Outcome Evaluation in Trauma Patients

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Chapter 1

General introduction and thesis outline

Outcome evaluation in trauma patients

Dramatic improvements in injury prevention, prehospital and hospital care have led to decreased mortality rates from traumatic injury.[1-4] Despite decreased mortality rates, trauma contributes both significantly as well as increasingly to the world's burden of disease and is responsible for the loss of a large amount of disability-adjusted life years (DALYs).[5,6] As a result, there is growing interest in the non-fatal injury burden, such as post-injury disability, functionality, and health-related quality of life (HRQoL).[7-10] It is clear that the functional and financial impact of trauma on patients and society extend beyond hospital stay. Traumatic injury carries the potential to result in longstanding adverse effects on patient's health-related quality of life, functionality, return to daily activities, and return to work.[11-13] Injuries that seem innocuous in comparison to life-threatening injuries, such as injuries to the hand, wrist, foot, and ankle, may be important determinants of long-term quality of life and disability.[14-16] For example, polytrauma patients with foot or acromioclavicular joint injuries have been reported to experience poorer health-related quality of life when compared to polytrauma patients without these injuries.[17,18]

Thus, trauma poses a heavy burden on both patients and society as a whole. Therefore, it is essential to understand how various injuries and their treatments affect trauma patients on the long term. Capturing these long-term outcomes regarding the patients' perspectives, outcomes that truly matter to patients, can be at least partially achieved by the use of patient-reported outcome measures (PROMs).

Patient-reported outcomes

PROMs, also known as self-report measures, are measures developed to collect patient-reported outcomes (PROs).[19] PROs pertain to any reports coming directly from patients about their functionality, satisfaction or other feelings in relation to health conditions and therapy, without interpretation by other parties such as clinicians.[20] PROs include but are not limited to perceptions and opinions regarding symptoms, functionality, satisfaction, and health-related HRQoL.[7]

There is a shift from volume-based to value-based healthcare. In the traditional, volume-based healthcare model, reimbursement was received upon providing a particular service, regardless of the outcome or need. In the newer, value-based model, healthcare provision as well as reimbursement decisions are based on value in terms of health-related quality of life for patients. In this model, value is defined as patient-relevant outcomes relative to costs of medical care. With the transition towards value-based healthcare, logically, PROs are becoming increasingly important.[21]

Long-term PROs can be used to inform clinical decision making, helping both patients and providers to make more informed decisions about the care delivered.[12,22] Providers will be able to set accurate expectations about the outcomes that are most important to patients. With information about these long-term outcomes, such as return to work, living without assistance, or walking abilities, patients will be able to make decisions about their treatment that are aligned with their personal goals.[12] More specifically, insights in outcomes reported by patients may reveal patient priorities as well as outcomes that are irrelevant to them.[23]

Furthermore, PROs provide opportunities to follow recovery processes and monitor treatment effects.[24] In addition, PRO data have the ability when obtained and used correctly, to improve and evaluate care, facilitate benchmarking between institutions, evaluate (cost-) effectiveness of the care provided, build a foundation for a learning health system, and to develop research projects.[12,24] The collection of long-term patient-reported outcomes has the tremendous potential to improve patient care and (cost-)effectiveness of healthcare.

Patient-reported outcomes measurement in trauma patients
Increased interest in PROs is apparent in all aspects of healthcare, and is reflected in the large number of studies using PROMs to assess outcomes.[19,22-25] Over the past three decades, the number of published articles involving PROs in general has increased consistently. Even though the amount of research projects reporting on PROs in trauma patients has increased simultaneously, this increase is not in line with the growth of PRO usage in other areas of medicine. Therefore, outcomes after trauma, especially polytrauma, are nowhere near fully characterized.[24] As a result, providers taking care of the (most severely) injured patients still rely on in-hospital outcomes and are limited in their ability to inform on expected recovery, loss of every day functioning and return to work. In line with this, these clinicians are limited in the capacity to provide personalized decision making. With treatment options for reconstruction and recovery after the initial (lifesaving) phase of trauma being many, trauma patients as well as healthcare providers and policy makers will benefit from increased knowledge of PROs after trauma.[24]

Various explanations for the limited availability of outcome information in trauma patients can be given.

First, and maybe most important, the innumerable variations in injury types, combinations, and severity, challenge outcomes measurement in trauma patients.[9,26] The many studies excluding polytrauma or multiply injured patients from outcome evaluations, emphasize this challenge.[27-29]

Second, inherent to the previous, concerns about unfair judgement causes healthcare providers to exclude patients from outcome comparisons.[30] This applies particularly to populations of trauma patients, in which concomitant injuries and severity of the injury may influence the impact measured. In addition, the care for the acutely injured differs from the elective surgery practice. For example, those performing elective procedures such as arthroplasties may deem a patient unsuitable for surgery based on medical or social factors, but this does not pertain to providers performing surgical treatment for acute injuries.[31] As a result, treatment effects of acute interventions may be affected by (non-optimized) preoperative conditions as well as postoperative complications.

Third, reimbursement decisions lean increasingly on outcome data. Considering that outcomes in (severely) injured patients may be suboptimal (as explained above), healthcare providers taking care of trauma patients may become even more hesitant to collect PROs.[32]

Fourth, trauma care is subject to the chain of trauma care, in which multiple specialties are involved, both parallel and serial. Eventual outcomes are subject to the individual elements in this chain while reflecting the overall care. As the progress in outcomes measurement has been slowed due to an approach in which every organization individually reinvents the wheel, one can imagine how outcomes measurement of trauma care with multiple specialties and organizations involved, lags behind.[24,30]

Hypotheses

With these hurdles overcome, increased availability of outcome information in trauma patients and increased knowledge of the adequate use and interpretation of this information may be achieved.

Outcomes measurement

In order to evaluate and understand PROs in trauma patients, complete outcome information needs to be available for as many patients as possible. Important determinants of the number and completeness of PROs available are the workload for those distributing surveys and patients' willingness to complete PROMs. A standardized outcomes measurement process is hypothesized to increase the number of patients approached. Distribution of outcome instruments that are easily completed is expected to increase response rates. As it is hardly impossible to achieve a maximal response rate, sound data on differences between responders and non-responders may aid in assessing the applicability and generalizability of the outcome data obtained.

Outcome evaluation

As described previously, the trauma population is highly heterogeneous due to the innumerable variations in *injury types*, *combinations*, and *severity*. In addition, as trauma is known to affect people of all ages and backgrounds, there is a wide variety in *pre-injury status*. However, it is hypothesized that precisely these characteristics may be useful to differentiate between the outcomes reported.

- *Injury types and combinations*
  It is believed that concomitant injuries affect the outcomes reported when evaluating a certain condition or treatment, thereby potentially underestimating outcomes or treatment effects. With polytrauma patients suffering multiple injuries by definition, outcomes in this population may be highly colored by accompanying injuries.
- *Injury severity*
  The mechanism responsible for traumatic injury may influence outcomes as well. High-energy mechanisms may cause injuries to be more severe and diminish opportunities for complete reconstruction and consequent recovery.
- *Pre-injury status*
  Pre-injury status, highly challenging to assess due to the unexpected nature of trauma, may either positively or negatively influence the outcomes measured. When evaluating outcomes and assess treatment effects in the heterogeneous trauma population with a highly different baseline status, a measure of general status may be a suitable adjusting variable.

Evaluation of the effects of these characteristics on outcomes may facilitate outcomes measurement and allow for outcomes measurement contingent on context.

Aims

Availability and expertise on the accurate usage of trauma outcome data is expected to benefit patients, patients' relatives, healthcare providers, and society. With better understanding of the effects of trauma on post-injury living, accurate expectations on recovery may be provided. Early identification of factors associated with poor outcomes may improve long-term outcomes. Optimal, individualized treatment strategies may be identified. Overall trauma care may be improved.
To eventually reach these objectives, this thesis aims to:

- evaluate processes of outcomes measurement in trauma patients;
- establish normative data on outcomes after a variety of traumatic injuries;
- identify characteristics associated with outcome measures after traumatic injury.

Outline

The challenges in outcome measurement in the most severely injured patients and consequential need for modern outcome measures are illustrated in **Chapter II (*Part I*)**. In ***Part II***, these modern, patient-reported outcomes are presented for (polytrauma) patients with musculoskeletal extremity injuries. **Chapter III** provides an overview of the differences in epidemiology, fracture morphology and the influence of energy transfer in distal radius fractures. It is investigated how injury-related factors such as polytrauma and high-energy injuries may be associated with different fracture morphology. This chapter provides a rationale for differences in patient-reported outcomes following different mechanisms and severity of injury. In a follow-up project, depicted in **Chapter IV**, it is explored how injury-related factors may be associated with different patient-reported outcomes of distal radius fractures. Incidence, fracture pattern and patient-reported outcomes after fractures of the hand in polytrauma patients are reported in **Chapter V**.

The following chapters concern injuries of the foot and ankle. Foot injuries are known to be diagnosed in delay in severely injured patients, whose care is focused towards treating the most life-threatening injuries first. Therefore, in **Chapter VI**, incidence, fracture pattern, and timing of diagnosis of foot fractures in polytrauma patients are portrayed. As there is no consensus on the optimal treatment of injuries of the Lisfranc and Chopart injuries, **Chapter VII** investigates patient-reported outcomes after open reduction internal fixation of these midfoot injuries. Additionally, (injury-related) factors associated with the outcomes measured are determined. **Chapters VIII** and **IX** focus on outcomes after subtalar arthrodesis for posttraumatic arthritis after calcaneal fractures. This procedure is considered a salvage procedure in patients with already diminished health-related quality of life due to pain or loss of function. Therefore, data on expected outcomes and factors differentiating between outcomes are needed to accurately counsel patients on expected results. In **Chapter X**, long-term patient-reported outcomes of operatively treated fractures of the tibial plafond are reported.

The final part, ***Part III***, focuses on (the process of) outcomes measurement in trauma patients. In **Chapter XI**, injury-related variation in patient-reported outcome following musculoskeletal trauma is researched by means of a systematic review of the literature. Experiences with routine incorporation of long-term patient-reported outcomes into the Dutch National Trauma Database are described and characterized in **Chapter XII**.

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Part 1

Outcome measurement in severely injured patients

– a shifting focus

Chapter 2

Severely injured patients benefit from in-house attending trauma surgeons

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Abstract

Introduction

There is continuous drive to optimize healthcare for the most severely injured patients. Although still under debate, a possible measure is to provide 24/7 in-house (IH) coverage by trauma surgeons. The aim of this study was to compare process-related outcomes for severely injured patients before and after transition of attendance policy from an out-of-hospital (OH) on-call attending trauma surgeon to an in-house attending trauma surgeon.

Methods

Retrospective before-and-after study using prospectively gathered data in a Level 1 Trauma Center in the Netherlands. All trauma patients with an Injury Severity Score (ISS) >24 presenting to the emergency department for trauma before (2011 – 2012) and after (2014 – 2016) introduction of IH attendings were included. Primary outcome measures were the process-related outcomes Emergency Department length of stay (ED-LOS) and time to first intervention.

Results

After implementation of IH trauma surgeons, ED-LOS decreased ($p = 0.009$). Time from the ED to the intensive care unit (ICU) for patients directly transferred to the ICU was significantly shorter with more than doubling of the percentage of patients that reached the ICU within an hour. The percentage of patients undergoing emergency surgery within 30 minutes nearly doubled as well, with a larger amount of patients undergoing CT imaging before emergency surgery.

Conclusions

Introduction of a 24/7 in-house attending trauma surgeon led to improved process-related outcomes for the most severely injured patients. There is clear benefit of continuous presence of physicians with sufficient experience in trauma care in hospitals treating large numbers of severely injured patients.

Introduction

Improved outcomes for severely injured patients treated at designated trauma centers within an inclusive trauma system are well established.[1-3] One of the cornerstones of designated trauma centers has been timely involvement of trauma surgeons in the management of severely injured patients. With ongoing centralization of patients and further differentiation of hospitals, the question arises if trauma surgeons should be in house at all times in centers treating severely injured patients. However, there is ongoing debate regarding the value of such an in-house (IH) attending trauma surgeon.[4-6]

In several Level 1 Trauma Centers, an IH attending trauma surgeon is available 24/7, whereas other institutions maintain an out-of-hospital (OH) on-call attending schedule with a reasonable response time.[7,8] In practice, OH on-call attending schedule means that a (senior) resident may serve as an in-house surgeon, while the attending surgeon participates in all major therapeutic decision-making and attends surgical procedures when needed.

Several studies have examined the effects of IH attending surgeons on process- and patient-related outcomes. On one side, there are studies that provide arguments that an IH attending improves efficiency of processes, such as faster decision-making, fewer errors, decrease of time to disposition and reduction in preventable deaths.[6,9-11] On the other side, there is no true consensus on the added value of 24/7 presence of an attending trauma surgeon in terms of overall mortality or hospital length of stay.[12,13]These latter outcomes are subject to the efficiency of the complete trauma care chain. Thus, when attempting to optimize the resuscitation process by introducing IH trauma surgeons, focus should be on process-related outcomes for this specific part of the chain. As stated by Durham et al, aggregate statistics and the use of surrogate markers to determine outcomes may not accurately portray the impact of attending surgeons on the quality of care.[6]

Recently, an IH attending schedule with two experienced trauma surgeons available 24/7 has been introduced in our hospital. The aim of the present study was to compare process-related-outcomes before and after the introduction of an institutional IH attending trauma surgeon schedule in a single large volume Level 1 Trauma Center in the Netherlands.

Methods

The University Medical Center of Utrecht is a Joint Commission International (JCI) accredited tertiary care facility with 1000 beds. Our hospital complies with all requirements as defined by the American College of Surgeons' Committee on Trauma (ACS-COT) for a Level 1 Trauma Center with the CT scan located nearby the Emergency Department (ED), thus not in the resuscitation bay.[7] Trauma team composition and tasks in our institution are described in detail by Kreb et al.[14] In July 2013, a shift from an out-of-hospital (OH) on-call to an in-house (IH) schedule for attending trauma surgeons took place. Before this change, trauma surgeons were available for consultation on-call with a senior resident in general surgery acting as house officer. Trauma surgeons were present during daytime trauma team activations and a selected amount of 'off hours' presentations. After July 2013, there was continuous presence of an IH trauma surgeon together with a resident of no specified level of experience (varying from junior to senior residents in general surgery). In case of a trauma team activation, this IH trauma surgeon was present at the bedside upon presentation of the patient. In addition, a second trauma surgeon was available on-call to perform or assist in surgical procedures or lead resuscitation at the ED if multiple victims arrived simultaneously. Hence, two trauma surgeons were present during surgery if needed. In the Dutch trauma model, trauma surgeons perform surgical procedures for both truncal (i.e. visceral) and extremity (i.e. osseous, including pelvic) injuries, but do not perform vascular reconstructions.[15] There were no other major changes after implementation of the in-house schedule (especially the location of the CT scan and operating room (OR) remained similar) except for 24/7 availability of an ICU bed for trauma patients, even in case of severe bed shortage, from the second year in the IH period onwards.

Study design and participants

After a waiver for approval by our institutional review board was achieved, we conducted a retrospective before-and-after study using prospectively gathered data from the Dutch National Trauma Database (DNTD) and the local emergency department, radiology, operating theatre and hospital logistics databases. Data embedded in these databases were prospectively gathered as required for national and local quality improvement programs. All severely injured patients presented to the ED with pre-notification of trauma between August 2011 (introduction of new electronic patient documentation system) and December 2012 and from January 2014 through December 2016 were included in the study. Patients presenting six months prior to or six months after the transition to the IH schedule (June 2013) were excluded to minimize possible effects of anticipation on and first implementation of the new schedule. Severely injured patients were defined as patients presenting with trauma resulting in Injury Severity Scores (ISS) >24 only, as we hypothesized that this group would benefit most from the new management model.[16] Children were enrolled in this cohort as well, since the same surgical trauma team performed the initial assessment of both adult and pediatric patients. Eligible patients were divided into two groups based on their dates of presentation; one group of patients who presented before the introduction of the IH system (2011 – 2012) and one group who suffered trauma in the time period after the introduction of the IH system (2014 – 2016).

Outcome measures and explanatory variables

The process-related outcomes were duration of emergency department length of stay (ED-LOS) and time to first intervention. ED-LOS was calculated utilizing ED arrival- and departure times as registered by ED staff members, which included finishing administration. Time to first intervention was based on emergency department disposition and categorized into the time between arrival at the ED and arrival at the CT scan, the operating room (OR) or the ICU. Secondly, we assessed in-hospital mortality, hospital length of stay (H-LOS), ED disposition, ICU admission and time to surgical procedures performed within 24 hours. Demographic and explanatory variables were extracted from the databases. Stability of trauma was defined according to triage by ED nurses. Triage color was scored based on the Emergency Severity Index and ranges from red to green, with red demanding immediate intervention and green indicating a low level of emergency.[17] Emergency surgeries, defined as any surgical procedure performed directly after ED departure, were categorized into anatomical region and level of emergency. Surgical emergency procedures included laparotomies, thoracotomies, pelvic packing and emergent vascular procedures, neurosurgical emergency procedures comprised all types of neurosurgical interventions (e.g. trepanation), orthopedic emergency procedures included fasciotomies and stabilization of the vertebral column, major pelvic and long-bone fractures, non-emergent orthopedic procedures consisted of stabilization of minor fractures and other non-emergent procedures encompassed all other procedures for non-life threatening conditions (e.g. wound treatments, oral and maxillofacial procedures).

Statistical analysis
Categorical and dichotomous variables were reported as numbers with percentages, continuous variables as medians with interquartile ranges (IQR). Bivariate analyses using chi-squared with continuity correction according to Yates' correction and Mann-Whitney U tests, as appropriate, were carried out in order to compare demographic, explanatory, and outcome variables between groups. All statistical analyses were performed using STATA® 13.1 (StataCorp LP, TX, USA). A p-value of <0.05 was considered statistically significant.

Results

Population
A total of 7780 patients presented for 7935 unique traumas during the study period. An overview of the patients presenting and their dispositions are shown in figure 1. In supplementary table 1, triage characteristics for all patients admitted for trauma are provided. Emergency Department length of stay (ED-LOS) and time to CT scan for the entire cohort are depicted in supplementary materials 2 and 3.

The population of patients presenting with ISS >24 consisted of 606 patients presenting for 606 unique traumas. Baseline characteristics of these patients are presented in table 1. There were no significant differences between patients presenting before and after the IH schedule with respect to baseline characteristics. In both groups, the majority of patients were male and nearly all patients suffered blunt trauma.

Process-related outcomes
Outcome variables are presented in table 2. ED-LOS was significantly shorter after implementation of the IH schedule (2.7 versus 2.1 hours; $p = 0.009$). There was no difference with respect to time to CT imaging, with a larger percentage of patients undergoing CT scanning after the introduction of in-hospital attendings (95% versus 90%; $p = 0.018$) (figure 2). After introduction of the IH surgeon, time from the ED to the intensive care unit (ICU) for patients directly transferred to the ICU was significantly shorter, with a decrease from a median time of 1.4 hours (IQR 1.1–2.5) to a median time of 1.2 hours (IQR 1.0–1.6) ($p = 0.004$). In addition, the percentage of patients who reached the ICU within 60 minutes increased from 15% to 33%. Figure 3 shows time to the intensive-care unit graphically.

Overall time from presentation at the ED to emergent surgical intervention (surgical intervention directly from the ED) did not change significantly (1.0 versus 1.0 hour, $p = 0.92$).

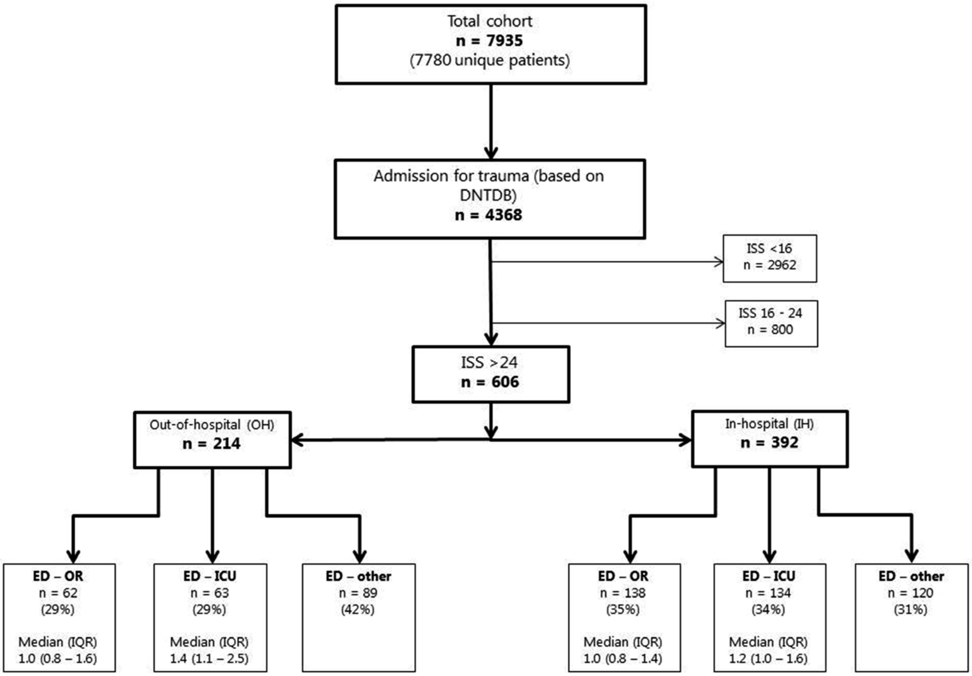


Figure 1. Flowchart of cohort.

Table 1. Baseline characteristics for patients with ISS >24 (n = 606).

	Out-of-hospital period (n = 214)	In-hospital period (n = 392)	
	Median (IQR)	Median (IQR)	*p*-value
Age at presentation (years)	47 (26 – 66)	50 (26 – 69)	0.53
Injury Severity Score	29 (26 – 34)	29 (26 – 35)	0.46
Glasgow Coma Scale*	14 (11 – 15)	14 (10 – 15)	0.46
	n (%)	n (%)	*p*-value
Male gender	150 (70)	254 (65)	0.22
Unstable trauma	137 (64)	254 (65)	0.92
Triage color**			
Red	131 (61)	270 (69)	
Orange	77 (36)	118 (30)	0.26
Yellow	2 (1)	4 (1)	
Green	0 (0)	0 (0)	
Missing	4 (2)	0 (0)	
Blunt trauma	206 (96)	385 (98)	0.23

*Glasgow Coma Scale available for 123 patients (57%) pre in hospital surgeon and 225 (57%) after.

table continues

**Triage color ranges from most emergent (red) to least emergent (green).
n = number; IQR = interquartile range.

However, the percentage of patients who had emergency surgery within 30 minutes of presentation increased from 4.8% to 8.0%. Of all patients demanding surgery within the initial 24 hours, a significantly larger amount had surgery within 1.5 hours of presentation in the second period (43% versus 58%; $p = 0.021$). Time to the OR for patients without pre-operative CT imaging decreased significantly (25% faster; 0.7 versus 0.5 hours; $p = 0.017$), whereas the percentage of patients who had surgery without prior CT scanning decreased (29% versus 14%; $p = 0.026$). Times to surgical intervention for all severely injured patients who demanded emergent surgical intervention are presented graphically in figure 4a. With IH attendings, the duration of emergency surgeries did not change significantly (1.5 versus 1.7 hours; $p = 0.37$) (figure 4b).

Patient-related outcomes
In-hospital mortality was comparable between both groups (24% versus 27%; $p = 0.48$). Median hospital length of stay did not differ between the two periods (14 versus 13 days; $p = 0.33$).

Table 2. Outcome variables for patients with ISS>24 (n = 606).

	Out-of-hospital period (n = 214)	In-hospital period (n = 392)	
	Median (IQR)	Median (IQR)	*p*-value
ED length of stay (hours)	2.7 (1.6 – 4.0)	2.1 (1.5 – 3.7)	**0.009**
Time to CT <24 hours (hours) (n = 565)*	0.4 (0.3 – 0.8)	0.5 (0.3 – 0.6)	0.59
Time to immediate ICU admission (hours) (n = 196)*	1.4 (1.1 – 2.5)	1.2 (1.0 – 1.6)	**0.004**
Time to emergency surgery (hours) (n = 200)	1.0 (0.8 – 1.6)	1.0 (0.8 – 1.4)	0.90
Without pre-operative CT (hours) (n = 38)	0.7 (0.6 – 0.9)	0.5 (0.4 – 0.7)	**0.016**
Duration of emergency surgery (hours) (n = 199)*	1.5 (1.0 – 2.2)	1.7 (1.2 – 2.2)	0.37
With emergent surgical procedure (hours) (n = 62)	1.4 (1.0 – 1.9)	1.5 (1.0 – 2.3)	0.96
	n (%)	n (%)	*p*-value
ED disposition			
Operating room	62 (29)	138 (35)	
Death in operating room	4 (6)	1 (1)	
Intensive care unit	63 (29)	134 (34)	0.25
Medium care unit	48 (22)	66 (17)	
Ward	32 (15)	41 (10)	
Deceased at emergency department	4 (2)	7 (2)	
Death on arrival	3 (1)	3 (1)	
Transfer	2 (1)	3 (1)	

table continues

	Out-of-hospital period (n = 214)	In-hospital period (n = 392)	
Intensive care unit admission	133 (62)	266 (68)	0.18
Emergency surgery (OR from ED)	62 (29)	138 (35)	0.14
Emergency surgery without pre-operative CT	18 (29)	20 (14)	**0.026**
Emergent surgical procedure	25 (40)	38 (28)	0.10
Emergent neurosurgical procedure	26 (42)	66 (48)	0.54
Emergent orthopedic procedure	6 (10)	16 (12)	0.88
Non-emergent orthopedic procedure	16 (26)	36 (26)	0.89
Non-emergent other procedure	3 (5)	10 (7)	0.74
Combined surgical types	13 (21)	21 (15)	0.43
Operation <48 hours of presentation	115 (54)	209 (53)	0.99
Operation during night/weekend shift	69 (60)	119 (57)	0.53
In-hospital mortality	52 (24)	107 (27)	0.48
	Median (IQR)	Median (IQR)	*p*-value
Hospital length of stay for admitted patients (days) (n = 579)	14 (6 – 25)	13 (5 – 26)	0.33

*No CT imaging <24 hours after arrival performed in 46 (8%); time to CT, time to immediate ICU admission and duration of emergency surgery missing in1 patient (0%).
n = number; IQR = interquartile range; ED = Emergency Department; OR = Operating Room; ICU = Intensive Care Unit.
Bold indicates statistically significant difference.

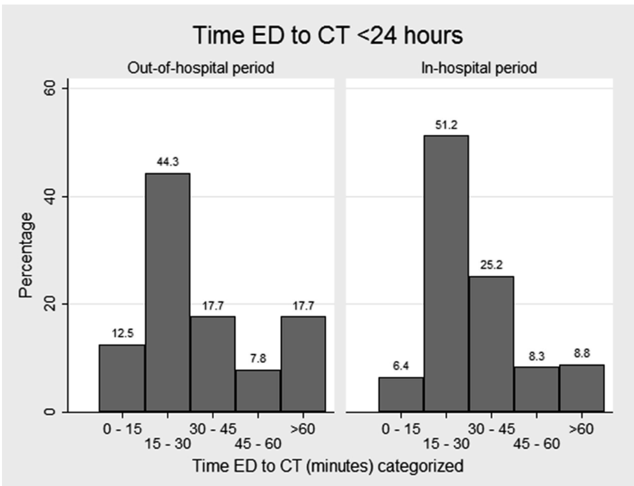


Figure 2. Time to CT <24 hours for patients with ISS>24 (n = 565).

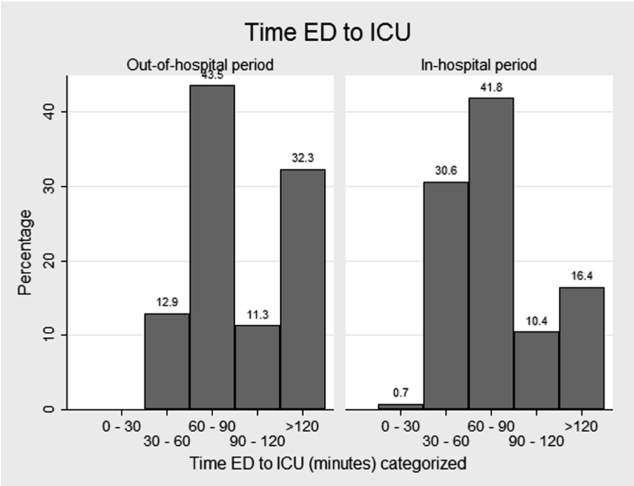


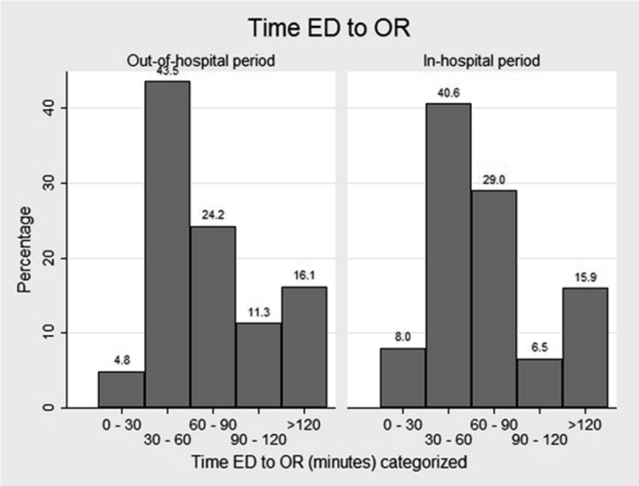
Figure 3. Time to ICU for patients with ISS>24 (directly from ED) (n = 196).

Discussion

After introduction of an in-house (IH) attending trauma surgeon schedule at our institution, there was significant acceleration of care-processes for severely injured patients, with a significant decrease in emergency department length of stay, a doubling in the percentage of patients that reached the ICU within an hour and a doubling in percentage of patients that arrived at the OR within 30 minutes.

At our institution, improving care for the most severely injured patients has always been of high priority. For example, video registration has been used to improve functioning of trauma teams.[18] With the recent introduction of an IH attending, process-related quality of care, based on disposition times, improved. It may very well be that the decreased ED-LOS and times to first disposition are the result of improved decision-making and leadership.

Although residents may become proficient in the initial evaluation and treatment of trauma patients, the "big picture" and accompanying treatment necessities may be visible for attending surgeons more quickly. Non-technical skills such as leadership, decision-making and situation awareness have been reported to be of utmost importance in the context of resuscitation in trauma patients.[19,20] As those non-technical skills typically develop with experience, one can imagine that presence of an experienced surgeon (attending) is necessary for optimal care of the injured. Positive effects of in-house trauma surgeons on resuscitation times and times to intervention have been described previously.[8-10,21] Interestingly, emergency disposition length of stay increased for patients with less severe trauma after introduction of IH surgeons. This reflects less efficient overall processes at de ED, such as prolonged administrative times and fewer availability of hospital beds. In the light of this, the shorter ED-LOS for severely injured patients emphasizes the contribution of trauma surgeons to the acute care of this vulnerable population even more.



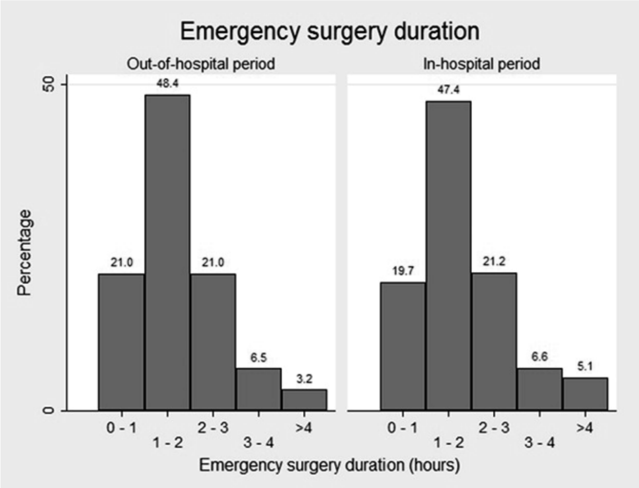


Figure 4. A: Time to OR for patients with ISS>24 (directly from ED) (n = 200); B: OR duration for emergency surgeries (directly from ED) (n = 199).

With implementation of the in-house schedule, time to the OR for patients without pre-operative CT imaging (most often due to severe instability) as well as the percentage of patients undergoing emergency surgery without prior CT scan, significantly decreased. This may be a reflection of faster decision-making as caused by presence of experienced surgeons, but is also likely to be the result of improved resuscitation processes in the last years. When a patient appears unresponsive, but becomes a transient responder, a CT-scan is deemed feasible in our institution. We expect the lower percentage of emergency procedures without previous imaging to be beneficial in terms of operative planning, higher amount of non-operative management and more accurate interventions, potentially leading to improved outcomes.

When comparing the IH and OH period, no changes in clinical decision making for interventions that require attending staff, such as nighttime surgeries, could be identified. This is due to the fact that the patient population (as apparent from our baseline characteristics) and the composition of the medical team as well as treatment strategies did not change over the study period. Therefore, the decision making itself did not differ and patients were treated similarly in both periods. For example, nighttime and weekend surgeries were performed in the OH period as well in order meet our standards of care. Even though decision making remained similar, our results clearly show that the time to interventions that require decision-making was significantly shorter after introduction of IH attending trauma surgeons.

Based on the triage characteristics in our cohort as well as existing literature, a relatively high percentage of severely injured and polytrauma patients is under triaged.[22] It was shown previously that under triaging and not activating a full trauma team increase the odds of mortality.[22,23] When taking this into account, presence of an IH experienced surgeon for all trauma team activations is even more important as one cannot completely rely on triage characteristics. In addition, injuries in patients who appear to be more severely injured than expected may be diagnosed and treated sooner with their presence.

As expected, it was not possible to show any effects of the IH attendings on mortality in this study. Our patient population consists almost solely of blunt trauma patients (where patients with penetrating injuries are suspected to benefit most from early presence of an experienced surgeon), the mortality rate is relatively low and the majority of trauma deaths in our institution is due to brain injuries.[24] Furthermore, the mandatory OH on-call response time was twenty minutes and with a senior surgical resident in house, resuscitation processes were already at a high standard for most patients. Unfortunately, we were not able to assess preventable deaths, functional recovery and quality of life, as that was beyond the scope of this study. As debated previously, in our pursuit to optimize trauma care, we aim to improve all individual elements in the chain of care in our hospital and thus focused on the process-related outcomes of the in-house schedule.

The volume of a trauma center might have impact on the efficiency analysis of IH attendings, as in-house staff is supposedly most beneficial for patients with poor baseline status (thus, a relatively small part of the total number of patients).[25] Therefore, the findings of our study are not generalizable to every institution delivering care to trauma patients. For low-volume trauma centers not dealing with severely injured patients frequently, having an IH attending may be less favorable due to the number of surgeons needed on the schedule, with increased costs and only little effects on outcomes and process-related factors expected. However, for larger volume hospitals treating multiple injured patients, an IH schedule is feasible and likely beneficial. The presence of IH attendings resulted in improved utilization of resources and reduced ED transit time, thereby increasing the availability of the resuscitation bays and nurses at the ED.

Our study has several strengths. First, as we excluded all patients presenting six months prior or after the transition to the IH schedule, we reduced possible effects of anticipation on and first implementation of the new call schedule on our outcomes. Second, our retrospective before-and-after study was based on prospectively gathered data continuously monitored by trained data managers and a trauma surgeon. Third, we present a large series with a large time span providing a complete overview of processes potentially influenced by trauma surgeons. This study also has its limitations. To our knowledge, there were no major transitions during our study period except for the attendance policy and 24/7 availability of ICU beds in the second half of the IH period. The availability of this latter resource will have influenced the shorter time to ICU admission in the in-house period. Therefore, this finding should not be attributed to continuous presence of IH attending surgeons alone. However, the availability of an ICU bed will not have affected the time to emergency surgery. As the time to this intervention also decreased in the second period, we do believe that part of the faster ICU admission also reflects the change in personnel structure (for example due to attending-to-attending communication with the ICU staff). The historical control design poses its limitations. We were not able to account for the precise difference in surgeon response time, as we did not have data on the arrival time of the out of hospital calls (mandatory response time was twenty minutes) and nor were we able to retrieve the number of cases in the OH period where an attending surgeon was present at the bedside on arrival. As trauma surgeons will have been present at presentation of severely injured patients during the out-of-hospital period as well, especially during daytime but also 'off hours', the results of the present study may even underestimate the true effects of continuous presence of experienced surgeons. During the IH period, AIS coding has been updated, which is known to reduce ISS scores.[26] This may have caused presence of more severely injured patients in the IH group, potentially causing another underestimation of the effects of IH trauma surgeons.

Conclusions

In conclusion, introduction of a 24/7 in-house attending trauma surgeon in a large volume Level 1 Trauma Center led to improved process-related outcomes, especially for the most severely injured patients. There is a clear benefit of the continuous presence of physicians with sufficient experience in trauma care in hospitals treating a large number of severely injured patients.

Supplementary table 1. Triage characteristics stratified by Injury Severity Score*.

	Out-of-hospital period (n = 1323)			In-hospital period (n = 3045)		
	ISS <16 n = 858	ISS 16 – 24 n = 251	ISS >24 n = 214	ISS <16 n = 2104	ISS 16 – 24 n = 549	ISS >24 n = 392
Stability (n (%))						
Unstable trauma	75 (9)	82 (33)	137 (64)	218 (10)	164 (30)	254 (65)
Stable trauma	783 (91)	169 (67)	77 (36)	1886 (90)	385 (70)	138 (35)
Triage color** (n (%))						
Red	105 (12)	82 (33)	131 (61)	275 (13)	171 (31)	270 (69)
Orange	626 (73)	159 (63)	77 (36)	1532 (73)	342 (62)	118 (30)
Yellow	110 (13)	6 (2)	2 (1)	253 (12)	33 (6)	4 (1)
Green	13 (2)	1 (0)	0 (0)	42 (2)	2 (0)	0 (0)
Missing	4 (0)	3 (1)	4 (2)	2 (0)	1 (0)	0 (0)

*Injury Severity Score (ISS) available for 4368 patients. No statistically significant differences between the two time periods.

** Triage color ranges from most emergent (red) to least emergent (green).

ISS = Injury Severity Score; n = number.

Supplementary table 2. Emergency Department length of stay* (hours) stratified.

	Out-of-hospital period (n = 2530)	In-hospital period (n = 5398)	
	Median (IQR)	Median (IQR)	*p*-value
Complete cohort (n = 7935)	3.0 (2.1 – 4.1)	3.2 (2.2 – 4.3)	**<0.001**
Triage color (n = 7888)			
Red	2.5 (1.7 – 3.7)	2.0 (1.4 – 3.4)	**<0.001**
Orange	3.2 (2.4 – 4.2)	3.5 (2.5 – 4.5)	**<0.001**
Yellow	2.9 (2.0 – 3.9)	3.3 (2.2 – 4.5)	**<0.001**
Green	1.7 (1.2 – 2.6)	2.2 (1.5 – 3.3)	**<0.001**
Stability (n = 7935)			
Unstable trauma	2.6 (1.6 – 3.9)	2.0 (1.4 – 3.2)	**<0.001**
Stable trauma	3.1 (2.2 – 4.1)	3.3 (2.4 – 4.4)	**<0.001**
Injury Severity Score (n = 4368)			
Polytrauma			
>24	2.7 (1.6 – 4.0)	2.1 (1.5 – 3.7)	**0.009**
16 – 24	3.3 (2.0 – 4.2)	3.4 (2.0 – 4.7)	0.41
Non-polytrauma			
<16	3.3 (2.4 – 4.4)	3.3 (2.3 – 4.4)	0.83

*Administrative times; may differ from real times. Available for 7928 encounters (100%).

n = number; IQR = interquartile range.

Bold indicates statistically significant difference.

Supplementary table 3. Time from ED to CT-scan (minutes) <24 hours* for admitted patients stratified.

	Out-of-hospital period (n = 1090)	In-hospital period (n = 2491)	
	Median (IQR)	Median (IQR)	*p*-value
Complete cohort (n = 3581)	30 (21 – 50)	28 (22 – 42)	0.05
Triage color (n = 4354)			
Red	27 (18 – 41)	27 (21 – 38)	0.52
Orange	30 (21 – 48)	28 (21 – 40)	**0.004**
Yellow	78 (45 – 152)	76 (41 – 124)	0.37
Green	125 (56 – 157)	89 (53 – 140)	0.73
Stability (n = 3581)			
Unstable trauma	27 (18 – 43)	27 (21 – 38)	0.47
Stable trauma	31 (22 – 52)	29 (22 – 44)	**0.010**
Injury Severity Score (n = 3581)			
>24	25 (18 – 45)	27 (20 – 38)	0.59
16 – 24	29 (19 – 48)	28 (22 – 40)	0.59
<16	31 (22 – 52)	29 (22 – 44)	**0.010**

*Administrative times; may differ from real times.
n = number; IQR = interquartile range.
Bold indicates statistically significant difference.

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Part 2

Long-term outcomes of extremity injuries in polytrauma patients

Hand & Wrist

Chapter 3

Epidemiology of distal radius fractures in polytrauma patients and the influence of high traumatic energy transfer

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Abstract

Introduction
For several extremity fractures differences in morphology, incidence rate and functional outcome were found when polytrauma patients were compared to patients with an isolated injury. This is not proven for distal radius fractures (DRF). Therefore, this study aimed to analyze fracture morphology in relation to energy transfer in both poly- and mono-trauma patients with a DRF.

