Fractures of the talus

Diagnostics, management and outcome

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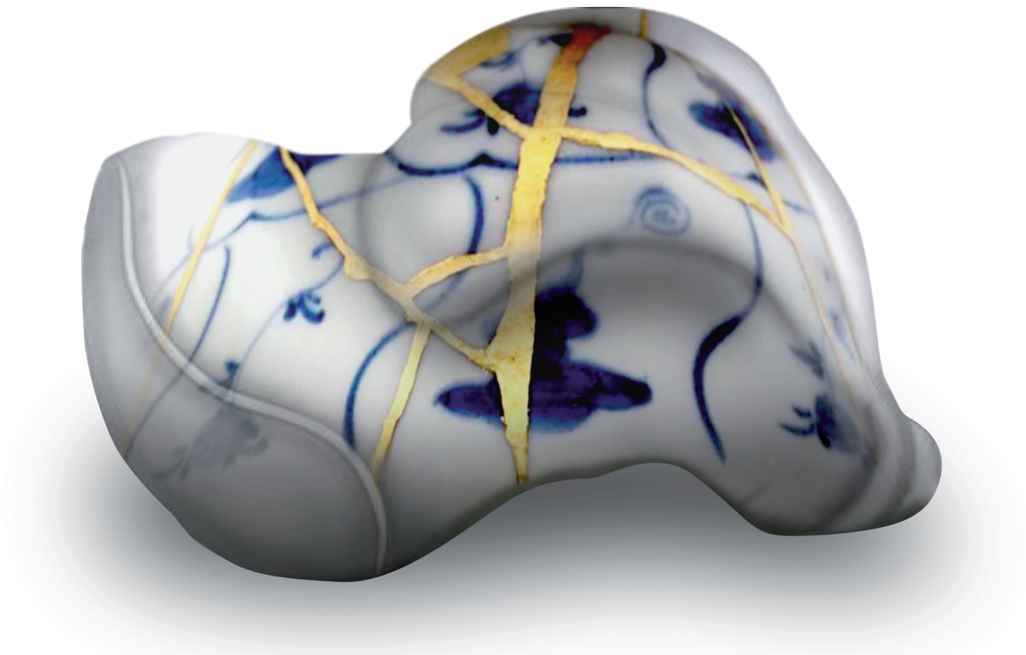
FRACTURES OF THE TALUS

DIAGNOSTICS, MANAGEMENT AND OUTCOME



Olivier Wijers

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diagnostics, management and outcome

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Fractures of the talus

diagnostics, management and outcome

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aan de Universiteit van Amsterdam
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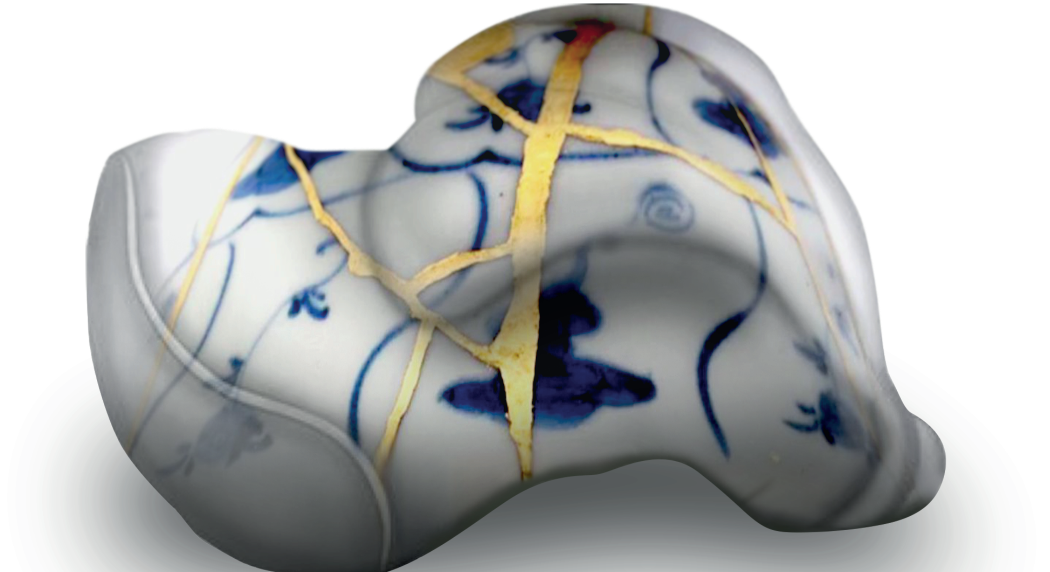


1

General introduction, aim and outline of this thesis

PROBLEM STATEMENT AND AIM OF THIS THESIS

Talar fractures are rare and often associated with impaired functional outcomes. The incidence has increased over the last decades, currently accounting for approximately 0.3 to 2% of all fractures. [3,7,15] Despite recent advances in the diagnosis and management of talar fractures, complication rates remain high, and the functional outcome is generally poor. [14]

The lack of detailed functional outcome reports and quality of life studies of isolated talar fractures may be explained by the nature of the trauma. Besides being uncommon, talar fractures are frequently caused by high velocity trauma and as such most of the time concomitant injuries are present. To measure the functional outcome or quality of life solely of a talar fracture in the presence of concomitant injuries remains challenging or even impossible.

Another possible explanation could be the heterogeneity between published papers. Various types of talar fractures are often analyzed in one group and different outcome measurements were used, making it hard to compare studies. Therefore, it remains unknown whether fractures of the talar neck, talar body, or combined talar neck and body are related to different functional outcomes. One might assume that standardization of talar fracture classification and scoring systems could improve the comparability of future studies.

The aim of this thesis was to provide an overview of the diagnosis, treatment complications and functional outcome of different types of talar fractures. This may contribute in clinical decision-making by improving patients' expectation management and tailor-made patient treatment strategies.

BRIEF HISTORY

Talus or 'Astragalus' or 'Knuckle-bone' historically refers to the bone in the hindfoot which articulates with the tibia and participates in forming the ankle joint. In ancient times, the Greeks and Romans used the Astragalus in gambling. It was shaped as some kind of dice with 6 sides and was made from the bone of horses, sheep or goats. Not surprisingly, it was often found in Greek and Roman tombs imitated in ivory, bronze, glass, and agate.[9] Figure 1 shows the Roman goddesses Latona, Niobe, Phoebe, Aglaia and Hileaera playing a game of astragali or knucklebones.[2]

Fig 1. Painting on marble by Alexander the Athenian discovered in Resina in May 1786.[2]

Knuckle-bones were also seen in use in the painting 'Children's Games' from Pieter Bruegel the Elder, painted in 1560 (Fig 2).[6] This painting displays children playing different games. On the bottom-left-corner of the painting two children are seen playing a game with the knuckle-bones. The bones are thrown up and caught in various ways, mostly on the dorsum of the hand as also seen in the painting described earlier by Alexander the Athenian (Fig 1).

Fig 2. Pieter Bruegel the Elder – Children's Games (detail) – Knucklebones[6]

The name 'Talos' was also used in a Greek myth for the first robot to walk the earth. He was a bronze giant forged by Hephaestus, the blacksmith god of technology. Its main task was defending the kingdom of Minos. He was walking around the island (with a circumference of 1050 km) three times a day and would drive strangers away by burning them alive or throwing huge rocks at them.[1] Interestingly, Talos was constructed with a single internal artery that went from his head to his feet. Pulsating in this artery was ichor, the mystical life-force of the gods. Talos was defeated by Medea, who attacked him at his weak spot; his ankle, where she removed a single nail that drained all of his ichor (Fig 3).[1] Luckily, our human body and talus has a few more arteries to count on, but it does resemble the precarious vascularization of the talus following extensive trauma.

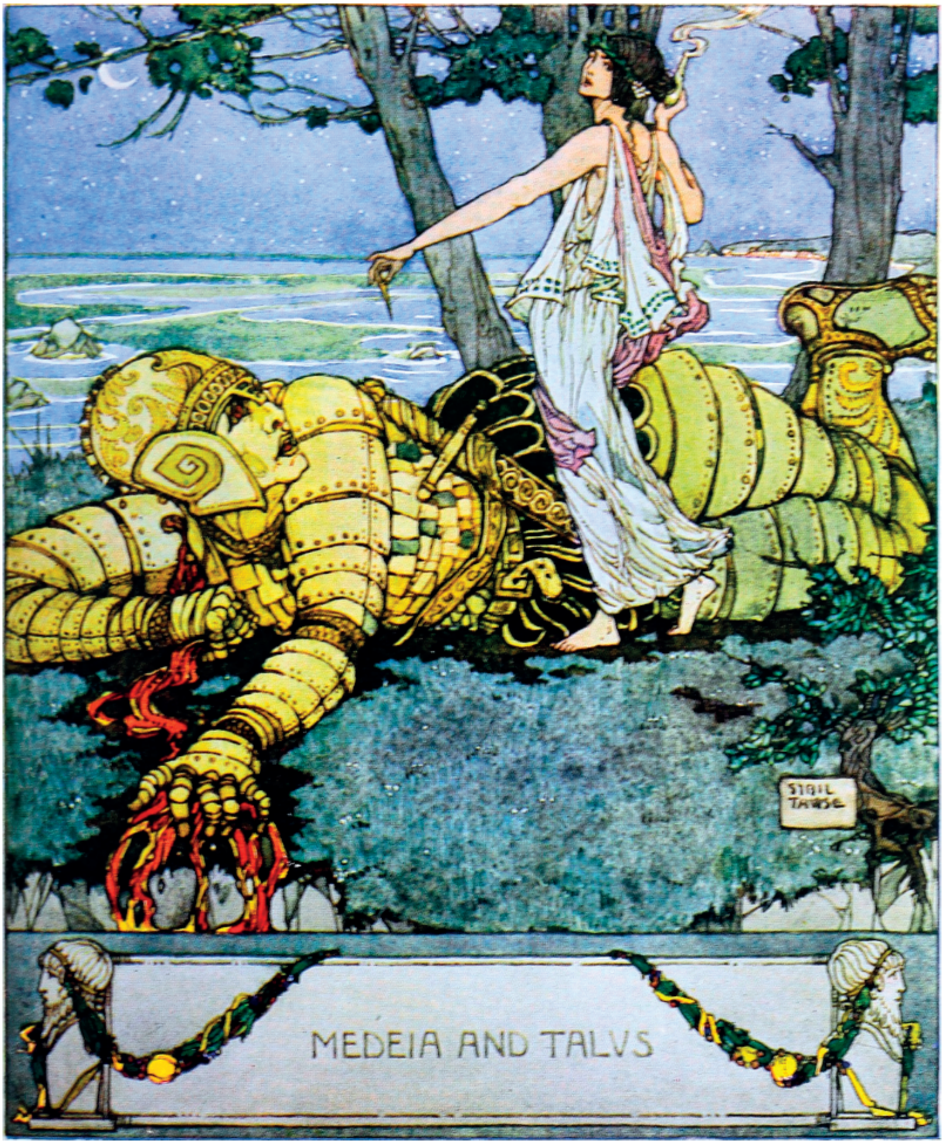
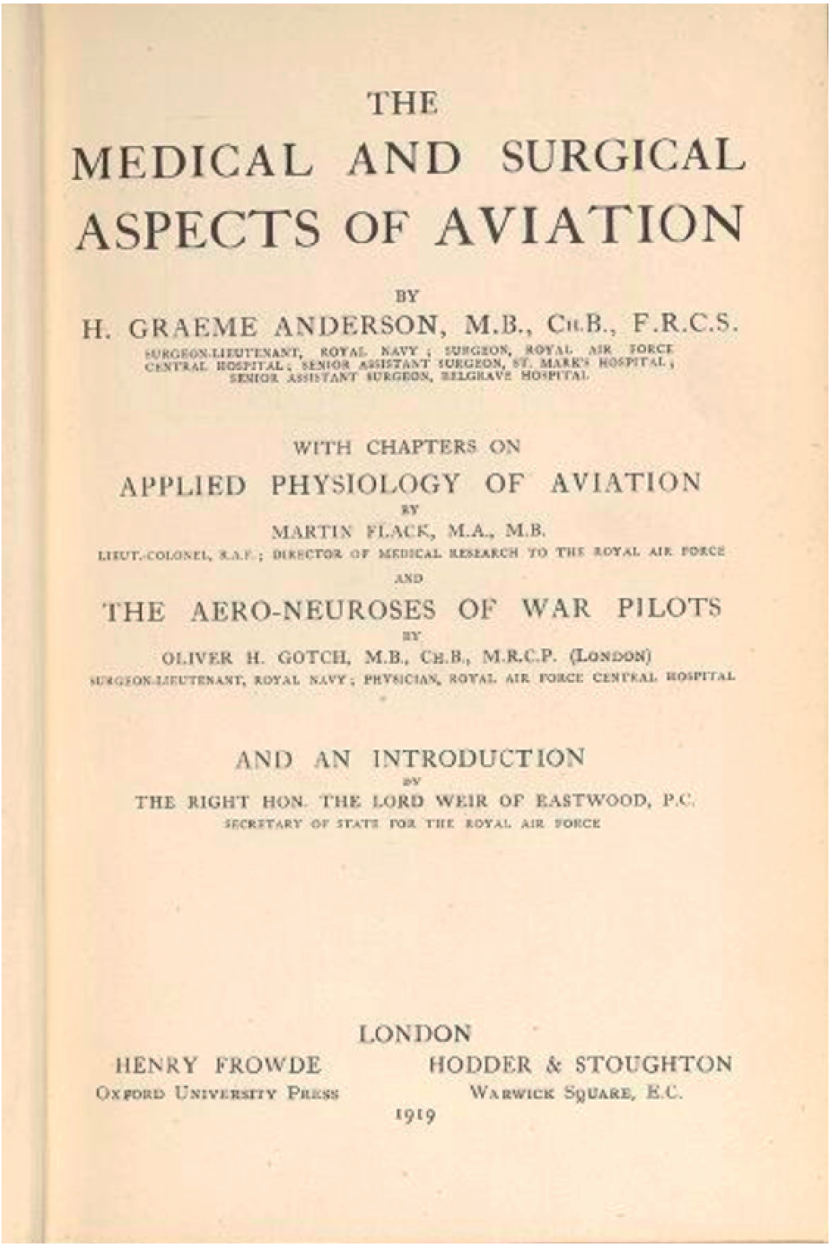


Fig 3. Painting 5th century BC displaying Medea defeating Talos by removing a nail from his ankle.[1]

In our times new challenges would present themselves. With the advent of aviation in the beginning of the 20th century individuals started experimenting with self-constructed flying machines which often crashed at sub-lethal speeds. Henry Graeme Anderson (1882-1925), a consulting surgeon to the Royal Flying Corps was the first to describe 18 talar fractures and/or dislocations following these airplane accidents (1919).[4] The mechanism of injury was described as 'when the aircraft strikes the ground at an angle, with the sole of the foot resting on the rudder bar, on impact the talus gets pressed into the instep just in front of the heel. The talus takes most of the force and becomes the seat of the fracture. Before the actual fracture occurs, the foot may be in a position of acute dorsiflexion, plantar flexion or inversion (Fig 4).[8] In the present day the term 'Aviators Astragalus' is obsolete due to the fact that non-lethal airplane crashes are very uncommon.



THE
MEDICAL AND SURGICAL
ASPECTS OF AVIATION

BY
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SURGEON-LIEUTENANT, ROYAL NAVY; SURGEON, ROYAL AIR FORCE CENTRAL HOSPITAL; SENIOR ASSISTANT SURGEON, ST. MARK'S HOSPITAL; SENIOR ASSISTANT SURGEON, BELGRAVE HOSPITAL

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APPLIED PHYSIOLOGY OF AVIATION
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AND
THE AERO-NEUROSES OF WAR PILOTS
BY
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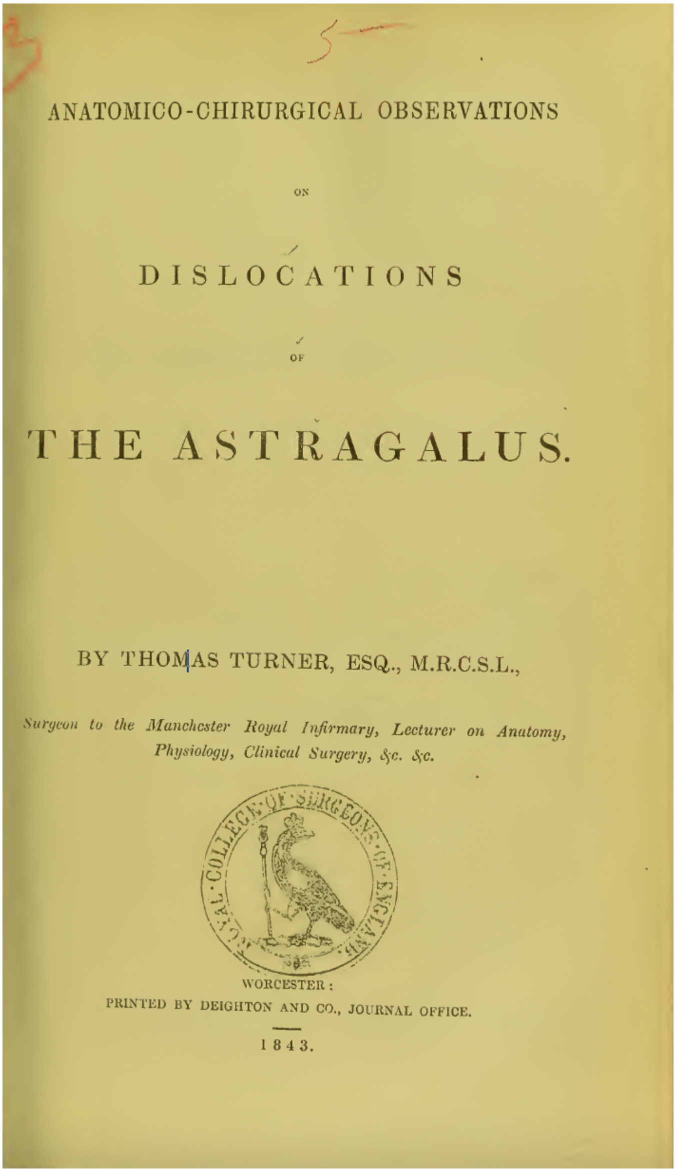
AND AN INTRODUCTION
BY
THE RIGHT HON. THE LORD WEIR OF EASTWOOD, P.C.
SECRETARY OF STATE FOR THE ROYAL AIR FORCE

LONDON
HENRY FROWDE
Oxford University Press
HODDER & STOUGHTON
Warwick Square, E.C.
1919

Fig 4. Anderson, H. Graeme. The medical and surgical aspects of aviation; London H. Frowde; 1919.[4]

After World War II Coltart et al. published an article describing 4000 ankle injuries, of which 228 (6%) involved the talus. More than half of these talar injuries were due to airplane crashes.[8] Throughout the years different articles and books were published on this subject. A nice example is the book 'anatomico- chirurgical observations on dislocations of the Astragalus' by Thomas Turner 1843, Surgeon to the Manchester Royal Infirmary (Fig 5 + 6). He describes the goal of his book very well and it has a lot of similarities with the current thesis: *"the author is anxious to assist in rescuing the surgeon from the painful dilemma in which he may be placed, for want of established rules to guide him in the arrangement and treatment of accidents occurring to the astragalus"*. Given the fact that standardized treatments and (international) guidelines are still lacking, the latter is an ongoing dilemma in current practice.

Fig 5. Thomas Turner (surgeon)[17]



ANATOMICO-CHIRURGICAL OBSERVATIONS

ON

DISLOCATIONS

OF

THE ASTRAGALUS.

BY THOMAS TURNER, ESQ., M.R.C.S.L.,

Surgeon to the Manchester Royal Infirmary, Lecturer on Anatomy, Physiology, Clinical Surgery, &c. &c.

ROYAL COLLEGE OF SURGEONS OF ENGLAND.

WORCESTER:

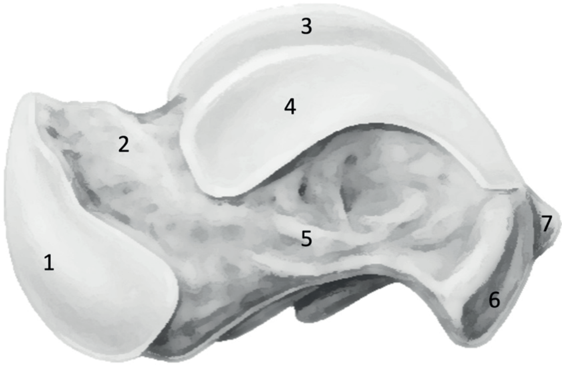
PRINTED BY DEIGHTON AND CO., JOURNAL OFFICE.

1843.

Fig 6. Turner, Thomas, Anatomico- chirurgical observations on dislocations of the Astragalus. 1843.

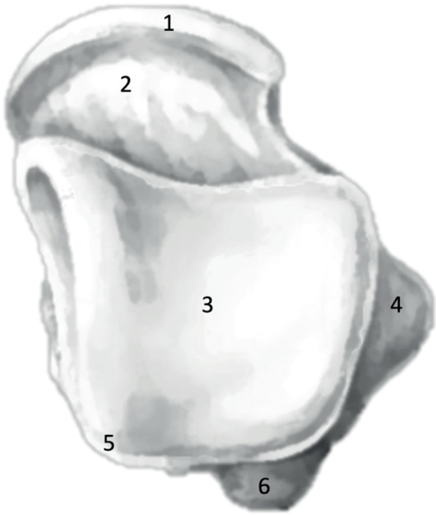
ANATOMY

The talus is divided into three anatomic regions, the talar head, neck, and body. [13] Approximately two-thirds of the talus is covered with cartilage. The talar head is covered with hyaline cartilage and articulates with the navicular and calcaneal bone. The talar body articulates with the calcaneus on the caudal site. The medial and lateral surfaces of the body articulate with the medial malleolus of the tibia and lateral malleolus of the fibula, respectively. In addition to this, cranially the talar body articulates with the distal tibia, thereby forming the talocrural joint. Between the head and the body is the neck of the talus, without an articular surface or cartilage. The lateral process extends from the lateral aspect of the talar body, articulating with the fibula superiorly. For anatomic details of the talus see figure 7 + 8.



1. Head
2. Neck
3. Articular surface distal tibia
4. Articular surface medial malleolus
5. Body
6. Medial tubercle (posterior process)
7. Lateral tubercle (posterior process)

Fig 7. Medial view talus



1. Head
2. Neck
3. Articular surface distal tibia/ body
4. Lateral process
5. Medial tubercle (posterior process)
6. Lateral tubercle (posterior process)

Fig 8. Superior view talus

The blood supply of the talus arises from extra- and intraosseous sources. The extraosseous source involves three main arteries and their branches. These arteries, in order of significance, are; posterior tibial, anterior tibial, and perforation peroneal arteries. The main branches that supply blood to the talus are the tarsal canal (a branch of the posterior tibial artery) and the sinus tarsi artery (a branch of the perforating peroneal artery). The tarsal canal artery supplies most of the talar body, whereas the talar neck is mainly supplied by the sinus tarsi artery. Extensive intraosseous anastomoses are present throughout the talus and are responsible for the survival of the talus in severe injuries. Initial fracture displacement, the timing of reduction, and soft-tissue damage are factors that can potentially affect the integrity of the talar blood supply and are assumedly main risk factors for complications such as avascular necrosis (AVN). [12]

CLASSIFICATION

There are numerous classifications used for talar fractures depending on the anatomic location of the fracture and the possible (sub)luxation. The Hawkins classification for talar neck fractures is used most frequently. In 1970, Hawkins classified talar neck fractures into three types.[10] In 1978, Canale and Kelly modified this classification by adding a fourth type in 1978.[5] Hawkins type I fractures are nondisplaced with the talus in anatomical position, with preservation of the talar neck vasculature. Type II fractures are displaced with associated subluxation or dislocation of the subtalar joint, whereas the tibiotalar and talonavicular joints remain in proper alignment. Vallier et al. shed new light on the Hawkins type II fractures, dividing them into those without (type IIA) and those with (type IIB) subtalar dislocation. This could help to predict the development of osteonecrosis since a subtalar dislocation might compromise the blood supply to a high degree. [18] Type III fractures have displacement with subluxation or dislocation of the subtalar and tibiotalar joints and are characterized by a normal alignment of the talonavicular joint. This pattern of malalignment is associated with an increased risk of injury to the posterior tibial neurovascular bundle. Type IV fractures demonstrate dislocation or subluxation of the subtalar, tibiotalar, and talonavicular joints and are thereby the most severe type. Talar body and neck fractures can be classified by use of the Marti/Weber classification. Type I fractures are classified as distal talar neck and talar head fractures with osteochondral flakes. Type II fractures are nondisplaced talar neck and body fractures, type III fractures are displaced fractures of the talar neck and body, and type IV fractures are characterized by proximal talar neck fractures with corpus tali dislocated out of the intermalleolar space or comminuted fractures.[11] Sneppen et al. classified talar body fractures into 6 types: type A compression fracture, type B coronal shearing fracture, Type C sagittal shearing fracture, type D fracture of the posterior process, type E fracture of the lateral process, type F crush fracture. [16]

OUTLINE OF THIS THESIS

This thesis is divided into two parts according to the anatomical location of the injury preceded by chapter 1, the introduction. Part 1 contains three chapters (2,3 and 4) regarding central talar fractures, involving fractures the talar body, talar neck or a combination of neck and body. Chapter 2 provides a review of the complications and functional outcomes following operative treatment of central talar fractures. Chapter 3 is focused on the functional outcome and quality of life in surgically treated central talar fractures. In chapter 4 we zoom in on the role of an external fixator in case of infected avascular necrosis after traumatic talus fractures. Part 2 of this thesis concerns the peripheral talar fractures. This is subdivided in fractures of the talar head (chapter 5), the lateral process (chapter 6), the posterior process (chapter 7+8) and the medial process (chapter 9). We end this thesis with a general discussion, thesis summery and future perspectives.

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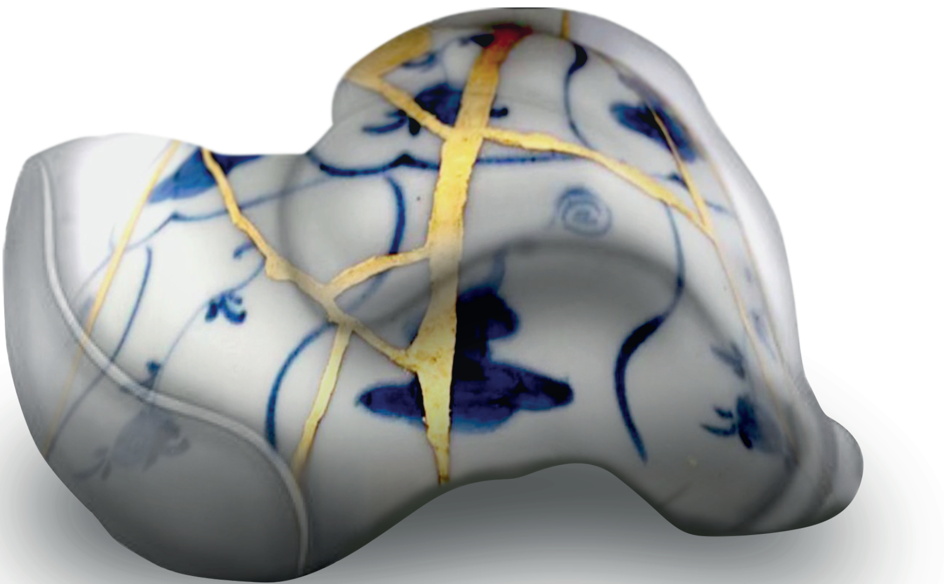
Part 1

Central talar fractures



2

Complications and Functional Outcome Following Operative Treatment of Talus Neck and Body Fractures: A Systematic Review

Olivier Wijers, MD[1], Jelle J. Posthuma, MD, PhD[1], Esmee W. M. Engelmann, MD[1], and Tim Schepers, MD, PhD[1]

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Foot & Ankle Orthopaedics (2022), Vol. 7(3) 1–10

ABSTRACT

Background: Central talar fractures are rare and often associated with impaired functional outcome. Despite recent advances in diagnosis and management of talus fractures, complications rates remain high and functional outcome is generally poor. This study aims to provide an overview of complication rates and functional outcome following operative treatment of talar neck and body fractures. This may help in clinical decision making by improving patients' expectation management and tailored treatment strategies.

Methods: A systematic review of the literature was conducted of studies published from January 2000 to July 2021 reporting functional outcome and/or complications following operative treatment of talar neck, body, or combined neck and body fractures. Keywords used were (Talar fracture) or (Talus fracture). Data on complication rates and functional outcome was extracted from selected articles.

Results: A total of 28 articles were included in our analysis reporting 1086 operative treated talar fractures (755 neck [70%], 227 body fractures [21%], and 104 combined body and neck fractures [9%]). The mean follow-up was 48 (range 4-192) months. Complications occurred frequently with; 6% surgical site infection, 8% nonunion, 29% avascular necrosis, 64% osteoarthritis, and in 16% a secondary arthrodesis was necessary. A wide variety in functional outcome was reported; however, there seems to be a correlation between fracture classification and postoperative complications.

Conclusion: Operative treatment of central talar fractures is associated with a high incidence of early and late complications and often leads to an impaired functional outcome. Standardization of talar fracture classification and scoring systems in combination with large sample-sized prospective studies are warranted to detect further predictive factors influencing tailormade treatment strategies and patient expectation management.

Level of Evidence: Level III, Systematic review of case series and case-control studies.

Keywords: talar fracture, talar neck, talar body, complications, functional outcome

INTRODUCTION

Talar fractures are rare and often associated with prolonged morbidity. The incidence has increased over the last decades, currently accounting for approximately 0.3% to 2% of all fractures.[2,10,36] Despite recent advances in diagnosis and management of talus fractures, complication rates remain high, and functional outcome is generally poor.[32] The latter is often due to the complex articular nature of the talus and impaired blood supply following injury.[16,35]

The talus is divided into 3 anatomic regions: the talar head, neck, and body.[30] About two-thirds of the talus is covered with cartilage, leaving only the area around the talar neck and the posterior aspect of the body for periosteal blood supply. The talar body articulates with the calcaneus on the caudal site. The medial and lateral surfaces of the body articulate with the medial malleolus (of the tibia) and lateral malleolus (of the fibula), respectively. The cranial side of the talar body articulates with the distal tibia. Between the head and the body is the neck of the talus, without an articular surface or cartilage.

The blood supply of the talus arises from extra- and intraosseous sources. The main branches that supply blood for the talus are the tarsal canal (a branch of the posterior tibial artery) and the sinus tarsi artery (branch of the perforating peroneal artery). The tarsal canal artery supplies most of the talar body, whereas the talar neck is mainly supplied by the sinus tarsi artery. Extensive intraosseous anastomoses are present throughout the talus and are responsible for the survival of the talus in severe injuries. Initial fracture displacement, the timing of reduction, and soft tissue damage are factors that can potentially affect the integrity of the talar blood supply.[27]

Differentiating between talar neck or body fractures can be challenging. Inokuchi et al[18] described the anatomical border, where fractures can be more clearly distinguished on the inferior surface of the talus than on the superior surface. Hereto, fractures that pass from the medial entrance through the lateral entrance of the tarsal sinus on the inferior surface should be diagnosed as neck fractures, and fractures that pass through the lateral border of the posterior subtalar joint should be diagnosed as body fractures.

Different classifications for the talar neck fracture have been introduced. The Hawkins classification is used most frequently. In 1970, Hawkins[17] classified talar neck fractures into 3 types. In 1978, Canale and Kelly[9] modified this classification by adding a fourth type. Modified Hawkins type I fractures are nondisplaced, with preservation of the talar neck vasculature. Type II fractures are displaced with associated subluxation or dislocation of the subtalar joint, whereas the tibiotalar and talonavicular joints remain in proper alignment. Vallier et al[42] shed new light on the Hawkins type II fractures, separating Hawkins type II fractures into those without (type

IIA) and those with (type IIB) subtalar dislocation. This could help to predict the development of avascular necrosis (AVN). Type III fractures have displacement with subluxation or dislocation of the subtalar and tibiotalar joints and are characterized by a normal alignment of the talonavicular joint; however, this pattern of malalignment may be associated with injury to the posterior tibial neurovascular bundle. Type IV fractures demonstrate dislocation or subluxation of the subtalar, tibiotalar, and talonavicular joints and thereby the most severe type. Talar body and neck fractures can be classified by use of the Marti-Weber classification. Type I fractures are classified as distal talar neck and talar head fractures with osteochondral flakes. Type II fractures are nondisplaced talar neck and body fractures, type III fractures are displaced fractures of the talar neck and body, and type IV fractures are characterized by proximal talar neck fractures with corpus tali dislocated out of the intermalleolar space or comminuted fractures.[25] Sneppen et al[37] classified talar body fractures into 6 types: type A compression fracture, type B coronal shearing fracture, type C sagittal shearing fracture, type D fracture of the posterior process, type E fracture of the lateral process, and type F crush fracture.

Currently, the appropriate approach and fixation methods for talar neck and/or body fractures are still under constant discussion.[16] Hence, there is a growing understanding that displaced fractures of the talus neck and/or body should be managed by open anatomic reduction and stable fixation, thereby minimizing the risk of complications and poor functional outcomes,[30] whereas nonsurgical treatment should only be reserved for nondisplaced fractures.

This study aims to provide a systematic review of the literature on complication rates and functional outcome following operative treatment of talar neck and body fractures. This may help in clinical decision making by improving patients' expectation management and tailored treatment strategies.

METHODS

A systematic review of the literature was performed of the following databases using the OVID search engine: MEDLINE, EMBASE, and CENTRAL databases (2000– July 2021). Because of the recent advances in therapeutic strategies of talar fractures, we chose to compare the results of the last 20 years. The initial review was performed in March 2021 and was updated in July 2021. The search strategy for each database is outlined in Figure 1.

