean FD (defined as the largest of the lateral and posterior displacement) is shown together with the mean MCS and SCS as measured on the mortise radiograph and the gravity stress radiographs.

	Group I GSR MCS < SCS + 3.0 mm (n=137)	*Group II GSR MCS ≥ SCS + 3.0 mm (n=55)*	*P-value*
Regular Mortise Radiograph MCS in mm, mean (SD, range)	3.5 (SD 0.94, 0.9-6.0),	4.4 (SD 1.38, 2.1-8.1)	<0.001
Regular Mortise Radiograph SCS in mm, mean (SD, range)	3.4 (0.62, 1.8-5.5)	3.4 (0.62, 1.8-4.8)	0.844
Regular Mortise Radiograph Lateral Diastasis in mm, mean (SD, range)	1.6 (0.94, .0-4.5),	2.0 (1.41, .0-6.4),	0.019
Regular Lateral Radiograph Posterior Diastasis in mm, mean (SD, range),	1.6 (1.12, .0-4.8)	2.8 (1.70, .0-10.9),	<0.001
Regular Radiograph Fibular Displacement (FD) in mm, mean (SD, range), SD	2.2 (0.90, 0-4.8),	3.2 (1.70, 1.1-10.9)	<0.001
GSR MCS in mm, mean (SD, range)	4.8 (1.10, 2.0-7.3)	8.1 (2.63, 5.6-23.5)	<0.001

Table 1. Radiographic characteristics of patients with and without ankle instability, according to the Medial Clear Space (MCS) and Superior Clear Space (SCS) on
on the gravity stress radiograph (GSR).

Mean FD on the regular radiographs was 2.2mm (SD 0.90, range 0-4.8mm) in group I. In group II, the mean FD was 3.2mm (SD 1.70, range 1.1-10.9mm) ($p<0.001$) The correlation coefficient of the FD in relation with the MCS on the GS radiograph was 0.408 ($p<0.001$).

The ROC curve for predicting instability is shown in figure 3. Using a threshold value of MCS ≥ SCS + 3mm for instability on the gravity stress radiograph, the corresponding AUC was 0.687 (95% CI 0.602-0.772).

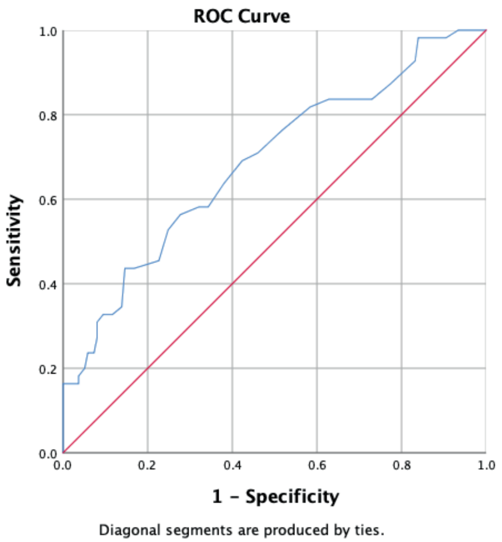

Figure 3. The Receiver Operating Characteristic (ROC) curve for patients with MCS ≥ SCS + 3.0 mm on the gravity stress radiograph (GSR).

When using a cut-off value of FD ≥ 2.0 mm, the sensitivity for predicting instability was 81.8% and specificity 41.6%. Alternatively, when using the cut-off value FD ≥ 3.0 mm, the sensitivity and specificity were 43.6% and 83.2%, respectively. These results are shown in table 2.

Cut-off	Sensitivity (%)	Specificity (%)	PPV(%)	NPV(%)
FD≥2.0 mm	81.8	41.6	36.0	85.1
FD≥3.0 mm	43.6	83.2	51.1	78.6

Table 2. Sensitivity, specificity, Positive Predictive Value (PPV) and Negative Predictive Value (NPV) of different scut-off values of Fibula Displacement (FD) for determining instability (GSR MCS ≥ SCS + 3.0 mm)

Discussion

This study investigates the predictive value of fibular displacement on regular ankle radiographs for deltoid rupture and thus instability of isolated type B ankle fractures. A cut-off value of MCS ≥ SCS +3mm on the gravity stress radiograph, resulted in an AUC of 0.68 for fibular displacement to indicate instability and showed only moderate correlation between the fibular displacement and MCS on the gravity stress radiograph (correlation coefficient of 0.41). This renders fibular displacement a poor predictor of ankle fracture instability.

Without existing consensus on the most accurate tool to diagnose medial injury, many surgeons use a MCS widening of more than 5 mm on the initial mortise view to indicate an unstable ankle fracture. [4,5,11,12] To date, this is seen as a gold standard. However, a recent study performed in our center concluded that if this cut-off value is used, many stable ankle fractures may be surgically overtreated. [10] This is why we preferred to set the MCS cut-off value at 3 mm for the current study.

As alternative diagnostic tools, the weightbearing and manual stress radiograph are also used to determine DDL rupture through measuring MCS widening. [6] The manual stress radiograph can, however, be painful and uncomfortable for the patient and is technician dependent. Therefore, it would be preferable to potentially eliminate the need for subjecting patients to a stress examination.

Also, there is a tendency to underestimate medial injury on the weightbearing radiograph. [10] The ultrasound has shown promising results in terms of specificity and sensitivity, but is not a feasible tool since an experienced radiologist is not always present. [13,14] Some studies labelled the MRI scan as gold standard, however with a sensitivity and specificity to diagnose deltoid rupture of 74% and 78% respectively, the MRI is still not the optimal nor best tool for diagnosing DDL injuries. [15] Moreover, the MRI comes with logistic difficulties and high costs.