Methods
This was a retrospective cohort study. All patients aged 16 years and older with a DRF were included. Patients with an Injury Severity Score of 16 or higher were classified as polytrauma patients. Injuries were defined as high or low energy. All DRFs were classified using the AO/OTA fracture classification system.

Results
A total of 830 patients with a DRF were included, 12% were polytrauma. The incidence rate of DRF in polytrauma patients was 3.5%. Ipsilateral upper extremity injury was found in >30% of polytrauma and high-energy monotrauma patients, compared to 5% in low-energy monotrauma patients. More type C DRF were found in polytrauma and high-energy monotrauma patients versus low-energy monotrauma patients. Operative intervention rates for all types of DRF were similar for polytrauma and high-energy monotrauma patients. Non-union rates were higher in polytrauma patients.

Conclusions
Higher energy mechanisms of injury, in polytrauma and high-energy monotrauma patients, were associated with more severe complex articular distal radius fractures and more ipsilateral upper extremity injuries. Polytrauma and high-energy monotrauma patients have a similar fracture morphology. However, polytrauma patients have in addition to more injured body regions also more non-union related interventions than high-energy monotrauma patients.

Introduction

The functional outcome of patients with upper extremity fractures in polytrauma is worse compared to patients with similar isolated extremity injuries.[1-4] While it is known that the incidence rate for distal radius fractures (DRF) is up to 17% for patients who sustain it as an isolated injury, the incidence rate for DRF in polytrauma patients is unknown.[3,5,6] In addition, prior studies found that extremity fractures sustained by polytrauma patients are different in the morphology of injury and incidence rate. In polytrauma patients with a displaced clavicle fracture the incidence rate was higher compared to patients with an isolated injury and less displaced fractures were found. In polytrauma patients with hand injuries a high rate of carpal and ligamentous injuries were found as opposed to phalangeal and metacarpal injuries frequently seen in patients with an isolated injury.[1,2]

Currently there is sparse data on the epidemiology, fracture pattern and concomitant injuries of distal radius fractures in polytrauma patients. A possible explanation is that most studies exclude polytrauma patients for methodological purposes.[7,8] Despite frequent anecdotes on different fracture patterns seen after high energy impact, little is known about the influence of high energy trauma mechanisms on fracture morphology and the epidemiologically different groups this creates.

Better understanding of the incidence rate and fracture morphology in polytrauma patients would provide insight on the scale and impact of DRF in these patients. Furthermore, it could serve as a basis for future studies on DRF in polytrauma patients. Since the bulk of polytrauma is the result of high energy trauma, we hypothesized that worse fracture morphology (complex articular fractures, type C in the AO-OTA Fracture classification system) was associated with higher energy trauma mechanisms.

Thus, the aim of this study was to determine the prevalence and fracture morphology of distal radius fractures in polytrauma patients in comparison to monotrauma patients. We also assessed the influence of the trauma mechanism (energy transfer) on fracture morphology and concomitant injuries in patients with distal radius fractures.

Methods

An institutional review board (IRB) waiver was obtained. A single, level 1 trauma, centre retrospective cohort study was performed. Patients in our region (Central Netherlands) are transported by the Regional Ambulance Service to 1 of the 10 hospitals. The region Central Netherlands consists of 9 level II and level III hospitals and 1 level I trauma center in a 2418-km^2 region with a population of 1.2 million people. The University Medical Center Utrecht is designated as a level I trauma center, offering trauma care at the highest level for severely injured patients. The 9 surrounding level II and III hospitals are designed to treat patients without severe injuries. This regional trauma network is based on an inclusive and integrated trauma system.[9] Patients with a DRF who presented at our institution between 2008 and 2015 were identified using ICD-9 codes (International Classification of Diseases). Demographics, type and number of operative interventions, complications from interventions and Gustilo classification, in case of an open fracture, were collected from the electronic medical record.

Interventions were categorized as primary or secondary surgery. Open- and closed reduction and internal fixation or the placement of external fixation were counted as primary surgery. All other procedures were counted as secondary surgery. Removal of hardware was not included in the analysis for secondary surgeries.

Concomitant injuries (fractures and injuries with Abbreviated Injury Scale (AIS)>1, excluding excoriations and lacerations) were collected from the electronic patient documentation. To analyse additional ipsilateral upper extremity injuries, the side was noted. The injuries were subdivided into regions; carpal, metacarpal & phalangeal, elbow & forearm and humeral bone & shoulder. Additional injuries to the Head, Thorax and Abdominal region were also noted in case of an injury with a AIS of >1.

Radiographic studies were reviewed to confirm the ICD coded diagnosis. Criteria for high-energy trauma were; fall ^{3} 3 meters or higher, car accident ^{3} 60km/h, motorcycle accident ^{3} 30km/h, vehicle shortening ^{3} 50cm, vehicle depression passenger side ^{3} 30cm, vehicle rollover, passenger thrown from vehicle, fatality in same vehicle, car or motorcycle versus pedestrian or bicyclist ^{3} 10km/h, motorcycle or bicycle vs motorcycle or bicycle or stationary object.

All patients aged 16 years and older were included. Polytrauma was defined as an Injury Severity Score (ISS) of 16 or higher, calculated using Abbreviated Injury Scale (AIS) scores.[10] Monotrauma patients were categorized based on the ISS, thus a patient with an ISS of <16 who sustained a high-energy trauma was noted as high-energy monotrauma patients. Due to the extent of the injuries sustained in polytrauma, it can be hypothesized that all polytrauma patients suffered high energy impact, despite this is not classified as such. All polytrauma patients with a low-energy trauma were analyzed to compared differences with high-energy polytrauma and monotrauma patients.

DRF radiographic studies were reviewed by two investigators (SF and QV) and classified as type A, B or C according to the Arbeitsgemeinschaft für Osteosynthesefragen-Orthopaedic Trauma Assocation (AO/OTA) classification . Type A1; isolated ulnar styloid fractures were excluded, as were epiphysiolysis. Type A; extra articular, type B; partial intraarticular, type C; complete intraarticular with metaphyseal fracture were included. Fractures were classified using both pre- and post-reduction radiographs and computed tomography scans when available. A second assessment by two other investigators (MH and FH) was performed when no consensus was reached. In further subgroup (1, 2 or 3) interpretation, only C3 fractures were identified because of the limited reliability for extensive subgroup differentiation.[11,12]

Statistical analysis

Continuous variables were presented as mean with standard deviation (SD). Categorical variables were presented as frequencies with percentages. Parametric tests were used for statistical analysis; chi-square test for dichotomous variables, Fisher exact when a cell count of 5 or less was observed, Student-t test and ANOVA for continues variables with dichotomous or categorical variables. For analysis of continuous data with outliers Mann-Whitney test was used. A *p*-value of ≤0.05 was considered significant. Statistical analysis was performed using SPSS version 21 (IBM Corp., Armonk, NY).

Results

A total of 830 patients with a distal radius fracture (DRF) were included and 102 patients (12%) had an ISS of 16 or higher and were considered polytrauma patients. The incidence of DRF in polytrauma patients was 3.5% (102 polytrauma DRF patients/ 2922 polytrauma patients admitted within the studied time period). Of the whole group, 249 patients (30%) suffered additional injuries. The mean age of the entire cohort was 53 years, 34% were males and 6 died due to the trauma. Table 1 depicts the baseline demographics for polytrauma and monotrauma patients after high- and low-energy trauma.

Table 1. Baseline demographics of poly- and monotrauma patients.

	Polytrauma n= 102		Monotrauma High-energy n= 107		Monotrauma Low-energy n= 621		*P*-value
Age in years (SD)	45.7	21	42.6	18	55.4	21	<0.001
Male gender	66	65%	69	65%	144	23%	<0.001
Injury Severity Score (SD)	25.9	8	9.5	3	7.6	2	<0.001
Mechanism of injury							<0.001
Fall < 3 meters	13	13%	2	2%	551	89%	
Fall ^{3} 3meters	43	42%	38	36%	2	0.3%	
Bicycle accident	5	5%	8	8%	39	6%	
Car accident	16	16%	25	23%	3	0.5%	
Motorcycle accident	20	20%	30	28%	5	1%	
Pedestrian involved in MVA	2	2%	2	2%	2	0.3%	
Associated head injury AIS>1	44	43%	2	2%	4	0.6%	<0.001
Associated thoracic injury AIS>1	59	58%	5	5%	1	0.2%	<0.001
Associated abdominal injury AIS>1	35	34%	4	4%	2	0.3%	<0.001
HET	82	80%					n. A.
Admitted hospital	100	98%	62	58%	41	6%	<0.001
ICU admittance	34	34%	3	5%	0	0%	<0.001
ICU days (SD)	3.9	9.8	0.2	1.3	0	0	0.001

Number with % unless otherwise indicated, SD; standard deviation, MVA; motor vehicle accident, ICU; Intensive care unit, AIS; Abbreviated injury score, HET; high-energy trauma, n.a.; not applicable, +/-; indicating direction of difference and comparable group, HET and LET (low energy) monotrauma patients with associated head/ thorax or abdominal injury sustained only AIS 2 injuries in these regions.

For the entire cohort, type A distal radius fracture (DRF) were the most prevalent with 43% (n= 356), followed by type C, 39% (n=325) and type B 18% (n=149) (table 2). In polytrauma and high-energy monotrauma patients, a higher ratio of type C (>50%) versus type A DRF was observed compared with low-energy monotrauma patients (p<0.001 and p<0.001). No difference in distribution of type C DRF was observed between polytrauma and high-energy monotrauma patients (p=0.682). Type C3 DRF were identified in 22 polytrauma (22%), 16 high-energy (15%) and 25 low-energy monotrauma patients (4%) (p<0.001). Type C3 DRF were more prevalent after high-energy (n=37, 20%) compared to low-energy trauma (n=26, 4%) mechanisms (p<0.001). Polytrauma and high-energy monotrauma patients had a higher rate of open fractures compared to low-energy monotrauma patients (8.8% and 9.3% versus 1.8%, both p<0.001). The distribution of all types of DRF for different age categories in the 3 groups is shown in figure 1.

Both polytrauma and high-energy monotrauma patients received more operative interventions for all types of DRF compared to low-energy monotrauma patients (Table 3). No difference in operative intervention rate between polytrauma and high-energy monotrauma was observed for all fracture types (type A p=0.698, type B p=0.055, type C p=0.438).

Table 2. Distribution of different fracture types in polytrauma patients, monotrauma patients after an high energy trauma (HET) and low energy trauma (LET).

	Total number	Fracture type			Open fractures
		A	B	C	
All patients	830	356 (43%)	149 (18%)	325 (39%)	27 (3%)
Polytrauma	102	23 (22%)	18 (18%)	61 (60%)	9 (9%)
HET monotrauma	107	26 (24%)	23 (22%)	58 (54%)	10 (9%)
LET monotrauma	621	307 (49%)	108 (17%)	206 (34%)	8 (1%)

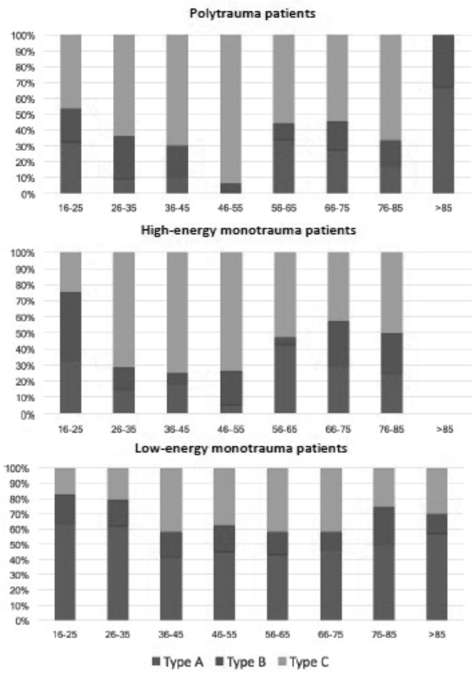

Figure 1. Distribution per age category of type A, B and C distal radius fractures in polytrauma, high-energy monotrauma and low-energy monotrauma patients.

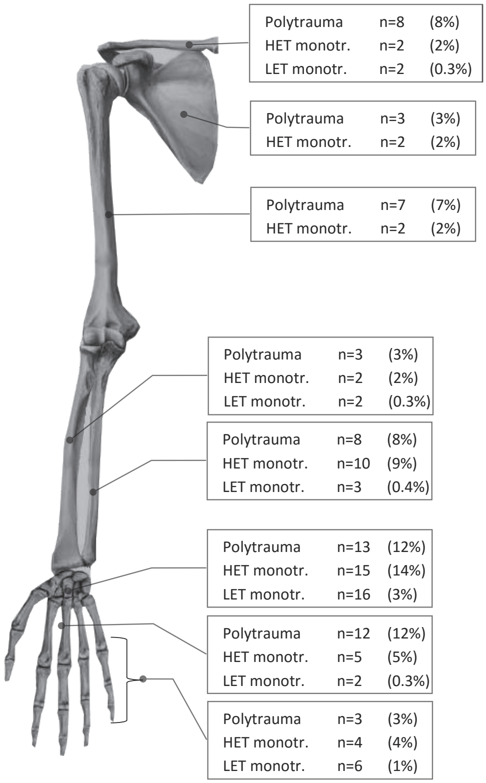

Figure 2. Distribution of all additional injuries per poly- and monotrauma patients (HET monotr.; High-energy monotrauma patients; LET monotr.; Low-energy monotrauma patients)

Within the polytrauma group 20 patients (20%) suffered a low-energy trauma. These patients were older than the other 3 groups (mean 66 years, SD 13), had similar admission (98% vs 100%) and ICU admission (34% vs 35%) rates as high-energy polytrauma patients and had a similar head and thoracic injury rates (55% and 40% respectively). The fracture morphology was different than the other 3 groups (40% type A, 20% B and 40% C) and the operative intervention pattern was more similar to low-energy monotrauma patients (more type A DRF interventions but less operative interventions in total compared to high-energy poly- and monotrauma patients, both $p<0.001$)

Additional ipsilateral upper extremity injuries were observed in 105 patients (13%) (154 sustained injuries). Polytrauma patients and high-energy monotrauma patients had more ipsilateral upper extremity injury compared to low-energy monotrauma patients (38% and 32% versus 5.2% respectively, $p<0.001$ and $p<0.001$ respectively). Carpal fractures (n=44, 5.4%), followed by metacarpal & phalangeal injuries (n=34, 4.1%) were the most prevalent (Figure 2). Of the patients with ipsilateral concomitant upper extremity injuries 17 (17/105, 16%) had injuries diagnosed after initial survey.

Table 3. Details of operative interventions in polytrauma, monotrauma patients after high energy trauma and patients after low energy trauma.

	Polytrauma patients n=102	High-energy Monotrauma n=107	Low-energy Monotrauma n= 621	*p*-value
Operation for DRF, n/ total (%)	68 (67%)	65 (61%)	176 (28%)	<0.001
Type A	11/ 23 (48%)	11/ 26 (42%)	53/ 307 (17%)	<0.001
Type B	10/ 18 (56%)	6/ 23 (26%)	18/ 108 (17%)	0.001
Type C	47/ 61 (77%)	48/ 58 (83%)	105/ 206 (51%)	<0.001
^{3}2 operations for DRF	26 (38%)	23 (35%)	45 (26%)	0.096
^{3}3 operations for DRF	4 (6%)	6 (9%)	1 (1%)	0.003
Time to first operation, d (SD)	6 (5)	5 (5)	9 (5)	<0.001
Type of primary operation*				<0.001
ORIF	53 (78%)	53 (82%)	163 (93%)	
CRIF	3 (4%)	3 (5%)	10 (6%)	
External fixator	12 (18%)	9 (14%)	2 (1%)	
Secondary surgery				
Nonunion operation	7 (10%)	1 (2%)	1 (1%)	<0.001
Revision of osteosynthesis	3 (4%)	2 (3%)	6 (3%)	0.905
Removal of osteosynthesis	9 (13%)	12 (19%)	32 (18%)	0.624
External fixator to ORIF	8 (67%)	7 (78%)	1 (50%)	0.655
Operation for infection	1 (2%)	3 (5%)	1 (1%)	0.187
Correction osteotomy radius	2 (3%)	1 (2%)	1 (1%)	0.333

DRF; distal radius fracture, SD; standard deviation, d; days*; 1 missing case, ORIF; open reduction and internal fixation, CRIF; closed reduction and internal fixation, +/-; indicating direction of difference and comparable group

Discussion

Our study demonstrated fracture morphology in combination with injury mechanism in both polytrauma and monotrauma patients with a DRF. This study found that the fracture morphology and incidence of concomitant soft tissue injuries were associated with the energy impact. High energy monotrauma patients with a DRF demonstrated similar fracture morphology as polytrauma patients. The incidence of concomitant ipsilateral upper extremity injury in polytrauma and high-energy monotrauma patients was high (30%) and 16% of these injuries were found after the initial survey. Although polytrauma and high-energy monotrauma patients sustain similar injuries, differences remain between these groups.

Most importantly, energy of trauma is associated with fracture morphology, concomitant injuries to the ipsilateral upper extremity and other body regions, number of operative interventions and non-union and it thus likely relevant for functional outcome. Therefore, outcome evaluation should be different for polytrauma and high-energy monotrauma versus those who sustain their injury through lower-energy mechanisms.

The incidence of DRF in polytrauma patients (3.5%) is lower compared to patients with an isolated DRF.[6] Furthermore, in polytrauma patients a higher rate of type C and C3 subtype DRF was found, especially in patients aged 20-45 years.[6] The main cause of polytrauma were high-energy trauma accidents, 80% in this study. The remaining 20% polytrauma patients showed a similar head and thoracic injury pattern, similar ISS, and had the same admission and ICU admission rate. These low-energy polytrauma patients were significantly older than the other 3 groups. This likely represents a group of geriatric polytrauma patients in which a low-energy trauma can result in similar injuries as seen in high energy polytrauma patients. Although these patients have multiple injuries, their DRF morphology is somewhat different, but resembles mostly high-energy polytrauma injury, therefore, this group is analysed as one.

Similar DRF classifications were observed in polytrauma and high-energy monotrauma patients. Therefore, we demonstrated that the fracture morphology of DRF depends on the energy transfer during the trauma. High-energy accidents, like fall from heights and high velocity traffic incidents, distribute more energy over a larger area. This could explain the lower incidence but higher severity of DRFs in polytrauma patients. The peak incidence of type C DRF was observed in patients aged 20-45 years old. The higher rate of high-energy traumas in these age categories are probable responsible for this effect. The higher incidence of males, and younger age are known epidemiologic characteristics of patients involved high energy accidents (i.e. fall from height, high velocity traffic accidents).[13] A study by Flinkkilä et al, examined all DRF in a region in Finland and did not find an association between trauma energy and fracture morphology.[14] However, different, less stringent definitions for high energy trauma and a lower number of high energy trauma patients might be responsible for the lack of association in their study.

Although DRF in polytrauma and high-energy monotrauma patients are radiographically categorized similar to those in low-energy monotrauma, substantial differences were observed. For example, in polytrauma and high-energy monotrauma patients more open fractures, higher rates of C3 fractures, a higher operative intervention rate for all types of DRF, more reoperations and more frequent use of external fixators was seen compared to low-energy monotrauma patients. Although more C3 type DRFs were observed in polytrauma and high-energy monotrauma patients compared to low-energy monotrauma, this only partially describes the injury severity of the fracture in these patients. The increased number of surgeries performed and the higher percentage of external fixation used, suggests an increased injury severity of the fractures that is not reflected by fracture classification. Higher energy transfer causes more additional damage, also to the soft tissues. This was reflected in the higher rate of additional ipsilateral injuries and open fractures. This could explain the higher rate of operative interventions for the same radiographic types of DRFs in polytrauma and high-energy monotrauma compared to low-energy monotrauma patients.

All patients were treated by the same surgical team. Thus, it is likely that the higher rate of external fixators with delayed definitive internal fixation indicates more severe soft tissue and is not institution or surgeon preference based.

A high rate (>30%) of concomitant ipsilateral upper extremity injuries in both polytrauma and high-energy monotrauma patients was found. This is in line with the observation that high-energy trauma cause more severe DRFs. Sixteen percent of these injuries were found after initial survey. Delayed diagnosed extremity injuries in polytrauma patients are a well-known phenomenon.[5] In this population distal extremity injuries were frequently diagnosed after the primary survey or even after discharge.[5] A challenging aspect in high-energy monotrauma patients, compared to polytrauma patients, is the lower admission rate. This limits the opportunity to re-evaluate the patient for additional injuries. The painful distracting injury of the DRF during the initial survey could lead to missed injuries in these patients.[15] The rate of ipsilateral extremity injuries in DRF patients after a high-energy accident underlines the need for a repeated examination, also in monotrauma patients.

Although polytrauma and high-energy monotrauma patients sustain similar injuries, outcome evaluation should be different. Injuries to other body regions, prioritization of care for life threatening injuries, prolonged sedation and ICU admittance and decreased ability to rehabilitate are all factors that can negatively influence outcome of polytrauma patients. Furthermore, in this study differences were supported by the higher rate of non-union related interventions found in polytrauma patients. This was not observed for high-energy monotrauma patients and therefore might not solely be attributable to energy transfer. It is hypothesized that the systemic inflammatory effects inherent to polytrauma patients play a role in fracture healing. Several animal studies have shown that systemic changes in leucocyte functioning in polytrauma patients could deteriorate fracture healing.[16,17] This was also found in studies which compared polytrauma patients with and without fracture healing disorders.[18] Interestingly, there are contradictory results on this matter and the influence of polytrauma appears to vary depending on the studied subgroup and bones affected.[19-22]

Injuries to other body regions can influence outcome of extremity injury in polytrauma patients. For example traumatic brain injury, severe thoracic injury or a lower extremity injury could dictate treatment priority and influence the ability to rehabilitate after a DRF. Other studies showed that functional outcome of extremity injuries in polytrauma patients was worse compared to (high-energy) monotrauma patients with similar injuries.[1,23] Our results and these studies indicate that outcome in polytrauma patients is multifactorial and therefore polytrauma and high-energy monotrauma patients should be considered as separate groups in outcome analysis.

Our study has several limitations. This study did not report on outcome. Previous studies showed different outcomes for polytrauma patients compared to monotrauma.[1,2] Furthermore, this study lacks information on osteoporosis, vitamin D deficiency and glucocorticoid use. This would have added to the interpretability of the fracture classification, especially in the older age categories.[24-26] Another limitation of this study is the potential of selection bias because the study was performed with data solely from a level 1 trauma center. Inclusion of patients from both level 1 and level 2 centers would have added to the interpretability. However, the large number of low-energy trauma patients included decreases the risk of selection bias. In addition, the patients presented at our level 1 trauma center are not solely polytrauma patients and can be presented by the same route as in level 2 trauma centers. General practitioner referral, patients presenting out of own consideration and ambulance overtriage (not severely injured but allocated to level 1 trauma center because suspected polytrauma) of 30.6% by ambulance personnel in our region are explanations for the presentation of low energy trauma and high energy monotrauma patients to our facility.[9] This adds to the interpretability and decreases the risk of selection bias. Finally, the classification of fractures was limited to group A, B, C and only type C3 was sub-classified. This latter was based on the large inter-observer variation in the AO classification regarding sub-classifications.[11,12] A prospective design with computed tomography of all included patients could provide further insight in the subgroup division.

Conclusions

The incidence of distal radius fractures (DRF) in polytrauma patients was 3.5%, this is low compared to a patients with an isolated DRF. The energy transfer determines fracture morphology and a similar fracture distribution with more type C distal radius fractures was observed in polytrauma and high-energy monotrauma patients. In polytrauma and high-energy monotrauma patients a high rate of ipsilateral upper extremity injury was found. Polytrauma and high-energy monotrauma patient with a DRF are comparable with regard to fracture type and distinctly different in this matter than low-energy monotrauma patients. However, polytrauma patient have in addition to more injured body regions also more non-union related interventions than high-energy monotrauma patients, indicating differences remain. Future studies, especially when focus on outcome measurements, should account for the 3 distinct groups regarding injury pattern in distal radius fractures.

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Chapter 4

Polytrauma and high-energy injury mechanisms are associated with worse patient-reported outcome scores after distal radius fractures

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Abstract

Introduction

Patient-reported outcomes (PROs) are increasingly relevant when evaluating the treatment of orthopaedic injuries. Little is known about how PROs may vary in the setting of polytrauma or secondary to high-energy injury mechanisms, even for common injuries such as distal radius fractures.

Questions/purposes

(1) Are polytrauma and high-energy injury mechanisms associated with poorer long-term PROs (EuroQol Five Dimension Three Level (EQ-5D-3L) and Quick Disabilities of the Arm, Shoulder, and Hand (QuickDASH) scores) after distal radius fractures? (2) What are the median EQ-5D-3L, EQ-VAS (EuroQol VAS), and QuickDASH scores for distal radius fractures in patients with polytrauma, high-energy monotrauma and low-energy monotrauma

Methods

This was a retrospective study with followup by questionnaire. Patients treated both surgically and conservatively for distal radius fractures at a single Level 1 trauma center between 2008 and 2015 were approached to complete questionnaires on health-related quality of life (HRQoL) (the EQ-5D-3L and the EQ-VAS) and wrist function (the QuickDASH). Patients were grouped according to those with polytrauma (Injury Severity Score (ISS) ≥ 16), high-energy trauma (ISS < 16), and low-energy trauma based on the ISS score and injury mechanism. Initially, 409 patients were identified, of whom 345 met the inclusion criteria for followup. Two hundred sixty-five patients responded (response rate, 77% for all patients; 75% for polytrauma patients; 76% for monotrauma high-energy; 78% for monotrauma low-energy ($p = 0.799$ for difference between the groups). There were no major differences in baseline characteristics between respondents and nonrespondents. The association between polytrauma and high-energy injury mechanisms and PROs was assessed using forward stepwise regression modeling after performing simple bivariate linear regression analyses to identify associations between individual factors and PROs. Median outcome scores were calculated and presented.

Results

Polytrauma (intraarticular: β -0.11; 95% confidence interval (CI), -0.21 to -0.02); $p = 0.015$) was associated with lower HRQoL and poorer wrist function (extraarticular: β 11.9; 95% CI, 0.4–23.4; $p = 0.043$; intra-articular: β 8.2; 95% CI, 2.1–14.3; $p = 0.009$). High-energy was associated with worse QuickDASH scores as well (extra-articular: β 9.5; 95% CI, 0.8–18.3; $p = 0.033$; intra-articular: β 11.8; 95% CI, 5.7–17.8; $p < 0.001$). For polytrauma, high-energy trauma, and low-energy trauma, the respective median EQ-5D-3L outcome scores were 0.84 (range, -0.33 to 1.00), 0.85 (range, 0.17–1.00), and 1.00 (range, 0.174–1.00). The VAS scores were 79 (range, 30–100), 80 (range, 50–100), and 80 (range, 40–100), and the QuickDASH scores were 7 (range, 0– 82), 11 (range, 0–73), and 5 (range, 0–66), respectively.

Conclusions
High-energy injury mechanisms and worse HRQoL scores were independently associated with slightly inferior wrist function after wrist fractures. Along with relatively well-known demographic and injury characteristics (gender and articular involvement), factors related to injury context (polytrauma, high-energy trauma) may account for differences in patient-reported wrist function after distal radius fractures. This information may be used to counsel patients who suffer a wrist fracture from polytrauma or high-energy trauma and to put their outcomes in context. Future research should prospectively explore whether our findings can be used to help providers to set better expectations on expected recovery.

Introduction

Patient-reported outcomes (PROs) are becoming increasingly important when evaluating the treatment of orthopaedic injuries.[14] Part of the challenge in implementing PROs is that outcomes are often context- and patient-dependent.[25] When measuring PROs within highly heterogeneous patient populations, such as a population of trauma patients, the statistical variance in measured PROs is often also correspondingly large, making an accurate comparison of treatment outcome and cost challenging.[26] To avoid this problem, many existing studies on PROs after musculoskeletal injury have focused on specific conditions or treatments using well-defined, homogenous patient populations. In this setting, patients with greater complications, such as those who sustain polytrauma or multiple (extremity) injuries, are often excluded.[4,28,33,35]

There is a gap in our understanding of PROs in patients who have sustained polytrauma with orthopaedic injuries and those with orthopaedic injuries sustained in the context of high-energy injury mechanisms.[11] For example, while it is well known that PROs after isolated distal radius fractures vary by age, gender, or articular stepoff, the variation in PROs is less understood in patients with multiple or high-energy injuries, even though wrist fractures occur in nearly 3.5% of patients with polytrauma.[3,10,15,19,23] Therefore, while articular stepoff and demographic characteristics may still be relevant factors, we do not know if the magnitude of their association is dwarfed by other factors related to a larger burden of injury.

Therefore, we asked: (1) Are polytrauma and high-energy injury mechanisms associated with poorer long-term PROs (EuroQol Five Dimension Three Level (EQ-5D-3L) and Quick Disabilities of the Arm, Shoulder, and Hand (QuickDASH) scores) after distal radius fractures? (2) What are the median EQ-5D-3L, EQ-VAS (EuroQol VAS), and QuickDASH scores for distal radius fractures in patients with polytrauma, high-energy monotrauma, and low-energy monotrauma?

Methods

Study design and setting
We obtained additional data regarding a patient cohort on which we have previously reported using followup questionnaires. In the previous study, we used the same cohort of patients to assess the incidence rate and fracture morphology of distal radius fractures in polytrauma patients compared with monotrauma patients.[10] In the present study, we

included patients whose injury occurred between January 2008 and December 2015, and followup examinations were performed in April and May 2018.

Participants

After obtaining an institutional review board waiver, using ICD-9 codes, we identified all patients who presented with a traumatic distal radius fracture at our Level 1 trauma center during the inclusion period for evaluation in this retrospective study. We reviewed the medical records (notes and available imaging) of all patients older than 16 years at the time of trauma and older than 18 years at the time of followup to determine eligibility. Patients who underwent their initial treatment at an outside facility and patients with no followup beyond the primary presentation were deemed ineligible. Eligible patients were divided into three groups: polytrauma, monotrauma high energy (high-energy monotrauma), and monotrauma low energy (low-energy monotrauma). Polytrauma was defined as an Injury Severity Score (ISS) ≥ 16. The ISS calculates injury severity based on the most severe injuries sustained per body region.[29] As a result, all patients with an ISS < 16 were considered to have monotrauma. The energy of injury mechanism was defined according to the Advanced Trauma Life Support guidelines.[32] Patients who did not meet the criteria for high-energy trauma were considered to have low-energy trauma. Patients who had died, were mentally impaired, had an insufficient command of the Dutch language, and resided outside the Netherlands were excluded for followup.

All patients with polytrauma and high-energy monotrauma and a random sample of 200 patients with low-energy monotrauma who sustained a wrist fracture were included. The 200 low-energy monotrauma patient sample was drawn from the total cohort of 621 low-energy monotrauma patients who were treated for a wrist fracture at our institution during the study period using a random number generator. We approached the selected patients to complete two questionnaires. To all patients eligible for followup, we sent a recruitment letter explaining the study, the two questionnaires, an informed consent form, and a stamped return envelope. If there was no response within 4 weeks of mailing the letter, we contacted patients by telephone to obtain verbal informed consent and administer the questionnaires. We varied the time of the calls to maximize the response rate.[28]

Questionnaires were completed after a median of 6 years since injury (IQR, 4–8 years; range, 2–10 years).

Demographics

The median age at the time of injury was 50 years (interquartile range (IQR), 31–63 years), with a median ISS of 9 years (IQR, 9–14 years; range, 4–50 years). Among the group of patients with polytrauma and high-energy monotrauma, most were men (69% respectively 60%), while most patients with low-energy monotrauma were women (81%) (Table 1). Among all patients with wrist fractures, 145 (52%) were treated operatively (79% of fractures in patients with polytrauma, 80% of fractures in patients with high-energy monotrauma, and 36% of fractures in patients with monotrauma low-energy trauma). Most patients who were surgically treated underwent open reduction internal fixation (120 of 145; 83%). The only difference between respondents and nonrespondents was presence of more severe fractures in polytrauma respondents than in polytrauma nonrespondents ($p = 0.026$) (Supplementary Table 1).

Variables, outcome measures, data sources, and bias

Medical records and imaging were reviewed to obtain data on the following characteristics: age at the time of trauma, gender, ISS, injury mechanism, AIS codes, bilateral fracture, concomitant ipsilateral upper extremity injury, Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association (AO/OTA) classification, open fracture, and surgical treatment. Distal radius fractures were reviewed and classified according to the AO/OTA classification by two investigators (SF, QV).[21] When there was uncertainty, two attending trauma surgeons (RM, FH) were consulted and group discussions led to consensus. To decrease interobserver variability during the analysis, all fractures were then grouped as extraarticular (23.A) or intraarticular (partial articular (23.B) and complete articular (23.C)) (thereby not accounting for radial styloid fractures). Concomitant injuries of the involved upper extremity were recorded and grouped based on anatomic location. Treatment choice was according to the treating surgeon's preference and based on the amount of displacement, rotation, and stability.

PROs at greater than > 2 years of followup were assessed using measures of general health-related quality of life (HRQoL) and wrist function. HRQoL was assessed using the EuroQOL five-dimensional questionnaire (EQ-5D-3L) and the EuroQOL VAS (EQ-VAS). The EQ-5D-3L is a standardized instrument to measure general health status based on the level of experienced problems (no problems, some problems, extreme problems) in five dimensions (mobility, self-care, usual activities, pain or discomfort, and anxiety or depression).[34] Scores were calculated using a scoring algorithm appropriate for a population of Dutch patients, with a possible range from -0.33 to 1.00.[27] The EQ-VAS was developed to record an individual's current self-rated health on a scale from 0 to 100. For both the EQ-5D and the EQ-VAS, higher scores represent higher HRQoL.[34] Patient-reported wrist function was evaluated using the QuickDASH questionnaire, consisting of 11 items to measure physical function and symptoms in patients with any or multiple musculoskeletal disorders of the upper limb. Scores range from 0 to 100, with higher scores indicating worse function.[2] The DASH has been shown to be reliable, valid, and responsive in a population of patients with hand and wrist trauma, and the QuickDASH is as precise as the DASH questionnaire in patients with upper extremity disorders.[7,16] More specifically, the DASH questionnaire has been described as a valid and reliable PRO measure to assess function and disability in Dutch patients with displaced wrist fracture.[18] Changes of approximately 14 points in the QuickDASH score represent minimal clinically important changes.[12,31]

Accounting for all patients

A total of 830 patients were identified initially. After randomly selecting 200 patients with monotrauma low-energy trauma and applying the exclusion criteria for followup, we approached 345 patients for followup by questionnaire. Questionnaires were completed by 265 patients with 277 fractures (12 patients sustained bilateral distal radius fractures), leading to a response rate of 77% for the total cohort; 75% for polytrauma patients; 76%

for monotrauma high-energy; 78% for monotrauma low-energy (p = 0.799 for difference between the groups) (Fig. 1).

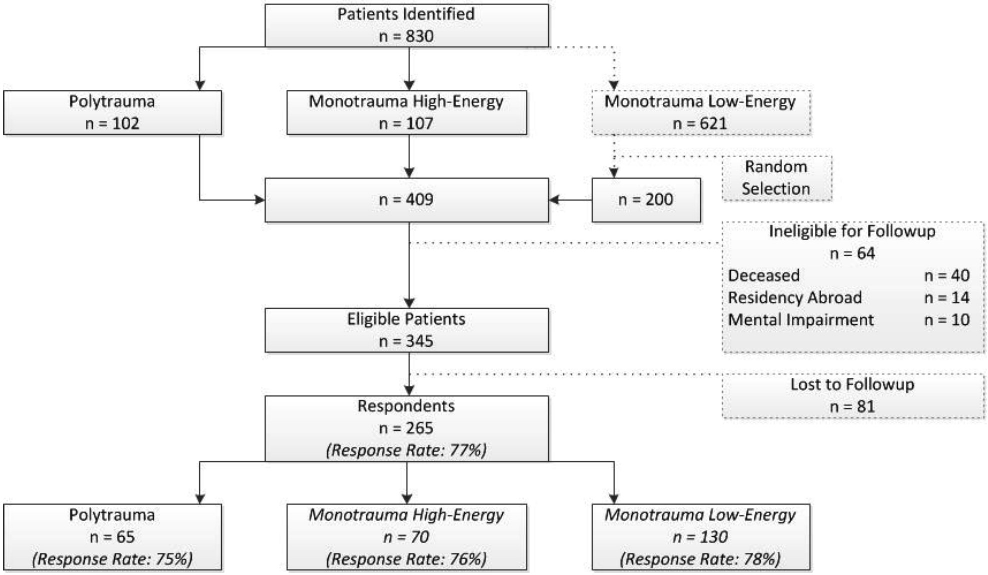

Fig. 1 Flowchart of the inclusion and response process.

Statistical analysis and study size

We calculated baseline characteristics as medians and IQRs for continuous variables and absolute numbers with percentages for categorical variables. We compared the baseline characteristics of respondents and nonrespondents in the four groups of interest using chi-square and Mann-Whitney U tests, and we compared response rates between the groups using ANOVA. Differences in PROs between the groups were calculated using Kruskal-Wallis tests. The strength of correlations among the three different outcome measures was assessed using Pearson's correlation coefficient. We first determined associations between individual factors and the PROs of interest with a simple bivariate linear regression analysis (Supplementary Table 2). The final models were selected with forward stepwise regression modeling to avoid overfitting. In this approach, factors associated with the outcome in the bivariate analysis were included in the multivariable regression model. Factors no longer associated with the outcome were omitted only if doing so did not increase the deviance of the model. Factors excluded from the bivariate analysis were reincorporated only if doing so reduced the overall deviance of the model.[30] Interaction terms were applied to the analyses. All statistical analyses were performed using STATA® 13.1 (StataCorp LP, College Station, TX, USA). A p value of < 0.05 was considered statistically significant.

Table 1. Demographic and injury characteristics.

	All respondents	**Polytrauma**	**High-Energy Monotrauma**	**Low-Energy Monotrauma**
Explanatory factors	**n = 265**	**n = 65**	**n = 70**	**n = 130**
Age at trauma (median, IQR)	50 (31 – 63)	45 (26 – 60)	44 (30 – 57)	58 (39 – 69)
Man (n, %)	112 (42)	45 (69)	42 (60)	25 (19)
ISS (median, IQR)	9 (9 – 14)	22 (19 – 29)	9 (9 – 10)	9 (4 – 9)
Time between fracture and follow-up (years; median, IQR)	6 (4 – 8)	5 (4 – 7)	6 (4 – 7)	6 (4 – 8)
Mechanism of trauma (n, %)				
Fall <3m	124 (47)	6 (9)	2 (3)	116 (89)
Fall >3m	50 (19)	27 (42)	23 (32)	0 (0)
Bicycle accident	16 (6)	3 (5)	7 (10)	6 (5)
Car accident	22 (8)	7 (11)	14 (20)	1 (1)
Motorcycle accident	41 (15)	18 (28)	21 (30)	2 (2)
Pedestrian involved MVA	4 (2)	2 (3)	1 (1)	1 (1)
Other	8 (3)	2 (3)	2 (3)	4 (3)
Associated head injury AIS >2 (n, %)	25 (9)	24 (37)	1 (1)	0 (0)
Associated thoracic injury AIS >2 (n, %)	38 (14)	37 (57)	1 (1)	0 (0)
Associated abdominal injury AIS >2 (n, %)	30 (11)	25 (38)	4 (6)	1 (1)
Bilateral DRF (n, %)	12 (5)	7 (11)	3 (4)	2 (2)
Concomitant ipsilateral upper extremity injury (n, %)	61 (23)	26 (40)	25 (36)	10 (8)
Metacarpal and phalangeal	18 (7)	9 (14)	7 (10)	2 (2)
Carpal	30 (11)	11 (17)	14 (20)	5 (4)
Distal humerus and elbow	13 (5)	6 (9)	6 (9)	1 (1)
Proximal humerus and shoulder	14 (5)	11 (17)	1 (1)	2 (2)
	n = 277	**n = 72**	**n = 73**	**n = 132**
AO classification (n, %)				
Type A	90 (32)	10 (14)	17 (23)	63 (48)
Type B	52 (19)	14 (19)	14 (19)	24 (18)
Type C	135 (49)	48 (67)	42 (58)	45 (34)
Open fracture (n, %)	12 (4)	6 (8)	6 (8)	0 (0)

n = number; IQR = interquartile range; ISS = Injury Severity Score; MVA = motor vehicle accident; AIS = Abbreviated Injury Scale; DRF = distal radius fracture; AO = Arbeitsgemeinschaft für Osteosynthesefragen.

Results

Polytrauma (intra-articular: β -0.11; 95% confidence interval (CI), -0.21 to -0.02; p = 0.015) was associated with somewhat lower HRQoL and modest poorer wrist function (extra-articular: β 11.9; 95% CI, 0.4–23.4; p = 0.043; intra-articular β 8.2; 95% CI, 2.1–14.3; p = 0.009). High-energy was associated with slightly worse QuickDASH scores as well (extra-articular: β 9.5; 95% CI, 0.8–18.3; p = 0.033; intra-articular β: 11.8; 95% CI, 5.7–17.8; p = <0.001). Older age was also slightly associated with lower HRQoL (values per year). For the QuickDASH, male gender was associated with somewhat better outcomes when accounting for HRQoL using EQ-5D-3L outcome scores (Table 2). Male gender was also associated with somewhat better QuickDASH scores when taking into account EQ-VAS scores as HRQoL measure(Supplementary Table 3).