Inclusion criteria for selecting articles to be included in the review:
1. Studies involving fractures of the talar neck and/or body in adult (>17-year-old) patiënts
2. Studies published between 2000 and 2021

Exclusion criteria included the following:

1. Studies that included <10 patients
2. Non–English-language studies
3. Inability to isolate results
4. Mean follow-up of <3 months
5. When the full article was not provided

Two authors performed the systematic review independently (Posthuma and Wijers). Results from all databases were combined, and duplicate titles were removed. Two reviewers assessed the articles at each stage of the filtering process (titles, abstracts, and full-length manuscripts). At all but the final stage, disagreement led to inclusion. At the final stage of selection, disagreement was resolved by consulting a third independent reviewer (Schepers) to provide consensus on the inclusion. After full-length articles to be included were selected, 2 authors performed data extraction using a data extraction form (Posthuma and Wijers).

Variables

The year of publication, type of study, number of patients, gender, age, mechanism of injury, type of fracture (anatomy), treatment, postoperative protocol, primary outcome, complications, and duration of follow-up was noted for systematic analysis of the available evidence.

Complications

Complications were defined as surgical site infection (SSI), nonunion, osteoarthritis, AVN, secondary arthrodesis, or other surgical intervention, as described by the authors of the studied publications.

Functional Outcomes

Several validated functional outcome scores were used such as the Foot Function Index (FFI), the American Orthopaedic Foot & Ankle Society hindfoot score (AOFAS), the Weber functional outcome score, and the musculoskeletal function assessment (MFA).

The FFI consists of 23 items grouped into 3 subscales: pain, disability, and activity limitations.8 The American Orthopaedic Foot & Ankle Society (AOFAS) hindfoot score is a functional outcome score out of 100 points in domains such as pain (45 points), function (40), and alignment (15 points). Based on the total score, patients were divided in groups according to the literature: a score of 90 to 100 was graded as an excellent result, 75 to 89 as good, 50 to 74 as fair, and less than 49 points was graded as a failure or poor outcome.[20] The Weber functional outcome score is based on the evaluation of 4 categories: pain, gait, activity, and radiographic findings. In all subgroups, 0 is a perfect result and 4 is defined as poor. The latter defines a score of 0-3 as excellent, 4-7 good, 8-12 fair, and 13-16 as poor. The musculoskeletal function assessment (MFA) score is a health status instrument with 100 self-reported health items, with the best score of 0.[12] The Hawkins score consists of 3 parts: pain, the presence of a limp, and range of motion of the ankle.[17]

RESULTS

After final selection, 28 full-length articles were included (Figure 1). Most studies were retrospective case series (86%), whereas only 1 prospective study was selected.[3]

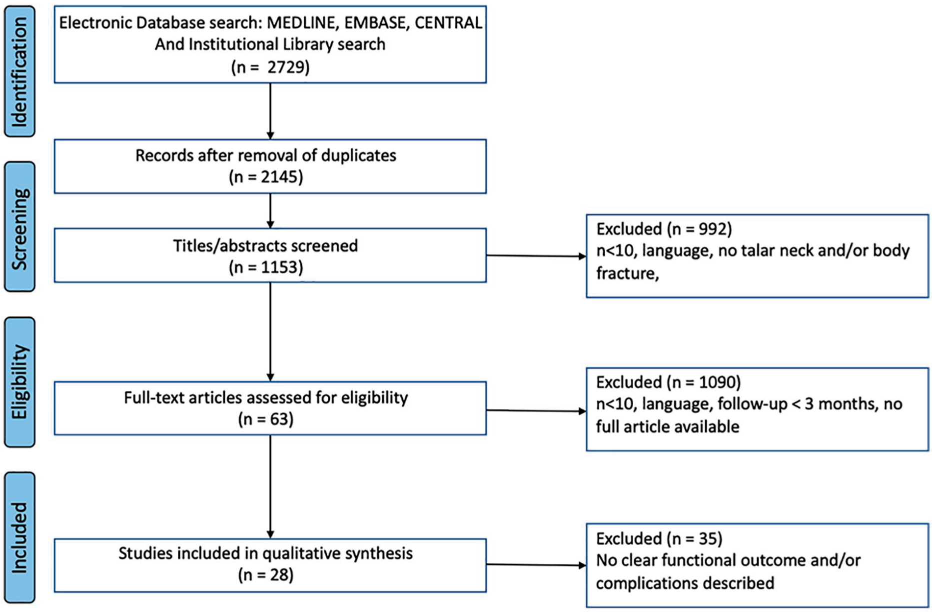

Figure 1. PRISM flowchart diagram of included articles.

A total of 755 talar neck, 227 talar body, and 104 combined talar neck and body fractures were reviewed. In the included studies, predominantly male patients were identified. The mean follow-up was 48 months (range 4-192). Further baseline characteristics of selected studies are presented in Table 1.[1,3-7,11,13-15,19,23,24,28,29,31,33,34,38-42,43,45-47]

Table 1. Baseline Characteristics of Operative Treatment of Talar Neck and/or Body Fractures

Study	Study Type	Year	Level of Evidence	N	Neck, n	Body, n	Neck and Body, n	Classification	Male, %	Age, y, mean (range)	Follow-up, mo, mean (range)
Pajenda[29]	RS	2000	IV	43	43	0	0	Hawkins	60	29 (16-73)	NR
Fleuriau Chateau[13]	CS	2002	IV	23	23	0	0	Hawkins OTA	43	28 (16-52)	20
Schulze[34]	RS	2002	IV	80	0	0	80	Hawkins Marti-Weber	84	33	72 (12-180)
Vallier[41]	RS	2003	IV	38	23	0	0	Hawkins OTA	70	34 (15-74)	38 (12-76)
Lindvall[22]	RS	2004	IV	26	19	7	0	Hawkins	42	37 (24-83)	74 (48-113)
Sanders[31]	RS	2004	IV	44	44	0	0	Hawkins OTA	55	24 (17-61)	62 (24-126)
Vallier[40]	RS	2004	IV	102	102	0	0	Hawkins OTA	61	33 (13 -77)	NR
Tezval[39]	RS	2007	IV	41	41	0	0	Hawkins Marti-Weber	68	35 (12-60)	36 (36-52)
Ebraheim[11]	RS	2008	IV	19	0	19	0	Boyd and Knight	68	31 (21-68)	26 (18-43)
Gomes de Sousa[15]	RS	2009	IV	10	4	6	0	Hawkins Marti-Weber	NR	39 (14-63)	59 (14-120)
Bastos[4]	RS	2010	IV	19	19	0	0	Hawkins	81	30 (18-41)	73 (14-169)
Bellamy[5]	RS	2011	IV	17	10	0	0	Hawkins	NR	27 (21-38)	16 (4-53)
Ohl[28]	RS	2011	IV	20	10	10	0	Hawkins Boyd and Knight	60	39 (17-76)	90
Abdelgaid[1]	CS	2012	IV	16	16	0	0	Hawkins NR	33 (14-53)	48 (36-60)	
Fournier[14]	RS	2012	IV	114	53	61	0	Hawkins	68	34 (15-71)	111 (7-351)
Yeganeh[47]	RS	2013	IV	30	28	2	0	Hawkins	90	38	36
Vallier[42]	RS	2014	IV	81	52	29	0	Hawkins	50	37	30
Xue[46]	RS	2014	IV	28	28	0	0	Hawkins	75	35	25 (18-50)
Annappa[3]	PS	2015	IV	20	20	0	0	Hawkins	80	29	28
Beltran[6]	RS	2016	IV	25	25	0	0	Hawkins	NR	NR	44 (12-78)
Maceroli[24]	RS	2016	IV	26	26	0	0	Hawkins	54	39	18 (12-42)
Stake[38]	RS	2016	IV	50	32	28	16	Hawkins Boyd and Knight	NR	27 (14-63)	55 (16-133)
Wu[45]	CC	2016	IV	29	29	0	0	Hawkins	69	41	24 (18-36)
Junge[19]	RS	2017	IV	26	11	15	0	Hawkins	NR	NR	30 (13-96)
Liu[23]	RS	2017	IV	22	22	0	0	Hawkins	55	29 (16-73)	30 (18-41)
Biz[7]	RS	2019	IV	28	9	19	0	Hawkins Sneppen	71	28 (16-52)	83 (49-119)
Von Winning[43]	RS	2020	IV	24	8	16	0	Hawkins	70	33	104 (15-192)
Sautet[33]	RS	2021	IV	81	58	15	8	Hawkins Sneppen	NR	34 (16-74)	12
Total				1081	755	227	104				48

Abbreviations: CC, case control study; CS, case series; PS, prospective study; NR, not registered; RS, retrospective study.

Complications

Postoperative complications were divided into early and late complications. Postoperative SSI within 90 days was found in 6% (61/944). Late complications included nonunion in 8% (48/636), AVN in 29% (279/966), secondary arthrodesis in 16% (124/800), and osteoarthritis in 64% (514/804). More detailed information is presented in Tables 2 and 3.

Table 2. Early and Late Complications After Operative Treatment of Talar Neck and/or Body Fractures Sorted by Study.

		Early	Late			
	Type	SSI, n/N (%)	Non-union, n/N (%)	AVN, n/N (%)	Secondary Arthrodesis, n/N (%)	Osteoarthritis, n/N (%)
Pajenda[29]	43 neck	8/43 (19)	0/43 (0)	4/43 (9)	9/43 (21)	24/43 (56)
Fleuriau Chateau[13]	23 neck	0/23 (0)	0/23 (0)	4/23 (17)	0/23(0)	3/23 (13)
Schulze[34]	80 neck + body	3/80 (4)	2/80 (3)	9/80 (11)	9/80 (11)	55/80 (69)
Vallier[40]	15 body 11 body + neck	4/38 (11)	0/26 (0)	10/26 (38)	4/26 (15)	17/26 (65)
Lindvall[22]	16 neck 8 body 2 neck + body	NR	3/26 (12)	13/26 (50)	2/26 (8)	26/26 (100)
Sanders[31]	44 neck	5/44 (11)	NR	8/44 (18)	22/26 (8)	18/26 (69)
Vallier[40]	102 neck	5/60 (8)	2/60 (3)	19/39 (48)	5/39 (13)	21/39 (54)
Tezval[39]	41 neck	NR	NR	5/41 (12)	NR	NR
Ebraheim[11]	19 body	3/19 (16)	1/19 (5)	7/19 (37)	NR	17/19 (89)
Gomes de Sousa[15]	4 neck 6 body	NR	NR	5/10 (50)	NR	5/10 (50)
Bastos[4]	19 neck	4/19 (21)	NR	4/19 (21)	3/19 (16)	15/19 (79)
Bellamy[5]	10 neck	NR	NR	7/17 (41)	NR	5/17 (29)
Ohl[28]	10 neck 10 body	1/20 (5)	12/20 (60)	4/20 (20)	5/20 (25)	18/20 (90)
Abdelgaid[1]	16 neck	0/16 (0)	1/16 (6)	1/16 (6)	0/16 (0)	1/16 (6)
Fournier[14]	53 neck 33 body 28 neck + body	6/114 (5)	NR	39/114 (34)	29/114 (25)	85/114 (75)
Yeganeh[47]	28 neck 2 body	5/30 (17)	18/30 (60)	12/30 (40)	0/30 (0)	30/30 (100)
Vallier[40]	52 neck 29 body	1/78 (1)	2/64 (3)	16/65 (25)	7/65 (11)	35/65 (54)
Xue[46]	28 neck	1/28 (4)	0/28 (0)	6/28 (21)	5/28 (18)	10/28 (36)
Annappa[3]	20 neck	0/20 (0)	1/20 (5)	7/20 (35)	NR	11/20 (55)
Beltran[6]	25 neck	1/24 (4)	1/24 (4)	10/24 (42)	1/24 (4)	15/24 (63)
Maceroli[24]	26 neck	1/26 (4)	3/26 (12)	7/26 (27)	4/26 (15)	10/26 (38)

Table 2. Early and Late Complications After Operative Treatment of Talar Neck and/or Body Fractures Sorted by Study. (*continued*)

		Early	Late			
	Type	SSI, n/N (%)	Non-union, n/N (%)	AVN, n/N (%)	Secondary Arthrodesis, n/N (%)	Osteoarthritis, n/N (%)
Stake[38]	32 neck 28 body 16 neck + body	3/52 (6)	1/52 (2)	45/52 (87)	3/52 (6)	51/52 (98)
Wu[45]	29 neck	2/29 (7)	0/29 (0)	9/29 (31)	5/29 (17)	10/29 (34)
Junge[19]	11 neck 15 body	2/26 (8)	NR	NR	8/26 (31)	NR
Liu[23]	22 neck	1/22 (5)	1/22 (5)	13/22 (59)	2/26 (8)	NR
Biz[7]	9 neck 19 body	1/28 (4)	0/28 (0)	7/28 (25)	0/28 (0)	22/28 (79)
Von Winning[43]	8 neck 16 body	0/24 (0)	NR	2/24 (8)	1/24 (4)	10/24 (42)
Sautet[33]	58 neck 15 body 8 neck + body	4/81 (5)	NR	6/81 (7)	NR	NR
Total		61/944 (6)	48/636 (8)	279/966 (29)	124/800 (16)	514/804 (64)

Abbreviations: AVN, avascular necrosis; NR, not registered; SSI, surgical site infection.

Table 3. Early and late complications after operative treatment of talar neck and/or body fractures sorted by fracture location.

	Early	Late			
Type of Fracture	SSI, n/N (%)	Nonunion, n/N (%)	AVN, n/N (%)	Secondary Arthrodesis, n/N (%)	Osteoarthritis, n/N (%)
Neck	29/381 (8)	17/325 (5)	112/430 (26)	60/329 (18)	168/330 (51)
Body	4/64 (6)	3/61 (5)	43/158 (27)	9/44 (20)	56/85 (66)
Neck and body	3/80 (4)	2/91 (2)	15/91 (16)	9/80 (11)	57/82 (70)
Total	36/525 (7)	22/477 (5)	170/679 (25)	78/453 (17)	281/497 (57)

Abbreviations: AVN, avascular necrosis; SSI, surgical site infections

Functional Outcome

Different functional outcome scores were used in the reviewed articles. The most frequently used outcome score was the AOFAS score in 15 of 21 articles (71%). In addition, other functional outcome scores were used, such as FFI, 4 of 21 (19%); MFA, 2 of 21 (10%); Hawkins, 2 of 21 (10%); and Weber, 1 of 21 (5%). More detailed information is presented in Table 4.

Table 4. Functional Outcomes After Operative Treatment of Talar Neck and/or Body Fractures.

Study	Functional Outcome Score	Functional Outcome[a]
Pajenda[29]	Weber	H1: good and excellent, 14/16 (95%); fair, 2/16 (13%)
		H2: good, 12/14 (85%); fair, 2/14 (14%)
		H3: satisfactory, 6/9 (67%); fair, 3/9 (33%)
		H4: satisfactory, 7/11 (63%); unsatisfactory, 4/11 (36%)
Schulze[34]	Hawkins	MW1: very good, 5/15 (33%); good, 3/15 (20%); fair, 4/15 (27%); poor, 3/15 (33%)
		MW2: very good, 3/14 (21%); good, 5/14 (36%); fair, 5/14 (36%); poor, 1/14 (7%)
		MW3: very good, 5/32 (16%); good, 9/32 (28%); fair, 11/32 (34%); poor, 7/32 (22%)
		MW4: very good, 1/19 (5%); good, 4/19 (21%); fair, 5/19 (26%); poor, 9/19 (47%)
Vallier[41]	FFI	Pain: 41/90; disability: 37/90; activity: 19/50
	MFA	Talar body fracture: mean score, 29.3
		Talar body and neck fracture: mean score, 29.5
Lindvall[22]	AOFAS	Talar neck fracture: presence of osteonecrosis, 46.7; no osteonecrosis, 76
		Talar body fracture: presence of osteonecrosis, 51.4; no osteonecrosis, 60.3
Sanders[31]	sMFA	Mean score: 71 ± 19
Vallier[41]	FFI	H2: 25.9; H3: 27.8
Tezval[39]	AHS	Satisfactory score: 39/50; pain score: 27/50
Ebraheim[11]	AOFAS	Mean score: 68.6 (range 44-94)
		Excellent: 4/19 (21%); good: 6/19 (32%); fair: 4/19 (21%); poor: 5/19 (26%)
Gomes de Sousa[15]	AOFAS	Talar neck fracture: mean score, 61
		Talar body fracture: mean score, 82
		Presence of AVN, 50; no AVN, 93
		Presence of osteoarthritis, 51; no osteoarthritis, 93
Bastos[4]	AOFAS	Mean score: 70.2
Ohl[28]	AOFAS	Mean score: 66.9 (range 45-88)
		Talar neck fracture: mean score, 64.6
		Talar body fracture: mean score, 69.2
Abdelgaid[1]	AOFAS	Mean score: 89.25 (range 74-100)
		Excellent: 8/16 (50%); good: 6/16 (38%); fair: 2/16 (12%)
Fournier[14]	AOFAS	Mean score: 70/100 (range 9-100)
		H1: 78.3; H2: 70.8; H3: 63.4; H4: 43.2
		Talar fractures with osteonecrosis and collapse: 45.5
Yeganeh[47]	AOFAS	Pain score: 65; motion score: 53; ROM score: 15
Xue[46]	AOFAS	Mean score: 78 (range 65-91)
Annappa[3]	AOFAS	Excellent: 4/20 (20%); good: 7/20 (35%); fair: 5/20 (25%); poor: 4/20 (20%)

Table 4. Functional Outcomes After Operative Treatment of Talar Neck and/or Body Fractures. (*continued*)

Study	Functional Outcome Score	Functional Outcome[a]
Stake[38]	AOFAS	Mean score: 73
Liu[23]	Hawkins	Mean score: 11.4 ± 3.4
	AOFAS	Mean score: 72.8 ± 17.3
Biz[7]	AOFAS	Excellent: 8/28 (29%); good: 9/28 (32%); fair: 9/28 (32%); poor: 2/28 (7%)
	FFI	Excellent: 3/28 (11%); good: 14/28 (50%); fair: 5/28 (18%); poor: 6/28 (21%)
Von Winning[43]	AOFAS	Mean score: 71.4 ± 22.9
	FFI	Mean score: 35.9 ± 28
Sautet[33]	AOFAS	Mean score: 74 (range, 12-100)
		Excellent: 16/81 (20%); good: 24/81 (30%); acceptable: 23/81 (28%); poor: 18/81 (22%)

Abbreviations: AHS, Ankle hindfoot scale; AOFAS, American Orthopaedic Foot & Ankle Society ankle-hindfoot rating system; CS, case series; FFI, foot function index; Hawkins, Hawkins score; PS, a prospective study; RS, retrospective study; SF-36, 36-Item Short Form Survey; sMFA, short Musculoskeletal Function Assessment Questionnaire; ROM, range of motion.
[a]H1, H2, H3, and H4 indicate Hawkins classification types I, II, III, and IV, respectively. MW1, MW2, MW3, and MW4 indicate Marti-Weber classification types I, II, III, and IV, respectively.

DISCUSSION

Operative treatment of central talar fractures is associated with a high incidence of early and late complications and often leads to an impaired functional outcome. Almost all articles were of low evidence (Level IV). Given the low incidence of this type of fracture, large volume prospective studies are hard to conduct. One prospective study by Annappa et al[3] was identified describing 20 operatively treated talar neck fractures that were prospectively followed up. Overall, results of articles were challenging to compare, given the heterogeneity of articles, especially given the various classification and functional outcome scores.

Subgroup Incidence

In our evaluation, 755 neck (70%), 227 body (21%), and 104 combined body and neck fractures (9%) were included, suggesting that the talar neck is more prone to traumatic injury than the body. A possible explanation for this is that the short and broad talar neck has a relatively weak cortex.[21] Another explanation can be found in the trauma mechanism. Fractures of the talar neck occur with forced dorsiflexion of the ankle in the setting of a high-energy axial load. The dense cortical bone of the anterior tibia is driven inferiorly and encounters the less-dense bone of the talar neck.[44]

Classification

Our study shows that the Hawkins classification for talar neck fractures and Marti-Weber for body and neck fractures are the most commonly used classification. These classifications are widely accepted and should be used as a standard to improve the comparability of future studies.

Complications and Functional Outcome

Complication rates were high, ranging between 6% SSI up to 64% osteoarthritis, following operative treatment of talar fractures. AVN occurred more often in cases of a combined neck-body fracture, than in cases of isolated body or neck fractures.[14] As expected, there seems to be a trend of increased complication rates with a longer follow- up period. Fournier et al[14] described an AVN rate of 34% following operative treatment of 114 talar neck and body fractures after a follow-up of 111 months, whereas only 7% AVN was observed in 81 talar neck and body fractures after 12 months by others.[33] In addition, up to 75% osteoarthritis after 111 months as observed by Fournier et al,[14] compared to 29% after a follow-up of 16 months as described by Bellamy et al.[5] Therefore, in patients suffering from a talar fracture, long and intensive follow-up is warranted for timely recognition of early and late complications. Especially given the correlation between the presence of complications and impaired functional outcome.[14,15,22] Lindvall et al[22] described an AOFAS score of 76 after operative treatment of talar neck fractures in the absence of AVN, whereas patients suffering from AVN reported a lower functional outcome score of 46.7. The same trend (but less pronounced) was seen in the talar body fractures (AOFAS score in absence of AVN 60.3 and presence of AVN 51.4).[38] The latter was also observed concerning AVN, where the AOFAS score on talar neck and/or body fractures was 93 in patients without AVN and functional outcome score was 50 in patients with AVN.[15] One explanation might be that postoperative follow-up differs considerably between studies, varying from standardized CT scans to articles in which follow-up imaging was not described. To compare studies in the future, we advocate for standardization of talar fracture follow-up with targeted imaging and functional outcomes scores, to improve the comparability of future studies. Given that the AOFAS score is the most commonly used, we consider this as the most appropriate score for future evaluation. In addition, specific gradings systems are available to rate the severity of subtalar arthritis, such as the Kellgren and Lawrence grading scale and the Paley gradings system.[26]

Preoperative Classification and Postoperative Functional Outcome

Several studies revealed that poor outcome was correlated with fracture severity.[11,14,29,33,41] Evaluating functional outcome in relation to the fracture classification, we observed a trend toward an impaired functional outcome in Hawkins type III and IV and MW type III and IV. Pajenda et al[29] described good and excellent results in 95% and 85% of the operatively treated Hawkins type I and II fractures, respectively. Only 67% and 63% of the patients having Hawkins III and IV fractures had satisfactory functional outcome scores. None of the patients scored an excellent or good outcome. In addition to this, 53% of the MW I and 57% of MW II fractures led to very good or good functional outcomes, which was only found in 44% and 26% of the MW III and

IV fractures.[34] A possible explanation might be that a higher classification is most likely due to higher energy trauma, which in turn is often associated with severe soft tissue and cartilage damage.

Anatomic reduction is a strong predictive factor for postoperative function.[33] Studies showed that poor reduction was associated with impaired functional outcome.[22] Given that comminuted and dislocated fractures might be a challenge to reduce toward an anatomic reduction, one may assume that more severe-type talar fractures are associated with impaired functional outcome. Another explanation might be that late complications rise on the severity of the fracture. For instance, in Hawkins type III fractures, all 3 major arterial sources to the talus are commonly injured, resulting in a high risk of AVN. Type IV fractures demonstrate dislocation or subluxation of the subtalar, tibiotalar, and talonavicular joints. In addition to the vascular disruption seen in type III injuries, disruption of blood supply to the head and neck fragments may be seen with this injury as well.

Talar Body vs Talar Neck vs Combined Talar Neck and Body Fractures

There were very few articles comparing differences in functional outcome between groups of talar neck, talar body, and combined talar neck and body fractures. In the studies we evaluated, there was no clear difference in functional outcome when comparing talar body, neck, and combined body and neck fractures. Vallier et al[41] described an MFA score after operative treatment of talar body fractures of 29.3 points and talar body and neck fractures of 29.5 points. The mean standardized MFA score for all patients in this series was 29.4, which was significantly higher than the reported mean reference value for patients with hindfoot injuries of 22.1 ($P < .001$). When comparing talar neck and talar body fractures, articles published conflicting results. Studies are hard to compare given lacking data and a variety of scoring systems for functional outcomes. Therefore, it remains unknown if talar neck, talar body, or combined talar neck and body are related to different functional outcomes. Comparable functional outcome after operative treatment of talar neck and talar body fractures was described by Ohl et al[28] (talar neck fractures: AOFAS score 64.6 vs talar body fractures: AOFAS score 69.2). Lindvall et al[22] showed that AOFAS scores upon talar neck fractures were better when compared to talar body fractures (talar neck: 76 vs talar body: 60.1). Interestingly, the opposite was found by Gomes de Sousa et al[15] describing an AOFAS score for talar neck fractures of 61 and after talar body fractures of 82.

The authors believe that functional outcomes are more dependent on the preoperative classification (eg, amount of dislocation and comminution) than the exact location of the fracture. In addition, the presence of postoperative complications (eg, AVN or osteoarthritis) seems to be a strong predictor, as described earlier. Furthermore, we focused only on talar fractures and did not describe concomitant injuries. Talar fractures are frequently caused by high-velocity trauma, so associated injuries are expected and can affect the different functional outcome.

CONCLUSION

Operative treatment of central talar fractures is associated with a high incidence of early and late complications and often leads to an impaired functional outcome. Large sample- sized prospective studies are warranted to detect further predictive factors influencing the currently unsatisfactory clinical outcome of patients. Standardization of talar fracture classification and scoring systems would improve the comparability of future studies. The AOFAS score is the most commonly used functional outcome score and should be considered to use in future studies, to make the comparison between studies possible. Nevertheless, there seems to be a trend toward a more impaired functional outcome and increased postoperative complications with increased severity of talar fractures. In addition, our studies showed an overview of commonly reported complications on operative treatment of talar body and/or neck fractures, which makes tailormade treatment strategies and patient expectation management more accurate.

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3

Functional outcome and quality of life in surgically treated talar neck and body fractures; how is it affected by complications

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ABSTRACT

Background: Since talus fractures are rare, study populations are frequently small. The aim of this study is to describe how surgical treatment of talar neck and body fractures and post-operative complications affect functional outcome and quality of life measured by validated questionnaires.

Methods: All patients following surgically treated talar neck and/or body fracture between January 20 0 0 and December 2019 at a level 1 trauma center were included in this retrospective cohort study. Primary outcomes were functional outcomes measured by Lower Extremity Functional Score (LEFS), the Foot Function Index (FFI), and the Quality of Life (QOL) measured by the EuroQol 5-dimension questionnaire (EQ-5D). Linear regression was used to assess the relationship between continuous variables and the outcome, and multivariable linear regression was used to identify the predictors of the functional outcome.

Results: Ninety patients were included, of which 73 responded to our questionnaires. The median followup time was 50.5 (interquartile range (IQR), 18.3–97.3) months. Our study showed the following results: a mean LEFS of 58.4 (range, 17–80), a median FFI of 15.7 (IQR, 3.5–35.2), a median EQ-5D index score of 0.83 (IQR, 0.81–1.00), a median patient satisfaction of 9.0 (IQR, 8.0–10.0), a patient reported health status of 76.8 (range, 20–100), and a mean AOFAS score of 75.7 (range, 28–100). Implant removal and secondary arthrodesis were associated with a reduced AOFAS outcome score ($p = 0.0\ 01$, $p < 0.0\ 01$), and implant removal was also a predictive factor for a less favorable LEFS outcome score ($p = 0.001$).

Conclusion: Patients who underwent implant removal and/or secondary arthrodesis had poorer functional outcome compared to patients who did not undergo additional procedures. Careful consideration of reintervention must be made in combination with patient expectation management. Future studies should focus on how to lower the rate of complications and the effect of secondary intervention with the use of validated questionnaires.

Keywords: Talar neck fractures Talar body fractures Ankle injuries Patient-reported outcomes Talus Trauma

INTRODUCTION

Fractures of the talus are relatively uncommon, comprising less than 1% of all fractures and 3% to 6% of foot and ankle fractures.[1]

The vascular supply of the talus is predominantly extra osseous since more than half (65%) of the surface is covered by cartilage and without muscular attachments. The vascular supply arises from three major arteries of the lower leg.[2,3] Therefore, the talus has a displacement-dependent risk of posttraumatic arthritis and avascular necrosis, particularly after fractures of the talar neck.[4] The reported incidence of postoperative complications varies widely between short term follow-up studies.[4]

Because talus fractures are rare, high-quality studies investigating the functional outcome and quality of life with validated questionnaires after surgically treated talar neck and body fractures are limited.[5–8] Consequently evidence based treatment protocols are lacking. This study describes how surgical treatment and various postoperative complications affect the functional outcome and Quality of Life in a large patient population treated in a level 1 trauma center.

PATIENTS AND METHODS

Design and patients

All patients presenting with talar neck and/or body fractures that were treated at a level 1 trauma center, between January 20 0 0 and December 2019, were analyzed in this retrospective cohort study. The national billing code (DBC) 241 and the surgical code 338733 were used to extract patients data from the electronic hospital database. This included patients presented to our emergency department, and patients that were referred from other hospitals. Patients were included with a fracture of the talar neck and/or body, and at least 6 months of follow-up. Patients were excluded when younger than 18 years on the last day of follow-up, patients with more than one year delay at presentation, and patients that demonstrated insufficient command of Dutch or English language. This study was performed after informed consent and institutional review board approval were obtained.

Variables

The electronic hospital database, picture archiving and communication systems (PACS) were used to extract clinical and radiographic data. Patient characteristics included: age, gender, American Society of Anesthesiologist classification (ASA), body mass index (BMI), smoking, and the mechanism of trauma. Fracture and surgical treatment characteristics included: type of fracture,[9,10,11] injured side, dislocation, open fracture (Gustilo-Anderson classification), previous treatment (including emergent reduction), definitive treatment, operative approach, duration of postoperative cast or equivalent, concomitant ipsilateral and contralateral extremity injuries. Previous treatment included external fixator, closed reduction and open reduction with K-wire. Definitive treatment was classified as Open Reduction Internal Fixation (screws only or with plate), primary arthrodesis, external fixator, partial bone excision. Operative approaches were categorized as anterior, medial, lateral, double, triple, medial malleolus osteotomy, and lateral malleolus osteotomy. Treatment was divided into early surgery (within 7 days after trauma) and delayed surgery (more than 7 days after trauma).

Outcome measures

The primary outcomes were functional outcome measured by the Lower Extremity Functional Score (LEFS, best score 80 points),[12] the Foot Function Index (FFI, best score 0 points),[13] and the Quality of Life (QOL) measured by the EuroQol 5-dimension questionnaire (EQ-5D).[14] The EQ-5D questionnaire consist of 5 items about mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. The patient reported health status and patient satisfaction were scored on a visual analogue scale (VAS) of 0 to 100, with 100 being the best possible outcome.

Secondary outcomes were functional outcome measured by the American Orthopaedic Foot and Ankle Society (AOFAS) Ankle hindfoot score (range 0 to 100) and postoperative complications. The AOFAS outcome was divided into 4 groups: a score of 90 to 100 was considered to be excellent; 75 to 89 (good); 50 to 74 (fair); and a score of 49 or lower was considered to be a poor outcome.[15] For comparative purposes we included the AOFAS, as it still remains one of the most frequently used outcomes score despite its weaknesses. The ceiling effect was defined as the percentage of patients with a maximum score in the functional outcome questionnaire. The floor effect was defined as the percentage of patients with a minimum score in the functional outcome questionnaire.

Collected postoperative complications included: wound dehiscence, surgical site infection, posttraumatic osteoarthritis (PTOA), avascular necrosis (AVN), malunion, nonunion, and re-intervention. Postoperative surgical site infection was divided into deep (treated with re-operation and antibiotics) and superficial infection (treated by administration of antibiotics). Re -interventions included: implant removal, secondary arthrodesis, joint debridement, and osteophyte removal. Indications for re-intervention for patients with unfavorable outcomes were pain, functional complaints, infections, PTOA, and AVN. Postoperative complications (PTOA, AVN, malunion, nonunion) were identified on conventional radiographs, and in some cases with additional computed tomography (CT) or magnetic resonance imaging (MRI).

Statistical analysis

All variables were reported using descriptive statistics. Q-Q plots were used to evaluate the normality of the variables and the patient-reported outcome measurements. Normally distributed continuous variables were reported using mean and range, and not normally distributed continuous variables using median and interquartile range (IQR). Categorical variables were expressed as frequencies and percentages.

In normally distributed outcomes (AOFAS and LEFS), the Student's *t*-test was used to assess the difference in outcome between variables with 2 groups. The One-Way ANOVA Test was used for categorical variables with more than two groups.

If not normally distributed, the outcomes (FFI, EQ-5D) were analyzed by the Mann-Whitney U test to assess the difference in outcome between variables with 2 groups. The Kruskal-Wallis H Test was used for categorical variables with more than two groups. Non-normally distributed outcomes were presented as median with IQR. In both normally and not normally distributed outcomes, linear regression was used to assess the relationship between continuous variables and the outcomes.

All variables with a $p < 0.1$ in univariate analysis, were evaluated as possible predictors with AOFAS, LEFS, FFI, and EQ-5D as dependent variables in a linear regression. Multivariate linear regression was used to identified the predictors of the functional outcome, using the following variables: age, gender, BMI, smoking, ASA-score, type of fracture, dislocation, open fracture, concomitant talus fractures (ipsilateral and contralateral), isolated talar neck and/or body fractures (without concomitant talus fractures), time of treatment (early and delayed surgery), postoperative complications, postoperative infection, AVN, posttraumatic osteoarthritis, re-intervention, implant removal, secondary arthrodesis, and other surgery. Variables were eliminated backwards, until only significant variables remained. The Bonferroni method was used to correct for multiple testing, using a p value of $0.05/27 = 0.002$ as significant. All statistical analyses are performed using the Statistical Package for the Social Sciences (SPSS) version 26.0 (IBM Corp., Armonk, New York).

RESULTS

Patient characteristics

A total of 90 patients were included in this study (the inclusion flowchart is described in Fig. 1), of which 61 were male patients. The median age of trauma was 32.5 (IQR 23.5–52.0) years. The most common trauma mechanism was fall from height (43/90). Sixty-one patients were referred to our department from other hospitals (61/90). The median follow-up time from the day of trauma was 50.5 (IQR, 18.3–97.3) months, with all patients having a follow-up time of more than 6 months and 81 patients of more than 12 months. Table 1 shows patient characteristics, and trauma mechanism.