All investigated radiographic tools have their advantages but none of them have proven to be sensitive enough without considerable disadvantages. Next to this, all tools are compared with different reference standards, making interpretation of the results less valuable. Whereas many studies use the MRI scan as gold standard, the ultrasound has, till date, shown the best results in terms of sensitivity for diagnosing instability in type B ankle fractures. [13,14]

There is consensus in the literature about the need for a diagnostic tool to diagnose deltoid injury. Diagnosing deltoid injury confirms the need for operative treatment. Excluding deltoid injury confirms that conservative treatment is safe. This emphasizes the importance of the deltoid integrity. [16]

Hence the search continues; how can we most reliably diagnose medial ligament injury? Can we also make use of the amount of fibular displacement on the mortise view to indicate instability?

In order to answer this question, the current study investigated the correlation of the fibular displacement on the initial trauma radiograph with medial injury. The advantage would be that fibular displacement can easily and non-invasively be measured on the initial mortise radiograph.

The current study did not find a significant correlation between the fibula displacement and medial clear space widening. This could be due to the relatively low number of included patients.

Based on the current literature, in case of a stable ankle type B fracture there is no reason to choose for operative treatment, independent of the fibular displacement. These stable fractures can safely be treated conservatively, with good results in terms of pain and function.] [3,17,18]

To our knowledge, only one study investigated the fibular displacement and its correlation with medial injury. Cavanaugh et al. performed a retrospective study to evaluate the predictive value of the fibular displacement in type B ankle fractures. They concluded that the fibula displacement is a strong predictor for medial clear space widening. [19] However, they only included 17 patients. Moreover, they used a cut-off value of MCS ≥ 5 mm on the gravity stress radiograph to diagnose deltoid rupture and then calculated sensitivity and specificity of the fibular displacement. Although commonly used, recent studies have suggested that applying the cut-off value of MCS >5mm on the gravity stress radiograph to diagnose medial injury may overestimate instability as a non-broken ankle also widens at least 1.2mm on a gravity stress radiograph, because of natural lateralization of the talus. [20]It might thus be necessary to make use of a higher cut-off value for MCS on the gravity stress radiograph in order to prevent false-positive results and surgical overtreatment. For this reason, we chose to use the cut-off value of MCS ≥ SCS + 3.0mm to indicate instability.

Another recently published study [21] retrospectively evaluated 92 patients with an unstable and surgically treated malleolar fracture of the ankle, and concluded that dislocation of the fracture presented an increased risk of inferior functional score at one year follow-up and non-return to sporting activity. However, the authors did not define fracture dislocation. Moreover, in their patients with a type B ankle fracture, 94% of the treated patients did return to their former sport activity level. They did not define whether patients with a dislocated fracture were also included in this type B cohort.

The current study is, to our knowledge, the first to investigate the fibular displacement and its correlation with medial injury in a large cohort of clinical patients. The ROC curve showed that when applying the threshold value of MCS ≥ SCS +3mm on the gravity stress radiograph, the fibular displacement (with different threshold values) does not have adequate predictive value for determining deltoid rupture. With an AUC of 0.68, fibular displacement cannot to be used to discriminate between stable and unstable ankles.

A possible limitation of this study is the relatively small number of patients with MCS ≥ SCS +3mm on gravity stress radiograph. Consequently, we may have underestimated the value of the FD for predicting instability. Moreover, the cut-off value of MCS ≥ SCS +3mm on gravity stress radiograph as threshold for instability is not yet acknowledged as the gold standard. However, based on the most recent literature including our own previous studies, this definition of instability based on MCS and SCS has shown the most accurate sensitivity and specificity in determining instability in type B ankle fractures. [6,10,12] Also, the retrospective nature of this study is another limitation.

In conclusion, this study did not find a correlation between fibular displacement and medial clear space widening. Based on the results of this study with a relatively small patient cohort, the amount of fibular displacement should not be used as a diagnostic measurement to indicate instability in type B ankle fractures nor as a parameter to choose between conservative or operative treatment.

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10

General discussion and clinical implications

Chapter 10 General discussion and clinical implications

Although the type B ankle fracture is the most commonly seen ankle fracture at the Emergency Department, the literature concerning its diagnostics and treatment has not led consensus in current practice. Not only in the Netherlands, but also internationally, there is no common pathway for diagnosing and treating an unstable ankle fracture. Over the last years, research has been done investigating multiple diagnostics. However, none of the investigated tools has led to a uniform diagnostic strategy. A protocol concerning radiologic tools to diagnose instability of type B ankle fractures does exist, but it does not give specific, well-argued, advice concerning which type of radiologic tool and cut-off value we should use. (1) In a well-developed country with a good health care system, such as the Netherlands, with protocols for any type of disease, it is unjustifiable that the care for a patient with a certain type of fracture depends on the hospital that he or she is visiting, or even on the specific surgeon that is on duty. Consensus exists that stable fractures can be treated safely conservatively, while unstable fractures need operative treatment. However, when different radiologic tools and cut-off are used, the same fracture is labeled as unstable by one surgeon but stable by the other, resulting in different treatment. There is need for a protocol on diagnosis and thus treatment of type B, stable and unstable, ankle fractures.

The primary aim of this thesis was to give insight in the current practice concerning diagnostics and treatment of type B ankle fractures, focusing on the decisional process and the type of treatment. The second aim was to provide recommendations and formulate a pathway for diagnosing medial injury, based on the existing literature concerning medial instability. Both topics are discussed below.