Table 2. Multivariable regression analyses.

	EQ-5D		**QuickDASH**	
Factors	**β regression coefficient* [95% CI]**	***p*-value**	**β regression coefficient* [95% CI]**	***p*-value**
Age at injury	-0.002[0.003, - 0.0001]	**0.036**	0.1 [-0.01 – 0.2]	0.097
Man	0.02 [-0.04 – 0.09]	0.602	-8.4 [-12.8 – -4.0]	**<0.001**
Injury description				
Low-energy monotrauma, extra-articular	Reference		Reference	
Low-energy monotrauma, intra-articular	0.04 [-0.04 – 0.12]	0.369	3.6 [-1.8 – 9.0]	0.191
High-energy monotrauma, extra-articular	0.06 [-0.07 – 0.19]	0.346	9.5 [0.8 – 18.3]	**0.033**
High-energy monotrauma, intra-articular	-0.03 [-0.12 – 0.06]	0.537	11.8 [5.7 – 17.8]	**<0.001**
Polytrauma, extra-articular	-0.13 [-0.31 – 0.04]	0.129	11.9 [0.4 – 23.4]	**0.043**
Polytrauma, intra-articular	-0.11 [-0.21 – -0.02]	**0.015**	8.2 [2.1 – 14.3]	**0.009**
EQ-5D index	--- [---]	---	-32.6 [-40.7 – -24.5]	**<0.001**
Model	Multivariable linear		Multivariable linear	

EQ-5D = EuroQOL 5-Dimensions; QuickDASH = Quick Disabilities of the Arm, Shoulder, and Hand; CI = confidence interval; EQ-VAS = EuroQOL Visual Analogue Scale.

*Positive regression coefficients denote higher outcome scores [indicating better health-related quality of life according to the EQ-5D and worse wrist function according to the QuickDASH].

Bold indicates statistical significance.

For polytrauma, high-energy trauma, and low-energy trauma, the respective median EQ-5D-3L outcome scores were 0.84 (range -0.33 to 1.00), 0.85 (range, 0.17–1.00), and 1.00 (range, 0.174–1.00). The VAS scores were 79 (range, 30–100), 80 (range, 50–100), and 80 (range, 40–100), and the QuickDASH scores were 7 (range, 0–82), 11 (range, 0–73), and 5 (range, 0–66), respectively (Fig. 2A-C). Taking into account the minimal clinically important difference (MCID) of 14, the reported differences are minor.[12,31]

All three outcome metrics were correlated: EQ-5D and EQ-VAS (correlation coefficient = 0.60, $p < 0.001$), QuickDASH and EQ-5D (correlation coefficient = -0.45, $p < 0.001$), and QuickDASH and EQ-VAS (correlation coefficient = -0.40, $p < 0.001$). In general, worse HRQoL scores (EQ-5D-3L and EQ-VAS) are correlated with worse wrist function (QuickDASH scores).

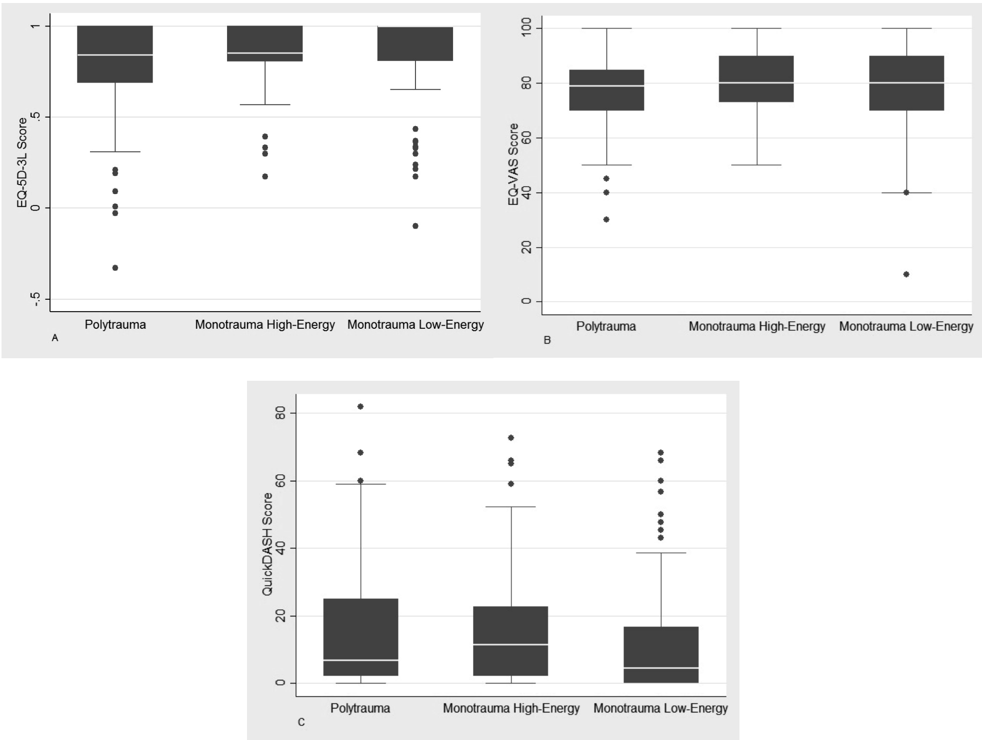

Fig. 2 (A) This graph shows EQ-5D-3L scores for patients with polytrauma, high-energy monotrauma, and low-energy monotrauma. Higher scores represent better HRQoL. (B) EQ-VAS scores for patients with polytrauma, high-energy monotrauma, and low-energy monotrauma are shown. Higher scores represent better HRQoL. (C) QuickDASH scores for patients with polytrauma, high-energy monotrauma, and low-energy monotrauma are shown. Higher scores represent worse wrist function.

Discussion

Patient-reported outcomes are increasingly important for patients, physicians, and health care policymakers. These PROs may be context specific. However, there is limited information on how PROs for extremity fractures vary in patients with polytrauma and those with fractures resulting from high-energy injury mechanisms. We observed that older age and polytrauma were associated with worse general HRQoL. Polytrauma, high-energy mechanisms, intraarticular involvement, and lower HRQoL were associated with worse QuickDASH wrist function scores.

First, this study was subject to response bias; however, we did have a relatively high response rate of 77% for this type of study, with comparable response rates between the three groups, and we identified no important differences in demographic characteristics between respondents and nonrespondents.[28] Second, questionnaires were completed at various lengths of followup. Outcome scores change over time but have also been described as plateauing after 1 year (especially HRQoL after trauma), and no questionnaires in the present study were completed before this point.[1,13] Furthermore, the followup duration was added to the regression analyses, but it was omitted from the final multivariable regression analysis because of a lack of association, as described in our statistical methods. Third, because this was a retrospective study, not all potential factors could be assessed. For example, function before the injury and patient psychological factors such as depression or self-esteem may have influenced the outcome measures, but these measures could not be examined retrospectively. Therefore, factors identified as associated with HRQoL and wrist function in the present study should not be seen as the only influential factors.[17] Fourth, since this study was conducted in a tertiary referral center, many patients did not receive routine followup at our institution. Therefore, long-term postoperative imaging studies assessing factors such as posttraumatic arthritis were not available for most patients and limited our ability to incorporate these clinical factors into the analyses. Fifth, because patients included in the present study were treated over a relatively large time span, technique-related and surgeon-related changes may have influenced the outcome measures. However, the followup duration, indicative of the period of treatment, was not associated with PROs.

Polytrauma was associated with slightly poorer HRQoL. Longer-term wrist function was associated with injury mechanisms, intraarticular involvement, and gender. Data on the influence of energy transfer on injury during trauma are relatively sparse. Our finding that higher-energy injuries were associated with worse QuickDASH scores, even in the absence of polytrauma, may reflect soft tissue damage associated with fractures resulting from high-energy trauma. During traumatic injury, although bony injury is evident in the resulting fracture, the damaging effects of energy dissipation into the surrounding soft tissues is less obvious.[22] Similar findings have been reported for calcaneal fractures.[37] Other studies have demonstrated differences between patients with polytrauma and those with monotrauma, and our findings are aligned with the findings of these studies.[15,36,37] Patients with polytrauma often have persistent pain and general disabilities that impact their long-term HRQoL, and because the scope of injuries for patients with monotrauma is smaller than that for patients with polytrauma, the difference is not surprising.[9,10,23] In addition, it is likely that we did not see an effect of intraarticular involvement and the injury mechanism because their contribution to general HRQoL is proportionally much smaller than that of polytrauma. The importance of articular surface involvement has been known since Knirk and Jupiter's classic paper, but the effect of gender on PROs is less clear.[5,19,20,24,38] We found that gender (women) was associated with worse wrist function. Differences between men and women in the levels of functioning, coping attempts, and pain behavior may play a role, but a future study is needed to investigate these differences.[8,20]

Patients who sustained distal radius fractures in the context of polytrauma or high-energy trauma reported slightly worse EQ-5D-3L scores. These patients also reported somewhat impaired wrist functioning compared with patients who sustained low-energy distal radius fractures as their only injury. Future, prospective studies should explore the clinical importance of the differences measured, as minimal clinically important differences for the QuickDASH have been reported to be higher than the differences reported in this study.[12,31] It is possible that these differences may have been influenced by other factors for which we could not account. We also found that the EQ-5D and EQ-VAS scores were strongly correlated with patient-reported wrist function using the QuickDASH, similar to a previous study that suggested that general health function may influence region-specific PROs.[36] The finding that EQ-VAS scores were correlated with wrist function implies that even a single question on self-reported health status can improve outcome measurement. Our results highlight the importance of obtaining general and region-specific measures of HRQoL when evaluating PROs after injury. Without adjusting for general health measures, nearly all patients who sustain wrist fractures in a polytrauma setting would be judged to have worse wrist function than a control group of patients with isolated distal radius fracture. Determining the importance of context on injuries will only increase in importance as health systems transition to value-based payment models based on the quality of delivered care, especially since musculoskeletal injuries are the fastest growing and largest cause for US Medicare spending.[6,11,39]

Conclusions

In conclusion, we found that polytrauma, high-energy injury mechanisms and worse HRQoL scores were independently associated with slightly inferior wrist function after distal radius fractures. In addition to relatively well-known demographic and injury characteristics (gender and articular involvement), factors related to injury context (polytrauma and high-energy trauma) may account for differences in patient-reported wrist function after wrist fracture.

This information may be used to counsel patients with distal radius fractures sustained in the context of polytrauma or high-energy trauma. Awareness of variation of PROs based on injury context may help physicians to better understand reported outcomes. Future research should explore whether this concept may be used to set better expectations on recovery and to target treatment options. It may also be investigated whether polytrauma and high-energy trauma affect outcomes after different types of orthopaedic injuries.

Supplementary Table 1. Comparisons of baseline characteristics between respondents and nonrespondents.

	Polytrauma			High-Energy Monotraua			Low-Energy Monotrauma		
Explanatory factors	Respondents	Nonrespondents	*p*-value	Respondents	Nonrespondents	*p*-value	Respondents	Nonrespondents	*p*-value
	n = 65	n = 22		n = 70	n = 22		n = 130	n = 36	
Age at trauma (median, IQR)	45 (26 – 60)	45 (22 – 63)	0.861	44 (30 – 57)	33 (22 – 52)	0.118	58 (39 – 69)	49 (28 – 66)	0.104
Man (n, %)	45 (69)	14 (64)	0.627	42 (60)	17 (77)	0.141	25 (19)	10 (28)	0.266
ISS (median, IQR)	22 (19 – 29)	27 (21 – 29)	0.535	9 (9 – 10)	10 (9 – 13)	0.477	9 (4 – 9)	9 (9 – 9)	0.352
Mechanism of trauma (n, %)									
Fall <3m	6 (9)	2 (9)		2 (3)	0 (0)		116 (89)	33 (92)	
Fall >3m	27 (42)	10 (45)		23 (32)	10 (45)		0 (0)	0 (0)	
Bicycle accident	3 (5)	2 (9)	0.471	7 (10)	0 (0)	0.549	6 (5)	1 (3)	0.845
Car accident	7 (11)	5 (23)		14 (20)	6 (27)		1 (1)	1 (3)	
Motorcycle accident	18 (28)	2 (9)		21 (30)	6 (27)		2 (2)	0 (0)	
Pedestrian involved MVA	2 (3)	0 (0)		1 (1)	0 (0)		1 (1)	0 (0)	
Other	2 (3)	1 (5)		2 (3)	0 (0)		4 (3)	1 (3)	
Associated head injury AIS >2 (n, %)	24 (37)	10 (45)	0.478	1 (1)	1 (5)	0.382	0 (0)	1 (3)	0.057
Associated thoracic injury AIS >2 (n, %)	37 (57)	14 (64)	0.581	1 (1)	1 (5)	0.382	0 (0)	0 (0)	n/a
Associated abdominal injury AIS >2 (n, %)	25 (38)	5 (23)	0.180	4 (6)	0 (0)	0.252	1 (1)	0 (0)	0.598
Bilateral DRF (n, %)	7 (11)	1 (5)	0.383	3 (4)	1 (5)	0.958	2 (2)	0 (0)	0.454
Concomitant ipsilateral upper extremity injury (n, %)	26 (40)	7 (32)	0.494	25 (36)	6 (27)	0.465	10 (8)	0 (0)	0.086
Metacarpal and phalangeal	9 (14)	5 (23)	0.327	7 (10)	4 (18)	0.302	2 (2)	0 (0)	0.454
Carpal	11 (17)	1 (5)	0.146	14 (20)	1 (5)	0.087	5 (4)	0 (0)	0.232
Distal humerus and elbow	6 (9)	4 (18)	0.255	6 (9)	3 (14)	0.485	1 (1)	0 (0)	0.598

table continues

	Polytrauma			High-Energy Monotraua			Low-Energy Monotrauma		
Explanatory factors	Respondents	Nonrespondents	*p*-value	Respondents	Nonrespondents	*p*-value	Respondents	Nonrespondents	*p*-value
Proximal humerus and shoulder	11 (17)	1 (5)	0.146	1 (1)	0 (0)	0.573	2 (2)	0 (0)	0.454
	n = 72	n = 23		n = 73	n = 23		n = 132	n = 36	
AO classification (n, %)									
Type A	10 (14)	9 (39)	**0.026**	17 (23)	8 (35)	0.453	63 (48)	16 (44)	0.663
Type B	14 (19)	2 (9)		14 (19)	5 (22)		24 (18)	5 (14)	
Type C	48 (67)	12 (52)		42 (58)	10 (43)		45 (34)	15 (42)	
Open fracture (n, %)	6 (8)	2 (9)	0.957	6 (8)	2 (9)	0.943	0 (0)	0 (0)	n/a

n = number; IQR = interquartile range; ISS = Injury Severity Score; MVA = motor vehicle accident; AIS = Abbreviated Injury Scale; DRF = distal radius fracture; AO = Arbeitsgemeinschaft für Osteosynthesefragen; n/a = not applicable.
Bold indicates statistically significant difference.

Supplementary Table 2. Bivariate linear regression analyses.

	EQ-5D		QuickDASH	
Explanatory factors	β regression coefficient* [95% CI]	*p*-value	β regression coefficient* [95% CI]	*p*-value
Age at trauma	-0.001 [-0.003 – 0.0003]	0.106	0.1 [0.03 – 0.3]	**0.015**
Time to follow-up	0.001 [-0.01 – 0.01]	0.884	-0.5 [-1.5 – 0.5]	0.341
Man	-0.004 [-0.06 – 0.05]	0.890	-5.4 [-9.7 – -1.0]	**0.016**
Polytrauma	-0.11 [-0.17 – -0.04]	**0.001**	3.4 [-1.6 – 8.4]	0.179
High-energy trauma	-0.06 [-0.11 – 0.002]	0.057	5.2 [1.0 – 9.5]	**0.017**
Associated head injury AIS >2	-0.04 [-0.14 – 0.05]	0.385	2.8 [-4.5 – 10.2]	0.449
Associated thoracic injury AIS >2	-0.14 [-0.22 – -0.06]	0.001	2.8 [-3.4 – 8.9]	0.376
Associated abdominal injury AIS >2	-0.04 [-0.13 – 0.05]	0.344	2.3 [-4.4 – 9.1]	0.497
Bilateral DRF	-0.02 [-0.16 – 0.12]	0.771	5.1 [-5.2–15.4]	0.333
Concomitant ipsilateral upper extremity injury	-0.03 [-0.10 – 0.04]	0.408	1.8 [-3.3 – 6.9]	0.490
Intra-articular DRF	-0.03 [-0.09 – 0.03]	0.399	2.9 [-1.7 – 7.6]	0.213

EQ-5D = EuroQOL 5-Dimensions; QuickDASH = Quick Disabilities of the Arm, Shoulder, and Hand; CI = confidence interval; AIS = Abbreviated Injury Scale; DRF = distal radius fracture.
*Positive regression coefficients denote higher outcome scores (indicating better health-related quality of life according to the EQ-5D and worse wrist function according to the QuickDASH).
Bold indicates statistically significant difference.

Supplementary Table 3. Multivariable regression analyses using EQ-VAS.

Factors	QuickDASH β regression coefficient* [95% CI]	*p*-value
Age at injury	0.1 [-0.04 – 0.2]	0.235
Man	-7.9 [-12.4 – -3.3]	**<0.001**
Injury description		
Low-energy monotrauma, extra-articular	Reference	
Low-energy monotrauma, intra-articular	3.4 [-2.1 – 9.0]	0.221
High-energy monotrauma, extra-articular	9.2 [0.2 – 18.1]	**0.046**
High-energy monotrauma, intra-articular	12.3 [6.1 – 18.5]	**<0.001**
Polytrauma, extra-articular	12.7 [0.9 – 24.5]	**0.034**
Polytrauma, intra-articular	9.9 [3.7 – 16.2]	**0.002**
EQ-VAS score	-0.5 [-0.6 – -0.3]	**<0.001**
Model	Multivariable linear	

EQ-VAS = EuroQOL Visual Analogue Scale; QuickDASH = Quick Disabilities of the Arm, Shoulder, and Hand; CI = confidence interval.

*Positive regression coefficients denote higher outcome scores (indicating worse wrist function according to the QuickDASH).

Bold indicates statistical significance.

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Chapter 5

Fractures and dislocations of the hand in polytrauma patients: incidence, injury pattern and functional outcome

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Abstract

Introduction

Injuries of the hand can cause significant functional impairment, diminished quality of life and delayed return to work. However, the incidence and functional outcome of hand injuries in polytrauma patients is currently unknown. The aim of this study was to determine the incidence, distribution and functional outcome of fractures and dislocation of the hand in polytrauma patients.

Methods

A single centre retrospective cohort study was performed at a level 1 trauma centre. Polytrauma was defined as patients with an Injury Severity Score of 16 or higher. Fractures and dislocations to the hand were determined. All eligible polytrauma patients with hand injuries were included and a Quick Disability of Arm, Shoulder and Hand questionnaire (QDASH) and Patient-Rated Wrist/Hand Evaluation (PRWHE) were administered. Patients were contacted 1 to 6 years after trauma.

Results

In a cohort of 2046 polytrauma patients 72 patients (3.5%) suffered a hand injury. The functional outcome scores of 52 patients (72%) were obtained. The Metacarpal (48%) and carpal (33%) bones were the most frequently affected. The median QDASH score for all patients with hand injury was 17 (IQR 0-31) and the PRWHE 14 (IQR 0-41). Patients with a concomitant upper extremity injury (p=0.002 for PRWHE, p0.006 for QDASH) and those with higher ISS scores (p=0.034 for PRWHE, QDASH not significant) had worse functional outcome scores. As an example, of the 5 patients with the worst outcome scores 3 suffered an isolated phalangeal injury, all had concomitant upper extremity injury or neurological injuries (3 plexus injuries, 1 severe brain injury).

Conclusions

The incidence of hand injuries in polytrauma patients is 3.5%, which is relatively low compared to a general trauma population. Metacarpal and carpal bones were most frequently affected. The functional extremity specific outcome scores are highly influenced by concomitant injuries (upper extremity injuries, neurological injuries and higher ISS).

Introduction

Fractures of the hand account for up to 20% of all fractures in a general trauma population, in which metacarpal and phalangeal bones are most frequently affected.[1-4] These injuries can cause significant functional impairment, diminished quality of life and delayed return to work.[5-7] However, the incidence, injury pattern and functional outcome of fractures and dislocations of the hand in polytrauma patients are currently unknown.

There is sparse data on the functional outcome of upper extremity injuries in polytrauma patients.[8-10] The available evidence suggests that in polytrauma patients both injury pattern and functional outcome of a specific injury may differ from patients with a corresponding isolated injury.[8-10] Several explanations can be considered to explain this difference. In polytrauma patients, life-threatening injuries dictate the priority of management. In addition, these patients are frequently admitted to the ICU, undergo prolonged sedation and are at risk for delayed diagnosed injuries of the hands.[11,12] These factors could very well result in a delayed onset of treatment, whether this concerns a surgical intervention or start of rehabilitation. Furthermore, concomitant injuries of the ipsilateral upper extremity, cervical spine or brain could obviously also affect the upper extremity functional outcome in these patients.

As mortality rates after severe trauma have decreased over the past decades, increased emphasis on functional outcome and morbidity is warranted.[13] It has been shown that especially severe extremity injuries may cause loss of long term functional capacity in polytrauma patients.[8,14] However, the role of hand injuries specifically has never been assessed. Data on the debilitating long term effects that hand injuries have in polytrauma patients would provide insight on the scale and impact of these injuries. Furthermore, it could serve as a basis for future studies on the role of factors that influence upper extremity outcome in polytrauma patients.

The aim of this study was to determine the incidence, distribution, time of diagnosis and functional outcome of fractures and dislocations of the hand in polytrauma patients.

Methods

Study design and setting

An institutional review board waiver was obtained. A single centre (level 1 trauma centre) retrospective cohort study with a follow up by questionnaire was performed. Data from January 2009 until December 2014 were derived from the Dutch National Trauma Database (DNTD) and electronic patient documentation. The DNTD contains prospectively collected documentation on demographics, trauma mechanism, injuries found during admission, findings from radiologic imaging and department of admission. Criteria for HET were according to the Advanced Trauma Life Support guidelines.[15] Delayed diagnosed injuries were identified by review of the electronic patient documentation.

All polytrauma patients aged 18 years and older were included and patients with hand injury were selected for follow up by 2 questionnaires. Polytrauma was defined as an Injury Severity Score (ISS) of 16 or higher, calculated using Abbreviated Injury Scale (AIS) scores.[16] A flowchart of the total number of included patients and lost to follow up is provided in figure 1.

Exclusion criteria for follow-up by questionnaire were: patients deceased during or after admission, traumatic amputation of any part of the affected upper extremity and when residing abroad. Patients who did not respond within three weeks were contacted by telephone to verbally administer the questionnaires.

Outcome parameters
All fractures and dislocations distal to the radius were included. Fractures and dislocations were described per region: carpal, metacarpal or phalangeal. To assess functional outcome, patient reported outcome measures were used (PROM). The Dutch language version of the Quick Disability of Arm, Shoulder and Hand questionnaire (QDASH) and Patient-Rated Wrist/Hand Evaluation (PRWHE) were used. The PRWHE is a hand and wrist specific questionnaire and has good measurement properties for the evaluation of hand injuries. It contains 15 items that cover two domains: pain (5 items) and functionality (10 items).[17,18] The QDASH is an 11-item questionnaire that addresses physical function and symptoms, of the preceding week, in patients with musculoskeletal disorders of the entire upper limb.[19] It has similar precision compared with the regular DASH (30 items).[20,21] Both scores range from 0-100, a score of 0 indicating no pain or disability and 100 severe disability.

For potentially confounding factors the association with the PROM scores were assessed. The selection of these factors was based on previous studies that assessed factors associated with functional outcome in polytrauma patients.[14,22]

Statistical analysis
The Shapiro-Wilk test and Q-Q plots were performed to determine if continues variables were normally distributed. Nonparametric tests were used for further statistical analysis. Continuous variables were presented as medians with interquartile range (IQR). Categorical variables were presented as frequencies with percentages. For analysis of dichotomous variables, the chi-square test was used. The Fisher exact test was used when a cell count of 5 or less was observed. Mann-Whitney U test was used for analysis of continues variables with dichotomous variables and the Kruskal–Wallis test for analysis with categorical variables. For continuous variables, Spearman's rank correlation was used. A p-value of ≤ 0.05 was considered significant. Statistical analysis was performed using SPSS version 21 (IBM Corp., Armonk, NY) for Windows.

Results
A total of 2046 polytrauma patients were included in this study and 72 (3.5%) sustained a fracture or dislocation in the hand. Of these 72 patients 6 died after trauma and 2 were unable to participate due to severe cognitive impairment. Fifty-two patients, of the 64 available for follow up, (81%) completed the questionnaire with a median follow up of 54 months (IQR 32-71) (figure 1). Demographics, trauma mechanisms and concomitant injuries of polytrauma patients with and without hand injuries are shown in table 1.

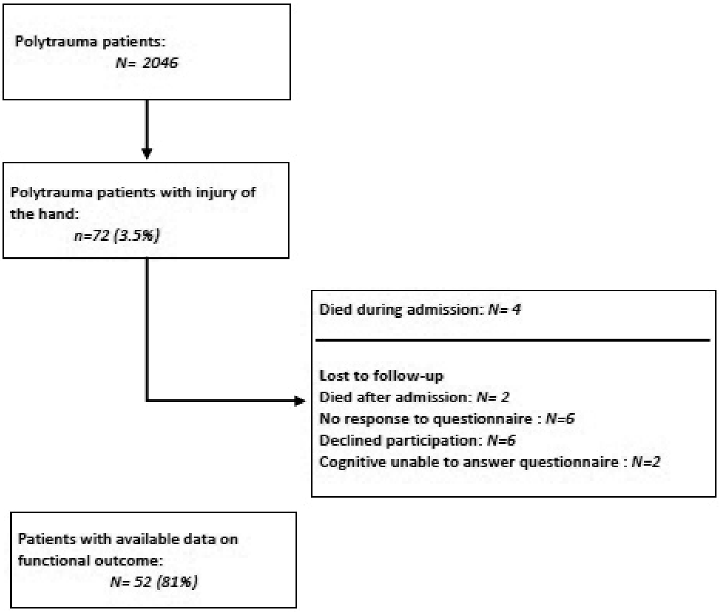

Figure 1. Flowchart of in- and excluded patients.

Table 1. Baseline characteristics of polytrauma patients with and without hand injury (n=2046).

	Polytrauma patients with hand injury n = 72		Polytrauma patients without hand injury n = 1974		*p*-value
Age at trauma, years*	44	(25 – 60)	53	(33 – 70)	**0.003**
Men, n (%)	51	(71)	1332	(67)	0.550
Time to follow up, months*	54	(32 – 71)	N/A		N/A
Length of hospital stay, days*	13	(8 – 22)	9	(4 – 19)	**0.010**
ISS at presentation, score*	24	(20 – 34)	22	(17 – 29)	**0.001**
GCS at presentation, score*	15	(11 – 15)	14	(9 – 15)	0.052
Intensive Care Unit admission, n (%)	29	(40)	833	(42)	0.746
Length of Intensive Care Unit stay, d*	3	(2 – 8)	4	(2 – 9)	0.360
Died during admission, n (%)	4	(6)	318	(16)	**0.013**
Head injury AIS ≥3, n (%)	38	(53)	1390	(70)	**0.001**
Thoracic injury AIS ≥2, n (%)	46	(64)	973	(49)	**0.015**
Abdomen injury AIS ≥2, n (%)	26	(36)	430	(22)	**0.004**
High energy trauma, n (%)	65	(90)	1017	(52)	**<0.001**
Mechanism of injury, n (%)					
Fall <3 meters	5	(7)	602	(30)	**<0.001**

table continues

	Polytrauma patients with hand injury n = 72		Polytrauma patients without hand injury n = 1974		*p*-value
Fall >3 meters	9	(13)	222	(11)	0.585
Pedestrian	1	(1)	76	(4)	0.521
Bicycle	9	(13)	366	(19)	0.190
Motorcycle	28	(39)	208	(11)	**<0.001**
Car	19	(26)	296	(15)	**0.007**
Other	1	(1)	204	(10)	**0.008**

*median shown with interquartile range.
AIS = abbreviated injury scale; GCS = Glasgow coma scale at presentation available for 82% of polytrauma patients without hand injury ; ISS = injury severity score; n = number; N/A = not applicable.
Bold indicates statistical significance.

Seventy-two patients sustained 119 injuries. Sixty-two patients (86%) sustained a fracture, 9 (12.5%) both a fracture and a dislocation and 1 (1.4%) only a dislocation. Metacarpal fractures were the most prevalent (48%). Twenty-four patients (33%) had multiple fractures and 11 patients (15%) had fractures in multiple regions. Sixty-four injuries (39%) were treated surgically. Indications for surgery were displacement, rotation or angulation deformity in 67% and a dislocation in 22%. The remaining indications were; severe soft tissue injury in 2 cases, a scaphoid non-union in 1 case and an internal fixation of 2 metacarpal fractures were performed to enable placement of an external fixator for a distal radius fracture. Details of fractures and intervention for each region are displayed in table 2.

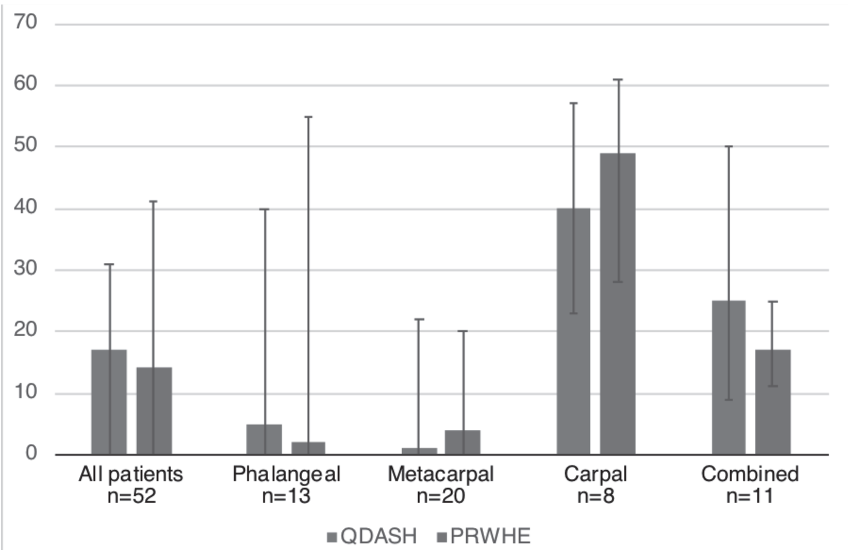

Figure 2. Patient-rated functional outcome score per affected region.

Table 2. Details of fractures and dislocations in polytrauma patients with hand injuries and subsequent intervention.

	n (%)		Intervention n (%)		ORIF/ CRIF/ other (n)
Hand injuries	119		46	(39%)	26 /10/ 10
Carpal	34	(29%)	15	(44%)	6/ 6/ 3
Scaphoid fracture	10	(8%)	5	(50%)	4/ 1/ 0
Lunate and perilunate dislocations	6	(5%)	5	(83%)	0/ 2/ 3*
CMC dislocations	5	(4%)	5	(100%)	2/ 3/ 0
Other fractures	13	(11%)	0	(0%)	-
Metacarpal	57	(48%)	24	(42%)	16/ 4/ 4**
II - V	47	(39%)	18	(38%)	12/ 2/ 4**
Thumb	11	(9%)	6	(55%)	4/ 2/ 0
Phalangeal	28	(24%)	7	(25%)	4/ 0/ 3***
II – V	20	(17%)	5	(25%)	2/ 0/ 3***
Thumb	6	(5%)	2	(33%)	2/ 0/ 0
DIP or PIP Dislocation	2	(2%)	0	(0%)	-

*; ligament reconstruction in 3 patients

**; external fixation in 2 patients

***; Suzuki frame, amputation due to crush injury and debridement with concomitant tendon rupture repair

CMC = carpometacarpal; DIP/PIP =distal/proximal interphalangeal joint; n = number.

The median QDASH score for the entire cohort was 17 (IQR 0-31) and 14 (IQR 0-41) for the PRWHE. For injury isolated to one region the QDASH and PRWHE scores were; phalangeal region 5 (IQR 0-40) and 2 (IQR 0-55), metacarpal; 1 (IQR 0-21) and 4 (IQR 0-20), carpal; 40 (IQR 23-57) and 49 (IQR 28-61) and multiple regions combined; 25 (IQR 9-50) and 17 (IQR 11-45) (figure 2).

Patients with a concomitant upper extremity injury (present in 25 of 52 respondents (48%)) had worse PRWHE and QDASH scores (median score of 25 versus 0 for PRWHE p=0.002 and 23 versus 0 for QDASH p=0.006). Patients with a higher ISS had a worse PRWHE score (R_s=0.295, *p*=0.034). A tendency towards a worse QDASH score was observed for patients with higher ISS (p=0.088). Although a trend was observed for worse functional outcomes in patients who suffered high energy trauma mechanism, this failed to reach statistical significance. Traumatic brain injury with a AIS of ^{3}3 was not associated with a worse functional outcome. Delay in diagnosis was not a significant factor for adverse functional outcome. The association of potentially confounding variables with the PROM scores are presented in table 3. As an example, in five patients with the worst scores (five highest scores) three sustained an isolated phalangeal injury, one a carpal injury and one a carpal and phalangeal injury. All of these patients had concomitant upper extremity injuries.

Table 3. Differences in functional outcome between groups according to various parameters.

Variable		n	PRWHE	IQR	*p*-value	QDASH	IQR	*p*-value
Age **	Cont.	52			0.532			0.964
Gender *	Male	35	12	39	0.557	9	27	0.405
	Female	17	25	46		23	45	
Glasgow Coma Scale **	Cont.	52			0.571			0.402
ICU admittance *		21	21	42	0.746	18	28	0.733
Traumatic brain injury ***	AIS 5	4	12	63	0.517	11	57	0.607
	AIS 4	12	8	35		14	34	
	AIS 3	4	29	35		25	17	
High energy trauma *		46	17	41	0.094	18	33	0.059
Concomitant upper extremity injury *		25	25	44	0.002	23	38	**0.006**
Injury severity score **	Cont.	52	+	*r*0.295	0.034			0.088

Statistical analysis used was = * Mann–Whitney U test, ** Spearman's rank, *** Kruskal–Wallis test.
PRWHE and QDASH scores presented as median with interquartile range (IQR).
+ = positive correlation with parameter.
AIS = abbreviated injury scale; Cont. = continuous variable; n = number; PRWHE = Patient Rated Wrist/Hand Evalutation; QDASH = Quick Disability Arm Shoulder Hand evaluation.
Bold indicates statistical significance.

Additionally, 3 of these patients suffered a concomitant brachial plexus injury, one had a severe traumatic brain injury and required a fasciotomy of a lower arm compartment syndrome and one patient sustained a concomitant open distal radius fracture, which was complicated by a non-union and infection.

Discussion

This is the first study to determine the rate, distribution and functional outcome of fractures and dislocations of the hand in polytrauma patients. The incidence of hand injuries in polytrauma patients was 3.5%. The metacarpal and carpal regions were most frequently affected. Outcome scores indicated severe functional loss in a significant number of patients. A concomitant upper extremity injury and higher ISS were associated with worse functional outcome. The additional injuries of the patients with the 5 worst PROM scores had more impact on the outcome than the examined hand injuries. It is therefore unclear if the frequently used functional outcome scores are suitable for polytrauma patients, as they do not account for the multiple factors involved in this population.

The incidence of hand injuries in polytrauma patients found in this study is low compared with the 15-20% that is reported for a general trauma population. The distribution of injuries is also different because a higher rate of carpal injuries and patients with multiple fractures (33%) was found in the present study.[1,3,4,23,24] Both findings could be explained by the difference in trauma mechanisms between polytrauma patients and a general trauma population. In a general population, isolated injuries to the hand are predominantly caused by a direct blow, fall from standing height or sporting injury.[24,25] In the present study these mechanisms were observed in only 8% of polytrauma patients. Low energy trauma mechanisms rarely cause multiple injuries with an Injury Severity Score of ^{3}16. In this study motorcycle and car crashes were the most frequently found mechanisms of trauma. In addition, 90% of polytrauma patients met the criteria for a high energy trauma (HET). The high rate of motorcycle crashes and HET mechanisms could be an explanation for the high rate of carpal injuries. Especially perilunate (fracture) dislocations are associated with HETs.[26] In a large multicentre study, in 166 patients with perilunate (fracture) dislocations, most resulted from HET such as motor vehicle accidents.[26]

The functional outcome scores of polytrauma patients with hand injuries indicates moderate to severe loss of functional capacity. For the entire cohort median PROM scores of 15 were found and 25% of patients had a PROM score of 30 or higher. The worst PROM scores were observed in polytrauma patients with injury to the carpal region (median QDASH 40 and median PRWHE 47) or multiple regions (median QDASH 25 and median PRWHE 17). These scores indicate severe functional loss when compared to the normative DASH value of 10.1 for an average population.[27] In addition, these scores are worse compared to patients with a similar isolated injury.[28-31] For example, in patients who sustained perilunate (fracture) dislocations as an isolated injury, mean DASH scores between 20 - 23 and mean PRWE scores between 13-27 were found.[28-31] Polytrauma patients with phalangeal or metacarpal injuries had median PROM scores of 5 or lower, which indicates normal functional capacity. However, 25% of these patients had a QDASH or PRWHE score of 20 or higher. In this study, 48% of the questionnaire respondents had a concomitant upper extremity injury. Furthermore, of the 5 patients with the worst PROM scores, 3 suffered an isolated phalangeal injury.

The scores in our cohort are most likely influenced by the selection of patients, as in this study only polytrauma patients were examined. In other studies, examining comparable injuries, polytrauma patients are excluded or make up only a small portions of the cohort.[28-31] In this study concomitant upper extremity injury and a higher ISS were associated with worse functional outcome scores. Concomitant upper extremity injuries could be responsible for severe pain and a decreased range of motion in the other joints of the extremity. This could affect the ability to perform hand specific tasks and thus influence functional outcome in polytrauma patients with a hand injury. Examples of concomitant injuries are plexus injury, multiple fractures on a single extremity or severe soft tissue injuries. A higher ISS indicates concomitant injuries to other body regions (e.g. brain injury, spinal cord lesion or thorax injuries). These concomitant injuries can have a significant impact on the functional outcome scores. In addition, both concomitant upper extremity injury and injury to other regions (head, spine, thorax, abdomen or lower extremities) could limit the ability to effectively participate in rehabilitation. Prolonged ICU admittance and priority of injuries dictates management. A delay in the onset of rehabilitation or surgical fixation of upper extremity injuries could occur and might negatively influence outcome although this was not observed in our study.

Although a trend towards worse scores in patients with HET was observed this failed to reach statistical significance. Severe traumatic brain injury (AIS ^{3}3) was also not associated with a worse functional outcome. Both factors were present in most of the patients in this study cohort and therefore might have lost their discriminative capability in the statistical analysis.

The functional outcome score of polytrauma patients with hand injuries in this study was multifactorial. This is also reflected by the fact that of the patients with the worst scores all had concomitant extremity injuries, 3 out of 5 had a brachial plexus injury and 1 a traumatic brain injury. Frequently used questionnaires for evaluation of upper extremity injuries, like the PRWHE and QDASH, do not account for concomitant injuries or other circumstantial factors. It can therefore be debated if these questionnaires are suitable for use in polytrauma patients. Future studies should aim to investigate if these questionnaires are applicable to polytrauma patients.

This study has several limitations. First, this is a retrospective study with follow up by questionnaire. Therefore, no objective measures of hand function, range of motion and strength were available. This would have added to the interpretability of the patient rated outcomes. However, trauma mechanism, sustained injuries and findings from radiologic studies were collected from a prospective database. Second, no long term radiographic parameters were available. This would have provided information on delayed union and post traumatic arthritis, which could have affected outcome. Last, the relatively small number of included patients could have caused a type II error.

Conclusions

The incidence of hand injuries in polytrauma patients is 3.5%, which is low compared with a general trauma population. Metacarpal and carpal bones were most frequently affected. Patients with carpal fractures or dislocations and injury in multiple regions of the hand had the worst functional outcome. Concomitant injuries to the upper extremity and a higher ISS were associated with a worse functional outcome. Patients with the worst scores had severe concomitant injuries. Polytrauma specific questionnaires, that account for the multifactorial basis of functional outcome, should be developed.

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Foot & Ankle

Chapter 6

Foot fractures in polytrauma patients; incidence, fracture pattern, and timing of diagnosis

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Abstract

Introduction

Due to prioritizing care and concomitant injuries, foot fractures in polytrauma patients often receive limited attention initially. However, as foot function is important, treatment and diagnosis of these fractures should be accurate. The aims of this study were to assess the incidence and distribution of foot fractures in polytrauma patients and to examine possible risk factors for delayed diagnosis of foot fractures.