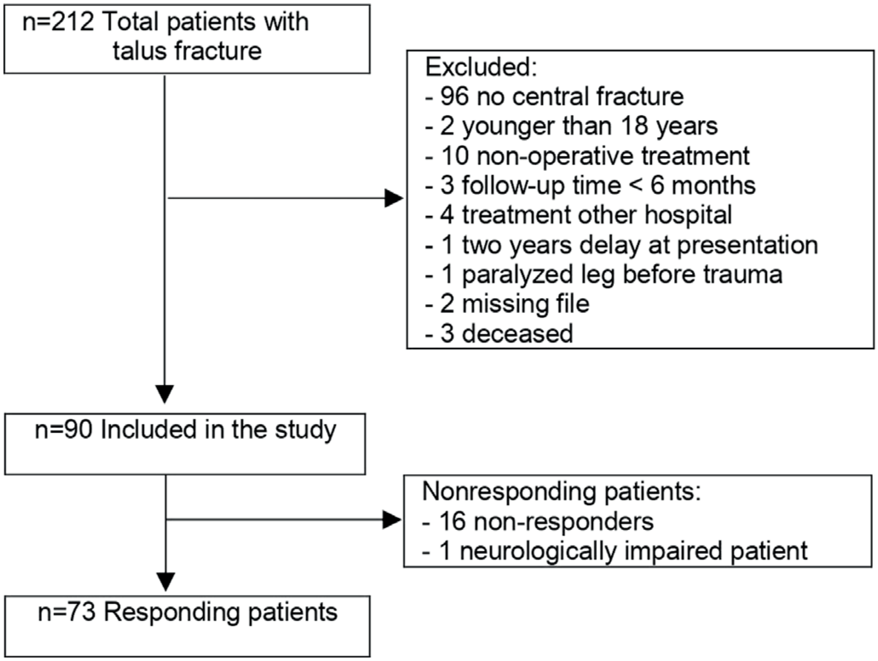

Fig. 1. Flow diagram for patient inclusion and exclusion.

Table 1 Demographic and patient characteristics, and trauma mechanism[a].

Total patients, n (%)	90 (100)
Age at trauma, years, median (IQR)	32.5 (23.5–52.0)
Male, n (%)	61 (67.8)
BMI, mean (range)	24.6 (16.4–44.5)
ASA Score, n (%)	
1	65 (73.9)
2	17 (19.3)
3	5 (5.7)
4	1 (1.1)
Smoking, n(%)	20 (23.5)
Trauma mechanism, n(%)	
Fall from height	43 (47.8)
Fall during daily activities	10 (11.1)
MVA	26 (28.9)
Sports	8 (8.9)
Blunt trauma	3 (3.3)

Abbreviations: MVA, motor vehicle accident; ASA, American Society of Anesthesiologist Classification.
[a] Percentages presented as the valid percentages.

Forty-seven patients had a fracture of the talar neck (47/90), and 43 patients had a fracture of the talar body (43/90). Two patients underwent bilateral surgery for talar neck and body fracture. Fracture characteristics, classification and treatment characteristics are shown in Table 2. Fig. 2 shows the treatment characteristics of dislocated and non-dislocated talar fractures. Most patients were treated with open reduction and internal fixation. A single patient underwent partial excision instead of correction osteotomy due to the high risk of AVN. Fig. 3 displays examples of talar neck fracture (Fig. 3 A) and body fracture (Fig. 3 B) with preoperative CT-scan, images during surgery, and postoperative results. Postoperatively, patients received a cast for an average of 4 (range, 0–20) weeks, and/or a bandage for 2.2 (range, 0–3) days.

Table 2 Fracture characteristics, classification and treatment characteristics n = 90.

Fracture side, n (%)	
Right	45 (50.0)
Left	41 (45.6)
Bilateral	4 (4.4)
Fracture-Dislocation, n (%)	57 (63.3)
Subtalar	30 (52.6)
Ankle	10 (17.5)
Subtalar and Ankle	17(29.8)
Open fracture, n(%)	11 (12.2)
Gustilo I	1 (1.1)
Gustilo II	0 (0.0)
Gustilo III	8 (8.9)
Hawkins[9], n(%)	47 (52.2)
2a	12 (13.3)
2b	20 (22.2)
3	15 (16.7)
Sneppen[10] , n(%)	43 (47.8)
1	7 (7.8)
2	22 (24.4)
5	14 (15.6)
Damage control surgery, n (%)	34 (37.7)
External Fixator	18 (20.0)
Closed reduction	13 (14.4)
Open reduction + K - wires	3 (3.3)
Type of definitive treatment, n (%)	
ORIF (Screws only)	48 (53.3)
ORIF (Screws + plate)	28 (31.1)
Primary arthrodesis	10 (11.1)
External Fixator	3 (3.3)
Partial bone excision	1 (1.1)

Table 2 Fracture characteristics, classification and treatment characteristics n = 90. (*continued*)

Time of definitive treatment, n (%)	
Early surgery, <7 days	22 (24.4)
Delayed surgery, >=7 days	68 (75.6)
Operative approach*, n (%)	
Anterior	2 (2.2)
Medial	10 (11.1)
Lateral	19 (21.1)
Double	50 (55.6)
Triple	3 (3.3)
Osteotomy	
Medial malleolar osteotomy	5 (5.5)
Lateral malleolar osteotomy	2 (2.2)

Abbreviations: ORIF, Open Reduction Internal Fixation.
[a] Data are presented as number with valid percentage.
**3 not applicable; by patients with fixator external.*

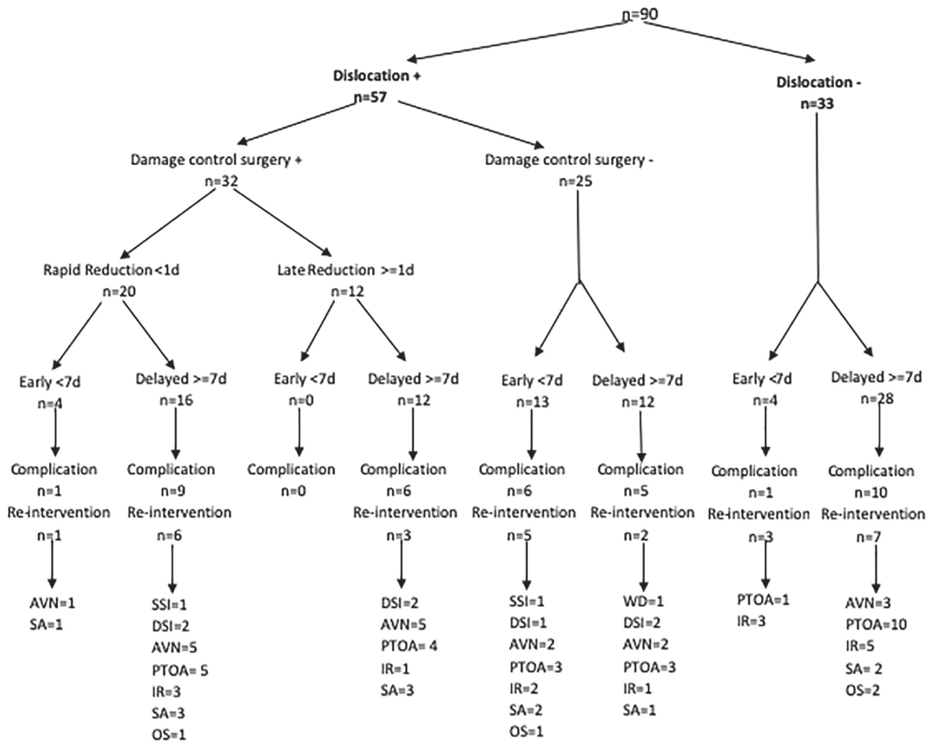

Fig. 2. Treatment characteristics and complications of dislocated versus non-dislocated talus fractures.
Abbreviations–AVN, avascular necrosis; SSI, superficial surgical site infection; DSI, deep surgical site infection; PTOA, post-traumatic osteoarthritis; WD, wound dehiscence; IR, implant removal; SA, secondary arthrodesis; OS, other surgery.
Complication–Number of patients with one or more post-operative complications.
*Re*intervention–Number of patients who underwent one or more re-interventions.

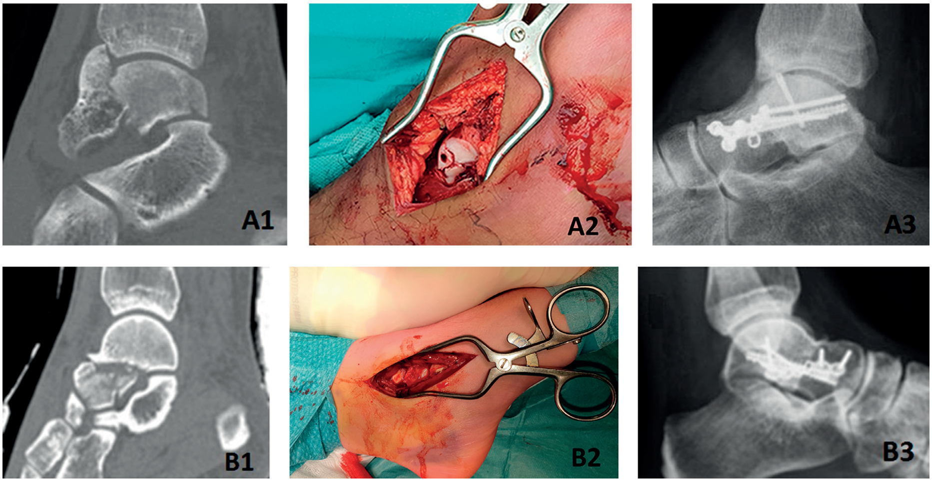

Fig. 3. A) Case 1, a fracture of the talar body–Preoperative computed tomography (CT) scan with a sagittal view (1), a perioperative image (2), and a radiograph with a sagittal view showing the postoperative result with screws and plates (3). B) Case 2, a fracture of the talar neck–Preoperative computed tomography (CT) scan with a sagittal view (1), a perioperative image (2), and a radiograph with a sagittal view showing the postoperative result with screws and plate (3).

In the total study population, 45 patients had an isolated talar fracture, and 52 patients had one or more contralateral and/or ipsilateral concomitant lower extremities fractures. Table S1 (Supplementary Appendix) displays the contralateral and ipsilateral concomitant lower extremities fractures, and the contralateral and ipsilateral concomitant talus fractures.

Primary outcome measures

Table 3 shows the functional outcome and the quality of life scores in the responding study population. The ceiling score was encountered in 6.9% for the LEFS, and 6.9% for the FFI. The floor effect was seen in 0% for the LEFS, and in 1.4% for the FFI.

Secondary outcome measures

Five patients reported a poor AOFAS outcome (neck n = 4, body n = 1). In three patients out of these five the talus was dislocated (neck n = 3), which was treated within 1 day by reduction and external fixator. All 3 patients with talar dislocation received their definitive surgery after more than 7 days, with 2 out of 3 patients developing posttraumatic arthritis (n = 2) and AVN (n = 2). In the group of patients reporting poor AOFAS scores, one or more postoperative complications occurred in 4 out of 5 patients: deep surgical site infection (n = 1), AVN (n = 2), and osteoarthritis (ankle n = 2, subtalar n = 2). Four patients underwent one or more re-interventions: implant removal (n = 4), secondary arthrodesis (ankle n = 1, subtalar n = 2), or other surgery (n = 1).

Table 3 Functional outcome and quality of life scores n = 73.

Available outcome measurements, n (%)	73 (81.1)
Functional outcome	
LEFS score, mean (range)	58.7(17–80)
FFI total, median (IQR)	15.7 (3.7–35.0)
Pain score	15.6 (3.9–40.0)
Disability score	16.1 (2.2–38.6)
Activity limitation score	7.0 (0–19.5)
Quality of life	
EQ-5D index, median (IQR)	0.83 (0.81–1.0)
Patient reported health status, mean (range)	77.0 (20–100)
Patient satisfaction, median (IQR)	9.0 (8.0–10)
AOFAS, mean(range)	75.9 (28–100)
Excellent outcome, n (%)	18 (24.7)
Good outcome, n (%)	19 (28.8)
Fair outcome, n (%)	29 (39.7)
Poor outcome, n (%)	5 (6.9)

Abbreviations: FFI, Foot Function Index; AOFAS, American Orthopaedic. Foot & ankle Society Score; LEFS, Lower Extremity Functional Scale; EQ-5D, EuroQol-5D. Data are presented

The ceiling score was encountered in 9.6% for the AOFAS. The floor effect was not observed. In the overall study population, 38 patients had one or more postoperative complications. In addition, two patients with contralateral talar neck (n = 1) and talar body fracture (n = 1), had posttraumatic arthritis on the contralateral side. Twenty-seven patients underwent one or more re-interventions. In 15 patients, the implant was removed. Reasons for removal were pain/functional limitations (n = 13), deep infection (n = 1) and AVN (n = 1). Twelve patients underwent secondary arthrodesis (ankle n = 4, subtalar n = 4, pan n = 4) due to posttraumatic osteoarthritis (n = 5), AVN (n = 3), or posttraumatic osteoarthritis combined with AVN (n = 4). One patient underwent ankle arthroplasty elsewhere. All complications and re-interventions are shown in Table 4. Fig. 2 shows the complications in dislocated and non-dislocated talus fracture groups.

Predictors of outcome

Table S2 and Table S3 (Supplementary Appendix) presents the univariate analysis, in which variables with $p < 0.1$ can be interpreted as possible predictors for the outcomes. Multivariate analysis is provided in Table S4 in the Supplementary Appendix.

Other outcomes

A significant association between the development of avascular necrosis and Hawkins classification was demonstrated ($p = 0.003$). There were more implant removals in patients with delayed surgery compared to patients with early surgery (10/68 vs 5/22, p = 0 .380). Furthermore, avascular necrosis (15/68 vs 3/22, p = 0.391) and posttraumatic osteoarthritis were more common in the delayed surgery group (22/68 vs 4/22, p = 0.202). Secondary arthrodesis was equally common in both groups (9/68 vs 3/22, p = 0.962). Of the aforementioned no differences reached significance.

DISCUSSION

Primary outcome measures

We could not find any studies using the LEFS measurement in surgically treated talar neck and/or body fractures to compare our results to with. In their study of talar fractures Vints et al. reported a mean total FFI of 29.4, a mean FFI pain score of 30.2, and a mean FFI disability score of 28.7.[8] In our study, the mean total FFI score was 21.7, the mean FFI pain score was 24.0, the mean FFI disability score was 24.5, and the mean FFI activity score was 14.4. The lower FFI scores found in our study, indicating a better outcome, may be due to the fact that the complication rate in our study was less compared to Vints et al. (42.2% vs 56.5%).[8]

The ceiling effect was seen in less than 10% and the floor effect was even lower. These are acceptable scores and comparable for a different study that investigated AOFAS score in calcaneal fractures.[16]

Secondary outcome measures

Although our study did not find a significant difference, the outcome scores did appear to be better in the talar body fracture group compared to the talar neck. These results are consistent with Fournier et al..[6] The mean AOFAS outcome was relatively high in our study (75.9), compared to the study of von Winning et al. and Sousa et al. who reported a score of 71.4 and 72.0 respectively in a small number of surgically treated talar neck and/or body fractures.[17,18]

There are different types of classification systems for talar neck and body fractures.[19] Talar fractures often occur from high velocity trauma, with a fracture pattern involving both the neck and body. Severe communication and dislocation is often seen making correct classification challenging.[4] In our study there was no significant association between type of fracture and the reported outcomes. Ultimately, the trauma surgeon must tailor the treatment based on the severity of the fracture on the CT scans, additional injuries and condition of the patient. To improve functional outcomes, patients were referred to the physiotherapist or underwent re-intervention.

Posttraumatic arthritis is the most common reported complication of talar neck and body fractures in literature with a wide range from 42 to 100%,[7,18,20] which was lower in our study

(26/90). Posttraumatic osteoarthritis was numerically more common in the delayed surgery group as compared to early surgery group (22/68 vs 4/22, p = 0.202).

The second most common complication was AVN (18/90), which is comparable with the current literature that reported a rate between 8% to 50%.[7,18,20] According to the current literature,[4,21] one would expect AVN to be more common in neck fractures, which was also found in our study (Table 4).

Table 4 Complications and re-intervention[a]. n = 90

Postoperative complications, n (%)	
Wound dehiscence	1 (1.1)
Surgical Site Infection	9 (10.0)
Superficial	2 (2.2)
Deep	7 (7.8)
Nonunion	0 (0.0)
Malunion	1 (1.1)
Avascular necrosis	18 (20.0)
Neck	11 (61.1)
Body	7 (38.9)
Post-traumatic osteoarthritis	26 (28.9)
Ankle osteoarthritis	16 (17.8)
Subtalar osteoarthritis	7 (7.8)
Ankle & subtalar osteoarthritis	3 (3.3)
***Re*-interventions**	
Implant removal	15 (16.7)
Secondary arthrodesis	12 (13.3)
Ankle arthrodesis	4 (4.4)
Subtalar arthrodesis	4 (4.4)
Pan arthrodesis	4 (4.4)
Ankle prosthesis	1 (1.1)
Other surgery (joint debridement/osteophyte removal)	4 (4.4)
Time between definitive surgery and reintervention, months[+]	18.9 (2–62)

[a] Data are presented as number with valid percentage.
[+] Time between definitive treatment and reintervention treatment, presented as mean with range.

Surgical site infection after surgical treated talar fracture has been reported between 1% to 8%.[8,21,22,23] In our study 9 patients had surgical site infection, of which 2 patients with a superficial infection, 7 patients with a deep infection, and 1 patient with a wound dehiscence. These results are fairly consistent with the results of the small studies reported in literature.[21] According to the literature, open fractures are associated with a high infection rate, which was also found in our study (n = 4, p = 0.002).[24]

In recent studies, the rate of malunion in surgically treated talar neck and body fractures varies between 0% to 59%.[11,22,25] In our study, only one patient suffered a malunion. Vallier et al. showed nonunion in 2 patients.[21] There were no such cases in the patients we studied.

Predictors of functional outcome

In the overall delayed surgery group, 9 patients with dislocated talus developed posttraumatic arthritis, and 11 patients AVN. Patients in the delayed surgery group with late reduction of the talus had 1.3 times higher risk of AVN, and 1.1 times higher risk of posttraumatic arthritis, compared to the same patient group with rapid reduction of the dislocated talus (Fig. 3). Patients with talus dislocation are usually treated urgently to reduce the risk of AVN.[20] However, in recent literature there is no clear relationship between timing of fixation and the development of AVN.[4] This increased risk of posttraumatic arthritis and AVN may be due to the severity and mechanism of the injury in which the vascular network has been disrupted.[3] The authors therefore advice early reduction to reduce the risk of AVN and posttraumatic arthritis.

In our study AVN was numerically more common in the delayed surgery group as compared to early surgery group, but not significant (15/68 vs 3/22, p = 0.391). This is consistent with the study of Buckwalter et al. (2017), about the timing of surgical reduction and stabilization of talus fracture-dislocations, examining 106 surgically managed talus fractures (process n = 5, neck n = 76, body n = 25).[26] In both studies, time of surgery was not significant for development of AVN.

Also, after multivariate analysis we did not find a statistically significant association between delayed surgery and postoperative complications, provided that any dislocations are treated as a fracture care emergency. Although, in our study delayed surgery was defined as surgery more than 7 days after day of trauma, in other studies delayed surgery is not always defined in the same way. For example, Vints et al. defined early surgery as time from trauma to surgery as less than 24 h, and delayed surgery as more than 24 h.[8] Historical recommendations for emergent surgical management remains controversial. Our report does not call for early open reduction and internal fixation. The severity of the fracture and adequate fracture re-alignment might be the main risk factor for postoperative complications and functional outcome.

In particular, implant removal and secondary arthrodesis were associated with reduced AOFAS outcome, and implant removal and dislocation for a less favorable LEFS outcome. Incidence of implant removal was numerically higher in the delayed surgery group. Likely, the patients with a re-intervention chose this option following informed consent due to a lower functional outcome, in the hope that this would improve. Unfortunately we did not obtain pre and post-secondary intervention outcome scores to prove this hypothesis. Furthermore, little is known about the influence of re-intervention on functional outcome. Therefore, careful consideration must be made before re-intervention, especially before implant removal, is decided upon.

Strengths

Our study has several strengths. First of all, we were able to perform our analysis with the use of four validated questionnaires to determine the functional outcome and quality of life in a large study population, with in total 90 patients with surgical treated talar neck and/or body fracture. Secondly, we were able to use our four validated measurements in a study population with a mean clinical follow-up time of 50.5 (IQR, 18.3–97.3) months. Thirdly, we had a high response rate of 73 out of 90 patients.

Limitations

However, there are some aspects in our study that should be taken into consideration. At first, our study is a retrospective cohort study, so no causal relationship can be established. Secondly, most patients suffered from concomitant (ipsi)lateral fractures, which made it hard to determine the impact of solely the talus fracture on the functional outcome and quality of life. Moreover, although the number of patients in this study was greater than in previous studies on talar fractures, it unfortunately remained too small for adequate statistical analyses. This study therefore focusses mostly on identifying possible predictors and discusses the meaning and rational behind them. Furthermore, CT and MRI were not performed in all cases to identify postoperative radiological complications. In addition a selection bias is introduced since our institution is a tertiary referral center for complex foot/ankle injury. Lastly, we did not obtain additional outcome scores after reintervention and as such have no data to present.

CONCLUSION

In conclusion, surgically treated talar neck and body fractures can cause debilitating postoperative complications. After reintervention, less favorable functional outcomes, which influences the quality of life, were observed. Patients who underwent either type of revision surgery did not have outcomes that were as good as patients who did not have revision surgery, which is of value in discussing prognosis with patients. Furthermore, due to the rare incidence, difficult diagnosis, and patient tailored treatment, it might be advantageous to centralize the treatment of talus fractures and treat them exclusively in centers with experienced surgeons. Future studies should focus on how to reduce the rate of complications and the effect of secondary intervention with the use of validated questionnaires.

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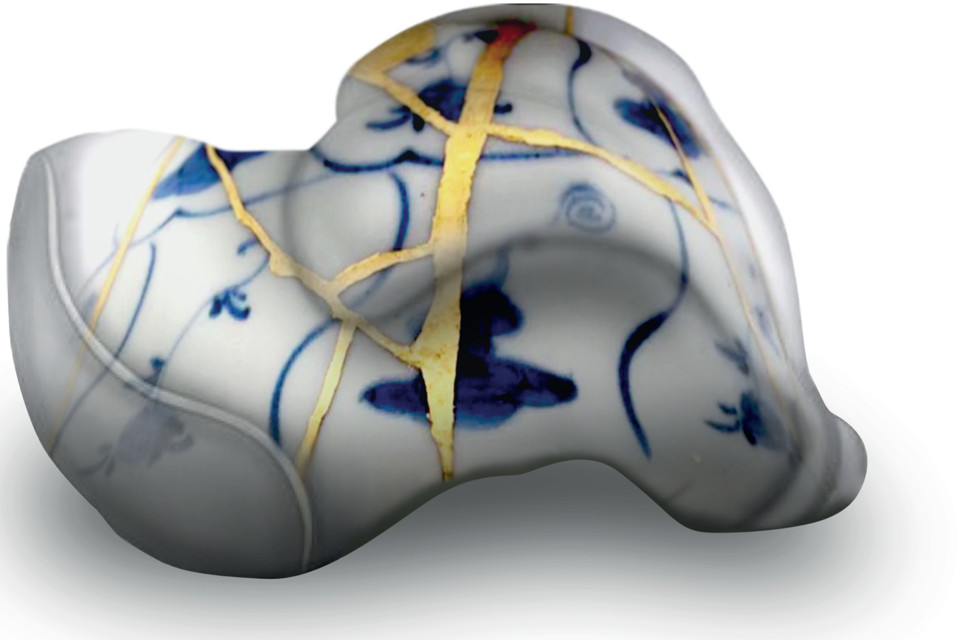

4

The role of external fixation in the management of infected avascular necrosis after traumatic talus fractures

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ABSTRACT

Purpose: Avascular necrosis (AVN) after fractures of the talus is a distinct and challenging clinical entity that is associated with poor outcomes. Although several articles are published on the management of posttraumatic AVN of the talus, very little is known about the management of infected AVN after talus fractures. Therefore, three cases of infected AVN were treated successfully by extensive debridement, external fixation and arthrodesis.

Methods: Three cases of infected AVN of the talus were encountered after a mean of 3 months (range 2–6 months) after initial reconstructive surgery. Suspected infection was confirmed by positron emission tomography scan (PET-CT). Management involved extensive debridement, PMMA cement if necessary and final fusion using medial external fixator, accompanied by culture guided antibiotics. Functional outcome was assessed using the Foot Function Index (FFI) and the American Orthopaedic Foot and Ankle Society hindfoot score (AOFAS). Quality of life (QOL) was measured by the EuroQol-5D (EQ-5D).

Results: After a mean follow up of 24 months (range 13–29), FFI index scores ranged from poor to good (23, 50, 56) with similar AOFAS scores indicating poor to fair functional outcome (38, 41, 71). The EQ-5D score was 0.78. Overall patient satisfaction was high with a mean VAS of 8.3 (range 8–9).

Conclusion: Infected talar AVN is a rare condition associated with severe long-term morbidity in term of joint function. The authors recommend extensive debridement and arthrodesis by means of external fixation, followed by post-operative culture-guided antibiotics for the treatment of infected avascular necrosis of traumatic talar fractures. Shared decision-making and expectation management are of crucial importance and may lead to high patient satisfaction despite low functional outcomes.

Level of evidence: IV, Retrospective case series.

Keywords: Avascular necrosis Osteonecrosis Infection Talus External fixator Blair osteotomy

1. INTRODUCTION

Avascular necrosis (AVN) of the talus is a major surgical challenge. Since the talus has no muscular attachments and is surrounded by ligaments and other bones, the soft tissue envelope is susceptible to open injuries, skin necrosis and wound complications after dislocation.[1,2] The bone is hidden by its anatomical site and has a complex arterial supply coming from three main channels: the posterior tibial artery via calcaneal branches and both the medial and lateral plantar branches through the sinus tarsi artery.[3–5] The posterior medial and inferior parts of the talus are nourished by these arteries. The superior talus and talar neck are supplied by the medial malleolar artery, originating from the dorsalis pedis. However, this threefold arterial source does not protect the talus from the development of avascular necrosis after injury because the majority of the talar surface is covered by cartilage.[5,6] Talar AVN occurs mostly after talar neck fractures and the median incidence reported in literature is 34.5%.[7–9] Rates increase up to 100% in Hawkins type III and IV fractures.[10,11] Although the incidence of AVN is positively related to the injury severity, it may occur even after early anatomic reduction.[5,7,12] Other risk factors include pre-existent inflammatory arthropathy, steroid use, smoking and alcoholism.[13]

AVN can lead to collapse of the talar dome, consequent degeneration, subtalar arthritis and disability of the ankle and subtalar joints.[6,14] This is associated with pain and decreased function. The primary management of AVN is non-weight bearing and analgesia.[13,15] If this fails, surgical joint-sparing modalities such as core decompression and bone grafting in Ficat Stage I and II AVN has been reported to decrease pain as well as progression of talar AVN.[2,15,16] The next steps are joint sacrificing procedures such as partial or total talar replacement, salvage procedures including joint arthrodesis and total ankle replacement and sacrificing the limb by amputation as the final resort.[2,13]. A severe complication in the course of post-traumatic talus AVN is infection, particularly osteomyelitis and infection of implants. Infected AVN is a debilitating disease that may result in poor outcome and even amputation.

Although there are many articles on the management of posttraumatic AVN of the talus, there is very little discussion of cases of infected AVN after talus fractures in literature.[1,17,18] The management thereof is largely based on evidence of infected AVN in ankle injuries and on local expertise. This report describes the clinical course, management and outcomes of three cases of infected AVN of talus fractures treated in a level-1 trauma center.

2. METHODS

Three cases of infected AVN were treated between January 1st, 2012 and March 31st, 2019. Institutional review board approval and informed consent were obtained. Patient-related, clinical and radiographic data were extracted from the electronic hospital database and PACS (picture archiving and communication system). Functional outcome was assessed using the Foot Function Index (FFI, total 230 points, index range 0 to 100, higher scores indicating greater impairment),[19] and the American Orthopaedic Foot and Ankle Society hindfoot score (AOFAS, best score 100 points). The AOFAS score was divided into groups according to the literature: a score of 90–100 was graded as an excellent result; 75–89 as good; 50–74 as fair, and less than 49 points was graded as a failure or poor outcome. Quality of life (QOL) was measured by the EuroQol-5D (EQ-5D). This included assessment of perceived general health on a Visual Analogue Scale (VAS) of 0–100, in which 100 represented excellent general health (EQ-VAS). Patient satisfaction was also measured using the VAS of 0–10, in which 10 represents the best possible satisfaction.

3. RESULTS

Patient characteristics and the most important clinical details are presented in Table 1. The treatment outcomes and patient satisfaction are demonstrated in Table 2.

Common characteristics among the three included cases included: motorbike accidents (2 out of 3), severely comminuted talar fractures of which 2 out of 3 were open fractures (both Gustilo Anderson grade three). All patients sustained other fractures and injuries, including

Table 1. Patient demographics and clinical information.

Case	Gender	Age (years)	Type	Diagnosis	Procedures	Time (months)	Cultures[a]	FU (months)
1	Male	26	Neck, corpus	PET-CT	9	7	*E. Cloacae* *E. Casseliflavus*	29
2	Female	61	Head, neck	PET-CT	5	6	*St. Aureus*	29
3	Male	38	Neck, corpus	PET-CT	5	4	*E. Faecalis*	13

Number of surgical procedures, time from injury to fusion, FU=follow-up.
[a] *Enterobacter cloacae, Enterococcus casseliflavus, Enterococcus faecalis:* gastrointestinal tract commensals. *Staphylococcus aureus:* skin flora.

Table 2. Validated outcomes, quality of life and patient satisfaction.

Case	FFI	AOFAS	EQ-5D	EQ-VAS	Satisfaction
1	50	44	0,78	80	9
2	23	71	0,78	80	8
3	56	38	0,78	50	8

FFI range 0–100 (highest score means greatest impairment), AOFAS 0–100 (highest score means best functional outcome), EQ-5D 0–1 (1 is perfect), EQVAS 0–100 (100 is perfect), satisfaction 0–10 (10 is greatest satisfaction).

transverse process and spinal body fracture, rib fractures, intra-articular distal radius and ulna fractures (case 1); calcaneal fracture, distal tibia and fibula fractures (case 2) and Weber C ankle injury (case 3). In all cases, AVN was found after reconstructive surgery and suspected infection was confirmed by findings on positron emission tomography (PET-CT). Signs of AVN on conventional imaging included sclerotic bone formation, joint space narrowing in combination with talar dislocation. CT showed an increase of diastasis of talar bone fragments and narrowing of the talocrural joint space with bone-to-bone contact between tibia and talus, possibly suggestive for AVN. PET-CT showed increased metabolic activity at the implants, infected AVN of the talus with local bone destruction of the anterolateral distal tibia, increased uptake at the screws and destruction of the talocrural joint, interpreted as osteomyelitis and arthritis in the talocrural joint. In case 3, when the patient returned with pain and instability without radiographic abnormalities, PET-CT showed an avital talus with increased sclerosis, further fragmentation and no progression of fracture consolidation, indicative of AVN and consequent increased nonunion. Management always involved extensive debridement, PMMA cement if necessary and final fusion using medial external fixator. In all three cases, significant bone less was present following debridement. To prevent further loss of height the talar neck and head including the talonavicular joint were preserved and a Blair arthrodesis was performed. To illustrate the key stages of operative management, intra-operative photos and imaging of case 1 are presented in Figs. 1–4,.

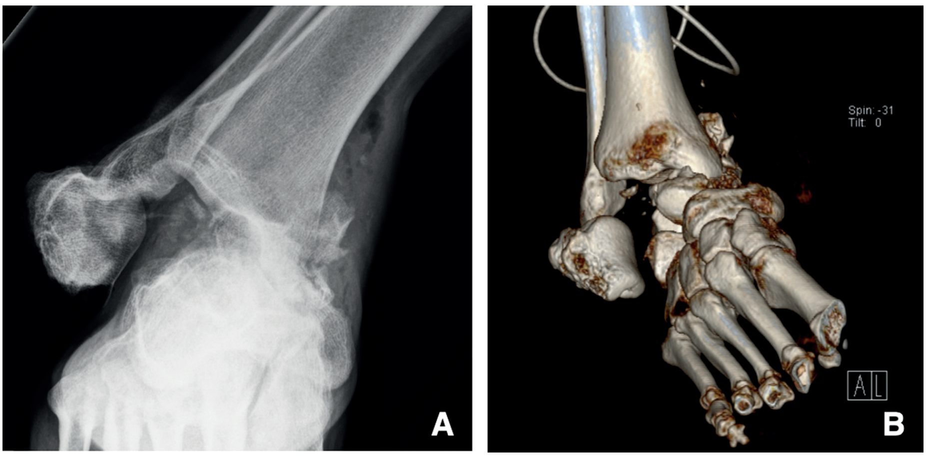

Fig. 1. Radiograph (A) and 3D CT reconstruction image (B) of a right open talus luxation fracture in a 26-year-old male motor bike driver.

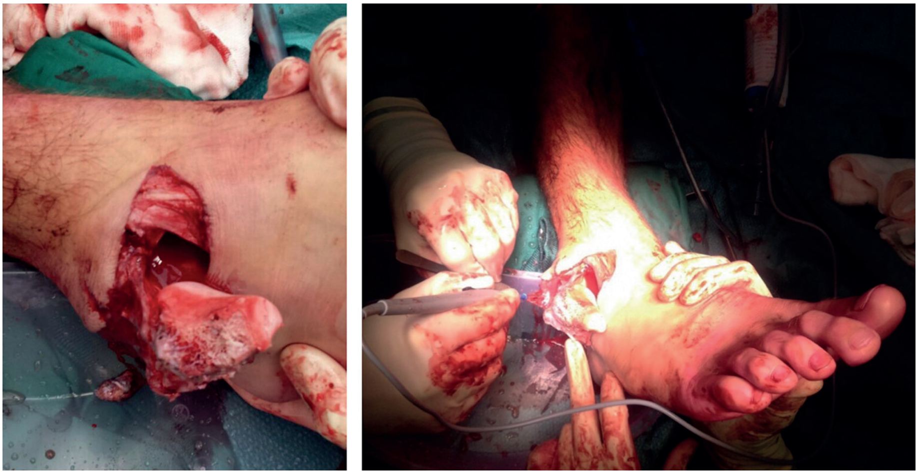

Fig. 2. Talar extrusion as observed during first procedure. Open reduction, removal of corpora libera, wound debridement and application of external fixator.