Current practice

Based on the nationwide survey among Dutch trauma and orthopedic surgeons described in **chapter 3** of this thesis, it was concluded that no consensus exists on how to diagnose instability of a type B ankle fracture. It shows that, in the Netherlands, trauma and orthopedic surgeons all have their own opinions on how to diagnose instability. Autonomy is appreciated in the surgical world. However, for the patients' best interests, it would be better to bundle our opinions and formulate a collective opinion supported by evidence-based literature.

We do know that unstable ankle fractures (i.e. a bimalleolar fracture or isolated fibular fracture with additional deltoid rupture) generally require operative treatment. (2,3) In this thesis, the accurate determination of instability of type B ankle fractures is studied and discussed, assuming that this instability has important clinical treatment consequences. However, is this assumption correct? Is it only the unstable ankle fracture that requires surgery, and can stable fractures safely be treated conservatively?

A study performed by Mittal et al., based on a combined randomized controlled trial and observational study, concluded that surgery is not superior to non-surgical management for stable type B ankle fractures in the short term, and that surgery is associated with an increased incidence of adverse events. (4) Their study ended with a 12-month follow-up questionnaire. To expand their follow-up duration and compare the *long-term* outcome of operative and non-operatively treated isolated type B fractures, the study described in **chapter 2** was performed. A large cohort of patients with stable ankle fractures was included and invited to fill out questionnaires concerning their functional outcome and pain after a mean follow-up of 5.3 years. The operatively and non-operatively treated patients showed no significant differences in outcome and pain. The operatively treated patients, however, required removal of the implants in 33%, which is quite a high percentage.

These two studies show that the majority of stable ankle fractures, with a MCS $\leq$ 6 mm, can indeed be safely treated conservatively with good clinical outcome. However, it is known that arthrosis of the joint, as the result of a non-congruent ankle joint, can still occur as a complication of a conservatively treated ankle fracture even 10 or 20 years after the trauma. To look further at the risk and clinical implications of this arthrosis, a study with an even longer follow-up period is necessary.

Moreover, since we have established that stable ankle fractures can safely be treated conservatively, the most accurate diagnostic to exclude instability is investigated. And if an ankle fracture is proven stable, could these ankle fractures also be treated with a brace? The common method of conservative treatment has been a cast or walking boot for 6 weeks, allowing for weightbearing depending on the pain. This treatment can cause stiffness of the ankle joint and may for many patients be quite uncomfortable. Therefore, van den Berg et al studied treatment of patients with a stable type B ankle fracture in a brace and showed that functional outcome of those fractures was similar compared to treatment with a cast. Stiffness, muscle wasting and pain can be prevented when people are treated with a brace immediately instead of a cast. (5)

Knowing that a stable ankle fracture can safely be treated conservatively in most cases, even while weightbearing in a brace, emphasizes the need to carefully identify those patients with an unstable ankle fracture, since they will require surgical treatment.

The conclusion of **chapter 2** accentuates the fact that we have to be careful not to surgically overtreat stable ankle fractures. Patients with an isolated, and thus stable, type B fracture should be prevented from having surgical treatment and its associated risks. Without proven instability, they can safely be treated conservatively. Dislocation of the fibular fracture should not be used as indicator for operative treatment, as can be read in **chapter 9.**

Of course, the decision to treat a fracture operatively or non-operatively is not only a medical technical decision. Today, physicians increasingly acknowledge the importance of patient-centered healthcare and shared-decision making. From this point of view, the study described in **chapter 4** was performed with the aim to give insight in the patients' opinion about outcome factors after treatment that would be the most important for them. As shown in **chapter 4**, self-sufficiency, walking and complete recovery are valued most by the patient. As physicians, we should always bear this in mind when making treatment decisions. Patients who intend to be mobile as soon as possible, with a proven stable ankle fracture, can for example be treated safely in a brace with immediate weight-bearing. In **chapter 4,** I emphasized that the best type of treatment does *not* only depend on the fracture type.

The search for diagnostics

Now that we have confirmed that most stable fractures can safely be treated conservatively, part II of this thesis focusses on how to confirm this stability and exclude instability.

We have argued for examination of the medial clear space (MCS) on the mortise radiograph to identify deltoid rupture. Many surgeons use a cut-off value of MCS ≥ 4mm to indicate instability. (6) However, even in cases with MCS ≥ 6mm, the deltoid ligament has been proven to be intact in 7.7%. (7) Thus, using the mortise radiograph with this cut-off value of MCS ≥ 6 mm may lead to surgical (over)treatment in a considerable number of stable ankle fractures. To reduce this risk, additional or alternative diagnostic tools are needed. For this reason, and based on the promising results of the gravity stress radiograph in the study described in **chapter 5,** the gravity stress radiograph was introduced in our local protocol. By adding an extra criterium with a high cut-off value (MCS > SCS + 2mm) to define instability on this radiograph, introduction of the gravity stress radiograph in the protocol was expected to reduce operative treatment. However, **chapter 6** shows the opposite outcome. Again, this unexpected and interesting finding made us question the cut-off values that had been used. Is it necessary to apply an even higher cut-off value when using this radiograph to determine instability? Is it the amount of physiological widening of the MCS on a gravity stress radiograph that introduces a potential overestimation of medial injury?