Methods

This was a retrospective study on all adult (≥18 years) polytrauma (ISS ^{3}16) patients admitted to a single level 1 trauma center between 2006 and 2016. Patients with foot fractures were identified by diagnosis codes. Data on demographics and trauma characteristics were collected from the Trauma Quality Improvement Program (TQIP®) database. Data on foot fractures, if applicable, were gathered from electronic patient documentation.

Results

Out of 4409 polytrauma patients, 221 (5.0%) sustained a total of 511 foot fractures. Metatarsal fractures were most common (41%), followed by calcaneal (17%), and talar (16%) fractures. Thirty percent of the fractures in 33% of all patients were diagnosed in a delayed fashion. This had treatment consequences in 8%. Delayed diagnosed fractures were more common in older patients (*p* 0.025), patients with a higher ISS (*p* 0.012), ICU admission (*p* 0.015), and concomitant head injury (*p* 0.020).

Conclusions

As one in twenty polytrauma patients sustains at least one foot fracture and a substantial amount of these fractures are diagnosed in a delayed fashion, physicians, regardless of their specialty, should have a high index of suspicion for injuries of the feet in polytrauma patients.

Introduction

Polytrauma patients are severely injured patients who suffer a diversity of injuries. It has been described that 8.5% of polytrauma patients sustain injuries of the foot.[1] In the care of polytrauma patients, it is key to diagnose and treat the most life-threatening injuries first. This prioritization in the initial phase, combined with the fact that polytrauma patients may suffer serious cerebral injuries or need sedation, potentially causes a delay in diagnosis of injuries of the feet (and presumably all extremity injuries).[2,3] Indeed, it has been reported that 8.1 to 38% of foot and ankle fractures have delayed diagnoses in multiple injured patients.[4,5] For injuries of the foot specifically, Ahrberg and colleagues reported that 26.1% of all foot fractures in their cohort of polytrauma patients were diagnosed in a delayed fashion.[1] With increasing survival of polytrauma patients, long-term functional outcomes are becoming increasingly important.[6] Pain and disability from a fracture below the knee such as a foot injury that initially seems innocuous in comparison to life-threatening hemorrhage or severe head-injury, is often a determinant of long-term patient quality of life.[7] Polytrauma patients with foot injuries have been shown to perform worse when compared to a similar group of patients without injuries of the feet.[8,9] A delay in diagnosis and treatment of foot fractures may negatively influence functional outcomes because of initial suboptimal care. Treatment of a delayed diagnosed fracture may be more challenging, for example when bone healing has started with malreduction of the fracture fragments. Furthermore, a patient's awareness of a 'missed' fracture may influence results.[1] Therefore, diagnosis and treatment of foot fractures should be prompt in order to prevent deterioration in outcomes.

The aims of the present study were to assess the incidence and distribution of foot fractures in polytrauma patients. Secondarily, we examined for possible risk factors for delayed diagnosis of foot fractures. This information may guide clinicians in accurately diagnosing and thereby treating foot fractures in this specific population.

Methods

Study design and participants

After approval by the Institutional Review Board (IRB), we performed a retrospective study using the prospectively collected Trauma Quality Improvement Program (TQIP®) database containing data on all trauma patients admitted to a single level 1 trauma center. All polytrauma patients, defined as patients with an injury severity score ³16, who presented between 2006 and 2016 and were 18 years or older at the time of trauma were selected from this database. Patients who suffered a foot fracture were identified by searching for International Classification of Diseases (ICD) codes (embedded in the database). Patients for whom little information on the foot fractures was available were excluded from foot-specific analyses.

Outcome measures and explanatory variables

For all eligible patients, data on demographics, date of injury, date of admission, transfer status, service of admission, hospital length of stay (H-LOS), ICU-LOS, mechanism of injury, Glasgow Coma Scale (GCS) at admission, ISS, AIS (Abbreviated Injury Scale), and mortality were extracted from the database. All fractures distal from the tibial plafond and distal fibula were considered foot fractures. To describe distribution of foot fractures, we categorized the fractures into fractures of the calcaneus, talus, tarsal bones (subdivided into navicular, cuboid, and cuneiform fractures), metatarsals (I versus II – V), and phalanges (I versus II – V). Specific data on the foot fractures were collected by an extensive review of medical records and imaging; specific locations and types of the foot fractures, date of diagnosis, date and type of surgery (if applicable), and complications. Any uncertainty or discrepancy between chart and imaging was reviewed by the senior author (MH) for final decision and clarification. A delay in diagnosis was defined based on existing literature as any diagnosis made after 24 hours from trauma but before discharge.[5,10]

Statistical analysis
Nominal variables are presented as numbers with percentages, continuous variables as medians with interquartile ranges (IQR). To compare explanatory variables between groups, Mann-Whitney U and Chi-squared tests were used as appropriate. To identify predictors for a delay in diagnosis, multivariable logistic regression was performed using explanatory values with p <0.10 in bivariate analyses. All statistical analyses were performed using STATA® 13.1 (StataCorp LP, TX, USA). A p-value of <0.05 was considered statistically significant.

Results

A total of 4394 unique patients presented for 4409 polytraumas (7 patients were injured multiple times) to our hospital during the study period. Foot fractures were present in 221, leading to an incidence of foot fractures in polytrauma of 5.0%. None of the patients who sustained foot fractures had multiple polytraumas in this time period.Median age at trauma was 43 for the traumas resulting in foot fractures (IQR 28 – 57) with the majority of patients being male (59%) (table 1). Concomitant thoracic injury was present in 165 patients (75%). Motor vehicle crashes (MVC's) were the most common mechanism of injury (observed in 43%), followed by falls (25%). When stratified by injury location, mechanisms of injury differed significantly (p <0.001). Metatarsal fractures were more frequently the result of MVC's when compared with calcaneal fractures (50% versus 38%) and less often due to falls (15% versus 34%).

Table 1. Baseline characteristics (n = 221).

	Median (IQR)
Age at trauma, years	43 (28 – 57)
ISS at presentation, score	26 (21 – 33)
GCS at presentation, score*	15 (11 – 15)
Hospital length of stay, days	10 (6 – 18)
ICU length of stay for patients admitted to ICU, days	6 (2 – 11)
	n (%)
Male gender	130 (59)

table continues

	Median (IQR)
ICU admission	131 (59)
Deceased during admission	12 (5)
Concomitant head injury	129 (59)
Concomitant thoracic injury	165 (75)
Concomitant abdominal injury	113 (51)
Mechanism of injury	
Motor vehicle crash	95 (43)
Fall (any height)	55 (25)
Motorcycle crash	33 (15)
Pedestrian	20 (9)
Bicycle	1 (0)
Gunshot	1 (0)
Other	16 (7)

IQR = interquartile range; GCS = Glasgow Coma Scale.
*GCS available for 218 (99%) patients.

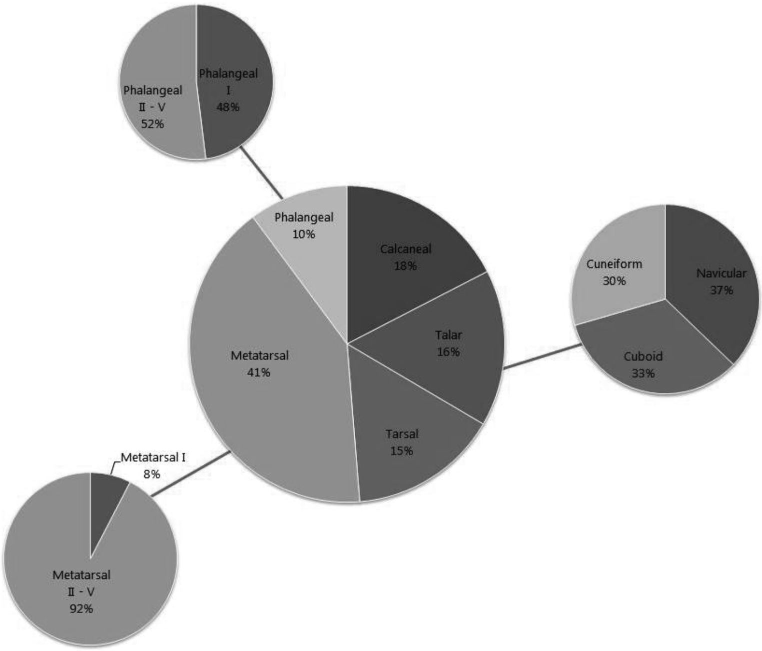

Figure 1. Fracture distribution (n = 511).

The 221 patients with foot fractures suffered a total of 511 fractures (figure 1, table 2). Most patients suffered a single foot fracture (95 patients, 43%), 57 (26%) suffered two different fractures, 27 (12%) were diagnosed with three fractures. Thirteen was the highest number of foot fractures observed in one patient. Metatarsal fractures had the highest incidence (41%), with nearly all metatarsal fractures involving the second to fifth metatarsal (194/210; 92%). Fractures of the calcaneus had the second highest incidence (17%), closely followed by talus (16%), and other tarsal (15%) fractures. Nine percent of the fractures were open injuries. The majority of fractures were treated conservatively, 26% (133 fractures) required surgical treatment.

Table 2. Foot fractures (n = 511).

	n (%)	Open fracture (%)	Surgery (%)	ORIF/CRIF/I&D only/amputation
Total	511	44 (9)	133 (26)	82/22/22/7
Calcaneal	89 (17)	11 (12)	34 (38)	23/2/8/1
Talar	82 (16)	11 (13)	34 (41)	27/4/2/1
Tarsal	78 (15)	2 (3)	15 (19)	9/4/0/2
Navicular	29 (6)	1 (3)	7 (24)	4/2/0/1
Cuboid	26 (5)	1 (4)	4 (15)	2/1/0/1
Cuneiform	23 (4)	0 (0)	4 (17)	3/1/0/0
Metatarsal	210 (41)	14 (7)	44 (21)	23/12/7/2
I	16 (3)	3 (19)	9 (56)	6/1/0/2
II - V	194 (38)	11 (6)	35 (18)	17/11/7/0
Phalangeal	52 (10)	6 (12)	6 (12)	0/0/5/1
I	25 (5)	3 (12)	3 (12)	0/0/2/1
II - V	27 (5)	3 (11)	3 (11)	0/0/3/0

n = number; CRIF = Closed Reduction Internal Fixation; I&D = Incision & Drainage.

Almost a third of the fractures (155; 30%) in 72 patients (33%) were diagnosed in a delayed fashion (table 3). Of all injuries diagnosed with delay, the median time from admission to diagnosis was 2 days (IQR 2 – 4). Fourteen days was the longest delay identified. To our knowledge, no injuries were diagnosed after discharge. None of the delayed diagnosed foot fractures were open fractures. Phalangeal and tarsal fractures were most often diagnosed in delay (both types in 38% of the time), followed by metatarsal fractures (34%). Fractures of the talus were diagnosed timely in 82%, fractures of the calcaneus in 79%. Of the 155 fractures that were diagnosed with delay, 13 (8%) needed operative treatment. Earlier diagnosis of these fractures potentially would have benefited two patients (two fractures) by avoiding a second surgery and anesthesia in both cases and shortening of length of stay in one case. However, no long term clinical impact or complications were observed.

In bivariate analyses, patients with at least one foot fracture diagnosed in a delayed fashion were significantly older compared to patients without a delayed diagnosis injury (DDI) (49 versus 41 years, *p* 0.025) (table 4). Patients with DDI also had significantly higher Injury Severity Scores (29 versus 25, *p* 0.012), had longer hospital lengths of stay (12 versus 10 days, *p* 0.009), were more often admitted to the intensive care unit (71 versus 54%, *p* 0.015) and more often suffered concomitant head injuries (69 versus 53%, *p* 0.020). There was no statistically significant difference between the presence of multiple foot injuries between both groups (*p* 0.572).

In a logistic regression model, the only factor independently associated with a delay in diagnosis of a foot injury was age of the patient with an odds ratio 1.03 (*p* 0.002; 95% confidence interval 1.01 – 1.04).

Table 3. Delayed diagnoses of injuries (n = 511).

			No delay	Delay
			n (% of total)	n (% of total)
Total			356 (70)	155 (30)
			n (% of no delay)	n (% of delay)
Surgery			120 (34)	13 (8)
Open fractures			44 (12)	0 (0)
			n (% of fracture type)	n (% of fracture type)
Locations				
	Calcaneal		70 (79)	19 (21)
	Talar		67 (82)	15 (18)
	Tarsal		48 (62)	30 (38)
		Navicular	18 (62)	11 (38)
		Cuboid	16 (62)	10 (38)
		Cuneiform	14 (61)	9 (39)
	Metatarsal		139 (66)	71 (34)
		I	13 (81)	3 (19)
		II - V	126 (65)	68 (35)
	Phalangeal		32 (62)	20 (38)
		I	16 (64)	9 (36)
		II - V	16 (59)	11 (41)

n = number.

Table 4. Patients with delay in diagnosis (n = 221).

	≥1 delayed diagnosis (n = 72)	No delayed diagnosis (n = 149)	
	Median (IQR)	Median (IQR)	*p*-value
Age at trauma, years	49 (29 – 64)	41 (27 – 55)	**0.025**
ISS at presentation, score	29 (22 – 35)	25 (19 – 29)	**0.012**
GCS at presentation, score*	15 (8 – 15)	15 (13 – 15)	0.734
Hospital length of stay, days	12 (7 – 25)	10 (6 – 16)	**0.009**
ICU length of stay for patients admitted to ICU, days	8 (3 – 13)	4 (2 – 10)	0.068
	n (%)	n (%)	*p*-value
Male gender	41 (57)	89 (60)	0.693
ICU admission	51 (71)	80 (54)	**0.015**
Deceased during admission	5 (7)	7 (5)	0.490
Concomitant head injury	50 (69)	79 (53)	**0.020**
Concomitant thoracic injury	53 (74)	112 (75)	0.803
Concomitant abdominal injury	40 (56)	73 (49)	0.360
Multiple foot injuries	43 (60)	83 (56)	0.572

IQR = interquartile range; GCS = Glasgow Coma Scale.

*GCS available for 146 patients (98%) with no delayed diagnosis.

Bold indicates statistically significant difference; $p < 0.05$ considered significant.

Discussion

We found an incidence of 5.0% for fractures of the foot in polytrauma patients, with metatarsal fractures being most common. In a third of all patients with foot fractures, there was a delay in diagnosis of at least one fracture. However, this only had treatment consequences in a limited number of cases.

The incidence of foot fractures presented in the present study is slightly lower than previously published work; Ahrberg et al. reported an incidence of foot fractures of 7.3% in a comparable German cohort; Probst et al. found a rate of 13.8% for a combination of foot and ankle fractures in another similar cohort from Germany.[1,11] In our population of polytrauma patients, metatarsal fractures were observed most frequently, followed by calcaneal and talar fractures. These findings are completely similar to previously published literature on polytrauma patients.[1,12]

Our relatively high rate of delayed diagnosed foot fractures is comparable to existing literature. In a similar cohort of polytrauma patients, 38% (23/61) of foot fractures were diagnosed with delay.[5] A literature review on missed injuries after trauma reported rates of missed foot and ankle injuries ranging from 8.1 – 25.8%, with missed injuries including all injuries found after initial assessment or ICU admission.[4] However, as patients included in that literature review had ISS scores <16 too, the results from this study are not completely comparable to our study. In particular, an ISS ≥16 has been found to be associated with missed injuries, potentially causing the higher rate of delayed diagnoses in our study.[13]

Older age, higher ISS, ICU admission and concomitant head injury were associated with DDI. Most likely, those factors contribute to a lower level of consciousness resulting in an impaired ability to communicate complaints. Unfortunately, we have not been able to identify clinically relevant factors that were independently associated with greater odds of a delayed diagnosed foot fracture. Potentially, this is because factors that may be associated with the risk of delayed diagnoses such as a patient's level of consciousness at the time of physical examination, the lack of early signs of foot fractures such as limited edema, or the thoroughness of the exam, are very hard to retrieve retrospectively. We believe this to be an important message on its own that underlines the importance of a thorough examination of the feet in polytrauma patients even more in order to lower the number of delayed diagnosed injuries.

At our institution, primary and secondary surveys are always carried out by the surgical service and tertiary surveys are more often performed by the trauma general surgery service than by orthopaedic trauma surgeons or residents. We believe this may contribute to the relatively high percentage of delayed diagnosed foot fractures as trauma surgeons tend to focus less on musculoskeletal injuries than orthopaedic trauma surgeons. This hypothesis is supported by the fact that DDI was more common in patients admitted to the ICU and tertiary survey in these patients was typically performed by the trauma surgeons. In addition, in a previous report covering a trauma center where the trauma surgeons treat both visceral and musculoskeletal injuries altogether, DDI was not more common in ICU patients.[5] We would like to emphasize that every clinician performing surveys in (poly)trauma patients, regardless of their specialty, should be suspicious for musculoskeletal (foot) injuries. Better understanding of the value of orthopaedic trauma surgery in hospitals may improve patient care and outcomes.[14,15] Additionally, this emphasizes the importance of the broad perception of the orthopaedic trauma surgeon in contrast to anatomic region specialists.

Only 13 of the 155 delayed diagnosed foot fractures required surgery (8%). Therefore, even though 30% of the foot fractures were initially missed, DDI only caused a change in treatment in a small percentage of cases. Although this may be somewhat of a relief for surgeons, patient perception of these missed injuries must be considered. Delayed diagnosis of fractures can diminish the trust that a patient has in both a surgeon, as well as an institution. Furthermore, it may also affect the patient's satisfaction with the care that they have received and overshadow other efforts, regardless of the actual outcome of the injury.[16] These missed fractures should therefore not be viewed as inevitabilities that rarely affect overall health, but instead as oversights that potentially erode the physician-patient relationship. Therefore, based on our findings, we would like to emphasize the necessity of meticulous physical examination of the feet in polytrauma patients to decrease the rate of delayed diagnoses of those injuries and their consequences. There may be a role for imaging modalities, such as whole body scans performed with low threshold, in decreasing the rate of delayed diagnoses as well.[17,18] In addition, implementation of a trauma tertiary survey checklist to include specific focused physical examination of the foot could increase diagnostic sensitivity.

This study has several limitations. First, this was a retrospective study of patient medical records. Therefore, we were limited by both the data available in the medical records, as well as its accuracy. Also, we based our cohort search on diagnosis codes. As coding may not be completely correct, we may have missed patients with foot fractures potentially causing a lower rate of foot fractures in our cohort than in reality. Furthermore, we were not able to assess very delayed diagnosed injuries if diagnosed at an outside facility after discharge, possibly leading to an underestimation of the true incidence of delayed diagnosed and missed foot fractures. As we focused on foot fractures alone, this study did not specifically separate out which of these had accompanying dislocations. When performing physical examination and reviewing imaging in polytrauma patients, physicians should be suspicious for dislocations as well. Last, we did not specify fracture classifications and other radiological parameters.

A strength of the present study is that we present the largest study on foot fractures in polytrauma patients so far. As a lot of studies combine both foot and ankle fractures, data on foot fractures in particular are hard to extrapolate. Furthermore, we were able to combine data on incidence, distribution, and timing of diagnosis in the same study.

Future research should aim to evaluate the effects of delayed diagnosed foot fractures on functional outcomes. More research on the value of tertiary surveys as performed by orthopaedic trauma surgeons is needed.

Conclusions

In conclusion, as one in twenty polytrauma patients sustains at least one foot fracture, physicians, regardless of their specialty, should have a high index of suspicion for these injuries when performing physical examination and especially focus on the metatarsal area. Our data may guide clinicians in earlier diagnosing foot fractures in polytrauma patients by alerting them of the extent of injuries diagnosed in a delayed fashion.

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Chapter 7

Functional outcomes of traumatic midfoot injuries

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Abstract

Introduction

Midfoot injuries are rare injuries, often the result of high-energy trauma and occurring in the context of multiple trauma. This study aimed to evaluate functional outcomes and health-related quality of life after open reduction and internal fixation for midfoot injuries at a level 1 trauma center treating complex foot injuries.

Methods

Retrospective single level 1 center study with follow-up by questionnaire. All adult patients who underwent open reduction and internal fixation (ORIF) for Lisfranc and/or Chopart injuries between 2000 and 2016 were included and invited to complete the American Orthopaedic Foot and Ankle Society (AOFAS) Midfoot Score, the EuroQOL Visual Analog Scale (EQ-VAS), and the EuroQOL five-dimensional questionnaire (EQ-5D-5L). Chart reviews were performed to collect demographic, injury, and treatment characteristics.

Results

Forty patients with 45 midfoot injuries were included. Follow-up was available for 29 patients (31 feet), leading to a response rate of 83%. The majority of patients suffered high-energy trauma and nearly all patients had a concomitant injury. Secondary arthrodesis was performed in 7/45 injuries. Median AOFAS score was 64 (IQR 47 – 78). Higher injury severity score (ISS) was associated with poorer functionality as measured with the AOFAS Midfoot Score ($p = 0.046$), concomitant injuries were associated with lower quality of life ($p = 0.01$). EQ-5D scores were significantly lower when compared to the Dutch reference population ($p < 0.001$).

Conclusions

Injuries of the midfoot have negative effects on mid- to long-term quality of life after trauma, with considerable potential for long-term impaired functionality. When counseling patients with these rare injuries after high-energy trauma mechanisms or in the context of multiple trauma, realistic expectations on postoperative recovery should be given.

Introduction

Previous studies have shown that functional outcomes in trauma patients are poorer when injuries of the foot are involved.[1,2] Two types of those injuries are the relatively uncommon midfoot injuries of the Lisfranc (tarsometatarsal) and Chopart (midtarsal) joints, occurring in respectively one in 55.000 and one in 28.000 people each year.[3,4] Typically, these midfoot injuries are the result of an axial load or twisting force exerted on a foot in plantarflexion, but may be caused by crush injuries as well.[3] Treatment choices for both Lisfranc and Chopart injuries range from conservative therapy to open reduction and internal fixation (ORIF) to primary arthrodesis. In case of operative treatment, controversy remains whether primary ORIF or arthrodesis should be favored.[5-7] In studies on surgical treatment and functional outcomes of midfoot injuries, major intra-articular fractures or crush injuries and polytrauma patients are often excluded.[6,8,9] However, as injuries of the Lisfranc and Chopart joints can very well be the result of high-energy trauma and consequently present this way, there is need for data on outcomes of those complex high-energy injuries.[10,11]

Therefore, this study aimed to evaluate functional outcomes and health-related quality of life after open reduction and internal fixation for midfoot injuries at a level 1 trauma center treating complex foot injuries. Factors associated with variation in functional outcomes were assessed. Secondarily, it was aimed to evaluate the rate of secondary fusion after primary ORIF and to describe characteristics of patients with midfoot injuries presenting to a level 1 trauma center.

Methods

Study design, setting and outcome parameters

After an institutional review board waiver was obtained, a single institution (level 1 trauma center) retrospective study with follow-up by questionnaire was performed. Patients were identified by procedure codes for operative treatment of the Lisfranc or Chopart joint. Eligible patients were identified through a chart review of medical records. All patients who underwent open reduction and internal fixation for (a combination of) uni- or bilateral traumatic Lisfranc and Chopart injuries between January 2000 and December 2016 and were at least 16 years at the time of injury and 18 years at follow-up were included. Patients who underwent initial operative treatment at an outside facility or had follow-up at an outside institution were excluded from the study. Injuries of the Lisfranc and Chopart joints, both midfoot joints and both treated based on the same principles with similar postoperative regimens at our institution, were combined as it was hypothesized that these injuries would affect functional outcomes in a similar way.[11] Our principles for the treatment of Lisfranc, Chopart, and combined injuries are to perform open reduction internal fixation when possible, explicitly avoiding primary arthrodesis, with thorough reconstruction of anatomic structures.

Data on explanatory variables were extracted from medical records. Explanatory variables included demographic variables, injury characteristics, surgical variables, and data on post-operative sequelae. Diabetes mellitus and osteoporosis were classified based on medical records, proper imaging and medication at the time of surgery. The energy of trauma was defined according to the Advanced Trauma Life Support Guidelines.[12] Concomitant injuries were categorized into those of the ipsilateral leg, the contralateral leg, and injuries above the hip joint. Injuries were categorized in complex and non-complex foot injuries. The injury was entitled complex if, besides one Lisfranc *or* Chopart injury, another fracture and/or dislocation that individually would also have required surgery (i.e. calcaneus fracture, talus fracture, concomitant Chopart *or* Lisfranc injuries) was present in the foot. Data collection was performed by two researchers (QV and TE); experienced trauma surgeons (FH and RH) were consulted when interpretation was non-conclusive.

To all eligible patients, a recruitment letter and two questionnaires were sent. Exclusion criteria for follow-up by questionnaire were death, no Dutch proficiency, and residence in a foreign country. Patients who did not respond within four weeks were contacted by telephone to verbally administer the questionnaires. In case of bilateral Chopart and/or Lisfranc injuries, the foot-specific questionnaire was attached twice; one for each foot. The questionnaires used were the American Orthopaedic Foot and Ankle Society (AOFAS) Midfoot Score, the EuroQOL Visual Analog Scale (EQ-VAS™), and the EuroQOL five-dimensional questionnaire (EQ-5D-5L™). The AOFAS Midfoot Score is a six-item questionnaire that solely concerns the foot with a maximum score of 100 points distributed over three categories: pain (one item), function (four items) and post-operative alignment (one item).[13] Post-operative alignment was assessed based on the most recent post-operative radiographic imaging. A high AOFAS score indicates a well-recovered patient. The EQ-VAS™ rates a patient's current general health status on a scale from 0 to 100. The EQ-5D-5L™ is a five-item questionnaire and scores a patient's general health.[14] It covers five dimensions (mobility, self-care, usual activities, pain/discomfort, and anxiety/depression) that are divided into five levels ranging from no problems to severe problems.[15] A higher score represents a better quality of life. Responses were also categorized into 'no problems' and 'problems', with 'problems' ranging from mild problems to inability to perform certain activities.[16]

Statistical analysis

Variables were presented as frequencies with percentages for categorical variables and medians with interquartile ranges (IQR) for continuous variables. In bivariate analysis, Spearman's rank correlation, Mann-Whitney U and Kruskal-Wallis tests were used as appropriate. The one-sample t-test was used to compare mean EQ-5D scores of the study population to the reference value for the general Dutch population and a population of trauma patients. A *p*-value of <0.05 was considered significant. Statistical analysis was performed using Stata® 13 (StataCorp LP, TX, USA) for Windows.

Results

Forty patients with 45 Lisfranc and Chopart injuries met our inclusion criteria. Two patients had bilateral midfoot injuries, three patients had both ipsilateral Lisfranc and Chopart injuries. Three patients were excluded because they underwent primary arthrodesis; all three suffered Lisfranc injuries as a result of low-energy trauma. Initial conservative treatment was reason for exclusion of two patients; both had high-energy injuries and underwent delayed operative treatment (one five months and one nearly eight months after trauma).

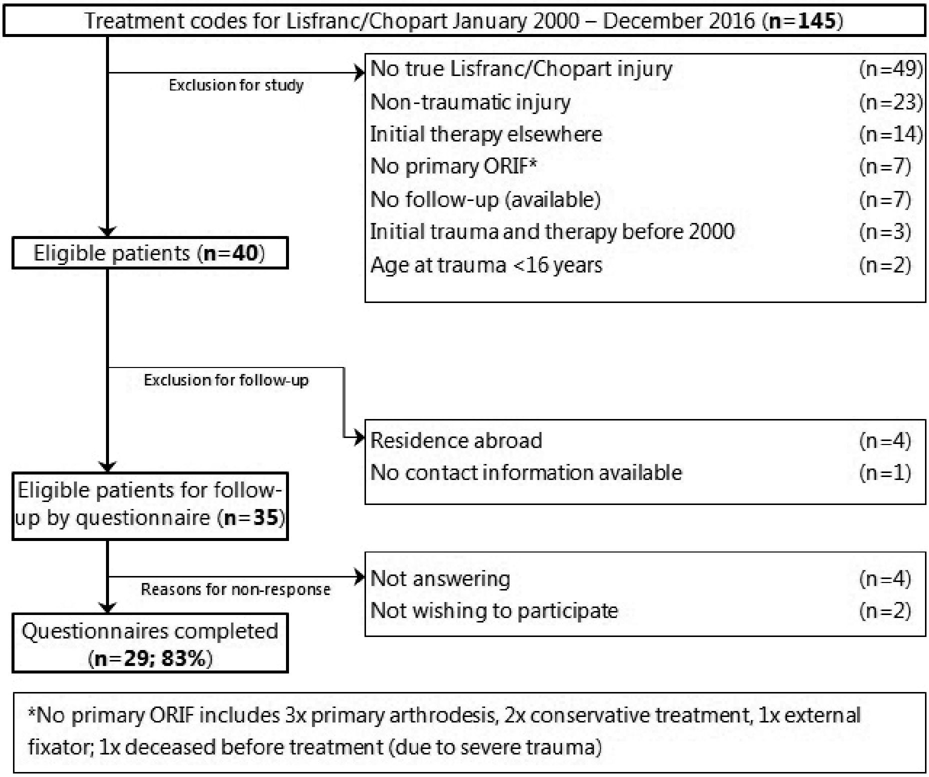

Figure 1. Flowchart of patient selection.

In the study cohort, median age at injury was 33 years (interquartile range (IQR) 26 – 47 years) and the majority of patients were male. Baseline characteristics are depicted in table 1. Injury Severity Scores (ISS) ranged from 1 to 43 with a median of 9 (IQR 4 – 17). In more than three-quarters of patients, the injuries were the result of high-energy impact. Lisfranc injuries occurred most frequently. The vast majority of patients (34/40) suffered any type of concomitant injury during the initial trauma, leaving six patients with isolated midfoot injury. Midfoot injuries were part of a complex foot injury in 21 cases. Injury characteristics are shown in table 2. In most cases (35/45), the postoperative course was uncomplicated. No complex regional pain syndrome (CPRS) occurred. Secondary arthrodesis was performed in seven patients after a median interval of 1.0 year (IQR 0.8 – 2.0 years) from initial treatment. Table 3 depicts the treatment characteristics. An example of our treatment strategy is shown in figure 2.

Table 1. Baseline characteristics (n = 40).

	Median (IQR)
Age at injury (years)	33 (26 – 47)
Body Mass Index (kg/m²)*	24 (21 – 29)
Injury Severity Score	9 (4 – 17)
	n (%)
Male gender	27 (68)
Smoking	
Yes	11 (28)
No	19 (48)
Diabetes	
Yes	2 (5)
No	35 (88)
Osteoporosis	
Yes	1 (3)
No	36 (90)
High energy trauma	
Yes	32 (80)
No	7 (18)
Mechanism of trauma	
Motor vehicle	19 (48)
Crush	6 (15)
Fall >3m	5 (13)
Fall <3m	4 (10)
Sports	3 (8)
Bicycle	2 (5)
Motorcycle	1 (3)

n = number; IQR = interquartile range; n/a = not applicable.
*Body Mass Index available for 30 patients (75%).

Table 2. Injury Characteristics (n = 45).

	Median (IQR)
Time between trauma and diagnosis (days)	0 (0 – 1)
	n (%)
Right side injury	28 (62)
Type injury	

table continues

			Median (IQR)
	Lisfranc		31 (69)
		Fracture-dislocation	25 (81)
		Dislocation	6 (19)
	Chopart		14 (31)
		Fracture-dislocation	14 (100)
		Dislocation	0 (0)
Open injury			
	Yes		4 (9)
	No		40 (89)
Deglovement			
	Yes		3 (7)
	No		41 (91)
Compartment syndrome			
	Yes		2 (4)
	No		41 (91)
Concomitant injury			39 (87)
	Above hip joint		27 (60)
	Contralateral lower extremity injury		18 (40)
	Ipsilateral lower extremity injury		31 (69)
	Ipsilateral complex foot injury		
		Yes	21 (47)
		No	23 (51)

ORIF = open reduction internal fixation; n = number; IQR = interquartile range.

Table 3. Treatment Characteristics (n = 45).

		Median (IQR)
Time between diagnosis and primary surgery (days)		11 (8 – 17)
Time between ORIF and secondary arthrodesis (years) (n = 7)		1.0 (0.8 – 2.0)
Time between primary surgery and implant removal (years) (n = 34)		0.3 (0.2 – 0.3)
		n (%)
Implant primary procedure		
	Screw(s) only	20 (45)
	Plate(s) only	7 (16)
	Combination	18 (40)
Complications primary procedure		

table continues

		Median (IQR)
	None	35 (78)
	Superficial wound infection	4 (9)
	Deep infection	2 (4)
	Implant failure	3 (7)
Compromised wound healing		7 (16)
Second procedure		
	None	31 (69)
	Secondary arthrodesis	7 (16)
	Revision	2 (4)
	Other*	4 (9)
Multiple procedures (>2)		8 (18)
Implant removal		
	Yes	36 (80)
	No	8 (18)

ORIF = open reduction internal fixation; n = number; IQR = interquartile range; n/a = not applicable.
*Other includes debasement of fifth phalanx, drainage of infected hematoma, muscle transplantation, and necrotectomy of infected tissue.

The questionnaires were completed by 29 out of 35 patients eligible for follow-up, leading to a response rate of 83%. An overview of the inclusion and response process is presented in figure 1. No patients underwent amputation of the injured foot. There were no differences between responders and non-responders with respect to age at trauma (p = 0.28), gender (p = 0.51) and injury type (p = 0.18). The AOFAS Midfoot Scale was completed for 31 feet by 29 patients and had a median score of 64 (IQR 47 – 78, range 20 – 100). Fourteen patients (45%) had good, 16 (52%) fair and 1 (3%) poor alignment. Median EQ-VAS score was 70 (IQR 61 – 80, range 45 – 99), median EQ-5D score 0.77 (0.61 – 0.81, range 0.38 – 1.00) (table 4).

The majority of patients experienced some degree of problems with mobility (21/29), usual activities (24/29) and pain/discomfort (26/29). Categorization of EQ-5D responses is presented graphically in figure 3. EQ-5D scores in our population were significantly lower when compared to the average value for the Dutch reference population of 0.87 (p <0.001) but did not differ significantly from the scores in a population of Dutch trauma patients (0.44).[17,18] However, four patients reported EQ-5D scores higher than the reference value of 0.87 (range 0.87–1.00).

For the five patients with the poorest AOFAS scores, the Injury Severity Score (ISS) ranged from 4 to 38. A similar ISS distribution was found in the five patients with the lowest quality of life (EQ-5D scores ranging from 0.38 – 0.51). Two patients were among both the group of patients with the poorest AOFAS scores as well as the group reporting the lowest EQ-5D scores.

In bivariate analyses, there were no significant associations between the explanatory variables and AOFAS scores except for Injury Severity Score. Higher ISS was associated with poorer functionality as measured with the AOFAS Midfoot Score (p = 0.046).

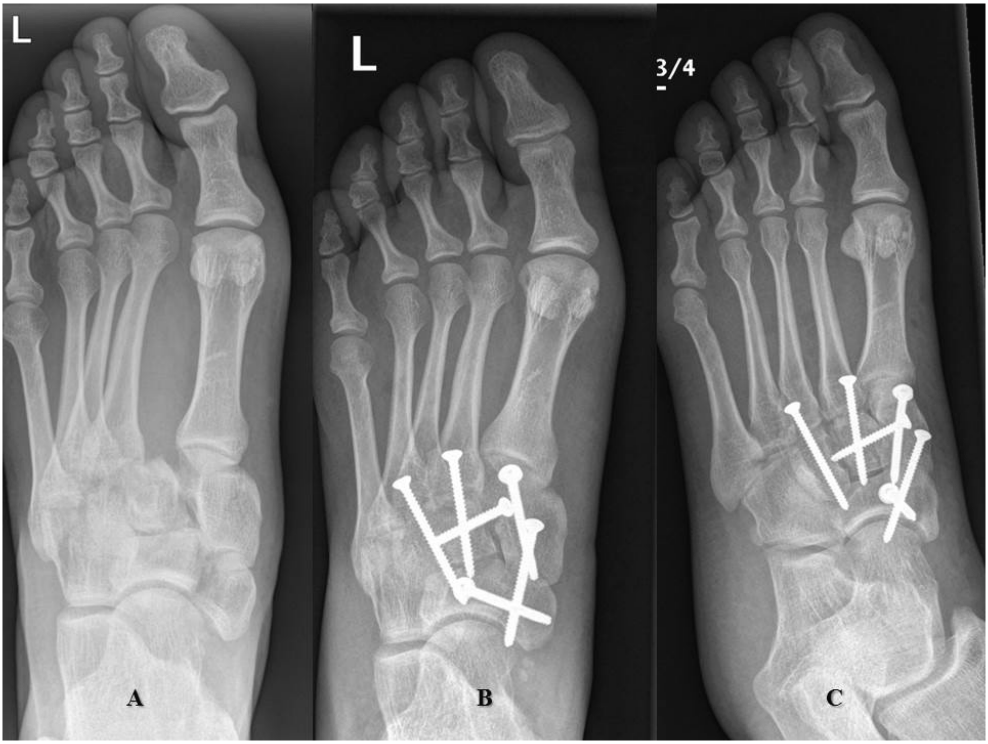

Figure 2. Pre- (A) and postoperative (B and C) imaging of a complex foot injury treated with ORIF.

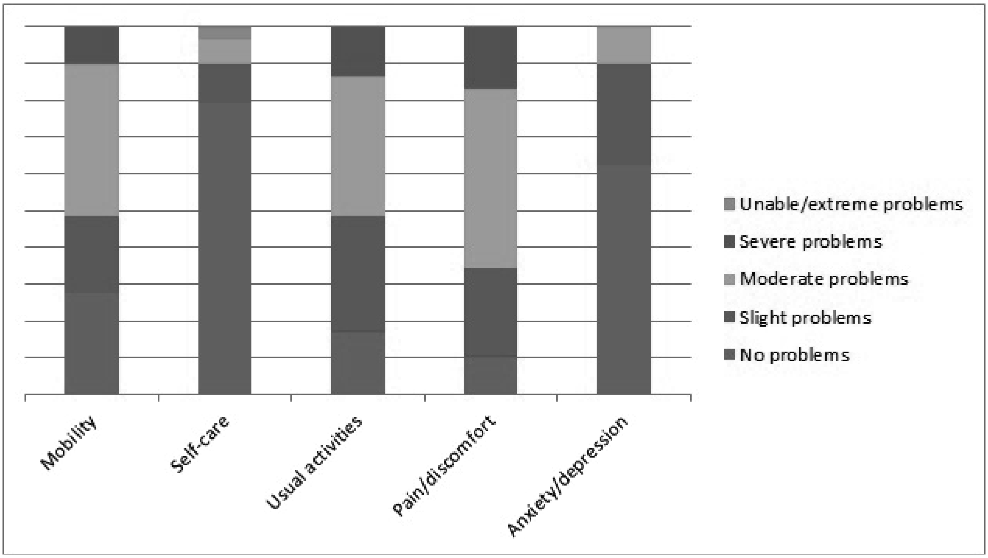

Figure 3. EQ-5D scores.

Table 4. Outcome scores.

	Median	IQR	Range
AOFAS Midfoot Scale (n = 31)	64	47 – 78	20 - 100
EQ-VAS (n = 29)	70	61 – 80	45 - 99
EQ-5D (n = 29)	0.77	0.61 – 0.81	0.38 – 1.00
	n	%	
Mobility			
No problems	8	28	
Problems	21	72	
Self-care			
No problems	23	79	
Problems	6	21	
Usual activities			
No problems	5	17	
Problems	24	83	
Pain/discomfort			
No problems	3	10	
Problems	26	90	
Anxiety/depression			
No problems	18	62	
Problems	11	38	

EQ-5D = EuroQol five-dimensional questionnaire; EQ-VAS = EuroQol Visual Analog Scale; AOFAS = American Orthopaedic Foot and Ankle Society; n = number; IQR = interquartile range.

No differences in AOFAS scores between patients with and without secondary arthrodesis were found (64 versus 64; $p = 0.54$). For the EQ-5D, there was a significant relationship between concomitant injuries and lower long-term quality of life (0.74 versus 0.88; $p = 0.01$). No differences in EQ-5D scores between patients with and without concomitant calcaneal fractures were observed ($p = 0.77$). A statistically significant association between AOFAS and EQ-5D scores ($p < 0.001$) was found.

Discussion

The majority of patients sustained injuries of the midfoot due to high-energy trauma, with the vast majority of all patients suffering at least one concomitant injury. Only a small number of patients required secondary arthrodesis. Intermediate to long-term functional outcomes revealed impaired functionality, with patients reporting significantly lower quality of life compared with a reference population but comparable with a population of trauma patients. Outcome measures were negatively influenced by presence of concomitant injuries.

A varying range of functional outcome scores after surgical treatment of Lisfranc and Chopart injuries has been reported and it has been demonstrated that full recovery after those injuries is rather uncommon (range 67 - 88).[4,7,8,11,19,20] However, in some of these studies, patients with concomitant and complex injuries were excluded and patients with conservative treatment (implicating less severe injuries) were included. Abbasian et al. as well as Ly and Coetzee, for example, excluded all patients with ankle, leg, or substantial foot injury apart from the Lisfranc pathology.[7,8] It may very well be that outcome measures are influenced by concomitant injuries and the severity of the sustained trauma, causing the relatively low outcomes in our cohort of severely injured patients.[21] This phenomenon, with polytrauma and concomitant injuries worsening outcomes after midfoot fractures and dislocations, has been previously described for injuries of the midfoot.[20,22]

Fractures of the feet have been reported to influence long-term health-related quality of life after (major) trauma.[23-25] This knowledge is used when counseling patients and making treatment decisions. Based on the results of the present study, injuries of the Lisfranc and Chopart joints seem to have similar effects on quality of life and functionality as previously described for, for example, (intra-articular) calcaneal fractures.[24,26-28] Even though midfoot injuries are not as frequently seen, the findings of the present study combined with existing literature may implicate that patients with midfoot injuries after high-energy trauma mechanism should be counseled in a comparable manner as patients with fractures of the os calcis.