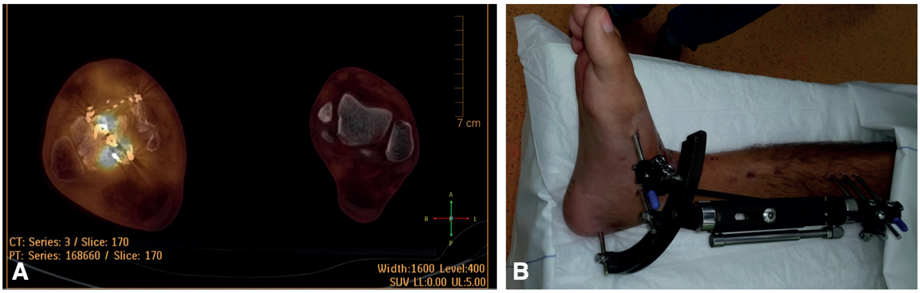

Fig. 3. (A) FDG-PET/CT showing infected implants and signs of septic avascular osteonecrosis of the talus, SUV max 6.5. (B) Postoperative photo after procedure 8: placement of monobody Orthofix® external fixator with three Schanze pins (calcaneus, navicular, first metatarsal, tibia).

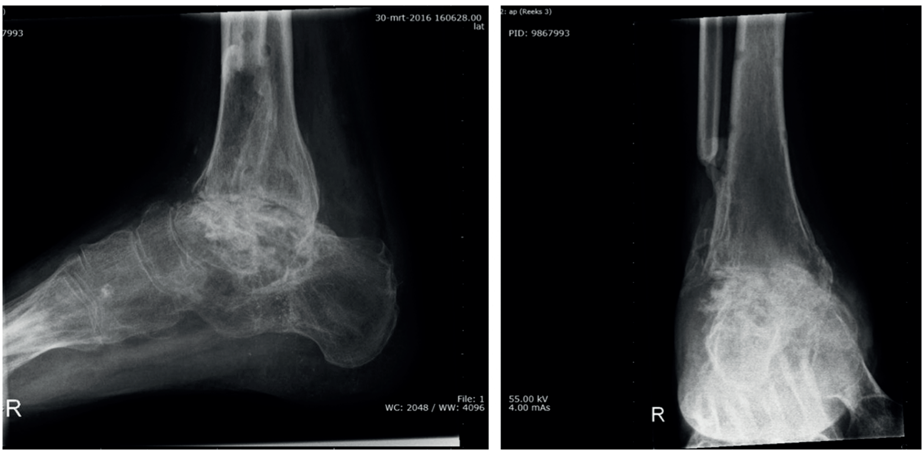

Fig. 4. Radiographs 6 weeks after final removal of the external fixator.

During surgery, deep tissue samples and bone specimens were obtained and sent for microbiological analysis, conforming deep tissue infection (Table 1). Post-operative antibiotics used were chosen according to the antibiogram and given for approximately 8–12 weeks.

4. DISCUSSION

4.1. Key message

Infected avascular osteonecrosis of the talus is a distinct clinical entity that should be managed on a case to case basis. In case of suspected infection, cultures should be obtained intra-operatively. While MRI is advocated in literature for the diagnosis and degree of osteonecrosis, PET-CT was the preferred imaging modality to confirm the clinical suspicion of infected AVN.[12] Recently, analysis of the efficacy of FDG-PET-CT to differentiate between aseptic and septic delayed union in lower extremity was found to be promising with a diagnostic accuracy of 70%.[20] In contrast to aseptic talar AVN, the recommended surgical approach of infected talar AVN is a combination of staged debridement with arthrodesis at a level depending on the anatomical site of injury, combined with culture-guided antibiotics. The early use of external fixators was found to be successful in our series.

4.2. Management

Even though isolated AVN following talar fracture is well managed with an arthrodesis using internal fixation, this strategy is presumed to fail in case of severe bone loss and infection.[1,16] It has been suggested in literature that primary subtalar arthrodesis in the setting of AVN could partially restore the talar vascularization due to calcaneal bone ingrowth.[14] The first step is adequate debridement of non-vital talus, antibiotic therapy based on deep tissue and bone samples, and removal of implants when involved. Next, talocrural arthrodesis could be performed with use of an external fixator. A monobody Orthofix® external fixator was applied on the medial tibia and VAC systems for the wounds with weekly changes until closure. Alternatively, debridement of the talocrural joint, use of a cement spacer and application of the external fixator may be the first step, followed by removal of the spacer, Blair osteotomy and arthrodesis depending on the amount of talar dome bone loss. Bone consolidation was monitored with radiographs and CT scan. When there were evident radiological signs of fusion, the external fixator was removed and patients were allowed to put weight on the talus in a removable cast for an additional 6 weeks.

Blair fusion was introduced in 1943 to deal with complications of extreme trauma to the talus.[21] It involves a sliding rectangular graft from the anterior distal tibia to fuse the talar head, resulting in a (close to) normal foot appearance and alignment, no limb shortening, weight bearing and ankle flexion and extension to some extent. The successful use of external fixation in patients with insufficient viable bone was reported in literature on complex ankle injuries.[22,23] In the setting of talar osteonecrosis and infection, Liener et al. managed 16 cases with tibiocalcaneal arthrodesis by use of external fixation, of which 7 later had amputations.[17] Almost 40 additional procedures were required to treat the infection, which indicates the difficulty and time involved in the management of talar AVN like we experienced. The risk of leg length discrepancy was decreased by callous distraction in rigid ring fixation.[17] Rochman et al. achieved tibiocalcaneal arthrodesis using the Ilizarov technique in 11 patients of which 7 suffered osteomyelitis or infected nonunion after talus fractures.[1] After debridement and preparation of bony surfaces, application of the circular ring external fixator (mean duration 7 months) and secondary lengthening led to successful fusion in 9 out of 11 patients with a mean AOFAS score of 65 out of 86.[1] Alternatively, Almasi et al. performed two-stage salvage tibiocalcaneal arthrodesis for infected osteonecrosis after total talus extrusion in a young female.[18] Total talectomy and implantation of antibiotic spacer was followed by tibiocalcaneal fusion, which was radiologically achieved after 8 months. Bone loss was compensated by autodigested and chemosterilized, antigen-extracted allogeneic bone. From another perspective. Whittle et al. advocated a preventive measure of primary talectomy in Gustilo Grade IIB open talar injuries to prevent infection.[24]

4.3. Antibiotics

Surgical debridement is the corner stone of management of osteomyelitis and infected talar AVN. Remarkably, only a small number of deep tissue and bone samples showed bacterial growth (3/18), possibly due to the start of antibiotics prior to sampling. Nevertheless, we recommend antibiotic treatment with type and duration according to the microbiological guidelines and antibiogram, usually for extended periods up to twelve weeks. The ideal timing of the start of antibiotic treatment is thus after the results of cultures are available.

4.4. Outcomes

The maximum AOFAS score after successful tibiocalcaneal fusion is 86, due to elimination of tibiotalar and subtalar motion. Our cases reported poor (n = 2, 44 and 38) to fair (n = 1, 71) AOFAS outcomes. FFI score index ranged from poor to good, which is similar to the AOFAS outcomes. It is important for both surgeon and patient to realize that even healing of osteonecrosis without infection may take two years.[12] Healing and rehabilitation of patients with AVN complicated by infection is thought to take much longer.[1] This puts a severe physical and emotional burden on the patient and there are reports of patients who, for this reason, opted for amputation.[17] In our study, all patients were ambulant, and one patient did surprisingly well despite the avascular talus. This has also been reported in previous studies on AVN.[12] The other two complained of persistent pain in ankle motion, stiffness and claw toes, which is in the line of expectation after complex AVN. These symptoms may be alleviated by long-term physiotherapy and exercise. Due to regular follow-up and good expectation management, the mean VAS on overall patient satisfaction was 8.3 despite the poor functional outcome scores.

4.5. Limitations

Although this is the first case series describing the management and outcomes of infected osteonecrosis of the talus, the findings may not necessarily apply to other patients.

5. RECOMMENDATIONS

Infected talar AVN is a rare condition associated with severe longterm morbidity in term of joint function. The presence of infection and bone loss imposes a great surgical challenge and the outcome of reconstructive surgery is unpredictable. In common with findings of other authors, the use of external fixation and arthrodesis is recommended for the treatment of infected avascular necrosis of talar fractures. In any case, it takes time, patience and experienced surgical hands to avoid chronic pain and to achieve a functional limb. Shared decision-making and expectation management are therefore of crucial importance.

Brief summary

What Is Already Known?

1. Talar AVN occurs mostly after talar neck fractures and the median incidence reported in literature is 34.5%, with rates up to 100% in Hawkins type III and IV fractures.
2. AVN is a debilitating disease that may result in poor functional
3. PET-CT is the preferred imaging modality to confirm the clinical suspicion of infected AVN.

What This Study Adds?

1. Management of infected talar AVN is a combination of staged debridement with arthrodesis and use of an external fixator, combined with culture-guided antibiotics for 8–12 weeks.
2. Peri-operative obtained deep tissue sampling may remain negative on microbiological investigation due to the start of antibiotics prior to sampling, indicating a need for a high index of suspicion.
3. Regular follow up in combination with continuous expectation management can result in good patient satisfaction despite poor functional outcomes.

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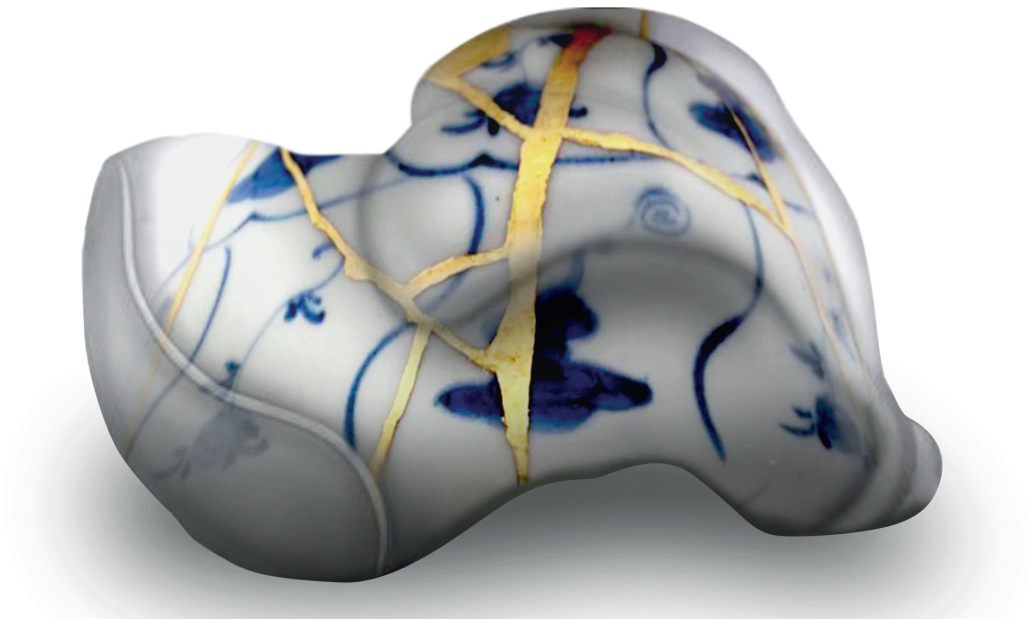
Part 2

Peripheral talar fractures

Talar Head



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Management and outcome of hindfoot trauma with concomitant talar head injury

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ABSTRACT

Background: Talar head fractures account for 2.6% to 10% of all talar fractures and are often associated with concomitant musculoskeletal injuries. The current literature only describes a total of 14 patients with talar head fractures and, with that, guidelines for management are lacking. The aim of the current study was to evaluate the management and long-term outcome of patients who have hindfoot trauma with concomitant talar head fractures.

Methods: This study includes a retrospective cohort of patients with talar head fractures. Patient characteristics, trauma mechanism, fracture characteristics, treatment, follow-up, and complications were reported. Functional outcome was assessed using the Foot Function Index (FFI) and the American Orthopaedic Foot & Ankle Society (AOFAS) hindfoot score. Quality of life was measured by the EuroQol-5D (EQ-5D). Twenty-one patients with acute fractures of the talar head were identified. The mean follow-up time was 4.9 years.

Results: All patients sustained additional ipsilateral foot and/or ankle injuries. Fifteen patients had operative management of their talar head fracture. There were no postoperative wound infections and no cases of avascular necrosis. All fractures united, and 29% of patients developed posttraumatic osteoarthritis. The overall mean FFI score index was 34.2, and the mean AOFAS score was 70.7. The mean EQ-5D index score was 0.74.

Conclusion: Talar head fractures always coincided with other (foot) fractures. Management and long-term functional outcome were affected by the extent of associated injuries. Due to the low incidence and high complexity of talar head fractures, early referral to dedicated foot surgeons and centralization of complex foot surgery is recommended.

Level of Evidence: Level IV, retrospective case series.

Keywords: talus, talonavicular, Chopart, foot fractures, trauma

INTRODUCTION

Talar fractures account for less than 1% of all fractures. Even more uncommon are fractures of the talar head, representing just 2.6% to 10% of all talar fractures.[5,10] This rare type of talar fracture was first described by Coltart[4] in 1952. Since its identification and description, only 14 cases of talar head fractures have been described in the literature (Table 1). Of those 14, only 5 cases were described as being isolated injuries to the talar head.[2,9] With this small sample size, demographics and treatment recommendations are lacking.

Trauma to the second largest tarsal bone is associated with challenging injury patterns. This may be largely due to the fact that the majority of the talus is covered with articular cartilage.[12,13] Fractures of the talus usually occur due to high-energy injuries and are often seen with concomitant musculoskeletal injuries.[6] The talus has a unique anatomy consisting of a body, neck, and head. The head is convex and articulates with the navicular anteriorly and calcaneus inferiorly, constituting the talonavicular and anterior subtalar joints.[1,20,21] Its vascular supply is mainly extraosseous, and there is a lack of tendon and muscle attachments.[12,13] Fractures of the talar head are often associated with peritalar fractures or dislocation.[4,5,7,9,10] The talar head is part of the medial column of the foot along with the navicular, cuneiforms, and first through third metatarsals. The stability of the medial column is crucial for maintenance of the longitudinal foot arch. Acute talar head fractures may involve the talonavicular junction of the Chopart joint that, along with the subtalar and calcaneocuboid joints, controls hindfoot motion.[2] Fractures of the talar head, particularly when nondisplaced, are difficult to diagnose and frequently missed on radiographs.[7,11,14]

Given that the talus plays a crucial part in midfoot stability, timely recognition and adequate management of talar head fractures are important for long-term functional outcome of the foot. Positive prognostic factors include early anatomical reduction and articular surface congruency.[9] Joint misalignment may lead to subtalar or talonavicular posttraumatic arthritis, resulting in instability and chronic pain, causing limitations in daily life.

The aim of the current study was to evaluate the management and long-term outcome of patients who had hindfoot trauma with concomitant talar head fractures treated in a level 1 trauma center.

Table 1. Previous Publications on Acute Talar Head Fractures.

Author	Year	n	Mean age, y	Mechanism	Injury pattern	Treatment	Functional outcome	Complications	FU, mo
Mulligan[14]	1986	1	27	Gymnastics	Head and neck[a] Nondisplaced	Nonoperative	No pain 100% ROM	—	21
Pehlivan[15]	2002	1	22	Walking (inversion)	Medial subtalar dislocation	Nonoperative	Mild pain 75% ROM	—	26
Vlahovich et al[22]	2005	1	33	Snowboarding	Subtalar impaction Nondisplaced	ORIF (screws)	Pain + swelling in prolonged activity	—	3
Matsumura et al[11]	2008	1	26	Wakeboarding	Impaction, displaced medial head and navicular[a]	Osteotomy, bone graft, screw fixation	No pain 100% ROM	—	12
Ibrahim et al[7]	2015	1	31	Stuck in mud (inversion)	Impaction Locked TNJ[a] dislocation	ORIF (TNJ bridge plate)	No pain 100% ROM	—	3
Kitamura et al[9]	2019	1	`30	Baseball	Isolated Impaction, displacement STJ	ORIF (screws)	No pain 100% ROM	—	65
Anderson[2]	2018	8	31	MVA (6) Height (1) Wakeboarding (1)	Isolated (4) Dislocation[a] (2)	ORIF (7, lag screws), Fragment excision (1)	PROMIS PF mean 42.95; PI 54.57; D 50.84, VAS 2.1/10	—	145

Abbreviations: D, depression score; FROM, full range of motion; FU, follow-up; MVA, motor vehicle accident; ORIF, open reduction internal fixation; PF, physical function; PI, Pain Interference score; PROMIS, Patient-Reported Outcomes Measurement Information System; ROM, range of motion; STJ, subtalar joint; TNJ, talonavicular joint; VAS, visual analog scale; —, no complications.
[a]Fracture.

METHODS

Design and Patients

A retrospective cohort of all trauma patients with talar head fractures who were treated at our level 1 trauma center between January 1, 2001, and July 1, 2019, was analyzed. Institutional review board approval and informed consent were obtained. Talar head fractures were defined as fractures of the talus involving the articular surface at the talonavicular articulation. Patients younger than 18 years at the day of trauma or with less than 6 months of follow-up time were excluded. Patient-related, clinical, and radiographic data were extracted from the electronic hospital database and picture archiving and communication system (PACS). All patients were evaluated at the outpatient clinic.

Variables

Variables included age at injury, sex, mechanism of trauma, and concomitant ipsi- or contralateral lower extremity injuries. Imaging was reviewed to categorize the fracture based on anatomical side, articular involvement, joint dislocation, and complexity. Data were collected on the type of treatment, follow-up, complications, and the possible need for implant removal. Complications were defined as postoperative wound infections, avascular necrosis (AVN), nonunion, chronic pain, posttraumatic arthritis, and secondary arthrodesis. Complications specific to talar head injuries were talonavicular osteoarthritis ± fusion and wound complications of the incision used to address the talar head injury. Functional outcome was assessed using the Foot Function Index (FFI; best score 0 points) and the American Orthopaedic Foot & Ankle Society (AOFAS) hindfoot score (best score 100 points). The AOFAS score was divided into groups according to the literature: a score of 90 to 100 was graded as an excellent result, 75 to 89 as good, 50 to 74 as fair, and less than 49 points was graded as a failure or poor outcome. Quality of life (QOL) was measured by the EuroQol-5D (EQ-5D). This included assessment of perceived general health on a visual analog scale (VAS) of 0 to 100, in which 100 represented excellent general health (EQ-VAS). Patient satisfaction was also measured using the VAS of 0 to 10, in which 10 represents the best possible satisfaction.

Statistical Analysis

The statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 24 (SPSS, Inc). Numeric data are expressed with means with standard deviation or median with range. Categorical data are shown as numbers with percentages. Independent sample 2-tailed *t* test with a significance level of .05 was used to compare means.

RESULTS

Demographics

Twenty-one patients with fractures of the talar head were identified. The majority were male (n = 13, 62%), with an overall average age at the day of trauma of 40.5 (range, 18-74) years. More than two-thirds of patients were referred from other hospitals (n = 15, 71%). Reasons for referral included foot and ankle expertise (n = 11), accidents occurred abroad (n = 2), and delayed referral in case of missed fractures (n = 2). The mechanisms of trauma, in descending order of frequency, were fall during daily activities (n = 8), fall from height (n = 6), motor vehicle accident (MVA, n = 5), sport (n = 1), and blunt trauma (n = 1).

Injury Pattern

Isolated talar head fractures were not encountered. Concomitant ipsilateral foot and/or ankle injuries other than the talus occurred in 71% of patients (n = 15) (Figure 1). The most common injury pattern was a fracture-dislocation (n = 13, 62%) at the talonavicular (n = 6), peritalar (n = 6), or talocrural (n = 1) joints. Half of our patients had a Chopart joint injury (n = 11).

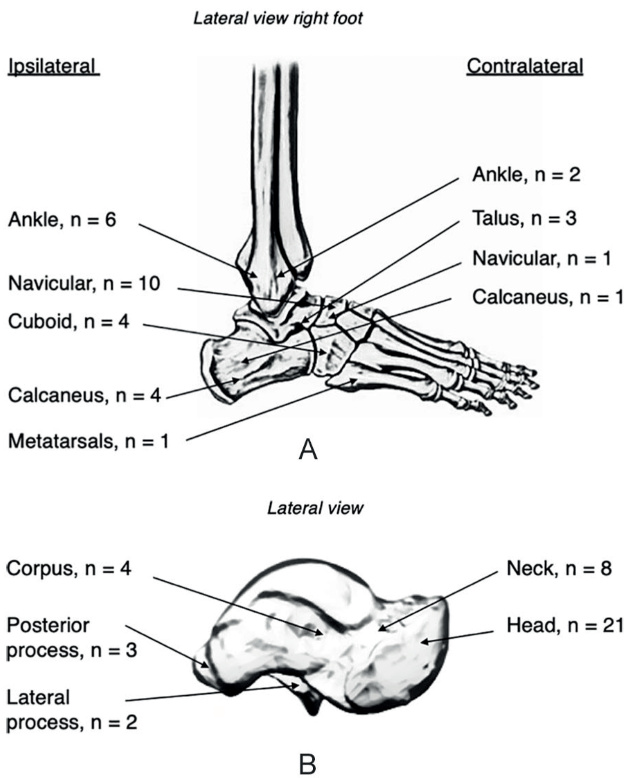

Figure 1. (A) Concomitant fractures. (B) Ipsilateral concomitant talus fractures.

Two patients had additional Lisfranc injuries. Eight patients (38%) had a talar head fracture without other talus fractures, but all of them sustained other foot fractures. Four patients (19%) sustained fractures to the contralateral foot and ankle, of which 2 patients had bilateral talar fractures after a fall from height.

All patients were diagnosed using both conventional radiography and computed tomography (CT) imaging. Four types of fractures were identified: impaction (52%, n = 11), complete transverse (19%, n = 4), medial shear (14%, n = 3), and avulsion (14%, n = 3) fractures (Figure 2).

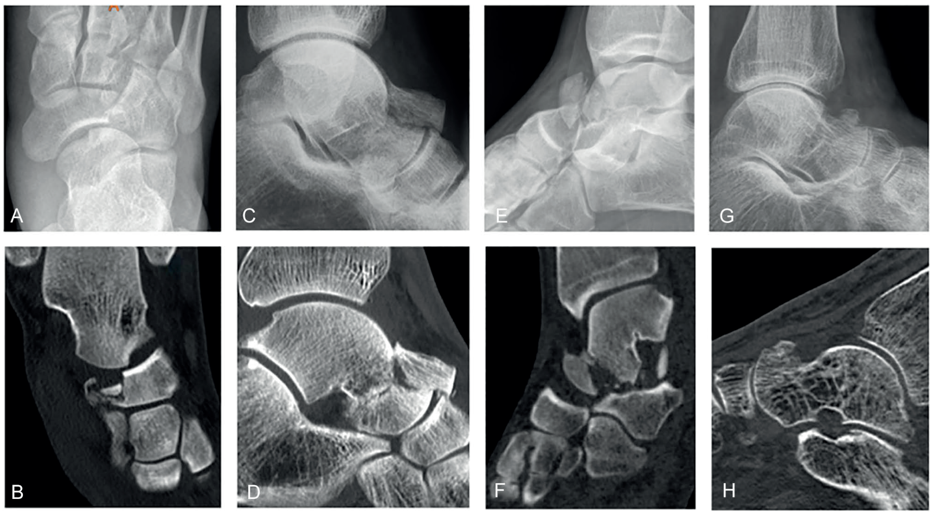

Figure 2. Four types of talar head fractures identified. Different fracture types of the talar head as shown in conventional radiographs (top row) and computed tomography scans (bottom row). (A, B) Impaction fracture of the talus head. (C, D) Complete transversal fracture of the talus head and fracture of the talus neck. (E, F) Medial shear fracture of the talus head, best seen in the sagittal plane. (G, H) Avulsion fracture of the talus head, first presented in our hospital at 4 months after trauma. Fracture was initially missed.

Management

In total, 15 of 21 patients (71%) were treated operatively, of whom 13 underwent open reduction and internal fixation (ORIF) of the talar head fracture (Figure 3). One patient underwent ORIF with simultaneous primary talonavicular arthrodesis due to a locked fracture-dislocation with a comminuted navicular fracture and talar head impaction injury. The median period between the date of trauma and definitive surgery in the other patients (n = 14) was 8 (range, 0-15) days. Two patients received an external fixator as bridge to definitive surgery (13%). A single-incision approach on the anteromedial side was used in the majority of cases (n = 10). The other cases were managed via a dual approach (anteromedial and lateral or dorsomedial). In 5 of 15 operated patients, the implants were removed due to pain and/or functional impairment. Seventy percent of patients treated operatively returned to their normal daily activities, including work (n = 7/10 patients who returned the survey).

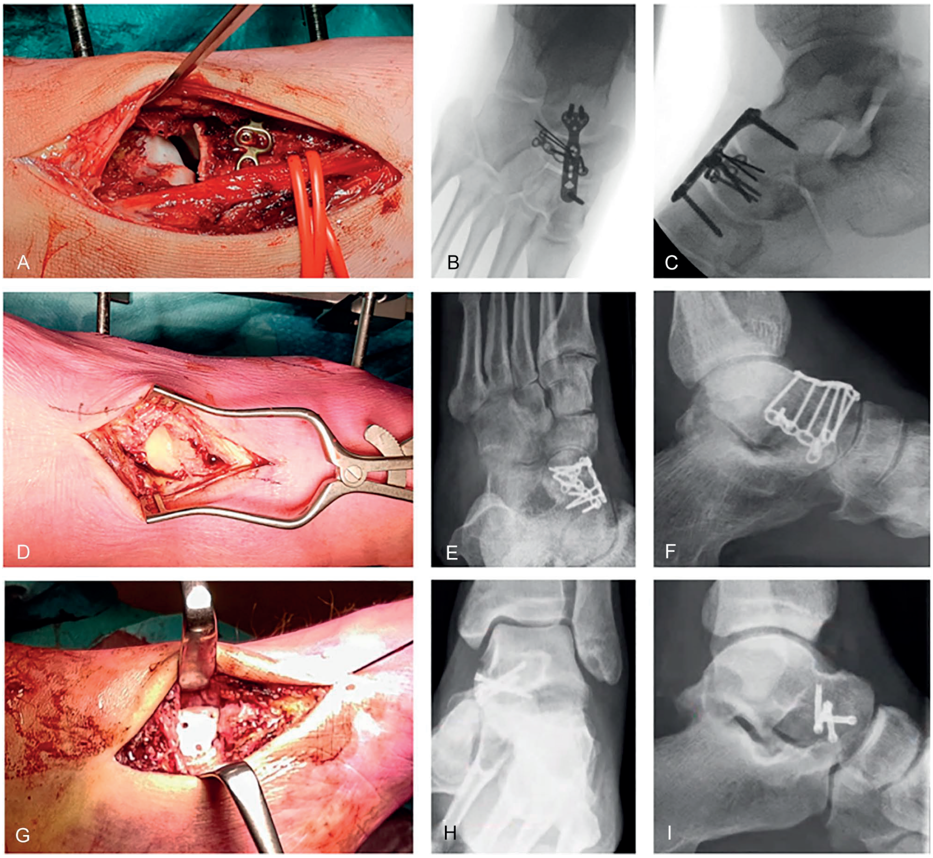

Figure 3. Examples of operative management. (A-C) Intraoperative images of an impaction fracture of the talus head with (A, B) concomitant comminuted lateral navicular fracture. Incision lateral of m. extensor hallucis longus (identified by vessel loops). Open reduction and internal fixation (ORIF) with 2.0 navicular plate and 2.7 bridge plate. (D-F) Complete transversal fracture of talus head with (C, D) associated neck fracture. Toes on the left side, dual approach via medial and anterolateral incisions. ORIF using 2 × 2.0 hand plate. (G-I) Medial shear fracture of the talar head as part of the (E, F) talonavicular fracture dislocation. ORIF using medial incision, 4× Headless Compression Screw 2.4 and K-wire due to talonavicular instability.

The remaining 6 talar head injuries were managed non-operatively (29%) due to no or minimal displacement (n = 6, including 3 avulsions). Nevertheless, all patients in our nonoperative group underwent ORIF for associated ipsilateral talus, foot, or tibia fractures. Four of them had Chopart injuries, of whom 2 had fracture dislocations. Four of 6 non-operatively managed patients who completed the survey returned to their normal daily activities (67%). The other 2 had complex bilateral (open) lower extremity fractures, including extensive soft tissue damage.

Functional Outcome and Quality of Life

One patient died during follow-up due to a nonrelated cause. Follow-up time was insufficient in 1 patient. Questionnaires were sent to the remaining 19 patients, of whom 16 responded, yielding a total follow-up rate of 84%. Two patients could not be reached, and the other patient did not want to participate. The mean follow-up time from the day of trauma was 4.9 (range, 0.9-18) years.

Treatment characteristics, functional outcome, and patient-reported outcome measures per group are demonstrated in Table 2. Differences in functional outcome and quality of life between the operative and nonoperative group were not statistically significant. Out of the 4 fracture types, the lowest mean score was found in the group with shear fractures and the highest score in the patients with avulsion fractures (Table 3). There was a clear trend toward better functional outcome and quality of life in patients without a fracture dislocation and without ipsilateral talus or other foot or ankle fractures (Table 4).

Table 2. Treatment Characteristics, Functional Outcome, and Quality-of-Life Scores.[a]

Characteristic	Total (n = 21)	Operative (n = 15)	Nonoperative (n = 6)	*P* value
Available outcome data, n	16	10	6	
Functional outcome				
FFI, mean (SD)	34.2 (25.1)	38.0 (26.0)	28.0 (24.6)	.458
AOFAS, mean (SD)	70.7 (18.6)	70.5 (19.8)	71.0 (18.2)	.961
Excellent, n	3	2	1	
Good, n	4	3	1	
Fair, n	6	3	3	
Poor, n	3	2	1	
Quality of life, mean (SD)				
EQ-5D index	0.74 (0.18)	0.75 (0.18)	0.73 (0.2)	.810
Patient satisfaction	7.6 (1.8)	8.0 (1.8)	6.8 (1.7)	.217

Abbreviations: AOFAS, American Orthopaedic Foot & Ankle Society; EQ-5D, EuroQoL-5D; FFI, Foot Function Index.
[a]P values calculated with 2-tailed independent sample *t* test.

Table 3. Trends in Functional and Patient-Reported Outcome per Talar Head Injury Type.[a]

Characteristic	FFI	AOFAS	EQ-5D	Satisfaction
Type of fracture (n)				
Impaction (8)	24.2 (0-65.7)	72.5 (48-100)	75 (50-90)	8 (5-10)
Shear (3)	63.9 (44.3-66)	43 (36-58)	50 (40-70)	8 (6-9)
Avulsion (3)	22.2 (5.2-68.2)	82 (74-100)	90 (80-96)	9 (9-9)
Transverse (2)	34.6 (11.7-57.4)	74 (71-77)	90 (90-90)	5.5 (5-6)
Fracture dislocation (n)				
Present (10)	46.5 (1.3-65.7)	64.5 (36-90)	70 (40-90)	7.5 (5-10)
Absent (6)	17.0 (0-68.2)	78 (67-100)	90 (70-96)	9 (5-9)
Ipsilateral talus fractures (n)				
Present (11)	44.3 (1.3-68.2)	71 (36-100)	80 (40-96)	9 (5-10)
Absent (5)	22.2 (0-66)	81 (43-100)	80 (50-90)	7 (5-9)
Ipsilateral other foot/ankle fractures (n)				
Present (12)	31.4 (0-65.7)	68.5 (36-100)	70 (40-90)	7.5 (5-9)
Absent (4)	31.3 (1.3-68.2)	83.5 (74-100)	90 (90-96)	9 (5-10)

Abbreviations: AOFAS, American Orthopaedic Foot & Ankle Society; EQ-5D, EuroQoL-5D; FFI, Foot Function Index.
[a]Satisfaction refers to patient satisfaction (0 to 10). Data presented as median with range.

Table 4. Overview of Included Patients Who Have Hindfoot Trauma With Concomitant Talar Head Injury.

Patient No.	Other ipsilateral lower extremity fractures	Type of talar head injury	AOFAS	FFI
1	Navicular	Impaction	100—excellent	0.0
2	Talus neck	Avulsion	100—excellent	5.2
3	Talonavicular luxation fracture, navicular	Impaction	90—excellent	1.3
4	Navicular, calcaneus	Avulsion	82—good	22.2
5	Navicular, cuboid	Impaction	81—good	21.3
6	Talus lateral process, talar luxation fracture	Transverse	77—good	57.4
7	Talus neck, posterior process talus, calcaneus, distal fibula and cuboid, Chopart luxation fracture	Impaction	75—good	48.7
8	Talus neck	Avulsion	74—fair	68.2
9	Distal tibia fracture, proximal fibula fracture, talus neck, navicular, calcaneus	Transverse	71—fair	11.7
10	Navicular, talus body, posterior talus, talonavicular luxation fracture	Impaction	70—fair	9.1
11	Navicular	Impaction	67—fair	27.0
12	Navicular, talus posterior process, talonavicular luxation fracture	Impaction	59—fair	35.7
13	Ankle luxation fracture, talus body, navicular, cuboid	Shear	58—fair	63.9
14	Lateral process talus, talus neck, open ankle luxation fracture	Impaction	48—poor	65.7
15	Distal fibula, talar/ankle luxation fracture	Shear	43—poor	66.0
16	Navicular, talonavicular luxation fracture	Shear	36—poor	44.3

Abbreviations: AOFAS, American Orthopaedic Foot & Ankle Society; FFI, Foot Function Index

Complications

No postoperative wound infections and no cases of avascular necrosis were observed. All fractures united, and 4 patients developed posttraumatic osteoarthritis (25%) at the talonavicular (TN, n = 3) and posterior talocalcaneal joint (PTC, n = 1). In total, 7 patients reported chronic foot pain (44%), including 4 patients in the operative group (including the patient with corrective osteotomy at 4 months after trauma) and 3 patients in the nonoperative group. Three patients managed operatively underwent secondary arthrodesis of the PTC joint (n = 2) or TN fusion (n = 1). All of them reported a decrease in pain afterward. No secondary arthrodesis was performed in the non-operatively treated patients. Overall, the complication rate specifically linked to the talar head injury was 3 of 16 (19%).