When looking at the results of **chapter 6**, we can see that, in stable type B ankle fractures, the gravity stress radiograph shows a physiological widening of the MCS of 1.2 mm more than is shown on the regular mortise view. Also, Pitakveerakul et. al [8] described that in nonfractured ankles, the gravity stress radiograph shows a significantly wider MCS than the mortise view. They found a mean MCS of 3.19 mm on the gravity stress radiograph versus a mean MCS of 3.01 mm on mortise view. ($p=0.02$). This leads to the conclusion that, taking into account this natural widening of MCS on the gravity stress radiograph, a higher cut-off value is required in order to be able to differentiate between stable and unstable ankle fractures. We therefore suggest to use MCS > SCS + 3mm on the gravity stress radiograph for diagnosing instability.

In our study investigating the gravity stress radiograph, the decision to recommend patients with an ankle fracture with an initial MCS ≥ 6 mm directly for surgery and to exclude them from this study, has led to the inclusion of only a small number of completely ruptured deltoid ligaments in the enlarged cohort of patients in **chapter 7.** Hence, the sensitivity and specificity of the gravity stress radiograph are less significant. The predictive value of the gravity stress in diagnosing medial injury seems to be less high than that based on the results of the study described in **chapter 5**. This made us question the current protocol that dictates the use of the gravity stress radiograph as a primary diagnostic tool.

After we had raised doubts about the value of the gravity stress radiograph, another study investigated the weightbearing radiograph, described in **chapter 7.** We used a cut-off value of MCS ≥ SCS + 2mm, which resulted in the weightbearing radiograph showing low sensitivity of 6%, but 100% specificity for diagnosing deltoid rupture. The main advantage of the weightbearing radiograph is that in case of no medial widening, the fracture is proven stable *while bearing weight*. This implies that, shortly after the trauma, the patients safely can start weightbearing, depending on the pain they experience. For many patients, it appeared to be too painful to immediately bear weight at the Emergency Department on the day of trauma. Therefore, the window that was chosen to perform a weightbearing radiograph was within a week after trauma. At this point, for none of the patients, it was too painful to perform the radiograph. It would, however, be interesting to measure the amount of exact weightbearing, using a balance or force-plate. Not fully weightbearing (i.e. putting more weight on the non-fractured leg) may of course influence the width of the MCS.

In 2016, Holmes et al. investigated 51 patients who were treated nonsurgical for a type B ankle fracture. (9) Determination of instability of the fracture was initially based on the gravity stress view and patients with MCS ≥ 7 mm or MCS ≥ SCS + 2mm were planned for surgical treatment. The other patients were included for the study and were followed at 1 week, 2 weeks, 6 weeks and 12 weeks with a full weightbearing radiograph. In case of widening of MCS on this weightbearing radiograph (unfortunately, the definition of widening was not reported), the patient was surgically treated. All other patients were allowed to fully bear weight in a brace. After a year, their functional outcome (AOFAS score) was excellent with low pain scores (VAS). This study once more confirms that ankle fractures with no widening of MCS on the weightbearing radiograph can be labeled stable and can safely be treated conservatively.

In order to give an overview of the current literature concerning diagnostics in type B ankle fractures, we performed a systematic review of existing studies in **chapter 8.** In this review, the ultrasound and gravity stress radiograph seem to have the best results in terms of sensitivity and specificity. Rosa (10) and Henari (11) compared the ultrasound with the gravity stress radiograph and an arthrogram respectively and found sensitivities of 100% and specificities of 90-100% for the ultrasound in determining deltoid rupture. Although the ultrasound has shown quite promising diagnostic values, it is not yet commonly used. Ultrasound requires the presence of an experienced radiologist, and technical availability. Not all radiologists are familiar with the scanning technique. It might be worthwhile to train more radiologists to perform the ultrasound for this purpose.

After having reviewed the literature and all different diagnostic tools, one final diagnostic method required clarification. **Chapter 9** was written to identify the role of fibular fracture displacement as diagnostic criterium for instability. In the survey performed in **chapter 3,** we concluded that the majority of trauma surgeons in the Netherlands use the fibular dislocation as indicator for instability. Therefore, we retrospectively investigated a large cohort of 192 patients with a type B ankle fracture and measured the fibular displacement. We compared dislocation of the fibula (in both anteroposterior and lateral direction) and widening of the MCS ≥ SCS + 3mm on the performed gravity stress radiograph. The ROC curves showed an AUC of 0.68 for the fibular fracture in predicting medial deltoid injury. We therefore advise that fibular displacement should not be used as an indicator to diagnose medial injury or fracture instability, nor should it influence the choice between operative or non-operative treatment.

Today, patients' autonomy and shared decision making are considered increasingly important. What we as doctors consider the best treatment is not always the best choice for a specific patient. This also appears to be true for the treatment of the type B ankle fracture. After establishing what the patient regards as most important in their healing process, both surgical and conservative treatment options should be discussed depending on the stability of the ankle. In case of a proven stable ankle fracture, non-operative treatment options in a cast or a brace, with allowed weightbearing, should be offered. This is consistent with the statement that we should transform our view of fixing the *fracture*, with a high focus on surgical treatment, to fixing the *patient*. Implications for ankle fracture treatment mean an open discussion with the patient about all possible types of treatment.

Looking back at the performed studies, not only in this thesis but in the whole literature, most unstable fractures with MCS > 6 mm are excluded immediately from any study. The consensus is that these fractures are unstable and require direct operative treatment. Because of this exclusion, we miss many complete deltoid ligament ruptures in the current studies. This makes it harder for any diagnostic tool to reach a significant sensitivity percentage and adds to the difficulty in selecting the most accurate tool in predicting deltoid rupture. As a result, we were forced to focus on *excluding* instability and hereby searching for the boundaries in treating safely conservatively. These boundaries can best be described as the correct and highest cut-off value for instability while still reaching good functional clinical outcome after conservative treatment.