It remains controversial whether the best results after surgical treatment for midfoot injuries are accomplished by internal fixation or by primary arthrodesis (PA).[5-7,11] Some authors have stated that primary arthrodesis should be considered in injuries with severe joint and/or cartilage destruction where reconstruction of the joint surface is not possible or to reserve this operation as a salvage procedure.[8,11,19] From our point of view, it should be attempted to avoid arthrodesis and its accompanying stiffness whenever possible. In addition, for combined injuries (both ligamentous and osseous injury), it is believed that fracture reconstruction combined with primary arthrodesis will lead to a somewhat distorted anatomy of the foot resulting in more stiffness. Indeed, in our population of severely injured patients with complex foot injuries, secondary arthrodesis was only deemed necessary in a small percentage of patients, with comparable rates of secondary arthrodesis (SA) after primary ORIF reported previously.[20,29] With no evidence on long-term outcomes after PA in the treatment of midfoot injuries, a small percentage of patients initially treated with ORIF demanding SA and increased risk on a complicated postoperative course after arthrodesis (adjacent joint arthritis, stiffness, loss of metatarsal arch, difficulty wearing shoes and sympathetic dystrophy), we believe that ORIF should be the treatment of choice.[11,29,30]

In the present study, a high response rate was reached, leading to a representative sample with minimal non-response bias. Since patients with concomitant injuries and complex foot injuries were included in this study, a realistic outcome pattern is provided for midfoot injuries due to high-energy and in the context of multiple trauma. The retrospective nature of this study poses several limitations. It was attempted to account for a number of them by reviewing charts thoroughly, having a second reviewer (QV) check more than 20% of the collected data, and holding group discussions to reach consensus if needed. However, it was not possible to account for all potential confounders due to the limits of the retrospective data.

Because of the small number of low-energy trauma as a result of the triage in our trauma region, it was not possible to compare these entities to their counterparts. Future research should target these areas. As the incidence of midfoot injuries is low, we included patients who suffered these injuries over a relatively large time span. This may have influenced the outcomes as certain factors, for example experience of the surgeons, may have changed over time and follow-up duration differed between patients. The low incidence of midfoot injuries also narrowed the possibility of grouping specific injuries for subanalyses. Furthermore, the AOFAS Midfoot score has not yet been validated in Dutch. However, we reached group consensus on translation of the original English questionnaire and are satisfied with its accuracy.

As injuries of the midfoot are relatively uncommon and nearly always occur with other injuries, we advocate for centralized treatment of those injuries to specialized hospitals with sufficient experience in complex foot injuries as well as other traumatic injuries. This may lead to better outcomes.

Conclusions

In conclusion, the results of this study show that injuries of the midfoot, treated at a level 1 trauma center, have negative effects on mid- to long-term quality of life after trauma, with considerable potential for long-term impaired functionality. When counseling patients with these rare injuries after high-energy trauma mechanisms or in the context of multiple trauma, realistic expectations on postoperative recovery should be given.

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Chapter 8

Functional outcomes and quality of life in patients with subtalar arthrodesis for posttraumatic arthritis

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Abstract

Introduction

Subtalar arthrodesis is a common salvage operation for posttraumatic subtalar arthritis, a condition frequently seen in patients who suffered major trauma. Functional outcomes in trauma patients may be influenced by concomitant injuries and the severity of the initial trauma. The aim of this study was to evaluate quality of life and functional outcomes of subtalar arthrodesis for posttraumatic arthritis in patients with severe or complex foot injuries.

Methods

This is a retrospective single center study with prospective follow-up. Patients who underwent subtalar arthrodesis for posttraumatic arthritis between 2000 and 2016 were included and invited to complete a Maryland Foot Score (MFS), a EuroQol five-dimensional (EQ-5D™) and Visual Analog Scale (EQ-VAS™) questionnaire, and four additional questions.

Results

Forty patients were included in the study, functional outcome scores were available for 30 patients (response rate 75%). Additional surgery of the fused foot was performed in 29 patients and 15 suffered multiple lower extremity injuries. Six patients were polytraumatized. Ninety percent of all patients would recommend the procedure to others, walking abilities improved in 69% and less pain was experienced in 76%. Median MFS score was 61 (IQR 53 – 72). Quality of life was significantly lower when compared to a reference population (p <0.001)

Conclusions

Satisfaction was high, as 90% of all patients would recommend subtalar fusion to others, even though the relatively poor outcome measures would suggest differently. Existing functional outcomes measures were influenced by concomitant injuries and additional procedures. This demands development of instruments suitable for severely injured patients with multiple or complex injuries.

Introduction

Subtalar arthrodesis is used for a variety of conditions, such as primary subtalar arthritis, congenital deformities, and inflammatory deformities.[1-3] The goals of subtalar fusion include pain relief, deformity correction, and functional improvement.[4] In trauma patients, subtalar arthrodesis is a common salvage operation for posttraumatic subtalar arthritis, mainly caused by calcaneal or talar fractures.[2,5-8] Patients who sustain these types of fractures frequently have additional injuries, such as trauma to the midfoot or ankle joints. Furthermore, fractures of the hindfoot are often found in polytraumatized patients and it has been demonstrated that lower extremity injuries have a detrimental impact on the functional recovery.[9] As a result of the above, outcomes in a population of patients who undergo subtalar fusion for posttraumatic arthritis may be influenced by concomitant injuries and a poorer overall state of health.

There is paucity of data on subtalar fusion focusing on trauma patients explicitly and the best results for posttraumatic arthritis have been described after arthroscopic procedures in patients with isolated subtalar arthritis with minimal or no deformity, no significant bone loss, and no need for a concomitant anterior foot procedure.[4,10-12]. However, it might be that most patients with severe foot injuries do not fit these criteria, causing an overestimation of functional outcomes of subtalar arthrodesis after major trauma. In addition, as poor quality of life after calcaneal fractures has been described, subtalar fusion might lead to improvement of this poor baseline situation.[13,14] The aim of the present study was to evaluate quality of life and functional outcomes of subtalar arthrodesis for posttraumatic arthritis in patients with severe or complex foot injuries.

Methods

Study design and setting

A single level 1 trauma centre retrospective cohort study with a follow-up by questionnaire was performed after institutional review board approval. Patients were selected by searching for operation codes for subtalar arthrodesis. All patients who underwent a subtalar arthrodesis for posttraumatic arthritis between January 2001 and January 2016 were invited to complete two questionnaires and four additional questions. Patients who deceased, resided in a foreign country, had amputation of the fused foot, were under the age of 16 at date of trauma or under the age of 18 during the conduct of the study, were excluded from participation. Patients who did not respond within 3 weeks were contacted by telephone to verbally administer the questionnaires.

Outcome measures and explanatory variables

Explanatory variables were derived from the Dutch National Trauma Database (DNTD) and electronic patient documentation. The DNTD contains prospectively collected documentation on demographics, trauma mechanism, sustained injuries, findings from radiologic imaging, and department of admission for all patients admitted to the University Medical Center Utrecht (UMCU) after a trauma. Data on smoking and BMI were omitted when recorded more than two months before or after the arthrodesis. A second researcher

(GA) crosschecked a random 20% sample of the retrospectively collected data to ensure a robust database. Patients were considered polytrauma when an ISS of 16 or higher as a result of injury in two or more body regions was found.[15]

The indication to perform a subtalar arthrodesis was made by a trauma surgeon based on clinical and radiologic assessment. Radiologic examination of the subtalar joint focused on signs of arthritis such as subchondral sclerosis, osteophytes, joint space narrowing, and deformation of the joint space. Clinical assessment was based on the expertise of the surgeon; in some cases effects of diagnostic steroid injection or diagnostic cast immobilization attributed to the decision-making. Postoperatively, the position of hardware and the degree of consolidation were assessed by radiologic imaging. Standard X-ray examination included antero-posterior and lateral weight-bearing views. In case a patient underwent bilateral subtalar fusion, only data on the first procedure were studied as not to violate the statistical assumption of independence.

Quality of life was assessed using the EuroQol five-dimensional (EQ-5D™) questionnaire. The EQ-5D™ covers five dimensions (mobility, self-care, usual activities, pain/discomfort, and anxiety/depression) that are all divided into three levels (no problems, moderate problems, or extreme problems) with lower scores representing poorer quality of life.[16] EQ-5D™ scores for the study population were calculated using the Dutch tariff.[17] Additionally, the EuroQol Visual Analog Scale (EQ-VAS™) was assessed. This score represents a patient's self-rated health status on a scale from 0 to 100, a score of 0 being the worst imaginable and a score of 100 being the best imaginable health state.

Functional outcomes were evaluated by the Maryland Foot Score (MFS). The MFS consists of 10 questions assessing pain and function, with a score of 100 representing a normal pain-free foot. MFS outcome scores are categorized into four categories; failure (<50), fair outcome (50-74), good outcome (75-89), and excellent outcome (90-100).[18]

In addition to the questionnaires, patients were asked whether 1) they underwent surgery to their feet in another hospital, 2) the subtalar arthrodesis reduced the pain in their feet, 3) the subtalar arthrodesis improved their walking abilities, and 4) they would recommend the subtalar arthrodesis to family and friends if they were in exactly the same situation as they were before the subtalar arthrodesis.

Statistical analysis

Continuous variables are presented as medians with interquartile ranges (IQR), categorical variables as frequencies with percentages. The Shapiro-Wilk test was performed to determine if continues variables were normally distributed; non-parametric tests were used for further analyses. Categorical variables were analyzed using the chi-square test and, in case of a cell count of 5 or less, the Fisher's exact test. The relations between continuous outcome measures and explanatory variables were assessed using the Mann-Whitney U test for dichotomous variables, the Kruskal-Wallis test for categorical variables, and the Spearman's rank correlation for continuous variables. EQ-5D™ scores were compared with values of a Dutch reference population of approximately the same age as the study subjects by the two-sample T-test.[19] Correlations between the EQ-5D™ and MFS scores were established using Pearson's correlation coefficient. Statistical analyses were performed using IBM SPSS Statistics version

24 (IBM Corp., Armonk, NY) for Mac. A *p*-value of <0.05 was considered significant.

Results

Baseline characteristics

A total of 40 patients met the inclusion criteria. Thirty out of 40 questionnaires (75%) were completed. An overview of the inclusion and response process is shown in figure 1. Two patients had to be excluded because of ineligibility for follow-up due to severe complications after the arthrodesis (amputation of the fused foot and talar extirpation because of avascular necrosis). Demographics, trauma mechanisms and initial injuries of all patients are depicted in table 1. No significant differences were found between responders and non-responders. The major part of the study population consisted of middle-aged men. The median ISS was 4 and 6 patients were polytrauma patients. All polytrauma patients had additional lower extremity injuries and an extra 9 patients suffered additional injuries to the lower extremities, making a total of 15 patients with multiple injuries to the affected limb. Most common were injuries to the ipsilateral foot or ankle (33%). Nineteen subtalar arthrodeses were performed for posttraumatic arthritis after a calcaneal fracture, a talar fracture (6 in total) being the second most frequent indication for subtalar fusion. Twenty patients received operative treatment for their initial foot injury, with four patients developing malunion of their fracture. An overview of the initial treatment and complications is provided in table 2.

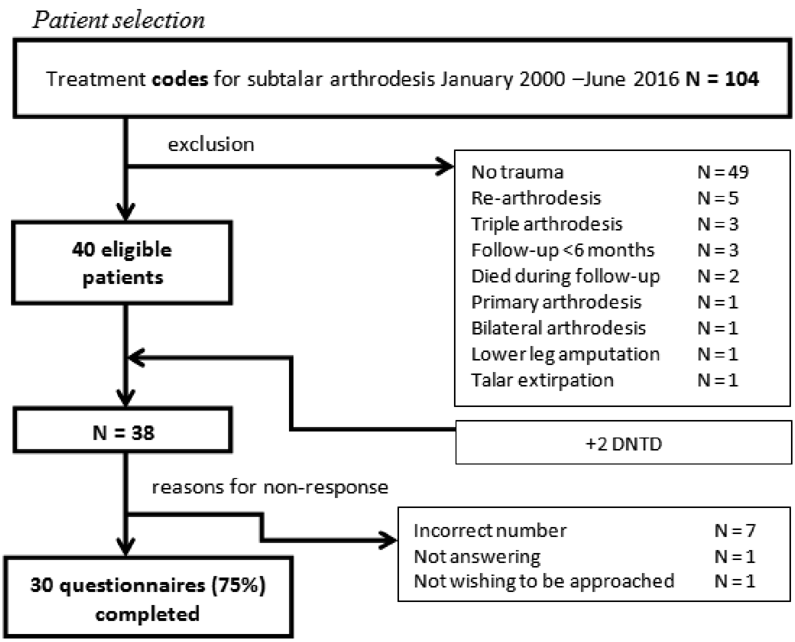

Figure 1. Flowchart of inclusion and response process.

Table 1. Baseline characteristics (n = 40).

	Median	IQR
Age *(years)*		
At trauma	37	26 – 47
At subtalar arthrodesis	45	33 – 53
At follow-up	51	42 – 58
Body Mass Index*	26	22 – 28
Injury Severity Score	4	4 – 9
	N	%
Men	29	73
Diabetes	2	5
Polytrauma	6	15
Mechanism of injury		
Fall <3m	11	28
Fall ≥3m	7	18
Motor vehicle accident	8	20
Motorcycle accident	3	8
Other/unknown	11	28
Additional lower extremity injuries		
Ipsilateral	13	33
Contralateral	11	28
None	25	63
Initial foot injury		
Calcaneal fracture	19	48
Talar fracture	6	15
Calcaneal + talar fracture	4	10
Ankle fracture	1	3
Ankle fracture + calcaneal/talar fracture	2	5
Luxation + calcaneal/talar fracture	3	8
Luxation	3	8
Minor trauma**	2	5

IQR = interquartile range; N = number
*Body Mass Index available for 26 patients (65%)
**Minor trauma includes ankle sprain and unknown minor trauma

Table 2. Initial treatment and complications of initial treatment and subtalar arthrodesis (n = 40).

Initial treatment	N	%
Operative management	20	50
Non-operative management	14	35
External fixation	4	10
Unknown	2	5
Complications of initial treatment	N (OM/NOM/ex-fix)	%
Superficial wound infection	0 (0/0/0)	0
Deep wound infection	7 (4/0/3)	18
Osteomyelitis	0 (0/0/0)	0
Malunion	4 (3/1/0)	10
No complications	17 (11/5/1)	43
Unknown	12* (2/8/0)	30
Complications of subtalar arthrodesis	N	%
Superficial wound infection	1	3
Deep wound infection	4	10
Failed arthrodesis	5	13
No consolidation	2	5
Delayed consolidation	9	23
Consolidation unknown	7	18
No complications	12	29
Other**	5	12

N = number; OM = operative management; NOM = non-operative management; ex-fix = external fixation
*Complications unknown for the unknown initial treatments (n = 2)
**Other complications include impingement, dystrophy

Subtalar arthrodesis

The median interval between trauma and subtalar arthrodesis was 23 months (IQR 13 – 50), the median interval between arthrodesis and follow-up by questionnaire 6.8 years (IQR 3.7 – 9.9). All arthrodeses were performed during an open procedure, no arthroscopic procedures took place. In most cases (31 patients) a single screw procedure was performed, 6 patients underwent treatment with two screws and in 3 cases no hardware was used. After nine months, in 22 patients good subtalar fusion was reached. Nine additional patients reached consolidation after this time span; resulting in a fusion rate of 94% (fusion was unknown in 7 cases). Additional procedures to the fused foot, including arthrodeses of other parts of the foot, alignment corrections, and tendon corrections, were performed in 29 patients.

Questionnaire results

The median EQ-5D™ score was 0.78 (IQR 0.41 – 0.78), the median EQ-VAS™ score 53 (IQR 44 – 75) (table 3). For the MFS, the median score was 61 (IQR 53 – 72) with 60% of all patients having a 'fair' MFS score (score 50 – 74) (table 3). Correlation between the MFS and EQ-5D™ scores was 0.69 (p <0.001). In comparison with a Dutch reference population (mean EQ-5D™ 0.89),(19) quality of life in our study population was significantly lower (*p* <0.001).

When comparing scores of those patients with additional injuries to the lower extremities and scores of those without, MFS scores were respectively 56 and 61 (*p* = 0.502). Patients who underwent additional procedures to the foot had median MFS scores of 55, compared with 67 in patients who did not undergo additional surgery (*p* = 0.162). In the group of patients who underwent additional procedures, a 'good' MFS score (score ≥75) was reported by only one patient (outcomes available for 21).

Table 3. Outcome scores (n = 30).

Questionnaire	Median	IQR
EQ-5D™	0.78	0.41 – 0.78
EQ-VAS™	53	44 – 75
MFS	61	53 – 72
	N	%
Excellent (MFS 90 – 100)	1	3
Good (MFS 75 – 89)	4	13
Fair (MFS 50 – 74)	18	60
Failure (MFS <50)	7	23
Additional questions*		
Less pain after arthrodesis	22	76
Improved walking abilities	20	69
Would recommend to family and friends	26	90

EQ-5D™ = EuroQol five-dimensional questionnaire; EQ-VAS™ = EuroQol Visual Analog Scale; MFS = Maryland Foot Score; N = number

*Additional questions were completed by 29 patients

Patient satisfaction

Ninety percent of all patients would recommend a subtalar fusion to their family and friends if they had been in the exact same situation as they were before the procedure. Less pain was experienced by 76% (n = 22) and improved walking abilities by 69% (n = 20). The patients who would not recommend the procedure were found to have high pain scores, severe limitations in walking abilities, low quality of life, and low MFS scores. Interestingly, the two patients with the worst quality of life scores would still recommend subtalar fusion.

Patients with poor outcome scores

Seven patients had an MFS score <50. Quality of life in this subgroup was lower when compared to patients with MFS scores ≥75 (n = 5) as well; 0.27 versus 0.81. Explanatory variables and outcome scores for patients with poor MFS scores versus good and excellent scores are presented in table 4. In the poor outcome group, 4 patients (75%) developed a complication after the subtalar fusion (infection, no consolidation) versus 0 (0%) in the other group. Furthermore, 6 patients (86%) with poor scores underwent additional procedures to the foot against 1 (20%) in group with better outcomes.

Table 4. Comparison of patients with poor and better MFS scores.

	MFS <50 (n = 7)	MFS ≥75 (n = 5)
	Median (IQR)	Median (IQR)
Age *(years)*		
At trauma	33 (25 – 42)	40 (26 – 49)
At subtalar arthrodesis	36 (27 – 55)	48 (27 – 55)
At follow-up	40 (45 – 64)	53 (37 – 62)
Injury Severity Score	9 (4-13)	4(4-8)
	N (%)	N (%)
Men	3 (43)	4 (80)
Polytrauma	1 (14)	0 (0)
Additional lower extremity injuries	4 (57)	2 (40)
Operative treatment for initial trauma	7 (100)	2 (40)
Additional procedures to foot	6 (86)	1 (20)
Complications of subtalar arthodesis	4 (57)	0 (0)
	Median (IQR)	Median (IQR)
EQ-5D™	0.27 (0.15 – 0.43)	0.81 (0.78 – 0.87)
EQ-VAS™	40 (20 – 70)	75 (63 – 90)

MFS = Maryland Foot Score; IQR = interquartile range; N = number; EQ-5D™ = EuroQol five-dimensional questionnaire; EQ-VAS™ = EuroQol Visual Analog Scale

Discussion

This study shows that patients who underwent subtalar arthrodesis for posttraumatic arthritis after severe or complex foot injuries experienced less pain and had improved walking abilities after the procedure. In total, 90% of all patients were satisfied with the results and would recommend a subtalar fusion to others. However, functional outcome scores in our cohort seem to be poor when compared to the sparse previously published data.

In only two out of 16 articles included in a review on outcomes of tarsal fusions for a variety of hindfoot conditions, a substantial amount of the included patients underwent open arthrodesis for posttraumatic arthritis.[4,20,21] Outcomes in these studies were assessed using the American Orthopaedic Foot and Ankle Society (AOFAS) hindfoot scale, ranging from 0 to 100 with a higher score representing a better outcome, similar to the MFS.[22] Garras et al. found a mean AOFAS score of 70.9 after subtalar distraction arthrodesis with allograft, Eid et al. reported an average score of 78 after minimally invasive arthrodesis with autograft.[20,21] A statistically significant correlation between MFS and AOFAS scores (r = 0.84, $p < 0.001$) in patients who underwent subtalar fusion for calcaneal fractures has been described.[7] Taking that into account, our median MFS score of 61 after subtalar fusion still appears to be slightly worse than previously described outcomes. The relatively poor outcome scores of our patients may be influenced by the concomitant injuries and the severity of the initial foot trauma since 15 patients (38%) suffered additional lower extremity injuries. Most likely, this is a result of the field triage as nearly only patients who underwent high-energy trauma were treated at our level 1 center. For example, Eid and colleagues excluded patients with severe varus malalignment of the heel and symptomatic calcaneocuboid arthritis, which may be responsible for the relatively good functional outcome scores in their study.[20] In addition, the majority of patients included in the present study required additional surgery to their feet due to concomitant injuries. This implicates that the outcome scores in the present study might not depict functional outcomes of subtalar arthrodesis alone; they may be affected by other injuries and procedures, leading to an underestimation of functional outcomes of subtalar arthrodesis on its own. This hypothesis is supported by the fact that nearly all patients with poor outcomes underwent additional surgery and that only one of these patients reported a 'good' MFS score. Even though not statistically significant, poorer MFS scores were found in patients with additional lower extremity injuries (56 versus 61) and additional surgery (55 versus 67). In a previously published study, 77% of 47 patients who underwent subtalar arthrodesis for either primary or secondary osteoarthritis reported that if given the choice once again, they would pursue the same course of treatment despite dissatisfaction with the postoperative results in 62%.[23] The recommendation rate is our cohort was slightly higher, as 90% would recommend this procedure to friends and family. The fact that even the patients with the poorest MFS scores experienced improvement and would recommend the procedure supports our hypothesis that existing questionnaires may not be suitable to measure specific outcomes in severely injured patients, because they do not account for concomitant injuries and other circumstantial factors. This is also implicated by the finding that the two patients with the worst quality of life scores would still recommend a subtalar fusion to others, as their disability may not be related to their hindfoot injury.

When compared with the general Dutch population, quality of life of the patients included in this study was significantly lower. Regardless of treatment type, calcaneal fractures are known to cause impaired health status.[24] In line with our results, Alexandridis et al. showed that calcaneal fractures, the most common cause of subtalar arthritis in the present study, sustain a life-altering trauma resulting in chronic disability and lower QOL when compared to a reference population.[14] In addition, MFS and EQ-5D™ scores were found to be highly correlated (Pearson's r 0.69; p <0.001). Correlation between foot injuries and quality of life has been reported before, with presence of a foot injury causing poorer quality of life.[25,26]

A majority of the patients with poor functional outcome scores (57%) developed a complication after the subtalar fusion against none in the group of patients with good outcomes. This suggests that a complicated postoperative course is an indicator of poor functionality. To our knowledge, no previous study reported the association between outcome after subtalar arthrodesis and postoperative complications.[23]

This study has several limitations. First, due to the retrospective design of part of the study, information bias may have occurred. Twenty percent of the database has been verified by another researcher (GA) to detect inconsistencies in all retrospectively collected data; less than 5% of the data were discrepant, and discrepancies were not consisted within one variable. Therefore, we consider this a minor limitation. Second, there is a risk of non-response bias. Because no significant differences in baseline characteristics were found between responders and non-responders and because of the high response rate, we believe that this was of limited influence on our results. Third, no baseline functional outcome scores were available. We tried to account for this by asking patients whether their walking abilities and level of pain improved after the subtalar arthrodesis. Fourth, functional outcomes were assessed by using the Maryland Foot Score. Both the AOFAS hindfoot scale and the MFS are two widely accepted scoring systems to assess functional outcomes after intra-articular fractures of the calcaneus, and are both highly correlated with indication for arthrodesis.[7] In contrast with the AOFAS hindfoot score, the MFS does not demand a clinical examination, which might lead to increased response rates. Unfortunately, the MFS has not yet been validated in Dutch. We reached group consensus on translation of the original English questionnaire and are convinced of its accuracy.

Conclusions

This study demonstrated that 90% of all patients who underwent subtalar fusion for posttraumatic arthritis were satisfied with the results of the procedure, even though the relatively poor functional outcome scores would suggest differently. In 29 patients additional surgery of the fused foot was peformed and 15 suffered multiple (lower extremity) injuries with 6 patients being polytraumatized. Most likely, functional outcome scores have been influenced by these additional injuries and procedures. Since existing questionnaires on functional outcomes do not take these factors into account, we would like to emphasize the need for development of instruments to assess outcomes in severely injured patients with complex or multiple injuries.

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Chapter 9

Factors influencing functional outcomes of subtalar fusion for posttraumatic arthritis after calcaneal fracture

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Abstract

Introduction
Subtalar arthrodesis is a common salvage operation for posttraumatic subtalar arthritis. This study aims to identify factors associated with functional outcomes and quality of life after subtalar fusion for posttraumatic subtalar arthritis after calcaneal fracture.

Methods
This is a retrospective study with follow-up by questionnaire in two level 1 trauma centers. Patients who underwent subtalar arthrodesis for posttraumatic arthritis after a calcaneal fracture between 2001 and 2016 were identified and contacted for completion of a survey consisting of the Foot and Ankle Ability measure (FAAM), Maryland Foot Score (MFS), PROMIS Physical Function (PROMIS PF, Short Form 10a) questionnaire, EuroQol five-dimensional (EQ-5D) questionnaire, and Visual Analog Scale (EQ-VAS). Exclusion criteria were initial subtalar arthrodesis at an outside facility, primary arthrodesis for fracture, initial arthrodesis earlier than 2001, amputation of the fused foot or leg, younger than 18 years of age at time of fusion, and inability to communicate in English.

Results
A total of 159 patients met our inclusion criteria. Eighty-four patients completed the questionnaires, resulting in a response rate of 59%. Median FAAM score was 79 (IQR, 48 – 90); median MFS 74 (IQR, 56 – 86); median PROMIS PF 45 (IQR, 38 – 51). Quality of life was significantly lower when compared to a reference population (*P* .001). Smoking was independently associated with worse outcomes for all questionnaires. Complications after fusion (such as non-union, implant failure, and infectious complications), high-energy, and ipsilateral injury were predictors for poorer outcomes too.

Conclusions
Acceptable functional outcomes and quality of life were observed after subtalar fusion. Smoking, complications after subtalar fusion, high-energy trauma, and presence of ipsilateral injuries were independently associated with worse functionality and quality of life.

Introduction

Development of subtalar arthritis is a common complication after calcaneal fractures.[7,23] Subtalar arthrodesis can serve as a salvage procedure in the treatment of subtalar arthritis and has been reported to be a useful technique for the treatment of this condition after intra-articular fractures of the os calcis.[7,12,29] Various studies have been performed to assess functional outcomes after subtalar fusion.[26] However, relatively few focused on subtalar fusion for posttraumatic conditions of the calcaneus only.[7,11,12,20,29] A couple of factors influencing functional outcomes of subtalar fusion have been described previously. For example, Radnay and colleagues found patients with initial nonoperative treatment of their calcaneal fractures to have poorer functional outcomes of subtalar fusion when compared with patients who underwent initial operative treatment.[20] Another study on functional outcomes of subtalar arthrodesis for a variety of indications showed that nonunion, diabetes mellitus, and being on workers' compensation were associated with worse physical function.[5] In addition, it has been described that injuries sustained after high-energy trauma and patients suffering multiple injuries perform worse on functional outcome.[11] To date, it has not been determined if trauma factors such as mechanism of injury and patient factors such as smoking, diabetes, and social consequences are of influence. There is still a lack of data on factors influencing variation in functional outcomes and quality of life after subtalar fusion for posttraumatic subtalar arthritis after calcaneal fractures. Therefore, the aim of this study was to identify factors independently associated with poor and better functional outcomes and quality of life. Awareness of these factors may guide both patients and clinicians in decision making and improve outcomes.

Methods

Study design and participants

This is a retrospective study with follow-up by questionnaire, approved by the institutional review board. All patients who underwent subtalar arthrodesis for posttraumatic arthritis after a calcaneal fracture at two level 1 trauma centers between 2001 and 2016 were identified by searching for Current Procedure Terminology (CPT) codes for subtalar arthrodesis and International Classification of Diseases (ICD) codes for calcaneal fractures in our institutions' Research Patient Data Registry (RPDR). There was no standardized protocol for the procedure of subtalar fusion; operative techniques were per the surgeon's preference. Subtalar arthritis was defined when persistent hindfoot pain was present and either the surgeon and/or the radiologist mentioned arthritis at least once in their notes. Patients who underwent initial subtalar arthrodesis at an outside facility, underwent primary arthrodesis, underwent initial arthrodesis earlier than 2001, had amputation of the fused foot or leg, were younger than 18 at time of fusion, or were unable to communicate in English were excluded from the study. All patients considered eligible were invited to participate by a recruitment letter sent by mail. Questionnaires were administered either over the phone or online through a weblink. All responses were collected and managed using REDCap (Research Electronic Data Capture) electronic data capture. REDCap is a secure, web-based application designed to support data capture for research studies.[10]

Outcome measures and explanatory variables

For all eligible patients, data on demographics, body mass index (BMI), diabetes smoking status at time of fusion, initial injury and treatment, and details of the subtalar arthrodesis and complications were extracted from medical records. BMI was included only when recorded within the three months before or after the arthrodesis. Energy of trauma was classified according to the Advanced Trauma Life Support guidelines, with high-energy trauma mechanisms including motor vehicle and motor cycle accidents, falls from height, and crush injuries.[14,28] Non-union was classified according to radiographic evaluation, clinical records, and operative notes. In the case of bilateral subtalar fusion, only data on the first procedure were collected as not to violate the statistical assumption of independence. Our primary outcome measures were functional outcomes as measured with the Foot and Ankle Ability Measure (FAAM), the Maryland Foot Score (MFS), and the PROMIS Physical Function (Short Form 10a) questionnaire. Secondarily, we assessed quality of life as measured with the EuroQol five-dimensional (EQ-5D) questionnaire and the Visual Analog Scale (EQ-VAS). The Foot and Ankle Ability Measure (FAAM) contains 21 questions on activities of daily living and is scored on a scale from 0 to 100 with higher scores indicating higher physical function. The questionnaire was developed as a measure for physical function of the lower leg, ankle, and foot and it has been shown to be reliable and responsive in a broad range of orthopaedic patients.[16] The Maryland Foot Score was developed to evaluate patients with foot injuries and to monitor the effectiveness of interventions and is frequently used in studies on outcomes of calcaneal fractures.[22,24] This questionnaire contains 10 questions on pain and functioning and scores range from 0 to 100, with scores <50 indicating 'failure' and scores >90 indicating 'excellent' outcomes.[22] The PROMIS Physical Function (PROMIS PF) questionnaire has been created by the National Institutes of Health in an attempt to standardize the measurement and reporting of health outcomes for research and clinical practice.[4] Mean PROMIS PF score of 50 is representative of the general US population.[3] The EQ-5D covers five dimensions (mobility, self-care, usual activities, pain/discomfort, and anxiety/depression) and a higher score represents better quality of life.[19] EQ-5D scores for the study population were calculated using a scoring algorithm appropriate for a population of North-American patients.[25] The EuroQol Visual Analog Scale (EQ-VAS) is an instrument to measure a patient's self-rated health status on a scale ranging from 0 to 100 with 100 being the best imaginable health state.

Statistical analysis

Categorical variables are presented as frequencies with percentages, continuous variables as medians with interquartile ranges (IQR). The Shapiro-Wilk test was performed to assess the distribution of continuous explanatory and outcome variables; both parametric and non-parametric tests were used for bivariate analyses as appropriate. EQ-5D scores of the study population were compared to the age-by-gender norms for a general North-American population of 0.88 by using the one-sample signed rank test.[8] To identify factors independently associated with outcome scores, multivariable linear regression analyses were conducted using explanatory values with p <0.10 in bivariate analysis. A two-tailed P value of <.05 was considered statistically significant. All statistical analyses were performed using STATA® 13.1 (StataCorp LP, TX, USA).

Results

A total of 159 patients fulfilled our inclusion criteria. Eighty-four patients completed the questionnaires and 17 were deceased during the follow-up period, leading to a response rate of 59%. The inclusion and response process is depicted in figure 1.

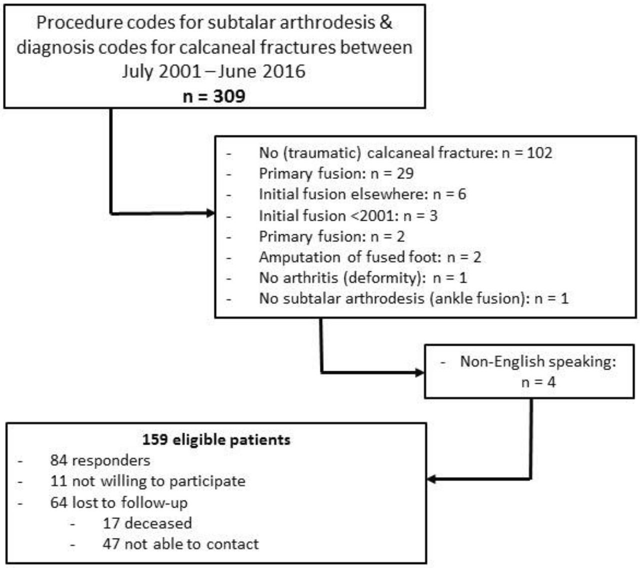

Figure 1. Flowchart of inclusion and response process.

To our knowledge, none of the deaths were related to the subtalar fusion and there was no correlation between initial high-energy trauma and death (*P* .682). The two amputations were performed in patients with multiple lower extremity fractures and were due to persistent pain and stiffness of the toes and midfoot as well as the hindfoot in one case and to recurrent infection originating from a hallux ulcer (without wound problems after subtalar fusion) in the other. One hundred patients (63%) were male with a median age of 48 (interquartile range (IQR), 39 – 55) at the time of subtalar fusion. Forty-six patients (29%) smoked in the period around the fusion. More than half of the calcaneal fractures (90; 57%) were the result of a fall from height and 89 (56%) of all fractures were of a high-energy mechanism. The majority of calcaneal fractures (108; 68%) were treated conservatively. Thirty-one patients (19%) sustained ipsilateral leg fractures (including fractures of femur, patella tibia, fibula, cuboid, etc.) at the time of their initial fractures. The median interval between calcaneal fracture and subtalar fusion was 1.4 years (IQR, 0.8 – 2.8; range, 0.1 – 36.4). All baseline characteristics are shown in table 1. A sinus tarsi approach was performed in 53% of all fusions, in 42% an extensile lateral incision was used, and none were arthroscopic procedures. The subtalar fusions were performed by a total of 19 different surgeons. In 54% of the fusions, additional procedures such as ostectomies, tendon procedures, and additional fusions (2x talonavicular fusion, 6x calcaneocuboid fusion), were performed at the same time as the subtalar fusion. Most patients (134; 84%) had an uncomplicated course following

Table 1. Baseline characteristics (n = 159).

	Total cohort (n = 159)	Responders (n = 84)	Lost to follow-up and non-responders (n = 75)	
	Median (IQR)	Median (IQR)	Median (IQR)	*P* value
Age at subtalar fusion	48 (39 – 55)	50 (41 – 55)	46 (37 – 55)	0.275
Body Mass Index (kg/m²)*	28 (25 – 30)	27 (25 – 30)	29 (26 – 31)	0.269
Time between injury and fusion (years)*	1.4 (0.8 – 2.8)	1.5 (0.8 – 3.0)	1.3 (0.7 – 2.5)	0.394
Time between fusion and questionnaire (years; median, IQR)	n/a	8.8 (4.3 – 12.2)	n/a	n/a
	n (%)	n (%)	n (%)	*P* value
Male sex	100 (63)	46 (55)	54 (72)	**0.025**
Smoking*	46 (29)	21 (25)	25 (33)	0.119
Diabetes*	7 (4)	3 (4)	4 (5)	0.563
Work-related injury*	43 (27)	19 (23)	24 (32)	0.145
Right sided fusion	82 (52)	46 (55)	36 (48)	0.394
Mechanism of trauma*				
Fall from height	90 (57)	46 (55)	44 (59)	
Fall not from height	14 (9)	8 (1)	6 (8)	0.730
Motor vehicle collision	28 (18)	13 (15)	15 (20)	
Other†	9 (6)	6 (7)	3 (4)	
High-energy trauma*	89 (56)	37 (44)	52 (69)	0.017
Ipsilateral leg fracture*	31 (19)	15 (18)	16 (21)	0.761
Primary fracture treatment				
Conservative	108 (68)	60 (71)	48 (64)	
Open reduction internal fixation	46 (29)	22 (26)	24 (32)	0.573
Closed reduction internal fixation	5 (3)	2 (2)	3 (4)	

*Body Mass Index available for 73 patients (46%); time between injury and fusion for 150 (94%); smoking status for 126 (79%); diabetes for 157 (99%); work-related injury for 135 (85%); mechanism of trauma for 141 (89%); high energy for 126 (79%); ipsilateral injury for 130 (82%).

†Other includes 3x motorcycle accident, 2x crush injury, 1x bicycle accident, 1x twisting injury, 1x sprain, 1x boating accident.

n = number; IQR = interquartile range.

Bold indicates statistical significance.

subtalar arthrodesis, 12 (8%) developed nonunion and six patients (4%) needed treatment for deep infection. In 52 patients (33%) the implants were removed, most often because of screw irritation. Table 2 provides information on the operative procedures performed. Autografts were used in 48% and the majority of fusions (93; 58%) were performed using two screws. We did not find significant differences in terms of baseline characteristics and fusion-related variables between patients who responded to the survey (responders) and patients who did not (patient who were lost to follow-up or not willing to participate), except that responders were more frequently female compared to non-responders (45 versus 28%; *P* .03), less often sustained high-energy trauma (44 versus 69%; *P* .02), and different numbers of screws were used to fuse the talus and calcaneus (*P* .03). Median interval between subtalar fusion and completion of the survey was 8.8 years (IQR, 4.3 – 12.2; range, 1.1 – 15.6).

Table 2. Specifications of subtalar arthrodesis (n = 159).

	Total cohort (n = 159) n (%)	Responders (n = 84) n (%)	Lost to follow-up (n = 75) n (%)	*P* value
Fusion approach*				
Sinus tarsi	85 (53)	45 (54)	40 (53)	0.762
Extensive lateral	66 (42)	37 (44)	29 (39)	
Other†	5 (3)	2 (2)	3 (4)	
Additional procedure during fusion‡	86 (54)	45 (54)	41 (55)	0.890
Complication after fusion				
No complication	134 (84)	70 (83)	64 (85)	0.530
Nonunion	12 (8)	7 (8)	5 (7)	
Deep infection	6 (4)	2 (2)	4 (5)	
Implant failure	3 (2)	2 (2)	1 (1)	
Superficial infection	2 (1)	2 (2)	0 (0)	
Malunion	1 (1)	1 (1)	0 (0)	
Malalignment	1 (1)	0 (0)	1 (1)	
Implant removal	52 (33)	23 (27)	29 (39)	0.130

*Fusion approach available for 156 patients (98%).
†Other includes 2x posterolateral, 1x posteromedial.
‡Additional procedures include ostectomies, talonavicular fusions, calcaneocuboid fusions, tendon procedures, etc.
n = number.

FAAM scores had a median of 79 (IQR, 48 – 90) (table 3). For the MFS, median score was 74 (IQR, 56 – 86) with 25 patients (32%) reporting a 'fair' outcome and 16 (20%) reporting 'excellent' outcome scores. For PROMIS Physical Function, our patients reported a median score of 45 (IQR, 38 – 51). Median EQ-5D score was 0.78 (IQR, 0.71 – 0.84), median EQ-VAS 80

(IQR, 68 – 89) (table 3). EQ-5D scores in our cohort were significantly lower than the norm of 0.88 for a general population of comparable age; P <.001. For the pain/discomfort dimension

Table 3. Outcome measures.

Questionnaire	Median	IQR
EQ-5D (n = 83)	0.78	0.71 – 0.84
EQ-VAS (n = 82)	80	68 – 89
PROMIS PF (n = 84)	45	38 – 51
FAAM (n = 84)	79	48 – 90
MFS (n = 79)	74	56 – 86
	n	%
Excellent (MFS 90 – 100)	16	20
Good (MFS 75 – 89)	23	29
Fair (MFS 50 – 74)	25	32
Failure (MFS <50)	15	19

EQ-5D = EuroQOL five-dimensional questionnaire; EQ-VAS = EuroQol Visual Analog Scale; PROMIS PF = Patient-Reported Outcomes Measurement System Physical Function; FAAM = Foot and Ankle Ability Measure; MFS = Maryland Foot Score; IQR = interquartile range; n = number.

Table 4. Multivariable analyses.