DISCUSSION

Our series demonstrated that all talar head fractures coincided with other foot fractures, often in the context of peritalar fracture-dislocations or Chopart injuries. Diagnosis of a talar head fracture warrants careful examination and caution for a more complex injury. Conversely, when a fracture- dislocation or Chopart injury is observed, all contours of the talus should be carefully assessed for possible head fractures. This is supported by evidence on complex foot fractures from Rammelt et al.[16] Involvement of the talar head was found in 14 of 61 patients with fractures at the Chopart joint. From the perspective of functional outcome and quality of life, patients with talar head fractures should be informed that their prognosis (of mostly fair to sometimes good long-term foot function) depends on the concomitant injuries (Table 3).

Injury Mechanism

Four different groups of acute talar head fractures were identified in our cohort: impaction, complete transverse, medial shear, and avulsion fractures. Avulsion fractures are thought to be underreported in literature due to the larger, distracting injuries. It is thought that inversion motion through the talonavicular joint leads to a comminuted or shear fracture, resulting in medial column shortening and irreducible fracture-dislocation.[10] Impaction injuries usually occur during high-energy trauma. Talar head fractures may also be the consequence of axial compression in full plantarflexion of the foot or, alternatively, hyperdorsiflexion as a result of impact against the anterior side of the tibia.[4,9,10] An interesting finding is that impaction injury was both the most common type of fracture in our series and was mentioned specifically in previous reports of patients with talar head fractures.[7,9,22] This may suggest that impaction is indeed a common cause of talar head fractures and that a high degree of suspicion of a talar head fracture should be raised in patients with impaction injuries to the foot, including talonavicular fracture dislocations. Early diagnosis of talar head fractures is crucial since this will influence articular congruity and thus management.

Imaging

In conventional radiography, the head of the talus overlaps the calcaneus on the anteroposterior view.[14] Therefore, CT should be performed to identify potentially subtle fractures, displacement, rotation, and/or extent into the neck or navicular bone.[12]

Management

Given the broad range of possible associated injuries found, it is impossible to present a general surgical plan or provide detailed recommendations on how to reduce and fix every type of talar head fracture. In general, patients with more extensive fractures of the talar head with dislocation, impaction, and/or intra-articular gaps or step-offs were managed with ORIF. Based on our findings and the literature, avulsion fractures and other nondisplaced talar head fractures can be managed non-operatively using a short leg cast or walking boot and nonweightbearing for approximately 4 weeks.[14] Clinical and radiological (using CT) healing should be evident to rule out secondary rotation or displacement prior to weightbearing.[7,10,12,14] In case of a larger fragment and/or in case of talonavicular joint instability, optimal management is ORIF to restore articular congruency.[2,7] This also applies to smaller displaced intra-articular fragments from the talar head or navicular. Severely comminuted fractures with soft tissue damage were treated with temporary external fixation followed by ORIF.

In case of severe comminution of the talar head and/or navicular and/or destruction of the joint otherwise, primary fusion of the talonavicular joint may be required.[8,17] Although preservation of the talonavicular joint should always be a major aim, secondary (salvage) arthrodesis is indicated for patients with persistent instability or pain due to posttraumatic osteoarthritis.

Operative Technique

In general, a single incision was made on the anteromedial side for optimal reduction and fixation without extensive soft tissue damage.[1,2] All transverse and medial shear fractures were approached in this way. As seen in our series and in the literature, a double-incision approach may be preferred in cases with impaction fractures (with concomitant navicular injuries) or if the fracture crosses the midline and extends to both sides of the talar head.[2,19] The dual approach usually involves a direct anteromedial longitudinal incision over the tip of the medial malleolus, across the navicular tuberosity to the proximal aspect of the medial cuneiform (visualization and mobilization, screw fixation, spanning plate application), and a second incision laterally using the distal part of the sinus tarsi approach (reduction and fixation). We suggest that the approach should be tailored to the specific fracture type and associated injuries (Figure 2).

When reconstruction is required, displacement or shortening of the medial column can be managed using a small external fixator from the talar neck to the cuneiform or navicular to facilitate disimpaction and reduction. Stability of the medial column and talonavicular joint is critical, and the talonavicular joint capsule should be repaired after fixation. Internal fixation can be achieved with subchondral cancellous lag screws or bioabsorbable pins. Bridge plating with a locking plate may be used in case of joint instability.[2,7] The role of percutaneous Kirschner wires is limited due to unstable fracture reduction and soft tissue complications.[1] Fragment excision may be considered only in the rare case of an irreparable fracture.[2] The usual postoperative protocol involves nonweightbearing for 2 to 8 weeks, followed by partial weightbearing in a walker and ankle mobilization exercises. Early exercises are allowed only if fixation is stable.

Functional Outcome

In the literature, functional outcome of talar head fractures has been reported using a validated outcome only once before. Anderson[2] showed that patients (n = 8) had decreased physical function and more pain compared to population norms. Regardless of the management type, about 70% of our patients returned to their normal daily activities during long-term follow-up. Mean FFI and AOFAS scores showed fair to good overall functional outcome, quality of life, and patient satisfaction. It should be noted that both patients treated operatively and non-operatively sustained associated talus or other ipsilateral foot injuries. The group with poor outcome included the case of missed fracture, a patient who underwent secondary subtalar fusion and a patient with a severe Chopart injury. A trend toward a slightly better FFI in the nonoperative group was observed (28.0 vs 38.0), yet AOFAS scores were similar and patient satisfaction appeared to be higher in the operatively managed group (8.0 vs 6.8). Although multivariate analysis could not be performed due to small sample size, a trend toward lower functional outcome was observed in patients with shear fractures. In comparison to other studies regarding patients with different types of talar fractures, our AOFAS score (mean, 70.7) was found to be slightly lower than the outcome of central (mean, 78.9, 76.1, and 71.4), lateral (mean, 75.0), and posterior process (mean, 78.7) talar fractures.[3,18,23-25] This supports our hypothesis that patients with (among others) talar head fractures usually face impaired functional outcome, interpreted as "fair" according to the AOFAS outcome measure. A possible explanation is that talar head fractures usually occur as part of more complex hindfoot trauma, as shown in this study. The finding that patients without a fracture dislocation and without ipsilateral talus or other foot or ankle fractures achieved higher functional outcome and quality-of-life scores was not surprising yet still relevant in clinical practice. Shared decision making and expectation management are essential and may lead to high patient satisfaction despite impaired functional outcome.

Complications

About a quarter of patients developed posttraumatic osteoarthritis in our series, compared to 50% reported in literature.[2] Operative complications were not found or reported in the literature. In particular, the incidence of avascular necrosis was found to be zero in both the literature and our series. This is probably due to the abundant blood supply to the talar head by the periosteal branches of the dorsal pedis artery and tarsal sinus artery that runs anteriorly.[2,7]

Limitations

This is the largest series of acute talar head fractures with validated outcome measures. Due to the very low incidence of this fracture, the sample size was small. No patients with isolated talar head fractures were found. Various types of talar head fractures were recognized, yet no conclusions on the difference between their functional outcome and prognosis could be drawn. Minimally displaced or avulsion fractures were managed well non-operatively. Others should be treated with ORIF. Another limitation is the high incidence of concomitant injuries, which likely biased the functional outcome and quality of life (Table 3).

CONCLUSION

Talar head fractures always coincided with other (foot) fractures. Next to the talonavicular joint, other Chopart joint articulations are at risk of injury when a talar head fracture is diagnosed. Both the medial and lateral column should therefore be carefully assessed for injury. Management and long-term functional outcome were affected by the extent of associated injuries. Due to the low incidence and high complexity of talar head fractures, early referral to dedicated foot surgeons and centralization of complex foot surgery are recommended.

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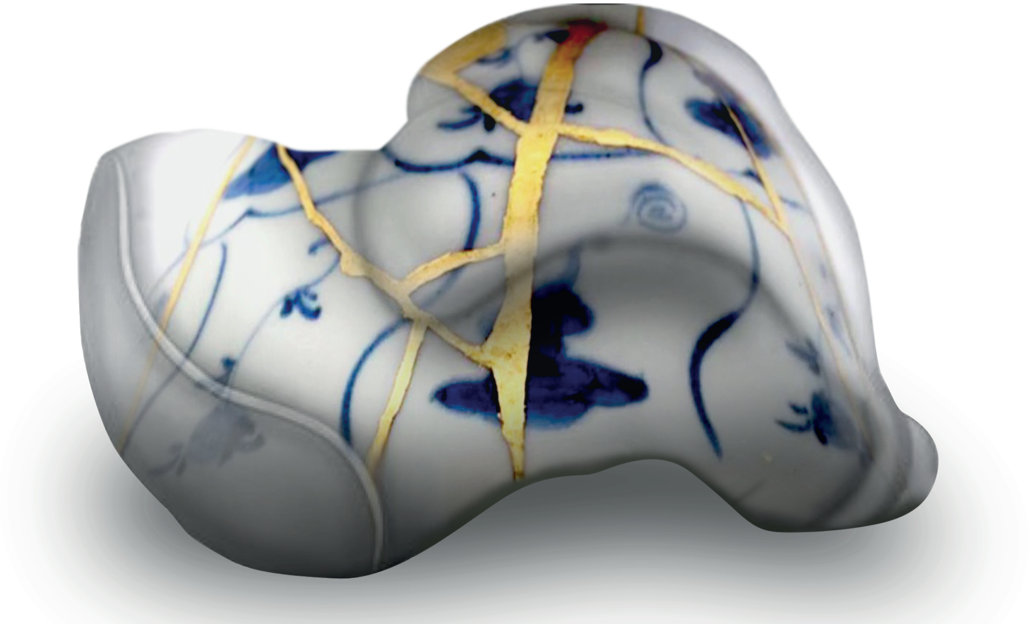
Lateral process



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Lateral process fracture of the talus: A case series and review of the literature

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ABSTRACT

Background: Fracture of the lateral process of the talus (LPFT) is a frequently overlooked injury that can lead to severe complaints if not treated adequately. The aim of this study was to evaluate treatment and long-term outcomes of LPFT through a review of the literature. Furthermore, we propose a modified classification based on severity and intra or extra-articular location of LPFT.

Methods: Patients diagnosed with LPFT and treated at a Level 1 trauma center between 2001 and 2018 were included. Fracture and treatment characteristics were recorded in combination with functional outcome and quality of life after a mean follow-up of 5.5 (range 0.8 to 17.2) years. A comprehensive literature search was performed to identify all case series regarding patients with LPFT

Results: Thirty-six patients were included. According to our modified classification, 1 patient had type 1A (2.8%), 6 patients had type 1B (16.7%), 10 patients had type 2 (27.8%), 11 patients had type 3 (30.6%), 6 patients had type 4A (16.7%), and 2 patients had type 4B (5.6%). Twenty-eight patients underwent operative fixation (78%). The median American Orthopaedic Foot and Ankle Society Hindfoot Score was 75 (range 12 to 100). The median Foot Function Index was 2 (range 0 to 9). The median score for the EuroQol-5D was 0.8 (range - 0.5 to 1), and the median score for health status component was 75 (range 30 to 98).

Conclusion: There is some room for conservative treatment of LPFT; however, we strongly believe that this should be considered only for nondisplaced, small-fragment, and extra-articular fractures. Surgical treatment leads to an overall good (long-term) outcome.

Level of Evidence: 4

Keywords: ankle injuries, lateral talar fracture, snowboarder's fracture, talus trauma

INTRODUCTION

Lateral process fracture of the talus (LPFT) was first described in 1943 by Marotolli,[1] followed by Bonnin[2] in 1950. LPFT is a rare condition, with an incidence of <1% of all fractures and <10% of all foot fractures.[3] Furthermore, LPFT accounts for 10% to 25% of all talar fractures.[4] Not surprisingly, LPFT is infrequently described in the literature, with fewer than 200 cases reported since 1943. Its functions include lateral stabilization of the ankle with assistance from the lateral talocalcaneal ligament, articulation with the fibula, and subtalar motion. LPFT is often described in snowboarders and after high-energy trauma. It is commonly thought to be caused by forced dorsiflexion and inversion of the ankle. However, several other biomechanical mechanisms, such as eversion, axial impaction, and exorotation, have been described.[5–7] The symptoms of an LPFT resemble the symptoms of ankle sprain and are, therefore, easily overlooked. Usually, radiographic workup involves radiography with mortise and lateral views of the foot. Lateral views of normal ankles demonstrate a V-shaped lateral talar process, which might be disrupted in LPFT. However, the sensitivity and specificity of a disrupted V-sign in LPFT are only 77% and 59%, respectively.[8] This leads to a high rate of misdiagnosis in LPFT, 33% to 41% (9,10). This may cause considerable delay in treatment, associated with increased morbidity due to malunion, nonunion, and/or osteoarthritis. The Hawkins classification for LPFT is based on the severity of the fracture.[9] Since then, this classification has since had several revisions.[11,12] Because of the low incidence of LPFT, long-term outcomes are lacking to optimize treatment.[13] Therefore, the aim of the study was to evaluate treatment and the long-term outcomes of LPFT in patients treated in a Level 1 trauma center with a review of the literature.

PATIENTS AND METHODS

Case Series

We present our experience with trauma patients with LPFT who were treated at our Level 1 trauma center between 2001 and 2018. Institutional review board approval and informed consent were obtained. Patients were identified in the electronic hospital database based on the billing code (DBC) 0303;241 and operation code 338733.

Patient, fracture, and treatment characteristics were collected from the electronic hospital database and the Picture Archiving and Communication System. Patient characteristics that were collected included age at the time of the trauma, sex, medical history, smoking, and the use of alcohol. Fracture characteristics recorded included mechanism of trauma, side of fracture, concomitant ipsilateral or contralateral lower extremity injuries, and type of fracture based on plain radiographs and computed tomography (CT) scans. For the classification of the LPFT, we modified the most recent classification for LPFT by Boack and Manegold[11] based on the severity, intra- or extra-articular location of the fracture, and the possible joint dislocation ranging from type 1A to 4B (Fig. 1). Our modified classification focuses solely on the lateral process fractures with possible joint dislocation and instability, whereas Boack and Manegold describe both lateral and posterior processes.

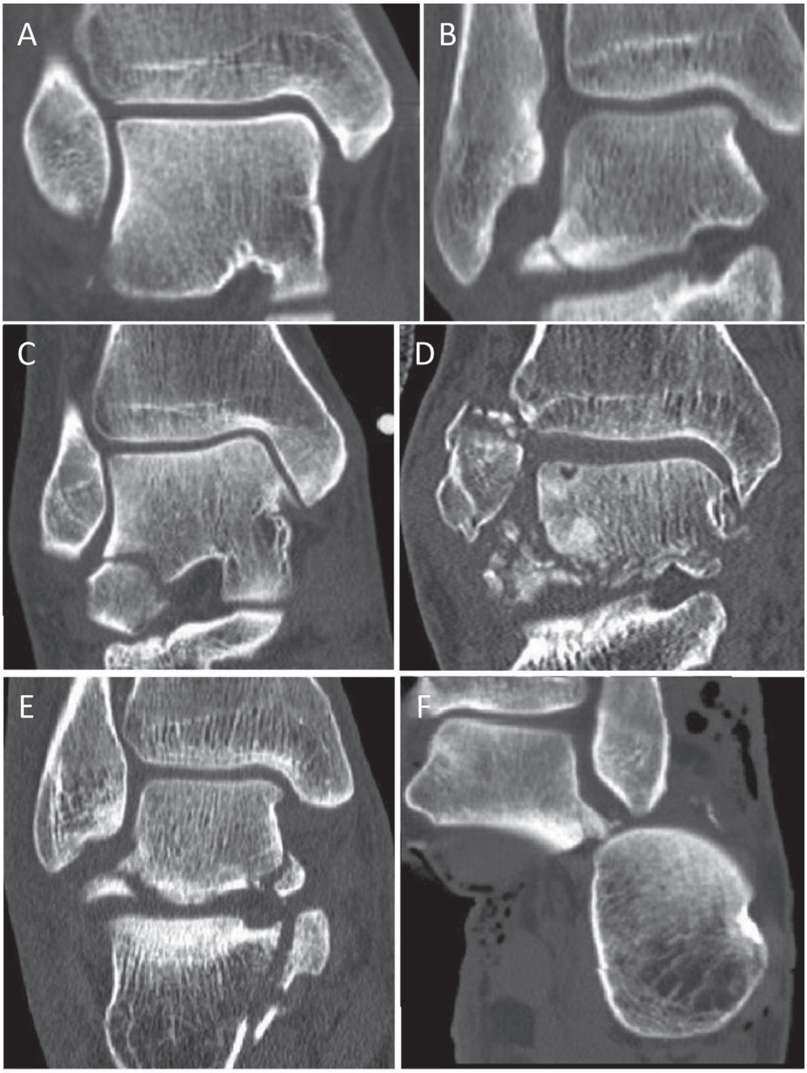

Fig. 1. Modified classification for lateral process of the talus (LPFT). (A) Type 1A: Computed tomography (CT) scan coronal view; small-fragment extra-articular. (B) Type 1B: CT scan coronal view; small-fragment intra-articular. (C) Type 2: CT scan coronal view; intermediate-fragment intra-articular. (D) Type 3: CT scan coronal view; comminuted or severe fracture intraarticular. (E) Type 4A: CT scan coronal view; LPFT combined with a sustentaculum tali fracture of the calcaneus without joint dislocation. (F) Type 4B: CT scan sagittal view; LPFT combined with total subtalar dislocation.

Treatment characteristics extracted from records included type of treatment, complications (operational site infection and secondary fusion), and need for implant removal. Functional outcome was assessed using the Foot Function Index (FFI, best score 0 points) and the American Orthopaedic Foot and Ankle Society Hindfoot Score (AOFAS, best score 100 points) The AOFAS score was divided into groups according to the literature: a score of 90 to 100 was graded as an excellent result, 75 to 89 was graded as good, 50 to 74 was graded as fair, and <49 was graded as a failure or poor outcome. Quality of life was measured with use of the EuroQol-5D (EQ-5D), which consists of a descriptive system and the EQ Visual Analog Scale (EQ VAS). The descriptive system includes 5 dimensions: mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. The EQ VAS is an assessment of perceived general health on a scale of 0 to 100, in which 100 represents excellent general health. Patient satisfaction was also measured using the VAS of 0 to 10, in which 10 represents the best possible satisfaction.

Statistical Analysis

The statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 24 (SPSS, Chicago, IL). Numeric data are expressed with median values, and categorical data are shown as numbers with percentages.

Literature Search

A literature search was performed to identify all case series of patients with LPFT. The electronic database to July 1, 2018, of the Cochrane Library, PubMed MEDLINE, EMBASE, and Google Scholar were explored by using the combination of the following search terms and Boolean operators: Talus OR Talar OR Snowboarder AND Lateral process OR Peripheral AND Fracture*. All studies after 2000 regarding patients with LPFT were included, if they treated more than 1 patient (case series), treated adult patients, and were in the English language. Additionally, a comprehensive search of all the reference lists was conducted to identify related studies. Number of included patients, fracture characteristics, treatments, outcomes, and complications were extracted from these publications.

RESULTS

Demographics

Thirty-eight patients were identified between 2001 and 2018 with an LPFT. One patient did not consent to the study, and in 1 patient, the electronic data were incomplete. The median follow-up was 5.5 (range 1 to 17.2) years. Of the remaining 36 patients, 13 were female (36%) with a median age of 35 (range 15 to 64) years at the time of injury. The trauma mechanism most commonly seen was a fall from height in 11 patients (30%). Six patients fell during daily activities (17%), 8 patients sustained a motor vehicle accident (22%), 5 patients experienced direct blunt trauma (14%), 5 patients had a sports-related injury (14%), and in 1 patient the trauma mechanism was not clear. Fifteen patients (42%) had an isolated injury of the talus, whereas 21 patients (58%) had concomitant lower extremity injuries. Fifteen of these concomitant lower extremity injuries were ipsilateral (calcaneus, n = 10; medial malleolus, n = 1; pilon, n = 1; metatarsal, n = 1; cuboid, n = 1; femur, n = 1) and 10 were contralateral (calcaneus, n = 2; talus, n = 5; pilon, n = 2; femur, n = 1). In 15 patients, solely the lateral process was fractured. Other concomitant fractures of the ipsilateral talus included posterior process (n = 7), corpus (n = 2), neck (n = 9), and head (n = 1). Fracture and patient characteristics are shown in Table 1.

Table 1. Fracture, treatment, and complication characteristics

Characteristic		n (%)
Fracture side	Left	n = 12 (33)
	Right	n = 19 (53)
	Both	n = 5 (14)
Open fracture	Yes	n = 2 (6)
	No	n = 34 (94%)
Type of fracture (modified classification)	Type 1A: Small-fragment extra-articular	n = 1 (3%)
	Type 1B: Small-fragment intra-articular	n = 6 (17%)
	Type 2: Intermediate-fragment intra-articular	n = 10 (28%)
	Type 3: Comminuted or severe fracture intra-articular	n = 11 (31%)
	Type 4A: LPFT combined with a sustentaculum tali fracture of the calcaneus without joint dislocation	n = 6 (17%)
	Type 4B: LPFT combined with subtalar or peritalar dislocation	n = 2 (6%)
Preceding operation	Fixator external	n = 3 (8)
	Closed reduction	n = 1 (3)
Type of surgery	ORIF	n = 26 (72)
	PA	n = 2 (6)
Complications	Infection	n = 1 (3)
	Implant removal	n = 11 (31)
	Implant removal and arthrodese	n = 2 (6)

Abbreviations: LPFT, lateral process of the talus; ORIF, open reduction and internal fixation; PA, primary arthrodesis.

In 8 patients (22%), the talus fracture was treated conservatively. In 28 patients, an operation was performed that included open reduction and internal fixation (n = 26, 72%) and primary arthrodesis (n = 2, 6%). In 3 polytrauma patients, the fracture was severely comminuted or dislocated, requiring an external fixator for initial stabilization. One patient underwent a closed reduction of the dislocated talus at the emergency department.

Functional Outcome, Treatment Satisfaction, and Quality of Life

A total of 18 patients (50%) returned the validated questionnaires. The median AOFAS Hindfoot Score for this group was 75 (range 12 to 100) points. Three patients had an excellent result, 8 patients had a good result, 5 patients had a fair result, and 2 patients had a poor outcome. The median FFI was 2 (range 0–9) points. Overall, patients scored a median of 9 (range 5 to 10) points on treatment satisfaction. The median score for the EQ-5D was 0.8 (range –0.5 to 1), and the median score for health status component was 75 (range 30 to 98).

Literature Search

A total of 95 articles were identified, of which 71 were excluded (Fig. 2). Of the 24 included articles, 3 case series were found (range 1 to 44 patients per article). In addition, 4 case series were included based on scanning reference lists (Fig. 2, Table 2). In general, displaced fractures were treated operatively, whereas nondisplaced fractures were mainly treated non-operatively.[7,14] Complication rates ranged from 4% to 45% and included osteoarthritis (15% to 38%), nonunion (4% to 39%), and secondary arthrodesis (10% to 15%) (7,9,10,12,15). Not surprisingly, nonunion has been reported to a much higher extent in displaced LPFT managed non-operatively (60%) compared with (early) operative fixation (5%). In addition, delayed diagnosis was observed in 14% to 70%. Functional outcome was mainly scored according to the AOFAS and ranging from 85 to 95 points.[15–18]

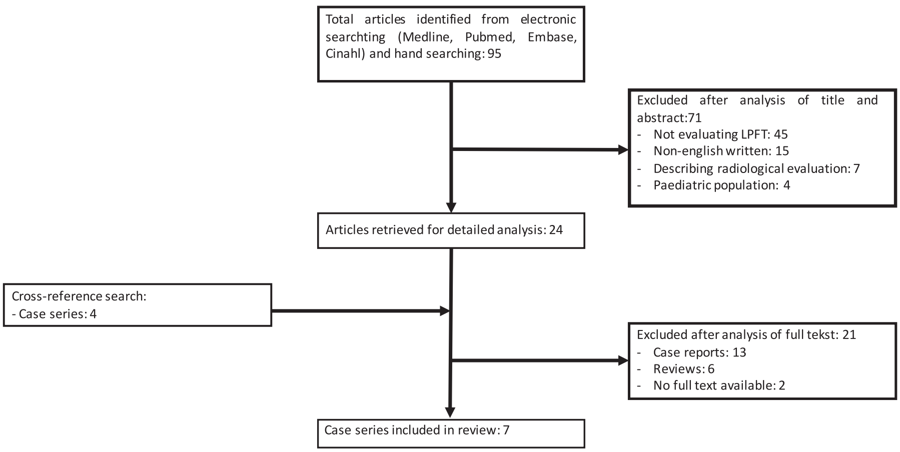

Fig. 2. Flowchart of selection process from initial search to inclusion.

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Table 2. Literature search

Author	n	Year	Male/ Female	Mean Age, y	Type (n)	Treatment (n)	Complications	Outcome	Follow-Up, mo
Hawkins et al.	13	1965	26/0	26	I: 2 II:6 III:5	Type I: 2× Conservative Type II: 6× Conservative Type III: 5× Conservative	Chronic pain 46% Malunion 8% Nonunion 39% Osteophytes 15%	ROM and pain	26
Inokuchi et al.	13	1996	23/39	37	?	8× Conservative 5× Operative	Osteoarthritis (after conservative treatment) 15%	Consolidation on radiography	Unknown
Maes et al.	7	2004	33/0	33	II:4 III: 3	TypeII: 2× ORIF and removal of small fragment 2× ORIF Type III: 2× ORIF 1× Osteotomy (delayed diagnosis)	Osteoarthritis 29% Delayed diagnosis 14% (10 months) Wound infection 14%	AOFAS Consolidation on radiography	72
Sariali et al.	43	2008	25/8	33	I: 25 II:5 III: 14	12× 45d foot cast non-weightbearing 2× Operative screw fixation	Delayed diagnosis 70% (mean: 46 months) Osteoarthritis 46% (delayed diagnosis group) Osteoarthritis 29% (direct diagnosis group) Wound infection 2% (Associated lesions 44%)		17
Valderrabano et al.	20	2010	18/11	29	I:3 III: 16 III:1	Type I: 3× Conservative Type II: 2× conservative 14× operative III: 1× Conservative	Secondary operative (type II and III) due to debridement 15%	AOFAS	42
Von Knoch et al.	23	2007	28/3	31	I: 1 II:15 III: 7	Type I: 1× Conservative Type II: 4× Conservative 11× Operative ORIF III: 2× Conservative 5× Operative ORIF	Malunion 4% (in conservative group) Osteoarthritis 45% (operative group) Associated injuries 88%	AOFAS	42
Mukherjee et al.	13	1974	26/11	37	?	Operative Conservative	Arthrosis 38% Delayed diagnosis 54%		20

Abbreviations: AOFAS, American Orthopedic Foot and Ankle Score; ORIF, open reduction and internal fixation; ROM, range of motion

DISCUSSION

Our study shows that in patients with LPFT, the outcome is generally good, when treated mainly operatively. Only small-fragment and extraarticular fractures should be treated non-operatively, which is supported by the literature review.

When reviewing the literature, guidelines for the treatment of LPFT are lacking. Therefore, we aimed to provide more insight into the longterm outcomes after treatment of an LPFT, by evaluating a large series of 36 patients. Only one other article has described a larger series of 44 cases.[15] This study had a mean follow-up of 17 months and also used the AOFAS score to evaluate the outcome. The overall results for the total patient group at the last follow-up was excellent in 52%, good in 23%, fair in 21%, and poor in 2%. Better results were seen in patients who were treated immediately after the trauma versus patients with a delayed diagnosis. In our study, the overall results were excellent in 17%, good in 44%, fair in 28%, and poor in 11%. Only 44% of the cases in Sariali et al.[15] had associated lesions versus 58% in our patient group. This could be a possible explanation for the differences in outcomes. The indication for operative treatment was not described, but because a large percentage underwent secondary and even tertiary surgery, the authors concluded that a broader indication for surgery as initial treatment is in place. To treat LPFT adequately, good diagnostics are essential. Ebraheim et al.[19] and Whisby et al.[20] advocated that CT is effective in assessing the size and displacement of the fragment. Therefore, in patients with a typical clinical presentation (pain and swelling of the ankle with local tenderness anterior to the tip of the lateral malleolus), a CT scan should be considered.[12,21] In some cases, the fracture can be seen on plain radiographs. A symmetrical V-shaped contour can be seen on a lateral view in patients with an intact lateral process, whereas in patients with LPFT, this V shape is asymmetrical. In case of any doubt, a CT scan is recommended.[8] Magnetic resonance imaging was not part of our acute diagnostic workup, but in case of persistent complaints or for the evaluation of ligamentous injury, an additional magnetic resonance image was obtained.

Only 42% of our patients had an isolated fracture of the lateral process. The majority had concomitant ipsilateral and/or contralateral injuries of the lower extremity. This is in contrast to what is described by Tinner and Sommer,[22] who report that LTPFs are mostly isolated fractures. Furthermore, they describe additional ipsilateral fractures of the talus in 10%. In our patient group, this number was 50%. A possible explanation is that our study group mostly consists of polytrauma patients who were seen in a Level 1 trauma center. It also underlines the importance of intensive imaging.

Hawkins type I fractures (small fragment) (42%) are more common than type II fractures (comminuted) (32%) and type III fractures (chip fracture) (24%).[13] McCrory and Bladin[12] describe

LPFT as type I for the chip fracture, type II for the small-fragment fracture, and type III for the comminuted fracture. Subsequently, Funk et al.[23] tried to improve the classification of LPFT by differentiating fractures in more detail. This classification, however, was intended for experimental studies and has not been adopted in the clinical setting. Subtalar injuries are a continuum of different injuries. We encountered a few combined injuries of LPFT and sustentaculum tali. We believe these represent a prestage of a full-blown subtalar or peritalar dislocation. We were unable to find any similar injuries in the literature. Our modified classification is solely focused on LPFT and is based on the severity, intra- or extra-articular location of the fracture, and possible joint dislocation ranging from type 1A to 4B (Fig. 1). We believe that this is a more complete and logical classification of LPFT.

Fall from height was the leading cause in our study for LPFT, followed by fall during daily activities. The exact biomechanical mechanism causing these injuries is not clear and remains a point of discussion. Cimmino[24] advocated the involvement of 3 forces: direct axial force, forced supination of the ankle, and direct external force. In contrast to this, Hawkins[9] described that the lateral talocalcaneal ligament is not strong enough to cause an avulsion fracture. Hawkins took the movements of the foot into consideration and concluded that external force from the calcaneus to the lateral process causes the fracture when the ankle is inverted and dorsiflexion force is applied to it. Fjeldborg[6] stated that when the foot is inverted, the lateral process becomes the only junctional area between the posterior joint surface and the talus, and that when dorsiflexion force is applied in that position, a fracture occurs because the external force is concentrated on the lateral process. We believe that LPFT after high-velocity accidents cannot simply be subscribed as caused by 1 type of trauma mechanism but rather is a combination of mechanisms, as described earlier.

Patients with small or intermediate-sized fractures were treated non-operatively in our population with a cast up to 16 (range 0 to 16) weeks. This wide range was mainly the result of concomitant fractures at the ipsilateral side for which sometimes longer use of a cast was indicated. For nondisplaced fractures, the literature recommends nonweightbearing immobilization for 4 to 6 weeks followed by a weightbearing cast for an additional 3 weeks.[3,22,25]

In our study, 79% of all patients underwent operative repair. All patients with a type 4A and 4B fracture were treated operatively, including 2 with primary arthrodesis. For all other fracture types, most patients underwent surgery (type 3, 64%; type 2, 80%; type 1B, 83%). Comorbidities and a delay in diagnosis were the most important reasons for conservative treatment. In contrast, all type 1A fractures were treated conservatively by means of cast immobilization.

Outcomes of LPFT depend on early recognition of the fracture without delay in treatment. Sariali et al.[15] found that osteoarthritis was more common in the delayed diagnosis population

(46%), compared with the early diagnosis population (29%). Moreover, long-term outcome is most dependent on the fracture characteristics. Restoration of anatomically joint surface and limitation of the degree of traumatic cartilage damage are the keys for a good outcome. Hawkins[9] showed that conservative treatment of type II and III fractures resulted in high morbidity; approximately 50% of the patients with a type II or III fracture treated with cast had complications such as chronic pain (46%) and nonunion (39%). These findings fit with the commonly accepted consensus that only the small chip fractures can be treated conservatively, whereas large-fragment, intra-articular, and comminuted fractures should be treated operatively. Von Knoch and Von Knoch[16] evaluated AOFAS scores after treating 23 patients with McCrory-Bladin type I (1 case, conservative), type II (15 cases, 11 operative), and type III (7 cases, 5 operative), leading to a mean AOFAS score of 94 after 42 months. These results are in line with the outcome described by Valderrabano et al.,[18] who treated the McCrory-Bladin type I fractures in a conservative manner and performed operative repair in the McCrory- Bladin type II fractures, leading to a mean AOFAS score of 93 after 3.5- year follow-up, suggesting that non-displaced type II (large-fragment) fractures may be better treated operatively to decrease future morbidity such as malunion, nonunion, joint stiffness, and chronic pain. This was supported by Maes et al.,[17] in which AOFAS scores were obtained from 7 patients with McCrory-Bladin type II and III fractures who were treated operatively with open reposition and internal fixation with removal of small fragments. In that study, the mean AOFAS score was 85 (74 to 100) after 10 years. Comparing these results with those of our study group, in our population the median AOFAS score was 75. Our slightly lower score might be the result of a higher percentage of severe and comminuted fractures, in some cases combined with joint dislocation, in our group.