Clinical implications

In the past, most attention was given to the mortise view and cut-off values of MCS indicating medial instability. The studies in this thesis suggest that other diagnostics are more predictive for determining stability and that the SCS should also be taken into consideration when formulating a cut-off value indicating instability.

To formulate a diagnostic strategy for medial instability in type B ankle fractures and to provide some guidance for treatment, this thesis makes the following recommendations based on the previously described studies:

- Diagnostics additional to the mortise view are necessary to exclude instability in type B ankle fractures
- For the gravity stress radiograph, the definition of MCS ≥ SCS + 3mm for medial injury should be used
- Fibular dislocation should not be used as an indicator for operative treatment
- The use of ultrasound for the diagnosis of medial ligamentous ankle injury in type B fractures should be further investigated, meaning that radiologists should become more involved in this diagnostic process
- In case of a patient having an MCS < 6 on the mortise view, safe conservative treatment can include a weightbearing radiograph after one week
- When making use of the weightbearing radiograph, the cut-off value of MCS > SCS + 2mm for operative treatment should be used
- Stable type B ankle fractures can safely be managed non-operatively, since functional outcomes for both surgical and non-surgical treatment are similar

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11

Summary

Chapter 11 Summary

Type B ankle fractures are frequently encountered at the Emergency Department. The difference between stable and unstable ankle fractures is crucial for the type of treatment. How to diagnose instability of type B ankle fractures remains a diagnostic dilemma and is the main subject of this thesis.

In **chapter 1**, the anatomical difference between stable and unstable fractures is explained with their type of treatments. It provides some background information in order to understand the importance of diagnosing medial injury. **Chapter 2** compares the outcome of patients with fibular fractures after surgical and non-operative treatment. It focuses on the functional outcome on the long-term. The existing literature only showed results with short follow-up time. A large cohort of 229 patients was included. With a mean follow-up of 5.3 years, there was no significant difference between the non-operative treatment and operative treatment in terms of function and pain. This chapter concluded that, without proven instability, type B fractures can safely be treated non-operatively.

To provide more insight in the current clinical practice of diagnosing medial injury and treatment of type B ankle fractures in the Netherlands, **chapter 3** was written. It describes a survey that was conducted amongst trauma- and orthopedic surgeons in 68 different hospitals concerning their use of radiologic diagnostics in the evaluation of instability of type B ankle fractures. The survey comprised one part on diagnostics and another part on the choice of treatment. Only 18.2% of the participants made use of additional diagnostics in addition to the regular mortise radiograph. All other surgeons made their choice of treatment based on the regular mortise directly after trauma and the same mortise view repeated after a week. More than half of the participants did not follow a protocol. The observed variation in use of diagnostics and treatment is not desirable and shows the need for more research and consensus.

The functional outcome of patients described in chapter 2 is also examined in **chapter 4.** The aim of this chapter was to assess which outcomes are important to patients with an ankle fracture and to assess which background and fracture characteristics might be associated with these outcomes. It described a cross-sectional survey among 335 patients with a type B/C or calcaneal fracture. All participants were asked to identify and rank 5 treatment outcomes that were the most important for them. The most important outcomes for patients were “self-sufficiency”, “walking”, and

“complete recovery”. Knowing what is important for the patient can be used in enhanced person-centered care and shared decision-making.

The second part of this thesis focused on the search for new diagnostics. It started with **chapter 5,** in which the gravity stress radiograph was investigated. Although the number of included patients was quite low (39), the results were promising. Measurements of the medial clear space of the regular and gravity stress radiographs were compared with MRI findings as reference standard. The gravity stress radiographs with medial clear space (MCS) ≥ 6 mm as threshold for instability led to a sensitivity of 100% and specificity of 91.7% for establishing deltoid ligament rupture. This chapter concluded that gravity stress radiographs have more discriminative ability for diagnosing type B ankle fractures with or without deltoid ligament rupture in comparison with regular mortise views. Based on this chapter, in our current local protocol, the gravity stress radiograph was added when the mortise view showed no evident instability (MCS 4-6mm).

In **chapter 6**, the effect of the introduction of this gravity stress radiograph on type of treatment was investigated. The application of a cut-off value of MCS ≥ SCS + 2 mm on the gravity stress radiograph was supposed to lead to less operative treatment compared to making use of the mortise view with MCS > SCS + 1 mm. This retrospective study analyzed 343 patients with an isolated type B ankle fracture. This patient cohort was divided into two groups based on whether an additional gravity stress radiograph was performed. The type of treatment (surgically vs. non-operatively) was compared. The secondary outcomes were patient-reported functional outcomes and pain. Contrary to the aim of introducing the radiograph, the use of the gravity stress radiograph (with cut off value MCS ≥ SCS + 2mm for operative treatment) did not result in reduced operative treatment of type B ankle fractures compared with the mortise view with MCS > SCS + 1mm. This questions the current cut-off values and made us think about the necessity of an even higher cut-off value for the gravity stress radiograph.

Next to the gravity stress radiograph, another radiographic diagnostic tool was investigated and has been described in **chapter 7.** Together with the gravity stress radiograph, the weightbearing radiograph was examined compared with the MRI scan in order to make the distinction between unstable fractures and stable fractures. Ninety patients were included. In all of them, a gravity stress radiograph was performed. In 51 patients, an additional weightbearing radiograph was performed. Making use of the cut-off value MCS ≥ SCS + 3mm for the gravity stress radiograph and the value MCS ≥ SCS + 2mm for the weightbearing radiograph, both showed 6% sensitivity and 100%

specificity. They can thus both accurately exclude deltoid ligament injury. In assessing stability of type B ankle fractures, both the gravity and weight bearing radiograph might have extra value in addition to the conventional mortise view.