	Regression coefficient	95% confidence interval	*P* value
FAAM			
Smoking	-17.72	-31.48 – -3.96	**0.013**
High-energy trauma	-18.40	-31.27 – -5.53	**0.006**
Complication after fusion	-5.11	-21.46 – 11.24	0.532
MFS			
Smoking	-15.67	-26.69 – -4.65	**0.006**
High-energy trauma	-19.60	-29.89 – -9.32	**<0.001**
Conservative fracture treatment	4.80	-6.02 – 15.63	0.376
Complication after fusion	-14.90	-27.73 – -2.08	**0.024**
PROMIS PF			
Smoking	-7.15	-11.47 – -2.83	**0.002**
High-energy trauma	-4.00	-8.13 – 0.14	0.058
EQ-5D			
Smoking	-0.14	-0.26 – -0.03	**0.014**
Ipsilateral injury	-0.09	-0.22 – 0.03	0.132
EQ-VAS			

table continues

	Regression coefficient	95% confidence interval	*P* value
Smoking	-12.39	-22.70 – -2.09	**0.019**
Ipsilateral injury	-13.05	-24.15 – -1.95	**0.022**

FAAM = Foot and Ankle Ability Measure; MFS = Maryland Foot Score; PROMIS PF = Patient-Reported Outcomes Measurement System Physical Function; EQ-5D = EuroQOL five-dimensional questionnaire; EQ-VAS = EuroQol Visual Analog Scale.
Bold indicates statistical significance.

of the EQ-5D, 21 patients (25%) reported no pain or discomfort, 52 (62%) moderate pain or discomfort, and 11 (13%) extreme pain or discomfort. We did not find associations between time since arthrodesis and outcome scores. In multivariable regression analyses, smoking was found to be an independent predictor of worse outcomes for all questionnaires. Complications after the subtalar fusion were associated with poorer functional outcomes as measured with the MFS; β (regression coefficient) -5.1, *P* .024. Sustaining an ipsilateral injury and high-energy trauma were associated variables (*P*.009) and were both found to influence outcome scores. High-energy injury was found to be the strongest predictor for worse FAAM and MFS scores; β respectively -18.4 and -19.6 (*P* .006 resp. <.001). Ipsilateral injury had the most effect on EQ-VAS scores; β -13.1, *P* .022. Results of the multivariable analyses are provided in table 4. In supplementary table 1, outcome scores stratified by level of traumatic energy transfer (high- versus low-energy) are depicted. Outcome scores for all outcome measures were significantly lower in the group of responders who sustained calcaneal fractures due to high energy.

Discussion

We present the largest series of functional outcomes of subtalar arthrodesis for posttraumatic subtalar arthritis after calcaneal fractures only. Our patients reported acceptable outcomes after fusion, with median scores for all questionnaires being around 75% of the maximum possible scores. However, both general health status and foot-specific outcomes are still relatively low when compared to healthy individuals, implicating that sequelae of calcaneal fractures can be debilitating. Patients who underwent subtalar fusion for both primary and secondary osteoarthritis have been reported to have significantly worse functional outcomes compared to normative populations.[5,11] Two previous studies using the Maryland Foot Score to assess outcomes after fusion for posttraumatic arthritis in patients who sustained calcaneal fractures reported scores of 61 (median) and 85 (mean); our median of 74 is comparable.[11,20]
Smoking was associated with worse outcomes for all outcome measures. Unfortunately, we were not able to ascertain if patients were still smoking at the time of completing the questionnaires since we only collected data on smoking status at the time of subtalar fusion. Regardless, this seems to be a very important finding. Perioperative smoking is well-known to affect postoperative healing and increase the risk of multiple other complications.[9] Ideally, patients should not be smoking in the peri-operative period. Since subtalar fusion is an elective procedure, (temporary) smoking cessation may be feasible. Various studies have shown that perioperative smoking cessation is an effective tool to reduce postoperative complications after orthopaedic procedures.[15,17,18] As complications are likely to be associated

with worse outcomes[27], smoking cessation programs may be useful in increasing functional outcomes after operative procedures such as subtalar fusion.

Sustaining the initial calcaneal fracture due to high-energy trauma was an independent predictor for worse functionality. In fractures due to high-energy, there is most often damage to surrounding tissues such as ligaments and muscles. Furthermore, high-energy mechanisms often result in multiple injuries. Indeed, high-energy and presence of an ipsilateral fracture were found to be associated in our cohort. We hypothesize that functional outcomes are influenced by the severity of the initial injury and concomitant injuries, as these may impair functionality too. Existing questionnaires do not take these factors into account, and therefore not just measure the outcomes of one specific condition such as a calcaneal fracture but also outcomes of for example an ipsilateral ankle fracture. This phenomenon seems very intuitive but has not yet been fully established in literature. So far, it has only been described for patients with severe foot injuries and polytrauma patients who sustained hand injuries.[6,11]

Presence of an ipsilateral injury was found to be associated with worse self-reported health. Sustaining multiple injuries from a single trauma is often the result of severe trauma. As suffering a major trauma is known to influence a patient's general quality of life, we believe this to be the reason that ipsilateral injuries were associated with poorer general health.[13]

Radnay and colleagues found that patients who underwent initial open treatment of their calcaneal fractures had better outcomes when compared to patients treated nonoperatively.[20] However, we were not able to detect this association in our multivariable analyses. This difference may be explained by the fact that surgeons involved in both studies used different criteria in the decision making of treatment of calcaneal fractures. Our rate of patients who underwent initial conservative treatment was relatively high compared to the aforementioned study (68% versus 38%). In our hospitals, conservative treatment of (intra-articular) calcaneal fractures is common since often the risk-benefit assessment favors nonoperative treatment when taking into account factors that are known to influence outcomes negatively such as receiving Workers' Compensation.[2]

Even though we looked at different surgery related factors, such as approach and type of surgery, we did not find associations between these variables and our outcome measures. Similarly, Yuan et al. did not identify significant differences in AOFAS and VAS scores in their study comparing three different operative approaches for subtalar fusions for various indications.[30] This finding is encouraging as it suggests that surgeons can select operative treatment and approach based on patient factors and their own preferences. However, we do believe that the nature of the arthritic changes (for example primary versus posttraumatic) and associated needs for concomitant procedures such as alignment corrections often demand a distinct type of procedure. Along with surgeon preference, this may also have contributed to the fact that no arthroscopic subtalar fusions were performed in our sample.

Response rate in this study was 59%. We attempted to reach response rates as high as possible by repeatedly calling patients over a time span of a couple of months at different times of day and night and during weekends too. A recently published study investigating feasibility of long-term follow-up in trauma care reports a 60% response rate.[21] Therefore, we believe we reached a satisfactory response rate, especially when taking into account that patients in the previously mentioned study were contacted 6 or 12 months after the injury, compared to up to over 15 years after subtalar fusion for some of our cohort. We did compare baseline characteristics and operative procedures between responders and non-responders. We did not find major differences. However, it is notable that non-responders were significantly more likely to have undergone high-energy injury. An explanation for this finding is that patients who are involved in high-energy trauma (for example high-speed motorcycle crashes and falls from great height) may represent a different population with different challenges to follow-up compared to patients who suffer a simple fall at home.

A strength of our study is that we were able to collect data on a large group of patients who underwent subtalar fusion for post-traumatic sequelae of calcaneal fractures. Since subtalar fusion is not a very common procedure, most previously published studies combined data on subtalar fusion for a variety of indications, making it harder to extrapolate the results to a population of patients who suffered calcaneal fractures.[26] Furthermore, we did not look at foot-specific questions only. We also provide data on general health status and believe that this data will be beneficial when counseling patients who are potentially undergoing subtalar fusion.

This study also has its limitations. First, this was a retrospective study. We attempted to control for confounding bias as much as possible by performing very thorough chart searches and collecting data on variables that potentially influence our outcome measures. However, it was not possible to account for all potential confounders due to the limits of the retrospective data. Physical function prior to the subtalar fusion, experience of the surgeon, patient psychological factors such as depression or self-efficacy, or substance abuse may have influenced our outcomes but were beyond the scope of this study. For example, a psychiatric history has been associated with lower EQ-5D scores in patients with calcaneal fractures in a prior study.[1] Therefore, predictors identified in the present study should not be seen as the only factors influencing outcomes after subtalar fusion and may have been confounded by other factors. When counseling patients using findings of the present study, this limitation should be considered. Second, we did find significant differences between responders and non-responders. This may have implications for the generalizability of our results. Therefore, the findings of the present study should be interpreted with those differences in mind. High-energy trauma, for example, was less frequently observed in the group of responders. However, when stratified by level of traumatic energy transfer, effects of high-energy on the outcome measures were obvious. Third, we were not able to assess the AOFAS score since this demands a clinical visit. This makes direct comparison of our results with other studies, that frequently report AOFAS scores, not possible. However, a good correlation between MFS and AOFAS scores has been described.[24] Fourth, we were not able to extract detailed data on the initial injury such as concomitant head injuries for a sufficient number of patients. As we hypothesize that other concomitant injuries may influence long-term outcomes, it is unfortunate that we were not able to analyze those. Last, as this was a retrospective study with prospective follow-up, we were not able to compare outcome scores before and after subtalar fusion.

Conclusions

In conclusion, patients reported acceptable functional outcomes after subtalar arthrodesis for posttraumatic arthritis after calcaneal fractures. Smoking, complications of the fusion procedure, high-energy trauma and presence of ipsilateral injuries were found to be independent predictors of worse functionality and general health. Data on the effects of peri-operative smoking cessation on functional outcomes of orthopaedic procedures are needed. As existing questionnaires do not take into account the impact of the initial trauma and presence of concomitant injuries, functional outcomes on a specific condition in patients with multiple injuries should be interpreted with caution. Our data can be used to counsel patients when considering subtalar fusion and to target opportunities for improvement of functional outcomes of this procedure.

Supplementary table 1. Outcome scores stratified by level of traumatic energy transfer.

	High-energy Median (IQR)	Low-Energy Median (IQR)	*P* value
FAAM (n = 84)	67 (38 – 85)	83 (67 – 93)	**0.010**
MFS (n = 79)	59 (42 – 81)	78 (68 – 91)	**0.004**
PROMIS PF (n = 84)	44 (36 – 46)	48 (40 – 53)	**0.013**
EQ-5D (n = 83)	0.78 (0.45 – 0.83)	0.81 (0.71 – 1.00)	**0.026**
EQ-VAS (n = 82)	75 (58 – 86)	80 (75 – 90)	**0.018**

IQR = interquartile range; n = numb er; FAAM = Foot and Ankle Ability Measure; MFS = Maryland Foot Score; PROMIS PF = Patient-Reported Outcomes Measurement System Physical Function; EQ-5D = EuroQOL five-dimensional questionnaire; EQ-VAS = EuroQol Visual Analog Scale.
Bold indicates statistical significance.

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Chapter 10

Long-term outcomes after operative treatment for tibial pilon fractures

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Abstract

Introduction
Fractures of the tibial plafond, generally known as pilon fractures, are associated with diminished long-term outcomes. Aims of the present study were to establish normative data on long-term functional outcomes and health-related quality of life (HRQoL) after operative treatment of pilon fractures on a large scale. Secondly, it was aimed to examine factors associated with these outcomes.

Methods
Retrospective study with follow-up by questionnaire in two level 1 trauma centers. Adult patients who underwent open reduction internal fixation for a tibial pilon fracture between 2000 and 2015 were contacted for completion of a survey consisting of the Foot and Ankle Ability Measure (FAAM), Patient-Reported Outcomes Measurement System Physical Function (PROMIS PF, Short Form 10a) and EuroQol 5-Dimensions 3-Level (EQ-5D-3L) questionnaires.

Results
Questionnaires were completed by 225 patients. Median FAAM was 74 (IQR, 57–82), median PROMIS PF 49 (IQR, 44–57), median EQ-5D-3L 0.81 (IQR, 0.71–0.84). HRQoL was significantly lower when compared to a reference population ($P < .001$). In multivariable regression analyses, smoking was associated with poorer HRQoL. Higher BMI, deep infection, and lower HRQoL were associated with worse ankle function.

Conclusions
Long-term patient-reported outcomes after operative treatment of pilon fractures reveal impaired functionality and lower HRQoL compared to an uninjured reference population. As pilon fractures can have significant effects on a patient's life, patients should be counseled about the expected long-term outcomes to set realistic expectations. This study emphasizes the importance of obtaining both general and region specific measures when evaluating outcomes after injury, in order to evaluate the injury of interest in the accurate context.

Introduction

Fractures of the tibial plafond, generally known as pilon fractures, can be roughly divided into fractures that result from low-energy rotational trauma and injuries that are the result of high-energy with axial loading.[1-3] The most common are high-energy fractures with falls from height, and motorcycle and motor vehicle crashes cause the majority of tibial plafond injuries.[3,4] These mechanisms often result in associated injuries of the lower extremity and other body regions. Amongst others, high-energy trauma typically results in significant damage of the surrounding soft tissues.[3-6] In addition to the already limited soft-tissue envelope surrounding the distal tibia, these soft tissue injuries contribute to the high rate of complications after open reduction internal fixation of pilon fractures.[2,5] High rates of infectious complications, posttraumatic arthritis, impaired union, nonunion, stiffness, and persistent pain after operative treatment of pilon fractures have been reported.[7-9]

It is hypothesized that associated injuries, postoperative complications and severity of the initial injury may influence long-term functioning of the lower extremity. Indeed, relationships between a multitude of factors and clinical outcomes have been described.[1-3,10] These factors include the amount of associated (soft-tissue) injury, development of posttraumatic arthritis, severity of the pilon fracture, management of the surrounding soft tissues, type of operative treatment, and anatomic restoration of the articular surface.[1-3,10] However, long-term functional outcomes after operative treatment for pilon fractures have only been described in relatively small cohorts.[7,9,11-14] Even though the negative influence of high-energy on the eventual outcome of a pilon fracture is generally accepted, no solid evidence on its true influence is available.[8]

Therefore, the aims of the present study were to establish normative data on long-term patient-reported functional outcomes and health-related quality of life after operative treatment of pilon fractures on a larger scale. Secondly, it was aimed to examine factors associated with these outcomes. This information will be useful to surgeons and healthcare providers in expectation management and clinical decision making regarding pilon fractures.

Methods

Study design and participants

This is a retrospective study with follow-up by questionnaire that was approved by our hospital institutional review board. Adult patients (age >18 years) who underwent open reduction internal fixation (ORIF) for a tibial pilon fracture between January 2000 and December 2015 at two level 1 trauma centers were identified using the institution's research patient data registry (RPDR) and a combined hospital operative database. Pilon fractures were defined as Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association (AO/OTA) 43-B and 43-C fractures, excluding fractures deemed mainly tibial shaft with extension into the tibial plafond, and trimalleolar ankle fractures with the posterior malleolar fragment involving less than 1/3 of the articular surface.[3,8,15] Patients who underwent operative treatment for the pilon fracture at an outside facility, who had amputation of the operated foot or leg, who died during follow-up, were mentally impaired, or were unable to communicate in English, were excluded. All eligible patients were approached through a recruitment letter. Questionnaires were administered through telephone interviews or online through a secured web link. Responses were collected and managed using REDCap (Research Electronic Data Capture). REDCap is a secure, web-based application designed to support data capture for research studies.[16]

Outcome measures and explanatory variables

Data on demographics, body mass index (BMI), smoking status, diabetes, American Society of Anesthesiologists (ASA) score, mechanism of injury, fracture and treatment characteristics, and postoperative infections were extracted from electronic patient documentation. BMI was only considered when reported within a range of six months prior to or after ORIF. Smoking was considered positive if a patient was a current smoker at the time of surgery or quit smoking less than two weeks prior to the fixation. Energy of trauma was subdivided into low- and high-energy and was classified according to the Advanced Trauma Life Support guidelines, with high-energy trauma mechanisms including motor vehicle and motorcycle accidents, falls from height, and crush injuries.[17,18] Fractures were classified by four orthopaedic surgeons according to the AO/OTA classification and in case of uncertainty, consensus was reached by group discussion. Deep infection was defined as any type of infection at the surgical site that demanded operative treatment, according to the treating surgeon based on clinical signs with or without positive cultures.[19] All surgical site infections that required non-operative treatments only (e.g. antibiotics, wound treatments), were considered superficial.

The primary outcome measure, patient-reported functional outcome, was measured using the Foot and Ankle Ability Measure (FAAM) and the PROMIS Physical Function (PROMIS PF) Short Form 10a questionnaires. Health-related quality of life (HRQoL), the secondary outcome measure, was assessed using the EuroQol 5-Dimensions 3-Levels (EQ-5D-3L) questionnaire. The FAAM questionnaire consists of 29 questions assessing physical function in patients with musculoskeletal disorders of the leg, ankle, and foot; 21 questions on activities of daily living with an additional sports subscale containing 8 questions.[20] Scores range from 0 to 100 with higher scores representing higher physical function. The PROMIS PF questionnaire can be used to measure general physical functioning for both research and clinical practice purposes, with a mean score of 50 being representative of the general population of the United States.[21,22] The EQ-5D-3L questionnaire is a standardized instrument to measure generic health based on the level of experienced problems (no problems/ some or moderate problems/ extreme problems) at the five dimensions mobility, self-care, usual activities, pain/discomfort, and anxiety/depression.[23] EQ-5D-3L scores for the study population were calculated using a scoring algorithm appropriate for a population of North-American patients, with higher scores representing better HRQoL.[23,24]

Statistical analysis

Distribution of continuous explanatory and outcome variables was assessed using the Shapiro-Wilk test. Frequencies and percentages were used to present categorical variables, medians and interquartile ranges (IQR) to display continuous variables. Baseline characteristics between responders and non-responders were compared using Chi-squared and Mann-Whitney tests The Student *t* test was used to compare EQ-5D-3L and PROMIS PF scores of the study population to the norms for a general North-American population of 0.88 and 50, respectively.[21,25] The strength of correlations between the three different outcome measures was assessed using Pearson's correlation coefficient. Associations between individual predictors and the patient-reported outcomes of interest were first determined by simple bivariate linear regression (Supplementary Table 1). The final models were selected by forward stepwise regression modeling to avoid overfitting. In this approach, predictors associated with the outcome by bivariate analysis were included in the multivariable regression model. Predictors no longer associated with the outcome were omitted only if doing so did not increase the deviance of the model. Predictors excluded at the bivariate analysis state were reincorporated only if doing so reduced the overall deviance of the model.[26] A two-tailed *P* value of <.05 was considered statistically significant. STATA® 13.1 (StataCorp LP, TX, USA) was used for the conduct of all statistical analyses.

Results

Inclusion criteria were met by 480 patients, of whom 225 completed the survey for a total of 229 tibial pilon fractures (four patients sustained bilateral injuries), leading to a response rate of 47%. Responders were significantly older (median age 48 versus 41 years; *P* <.001), consisted of fewer males (61 versus 70%; *P* .04), and fewer active smokers (18 versus 32%; *P* .001) when compared with non-responders. The main reason for non-response to follow-up by questionnaire was inability to contact the patients (in 217 cases; 85%), with no current address available for 30 of these patients (14%). Thirty-eight patients refused to participate (38; 15%).

Median age at injury for the population of responders was 48 (IQR, 37 – 58) years; the majority of patients were male (61%). Baseline characteristics are depicted in table 1. Three quarters of their fractures (171; 75%) were type C fractures and 51 fractures (22%) were open injuries. High-energy trauma mechanisms caused 127 pilon fractures (56%). Table 2 shows the fracture and treatment characteristics. Median interval between injury and definitive internal fixation was 6 (IQR, 1 – 16) days. Half of the fractures (116; 51%) were treated with temporizing external fixation. Postoperative deep infection occurred in 28 cases (12%); superficial infection occurred in 26 cases (11%).

Patient-reported outcome questionnaires were completed after a median duration of 82 (IQR, 45 – 120) months from injury. Median FAAM score was 74 (IQR, 57 – 82) and 14 (IQR, 8 – 22) for the sports subscale (table 3). PROMIS Physical Function scores had a median of 49 (IQR, 44 – 57), mean PROMIS PF score was 50 (standard deviation 7.8). HRQoL, measured using the EQ-5D-3L, was reported to be 0.81 (IQR, 0.71 – 0.84), significantly lower when compared to the 0.88 reference population score (*P* <.001).(25) For the ED-5D-3L mobility dimension, nearly half of the patients (97 (44%)) reported problems in walking about. However, physical function mobility measured using the PROMIS PF was comparable to the general uninjured American population (*P* .90). All three outcome metrics were correlated; FAAM and PROMIS PF (correlation coefficient=0.79, p<0.001), FAAM and EQ-5D-3L (correlation coefficient=0.69, p <0.001), and PROMIS PF and EQ-5D-3L (correlation coefficient=0.50, p <0.001). In general, worse HRQoL metrics (EQ-5D-3L scores) were proportional to FAAM and PROMIS PF scores.

Table 1. Baseline characteristics (n = 225).

	Median	IQR
Age at injury (years)	48	37 - 58
Body Mass Index (kg/m²)*	27	24 – 30
	n	%
Male gender	137	61
Active smoking	40	18
Diabetes	13	6
ASA score*		
1	63	29
2	137	64
3	15	7
Mechanism		
Fall	147	65
Motorcycle crash	49	22
Sports-related	15	7
Other	14	6
High-energy trauma	127	56

ASA = American Society of Anesthesiologists; IQR = Interquartile Range; n = number.
*Body Mass Index was available for 198 patients (88%), ASA score for 215 (96%).

Table 2. Fracture and treatment characteristics (n = 229).

	Median	IQR
Interval between injury and ORIF (days)	6	1 – 16
	n	%
AO type 43-C	171	75
Left side fracture	118	52
Open fracture	51	22
Temporizing external fixation	116	51
Deep infection	28	12
Superficial infection	26	11

ASA = American Society of Anesthesiologists; AO = Arbeitsgemeinschaft für Osteosynthesefragen; IQR = Interquartile Range; n = number; ORIF = open reduction internal fixation.

Table 3. Outcome measures.

Questionnaire	Median	IQR
FAAM (n = 223)	74	57 – 82
FAAM Sports Subscale (n = 211)	14	8 – 22
PROMIS PF (n = 211)	49	44 – 57
EQ-5D-3L (n = 219)	0.81	0.71 – 0.84

EQ-5D = EuroQOL 5-Dimensions 3-Levels; FAAM = Foot and Ankle Ability Measure; IQR = interquartile range; n = number; PROMIS PF = Patient-Reported Outcomes Measurement System Physical Function.

Table 4. Multivariable regression analyses.

	FAAM			PROMIS PF			EQ-5D-3L		
	β regression coefficient*	95% CI	*p*-value	β regression coefficient*	95% CI	*p*-value	β regression coefficient*	95% CI	*p*-value
Interval between injury and follow-up	-0.03	-0.07 – 0.02	0.22	---	---	---	---	---	---
Body Mass Index	-0.4	-0.7 – -0.1	0.01	-0.2	-0.4 – -0.04	0.02	-0.004	-0.01 – 0.0004	0.08
Active smoking	-4.4	-9.3 – 0.5	0.08	-0.5	-3.3 – 2.3	0.71	-0.19	-0.27 – -0.12	<0.001
Diabetes	-3.4	-10.4 – 3.6	0.34	-3.5	-7.6 – 0.6	0.09	---	---	---
ASA score									
1	0.4	-3.5 – 4.4	0.83	1.3	-0.9 – 3.5	0.26	---	---	---
2	reference value			reference value			reference value		
3	0.7	-5.9 – 7.2	0.84	-4.0	-7.7 – -0.3	0.04	---	---	---
High-energy trauma	---	---	---	-1.7	-3.6 – 0.3	0.09	-0.04	-0.09 – 0.02	0.169
Deep infection	-6.4	-11.7 – -1.0	0.02	-3.0	-6.1 – 0.1	0.06	-0.0002	-0.08 – 0.08	0.995
EQ-5D-3L	56.6	47.4 – 65.7	<0.001	19.2	13.9 – 24.6	<0.001	---	---	---
Model	Multivariable linear			Multivariable linear			Multivariable linear		

AO = Arbeitsgemeinschaft für Osteosynthesefragen; ASA = American Society of Anesthesiologists; CI = confidence interval; EQ-5D = EuroQOL 5-Dimensions 3-Levels; FAAM = Foot and Ankle Ability Measure; PROMIS PF = Patient-Reported Outcomes Measurement System Physical Function.
*Positive regression coefficients denote higher outcome scores (indicating better ankle functioning according to the FAAM, better physical functioning according to the PROMIS PF, and better health-related quality of life according to the EQ-5D-3L).
Bold indicates statistically significant difference.

In multivariable regression analyses, higher BMI (regression coefficient (β) -0.4; 95% Confidence Interval (CI) -0.7 – -0.1; *P* .01), deep infection (β –6.4; 95% CI -11.7 – -1.0; *P* .02), and lower HRQoL (assessed using the EQ-5D-3L) (β 56.6; 95% CI 47.4 – 65.7; *P* <.001) were found to be independently associated with worse ankle function measured with the FAAM (table 4). Factors associated with lower PROMIS PF scores were higher BMI (β -0.2; 95% CI -0.4 – -0.004; *P* .02), ASA 3 score (β -4.0; 95% CI -7.7 – -0.3; *P* .04), and lower HRQoL (β 19.2; 95% CI 13.9 – 24.6; *P* <.001). Active smoking status was independently associated with lower HRQoL assessed using the EQ-5D-3L (β -0.1; 95% CI -0.2 – -0.1; *P* <.001).

As there was an association between smoking and EQ-5D-3L scores, the effects of smoking were less apparent when including EQ-5D-3L in the regression analyses.

Discussion

The results of this study report on long-term outcomes (>2 years) for the largest cohort of patients who have underwent operative repair for tibial plafond fractures to our knowledge.[7,9,11-14,27,28] Our results reveal impaired long-term functionality of the ankle after pilon fractures. Global physical function seems unaffected in the long term, while HRQoL was significantly lower compared to the age-by-gender norms for a general North-American population. We observed that smoking was associated with worse general HRQoL. Higher BMI, occurrence of deep infection, and worse HRQoL were correlated with worse ankle function.

Similar to our findings, Cutillas-Ybarra reported significantly lower HRQoL, measured using the Short Form (36) Health Survey (SF-36), in their population of patients with tibial plafond fractures when compared to a reference population.[13] Other studies investigating long-term health status and functionality after treatment of pilon fractures showed comparable results, indicating that pilon fractures can have significant effects on a patient's life post-treatment.[7,11,12,14] HRQoL measured in our study population was in fact similar or even worse when compared to values described for patients suffering from a variety of chronic conditions such as malignant breast neoplasms or asthma.[29]

One previous study has shown a correlation between general health function and region-specific patient-reported outcomes.[30] Our results highlight the importance of obtaining both general and region specific measures when evaluating outcomes after injury. This is especially important when evaluating injuries that typically occur in the context of multiple trauma, like pilon fractures, where outcomes are likely to be affected by concomitant injuries and the severity of the initial trauma.[31,32] Adjusting with general health measures allows the region-specific injury of interest to be assessed in the right context.

In our study, the only factor independently associated with worse long-term results for all outcome measures was active smoking status at the time of definitive fixation of the pilon fracture. Due to the retrospective nature of the study, it was not possible to ascertain if patients were still smoking at the time of follow-up by questionnaire. Furthermore, non-responders were significantly more often smoking at the time of injury and therefore, the effects measured may even be an underestimation of the true impact of tobacco use. Smoking is known to affect HRQoL and function, and hence, the lower outcome scores in our cohort may be attributed to smoking, perhaps even regardless of the pilon fractures. In addition, low income and low level of education have been reported to influence HRQoL after pilon fractures negatively and these factors have also been associated with higher rates of daily smoking.[7,33,34]

Perioperative smoking is associated with an increased risk of postoperative complications as well.[35] Therefore, it is assumed that confounding plays an important role in assessing relationships between smoking and outcomes of pilon fractures, perhaps providing an opportunity for future research.

Unfortunately, pilon fractures demand acute treatment, leaving almost no room for smoking cessation. However, even though no definite conclusions on the relationship between smoking and outcomes of operatively treated pilon fractures can be drawn, we believe that the available evidence should be used to counsel active smokers scheduled to undergo operative repair of pilon fractures and to offer these patients smoking cessation interventions.

This study has several limitations. First, the study had a retrospective design. Due to the retrospective nature of this study, it was not possible to account for all variables that carry potential to influence the outcome measures. Amongst others, low income has been shown to influence outcomes of pilon fractures but was impossible to evaluate for our cohort from the available data.[7] Furthermore, it is possible that operative factors such as the quality of reduction affect outcomes. Unfortunately, this was beyond the scope of our study and long-term postoperative imaging was not available for a sufficient amount of the included patients (as this study was conducted at two tertiary referral centers with many patients not receiving routine follow-up at these institutions). Factors of influence on our outcome measures, as identified in this study, should therefore not be seen as the only factors influencing HRQoL and functionality after operative treatment of a pilon fracture and may have been confounded by factors. Second, the response rate was relatively low. We believe this to be due to the relatively long interval between surgery and follow-up and the potentially more transient nature of a trauma patient population. Given the complexity of surgery for these injuries, many patients are also transferred in from community hospitals for their surgery and so these patients may have followed up at outside institutions. In addition, there were differences in baseline characteristics between responders and non-responders. Third, as included patients were treated over a long period of time, changes in treatment techniques and surgeon experience will have taken place. These changes may have affected the outcomes measured. Therefore, the results of the present study are not completely generalizable to all patients who suffer pilon fractures. Nonetheless, to our best knowledge, we still present the largest series on long-term outcomes after pilon fractures to date and believe our data can be used as normative data for a selected group of patients.

Conclusions

Pilon fractures can have significant effects on a patient's life and should therefore be seen as potentially disabling injuries. Long-term ankle functioning was found to be around 75% of full function, with nearly half of all patients experiencing problems in walking about. Especially in patients who have poor HRQoL, are smokers, have a high body mass index, or developed a deep surgical site infection impaired long-term outcomes can be expected. Regardless of associated factors, patients with a history of a pilon fracture do not enjoy the same health-related quality of life as individuals in the general population. It is important to counsel patients about the severity of their injury and potential long-term outcomes in order to set realistic expectations. This study emphasizes the importance of obtaining both general and region specific measures when evaluating outcomes after injury, in order to evaluate the injury of interest in the accurate context.

Supplementary Table 1. Bivariate linear regression analyses.

	FAAM			PROMIS PF			EQ-5D-3L		
	β regression coefficient*	95% CI	*p*-value	β regression coefficient*	95% CI	*p*-value	β regression coefficient*	95% CI	*p*-value
Interval between injury and follow-up	0.04	-0.02 – 0.09	0.18	0.004	-0.02 – 0.03	0.75	0.0004	-0.0001 – 0.001	0.11
Age at injury	0.03	-0.14 – 0.20	0.72	-0.07	-0.14 – 0.01	0.09	0.001	-0.0004 – 0.003	0.15
Body Mass Index	-0.8	-1.2 – -0.3	**0.001**	-0.4	-0.6 – -0.2	**<0.001**	-0.004	-0.01 – 0.0004	**0.08**
Male gender	0.4	-4.5 – 5.2	0.09	0.2	-2.0 – 2.4	0.84	-0.007	-0.06 – 0.05	0.78
Active smoking	-13.5	-19.4 – -7.6	**<0.001**	-3.1	-6.0 – -0.2	**0.04**	-0.16	-0.23 – -0.10	**<0.001**
Diabetes	-9.7	-19.6 – 0.3	0.06	-6.4	-11.1 – -1.7	**0.01**	-0.08	-0.19 – 0.03	0.17
ASA score									
1	3.6	-1.8 – 9.0	0.19	2.0	-0.4 – 4.4	0.11	0.03	-0.03 – 0.09	0.27
2	reference value			reference value			reference value		
3	1.0	-8.6 – 10.7	0.83	-3.6	-7.9 – 0.7	0.10	0.02	-0.08 – 0.13	0.68
High-energy trauma	-2.5	-7.2 – 2.2	0.30	-1.8	-4.0 – 0.3	0.09	-0.04	-0.09 – 0.01	0.16
AO type 43C	-4.1	-9.5 – 1.2	0.13	0.6	-1.8 – 3.0	0.61	-0.05	-0.11 – 0.01	0.13
Open fracture	-0.6	-6.3 – 5.2	0.84	-1.1	-3.6 – 1.5	0.41	0.02	-0.04 – 0.09	0.47
Temporizing external fixation	-5.6	-10.2 – -0.9	**0.02**	-2.7	-4.8 – -0.6	**0.01**	-0.05	-0.10 – 0.004	0.07
Deep infection	-8.1	-15.2 – -1.1	**0.02**	-2.9	-6.2 – 0.5	0.09	-0.05	-0.13 – 0.02	0.17

AO = Arbeitsgemeinschaft für Osteosynthesefragen; ASA = American Society of Anesthesiologists; CI = confidence interval; EQ-5D = EuroQOL 5-Dimensions 3-Levels; FAAM = Foot and Ankle Ability Measure; PROMIS PF = Patient-Reported Outcomes Measurement System Physical Function.

*Positive regression coefficients denote higher outcome scores (indicating better ankle functioning according to the FAAM, better physical functioning according to the PROMIS PF, and better health-related quality of life according to the EQ-5D-3L).

Bold indicates statistically significant difference.

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Part 3

Patient-reported outcome measurement in trauma patients

Chapter 11

Injury-related variation in patient-reported outcome after musculoskeletal trauma: a systematic review

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Submitted.

Abstract

Introduction
A better understanding of the factors related to patient reported outcome is needed to create effective value-based payment strategies for orthopaedic trauma patients. The purpose of this study was to explore injury-related characteristics that differentiate patient-reported outcomes (PROs) following traumatic musculoskeletal injury.

Methods
A systematic review of the literature was performed and we searched for English-language articles in PubMed/MEDLINE, Google Scholar, and the Cochrane Database of Systematic Reviews (January 1995 - September 2018). We included studies that compared PROs of musculoskeletal trauma based on injury characteristics, and excluded studies related to development or validation of outcome tools without implementation, measurement, or comparison. Study quality was assessed using the modified Oxford Center for Evidence-based Medicine rating system.

Results
A total of 21 studies that reported on a total of 10,186 patients were included (5 were prospective cohort studies, 8 were matched control retrospective cohort studies, and 8 were retrospective cohort studies). Median minimum follow-up was 3 years (range 0.5-10 years). Injury-related factors associated with worse PROs were polytrauma or multiple injuries (10 studies), neurotrauma (11 studies), and high-energy injury mechanism (7 studies). Among all studies, 32 different outcome metrics were used (17 general health status metrics and 15 limb-specific metrics) making meta-analysis infeasible.

Conclusions
Based on the results of the included studies, we propose a framework where musculoskeletal injures occur in one of four scenarios that is associated with a different, context-dependent outcome: (1) Polytrauma with neurotrauma, (2) Polytrauma without neurotrauma, (3) High-energy monotrauma, (4) Low-energy monotrauma. We propose future studies should measure at least two types of PROs: (1) a health-related quality of life metric to assess global disability, and (2) a limb-specific instrument.

Introduction

Recent health policy efforts have focused on reducing costs and improving quality of medical care using value-based payment strategies, like episode-of-care or bundled payments.[1-3] In general, value-based care models have been targeted toward high cost episode-of-care conditions such as cardiovascular treatment or arthroplasty for end-stage osteoarthritis.[3,4] Given that the cost of care for musculoskeletal injuries accounts for 6.1% of total Medicare spending and affects almost a quarter of significantly injured patients, the next area for broad implementation of value-based payment strategies is possibly orthopaedic trauma.[4-6] Most orthopaedic surgeons recognize that orthopaedic trauma patients present diversely, as there are almost innumerable combinations of injuries from different mechanisms and contexts. As a result, standardized quality measurement has been difficult to implement for this population.[3]

While it is intuitive that a total hip arthroplasty performed for osteoarthritis, tumor, or fracture is different, the heterogeneity of orthopaedic trauma care is more subtle and established methods for measuring outcomes for elective orthopaedic procedures are unlikely to translate easily.[3,5] For example, a common framework for judging post-intervention PRO for elective procedures is presented in Figure 1: post-operative function is compared to pre-operative function in the same patient (essentially a paired analysis).

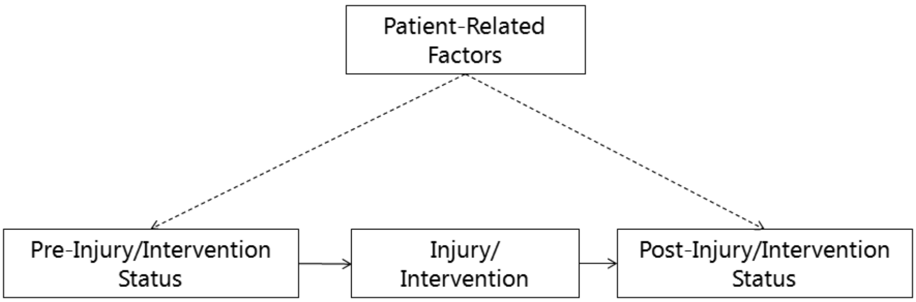

Figure 1. Current framework for assessment of outcomes after injury or intervention. Patient-related factors can affect both pre- and post-states (dotted line), but are controlled when comparing within the same patient.

But because the pre-injury status for trauma patients is less clear and subject to recall bias, this framework is difficult to apply without additional assumptions that vary by patient and injury context. As a result, these factors make implementation of value-based care models for trauma patients particularly challenging. For instance, recent studies demonstrated that if bundled payment strategies designed for a total joint population were applied with minimal allowance for trauma patient heterogeneity, short-term outcome, and post-operative complication rate, value-based payment strategies would likely fail to cut costs or improve outcomes.[3,7] In addition, since almost two-thirds of trauma patients are uninsured or on Medicare/Medicaid, increased cost-sharing without consideration of patient heterogeneity would leave hospitals and physicians underfunded while simultaneously increasing the personal financial burden of patients.[8] Yet, appropriately designed value-based payment models can help stem rapid increases in healthcare costs by shifting financial incentives away from volume and toward quality.[4,9]

In this context, while many studies have investigated cost control, less is known about outcome measures and quality when evaluating trauma care.[6,7] This is partly because acutely injured patients enter the medical system in a completely different manner than elective patients due to the unexpected nature of trauma.[7] In order to create effective value-based payment strategies for (orthopaedic) trauma patients, as well as to guide expectation management and clinical decision making, we need better understanding of not only the cost of care, but also factors associated with outcome. Thus, in this review we explore the effects of injury-related characteristics on patient-reported outcome (PROs) following traumatic musculoskeletal injury. While other factors like patient demographics and socioeconomics are related to outcome, we focus on injury-related factors in this review because current clinical care and financial billing are injury-based and injury type is known to be correlated with the cost of care.[3,5,7,10] Our goal is to present a conceptual framework that helps patients and physicians understand what injury-related factors result in patient-reported outcome differences following traumatic injury and illustrate why this differentiation is important when transitioning to value- or incentive-based care, as supported by available literature.[11]

Methods

A literature search of PubMed/MEDLINE, Google Scholar, and the Cochrane Database of Systematic Reviews through September 1, 2018, using search terms and synonyms for *injuries*, *trauma*, and *patient outcome assessment*. Non-English language articles, studies related to development or validation of outcome tools without implementation or measurement, and articles published before January 1995, were excluded. Bibliographies of retrieved studies were reviewed for inclusion of other relevant studies. Articles were reviewed for their ability to contribute to current understanding of injury-related factors that differentiate between patient reported outcomes following traumatic musculoskeletal injury. Priority was given to clinical trials, large longitudinal observational studies, and more recently published articles. Study quality of included articles was independently assessed by 2 reviewers (ARB and QMJV) using the modified Oxford Center for Evidence-based Medicine rating system.[12] Disagreements were resolved by discussion with a third independent reviewer (RMH).

Results

Search

The electronic searches yielded 880 articles. After removing duplicates, 686 articles were screened on title and abstract. A total of 41 possible relevant studies from the initial search were assessed on full-text for eligibility and references were checked for suitable related citations. Of this group, 20 articles were excluded (4 were clinical summaries, 10 compared to a non-trauma population or had no comparison to other injuries, and 6 did not measure any PROs). In total, 21 studies could be included for analysis. Of all included studies, 5 were prospective cohort studies, 8 were matched control retrospective cohort studies, and 8 were retrospective cohort studies. The search results, reasons for exclusion, and selection process are summarized in the flowchart in Figure 2.