With a median follow-up of 5.5 years, we found 1 wound infection after surgery, and in 11 cases, the implant was removed because of patient complaints. Because of complete destruction of the joint surface with cartilage damage, an arthrodesis was performed in 2 patients at 14 and 34 months after the initial operation. Our results are similar to the outcomes of other studies where a wide range of complications are described.[7,15]

A limitation of this study is the high rate of concurrent injuries what undisputedly effects the choice of treatment and the overall outcome. Next to this we must acknowledge the possibility of underreporting simple extra-articular fractures, type 1A, because they are easily overlooked.

In conclusion, LPFT can lead to severe complaints when not treated on time and adequately. Therefore, caution should be warranted regarding anterolateral ankle pain (below malleolus) during inversion and dorsiflexion. Given the low sensitivity and specificity of conventional radiography, CT should be considered in these patients. There is some room for conservative treatment of LPFT, but we strongly believe that this should be considered only in small- fragment and extra-articular fractures. In addition, operative treatment should be the first choice in large-fragment, intra-articular, and/or comminuted LPFT, because of the better (long-term) outcomes and lower complication rates.

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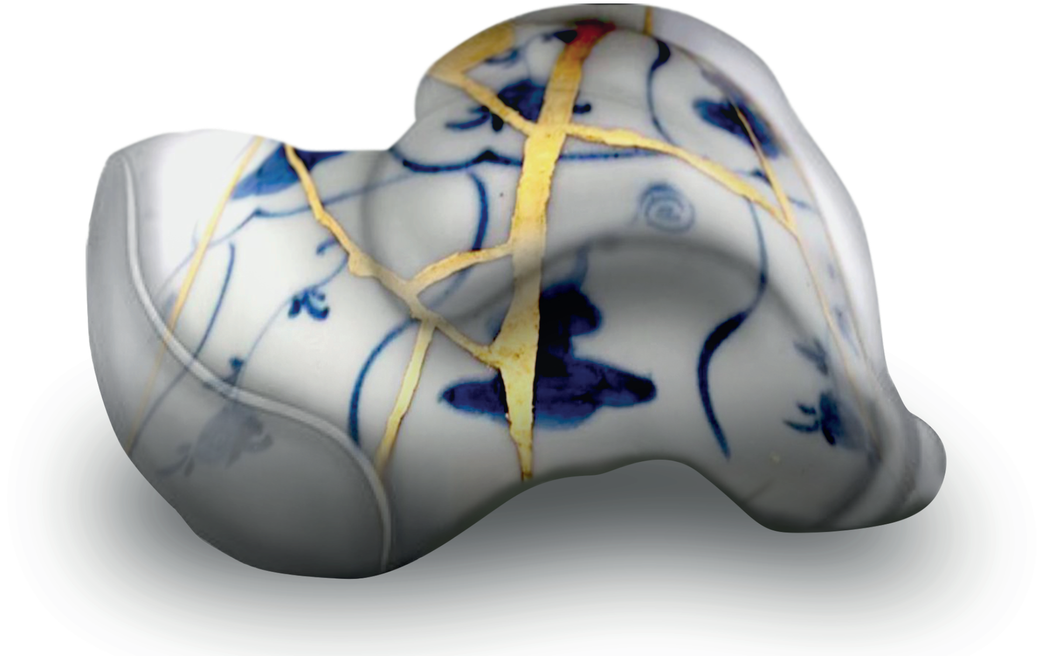
Posterior Process



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Functional outcome and quality of life after (non) operative treatment of posterior process fractures of the talus

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ABSTRACT

Background: Fractures of the posterior process of the talus are frequently overlooked, possibly leading to nonunion, arthritis, and chronic pain. Given the rare occurrence, previous case series have been small and without functional outcome scores. Therefore, we aimed to provide evidence on outcomes after nonoperative and operative management of posterior process fractures of the talus.

Methods: All patients treated at a level 1 trauma center between 2012 and 2018 were retrospectively evaluated. Patient, fracture, and treatment characteristics were collected, and functional outcome as well as quality of life were assessed. Twenty-nine patients with posterior process fractures of the talus were identified in our database.

Results: The most frequently seen mechanism of trauma was fall from height in 13 patients (44.8%). Twenty-two patients underwent primary arthrodesis or operative reduction and fixation of the fracture (75.9%). Eighty-two percent of the patients returned the questionnaires with a mean follow-up of 6 years. The 2 patients with primary arthrodesis were excluded from outcome analysis. The mean Foot Function Index score was 1.8 (range 0.0-10). The mean American Orthopaedic Foot & Ankle Society (AOFAS) score was 78.7 points (range 0-100). The mean quality of life EuroQol-5D (EQ-5D) index score was 0.78 (range –0.26 to 1). The mean visual analog scale (VAS) on overall patient satisfaction was 8.2 (range 1-10).

Conclusion: Operative management of extended posterior talar fractures was found to provide good functional outcome, quality of life, and patient satisfaction. Although the patients treated non-operatively were found to have less severe injuries, they demonstrated worse overall outcome, which is supportive of surgical management. Nonoperative treatment is therefore only justified in selected patients.

Level of Evidence: Level IV, retrospective case series.

Keywords: posterior process fracture, Cedell fracture, ankle injuries, talus, trauma

INTRODUCTION

In general, talar fractures are uncommon, constituting less than 1% of all fractures in the human body and between 3% and 6% of fractures of the foot.[10] Talar fractures and, in particular, the more severe talar fracture patterns are increasingly being seen because of improved survival from serious injuries.[11] In 1974, Cedell was the first to describe a series of posteromedial process fractures of the talus.[2]

Because the posterior process involves both the tibiotalar (posterior ankle) and talocalcaneal (posterior facet of the subtalar) joints, even minimal displacement of the fracture fragment may lead to significant long-term consequences, including joint misalignment and posttraumatic arthritis. Diagnosing fractures of the posterior process of the talus can be challenging, given its clinical and radiographic similarity to an ordinary ankle sprain.[2,7,8] Standard imaging workup includes ankle radiographs and an additional computed tomographic (CT) scan in cases with a high index of suspicion, which is superior in the assessment of size, displacement, and comminution of talar process fractures.[4,5,7]

Because of its rare occurrence, previous case series have been small and without functional outcome scores. Therefore, this study aimed to gain insight in the management and outcomes of posterior process fractures of the talus treated in a level 1 trauma center.

METHODS

Design and Patients

We analyzed a retrospective cohort of all trauma patients with posterior process fractures of the talus who were treated at a level 1 trauma center between January 1, 2012, and December 31, 2018. Institutional review board approval and informed consent were obtained. Patients were included from the electronic hospital database using the billing code (DBC) 241 and surgical code 338733. All cases were reviewed and patients with involvement of the posterior process were included in this study. Patients younger than 18 years at the day of last follow-up were excluded.

Variables

Patient-related clinical and radiographic data were extracted from the electronic hospital database and PACS (picture archiving and communication system). Variables included age at injury, gender, American Society of Anesthesiologists (ASA) classification, mechanism of trauma and concomitant ipsi- or contralateral lower extremity injuries. Imaging was reviewed by a radiologist and a trauma surgeon in order to categorize the fracture based on anatomical side, intra- or extra-articular location, joint dislocation, and complexity. With respect to management, data were collected on the type of treatment, follow-up, complications, and the possible need for implant removal. Functional outcome was assessed using the Foot Function Index (FFI, best score 0 points) and the American Orthopaedic Foot & Ankle Society hindfoot score (AOFAS, best score 100 points). The AOFAS score was divided into groups according to the literature: a score of 90 to 100 was graded as an excellent result; 75 to 89 as good; 50 to 74 as fair, and less than 49 points was graded as a failure or poor outcome. Quality of life (QOL) was measured by the EuroQol-5D (EQ-5D). This included assessment of perceived general health on a visual analog scale (VAS) of 0 to 100, in which 100 represented excellent general health (EQ-VAS). Patient satisfaction was also measured using the VAS of zero to 10, in which 10 represents the best possible satisfaction.

Demographics

Twenty-nine patients with posterior talar process fractures were identified. There were slightly more men (n = 16, 55%) with an overall average age at the day of trauma of 42 years (range 14-79). Thirteen patients were referred from other hospitals (44.8%). The most frequently seen mechanism of trauma was fall from height in 13 patients (44.8%). Patient and trauma characteristics are described in Supplementary Table S1. In 15 patients, the medial posterior process was fractured (51.7%), in 7 patients, the lateral posterior process (24.1%) and in 7 patients the complete posterior process (24.1%). In 6 patients the posterior process of the talus was fractured without any other concomitant ipsilateral lower extremity fractures. Fracture characteristics are described in Figure 1. One patient died during follow-up because of a colorectal carcinoma. The questionnaires were sent to the remaining 28 patients, of whom 23 responded (82%), leading to a loss to follow-up of 18% (n = 5), of which 2 patients were mentally disabled, 1 patient had severe neurologic damage during the trauma and was not able to fill in the questionnaires, and 2 patients did not reply. The mean follow-up time from the day of trauma was 6.0 years (range 1.3-17.7 years). All patients were evaluated at the outpatient clinic. Because primary arthrodesis and open reduction and internal fixation (ORIF) cannot be rightfully compared by means of functional outcome, we excluded the 2 patients with primary arthrodesis in the outcome analyses.

Statistical Analysis

The statistical analysis was performed using the Statistical Package for the Social Sciences, version 24 (IBM Corp, Armonk, NY). Numeric data are expressed with means, and categorical data are shown as numbers with percentages.

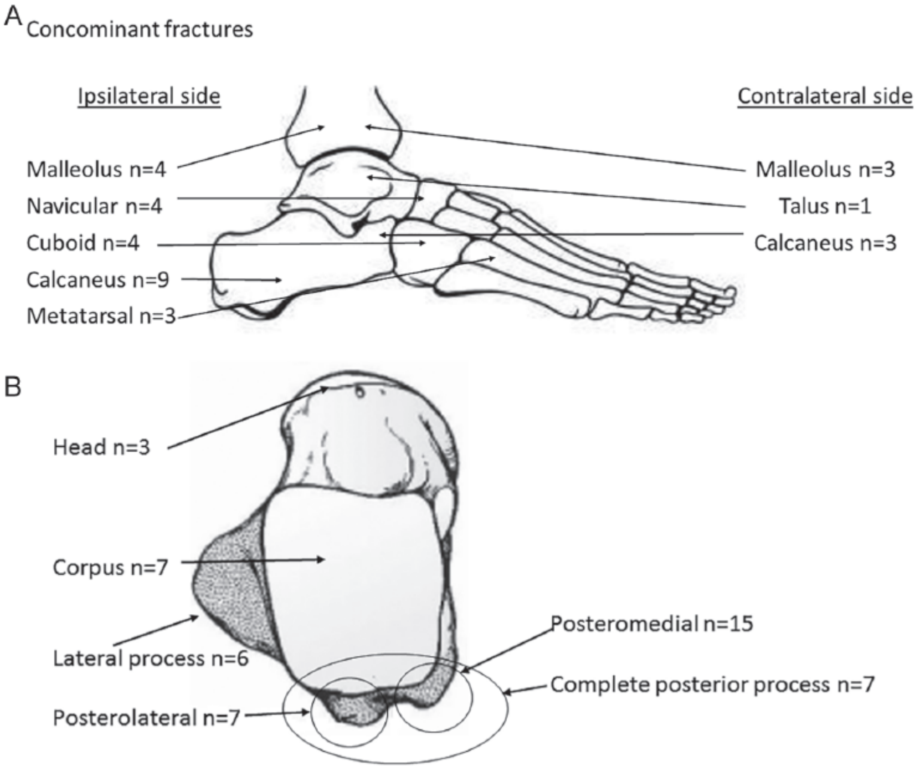

Figure 1. (A) Concomitant fractures. (B) Ipsilateral concomitant talar fractures, superior view.

RESULTS

Twenty-two patients underwent operative reduction and fixation of the fracture (75.9%). In 2 of these patients, this was combined with primary arthrodesis (6.9%). Two examples of preoperative CT images in combination with the postoperative results are shown in Figure 2. The mean duration between the day of trauma and the definitive surgery was 15 days (range 2-60 days). Seven patients underwent another operation before the definitive operation (24.1%). This consisted of an external fixator in 4 patients (13.8%) and closed reduction in 2 patients (6.9%), and 1 patient underwent several operations with wound irrigation and debridement because of a wound infection after an open fracture (3.4%). In 7 of 22 operated patients, the implants were removed (31.8%).

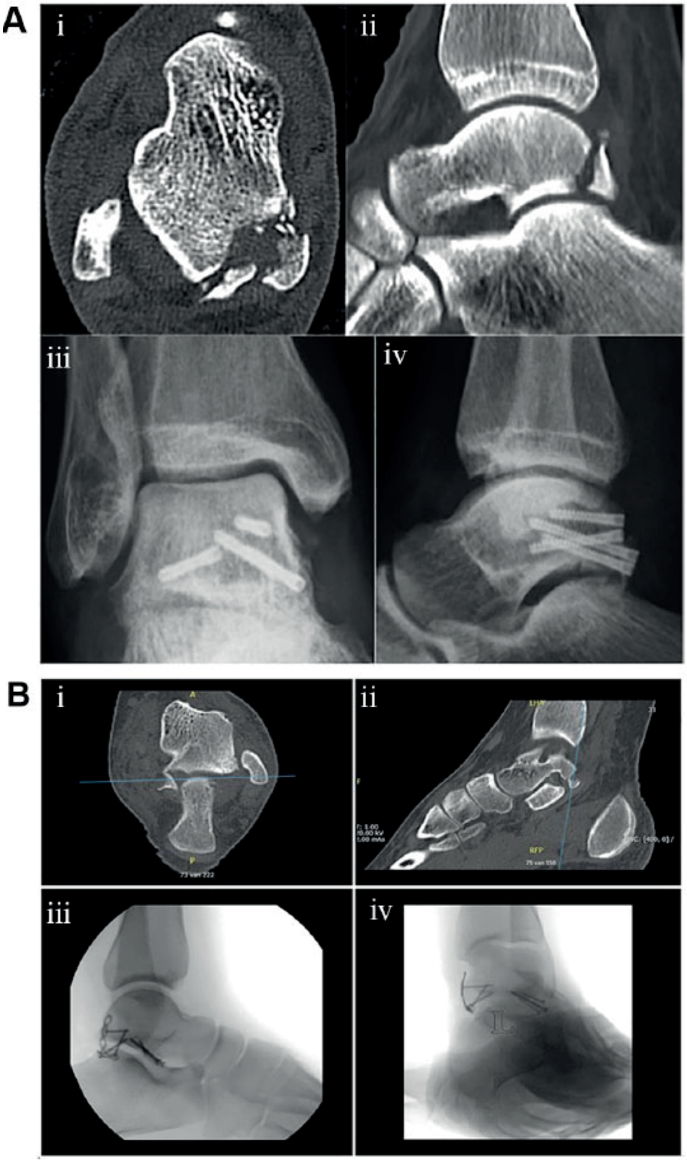

Figure 2. (A) Preoperative computed tomographic (CT) scanning in combination with postoperative results. (i, ii) CT scan with axial and sagittal view showing a fracture of the complete posterior process. (iii, iv) Radiographs, coronal and sagittal view, showing postoperative results with 4 screws. (B) Preoperative computed tomographic (CT) scanning in combination with postoperative results. (i, ii) CT scan with coronal and sagittal view showing a fracture of the posteromedial process. (iii, iv) Radiographs, sagittal and coronal view, showing postoperative results with plate and screws.

Four out of five non-operatively treated patients who completed the survey returned to their normal daily activities (80%). Two of the nonoperative managed patients developed arthritis of the posterior talocalcaneal joint for which arthrodesis was performed. Two-thirds of patients treated operatively returned to their normal daily activities (n = 11 out of 16 patients who returned the survey, 68.8%). One-third of the operatively managed patients underwent implant removal (n = 7, 31.8%). For all included patients, the mean FFI score was 1.8 (range 0.0-10). According to the AOFAS score, 4 patients had an excellent outcome, 11 had a good outcome, 5 had a fair outcome, and in 1 patient the outcome was poor with a mean total score of 78.7 points (range 0-100). The mean quality of life EQ-5D index score was 0.78 (range –0.26 to 1). The mean VAS on overall patient satisfaction was 8.2 (range 1-10). Treatment characteristics, functional outcome, and quality of life scores are described in Table 1.

Table 1. Treatment Characteristics, Functional Outcome, and Quality of Life Scores.[a]

Treatment	Total Group (N = 29)	Operative (n = 22, 75.9%)	Nonoperative (n = 7, 24.1%)
ORIF, n		20	–
Primary arthrodesis, n		2	–
Available outcome measurements, n	21	16	5
Functional outcome			
FFI, mean (range)	1.8 (0 to 10)	1.51 (0 to 6.83)	2.59 (0 to 10)
AOFAS, mean (range)	78.7 (0 to 100)	81.6 (51 to 100)	69.6 (0 to 100)
Excellent outcome, n	4	3	1
Good outcome, n	11	8	3
Fair outcome, n	5	5	0
Poor outcome, n	1	0	1
Quality of life			
EQ-5D index	0.78 (–0.26 to 1)	0.82 (0.25 to 1.00)	0.63 (–0.26 to 1)
Patient satisfaction	8.2 (1 to 10)	8.63 (5 to 10)	6.8 (1 to 10)

Abbreviations: AOFAS, American Orthopaedic Foot & Ankle Society Score; EQ-5D, EuroQol-5D; FFI, Foot Function Index; ORIF, open reduction internal fixation.
[a]Data are presented as mean with range.

DISCUSSION

Posterior processus fractures of the talus occur rarely isolated but are rather part of a larger injury. In general, patients with more extensive fractures of the posterior process with dislocation and/or intra-articular gaps or step-offs (>3 mm) were managed by ORIF. Operative management of extensive posterior talar fractures was found to provide good functional outcome, quality of life, and patient satisfaction. Although the fractures treated non-operatively were found to have less severe injuries, they demonstrated worse overall outcome, which is thus supportive of surgical management. In our case series, the majority of patients sustained a talar fracture due to high energy trauma (n = 19, 65.5%). Only 2 of these 19 patients had an isolated posterior process fracture, indicating that this type of fracture was mostly associated with other fractures or injuries such as ipsi- and/ or contralateral fractures of the lower extremities. This was thought to be due to the fact that our hospital is a level 1 trauma center, compared to level 2 and 3 centers in the literature, where a higher percentage of isolated talar fractures was described. Standard trauma radiographs of the ankle were made in all patients. In addition to the routine trauma radiographs, a CT scan was made in all our patients for the assessment of size, displacement, comminution, articular involvement, and for preoperative planning.[4,5] In our case series, all patients with fractures of the posterior process with dislocation and/or intra-articular gaps or step-offs (>3 mm) were treated operatively (n = 22, 75.9%). The non-operatively managed group consisted of patients with isolated avulsion fractures or fractures without or with minimal dislocation (n = 7, 24.1%). Severely comminuted fractures (n = 2) with joint dislocation were treated with external fixation followed by early subtalar arthrodesis 20 and 60 days after trauma, respectively, which is consistent with previous literature.[1,3,4,6,9]

Comparing functional outcome, quality of life, and patient satisfaction between operative and nonoperative groups, operative management was found to be superior (Table 1). Considering that the fractures in the operative group were more severe and dislocated emphasizes the importance of a predominant surgical approach in this type of fracture. Avascular necrosis of either the posterior process or talar body, narrowing of the subtalar joint space, and arthritis have been reported in literature. The latter was not observed in our series.

Limitations

Despite the retrospective design, this is a large consecutive case series. Moreover, it used validated outcome scores to systematically evaluate functional outcome of this relatively rare type of fracture. In only 6 patients the posterior process of the talus was fractured without any other concomitant ipsilateral lower extremity fractures, probably because of the study being conducted at a level 1 trauma center. It was not possible to determine the effect size of the talus fracture to the functional outcome and quality of life due to the presence of concomitant ipsilateral lower extremity fracture.

CONCLUSION

Operative management of extensive posterior talar fractures was found to provide good functional outcome, quality of life, and patient satisfaction. Although the fractures treated non-operatively were found to have less severe injuries, they demonstrated worse overall outcome, which is supportive of surgical management. Nonoperative treatment is therefore only justified in selected patients.

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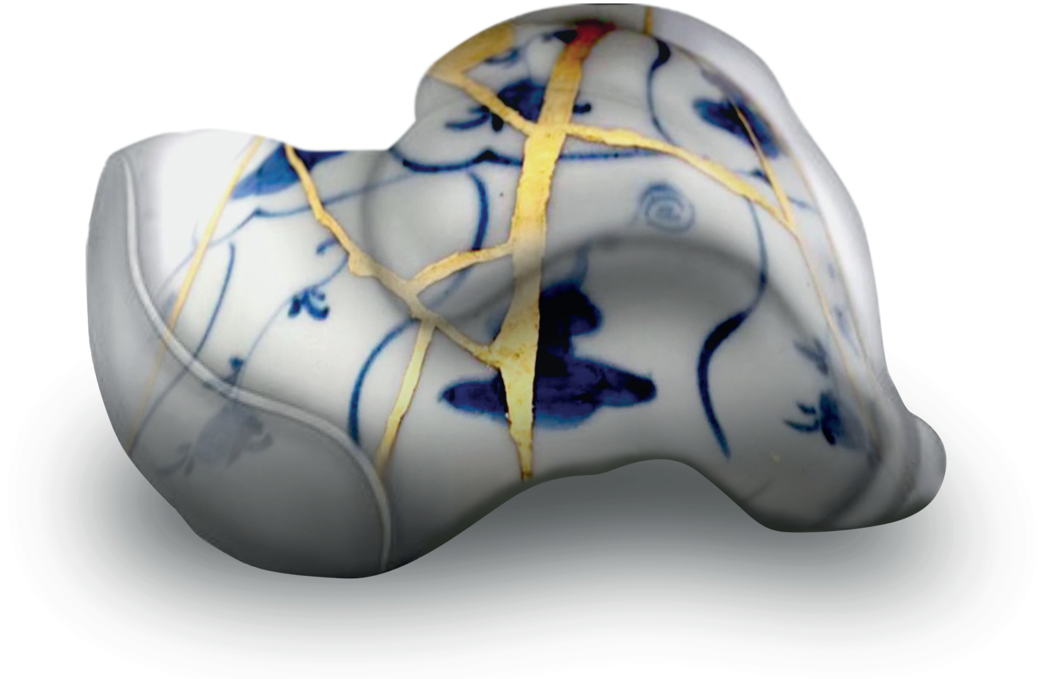
Posterior Process



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Systematic review: Diagnostics, management and outcome of fractures of the posterior process of the talus

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ABSTRACT

Background: Fractures of the posterior process of the talus are rare and frequently overlooked, possibly leading to pseudo-arthrosis and chronic pain. To gain more insight into the diagnosis, treatment and outcome of fractures of the posterior process of the talus (PPTF), a systematic review of the current literature was performed to provide recommendations for the management of PPTF.

Methods: A literature search in the electronic databases of PubMed, EMbase, Google Scholar and Cochrane library was performed in January 2020 to identify all clinical studies on PPTF with more than three patients. Amongst other variables, the type of study, number of patients, mechanism of injury, type of fracture (anatomy), imaging modality, treatment, postoperative protocol, outcomes, complications and duration of follow-up were noted for systematic analysis of the available evidence, adherent to the PRISMA guidelines.

Results: Seven original studies were included with a total of 66 patients. More than one third of patients presented with a (sub)talar joint dislocation (n = 25, 37.9%) and 51.5% sustained associated ipsilateral lower extremity fractures (n = 34). Delayed diagnosis occurred in 36.4% of patients (n = 24). Out of 48 patients with outcome data available, 41.7% (n = 20) reported impaired function. In the non-operative group, 64.7% (n = 11) had impaired functional outcome, compared to 33.3% (n = 6) in the ORIF group, and 30.8% (n = 4) in the fragment excision group ($p < 0.001$). One third of the patients developed one or more complications (n = 25, 37.9%), mostly found in the non-operatively treated group (73.7%, n = 14) compared to ORIF (25.0%, n = 8, $p < 0.001$).

Conclusion: Early recognition and timely treatment is warranted in order to achieve pre-injury functional outcome and reduce morbidity. Given the significantly higher complication rate and lower return to the previous level of functionality reported after non-operative treatment, ORIF is recommended if there is (even minimal) displacement, articular involvement or if the fracture extends into the talus body.

Level of evidence: IV

Keywords: Posterior process fracture, Cedell fracture, Foot injury, Talus, Trauma, Shepherd fracture, Stieda's process

INTRODUCTION

Talar fractures constitute 0.32% of all fractures and usually involve the talar head and neck.[1] Posterior process fractures of the talus (PPTF) are rare. Shepherd was the first in history to describe a fracture of the lateral posterior tubercle in 1882.[2] A century later, Cedell was the first to publish a case series (n = 4) of posteromedial process fractures of the talus in 1974.[3] The posterior talar process consists of a lateral (Stieda's process) and medial tubercle. The posterior lateral talocalcaneal and talofibular ligament are attached to the lateral tubercle whereas the posterior part of the deltoid and the medial talocalcaneal are attached to the medial tubercle. The groove for the flexor hallucis longus (FHL) is situated in between the two tubercles. Thus, fracture of the entire posterior process could lead to detachment of the posterior talofibular and part of the deltoid ligament, potentially causing ankle instability. Fractures of the posterior talus may cause damage in two joints: the posterior facet of the subtalar joint and the tibiotalar joint, increasing the risk of osteoarthritis, persistent pain and reduced function.[4] PPTF is described both due to direct and indirect trauma, including sports injuries, falls from height and motor vehicle accidents.[5] Cedell previously described the lesions in his case study of young active sportsmen as avulsion fractures after an acute increase of tension in the posterior tibiotalar ligament (PTTL) with forced dorsiflexion in pronation.[3] Since then, alternative mechanisms of injury have been suggested, including forced plantar flexion with or without inversion of the ankle, resulting in compression of the posterior process between the calcaneus and tibia.[6,7] Given the clinical similarity to an ankle sprain and the high false negative rate on conventional radiography, PPTF is prone to misor delayed diagnosis.[8,9] Due to the low incidence and lack of high-quality studies, guidelines and clear recommendations for the management of PPTF are not available. To gain more insight into the diagnosis, treatment, and outcome of PPTF, a systematic review of the current literature was performed to provide recommendations for the management of PPTF.

METHODS

Eligibility criteria

All clinical studies concerning PPTF with full text availability were included in the review. Publications from predator or chiropractic journals were excluded.[10] Case series with less than three patients, cadaver studies, and reviews were excluded from the analysis. Non-English studies were translated if required. There were no limitations with respect to patient age or the year of publication. This review adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines.

Search strategy and information resources

The electronic databases of PubMed, EMbase, Google Scholar and Cochrane library were searched in January 2020 to identify all studies including case series (n > 3 patients) on posterior process fractures of the talus. The following search terms and Boolean queries were used: Talus OR Talar AND Posterior OR Cedell OR Shepherd OR Stieda AND Fracture. To obtain additional studies, a comprehensive search of all references in the included studies was performed.

Variables

The year of publication, type of study, number of patients, gender, age, mechanism of injury, type of fracture (anatomy), imaging modality, treatment, postoperative protocol, primary outcomes, complications and duration of follow-up were noted for systematic analysis of the available evidence. Complications were defined as wound infection, chronic pain, impaired range of motion (ROM), non-union as described by the authors, post-traumatic osteoarthritis and secondary arthrodesis or other surgical intervention.

Qualitative synthesis, e.g. systematic review of included articles, was performed.[11] After the literature selection process, none of the studies could be included for quantitative synthesis, also called meta-analysis, due to clinical, methodological and statistical differences between included papers. Descriptive analysis was performed for all included studies.

Statistical analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences, version 24 (IBM Corp, Armonk, NY). Numeric data are expressed as means or median. Categorical data are shown as numbers with percentages. The Z-score test and Fisher exact test (using a 3 ×2 contingency table) with a significance level of 0.05 were used to compare percentages.

RESULTS

Following systematic literature search and selection, seven original research articles were included for analysis (Fig. 1). Details of included articles are listed in Table 1. All studies were retrospective case series (level IV evidence) and were published between 1974 and 2019. A total number of 66 patients with a range of 4–29 patients per article were included. Gender was mentioned for 56 patients of which 58.9% was male (n = 33). The average age at injury was 34.3 years (data available for n = 66).

Fracture types

The majority of publications included fractures of the posteromedial part of the talus (Cedell fractures, n = 5), one eligible study did not describe the type of PPTF[12] and one study included

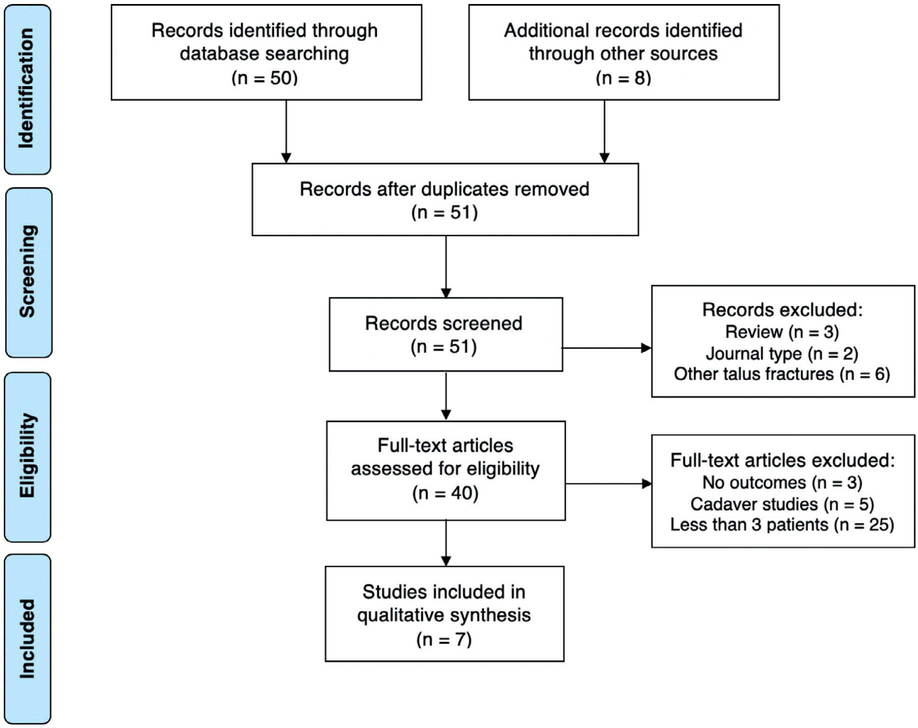

Fig. 1. Flow diagram (PRISMA 2009).

all types.[13] In total there were 43 Cedell fractures (65.2%), seven Shepherd fractures (10.6%), seven fractures of the entire posterior process (10.6%) and nine fractures of an unknown type (13.6%).

Trauma mechanism

The mechanisms of injury included: fall from height (n = 22), motor vehicle accidents (MVA, n = 16), fall during daily activities (n = 8), sports injuries (n = 7), direct trauma (n = 3), or not reported (n = 10). The motion during trauma, reported in only 11 cases, were inversion (n = 4), forced plantar flexion (n = 3), dorsiflexion (n = 3) or direct impact (n = 1).[4,12] More than one third of patients presented with a (sub)talar joint dislocation (n = 25, 37.9%) and 51.5% of patients sustained associated ipsilateral lower extremity fractures (n = 34).

Imaging

Except for the first and oldest publication by Cedell,[3] imaging workup was done using both radiography and CT in all studies. Delayed diagnosis or missed fractures (all radiographic non-union) were found in more than one third of all patients (n = 24, 36.4%). In fact, the oldest five out of seven studies primarily described fractures missed at the initial trauma assessment. The mean period between injury and the beginning of treatment in this group was 38 weeks for

Table 1 Characteristics and details of included studies.

Author	Year	N	Age (y)	Mechanism	Delay	Other ipsil. #	Treatment (n)	Outcome	Impaired function	Complications	FU (m)
Cedell[3]	1974	4	26	Sport (4)	4/4	0/4	Fragment excision (3), non-operative (1)	Sports	0/4	0	21
Veazey[12]	1992	9	38	Not reported (9)	9/9	0/9	Fragment excision (9)	Pain, function	3/9	3/9 Chronic pain (3), sural neuroma (2), subtalar arthritis (1), secondary fusion (1)	27
Ebraheim[8]	1995	4	35	MVA (4)	2/4	4/4	Recent: ORIF (2) Delayed: non-operative (1), fragment excision (1)	Pain, ROM	2/4	3/4 Chronic pain (2), nonunion (1), osteoarthritis (1), secondary fusion	10
Nyska[4]	1998	4	30	Height (2), daily activities (2)	4/4	1/4	Non-operative (4)	Pain, ROM, activity	4/4	4/4 Chronic pain	30
Giuffrida[20]	2003	6	34	Height (4), MVA (1), direct trauma (1)	4/6	2/6	Non-operative (6)	Pain function	5/6	6/6 Chronic pain (5), osteoarthritis (6), secondary fusion (5)	10
Swords[14]	2018	10	35	MVA (5), height (3), daily activities (1), direct trauma (1)	0/10	4/10	ORIF (10)		Not reported	2/10 Ankle cheilectomy (1), gastrocnemius recession (1)	58
Wijers[13]	2019	29	42	Height (13), MVA (6), daily activities (5), sport (3), direct trauma (1), not reported (1)	1/29	23/29	Recent: ORIF (19), ORIF + primary arthrodesis (2), non-operative (7). Delayed: ORIF (1)	AOFAS, FFI, EQ-5D	6/21	7/29 Chronic pain (5), osteoarthritis (6), wound infection (1)	72

Columns from left to right: first author, year of publication, number of patients, mean age (years), mechanism of injury, number of patients with delayed diagnosis / total number of patients, associated other ipsilateral fractures, treatment (number of patients), outcome variable, number of patients with impaired function / total number of patients, complications (number of patients), mean follow-up (months). MVA: motor vehicle accident, Height: Fall from height, ORIF: open reduction internal fixation, ROM; range of motion.

operative treatment (median 38, range 3–52 weeks) and 12 weeks for non-operative treatment (range 6 weeks to 4 years, mean 36 weeks).