In order to give an overview of the current literature, a systematic review was performed and described in **chapter 8.** All studies concerning radiologic diagnostic tests to determine medial injury in type B ankle fractures were examined. Eight studies were included. The ultrasound showed the highest sensitivity of 100% and specificity between 90-100% in evaluating medial integrity. The gravity stress radiograph showed a sensitivity of 71-100% and a specificity between 88% and 92%. The mortise, external rotation stress test, and MRI had lower sensitivity and specificity values. Therefore, the most accurate diagnostic tools for diagnosing deltoid integrity seem to be the ultrasound and gravity stress radiographs. Further prospective research is of course needed to confirm these results.

Chapter 9 investigates the fibular displacement itself as predictor of medial injury. It appears from the survey in chapter 3 that many surgeons make use of the fibular displacement as indicator of instability and thus operative treatment. This chapter evaluates the value of the fibular fracture displacement in predicting medial clear space widening on the gravity stress radiograph. 192 patients with an isolated type B fibular fracture were retrospectively included. Both a regular mortise and gravity stress radiograph were made. In predicting instability, the fibular displacement demonstrated an area under the curve (AUC) of 0.68 and a correlation coefficient of 0.41 with the medial clear space on gravity stress radiograph. This chapter concluded that fibular displacement on regular mortise view is a poor predictor of instability in type B fibular fractures and that it should not be advised to use the fracture displacement as parameter for operative treatment.

The general discussion in **chapter 10** presents an overview of issues that remain to be studied. The current practice of evaluating instability in ankle fractures has a very high variability rate and most attention is given to the medial clear space on the mortise view. This thesis suggests that other diagnostics are more accurate in determining stability.

To conclude, stable type B ankle fractures, with a MCS < 6 mm on the mortise view, can safely be managed conservatively with performance of the weightbearing radiograph within a week. When making use of the gravity stress radiograph, the cut-off value of MCS $\geq$ SCS + 3mm should be applied, while for the weightbearing radiograph the MCS ≥ SCS + 2 mm is advised. The results of ultrasound are promising and should be further investigated.

12

Nederlandse samenvatting

Chapter 12 Nederlandse samenvatting

Op de Eerste Hulp van ziekenhuizen worden veel type B enkelfracturen gediagnosticeerd. Het verschil tussen stabiele en instabiele fracturen is van groot belang voor de keuze van behandeling. De manier waarop instabiliteit van deze type B fracturen beoordeeld kan worden is een diagnostisch dilemma en het hoofdonderwerp van dit proefschrift.

Hoofdstuk 1 start met een uitleg over het anatomische verschil en daarmee het verschil in behandeling tussen stabiele en instabiele enkelfracturen. Het geeft achtergrondinformatie om het belang van het diagnosticeren van mediaal ligamentair letsel bij type B enkelfracturen beter te kunnen begrijpen. **Hoofdstuk 2** vergelijkt de uitkomsten van patiënten met fibula fracturen na operatieve en conservatieve behandeling. De focus van dit onderzoek lag op functionele uitkomsten op lange termijn. Eerdere literatuur heeft alleen resultaten laten zien van studies met een korte follow-up. In deze studie werden 229 patiënten geïncludeerd met een gemiddelde follow-up tijd van 5.3 jaar. Er bleek geen significant verschil tussen de conservatief en operatief behandelde patiënten wanneer gekeken werd naar functionele uitkomsten en pijn. Dit hoofdstuk concludeert dan ook dat type B enkelfracturen zonder bewezen instabiliteit veilig conservatief behandeld kunnen worden.

Om meer inzicht te geven in de huidige Nederlandse praktijk voor het behandelen van type B enkelfracturen, het diagnosticeren van mediaal ligamentair letsel en het behandelen van de fractuur, is **hoofdstuk 3** geschreven. Dit hoofdstuk beschrijft een vragenlijst die is afgenomen onder trauma- en orthopedisch chirurgen in 68 verschillende ziekenhuizen. De vragenlijst bevatte vragen over het gebruik van diagnostiek bij het beoordelen van instabiliteit van type B enkelfracturen. De vragenlijst bestond voor een deel uit vragen over diagnostiek en voor een deel uit vragen over de keuze van behandeling. Slechts 18.2% van de respondenten gaf aan überhaupt gebruik te maken van aanvullende diagnostiek naast het reguliere gebruik van de mortise röntgenfoto. Alle andere chirurgen gaven aan hun keuze voor een behandeling te baseren op de reguliere mortise foto direct na het trauma, in combinatie met een herhaling van deze foto een week na het trauma. Meer dan de helft van de respondenten gaf aan geen gebruik te maken van een protocol. Deze variëteit in gebruik van diagnostiek en behandeling is niet wenselijk en toont aan dat er meer onderzoek nodig is om tot consensus te komen.

De functionele uitkomst na behandeling van een enkelfractuur, zoals reeds onderzocht in hoofdstuk 2, wordt nader bekeken in **hoofdstuk 4.** Het doel van dit hoofdstuk is om erachter te komen welke uitkomsten voor patiënten met een enkelfractuur in hun revalidatietraject het belangrijkste zijn. Bovendien wilden wij onderzoeken welke achtergrond- en fractuur karakteristieken met deze uitkomsten geassocieerd zouden kunnen zijn. Het hoofdstuk beschrijft een vragenlijst afgenomen onder 335 patiënten met een type B/C enkelfractuur of calcaneus fractuur. Alle patiënten werd gevraagd om een top-5 te maken van uitkomsten van behandeling die het belangrijkst voor de patiënt waren. De belangrijkste uitkomst-parameters bleken "zelfstandigheid", "lopen" en "volledig herstel". De wetenschap dat deze uitkomsten de hoogste prioriteit hebben bij patiënten kan bijdragen aan een efficiëntere en betere "shared decision-making".