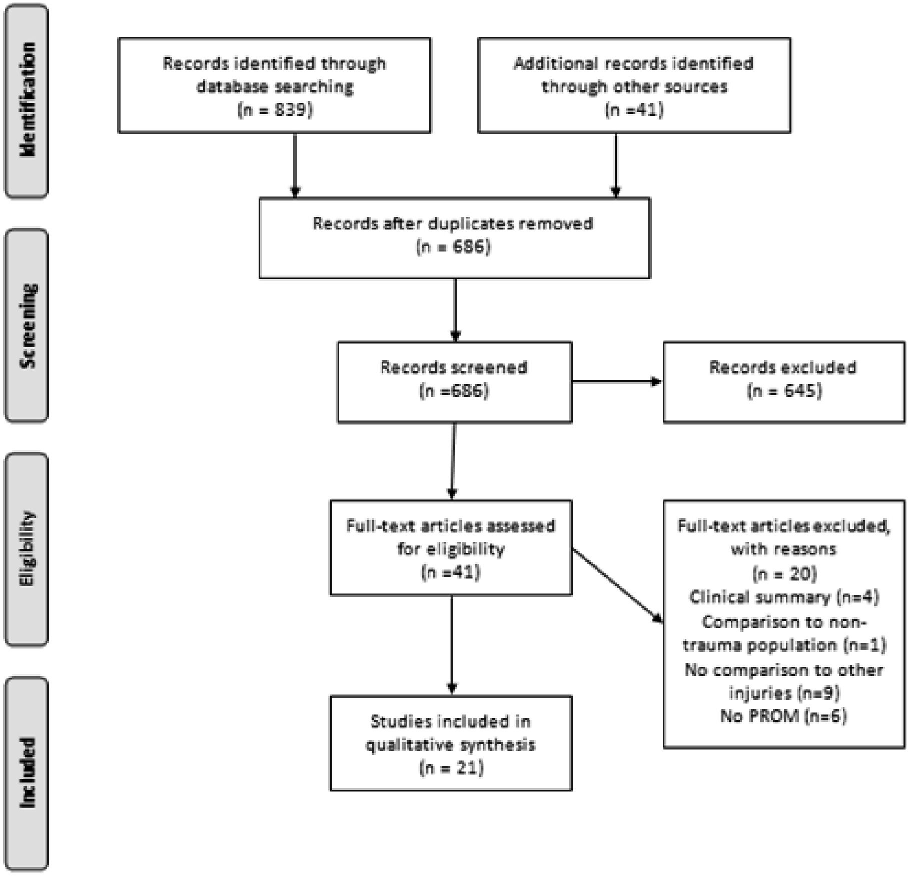

Figure 2. Flowchart of the articles included in the systematic review of injury-related factors associated with patient-reported outcomes following musculoskeletal injury.

Quality Assessment

Tables 1-2 briefly summarize the study population, outcomes, and quality assessment across all included articles. All prospective studies had a modified Oxford Center for Evidence-based Medicine rating of 2, while all retrospective case-control and cohort studies had a rating of 3.

Table 1. Prospective cohort studies examining injury-related factors in outcomes after trauma; *Rating 1-5 based on modified Oxford Centre for Evidence-based Medicine rating system.

Source	Study Population	Outcome Instruments [Follow-up]	Findings	Quality Rating*
Prospective Cohort Study				
Gross et al, 2012[38]	45 polytrauma patients with TBI compared to 66 polytrauma patients	GOS, EQ-5D, EQ-VAS, SF-36, NHP, TOP [2 years]	Both groups had markedly reduced functional outcome and QoL compared with pre-injury status (p<0.05)	2
Holtslag et al, 2007[39]	359 adult trauma patients with ISS≥16	GOS, EQ-5D [1-2 years]	Neurotrauma was associated with GOS<5 (p<0.05) Neurotrauma and lower extremity injuries were associated with decreased EQ-5D scores (p<0.01)	2
Turchin et al, 1999[13]	28 multiply injured patients with foot injuries were matched to 28 multiply injured patients without foot injuries	SF-36, WOMAC, BCH Grade [>2 years]	SF-36 scores were worse for patients who had foot injuries (49 vs 66, p=0.008) WOMAC and BCH grades for lowe extremity function were worse in the patients with foot injuries (p<0.001) There was strong correlation between SF-36 scores and WOMAC/BCH-Grade in patients with and without foot injuries (r=0.71-0.88)	2
Holbrook et al, 1999[40]	1048 trauma patients	QWB [1.5 years]	The majority of patients (80%) at the 18-month follow-up continued to have QWB scores below the healthy norm of 0.800. Serious extremity injury was a significant predictor of QWB outcome (p<0.05)	2
Holbrook et al, 1998[41]	1048 trauma patients	QWB, ADL [>0.5 years]	After major trauma, QWB scores at discharge showed a significant degree of functional limitation (mean, 0.401 +/- 0.045). At 6-month follow-up, QWB scores continued to show high levels of functional limitation (mean, 0.633 +/- 0.122) Injury to the extremities was significantly and negatively associated with 6-month QWB scores (p<0.05)	2

TBI =Traumatic Brain Injury, ISS = Injury Severity Score, QoL=Quality of Life

General Health Status Measures

GOS=Glasgow Outcome Scale, SF-36=Short Form (36), EQ-5D=EuroQoL 5-dimensional questionnaire, EQ-VAS=EuroQoL visual analog scale, TOP=Trauma Outcome Profile, QWB=Quality of Well Being scale,

table continues

ADL=Activities of Daily Living Scale, NHP=Nottingham Health Profile
Region-specific Outcome Measures
WOMAC=Western Ontario and McMaster Universities Osteoarthritis Index, BCH Grade=Boston Children's Hospital Grading System, AAOS Global Foot and Ankle Scale
Table 2: Retrospective Matched-control and cohort studies examining injury related factors in outcomes after trauma; *Rating 1-5 based on modified Oxford Centre for Evidence-based Medicine rating system

Table 2. Retrospective matched control and cohort studies examining injury related factors in outcomes after trauma; *Rating 1-5 based on modified Oxford Centre for Evidence-based Medicine rating system

Matched Control Cohort study				
Macke et al, 2017[42]	307 multiply-injured patients with upper extremity injury were compared to 322 patients without upper extremity injury	HASPOC, SF-12, Employment status [>10 years]	No significant differences between the two groups Patients with a brachial plexus injury had worse HASPOC score ($p<0.05$)	3
Andruszkow et al, 2013[43]	229 patients with upper extremity injury/no TBI vs 32 patients with upper extremity injury/TBI vs 20 patients with TBI/no upper extremity injury	HASPOC, SF-12, GOS [>10 years]	Additional TBI in multiple trauma patients led to reduced function (HASPOC, GOS; $p<0.05$)	3
von Ruden et al, 2013[44]	88 patients with severe polytrauma (ISS≥50) were compared to 1347 polytrauma patients with ISS<50	GOS, SF-36, Quality of life index, TOP [6 years]	ISS≥50 polytrauma patients had higher incidence of severe neurotrauma and extremity injuries ($p<0.05$) Long term outcomes of severely injured trauma patients was worse than for patients with ISS<50 ($p<0.05$) More distal extremity injuries had greater functional disability that affect daily life	3
Zeckey et al, 2011[45]	125 polytrauma patients with head injury were compared to 125 polytrauma patients without head injury	HASPOC, SF-12, GOS	Significant difference was shown for the GOS only (GOS head injury 4.3 ± 0.3 vs no head injury 4.9 ± 0.2, $p = 0.01$)	3
Steel et al, 2010[46]	398 multiply injured patients with TBI were compared to 222 multiply injured patients without TBI	SF-12 [>10 years]	Patients with TBI had significantly worse SF-12 scores (psychological subscale, $p<0.05$), but no difference in standardized physical subscale score	

table continues

Matched Control Cohort study				
Tran et al, 2002[47]	14 polytrauma patients with foot injuries were compared to 14 polytrauma patients without foot injury	SF-36, AAOS Global Foot and Ankle Scale, Shoe Comfort	SF-36 scores were worse for patients with foot injuries (p<0.05) Region-specific scores were also worse for patients with foot injuries (p<0.05)	3
Michaels et al, 2001[48]	100 trauma patients with orthopaedic injuries compared to 65 patients without orthopaedic injuries	SF-36, SIPw [0.5-1 year]	After controlling for ISS, patients with orthopaedic injuries had worse scores 6 months after injury on the SF-36 bodily pain, physical function, and role-physical domains (p<0.05). By 12 months after injury, orthopaedic patients had relatively worse scores on the SIPw score and six of eight SF36 domains (bodily pain, physical function, role-physical, mental health, role-emotional, and social function, p<0.05)	3
Gallay et al, 1998[49]	12 polytrauma patients with a displaced acromioclavicular (AC) joint injury were matched to two groups (12 patients with isolated AC injury and 12 polytrauma patients without AC injury)	SF-36, SPADI, SSRS, SST, SSI, M-ASES, Return to work [~2-4 years]	Shoulder function in polytrauma patients with AC injury was inferior to patients with an isolated AC injury and polytruma patients without AC injury General health status (SF-36) was worst for polytrauma patients with AC injury, followed by polytrauma patients without AC injury, then patients with isolated AC injury (p<0.05) 100% of isolated AC patients returned to work, but only 67% of polytrauma patients returned to work	3
Retrospective Cohort Study				
van der Vliet et al, 2018[50]	84 patients who underwent subtalar arthrodesis for posttraumatic arthritis after a calcaneal fracture	PROMIS PF, EQ-5D, EQ-VAS, FAAM, MFS [4-12 years]	Quality of life was significantly lower when compared to a reference population (p=0.001) High-energy injury mechanism was associated with worse region-specific outcome measures (FAAM/MFS, p<0.01). Additional ipsilateral injury was associated with worse general health status/quality of life (EQ-5D/EQ-VAS, p<0.05)	3
Hatamabadi et al, 2017[51]	1471 patients hospitalized for a road traffic injury	Mortality, GOS [1 year]	79% of patients fully recovered Injury-related factors associated with worse outcome were neurotrauma (p=0.002), multiple trauma (p=0.01), and higher energy mechanism/ISS (p<0.001)	3

table continues

Matched Control Cohort study				
Ferree et al, 2017[16]	2046 polytrauma patients; 72 had a hand injury	QDASH, PRWHE [1-6 years]	Patients with concomitant upper extremity injury (p=0.002) and those with higher ISS scores (p=0.034) had the worse outcome scores Worst outcomes in patients with neurotrauma (spine/brachial plexus/TBI)	3
Ferree et al, 2017[15]	152 patients with a displaced midshaft clavicle fracture (71 polytrauma)	QDASH [~4 years]	Polytrauma patients had worse QDASH score compared to monotrauma patients (12 vs. 5, p=0.002) Polytrauma patients were more likely to have high-energy trauma (52% vs. 19%, p<0.001) and to have sustained neurotrauma (55%)	3
Pape et al, 2010[52]	637 adult patients with ISS>16	SF-12, HASPOC [>10 years]	Traumatic amputation and presence of a severe spine injury were associated with worse outcome (p<0.01) Poorer physical functioning was reported by patients who had suffered a lower extremity vs upper extremity injury(p<0.05) Two or more articular injuries or a combination shaft and articular injury resulted in unfavorable outcome scores (p<0.05)	3
Livingston et al, 2009[53]	241 trauma patients admitted for ≥10 days to the ICU	GOS, FIM [~3 years]	70% of patients considered them selves to be less active and only ~50% had returned to work or school Severe neurotrauma (p=0.06) and extremity injury (p=0.01) were associated with decreased FIM	3
Zelle et al, 2005[29]	389 polytrauma patients with lower extremity fracture	HASPOC, SF-12, TAS, Inability to work, modified KO score, Lysholm score [>10 years]	Lower extremity functional status of patients with below-knee injuries was worse than those with above knee injuries (modified KO, Lysholm, p<0.05) Lower extremity functional status of combined injuries was worse than isolated injuries (p<0.05) HASPOC, SF-12, TAS, and inability to work was worse for patients with injuries below the knee joint (p<0.05)	3

table continues

Matched Control Cohort study				
Mkandawire et al, 2002[54]	158 patients with a musculoskeletal injury and ISS>15	Bull Disability Scale [5 years]	Patients with multiple extremity injuries or combinations of pelvic and lower extremity or shoulder girdle and upper extremity injuries were much more likely to have continuing disability compared with those sustaining single bone injuries of that limb	3

General Health Status Measures

GOS=Glasgow Outcome Scale, SF-36=Short Form (36), SF-12=Short Form (12), PROMIS PF=Patient-Reported Outcomes Measurement System Physical Function, EQ-5D=EuroQol 5-dimensional questionnaire, EQ-VAS=EuroQoL visual analog scale, FIM=modified Functional Independence Measure, Quality of Life Index, TOP=Trauma Outcome Profile, Bull Disability scale, HASPOC=Hannover Score for Polytrauma Outcome, Employment Status/Inability to work, TAS=Tegner Activity Score, QWB=Quality of Well Being scale, ADL=Activities of Daily Living Scale, SIPw=Sickness Impact Profile work scale, NHP=Nottingham Health Profile

Region-specific Outcome Measures

Upper Extremity: QDASH=Quick Disability of Arm, Shoulder and hand questionnaire, PRWHE=Patient-Rated Wrist/Hand Evaluation, SPADI=Shoulder Pain and Disability Index, SSRS=Subjective Shoulder Rating Scale, SST=Simple Shoulder Test, SSI=Shoulder Severity Index, M-ASES=Modified Shoulder and Elbow Surgeons Form

Lower Extremity: FAAM=Foot and Ankle Ability Measure, MFS=Maryland Foot Score, WOMAC=Western Ontario and McMaster Universities Osteoarthritis Index, BCH Grade=Boston Children's Hospital Grading System, AAOS Global Foot and Ankle Scale, Shoe Comfort, Karlstom-Olerud score, Lysholm score

Study Population

Among all studies, the outcomes of 10,186 patients were assessed. Median minimum follow-up was 3 years (range 0.5-10 years). All 21 studies included patients who sustained musculoskeletal injuries; 5 studies were focused on upper extremity injuries, 4 studies considered only lower extremity injuries, 2 studies considered combinations of injuries, and 10 studies examined the role of musculoskeletal injuries on patients with polytrauma (Injury Severity Scale score ≥16). Only five studies explicitly considered extremity injuries in different contexts as the primary analysis.

Outcome Metrics

Among all studies, 32 different outcome metrics were implemented (17 general health status metrics and 15 region-specific metrics). Seven different patient reported outcome measures (PROMs) were used for upper extremity function, while eight different PROMs were used for lower extremity function. Overall, the median number of PROMs per study was two (range 1-7). The most common PROMs used for general health status were the Short Form-36/12 (SF-36/SF-12, 12 studies), Glasgow Outcome Scale (GOS, 7 studies), and the Hannover Score for Polytrauma Outcome (HASPOC, 5 studies).

Fourteen articles only measured general health status and two articles only measured condition-specific PROMs. Five studies measured both general health and condition-specific PROMs. Of these, one article compared the correlation between general health and condition-specific outcomes, and reported close correlation between them.[13]

Injury-Related Factors Associated with Outcomes
Injury-related factors associated with worse PRO were muskoloskeletal injuries sustained in the context of polytrauma or multiple (orthopaedic and non-orthopeadic) injuries (10 studies), neurotrauma (traumatic brain injury, spinal cord/plexus injury; 11 studies), and high-energy injury mechanism (7 studies). Polytrauma/multiple injuries and neurotrauma tended to be associated with worse general health outcome measures, while high-energy trauma was typically associated with worse limb-specific function. We highlight relevant studies and areas of overlap in Figure 3.

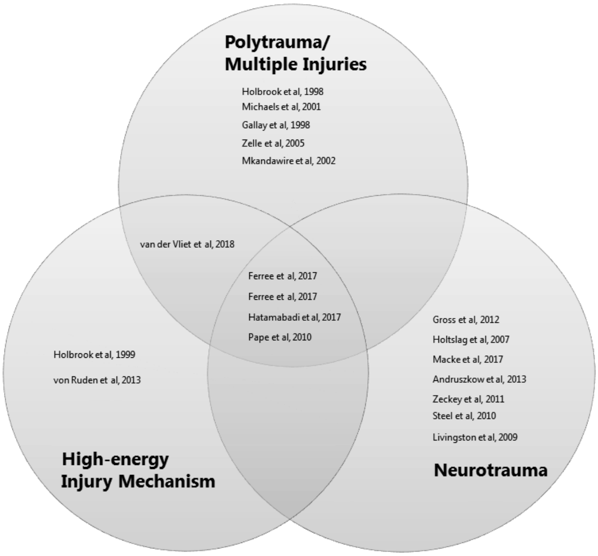

Figure 3. Grouping of injury-related factors identified in included studies that were associated with different patient-reported outcome for musculoskeletal injury (including areas of overlap as illustrated in a Venn diagram).

Discussion
Injury-related factors associated with patient-reported outcome after musculoskeletal trauma were largely related to injury mechanism and associated injuries (Figure 3). In our framework, based on the presented literature review and clinical experience, we identified four broad injury scenarios where outcomes of musculoskeletal extremity injuries varied: (1) Polytrauma/multiple injuries with neurotrauma, (2) Polytrauma/multiple injuries without neurotrauma, (3) High-energy monotrauma, and (4) Low-energy monotrauma (Figure 4). Polytrauma/multiply injured patients were significantly different than patients who sustained isolated injuries in terms of injuries sustained, with polytraumatized patients more often suffering from persistent pain and global disabilities that affected limb-specific PRO.[13,14]

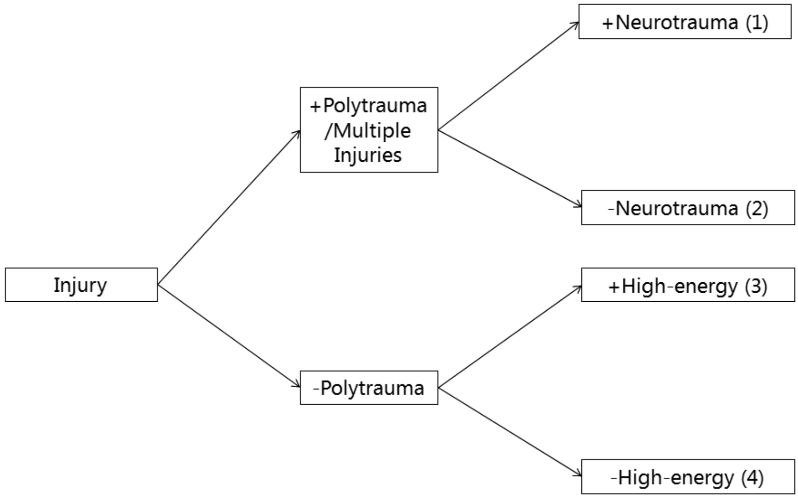

Figure 4. Four broad groups of injury scenarios where outcomes of musculoskeletal extremity injuries widely vary: (1) Polytrauma with neurotrauma, (2) Polytrauma without neurotrauma, (3) High-energy monotrauma, (4) Low-energy monotrauma.

In addition, energy transfer was associated with different injury mechanisms that resulted in different types of extremity injuries with disparate morphologic features and PROs.[15-17] As it can be hypothesized that all polytrauma/multiply injured patients suffered high energy impact based on the extent of the injuries sustained, energy transfer was not used to further categorize these patients. The included studies also suggest that analysis of PROs of extremity injury treatment without considering injury context, such as concomitant injury, can lead to significantly different expected results of treatment.

Caring for patients with significant injuries, like polytrauma, is inherently different when the primary goal of treatment is to focus on life- and limb-preservation first, and subsequently focus on less significant extremity injuries.[21,22] This prioritizing of initial care may cause a delay in diagnosis, treatment, and/or rehabilitation and affect PROs. These factors must be considered when transitioning away from fee-for-service standards to bundled payments tied to quality, otherwise institutions which care for more severely injured patients will artificially appear to have poorer outcomes when compared to less complex cases.[7] In addition, this may result in unfair reimbursements for centers caring for (severely) injured patients.[8]

Understanding the basis for injury-related variation in PROs is especially important as value-based insurance models become more prevalent in orthopaedic trauma surgery. Given that musculoskeletal injuries occur frequently and are the fastest and largest drivers of Medicare spending, changes to payment models by incorporating episode of care or bundled payments is reasonable if such changes can be balanced with accurate quality metrics.[4,5,7] Yet, trauma patients are different than other orthopaedic surgical patients and evaluation of pre- and post-intervention outcome evaluation is difficult due to the unexpected nature of trauma. Pre-injury information about patients is often either missing/unavailable or subject to patient recall bias making it challenging to assess outcomes using pre-injury status as a baseline. As a result, counseling patients on average expected outcomes or benchmarking across different trauma populations is not easy.[18] One strategy to overcome this hurdle is to collect pre-injury baseline information by proxy or directly from the patient, and future study is needed to see if this can be feasibly introduced into current trauma outcome measurement pathways.[19,20] However, this strategy faces important challenges. Recall bias as well as limited possibilities of obtaining (adequate) information in patients with altered mental status (for example due to neurotrauma or substance abuse) decrease its (wide) usefulness. A different strategy, that may be very feasible, is to compare an individual's reported outcome to a group of similar patients based on injury mechanism, concomitant injury and polytrauma as proposed by our framework (Figure 4). For example, a patient who sustained a distal radius fracture in the context of polytrauma without neurotrauma would be compared to a similar cohort.

Trauma patients and the injuries they sustain are typically heterogeneous. In line with the framework presented in our study, others have also shown that long-term outcomes are distinct for patients with neurotrauma, polytrauma/multiple injuries, or isolated orthopedic injury.[23,24] Our hope is that by grouping these patients into these 4 general categories, better estimates of benchmark and expected outcome data can be obtained (Figure 4).[6,7] Much of the current literature on incorporating value-based care has focused on cost containment, but the next step is to understand how outcome measures vary, and our study represents one step in that direction.[6] Future studies will be required to determine which specific quality measures to institutionalize, how to modify them for different injury contexts, and then how to incorporate them into new payment models (e.g. Surgical Hip and Femur Fracture Treatment bundle or other new voluntary bundles).[6]

Our review also highlights how the multiplicity of PROMs used makes comparison between and within studies exceedingly challenging. Out of 21 included studies, 32 different metrics were used. This was the primary reason we were unable to complete a quantitative meta-analysis, and this has been described in other contexts.[14,25,26] The reason for this variation has historical roots. Traditionally, mortality was the only outcome of interest when evaluating treatment of trauma patients.[27,28] As greater numbers of patients survive after trauma, there is increasing interest in functional patient-reported outcome data.[22] Yet, there is also a lack of tailored instruments and consensus opinion on the most optimal tool for trauma patients. Consistent with our framework, we suggest that contemporary measurement of PROs following musculoskeletal injury should have at least two components: (1) a health-related quality of life metric (HRQoL, e.g. EQ-5D, SF-36, PROMIS Global) to assess global disability, and (2) a condition-specific instrument (e.g. QuickDASH for distal radius fractures). While this strategy has been proposed for polytrauma patients, we suggest broader application to all musculoskeletal injuries to allow for more accurate assessment of injury-related outcome contingent on context.[29] In addition, identification of injury patterns known to perform poorly may help improve relevant long-term outcomes through changes to management and approach.[30,31] Patient-related factors undoubtedly have a strong influence on PRO and this should be a focus of future research.[32,33] Finally, when optimizing knowledge on PROs an their use, the attribution of physician-based outcomes should also be considered.

Our study has several limitations. Many of the included studies are older and use legacy PROM instruments that are now known to have significant floor- or ceiling-effects.[34–37] In addition, there were very few direct comparative studies by injury mechanism or associated injuries. Combined with the plethora of PROM metrics used, this made it infeasible to conduct a pooled meta-analysis in reasonable fashion, although we did attempt to illustrate general patterns. Definitions for polytrauma in the included studies varied. As a result, comparisons between studies and generalizability of the results may be subject to differences between the studied cohorts. Various types of neurotrauma were grouped together. However, as neurologic injuries have a wide range of severity, results of the included studies as well as our framework may not be generalizable to all these possible injuries. Finally, many factors other than anatomical injury are known to affect functional outcomes following trauma, but we focused on injury-related factors as a first step in understanding variation in PROM after musculoskeletal injury. Future studies should explore the contribution of demographic, injury specific, and socioeconomic influences.[10]

Conclusions

In this review, we explored injury-related characteristics that can be used to differentiate between PROs following traumatic musculoskeletal injuries. Based on the results of the included studies, we propose a framework where musculoskeletal injuries occur in one of 4 scenarios that are associated with different, context-dependent outcomes. We also propose that measurement of PROs should include at least one measure for HRQoL and another for condition-specific outcome. Understanding injury variation is important when transitioning to value- or incentive-based care that does not simply cut costs, but also improves the quality of care.

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Chapter 12

Routine incorporation of long-term patient-reported outcomes into a Dutch trauma registry: a prospective study

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Abstract

Introduction

Routine collection of post-discharge patient-reported outcomes within trauma registries can be used to benchmark quality of trauma care. This process is dependent on geographic and cultural context, but results are lacking regarding the European experience. We aimed to investigate the feasibility of routine inclusion of longer-term patient-reported health-related quality of life (HRQoL) in a Dutch National Trauma Database and to characterize these outcomes in a prospective cohort study.

Methods

All adult patients (≥18 years) who presented for traumatic injury in 2015-2016 were included. Exclusion criteria were death, mental impairment, insufficient command of Dutch language and residency outside the Netherlands. Primary outcomes were process-related measures of feasibility (response rate, response methods and reasons for non-response). Secondary outcomes were HRQoL measures (EuroQOL 5-Dimensions 3-Level (EQ-5D-3L) with added cognitive dimension and Visual Analogue Scale (EQ-VAS)).

Results

2025 unique patients met the initial inclusion criteria, with 1753 patients eligible for follow-up. Of these, 1315 patients participated (response rate 75%). The majority of questionnaires, 990 (75%), were completed on paper, with an additional 325 (25%) through telephone interviews. Primary reason for non-response was lack of contact information (245/438 non-responders; 56%). Median EQ-5D score was 0.81 (IQR 0.68–1.00) and median EQ-VAS score was 78 (IQR 65–90). Compared to a Dutch reference population (mean EQ-5D = 0.87), EQ-5D scores were significantly lower (p<0.001).

Conclusions

Routine collection of HRQoL is feasible within European health systems, like in the Netherlands. Further integration of these measures into trauma registries may aid worldwide benchmarking of trauma care quality.

Introduction

Trauma registries have been created in many countries to collect data for quality assessment and improvement of trauma care at the regional and national level.[1,2] Historically, the primary outcome tracked by these registries has been in-hospital mortality. However, as trauma care improved, in-hospital mortality markedly decreased and its use as the sole patient outcome variable is no longer sufficient.[2-5] As a result, trauma registries evolved to incorporate functional status at discharge, but studies have since shown that outcomes collected at discharge do not predict the long-term outcomes valued by patients (i.e. disability and quality of life).[6,7] Given that the vast majority of trauma patients survive their injuries, the most recent iterations of trauma registries have started to incorporate post-discharge, longer-term patient-reported outcomes (PROs). Incorporating these outcomes into existing trauma registries is necessary for benchmarking institutions, informing clinical decision making, and evaluating and improving overall quality of trauma care.[8,9] In fact, it is now well accepted that systematic outcomes measurement is essential for value improvement, the ultimate goal of trauma registries.[2,10]

Routine, population-based follow-up of adult trauma survivors following hospital discharge was first successfully reported in the Australian Victorian State Trauma Registry (VTSR) in 2006.[11] The data from the VTSR has proven to be a valuable resource for international benchmarking of trauma care and for research into post-trauma PROs.[12-15] As a result, the methodology of the VTSR has now been adapted and investigated for use with trauma registries in the United States, Hong Kong, and New Zealand.[8,16,17] Yet, two recent studies have suggested that routinely including PROs into trauma registries can vary by cultural context. The FORTE project in the United States demonstrated that incorporation of PROs was feasible, but that better methods for collection of the data were needed because of low response rates, even when using the original VTSR methodology with additional financial incentives.[8] Similarly, implementation of routine post-discharge PROs collection for trauma patients in Hong Kong demonstrated differences in response rate and outcomes compared to patients in Australia.[13] Comparable data is unavailable for Europe, as there are no reports of prospective routine collection of post-discharge PROs in any European country.[7-9,11]

Given the importance of geographical and cultural context emphasized by prior work, we investigated the feasibility of routine inclusion of long-term patient-reported health-related quality of life in the Dutch National Trauma Database (DNTD) using process-related outcomes. Our project was also motivated by the fact that the Dutch Ministry of Health commissioned the National Health Care Institute to carry out the Outcome Information for Joint Decisions program, a program framed to collect outcome information on 50% of the complete burden of disease in the Netherlands.[18] As trauma related injuries account for a substantial part of this burden, the Dutch National Trauma Database (DNTD) provides an important target area.[19] We hypothesized that incorporating PROs into the DNTD was possible. As a secondary objective, we sought to characterize the long-term outcomes of Dutch trauma patients after injury.

Methods

Data Sources and Patient Population

Study Design: Prospective cohort study.

Setting: The University Medical Center Utrecht is a Joint Commission International (JCI) accredited tertiary care facility with 1000 beds, complying with all requirements defined by the American College of Surgeons' Committee on Trauma.[20] This center is the designated level 1 trauma center of an inclusive trauma system situated in the Central Netherlands region, serving approximately 1.2 million people in collaboration with nine level II and III centers.[21]

Patient Population: Eligible patients were identified from the Dutch National Trauma Database (DNTD). The DNTD is a prospectively collected database of all admitted trauma patients, continuously monitored by trained data managers and trauma surgeons. Adult patients (≥18 years) who presented to our institution for assessment of traumatic injury between January 1, 2015 and December 31, 2016, were included. Deceased patients, mentally impaired patients, patients with insufficient command of Dutch language and patients residing outside the Netherlands were excluded (Figure 1). The vital status was assessed using the municipal personal records database.

Patients who were eligible for follow-up were sent a recruitment letter explaining the healthcare evaluation together with a questionnaire assessing health-related quality of life (HRQoL), and a stamped return envelope. Letters were mailed to the home addresses listed in the electronic medical record (EMR). Patients with multiple trauma admissions during the current study period were approached only once. Recruitment letters were sent in batches four times a year; patients were included in a given batch if they were within approximately three months of one year post-injury. If no response was received within three months after sending out the initial letter, a reminder letter was sent. The process of sending recruitment and reminder letters was performed by a trained data manager and a secretary. In case of non-response after both letters, patients were contacted by telephone for verbal administration of the questionnaire. Interviews were carried out by a trained medical student and a member of the research team (QV). The timing of the telephone calls was varied in an attempt to maximize response rate.[8] After three failed telephone calls, a patient was deemed a non-responder.

Outcome measures

Primary outcomes were process-related measures of feasibility (response rate, response methods, workload, and reasons for non-response). Response rate was defined as the number of patients that responded to the questionnaire divided by the total amount of patients eligible for follow-up. Workload was estimated using the unit time estimate derived from time-driven activity-based costing methods.[22] Secondary outcomes were HRQoL measures (EuroQOL 5-Dimensions 3-Level (EQ-5D-3L) with an added cognitive dimension (EQ-6D-3L) and EuroQOL Visual Analogue Scale (EQ-VAS)).[23] The EQ-5D-3L covers five dimensions (mobility, self-care, usual activities, pain/discomfort, anxiety/depression, and cognition), with three possible levels for all dimensions (no problems, some problems, extreme problems).[24] The EQ-5D scores for the study population were calculated using a scoring algorithm appropriate for a population of Dutch patients, with a possible range from -0.33 – 1.00.[25] The EQ-VAS is an instrument developed for recording an individual's current self-rated health on a scale from 0 to 100. For both the EQ-5D and the EQ-VAS, higher scores represent higher health-related quality of life.[26]

Explanatory variables
Data on patient demographics, Injury Severity Score (ISS), and injury locations were obtained from the DNTD. Injuries were categorized as serious head, thoracic, or abdominal injury if the Abbreviated Injury Scale (AIS) was greater than 2 in the respective regions. Minor injuries to the extremities were excluded by only including upper or lower extremity injury with AIS >1.

Statistical analysis
Responses were collected into a Microsoft Office Excel 2010 database. Descriptive statistics were calculated. Categorical variables were reported as numbers with percentages. Continuous variables were reported as medians with interquartile ranges (IQR) after applying Shapiro-Wilk normality tests. Bivariate analyses using chi-squared and Mann-Whitney U tests were performed in order to compare baseline characteristics between responders and non-responders. Multivariable linear regression analyses were conducted to identify demographic and injury-related factors associated with EQ-5D scores. EQ-5D scores of the study population were compared to the norms for the general Dutch population (0.87) using the Student's t-test.[27] All statistical analyses were performed using STATA® 13.1 (StataCorp LP, TX, USA). A *p*-value of <0.05 was considered statistically significant. This project was approved by the University Medical Center Utrecht Institutional Review Board.

Results

A total of 2025 unique patients met the initial inclusion criteria. Subsequently, 272 patients were excluded as they were found to be deceased (212/272), mentally impaired (26/272), lacked Dutch language proficiency (19/272), or resided outside of the Netherlands (15/272), resulting in 1753 patients eligible for follow-up. Within this cohort of eligible patients, 1315 patients responded, leading to a response rate of 75%. Median follow-up after the index trauma was 1.6 years (IQR 1.4 – 2.0, range 1.0 – 3.0). Figure 1 describes the inclusion and response process of patients. Table 1 describes participants' demographic and clinical characteristics based on inclusion-exclusion criteria.

The majority of questionnaires, 990 (75% of 1315 responders), were completed on paper, with an additional 325 (25%) completed through telephone interviews. After sending the initial recruitment letters, questionnaires were returned by 802 patients (802/990 mail responses; 81%). Sending reminder letters yielded 188 additional returned questionnaires. Of the 325 patients that completed the questionnaire over the telephone, 197 patients were successfully reached after the first attempt (60% of 325), 80 patients were successfully reached after the second attempt (25%), and 41 patients were successfully reached after the third attempt (13%). A record of the number of attempts was missing for 8 patients so they were unclassified (2%).

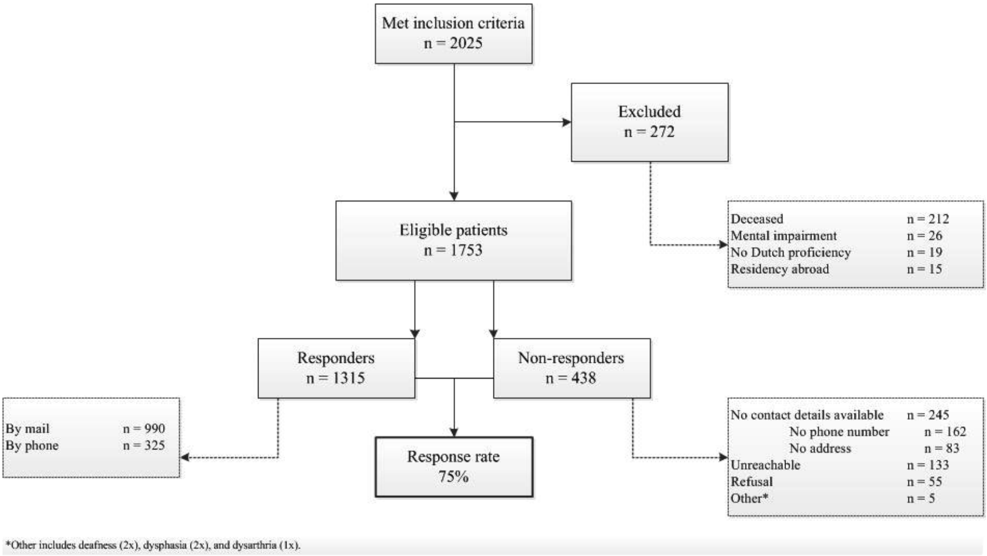

Figure 1. Flowchart of inclusion and response process.

It was estimated that approximately 620 working hours per year, comparable to 0.3 to 0.5 full time equivalent (FTE) employee (adjusting for up to 20% error in estimates), was needed to complete the entire process (including identifying eligible patients, sending out recruitment and reminder letters, contacting patients by telephone, data processing, auditing, and monitoring).

Table 1. Demographic and clinical characteristics.

	Total cohort (n = 2025)	Eligible patients (n = 1753)	Ineligible patients (n = 272)
	Median (IQR)	Median (IQR)	Median (IQR)
Age at injury (years)	54 (34 – 70)	52 (33 – 66)	71 (54 – 83)
Injury Severity Score (n = 1960)	9 (5 – 17)	9 (5 – 16)	10 (5 – 25)
	n (%)	n (%)	n (%)
Male gender	1336 (66)	1176 (67)	160 (59)
Severe head injury	544 (27)	430 (25)	116 (43)
Severe thoracic injury	366 (18)	312 (18)	57 (21)
Severe abdominal injury	67 (3)	57 (3)	11 (4)
Extremity injury	878 (43)	763 (44)	113 (42)
Upper extremity	473 (23)	410 (23)	60 (22)
Lower extremity	543 (27)	471 (27)	68 (25)

IQR = interquartile range; n = number.

The primary reason for non-response was lack of current contact information (245/438 non-responders; 56%). Another 133 patients could not be reached after sending two letters and following three phone call attempts (133/438; 30%). Only 55 patients (13%) were reached but refused to participate (Figure 1).

Table 2 compares the demographic and clinical characteristics of responders and non-responders. These groups were similar in most characteristics, but, on average, responders were of older age ($p<0.001$) and had higher ISS score ($p<0.001$) than non-responders.

Table 2. Demographic and clinical characteristics of responders versus non-responders.

	Responders (n = 1315)	Non-responders (n = 438)	p-value
	Median (IQR)	Median (IQR)	
Age at injury (years)	55 (37–69)	39 (27–56)*	**<0.001**
Injury Severity Score (n = 1960)	9 (5–17)	9 (4–14)*	**<0.001**
	n (%)	n (%)	
Male gender	879 (67)	297 (68)	0.71
Severe head injury	332 (25)	96 (22)	0.34
Severe thoracic injury	241 (18)	68 (16)	0.57
Severe abdominal injury	43 (3)	13 (3)	0.94
Extremity injury	570 (43)	195 (45)	0.86
Upper extremity	318 (24)	95 (22)	0.17
Lower extremity	351 (27)	124 (28)	0.51

IQR = interquartile range; n = number.

Bold indicates statistically significant difference.

Median EQ-5D score was 0.81 (IQR 0.68–1.00; range -0.33–1.00) and median EQ-VAS score was 78 (IQR 65–90; range 0–100). EQ-6D composite and component scores are summarized in Table 3 and the distribution of responses per dimension is presented graphically in Figure 2. When compared to a Dutch reference population (EQ-5D = 0.87), EQ-5D scores in our population were significantly lower (p <0.001). For the cognitive dimension, 791 patients (62%) reported no problems, 381 (30%) some problems, and 106 (8%) severe problems.

Using multivariable linear regression analyses, factors independently associated with worse HRQoL (EQ-5D score) were: older age at injury (coefficient [95% CI] = -0.002 [-0.003, -0.001]; p <0.001), higher ISS (coefficient [95% CI] = -0.004 [-0.006, -0.001]; p 0.002), female gender (coefficient [95% CI] = -0.057 [-0.093, -0.020]; p 0.003), and lower extremity injury (coefficient [95% CI] = -0.071 [-0.109, -0.032]; p <0.001) (Table 4).

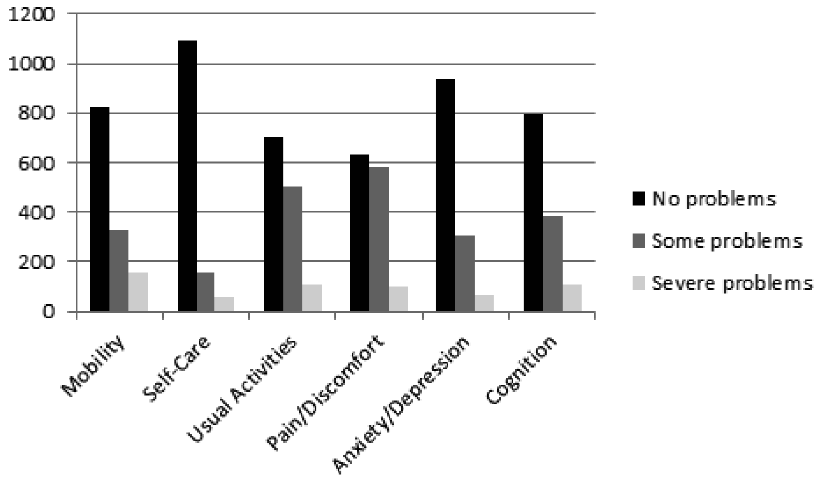

Figure 2. Graphic presentation of outcome scores.

Table 3. Outcome scores of patients.

	Median	IQR		Range
EQ-5D (n = 1298)	0.81	0.68 – 1.00		-0.33 – 1.00
EQ-VAS (n = 1273)	78	65 – 90		0 – 100
	n		%	
Mobility (n = 1308)				
No problems	820		63	
Some problems	329		25	
Extreme problems	159		12	
Self-Care (n = 1309)				
No problems	1092		83	
Some problems	159		12	
Extreme problems	58		4	
Usual Activities (n = 1310)				
No problems	701		54	
Some problems	501		38	
Extreme problems	108		8	
Pain / Discomfort (n = 1308)				
No problems	629		48	
Some problems	582		45	
Extreme problems	97		7	
Anxiety / Depression (n = 1307)				

table continues

		Median	IQR	Range
	No problems	935	72	
	Some problems	306	23	
	Extreme problems	66	5	
Cognition (n = 1278)				
	No problems	791	62	
	Some problems	381	30	
	Extreme problems	106	8	

IQR = interquartile range; n = number; EQ-5D = EuroQOL 5-Dimensions; EQ-VAS = EuroQOL Visual Analogue Scale.

Table 4. Regression analyses.

	Regression coefficient*	95% CI	*P* value
Age at injury	-0.002	-0.003 – -0.001	**<0.001**
Injury Severity Score	-0.004	-0.006 – -0.001	**0.002**
Interval between injury and questionnaire	-0.030	-0.066 – 0.007	0.109
Male gender	0.057	0.020 – 0.093	**0.003**
Severe head injury	0.004	-0.038 – 0.047	0.838
Severe thoracic injury	0.017	-0.029 – 0.063	0.460
Severe abdominal injury	0.038	-0.057 – 0.133	0.435
Upper extremity injury	0.016	-0.024 – 0.055	0.441
Lower extremity injury	-0.071	-0.109 – -0.032	**<0.001**
Model	Multivariable linear		

CI = confidence interval

Bold indicates statistically significant difference.