Management

With respect to management, most patients were treated operatively with open reduction and internal fixation (ORIF) (n = 32, 48.5%), followed by non-operative treatment (n = 19, 28.8%), fragment excision (n = 13, 19.7%) or primary arthrodesis (n = 2, 3.0%) (Table 1). In the group of cases with delayed diagnosis (n = 24), most patients were treated with fragment excision (n = 13, 54.2%), via a lateral (n = 7) or medial (n = 6) approach, compared to 10 patients who were managed without surgery (41.7%) and one patient with ORIF at three weeks after trauma. In the group of patients diagnosed immediately after trauma (n = 42), the majority was managed operatively with ORIF through a posteromedial approach (n = 31, 70.5%) or primary arthrodesis (n = 2) compared to nine patients treated non-operatively (21.4%).

ORIF was performed in three studies. Ebraheim et al. used K-wire or screw fixation without providing further details.[14] Swords et al. reported the use of a mini fragment plate (2.0 or 2.4 mm) slid over provisional K-wires holding the anatomic reduction and secured by 2.4 or 2.7 mm screws (using lag technique or standard fashion in case of comminution or bone loss). [15] Wijers et al. did not mention the type of ORIF.[13] In general, the postoperative treatment consisted of 3 to 6 weeks of nonweightbearing, with or without casting, followed by 2 to 4 weeks of partial weightbearing and physiotherapy. Non-operative treatment usually involved closed reduction and immobilization in a cast, boot or brace for 2 to 7 weeks.

Functional outcome

The mean period of follow-up of the included studies was 32.6 months (median 27, range 10 to 72 months). The most recent study by Wijers et al. was the only study in which validated outcome scores were reported for 21 patients.[13] The mean Foot Function Index score was 1.8 (range 0.0–10, 0 = perfect), mean AOFAS score was 78.7 (range 0–100, 100 = perfect) and mean quality of life EQ5D was 0.78.[13] Five out of seven studies descriptively reported outcome, including pain, function, range of motion and return to sports and/or daily activities. One study did not report outcome.[15] As a result, outcome data was available for 48 patients including all patients with delayed diagnosis. For the patients treated directly after trauma, data were available for 17 patients treated with ORIF and 7 non-operatively treated patients.

Out of the 48 patients, 20 reported impaired function (41.7%) of which 70% were patients with a delay in diagnosis (n = 14), 45% had additional ipsilateral lower extremity fractures (n = 9) and 45% presented with a (sub)luxation (n = 9). In the non-operative group, 64.7% (n = 11) had impaired functional outcome, compared to 33.3% (n = 6) in the ORIF group and 30.8% (n = 4) in the fragment excision group ($p < 0.001$). Of the cases diagnosed in time, 70.6% of patients in the ORIF group (n = 12) and 71.4% (n = 5) of the non-operative group returned to their daily activities and sports without complaints. Of the cases with a delayed diagnosis, 69.2% (n = 9) of patients after fragment excision compared to only 10% (n = 1) of patients after non-operative treatment had achieved non-impaired functional outcome ($p < 0.001$).

Complications

Complications were analysed for the total number of 66 patients. One third of the patients developed one or more complications (n = 25, 37.9%). The most common complication included chronic pain (n = 19, 28.8%), followed by symptomatic posttraumatic osteoarthritis (n = 14, 21.2%) and secondary arthrodesis (n = 7, 10.6%). All secondary arthrodesis were subtalar joint (STJ) fusions, of which five fractures were initially missed injuries.

Most complications were found in the non-operatively (both delayed and timely) treated group with a rate of 73.7% (n = 14) compared to 25.0% (n = 8) in the ORIF group ($p < 0.001$). One quarter of non-operatively managed patients eventually underwent STJ fusion (n = 5, 26.3%) compared to one patient in the fragment excision and one patient in the ORIF group ($p < 0.001$). In the ORIF group, complications included four cases of painful posttraumatic osteoarthritis, one wound infection, one STJ fusion in a patient with complete destruction of the talus and two other surgical re-interventions (ankle cheilectomy and gastrocnemius recession). Additionally, there was an implant removal rate of 18.8% due to persistent pain and limited range of motion (n = 6). In the fragment excision group the complication rate was 23.1% (n = 3), of which there were two cases of painful sural neuromas after a lateral approach.

DISCUSSION

Key findings

PPTF was found to be associated with (sub)talar joint dislocation and/or other concomitant lower extremity fractures. Standard imaging workup included CT, yet timely diagnosis may still be challenging given the high rate of delayed diagnosis found in the literature. Most patients who were diagnosed immediately were treated operatively with ORIF through a posteromedial approach and more than two thirds of patients returned to their daily activities and sports without complaints. In case of delayed or missed diagnosis and persistent ankle pain, fragment excision was found to be the most common treatment strategy with the best results. In total, one third of patients developed one or more complications. A significantly higher rate of impaired function and complications were found in the non-operative (both delayed and timely treated) group.

Type and mechanism of injury

Review of the literature demonstrates that PPTF rarely involves the entire posterior process.[1] Isolated fractures of either the medial or lateral tubercle are more common.Various mechanisms of injury resulting in PPTF were described in the literature. Cedell suggested forced dorsiflexion in pronation,[3] while Veazey and Dougall proposed acute dorsiflexion following direct trauma causing avulsion of the PTTL and associated fractures of the sustentaculum tali and lateral malleolus.[12,16] In contrast, others proposed that PPTF occurred due to forced plantar flexion with or without inversion of the ankle, resulting in compression of the posterior process between the calcaneus and tibia inversion of the ankle.[6,7,17] Alternatively, it has been hypothesized that this type of talar fracture is a consequence of direct impingement in plantar flexion in which the posterior tibial margin impresses on the posterior talar body.[18] PPTF can therefore either be caused by indirect force such as in basketball injuries or by direct force, such as during high-velocity trauma or falls from height. Indirect trauma may result in an avulsion fracture caused by forced dorsiflexion and pronation, or a (mostly non-displaced) split fracture after plantar flexion and supination by landing or sliding offthe stairs. Entire posterior process fractures were mainly caused by high-energy trauma and rarely occurred as an isolated injury.[1]

Diagnosis

Timely diagnosis is crucial for the functional outcome, given the high rate of complications and impaired function in patients in whom PPTF was missed during initial trauma assessment. Next to the three routine trauma views, conventional radiographic workup may include additional oblique views (30-degree, 45-degree and 70-degree external rotation). Giuffrida et al. argued that a delayed diagnosis was due to misdiagnosis of the fracture fragment as os trigonum. They referred to the radiographic aspect of a posteromedial process fracture as the "pseudo os trigonum sign".[19] Since the sensitivity of radiography for the recognition of talar fractures is only 78%, a CT scan should be made at a low threshold in case of high suspicion or persistent complaints following negative conventional imaging.[14,20] In addition, CT imaging was recommended for the assessment of size, displacement, comminution and articular involvement to guide treatment.[14,19] Veazey et al. described the beneficial use of a 99Tc bone scan in 1992, however, no studies have since described the use of this scan for PPTF.[12] MR imaging of the ankle in patients with severe hind foot pain and/or instability following a traumatic incident was advocated by various authors, in order to evaluate the cortical margins for fractures and peripheral areas of the bone for marrow edema.[8] However, this modality was not found in our review. An interesting finding was that almost all patients with a delayed diagnosis were found in the oldest studies from 1974 until 2003. This may be due to recent advances in radiology, e.g. CT technology and interpretation, or increased awareness and recognition of rare foot fractures including PPTF among surgeons.

Management

Information regarding the indication for surgery (fragment excision or fixation) was not always provided. Nevertheless, the authors of publications including patients treated with ORIF, stated that in general, non-displaced or minimally displaced fractures were treated non-operatively, whereas patients with displaced fractures and soft-tissue conditions fit for surgery were managed with ORIF.[13–15] Veazey et al. published the largest case series of fragment excision and included patients who presented after unsuccessful non-operative management.[12] Fragment excision was done at a mean time of 9.4 months after injury.[12] Interestingly, no cases of fragment excision were described since 1995, suggesting this method may have been abandoned.

Based on the literature, non-operative treatment is not recommended due to poor functional outcome and persistent pain. There is some consensus in the literature that ORIF is the treatment of choice for posterior process fractures with dislocation and/orintra-articular gaps or step-offs (> 3 mm).[6,13,14,18,21,22] No other clear indications for surgery were mentioned in the literature. Two main approaches are recommended for open reduction and internal fixation of PPTF: the posteromedial approach and the oblique medial malleolar osteotomy approach, associated with a lower risk of surgical neurovascular damage.[15,23] Two examples from our database of PPTF cases are demonstrated in Fig. 2. In case of a missed diagnosis, unsuccessful non-operative management or non-union, the fragment should be excised using a medial (and/or lateral in case of entire posterior process fractures) approach with special attention for the sural or tibial nerve to prevent the development of painful sural neuromas. Ligament instability depends on the size and location of the fragment. The posteromedial approach may be easier because the FHL tendon can be used as a guide. The posterolateral approach is less favorable due to the risk of injuring the sural nerve as seen in the series by Veazey et al. in which two patients developed a sural neuroma.[12] There was no consensus between the included studies on when to fix, when to excide or when to fuse.

Functional outcome

Based on our analysis, patients with PPTF are at serious risk of developing impaired function, especially in case of a delayed diagnosis. Only one third of non-operatively managed patients returned to their normal daily activities, job or sports. The operatively managed group did significantly better, with a return to daily activities and sports in two thirds of patients in both the ORIF and fragment excision group.

Nyska et al. described four initially missed cases of fractures of the posterior process of the talus that were treated non-operatively with either prolonged cast immobilization or early weightbearing and mobilization.[4] The results in all cases were poor with malunion and early degenerative arthritis. Giuffrida et al. identified six cases of posteromedial talar facet fractures that were misdiagnosed as os trigonium fractures and were treated non-operatively.[19] Five out

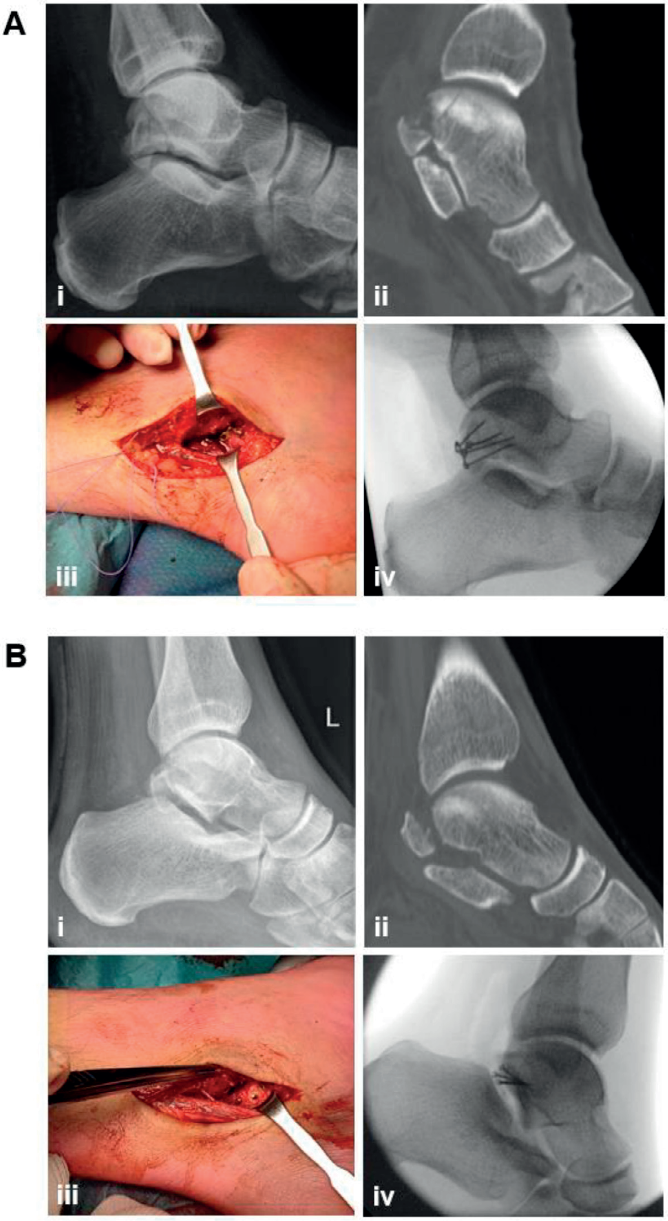

Fig. 2. Two cases of PPTF (A) Preoperative lateral radiograph (i) and computed tomographic (CT) image in the sagittal plane (ii) of a patient with a posteromedial talus fracture with dislocation. The intraoperative photograph shows the posteromedial approach for ORIF using a small 1.5 hand plate and 4 screws, with postoperative results shown in the postoperative lateral radiograph (iv). (B) Preoperative lateral radiograph (i) and computed tomographic (CT) image in the sagittal plane (ii) of a patient with a multifragmentary posteromedial talus fracture (largest 19 ×9 mm in axial view) with diastasis (maximal 8 mm). The intraoperative photograph shows the posteromedial approach for ORIF using 3 ×1.5 screws, after removal of smaller fragments (2–3 mm), with postoperative results shown in the postoperative lateral radiograph (iv).

of six patients underwent secondary arthrodesis due to pain, subtalar joint subluxation and radiographic osteoarthritis. This demonstrates that high clinical suspicion and early diagnosis is crucial, as missed or overlooked injuries show less favourable results, which is a common issue in foot and ankle trauma.[24]

One third of patients developed one or more complications including chronic pain, post-traumatic osteoarthritis or secondary arthrodesis. A significantly higher number of complications were found in the non-operatively (both delayed and timely) treated group compared to patients treated with ORIF. One quarter of non-operatively managed patients underwent secondary arthrodesis, which should be taken into account and discussed with the patient. There is no evidence that Cedell fracture fragment characteristics such as size and articular involvement are related to clinical presentation and joint stability.[19]

Limitations

The study size in the majority of papers was very low and substantial methodological and clinical heterogeneity between studies was observed, such as missed versus recent trauma, type of injury, treatment and outcome measures. Meta-analysis of disparate data could therefore not be performed. Another drawback of the available evidence is the lack of studies that used patient reported outcome measures. In clinical practice, the treatment strategy may also be influenced by the patient's age and related degree of activity and required foot function. Due to small patient numbers in different age groups, no evidence-based conclusions could be drawn. Another important limitation is that many patients sustained concomitant injuries that were likely to bias functional outcome yet could not be further assessed due to the lack of information provided.

CONCLUSIONS

Early diagnosis and timely treatment are warranted in order to achieve pre-injury functional outcome and reduce morbidity. A low threshold for CT-imaging is mandatory in acute foot trauma or in case of persistent complaints. Given the significantly higher complication rate and lower return to the previous activity level reported after non-operative treatment, ORIF is recommended in case of (even minimal, > 3 mm) displacement, articular involvement or if the fracture extends into the body of the talus.[6,13,14,18,21,22] Alternatively, fragment excision may be indicated for smaller, impinging fragments and in case of previously missed fractures, while non-operative treatment is reserved for non-displaced fractures only. Like in any other injury, it is recommended to tailor management to the patient's needs a needs.

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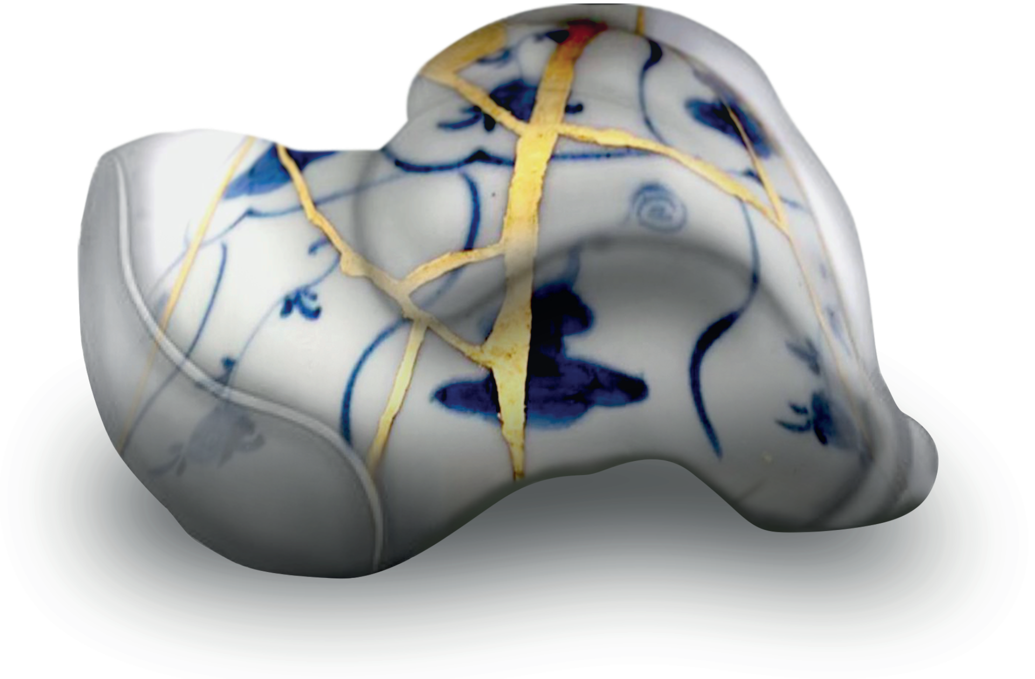
Medial Process



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Extra-articular Medial Impression Fracture of the Talus: A Previously Undescribed Injury

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Tim Schepers, MD, PhD

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ABSTRACT

Background: Peripheral fractures of the talus are uncommon. Almost all the literature regarding talar fractures consists of central intra-articular fractures, whereas studies about peripheral talar fractures are lacking. The aim of this study is to increase awareness in diagnosing an unusual peripheral extra-articular medial impression fracture of the talus.

Methods: This study includes a retrospective case series of patients with an extra-articular medial impression fracture of the talus. Patient characteristics, trauma mechanism, diagnostics, fracture characteristics, and treatment were reported.

Results: Eight consecutive patients with an extra-articular medial impression fracture of the talus were identified. In 80%, the trauma mechanism was a supination or inversion injury of the ankle and foot. An X-ray was obtained in all patients; in 7 (88%) patients, a computed tomography scan was done, and an additional magnetic resonance imaging was done in 3 (38%) patients. In 4 patients (50%), the correct diagnosis was missed at first presentation. The delay between injury and diagnosis was 0 to 180 days (of 36 days on average).

Conclusion: This is the first case series to describe patients with a peripheral extra-articular medial impression fracture of the talus. Good clinical examination and judicious use of diagnostic imaging are a necessity to find the talar impression fractures in a timely manner, and treatment can be started immediately.

Levels of Evidence: Level V

Keywords: talar fractures; ankle injuries; trauma; tarsal tunnel syndrome; fractures; sprains; strains

INTRODUCTION

The talar anatomy is unique because no muscular attachments are present, and more than half (65%) of the surface is covered by articular cartilage.[1,2] Fractures of the talus are uncommon with an estimated incidence ranging between 0.1% and 0.85% of all fractures.[2,3] Because they are rare, most of the literature comprises retrospective case series. This hampers the creation of high-quality guidelines on the optimal management of different talar fractures.

Currently, the most common classification of talar fractures is into fractures of the head, the neck, and the corpus from which the posterior and lateral process emanate.[2,4,5] Alternatively, they are divided into peripheral and central fractures. Neck and corpus fractures are considered central injuries, whereas the process fractures are deemed peripheral fractures. Of importance for the treatment and the clinical outcome is whether the fracture is located intra-articularly or extra-articularly. Because of the fact that a large percentage of the talus is covered with cartilage, the percentage of intra-articular injuries is greater than the extra-articular injuries. Subsequently, almost all the literature is related to intra-articular fractures.[1,2,6,7] One previously described example of an extra-articular fracture is a dorsal avulsion fracture.[8] We present a case series of 8 patients with an unusual extra-articular medial impression fracture of the talus that, to the best of our knowledge, has not been previously described in the medical literature. The aim of this study is to increase awareness in diagnosing an unusual peripheral extra-articular medial impression fracture of the talus.

PATIENTS AND METHODS

The present study describes a retrospective series of trauma patients who presented to our emergency department or outpatient clinic of a level 1 trauma center between January 1, 2000, and August 1, 2017. Consecutive patients with an extra-articular medial impression fracture of the talus were included.

The mechanism of trauma was evaluated by assessing the patient's history. After clinical examination with suspicion of an ankle injury, a standard X-ray was done with an anterior-posterior (mortise) view and a lateral view. When there was any suspicion of a talar fracture an extra computed tomography (CT) scan was done with coronal, axial, and sagittal views and 3D reconstruction. In case of persisting complaints or evaluation of ligamentous injury, an additional magnetic resonance imaging (MRI) scan was obtained. All radiographic images were reviewed by a radiologist and a trauma surgeon. Indication for surgery was made by the trauma surgeon based on fracture characteristics. Patient characteristics (age at trauma and gender), trauma mechanism, diagnostics needed to diagnose, fracture characteristics (type of fracture and affected side), and treatment were extracted from the electronic medical files, picture archiving, and communication system. The patients were evaluated at the outpatient clinic until the fracture was consolidated.

RESULTS

A total of 8 consecutive patients with an extra-articular medial impression fracture of the talus were identified. Male patients were on average 39 years old, whereas female patients were 54 years old. Patient, injury, and treatment characteristics are described in Table 1.

Table 1. Patiënt, Injury, and Treatment Characteristics.

Case No.	Gender	Age (years)	Side	Trauma	Time to Diagnosis (days)	Imaging	Treatment
1	M	18	L	Inv+Ev	15	X, CT	Surgical
2	F	52	L	MVA	0	X, CT, MRI	Delayed surgical 4 months
3	M	53	L	Inv (dislocation)	0	X, CT	Nonoperative
4	M	43	R	Inv	5	X, CT	Nonoperative
5	F	64	R	Inv	90	X, CT	Nonoperative
6	F	39	R	Inv	0	X, CT, MRI	Nonoperative
7	M	43	L	MVA	180	X, MRI	Nonoperative
8	F	54	L	Inv	0	X, CT	Nonoperative

Abbreviations: M, male; F, female; L, left; R, right; Inv, inversion; Ev, eversion; X, X-ray; CT, computed tomography; MRI, magnetic resonance imaging; MVA, motor vehicle accident.

In all but 2 cases (patients 2 and 7), the trauma mechanism was a supination or inversion injury of the ankle and foot. This happened to 3 patients during sports (patients 1, 5, and 8) and in 3 patients during regular daily activities (patients 3, 4, and 6). In 1 case (patient 3), the emergency personnel reported that a reduction maneuver was performed because of expected fracture dislocation of the ankle. Two patients had a motor vehicle accident (patients 2 and 7).

The correct diagnosis was missed at first presentation at the emergency department in 4 cases. In these cases, the time to diagnosis was 5, 15, 90, and 180 days, respectively (median 52 days). The correct diagnosis was made in all these cases after additional CT or MRI scans were done for persisting complaints.

In all cases, orthogonal X-ray studies were obtained. In only 2 of these, small fragments were visible on the medial side. In 7 out of 8 cases, the initial X-ray was combined with a CT scan. In

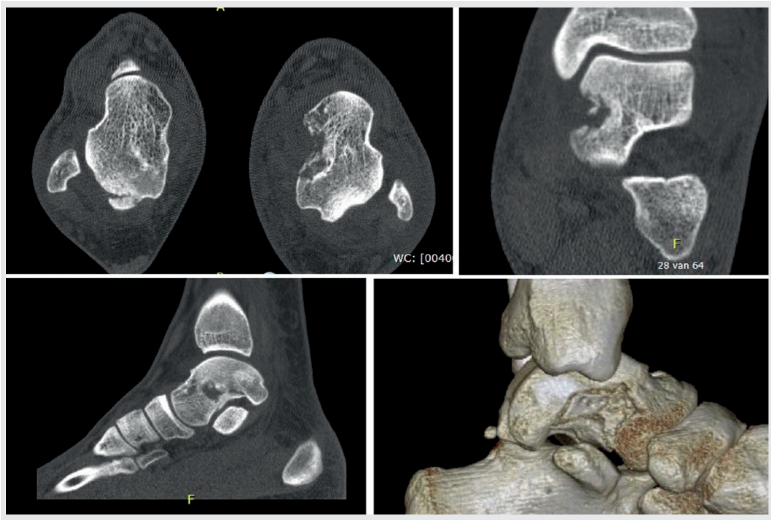

Fig. 1. Medial impression fracture of the talus on computed tomography (case 1): A. Coronal view. B. Axial view. C. Sagittal view. D. 3D reconstruction medial view.

Fig. 2. Medial impression fracture of the talus on conventional radiograph and computed tomography (case 4): A. Anteroposterior view on radiograph. B. Axial view on computed tomography. C. Coronal view on computed tomography. D. Sagittal view on computed tomography.

all cases, an extra-articular medial impression fracture of the talus was visible on CT examination, including 3D CT reconstructions (Figures 1 and 2).

In 3 cases, an MRI scan was made because of persisting complaints and evaluation of extensive ligamentous injury, all of which showed the extra-articular medial impression fracture slightly more anterior than the insertion of the deep portion of the deltoid ligament. In case 2, 6 weeks after trauma, the MRI showed a longitudinal partial rupture of the posterior tibial tendon, an injured calcaneofibular ligament (CFL), an anterior talofibular ligament (ATFL), and a deltoid ligament in combination with an avulsion fracture of the medial malleolus. In case 6, 3 weeks after trauma, a complete rupture of the ATFL (grade 2/3) and a rupture of the CFL (grade 1) were seen laterally and a partial rupture of the deltoid ligament of the deep compartment (grade 2) medially. In case 7, the MRI scan was done after 180 days because the injury was overlooked initially. The MRI showed an injury to the deeper compartment of the deltoid ligament, the ATFL, and the CFL.

A detailed study of the medial talar impression fractures revealed that the fracture was a result of what seemed a direct impression of the medial malleolus at severe inversion combined with dorsiflexion. Only in a single case (case 4) was the fracture a result of impression of the navicular bone.

Operative Treatment

An operative treatment was deemed necessary in patients 1 and 2. In patient number 1, a tarsal tunnel release was performed after 2 years because of compression of the posterior tibial nerve caused by scar tissue. In patient number 2, the initial procedure comprised a cortical bone graft of the defect using a graft from the distal tibia (Figure 3).

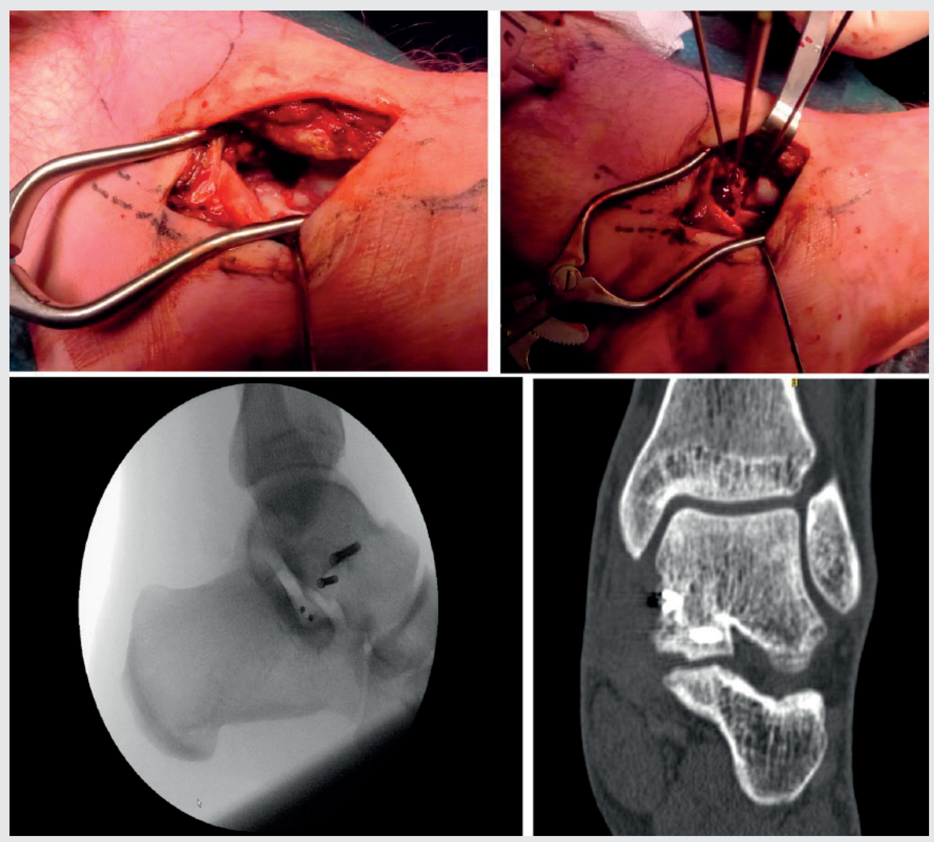

Fig. 3. Perioperative views (case 1): A. Medial incision showing the talus defect. B. Bone graft fixation using K-wires. C. Lateral view on radiograph showing bone graft fixation with 2 screws. D. Axial view on computed tomography showing the filled medial talar defect with 2 screws after 1 year.

DISCUSSION

In this study, we describe 8 patients with a peripheral extra-articular medial impression fracture of the talus, which to the best of our knowledge, has not been previously described in the literature. Not much is written about different peripheral extra-articular talar fractures.[4,5,9,10] Peripheral talar fractures include lateral process fractures, posteromedial talar body fractures, and talar head fractures. Because the talus contributes to 3 joints of the foot and up to 65% of the talar surface is covered by articular cartilage, the majority of the reported talar fractures are of an intra-articular nature.[3]

Only 2 other case reports about a peripheral extra-articular medial fracture of the talus were found in the literature. Neither of these describe impression fractures specifically. Kostlivý et al[9] describe a case with a medial extraarticular avulsion fracture of the talus in combination with a fracture of the medial malleolus, a chondral fracture of the talar trochlea, and a partial rupture of the deltoid ligament after a fall from a horse. Excision of the avulsed cartilage fragment was performed in combination with open reduction and internal fixation of the avulsed bony fragment and malleolus, which resulted in full functional recovery. In the prospective study by Fallat et al,[11] 639 patients with ankle sprains were included. The authors used a standardized evaluation during the initial examination. Only 1 case (0.2%) of a medial talar avulsion fracture was reported.

Peripheral talar fractures are frequently overlooked on initial presentation, which may partly be because they are mistakenly diagnosed as ankle sprains.[4,12] Typical clinical signs of talar fractures are acute local tenderness, swelling, and hematoma in combination with pain on active and passive range of motion of the ankle and the subtalar joints. The medial side of the talus was the most prominent painful area in our patient group.

Peripheral talar fractures may not be found on conventional radiographs because findings are often very subtle. Up to 40% of these fractures are misdiagnosed at the initial presentation.[4,12] With clinical suspicion of a talar fracture, a structural clinical evaluation must be combined with a CT scan with coronal, axial, and sagittal reconstructions.[13] When a talar fracture is seen on the conventional radiographs, a CT scan is also advised for correct classification of the fracture and, where necessary, preoperative planning.

MRI scans can be helpful in the initial assessment to evaluate ligamentous injury. In our series, we found that in all 3 patients who underwent a MRI scan, the ATFL and the CFL were ruptured. We hypothesize that in the rest of the patients with persisting complaints, these lateral ligaments were also at least partly ruptured. Undertreatment of these ruptures could possibly lead to prolonged complaints. We, therefore, argue that a MRI scan should be part of the routine workup in case of suspicion of an unstable subtalar joint during initial examination. Furthermore, the MRI scan is useful during follow-up for the assessment of talar osteonecrosis.[14]

The trauma mechanism responsible in nearly all our cases was forced inversion-dorsiflexion of the ankle. In this type of trauma, injuries occur at predetermined locations along the supination line.[12] Therefore, compression fractures of the talus can be found on the medial side, as seen in our patients.

A fall from height with forced dorsiflexion and motor vehicle accidents are frequently described as causative incidents.[15] In their case report, Kostlivý et al[9] describe that pronation and dorsiflexion leads to avulsion of a bone fragment of the medial aspect of the talar dome simultaneously with rupture of the remaining fibers of the deep tibiotalar portion of the deltoid ligament. The most closely resembling peripheral fracture at the medial side of the talus is the fracture of the medial tubercle of the posterior process. The mechanism of injury of this type of fracture is thought to be a pronation-dorsiflexion force causing avulsion of the insertion of the posterior deltoid ligament.[4]

Talar fractures can present as an isolated fracture in combination with additional injuries. The talus consists of strong subchondral cortical bone. This explains why a high percentage of patients sustaining talar fractures are multiply injured.[3,15,16] A commonly reported additional injury to the talar fracture is an ipsilateral fracture of the medial malleolus.[15] In our case series, the medial malleolus was part of the trauma mechanism that caused the medial impression fracture of the talus.

In peripheral extra-articular talar fractures, the size, displacement, and comminution of the fracture fragments will determine the need for operative or conservative treatment. What is important is anatomical reduction, restoration of axial alignment, and preservation of motion. This minimizes the risk of early subtalar degenerative changes and helps avoid long-term complications, including malunion, nonunion, and also severe subtalar joint osteoarthritis. The standard treatment for extra-articular medial impression fracture of the talus is immobilization and physiotherapy.[1,4,17] In the case of small, undisplaced extra-articular chip or avulsion fractures without instability, nonoperative treatment is also the treatment of choice. Minimally displaced intra-articular fragments should be managed by excision of the fragment. In all other displaced intra-articular fractures, anatomical reduction and internal fixation is necessary to restore joint mechanics, facilitate fracture union, and allow early range of motion.[2,3,18] In one of our patients, the defect of the medial compression fracture caused by the medial malleolus resulted in instability of the subtalar joint. A cortical bone graft was placed to fill the defect using a graft from the distal tibia, thus restoring ankle stability. When treated non-operatively, deformity of the talar bone can lead to compression of the posterior tibial nerve and may require secondary intervention. In this case series, a talar tunnel release was performed in 1 patient 2 years after initial trauma because of symptomatic compression of the posterior tibial nerve.