Het tweede deel van dit proefschrift gaat over de zoektocht naar nieuwe diagnostiek voor mediaal ligamentair letsel bij type B enkelfracturen. Het begint met **hoofdstuk 5,** waarin de afhangende foto onderzocht werd. Ondanks het feit dat het aantal geïncludeerde patiënten klein was (39), waren de resultaten veelbelovend. De metingen van de medial clear space (MCS) op de reguliere mortise foto en op de afhangende foto werden vergeleken met bevindingen op de MRI, die als referentiestandaard gebruikt werd. De afhangende foto met MCS ≥ 6 mm als afkapwaarde voor instabiliteit, liet een sensitiviteit zien van 100% en een specificiteit van 91.7% voor een ruptuur van het ligamentum deltoideum. Dit hoofdstuk concludeert dat de afhangende foto meer discriminerend vermogen heeft in het diagnosticeren van een ruptuur van het ligamentum deltoideum dan de reguliere mortise röntgenfoto. Als gevolg van dit onderzoek is aan ons lokale protocol toegevoegd dat bij twijfel over instabiliteit op de mortise foto (MCS 4-6 mm) er een afhangende foto gemaakt dient te worden.

In **hoofdstuk 6** wordt het klinisch effect van de introductie van deze afhangende foto onderzocht. De hypothese was dat introductie van de afhangende foto met afkapwaarde MCS ≥ SCS (superior clear space) + 2mm voor instabiliteit zou leiden tot minder operaties in vergelijking met alleen de mortise view met afkapwaarde MCS > SCS + 1mm. Dit hoofdstuk beschrijft een retrospectieve studie van 343 patiënten met een geïsoleerde type B enkelfractuur. Het patiënten cohort werd verdeeld in een tweetal groepen afhankelijk van de al dan niet verrichte afhangende foto. Vervolgens werd de behandeling (conservatief vs. operatief) tussen deze twee groepen vergeleken. Secundair werd de functionele uitkomst en pijn gemeten. In tegenstelling tot de hypothese heeft de introductie van de afhangende foto <u>niet</u> geleid tot minder operatieve behandelingen van type B enkelfracturen. Hierdoor zijn wij gaan twijfelen over de huidige afkapwaarde van MCS ≥ SCS + 2mm op de afhangende foto. Wellicht is een hogere afkapwaarde nodig om accuraat de instabiele enkelfractuur te kunnen aantonen.

Naast de afhangende foto werd in **hoofdstuk 7** een ander diagnostisch middel onderzocht: de belaste foto. De belaste foto werd, net als de afhangende foto, vergeleken met de MRI scan om te onderzoeken hoe goed de foto differentieert tussen een stabiele en instabiele enkelfractuur. 90 patiënten werden geïncludeerd. Allen ondergingen een afhangende foto. Bij 51 patiënten werd aanvullend nog een belaste foto verricht. Zowel de afhangende foto met afkapwaarde MCS ≥ SCS + 3mm als de belaste foto met afkapwaarde MCS ≥ SCS + 2mm toonden een sensitiviteit van 6% en een specificiteit van 100%. Beide röntgenfoto's excluderen mediaal letsel accuraat. Bij het bepalen van de stabiliteit van type B enkelfracturen hebben deze radiologische foto's volgens dit hoofdstuk toegevoegde waarde als aanvulling op de reguliere mortise foto.

Om een overzicht te geven van de bestaande literatuur is een systematische review verricht en beschreven in **hoofdstuk 8.** Studies over een radiologische test om mediaal letsel in type B enkelfracturen te diagnosticeren werden bestudeerd. Acht studies zijn geïncludeerd. De echo toonde de hoogste sensitiviteit van 100% en specificiteit tussen de 90-100% om mediaal letsel te diagnosticeren. De afhangende foto liet een sensitiviteit van 71-100% zien en een specificiteit tussen de 88% en 92%. De mortise foto, de "external rotation" stress foto en de MRI hadden allen een lagere sensitiviteit en specificiteit voor het aantonen van mediaal ligamentair letsel. Op basis hiervan wordt geconcludeerd dat de echo en de afhangende foto de meest accurate radiologische testen zijn voor het diagnosticeren van mediaal letsel bij type B enkelfracturen. Er is echter meer prospectief onderzoek nodig om deze resultaten verder te onderbouwen voor de klinische praktijk.

Hoofdstuk 9 onderzoekt de dislocatie van de fibulafractuur zelf als voorspeller van mediaal letsel. Uit de vragenlijst van hoofdstuk 3 bleek dat veel chirurgen gebruik maken van de fibula dislocatie in hun besluitvorming betreffende instabiliteit en deze dus als indicator gebruiken voor operatieve behandeling. Dit hoofdstuk evalueert de waarde van de fibula fractuur dislocatie in het voorspellen van de medial clear space verwijding op de afhangende foto. 192 patiënten met een geïsoleerde type B fibula fractuur werden geïncludeerd in deze retrospectieve studie. Alle patiënten hadden een reguliere mortise en afhangende foto ondergaan. De area under the curve (AUC) van de fibula dislocatie was 0.68 in het voorspellen van instabiliteit. De correlatie coëfficiënt in vergelijking met de medial clear space op de afhangende foto was 0.41. Dit hoofdstuk concludeert dan ook dat de fibula dislocatie op de reguliere mortise foto geen goede voorspeller is van instabiliteit van type B fracturen. Het wordt dan ook niet geadviseerd om dislocatie van de fractuur als parameter voor operatieve behandeling te gebruiken.

De algemene discussie in **hoofdstuk 10** bespreekt de onderwerpen waar nog geen consensus over is bereikt. De door chirurgen toegepaste diagnostiek bij type B fracturen is erg wisselend. De meeste aandacht wordt momenteel nog gegeven aan de medial clear space op de mortise foto. Uit dit proefschrift blijkt echter dat andere diagnostische testen meer waarde hebben in het voorspellen van instabiliteit van type B enkel fracturen. Hiermee kunnen operaties (met alle bijkomstige anesthesiologische en operatieve risico's en kosten) in de toekomst voorkomen worden met eenzelfde functioneel resultaat voor de patiënt.

Conclusie

Stabiele type B enkelfracturen met een MCS < 6 mm op de mortise view kunnen veilig conservatief behandeld worden mits een belaste foto na een week gemaakt wordt. Wanneer er gebruik gemaakt wordt van de afhangende foto dient de afkapwaarde MCS $\geq$ SCS + 3mm voor instabiliteit toegepast te worden. Bij de belaste foto wordt geadviseerd de afkapwaarde MCS $\geq$ SCS + 2mm aan te houden. De resultaten van de echo zijn veelbelovend en dienen verder uitgezocht te worden.

A

Appendices

Appendices

List of publications and presentations

Publications

Van Leeuwen CAT, Hoffman RPC, Hoogendoorn JM Long-term outcome in operatively and non-operatively treated isolated type B fibula fractures. *Injury* 2019 Dec;50(12):2318-2323.

Van Leeuwen CAT, Hoffman RPC, Donken CCMA, van der Plaat LW, Schepers T, Hoogendoorn JM. The diagnosis and treatment of isolated type B fibular fractures: Results of a nationwide survey. *Injury*. 2019 Feb;50(2):579-589.

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Geïsoleerde distale fibulafracturen (AO type 44B): uitkomsten op middellange termijn van conservatieve vs operatieve behandeling (Wetenschapsmiddag Haaglanden Medisch Centrum 2017, **van Leeuwen CAT** et al).

De toegevoegde waarde van de *afhangende en belaste foto* in het voorspellen van ligament deltoideum letsel in SER-type enkelfracturen (TOWN 2018, **van Leeuwen CAT** et al.)

Geïsoleerde distale fibulafracturen (AO type 44B): uitkomsten op lange termijn van conservatieve vs. operatieve behandeling (Traumadagen 2018, **van Leeuwen CAT**, Hoogendoorn JM).

Geïsoleerde distale fibulafracturen (AO type 44B): uitkomsten op middellange termijn van conservatieve vs. operatieve behandeling (Assistentensymposium NVT 2018, **van Leeuwen CAT** et al.)

The diagnosis and treatment of isolated type B fibular fractures: results of a nationwide survey (ECTES 2019, **van Leeuwen CAT** et al.)

De toegevoegde waarde van de *belaste* en *afhangende* röntgenfoto in geïsoleerde type B distale fibula fracturen (Assistentensymposium NVT 2020, **van Leeuwen CAT**, Hoogendoorn JM)

Geïsoleerde type B distale fibulafracturen: toegevoegde waarde van diagnostiek in keus voor behandeling. (Traumadagen 2021, **van Leeuwen CAT**, Hoogendoorn JM).

The value of additional gravity stress radiographs for decision-making in the treatment of isolated type B distal fibular fractures (NVT assistenten symposium 2021, **van Leeuwen CAT** et al.)

Poster presentations

De toegevoegde waarde van de belaste en afhangende röntgenfoto bij geïsoleerde type B fibula fracturen. (Traumadagen 2019, **van Leeuwen CAT** et al.)

Diagnose en behandeling van geïsoleerde type B fibula fracturen: resultaten van een nationale enquête (Traumadagen 2018, **van Leeuwen CAT** et al.)

Outcomes of treatment of foot- and ankle fractures: which are important to the patient? (ECTES 2019, **van Leeuwen CAT** et al.)

The diagnosis and treatment of isolated type B fibular fractures: results of a nationwide survey (ECTES 2019, **van Leeuwen CAT** et al.)

D

Dankwoord

Dankwoord

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To the moon and back.

Curriculum vitae

Claar van Leeuwen was born on 24th November 1992 in Apeldoorn, the Netherlands. After graduating *cum laude* from the Gymnasium Apeldoorn in 2010, she went to Juniata College, Pennsylvania, United States, to study business and play field hockey. After a year in the USA, she decided to abandon her business ambitions. She started studying Medicine at the University of Leiden in 2011.

From 2013 to 2017 Claar worked as an allocation employee at Eurotransplant in Leiden. She conducted research on pancreas transplantation supervised by dr. Dries Braat. In 2013-2014, she was the President of the organization committee of the Medisch Interfacultair Congres (MIC).

After completing her degree in 2017, she started working as surgical resident not in training (ANIOS) at Haaglanden Medical Center in the Hague. This is where she started scientific research supervised by dr. J.M. Hoogendoorn. After a year, she started as surgical resident in training (AIOS) at Haaglanden Medical Center in July 2019.

From 2019, she has combined her surgical training with scientific research in the field of trauma surgery. In October 2022, she will continue her training at the Leiden University Medical Centre, Leiden. She expects to complete her training in 2025.