Because of the tenuous blood supply of the talus and its many articulations, different talar fractures carry their own distinct set of complications and outcomes. Frequently described complications are avascular necrosis, posttraumatic subtalar arthrosis, delayed union, nonunion, impingement syndromes, and tarsal tunnel syndrome.[1-3,5-7,15]

Because this is a case series with a low case number, we can only describe the characteristics of these types of peripheral talar fractures. Further research is required with large patient numbers to draw conclusions about a standard treatment.

CONCLUSION

To the best of our knowledge, this is the first case series to present extra-articular medial impression fractures of the talus. The mechanism of trauma was a supination injury in all but 2 cases. Good clinical examination and judicious use of diagnostic imaging modalities are a necessity to find these elusive talar impression fractures in a timely manner, so that treatment can be started immediately.

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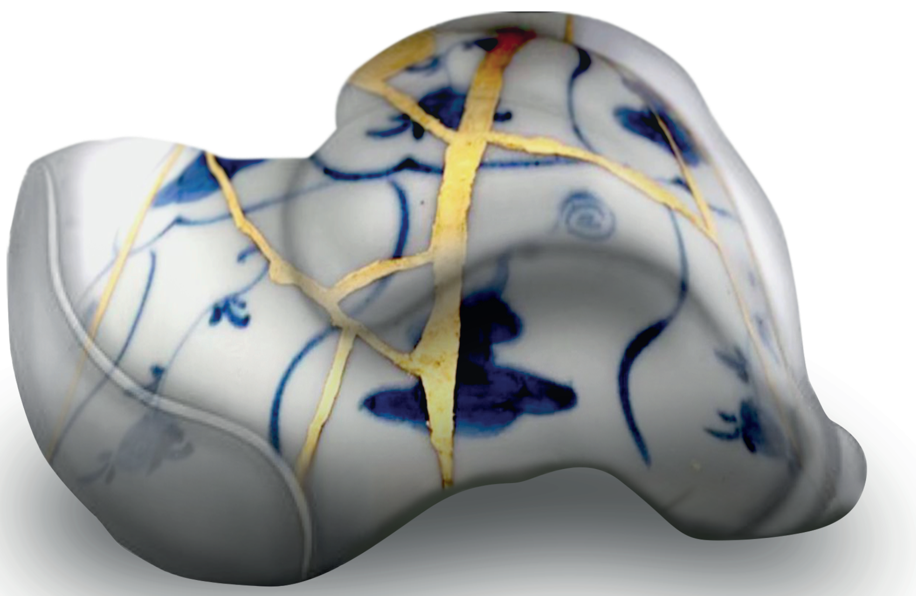

10

General discussion

DIAGNOSTICS

Talar fractures are uncommon and can share clinical findings with an ankle sprain. Therefore, they are frequently overlooked and prone to missed or delayed diagnosis.[18,20] Evidence showed that delayed recognition of a talar fracture may have severe consequences since delayed treatment leads to impaired functional outcomes.[10] Standard imaging workup includes plain radiographs of the ankle in lateral and mortise views. Additional radiographic views may be used to detect peripheral fractures. Although plain radiography has low costs, is time efficient and generally available, the sensitivity for the recognition of a talar fracture is only 74%.[4] Especially talar dome, osteochondral fracture, lateral process fracture, and posterior (posteromedial and posterolateral) process fracture are the most frequently missed fracture sites on plain radiology.[4] In our study with 8 extra articular medial impression fractures of the talus the correct diagnosis was missed in 50 % at first presentation at the emergency department. The median time to diagnose was 52 days and in all these cases the correct diagnosis was made with the use of an additional CT or MRI scan.[35] Therefore, the use of computed tomography (CT) as golden standard is advised. [4]Not surprisingly, in a study of 132 talar fractures, it was found that in 93% of the patients, a CT-scan revealed additional information that was not identified on initial plain radiography.[4] Especially the displacement, articular involvement, and comminution of talar fractures cannot be appreciated as well on plain radiology. We suggest that, if the patient presents after a high-velocity trauma and/or swelling and hematoma of the ankle, along with a painful range of motion, this should raise the suspicion of a central talar fracture. A distorsion/inversion trauma with acute local tenderness, swelling, hematoma and pain with active and passive range of motion of the ankle and the subtalar joints should raise the suspicion of a peripheral talar fracture. In these cases, an additional CT scan should be performed to diagnose or rule out any kind of talar fracture.[17]

MRI scanning was found not to be commonly used in the early stage, however may prove useful if the patient presents with persistent complaints 4-6 weeks following injury. MRI can identify osteochondral lesions and it can be helpful in the assessment of ligamentous injuries. In one of our series, in all 3 patients that had an additional MRI scan, the anterior talofibular ligament, and the calcaneofibular ligament were ruptured.[35] These findings often do not result in an operative treatment but can tribute to good patient expectation management and targeted physiotherapy. PET-CT was the preferred imaging modality to confirm the clinical suspicion of infected AVN.[8] Recently, analysis of the efficacy of FDG-PET-CT to differentiate between aseptic and septic delayed union in the lower extremity was found to be promising with a diagnostic accuracy of 70%.[32]

CLASSIFICATION

The classification of talar fractures can be challenging. Simple classifications are easy in day-to-day use, but may include different fracture types into a single group. More complex classifications with numerous subgroups are a possible solution for this problem, but these are more prone to a low inter-observer reliability. Due to the fact that talar fractures are frequently caused by high velocity trauma the fracture pattern within the talus is often complex and extends to different anatomical regions of the talus. Capturing or describing these complex talar fractures within one classification group is therefore challenging and sometimes even impossible. Different classifications have been used concerning the anatomical location, degree of displacement, and the number of affected joints. Our study by Wijers et al. showed that the Hawkins classification for talar neck fractures and Marti-Weber for body and neck fractures are the most commonly used.[3,13,36] The Sneppen classification is most frequently used for fractures of the talar body.[26] To distinguish between body and neck fractures Inokuchi et al. suggested to use the fracture pattern on the inferior surface of the talus rather than the superior surface.[14] Talar neck fractures were more frequently seen in our systematic review compared to talar body fractures.[36] Also in our retrospective study with the results of 90 central talar fractures there was a mild predominance for talar neck fractures compared to talar body fractures, n= 47 vs n= 43 respectively.[33] A possible explanation for this is the relatively weak cortex of the talar neck which is more prone for traumatic injury compared to the talar body. The Hawkins – Canale classification provides descriptive and prognostic information that correlates well with the vascular supply of the talus. The more displacement the higher the Hawkins classification type and increased risk of an AVN. Previous studies have reported an incidence of AVN after a talar neck fracture of; 14% for Hawkins type I, 20% to 50% for Hawkins type II, 80% to 100% for Hawkins type III, and nearly 100% for Hawkins type IV.[13,22,27]

Peripheral talar fractures are less frequently seen compared to central talar fractures and occur mostly as a part of a more extensive injury with concomitant fractures.[9,34] In our systematic review with 66 patients with posterior process fractures of the talus 51.5% sustained associated ipsilateral lower extremity fractures.[9] Engelmann et al. described 21 talar head fractures all with ipsilateral concomitant injuries mostly in the context of peritalar fracture-dislocations or Chopart injuries.[7] No specific classification system exist for talar head fractures. An impaction of the talar head was seen in more than half of the patients followed by a complete transverse fracture in 19 %.[7]

In chapter six we focused on lateral process talar fractures.[37] The majority of these peripheral lateral process fractures had concomitant and/or contralateral injuries of the lower extremity. To improve inter-observer reliability for the use of date in future studies we modified the classification of lateral process fractures. Our model is based on the severity, intra- or extra-articular location of the fracture, and possible joint dislocation ranging from type 1A to 4B.[37]

OPERATIVE VS. NONOPERATIVE TREATMENT

The combination of patient characteristics, condition of the soft tissue, fracture characteristics, and concomitant injuries makes every patient unique. Tailor-made treatment and management of expectation are mandatory. Given all these variables, selection for operative or nonoperative treatment remains challenging. The talus contributes to three joints of the foot. Consequently, up to 65% of the talar surface is covered by articular cartilage and the majority of the reported talar fractures are intra-articular. The main goal of an operation is achieving anatomical reduction and articular alignment. In general, non-displaced or minimally displaced extra articular fractures can be treated non-operatively, whereas patients with displaced extra articular fractures and soft-tissue conditions fit for surgery are suitable for operative management by means of ORIF. In case of a central and thus intra-articular fractures, only non-displaced or minimally displaced fractures are accepted for non-operative management. In these cases operative treatment should be pursued more aggressively. Unfortunately, literature does not provide a clear guideline of the amount of dislocation that can be accepted for non-operative management in intra- and extra articular fractures. Our systematic review which focused on the complications and functional outcome of surgically treated central talar fractures and included 28 articles did not provide a clear answer because the exact indication for operative treatment was lacking in most studies.[36] We suggest that an intra-articular displacement of < 2 mm is suitable for non-operative treatment.

Nevertheless, central talar fractures are associated with a high incidence of early- and late complications, often leading to impaired functional outcomes.[36] Lindvall et al. showed a union rate of 88% after operative treatment of central talar fractures. In his cohort, all nineteen closed fractures united without additional operations. He suggests that displaced talar neck and/or body fractures should be treated with open reduction and internal fixation.[16] Veazey et al. focused a study on the posterior process of the talus and advocated for fragment excision when non-operative treatment fails to consolidate.[30]

FUNCTIONAL OUTCOME AND QUALITY OF LIFE

In general, a poor outcome and reduced quality of life (QOL) is related to fracture severity.[5,11,21,23,29] Pajenda et al. described good and excellent results in the operatively treated Hawkins type I and II fractures. Only 67% and 63% of the patients having Hawkins III and IV fractures had satisfactory functional outcome scores. None of these patients scored an excellent or good outcome.[21] Surprisingly, our study involving 90 patients which focused on surgically treated talar neck and body fractures did not show a significant association between type of fracture and the reported outcomes. The median Foot function index was 15,7 (3,7 – 35), the mean AOFAS score was 75,9 (28-100) and the QOL EQ-5D index was 0,83 (0,81 – 1).[33] This can be explained by our strategy only to accept minimal intra-articular displacement for non-operative management. A higher classification is most likely due to a higher energy trauma, which is associated with severe soft tissue and cartilage damage and concomitant injuries. Schulze et al. reviewed 79 patients with 80 talar fractures. In their study, they made use of the Marti/Weber classification and found a reduced post-operative range of motion of the ankle and subtalar joint with higher classifications, and thus higher degree of severity of the fracture.[24] Elgafy et al. described a series of 60 different talar fractures with an average follow-up of 30 months. Assessment with three different rating scores; American Orthopedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot Score, Maryland Foot Score, and Hawkins Evaluation Criteria showed that process fractures had the best results above central fractures.[6] When we compare the AOFAS score of our study describing posterior process fractures to our study with central fractures we also see slightly better results in de posterior process group, AOFAS 78,7 vs. 75,9 respectively.[33,34] This is in line with the result of Elgafy et al. described earlier.[6] Anatomic reduction with articular alignment is a strong predictive factor for better postoperative function.[23] The AOFAS score was the most commonly used outcome score and should be considered in future studies, to make the comparison between studies possible.

COMPLICATIONS

Overall, patients selected for operative treatment have a more severe/ dislocated fracture compared to patients treated non-operatively. Logically operated patients are therefore more prone to the development of surgery related complications and impaired functional outcome. In our study with 90 patients with surgically treated central talar fractures, 5 patients scored a poor AOFAS score. Four of these patients had a postoperative complication which needed re-intervention.[33]

For some of the described complications, we must account for the diagnostic tools used to detect the complication. Studies that used a standard CT scan rather than plain radiography in the follow-up, in case of for example posttraumatic arthritis, will detect a much higher arthritis rate.

Overall, the open fractures fared much worse than the closed fractures with a much lower union rate, a higher rate of osteonecrosis, and substantially higher reoperation and infection rates.[16] This was also in line with our study where open fractures were associated with a high infection rate compared to the infection rate in closed fractures (p=0,002).[33]

Posttraumatic arthritis is the most commonly reported complication of talar neck and body fractures with a wide range from 42 to 100%[1,16,38], which was lower in our study (29%).[33] Posttraumatic osteoarthritis was numerically more common in the delayed surgery group as compared to the early surgery group (22/68 vs 4/22, p = 0.202).[33]

Due to the tenuous blood supply talar fractures have a displacement-dependent risk of avascular necrosis, particularly after talar neck fractures. Overall, a greater initial fracture displacement as described with the Hawkins classification is associated with an increased rate of AVN. AVN was the second most common complication we found in our study (18/90)[33], which is comparable with the current literature that reported a rate between 8% and 50%.[1,16,25,38] Halvorson et al. reported in their review, including 19 studies with a total of 848 fractures, an overall AVN rate of 33,3%.[12] Vallier et al. retrospectively reviewed 102 talar neck fractures and observed a significantly higher osteonecrosis rate in patients with open fractures than in patients with closed fractures of the talar neck. Out of the 11 patients with an open fracture 9 developed osteonecrosis ($p < 0.05$). Also a significant association between the comminution of the talar neck and osteonecrosis was noted.[28]

Post-traumatic talus AVN is classically managed with a intramedullary (hindfoot) fusion nail. However, newer (experimental) therapies have emerged, such as vascularized bone grafting and total talus replacement.[15]

We observed a surgical site infection rate of 10 % (9/90) in patients with surgically treated talar neck and body fractures. Two patients suffered a superficial infection and 7 patients had a deep infection.[33] These results are slightly higher than reported in literature with an infection rate of 1% to 8%.[19,28,29,31] In our systematic review of patients following operative treatment of talus neck and body fractures we observed an overall infection rate of 6% (61/944) at 90 days follow-up.[36] According to the literature, open fractures are associated with a high infection rate. Elgafy et al. reported an infection in 4 four patients (6,6%) of which three were open fractures.[6]

Vallier et al. observed a superficial infection rate of 8% which were all managed successfully with oral antibiotics. Only one deep infection occurred postoperatively in this study group after treatment of a Hawkins type-IIIA open talar body fracture and associated bone loss. The infection resolved after two subsequent operative procedures for irrigation and débridement combined with six weeks of intravenous antibiotics.[29]

A possible solution for severe complications, such as talar dome collaps after AVN, is secondary arthrodesis. Our systematic review reporting the results of surgically treated central talar fractures showed a secondary arthrodesis rate of 16 %.[36] Blair fusion was introduced in 1943 to deal with these severe complications.[2] Many other forms of fusion, including the aforementioned, hindfoot nail have emerged since. Future research should not only focus on which fusion should be recommended, but also on how to prevent the need for secondary procedures, as these lower the rate of patient satisfaction.[33]

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11

Thesis summery and future perspectives

This thesis focuses on the diagnostics, management and outcome of talar fractures. This thesis is divided according to anatomical regions of the talus. The aim was to provide guidance in clinical decision-making by improving patients' expectation management and tailor-made patient treatment strategies.

Chapter 1 describes the talus in a historical context. We also give a short overview of the anatomy, blood supply and classification of talar fractures. In **chapter 2** we performed a systematic review to describe the complications and functional outcome following operative treatment of talar neck and body fractures. A total of 28 articles were included in this review reporting 1086 operative treated central talar fractures. Operative treatment was associated with a high incidence of early and late complications which often leads to an impaired functional outcome. Due to the heterogeneity of the studies with different talar fracture classification and scoring systems, conclusions were hard to make. We proposed standardization of talar fracture classification and scoring systems in combination with large sample-sized prospective studies to detect further predictive factors influencing tailormade treatment strategies and patient expectation management.

Chapter 3 describes, in a retrospective cohort study, the functional outcome and quality of life in surgically treated talar neck and body fractures. Ninety patients were included, of which 73 responded to the questionnaires. Patients who underwent implant removal and/or secondary arthrodesis had poorer functional outcome compared to patients who did not undergo additional procedures. Careful consideration of reintervention must be made in combination with patient expectation management. Chapters 2 and 3 describe different complications after central talar fractures whereas **chapter 4** focuses on the management of infected avascular necrosis with the use of an external fixator after traumatic talus fractures. Three cases of infected AVN of the talus, confirmed by PET-CT, were encountered after a mean of 3 months after initial surgery. In all cases, management involved extensive debridement and arthrodesis by means of external fixation, followed by post-operative culture-guided antibiotics. After a mean follow up of 24 months FFI index scores ranged from poor to good with similar AOFAS scores indicating poor to fair functional outcome. The EQ-5D score was 0.78. Overall patient satisfaction was high with a mean VAS of 8.3. These cases demonstrate the crucial importance of shared decision-making and expectation management with high patient satisfaction despite low functional outcomes. 11

Chapters 5 – 8 covers peripheral talar fractures starting with the evaluation of management and outcome of hindfoot trauma with concomitant talar head injury in **chapter 5**. In this retrospective cohort study 21 patients were included, all with additional ipsilateral foot and/or ankle injuries. Fifteen patients had operative management of their talar head fracture. There were no postoperative wound infections and no cases of avascular necrosis. All fractures united, and 29% of patients developed posttraumatic osteoarthritis. The overall mean FFI score index was 34.2, and the mean AOFAS score was 70.7. The mean EQ-5D index score was 0.74. Management and long-term functional outcome were affected by the extent of associated injuries. Considering the high complexity of talar head fractures, early referral to dedicated foot surgeons and centralization of complex foot surgery is recommended. **Chapter 6** is a case series and review of the literature of patients with lateral process fractures of the talus. Furthermore, we proposed, in this study, a modified classification based on severity and intra or extra-articular location of LPFT. Thirty-six patients were included with a mean follow-up of 5.5 years. Twenty-eight patients underwent operative fixation (78%) which led to an overall good (long-term) outcome. The authors believe conservative treatment should only be considered for non-displaced, small-fragment, and extra-articular fractures. **Chapter 7** continues with posterior process fractures of the talus. In this retrospective study we aimed to provide evidence on outcomes after non-operative and operative management of posterior process fractures of the talus. Twenty-nine patients with posterior process fractures of the talus were identified of which 22 patients underwent primary arthrodesis or operative reduction and fixation of the fracture (75.9%). Operative management was found to provide good functional outcome, quality of life, and patient satisfaction. Although the patients treated non-operatively were found to have less severe injuries, they demonstrated worse overall outcome, which is supportive of surgical management. Nonoperative treatment in posterior process fractures of the talus is therefore only justified in selected patients. We also focused on the posterior process of the talus in **chapter 8**. In this systematic review we tried to gain more insight into the diagnosis, treatment and outcome of fractures of the posterior process of the talus (PPTF) to provide recommendations for the management of PPTF. Seven original studies were included with a total of 66 patients. Out of 48 patients with outcome data available, 41.7% ($n = 20$) reported impaired function. In the non-operative group, 64.7% ($n = 11$) had impaired functional outcome, compared to 33.3% ($n = 6$) in the ORIF group, and 30.8% ($n = 4$) in the fragment excision group ($p < 0.001$). One third of the patients developed one or more complications ($n = 25$, 37.9%), mostly found in the non-operatively treated group (73.7%, $n = 14$) compared to ORIF (25.0%, $n = 8$, $p < 0.001$). Given the significantly higher complication rate and lower return to the previous level of functionality reported after non-operative treatment, ORIF was recommended if there is (even minimal) displacement, articular involvement or if the fracture extends into the talus body.

Chapter 9 describes the first case series of patients with extra-articular medial impression fracture of the talus. Eight consecutive patients were included. In 80%, the trauma mechanism was a supination or inversion injury of the ankle and foot. The correct diagnosis was missed in 50% of the patients at first presentation with an average delay between injury and diagnosis of 36 days. Good clinical examination and judicious use of diagnostic imaging are a necessity to find the talar impression fractures in a timely manner.

FUTURE PERSPECTIVES

Operative treatment of central talar fractures is associated with a high incidence of early and late complications and often leads to an impaired functional outcome. Therefore, understanding of the bony and vascular anatomy and respect for soft tissues is crucial in maximizing the likelihood of a successful outcome. To date, (international) guidelines for a more standardized management of talar fractures are lacking. We believe that a guideline may help clinicians with 1) a better (tailor-made) management to improve functional outcomes and 2) improved patient counseling and thereby improving patient satisfaction.

A major contributing factor why no guideline exists is the heterogeneity of published studies. Given that various classification and functional outcomes scores were used, comparing studies and performing a meta-analysis is currently unreliable. Therefore, we believe that standardization of talar fracture classification and scoring systems with high inter-observer reliability in future studies would improve the comparability of future studies. On the other hand, due to the fact that talar fractures are often as a result of a high energy trauma, the fracture pattern can be complex and extends throughout the entire talus and not restrict to one anatomical area. With this in mind its maybe better to exactly describe the full extension of the fracture in detail rather than to try to fit the fracture in one classification.

Additionally, currently available data is mainly extracted from retrospective studies, which are considered as less reliable as prospective data. Therefore, large sample-sized prospective studies would be interesting to detect further predictive factors that can help to improve the management of talar fractures in the future.

Given that establishing the exact diagnosis can be challenging and to provide more insight into fracture characteristics for pre-operative planning, a CT scan is mandatory in all patients in which a talar fracture is suspected. We only advise an MRI in case of persistent complaints where a ligamentous injury or potential AVN is suspected. In addition, PET CT should be used in patients with a possible fracture related infection. Intraoperative assessment of the quality of the reduction may be challenging. Nowadays, more hospitals have a 3D CT scan available for intra-operative scanning. With this tool, optimal reduction and articular alignment can be achieved to prevent future osteoarthritis.

Surgical site infection rates could possibly be lowered with well-planned surgical approaches and timing. The rate of AVN is most likely more related to the extent of the injury rather than the timing of the definitive fixation, provided that any dislocation is resolved as an emergency. Nonetheless, the literature on the timing of the definitive fixation and its effect of the chance of AVN is scarce and not very robust. Future research may play an important role here as well.

Furthermore, due to the rare incidence with an estimation of 3 talar fractures annually in an average peripheral hospital, difficulty in establishing correct diagnosis, need for patient-tailored treatment, and the knowhow of how to deal with possible severe complications it might be advantageous to centralize the treatment of talus fractures and treat them exclusively in centers with surgeons and/or surgical teams with experience in talar injuries. Future studies should focus on how to reduce the rate of complications and the effect of secondary intervention with the use of validated patient reported outcome measures.

This thesis showed that even in case of an impaired functional outcome, provided good communication and expectation management, overall good satisfaction and quality of life can be obtained.

A

Appendices

NEDERLANDSE SAMENVATTING

Dit proefschrift richt zich op de diagnostiek, behandeling en uitkomst van talus fracturen. Het proefschrift is ingedeeld op basis van de anatomische regio's van de talus. Het doel van dit proefschrift is het verbeteren van op maat gemaakte behandelstrategieën en het optimaliseren van het verwachtingsmanagement van patiënten met een talus fractuur. Daarvoor bieden wij handvaten voor clinici, die kunnen helpen bij de klinische besluitvorming.

Hoofdstuk 1 beschrijft de talus in een historische context. Ook geven wij een kort overzicht van de anatomie, vascularisatie en classificatie van talus fracturen. In **hoofdstuk 2** beschrijven wij de complicaties en de functionele uitkomst na operatieve behandeling van talus nek en corpus fracturen in een systematic review. In deze studie zijn in het totaal 28 artikelen geïncludeerd waarin 1086 operatief behandelde centrale talus fracturen worden beschreven. Een operatieve behandeling ging gepaard met een hoge incidentie van vroege en late complicaties, wat vaak resulteerde in een verminderde functionele uitkomst. Vanwege de heterogeniteit van de onderzoeken, met verschillende classificatie- en scoringsystemen voor talus fracturen, is het echter een uitdaging om betrouwbare conclusies te trekken. Om in de toekomst een betere uitkomsten te genereren, is het noodzakelijk om de classificatie- en scoresystemen voor talus fracturen te standaardiseren. Zodoende zou, met grote prospectieve studies, voorspellende factoren kunnen worden gedetecteerd die van invloed zijn op de gepersonaliseerde behandelstrategieën en op het verwachtingsmanagement van de patiënt.

Hoofdstuk 3 beschrijft, in een retrospectieve cohortstudie, de functionele uitkomst en kwaliteit van leven bij operatief behandelde talus hals en corpus fracturen. Negentig patiënten werden geïncludeerd, waarvan 73 reageerden op de vragenlijsten. Patiënten die osteosynthese materiaal lieten verwijderen en/of secundaire artrodese ondergingen, hadden een slechtere functionele uitkomst in vergelijking met patiënten die geen aanvullende procedures ondergingen. Een secundaire interventie moet dus een goed overwogen besluit zijn waarbij het verwachtingsmanagement van de patiënt centraal staat.

De hoofdstukken 2 en 3 beschrijven verschillende complicaties van centrale talus fracturen, terwijl **hoofdstuk 4** zich alleen richt op de behandeling van geïnfecteerde avasculaire necrose (AVN) bij talus fracturen door middel van een externe fixateur. Er worden 3 casus van geïnfecteerde AVN beschreven waarbij de diagnose bevestigd werd middels PET-CT. De gemiddelde tijd tussen de presentatie van deze complicatie en de initiële operatie was 3 maanden. In alle gevallen bestond de behandeling uit een uitvoerige debridement en artrodese door middel van een externe fixateur, gevolgd door postoperatieve antibiotica op basis van kweken. Na een gemiddelde follow-up van 24 maanden varieerden de FFI-indexscores van slecht tot goed met vergelijkbare AOFAS-scores, wat wijst op een slechte tot redelijke functionele uitkomst. De

EQ-5D-score was 0,78. Over het algemeen was de tevredenheid van de patiënten hoog met een gemiddelde VAS van 8,3. Deze 3 casus tonen het cruciale belang aan van 'shared decision making' met daarbij goed verwachtingsmanagement van de patiënt. Het resulteerde namelijk in een hoge patiënttevredenheid ondanks lage functionele uitkomsten.

Hoofdstukken 5-8 gaan nader in op perifere talus fracturen, te beginnen met de evaluatie van de behandeling en uitkomst van trauma aan de achtervoet, met gelijktijdig letsel aan het talus hoofd in **hoofdstuk 5.** In deze retrospectieve cohortstudie werden 21 patiënten geïncludeerd met letsel aan de ipsilaterale voet en/of enkel. Vijftien patiënten werden operatief behandeld aan een fractuur van het talus hoofd. Er waren geen postoperatieve wondinfecties en geen gevallen van AVN. Alle fracturen consolideerden volledig, en 29% van de patiënten ontwikkelde post-traumatische artrose. De gemiddelde FFI-score index was 34,2 en de gemiddelde AOFAS-score was 70,7. De gemiddelde EQ-5D-index score was 0,74. De behandeling en de lange termijn functionele uitkomst werden beïnvloed door de uitgebreidheid van het letsel. Gezien de hoge complexiteit van dit soort letsel werd geadviseerd om patiënten in een vroeg stadium te verwijzen naar gespecialiseerde voet chirurgen. Daarbij werd ook geopteerd voor de centralisatie van complexe voet/ enkel chirurgie.

Hoofdstuk 6 is een case series en literatuuroverzicht van patiënten met laterale processus fracturen van de talus (LPFT). Daarbij stelden we in deze studie een gemodificeerde classificatie voor op basis van de uitgebreidheid en intra- of extra-articulaire locatie van LPFT. Zesendertig patiënten werden geïncludeerd met een gemiddelde follow-up van 5,5 jaar. Achtentwintig patiënten ondergingen operatieve fixatie (78%), wat leidde tot een algehele goede (lange termijn) uitkomst. De auteurs zijn van mening dat conservatieve behandeling alleen moet worden overwogen voor niet-verplaatste, kleine fragmenten en extra-articulaire fracturen.

Hoofdstuk 7 gaat verder met fracturen van het posterieure proces van de talus. In deze retrospectieve studie beschrijven wij de uitkomst na conservatief en operatief behandelde fracturen van het posterieure proces van de talus. Negenentwintig patiënten met een fractuur van het posterieure proces van de talus werden geïdentificeerd, waarvan 22 patiënten een primaire artrodese of open repositie met interne fixatie van de fractuur ondergingen (75,9%). Een operatieve behandeling zorgde voor een goede functionele uitkomst, kwaliteit van leven en patiënttevredenheid. Ondanks dat de patiënten die conservatief werden behandeld minder ernstig letsel hadden, vertoonden ze een slechtere algehele uitkomst, wat pleit voor een operatieve behandeling.

In **hoofdstuk 8** richtten we ons ook op het posterieure proces van de talus. In deze systematic review probeerden we meer inzicht te krijgen in de diagnose, behandeling en uitkomst van fracturen van het posterieure proces van de talus (PPTF) om aanbevelingen te doen over de behandeling van PPTF. Zeven studies werden geïncludeerd met in het totaal 66 patiënten. Van de 48 patiënten met beschikbare uitkomstgegevens meldde 41,7% (n = 20) een verminderde functie. In de conservatieve groep had 64,7% (n = 11) een verminderde functionele uitkomst, vergeleken met 33,3% (n = 6) in de ORIF-groep en 30,8% (n = 4) in de fragment excisie-groep (p <0,001). Een derde van de patiënten ontwikkelde een of meer complicaties (n = 25, 37,9%), voornamelijk in de conservatief behandelde groep (73,7%, n = 14) in vergelijking met ORIF (25,0%, n = 8, p <0,001). Gezien het aanzienlijk hogere complicatiepercentage en het lagere terugkeerniveau van functionaliteit na een conservatieve behandeling, werd ORIF aanbevolen als er sprake was van (zelfs minimale) verplaatsing, intra-articulair verloop of als de fractuur zich uitbreidde tot in het corpus van de talus.

Hoofdstuk 9 beschrijft de eerste case series van patiënten met een extra-articulaire mediale impressie fractuur van de talus. Acht patiënten werden geïncludeerd. In 80% was het traumamechanisme een supinatie- of inversie trauma van de enkel en voet. De correcte diagnose werd bij 50% van de patiënten bij de eerste presentatie gemist, met een gemiddelde vertraging tussen letsel en diagnose van 36 dagen. Goed klinisch onderzoek en gerichte diagnostische beeldvorming zijn noodzakelijk om mediale impressie fracturen van de talus tijdig te diagnosticeren.

PHD PORTFOLIO

PhD period: 2018 – 2024

PhD supervisor: Dr. T. Schepers

MD training	YEAR	Workload (etcs)
ANIOS Chirurgie Flevoziekenhuis	2013	-
ANIOS Amsterdam UMC	2014	-
AIOS Spaarne Ziekenhuis	2015-2016	-
AIOS OLVG	2016+ 2020-2021	-
AIOS Amsterdam UMC	2019	-
Trauma resident, Groote Schuur Hospital, Kaapstad ZA		-
General courses		
Good Clinical Practice (GCP) Training + examen	2023	0.9
Non-Technical Skills for Surgeons Masterclass	2021	0.9
Cursus Medisch Leiderschap	2021	1.5
Basic methods and reasoning in Biostatistics	2012	0.9
Specific courses		
Definitive Surgery and Anaesthesia in Trauma Care course	2021	0.5
AO Trauma Course: Tibia Plateau and Pilon Fractures	2021	0.5
Hospital Major Incident Management and Support (HMIMS)	2021	-
AO Trauma course: Advanced Principles of Fracture Management (Davos)	2021	0.5
Advanced Trauma Life Support Refresher Course	2019	-
Emergency Management of Severe Burns	2019	-
MSc Orthopaedic Trauma Sciences Cadaveric Programme (Londen)	2019	0.5
Fundamental Critical Care Support	2016	-
Seminars		
Weekly department seminars	2015 - 2021	3.75
Regionaal refereren region II	2015 - 2021	0.4
Monthly research meetings Trauma Unit	2017 - 2021	3.1
(Inter)national conferences		
Assistentensymposium Traumachirurgie	2015 - 2021	0.25
Traumadagen NVT	2015 - now	2.5
NVvH Chirurgendagen	2014 - now	2.5
NVvH Najaarsdag	2014 - now	1.25
Oral presentations		
Complex Voet en Enkelletsel, NVT assistenten symposium	2021	0.5
Traumatologie en Psychiatrie: Samen werken of samenwerken	2013	0.5

Teaching		
AO Approaches LUMC (Faculty)	2023	0.5
ATLS instructor	2021 - now	0.5
AO Clinical training modules: Osteosynthesis with plate and screws (Faculty)	2020	0.5
Mentoring		
Supervisor scientific medical master thesis, Universiteit van Amsterdam; Complications, functional outcome and quality of life in surgically treated central talar fractures; Demirci, H	2020	1

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ABOUT THE AUTHOR

Olivier Wijers was born on the 20th of October 1983 in Naarden, the Netherlands. He attended the Pierson College in ‘s Hertogenbosch. After graduation, he moved to Leiden in 2003 to study Medicine at the Leiden University Medical Centre. After passing his doctoral exam, he started working as a surgical resident (not in training) at the Flevoziekenhuis in Almere under the supervision of Dr. Paul Verbeek. This was followed by a surgical residency (not in training) at the Amsterdam University Medical Center location AMC (AMC) in Amsterdam. In 2015 he started his General Surgery training in the Spaarne Hospital in Hoofddorp followed by the Onze Lieve Vrouwe Gasthuis (OLVG) Hospital in Amsterdam. During his time as a surgical resident, he went on a mission with ‘Operation hernia’ in Ghana for inguinal hernia repair under supervision of Dr. M.P Simons. From 2019 until 2021 he specialized in Trauma surgery at the AMC and the OLVG. During this time, he followed an extra traineeship on ‘visceral trauma’ at the Groote Schuur Hospital in Cape Town, South Africa. Simultaneously with his surgical residency, he started in 2018 his research project on talar fractures at the AMC under supervision of Dr. T. Schepers, which led to the writing of this thesis. After finishing his surgical training, he started as a Trauma fellow at the St. Antonius Hospital in Utrecht. In 2022 he moved to Rotterdam to work at the Franciscus Gasthuis & Vlietland Hospital as a trauma consultant.