*Positive regression coefficients denote higher EuroQOL 5-dimensions (EQ-5D) scores.

Discussion

Our study indicates that routine inclusion of long-term patient-reported outcomes in a Dutch trauma registry is feasible, with a high response rate and little response bias. Approximately one year after the traumatic event, health-related quality of life of the patients was moderately inferior compared to the general Dutch population, but was similar to outcomes reported from outside Europe.[8,9,13] Factors independently associated with worse long-term outcome were older age, higher ISS, female gender, and lower extremity injury.

Many prior projects have attempted to assess patient outcomes after a variety of injuries and treatments by focusing on a narrowly defined subset of the population at a particular time period.[9,28,29] However, a drawback to this approach is that information pertaining to patients and health systems is limited by study design.[30,31] This is especially true for trauma patients and trauma systems where it is not uncommon to have high refusal rates and significant follow-up disparity.[9,30,32,33] As a result, these study designs are not sufficient to evaluate or benchmark the quality of care at the institutional, regional, or national level. Thus, recent studies have emphasized the routine inclusion of PROs and HRQoL metrics within trauma registries.[8,13,16] This framework allows for the collection of comprehensive, normative data on the long-term outcomes of patients who sustain trauma, summarizes the care received within health systems, and meets regulatory requests for data collection that can facilitate quality improvement, cost-effectiveness, resource utilization and benchmarking studies.

When we adopted this framework in our health system, we found that routine inclusion of HRQoL in a Dutch trauma registry was feasible, with high follow-up percentage and low response bias. Prospective collection of outcome data likely led to much higher response rates compared to retrospective collection. We also found that outcomes approximately one year after injury were lower compared to the Dutch reference population.[34] Unlike similar studies in the United States or Hong Kong, only a small percentage of patients refused to participate when asked to respond by paper or telephone questionnaire, even when no additional incentive was provided. This finding highlights another scenario where different geographic and cultural context led to variation in practical implementation of the same adapted protocol.[8,13,16] Patients within the Netherlands may have been more eager to participate in order to share information on their health status and thereby contribute to quality improvement programs. Similar to the problems encountered in the efforts of incorporating PROs into Australian and North American trauma registries, the main reason for non-response in our population was the lack of current contact details.[8,9] Targeting this problem may lead to a higher response rate. Hospitals should be encouraged to document and verify patient contact information, and patients should be instructed to inform the hospital of changes to contact information. With the advent of EMRs, automatic alerts for providers and staff can be incorporated into the EMR to highlight when a patient has missing or inadequate contact details.

In our study, the majority of questionnaires were completed on paper, and an additional third were administered successfully over the phone. While this led to satisfactory response rates in our setting, future work should investigate the use of other administration modalities, especially since the majority of non-responders were younger patients who may use email or smartphone applications as their primary communication tools.[35] Currently, we are exploring the use of a web-based platform for the distribution of patient-reported outcome measures (PROMs).

Responders and non-responders differed significantly with respect to age and ISS. Similar age-related differences between responders and non-responders have been identified previously.[8,9] In our catchment area, many young patients may be students who move more frequently and whose contact information changes more often. Higher ISS in responders has also been documented in the Victorian State Trauma Registry.[9] As ISS was independently associated with worse quality of life, results of the present study as well as previous studies may underestimate HRQoL in the complete trauma population. A potential explanation for the differences in injury severity is that patients who suffer less severe trauma, with higher odds of returning to pre-injury health status, are less inclined to document their quality of life as they are not confronted with the consequences of their injuries on a daily basis. Differences between responders and non-responders affect generalizability of studies measuring outcomes after trauma, and our study found patterns similar to those observed in other countries.[33]

Due to the unexpected nature of trauma, pre-injury baseline information about patients is often either missing or subject to patient recall bias. This can make it challenging to counsel patients on average expected outcomes or to benchmark across different trauma populations.[13] By routinely incorporating outcomes into trauma registries for all patients, results on average converge to expectations for the general population as the sample size grows. Statistically, this information can then be used to counsel patients and provide benchmarking information for a cohort of patients on average.[36]

Even though routine inclusion of patient-reported outcomes in a Dutch trauma registry was deemed feasible, our results were only accomplished with major time investment. Sending out letters, processing returns and conducting telephone interviews created an important time burden for our data managers (0.3 – 0.5 FTE). In order for the standard incorporation of PROs to be sustainable, additional technological and financial support and manpower are required. With trauma registries being established to improve care, their contents should be curated to allow for accurate, updated data.

Our study has several limitations. First, the study population was limited to one level 1, tertiary referral center that typically serves severely injured patients and patients with significant comorbidities, which may not be representative of the whole trauma population. Further validation in other settings (especially the complete Dutch Trauma Registry) will be important, but inclusion of functional outcomes that can be compared to population norms should improve generalizability.[8] Second, for some patients, telephone interviews were performed more than one year after trauma as the protocol for phone interviews was added to the initial protocol to boost response rates. Therefore, in our regression analyses, we adjusted for the interval between trauma and completion of the questionnaire. Third, as there is lack of tailored instruments for trauma patients and no consensus on the most optimal tool, making comparisons with similar projects and registries is difficult. We chose to use the EQ-5D with added cognitive dimension and EQ-VAS as they are questionnaires that can discriminate between a wide variety of health states.[26] Keeping our questionnaire simple and short is one reason we believe that our response rate was high. Fourth, we chose to exclude patients that were mentally impaired or had no proficiency of the Dutch language. This may have introduced bias in our results, especially since patients with severe traumatic brain injury could have been excluded. However, as the number of patients that were excluded based on these criteria was low, we believe the effects to be minimal. Nonetheless, future study should be directed towards the use of proxy questionnaires and non-Dutch versions of the questionnaires for outcome evaluation in a Dutch trauma population.

Conclusions

Routine collection of HRQoL is feasible within European health systems, like in the Netherlands. Paper and telephone questionnaire methods have high response rate even when no incentive is provided, but lack of response among younger patients highlights the importance of accurate contact information and exploration of electronic communication modalities. In addition, collection of this data demonstrates that trauma patients in the

Netherlands continue to report some impairment compared to the general population approximately one year following injury. Further integration of PROs and HRQoL into trauma registries may aid with worldwide benchmarking of the quality of trauma care and decrease the gap in our understanding of the impact of trauma on both patients and society.

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Chapter 13

General discussion, future perspectives and conclusions

General discussion

This thesis focused on patient-reported outcomes in trauma patients. It provides insights regarding measurement of these outcomes in a population of trauma patients specifically as well as trauma-specific factors associated with the outcomes.

Outcomes in trauma; a shifting focus

For decades, outcomes measurement has focused on clinical status, with in-hospital or 30-day mortality as the ultimate outcome measure. Functional status, frequently the main reason for patients to seek care, used to be left out when evaluating treatments or conditions.[1] However, over the past years, an increasing interest in patient-reported outcomes (PROs) has been developed.[2,3] In fact, systematic outcomes measurement is now seen as the sine qua non of value improvement.[4] Besides playing an important role in clinical decision making and expectation management, patient-reported outcomes may be utilized to enable quality improvement, to enable benchmarking between institutions, to develop bundled payment programs, and to aid reimbursement decisions.[5-7] Recently, the Dutch Ministry of Health commissioned the National Health Care Institute to carry out the Outcome Information for Joint Decisions program, a program framed to collect outcome information on 50% of the complete burden of disease in the Netherlands.[8]

A shift towards the use of PROs can be observed in the evaluation of trauma care, especially for musculoskeletal injuries.[2,5] This shift is partially attributable to increasing survival in trauma patients, causing mortality to be no longer sufficient as the sole outcome measure to evaluate the quality of care provided.[9-11] With decreasing mortality rates, reflecting improvements in injury prevention, prehospital and hospital care, alternative outcome measures need to be identified.[9,11,12] Final functional outcomes in trauma patients likely reflect at least partially the result of the overall care, involving multiple specialties and processes and are thus subject to the entire chain of trauma care. Therefore, long-term PROs could either reflect results of individual elements (such as pre-hospital care or surgical procedures), a combination of different elements, or the total provided care of the entire chain.[4] A strategy to overcome this hurdle, as shown in this thesis (**Chapter II**), is to evaluate chain-related outcomes individually. Measuring these outcomes could guide quality improvement efforts and ultimately improve outcomes that truly matter for patients. However, measuring outcomes that matter for patients (patient-reported outcomes), in a population of trauma patients specifically, faces several challenges.

Outcomes measurement in trauma; challenges

Absence of baseline information

One of the challenges of evaluating PROs in trauma patients is the absence of baseline information, due to the unexpected nature of trauma. As a result, it is difficult to assess treatment effects and trauma-related functional impairment and to counsel patients on average expected outcomes.

However, in trauma patients baseline information is particularly important. In general, patients suffering from acute trauma have a fairly high level of pre-injury functioning that acutely lowers due to trauma. In contrast to other diseases and conditions, where baseline functioning may be already slowly diminishing or is already relatively poor, ideal outcomes in trauma patients is recovery to pre-injury level of functioning. Therefore, treatment effects are targeted towards regaining this functionality. It is essential to establish to what extent this goal is met in order to evaluate the effect of treatment in trauma patients. Furthermore, it is important to determine if this target recovery is achievable at all. In other words, information on baseline status is necessary. This concept is explained graphically in Figure 1.

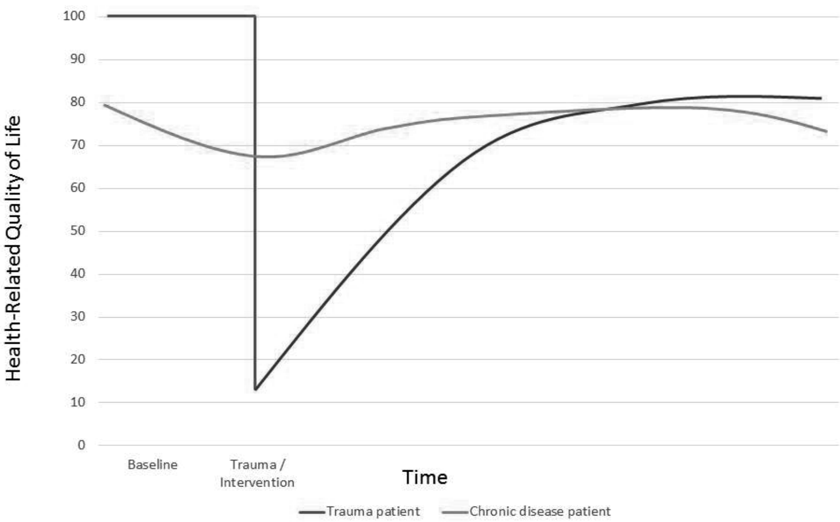

Figure 1.

In this thesis, we used outcomes reported in a general population for comparisons to overcome the lack of baseline status, as it may be assumed that trauma affects people of all ages and social backgrounds. However, as some studies suggest that trauma patients may not be completely representative of the general population, these comparison should be interpreted with some caution.[13-16]

A different approach could be retrospective collection of pre-injury patient-reported health status.[13,15,17] A drawback to this approach is that these outcomes are subject to patient recall bias.[15,16] This approach will be subject of further research following the projects of this thesis.

Another strategy to overcome the lack of baseline information may be routine collection of PROs on a large scale, as shown feasible in this thesis (**Chapter XII**). Routine incorporation of these outcomes into registries, causes results on average to converge to expectations for the general population as the sample size grows. Statistically, this information can then be used to counsel patients, to evaluate nonfatal injury burden, and to provide benchmarking information for a cohort of patients on average.[18]

Injury characteristics

Not only in studies validating patient-reported outcome measures (PROMs) but also in studies reporting on PROs, (poly)trauma patients are often omitted.[19-21] Trauma patients may suffer from a combination of injuries and especially in polytraumatized patients, injuries in multiple body regions may be sustained. Because most studies use strict in- and exclusion criteria, the typically heterogeneous (poly)trauma patient population is often excluded. In addition, patients with traumatic brain injury, representing a significant part of polytrauma patients, are often excluded from studies using outcomes reported by patients.[22,23] Furthermore, with physicians being concerned about being judged unfairly, certain types of patients, such as severely injured patients or patients with extensive ipsilateral injuries, are often excluded from outcome comparisons.[4]

Patient characteristics

Especially the most severely injured trauma population is known to be complex, with a relatively high prevalence of traumatic brain injury and its sequelae, substance abuse, psychiatric disorders, dementia, and no proficiency of the main language spoken. In addition, trauma patients do not receive standard long-term follow-up and follow-up may be troubled by logistic issues such as institutionalization in prisons, psychiatric institutions, or nursing homes.[24,25]

Non-response bias

Non-response bias may comprise all projects reporting on PROs, as there may be differences between respondents and non-respondents. Since non-response bias affect external validity, it is key to achieve high response rates in these types of projects.[26] Mainly because of the characteristics described above, achieving a high response rate in trauma patients can be challenging. In addition, nationality and cultural differences may play an important role in trauma patients' willingness to respond to surveys. The effects of these differences are clearly visible in the projects in this thesis. Response rates for studies reporting on PROs conducted in the Netherlands were higher than those conducted in the United States (with the same methodology used). Results from the efforts of routinely incorporating PROs in the Dutch trauma registry described in this thesis, also revealed differences in response rates when compared to similar projects in other countries.[27-29] Both from projects in this thesis as well as existing literature, it is known that younger patients and less severely injured patients are less likely to respond to surveys.[28,29] Therefore, results from studies reporting PROs may not be applicable to the entire trauma population.

No consensus on optimal PROMs

The very limited availability of trauma-specific PROMs and lack of consensus on optimal PROMs for trauma patients, pose another challenge for outcomes measurement in these patients. Driven by the unavailability of instruments suitable for valid assessment of relevant QoL domains in multiply injured patients, the Polytrauma Outcome Chart (POLO-Chart) was developed in the early 2000s. This questionnaire consists of 57 items and measures all relevant trauma-related aspects of QoL in combination with the Glascow Outcome Scale and two HRQoL measures.[30] The disease-specific module of this instrument, the Trauma Outcome Profile (TOP), assesses the physical, psychological, social, and functional domains of QoL.[31] Unfortunately, these instruments, comprising nearly all items necessary to assess outcomes in trauma patients, are not being used widespread. This is believed to be partially attributable to the large number of questions that needs to be completed, which requires great effort from both patients and physicians (*see Future Perspectives*).

In addition to the available literature on PROM use in trauma patients, the systematic review included in this thesis shows clearly that a wide variety of questionnaires is being used to evaluate outcomes, indicating inconsistent outcomes measurement. In addition, as most of the outcome measures used have not been validated in (poly)trauma patients specifically, the value of the outcomes reported should be interpreted with that limitation in mind.[2,14,32]

Outcomes of extremity injuries; factors of influence

Musculoskeletal injuries contribute a large amount to suffering and disability globally.[33] These musculoskeletal injuries often occur in the context of polytrauma or multiple trauma, clearly shown in this thesis. Due to the challenges described before, there is limited knowledge on the outcomes of these injuries and factors associated with a deterioration in the outcomes.

Because of prioritizing in the acute care for trauma patients, focused on diagnosing and treating the most life-threatening injuries first, injuries to the extremities often receive limited attention initially. This prioritization combined with possible concomitant traumatic brain injury or need for sedation, may cause injuries of the extremities to be diagnosed in delay (shown for injuries of the hands and feet in (**Chapters V** and **VI**).[34] Regardless the potential limited attention, late diagnosis and late treatment these injuries may receive at the start of care, long-term sequelae of (especially high-energy) musculoskeletal injuries can be significant. For calcaneal fractures, this thesis reported posttraumatic sequelae so invalidating that a salvage procedure was needed (**Chapters VIII** and **IX**). Clearly shown in this thesis is that musculoskeletal injuries to the extremities carry the potential to cause significant long-term functional impairment and diminished health-related quality of life (HRQoL). Results of the prospectively collected data on longer-term HRQoL after trauma (**Chapter XII**), indicate that injuries that may appear most relevant at first, such as severe thoracic or abdominal injuries, do not affect longer-term outcomes. However, injuries to the lower extremity were found to be associated with lower HRQoL. This finding was supported by existing literature and targets areas for improvement and opportunities for future research.[35-37]

Considering that extremity injuries influence long-term outcome and are associated with decreased HRQoL and functionality in many patients, it is important to gain insight in factors that influence these outcomes. Identifying such factors may aid in setting patient expectations, making treatment decisions, and supporting adequate and justified reimbursement strategies.

In this thesis, it was shown that PROs were negatively influenced by presence of concomitant injuries. Naturally, this concept is very intuitive. For example, when assessing upper extremity functioning in a patient with both a distal radius and an elbow fracture or in a patient with both a distal humeral bone fracture and a spinal cord lesion, functioning may be influenced by both injuries. However, as patients with multiple injuries are often excluded in studies reporting PROs (described above), this was not fully established yet.

In addition, the energy of trauma was found to be associated with outcomes after fractures of the extremities. In case of a high-energy trauma mechanism, these high-energy (axial) forces are applied to tissues in a rapid fashion. Due to the viscoelastic characteristics of bone, a large amount of the energy is absorbed before the bone eventually fractures. When the fracture occurs, this energy is released and transferred to the surrounding soft tissues (again), causing (significant) damage to the surrounding soft tissues.[38] High-energy foot fractures for example have been described to be associated with increased soft tissue damage as well as neurovascular compromise.[39] Logically, with this pathophysiology in mind, fractures sustained due to high-energy versus low-energy represent different entities. As a result of this, it is understandable that the outcomes differ as well. Similar to the findings concerning the influence of concomitant injuries on PROs after musculoskeletal trauma, this concept seems intuitive but has, to our knowledge, not been described previously. It is however essential to understand the outcomes reported and their context completely.

In addition to presence of concomitant injuries and energy transfer, HRQoL, a measure of general functioning, was found to be associated with limb-specific outcomes (**Chapters IV** and **X**). Based on these findings, it is assumed that the mechanism of injury determines the type of injury, the amount of injuries sustained, and general functioning. Injury type, presence of concomitant injuries, and general functioning are associated with limb-specific outcomes.

Future perspectives

To overcome the challenges of outcomes measurement in trauma patients

With decreasing mortality rates and increasing emphasis on outcomes that matter to patients, outcome evaluation in trauma patients should be reformed. Outcomes that truly matter for trauma patients specifically and outcome measures that accurately portray their actual outcomes as well as optimized administration methods and modalities need to be identified.

In terms of administration methods, the right balance between a reasonable amount of questions that can be completed within a reasonable amount of time and the attainment of sufficient patient-reported information is very important. One reason for the high response rates reported in this thesis, is likely to be the fact that questionnaires were short. There is a grey area between many patients responding to a few questions and many information provided by a few patients. The maximum amount of questions that trauma patients on average are willing to complete and the minimum amount of questions that is needed to evaluate outcomes accurately, need to be identified.

Routine incorporation of long-term patient-reported outcomes into the Dutch trauma registry was shown feasible for one of the regions in the Netherlands (**Chapter XII**). The experiences in this one region could be used to routinely incorporate these measures into the national trauma registry. Based on the findings reported in this thesis, this is likely to occur in the near future. The experiences may also be used to incorporate outcomes in registries outside the Netherlands. Worldwide availability of patient-reported outcomes into trauma registries can aid with worldwide benchmarking of the quality of trauma care, guiding (international) quality improvement programs and decrease the gap in our understanding of the impact of trauma on both patients and society.

In terms of administration modalities, effects of newer, digital administration methods should to be investigated. Younger patients, who may use email or smartphone applications as their primary communication tools, are known to comprise the majority of non-respondents. By offering administration modalities matching their preferences, response rates and generalizability of the results may increase.[40] In addition, digital administration modalities may decrease workload and increase data accuracy. Currently, the use of a web-based platform for the distribution of PROMs is being explored and should be further evaluated.

Last, it should be emphasized that a so called questionnaire fatigue should be avoided at all costs. With increasing interest in patient-reported outcomes, questionnaires are distributed by many specialties, healthcare providers, hospitals, and so on. With trauma patients typically being treated by a variety of medical specialties and often admitted to different wards (for example the intensive care unit and a regular ward), a questionnaire overload may occur and eventually result in high non-response rates. With the increasing importance and widespread use of patient-reported outcomes, strategies to overcome this problem need to be found. A feasible strategy, taking into account difficulties in data exchange between institutions as well as local data protection acts, would be to collect outcomes on a hospital (macro) level instead of a specialty or unit (micro) level.[41] Especially measures of general functioning can be used by a variety of specialties as well as health policy makers. Recording which questionnaires have been answered by which patients at which points during follow-up, easily retrievable from the electronic medical record or a data entry platform, may limit the amount of questionnaires administered to patients and thereby decrease the chances of the development of questionnaire fatigue.

To evaluate outcomes of extremity injuries correctly

When evaluating PROs after musculoskeletal injuries to the extremities, injury context and general functioning should be considered. These factors should also be taken into account when developing value-based reimbursement strategies. Without taking into account the factors identified to be associated with outcomes in this thesis, value-based reimbursement may be unfair for those treating the most severely injured, especially when classification of severity of injury is not adequately embedded yet.[42,43] Even more, as demonstrated in this thesis, fracture classification alone cannot differentiate between low and high energy injuries nor does it encompass the amount of soft tissue injury. Extensive classification systems are needed to compare musculoskeletal injuries and evaluate their outcomes.

As existing questionnaires are not developed for patients suffering from a combination of injuries and do not take into account the factors mentioned previously, the measurement of PROs in trauma patients should be customized. Outcome evaluation should be performed in the accurate context, possibly by using the framework presented in this thesis. The factors associated with outcomes in trauma patients as defined in this thesis may be used to develop questionnaires to evaluate outcomes in trauma patients specifically. Another possibility could be to identify adjustment variables to enable outcomes measurement in trauma patients using existing questionnaires.

With the trauma population and its injuries known to be heterogeneous and difficult to evaluate, and available outcome measures found to be insufficient, a combination of different methods of outcome evaluation should be proposed. A proposal based on the findings of this thesis as well as clinical practice, is to perform outcome evaluation in trauma patients based on a model consisting of five rings (The Olympic Model; Figure 2);

- Injury-specific outcome
- General functioning
- Injury factors
- Patient expectations
- Physician's judgement

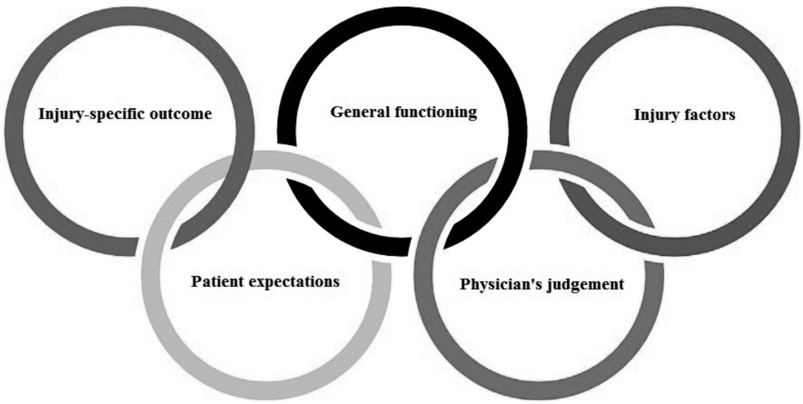

Figure 2.

In this model, the first ring, of course, comprises an injury-specific PROM, evaluating functioning of the injured body part(s). The second ring assesses general functioning, measured using an HRQoL measure. This ring is especially important as general functioning was found to be associated with the limb-specific outcomes. In the third ring, injury factors are assessed. For example, in case of a spinal cord lesion at the cervical level or ipsilateral elbow injury, assessing hand functioning without taking into account this injury,would be unfair (**Chapter V**). Other examples include taking into account the Glasgow Coma Scale in case of neurological injury or the use of an ambulatory aid after a lower extremity injury. In the fourth ring, patient expectations are considered. Patients may adapt expectations based on the severity of the initial injury and level of disability, and eventual outcomes may not be predetermined by the nature of the injury or other pre-existing characteristics.[44] By implementing this ring, a surrogate evaluation of the pre-injury condition may be approximated. This was clear from **Chapter VIII**, where patient satisfaction and outcome scores clearly differed. When only taking into account outcome scores, the outcomes that are actually experienced and valued by patients may be judged unfairly. Physician's judgement is incorporated in the fifth and final ring. Even though patient-reported outcomes are increasingly important, the doctor's opinion should not be completely omitted in the evaluation of outcomes of a care episode.[45] In trauma patients, the severity of the injury and amount of tissue damage may determine the eventual outcomes. Despite the best efforts, perfect surgical procedures and extremity reconstructions, full recovery may not be achievable. Especially in such cases, and imaginably in all cases, an expert opinion of the quality of treatment is adamant. Incorporating the physician's opinion in outcome evaluation may ensure that the outcomes and treatments evaluated are valued accurately.

Conclusions

In conclusion, without taking into account injury mechanism, concomitant injuries, and general functioning, and by focusing on the available PROMs alone, outcome evaluation in trauma patients is inadequate. When the shift towards value-based healthcare is going to be continued, efforts towards a better understanding of outcome evaluation in the typically heterogeneous and challenging trauma population should be made.

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Part 4

Appendices

Summary

Historically, the primary outcome to evaluate trauma care has been in-hospital mortality. With dramatic improvents in trauma care over the past years, in-hospital mortality markedly decreased and its use as the sole patient outcome variable is no longer sufficient.

Despite decreased mortality rates, trauma contributes both significantly as well as increasingly to the world's burden of disease. In addition, trauma carries the potential to result in longstanding adverse effects on patient's health-related quality of life, functionality, return to daily activities, and return to work. Injuries that seem innocuous in comparison to life-threatening injuries, such as injuries to the hand, wrist, foot, and ankle, may be important determinants of long-term quality of life and disability.

With decreased mortality rates, alternative outcome measures need to be identified. Considering the effects of traumatic injury decribed above, there is growing interest in measuring the non-fatal injury burden, including long-term health-related quality of life (HRQoL) and post-injury functionality. Capturing these long-term outcomes regarding the patients' perspectives, outcomes that truly matter to patients, can be at least partially achieved by the use of patient-reported outcome measures (PROMs). PROMs, also known as self-report measures, are measures developed to collect patient-reported outcomes (PROs). PROs pertain to any reports coming directly from patients about their functionality, satisfaction or other feelings in relation to health conditions and therapy, without interpretation by other parties such as clinicians.

Knowledge on PROs after traumatic injury is sparse. As polytrauma patients are often excluded in studies reporting on PROs after trauma, data on PROs in polytrauma patients is even more sparse. Availability and expertise on the accurate usage of trauma outcome data, including PROs, is expected to benefit patients, patients' relatives, healthcare providers, and society. With better understanding of the effects of trauma on post-injury living, accurate expectations on recovery may be provided. Early identification of factors associated with poor outcomes may improve long-term outcomes. Optimal, individualized treatment strategies may be identified. Overall trauma care may be improved.

To eventually reach these objectives, this thesis aims to:

- evaluate processes of outcomes measurement in trauma patients;
- establish normative data on outcomes after a variety of traumatic injuries;
- identify characteristics associated with outcomes after traumatic injury.

The challenges in outcome measurement in the most severely injured patients and consequential need for modern outcome measures are illustrated in **Chapter II** (**Part I**). In this chapter, it is shown that introduction of a 24/7 in-house attending trauma surgeon led to improved process-related outcomes for the most severely injured patients. With implementation of a system with 24/7 in-house trauma surgeon coverage, length of stay at the emergency department and time from the emergency department to the intensive care unit decreased significantly. The percentage of patients undergoing emergency surgery within thirty minutes nearly doubled, with a larger amount of patients undergoing CT imaging before emergency surgery.

In **Part II**, patient-reported outcomes are presented for (polytrauma) patients with musculoskeletal extremity injuries. **Chapter III** provides an overview of the differences in epidemiology, fracture morphology and the influence of energy transfer in distal radius fractures. Higher energy mechanisms of injury, in polytrauma and high-energy monotrauma patients, were associated with more severe complex articular distal radius fractures and more ipsilateral upper extremity injuries compared to low-energy monotrauma patients. Distal radius fractures in polytrauma and high-energy monotrauma patients had similar morphology. In **Chapter IV**, it is explored how injury-related factors may be associated with different patient-reported outcomes of distal radius fractures. It was shown that high-energy injury mechanisms and worse HRQoL scores were independently associated with slightly inferior wrist function after wrist fractures. Along with relatively well-known demographic and injury characteristics (gender and articular involvement), factors related to injury context (polytrauma, high-energy trauma) may account for differences in patient-reported wrist function after distal radius fractures.

Incidence, fracture pattern and patient-reported outcomes after fractures of the hand in polytrauma patients are reported in **Chapter V**. The incidence of hand injuries in polytrauma patients was 3.5%, which is relatively low compared to a general trauma population. Metacarpal and carpal bones were most frequently affected. The functional extremity specific outcome scores were highly influenced by concomitant injuries; presence of upper extremity injuries, neurological injuries and higher injury severity score (ISS).

In **Chapter VI**, incidence, fracture pattern, and timing of diagnosis of foot fractures in polytrauma patients are portrayed. Five percent of polytrauma patients sustained at least one foot fracture. Metatarsal fractures were most common, followed by calcaneal and talar fractures. Thirty percent of the fractures in 33% of all patients were diagnosed in a delayed fashion.

Chapter VII investigates patient-reported outcomes after open reduction internal fixation of Lisfranc and Chopart injuries, as there is no consensus on the optimal treatment of these injuries. The majority of the included patients suffered high-energy trauma and nearly all patients had a concomitant injury. Functional outcome scores showed impaired functionality. Higher ISS was associated with poorer functionality, concomitant injuries were associated with lower HRQoL. HRQoL scores were significantly lower when compared to the Dutch reference population.

Chapters VIII and **IX** focus on outcomes after subtalar arthrodesis for posttraumatic arthritis after calcaneal fractures. In **Chapter VIII**, impaired functionality and lower HRQoL compared to a reference population were described after subtalar arthrodesis. However, nearly all patients (90%) would recommend the procedure to others, walking abilities improved in 69% and less pain was experienced in 76% when compared to the period before fusion. It was concluded that existing functional outcome measures were influenced by concomitant injuries and additional procedures, demanding development of instruments suitable for severely injured patients with multiple or complex injuries. **Chapter IX**, reporting on a larger cohort of patients undergoing salvage fusion after calcaneal fractures, provides normative data on functionality and HRQoL. HRQoL was significantly lower when compared to a reference population. Smoking, complications after subtalar fusion, high-energy trauma, and presence of ipsilateral injuries were independently associated with worse functionality and HRQoL.

In **Chapter X**, long-term patient-reported outcomes of operatively treated fractures of the tibial plafond are reported. These outcomes revealed impaired functionality and lower HRQoL compared to an uninjured reference population. In multivariable regression analyses, smoking was associated with poorer HRQoL. Higher BMI, deep infection after surgery, and lower HRQoL were associated with worse ankle function. This study emphasized the importance of obtaining both general and region-specific measures when evaluating outcomes after injury, in order to evaluate the injury of interest in the accurate context.

Part III, focuses on (the process of) outcomes measurement in trauma patients. In **Chapter XI**, injury-related variation in patient-reported outcome following musculoskeletal trauma is researched by means of a systematic review of the literature. Among the 21 included studies, 32 different outcome metrics were used (17 general health status metrics and 15 limb-specific metrics). Based on the results of the included studies, a framework where musculoskeletal injures occur in one of four scenarios that is associated with a different, context-dependent outcome was proposed: (1) Polytrauma with neurotrauma, (2) Polytrauma without neurotrauma, (3) High-energy monotrauma, (4) Low-energy monotrauma. It was suggested that future studies should measure at least two types of patient-reported outcomes: (1) a health-related quality of life metric to assess global disability, and (2) a limb-specific instrument.

Experiences with routine incorporation of long-term patient-reported outcomes into the Dutch National Trauma Database are described and characterized in **Chapter XII**. In this prospective study, routine collection of a HRQoL measure at one year post-trauma was shown to be feasible. A response rate of 75% (1315/1753 eligible patients) was achieved. HRQoL in this cohort of patients was lower when compared to a Dutch reference population.

This thesis concludes that, without taking into account injury mechanism, concomitant injuries, and general functioning, and by focusing on the available PROMs alone, outcome evaluation in trauma patients is inadequate. When the shift towards the use of PROMs as outcome measures and value-based healthcare is going to be continued, efforts towards a better understanding of outcome evaluation in the typically heterogeneous and challenging trauma population should be made.

Dutch summary
Nederlandse samenvatting

Onder traumazorg verstaan we de medische zorg voor patiënten die letsel hebben opgelopen ten gevolge van een ongeval. Van oudsher was mortaliteit in het ziekenhuis de primaire uitkomst om deze traumazorg te evalueren. De traumazorg is de afgelopen jaren echter sterk verbeterd, waardoor de mortaliteit van traumapatiënten in het ziekenhuis daalde en niet langer geschikt is als de enige uitkomstmaat.

Hoewel traumatisch letsel (letsel veroorzaakt door een ongeval) steeds minder vaak tot de dood leidt, heeft trauma een significant en toenemend effect op de wereldwijde ziektelast. Daarnaast kan trauma leiden tot verminderde gezondheidsgerelateerde kwaliteit van leven en functionaliteit en kan traumatisch letsel nadelige effecten hebben op het hervatten van dagelijkse activiteiten en werkzaamheden. Juist díe letsels die vlak na een groot trauma (met bijvoorbeeld letsel van het hoofd en de grote organen) onbelangrijk lijken, kunnen op de lange termijn een belangrijke invloed hebben op kwaliteit van leven en functionaliteit. Hierbij valt te denken aan letsels van de hand, pols, voet en enkel.

Omdat mortaliteit niet langer gebruikt kan worden als enige uitkomstmaat in de evaluatie van traumazorg, moeten alternatieve uitkomstmaten worden gevonden. Gezien de potentiële effecten van traumatisch letsel die hierboven al werden beschreven (onder andere verminderde gezondheidsgerelateerde kwaliteit van leven en functionaliteit na trauma), is het belangrijk te zoeken naar uitkomstmaten die dergelijke uitkomsten kunnen objectiveren. Het streven hierbij is het meten van lange-termijn uitkomsten die daadwerkelijk belangrijk zijn voor patiënten, bijvoorbeeld in welke mate de functionaliteit van een hand is beperkt na een botbreuk van de hand. Dergelijke metingen kunnen worden verricht door gebruik te maken van zogenaamde patiënt-gerapporteerde uitkomstmaten (patient-reported outcome measures: PROMs). PROMs zijn vragenlijsten die door patiënten zelf worden ingevuld en zijn ontwikkeld om patiënt-gerapporteerde uitkomsten (patient-reported outcomes: PROs) te meten. PROs zijn alle uitkomsten die direct afkomstig zijn van patiënten zelf en iets zeggen over hun functionaliteit, tevredenheid of andere ervaringen met betrekking tot hun gezondheid en behandeling, zonder interpretatie door bijvoorbeeld artsen.

Tot op heden is er relatief weinig bekend over PROs na traumatisch letsel. Bovendien worden polytraumapatiënten, patiënten die meerdere letsels hebben opgelopen, in veel studies buiten beschouwing gelaten. Daardoor is er over deze specifieke patiëntengroep nog minder bekend. Beschikbaarheid van uitkomstdata na trauma (inclusief PROs) en expertise over het juiste gebruik van deze data kan gunstige gevolgen hebben voor zowel patiënten en hun naasten als zorgverleners en de samenleving. Met meer kennis over de effecten die trauma kan hebben op de lange termijn, kunnen er beter en meer accuraat verwachtingen worden geschept over het te verwachten herstel. Als er factoren bekend zijn die geassocieerd zijn met beter of juist slechter herstel op de lange termijn, kunnen deze worden gebruikt om behandelingen te optimaliseren om zo de uiteindelijke uitkomsten te verbeteren. Optimale, geïndividualiseerde behandelingsstrategieën kunnen worden ontwikkeld. De traumazorg zal hiermee in zijn geheel kunnen worden verbeterd.

Om deze doelstellingen uiteindelijk te behalen, streeft dit proefschrift om:
- het proces van het meten van uitkomsten in traumapatiënten te evalueren;
- uitkomstdata na een aantal verschillende traumatische letsels te vergaren;
- karakteristieken geassocieerd met uitkomsten na traumatisch letsel te identificeren.

De uitdagingen die men tegenkomt bij het meten van uitkomsten in de meest ernstig gewonde patiënten en de daaruit volgende noodzaak voor nieuwere, moderne uitkomstmaten, komen naar voren in **Hoofdstuk I** (**Deel I**). In dit hoofdstuk laten we zien dat continue (dus 24/7) aanwezigheid van een traumachirurg zorgde voor een verbetering in proces-gerelateerde uitkomsten voor de meest ernstig gewonde patiënten in vergelijking met een periode zonder continue aanwezigheid van traumachirurgen (waarin deze chirurgen bereikbaarheidsdiensten hadden). Met de continue aanwezigheid van ervaren traumachirurgen nam de ligduur op de spoedeisende hulp af en waren de patiënten eerder op de intensive care. Ook het percentage patiënten dat een spoedoperatie onderging binnen dertig minuten na presentatie verdubbelde, terwijl een groter percentage van deze patiënten nog een CT-scan onderging voor de spoedoperatie. Hoewel het versnellen van deze processen waarschijnlijk wel degelijk invloed zal hebben op de kwaliteit van zorg en uiteindelijke uitkomsten, was het niet mogelijk om een effect op de overleving aan te tonen. In **Deel II** worden patiënt-gerapporteerde uitkomsten van (polytrauma (ernstig gewonde)) patiënten met breuken van de hand, pols, voet en enkel gepresenteerd. **Hoofdstuk III** toont hoe het type polsbreuk en het percentage patiënten dat een breuk van de pols oploopt verschilt afhankelijk van de energieoverdracht van het ongeval (een hoge versus een lage energieoverdracht). Traumamechanismen waarbij er sprake is van overdracht van veel energie (de zogenaamde hoogenergetische traumamechanismen, zoals een auto-ongeval met grote snelheid of een val van hoogte) waren in dit hoofdstuk geassocieerd met meer complexe polsbreuken en meer letsels van de aangedane arm in vergelijking met patiënten die een polsbreuk opliepen ten gevolge van laagenergetische traumamechanismen (bijvoorbeeld een val vanuit stand). In **Hoofdstuk IV** wordt onderzocht hoe factoren gerelateerd aan het initiële trauma, onder andere de mate van energieoverdracht en de opgelopen letsels, patiënt-gerapporteerde uitkomsten na breuken van de pols beïnvloeden. Hoogenergetische traumamechanismen en lagere gezondheidsgerelateerde kwaliteit van leven waren onafhankelijk geassocieerd met slechtere polsfunctie. Deze factoren zorgen samen met reeds bekende factoren (zoals geslacht en betrokkenheid van het gewrichtsoppervlak) voor verschillen in patiënt-gerapporteerde uitkomsten na breuken van de pols.

De incidentie van breuken van de hand, de locatie in de hand waar deze breuken voorkomen en de patiënt-gerapporteerde uitkomsten van deze breuken in polytraumapatiënten worden gepresenteerd in **Hoofdstuk V**. Breuken van de hand komen voor in 3.5% van de populatie polytraumapatiënten. Dit percentage is relatief laag in vergelijking met de algehele traumapopulatie. De middenhands- en handwortelbeentjes waren het meest vaak aangedaan. De patiënt-gerapporteerde functionaliteit van de hand werd beïnvloed door aanwezigheid van bijkomende letsels; bijkomende letsels van de armen, het hoofd en een hogere injury severity score (ISS: score die de ernst van het traumatische letsel weergeeft).

Hoofdstuk VI toont de incidentie van fracturen van de voet, de locatie in de voet waar deze breuken voorkomen en de timing van het stellen van de diagnose van deze breuken in polytraumapatiënten. Vijf procent van de polytraumapatiënten had tenminste één voetbreuk. De middenvoetsbeentjes waren het meest vaak aangedaan, gevolgd door het hiel- en sprongbeen. Dertig procent van alle breuken in 33% van de patiënten werd vertraagd gevonden.

Hoofdstuk VII onderzoekt patiënt-gerapporteerde uitkomsten na operatieve behandeling van letsels van de middenvoet, gezien er geen consensus is over de optimale behandeling van deze letsels. De meerderheid van de in deze studie geïncludeerde patiënten liep een letsel van de middenvoet op ten gevolge van hoogenergetisch trauma en bijna alle patiënten hadden een bijkomend letsel. Patiënt-gerapporteerde uitkomsten lieten verminderd functioneren zien. Een hogere injury severity score was geassocieerd met verminderd functioneren, bijkomende letsels waren geassocieerd met lagere gezondheidsgerelateerde kwaliteit van leven. Gezondheidsgerelateerde kwaliteit van leven was lager in vergelijking met de Nederlandse referentiepopulatie.

Hoofdstukken VIII en **IX** gaan over uitkomsten na subtalaire arthrodese voor posttraumatische artrose na breuken van het hielbeen. Bij deze operatie wordt het onderste spronggewricht operatief vastgezet om pijnklachten ten gevolge van een eerdere breuk van het hielbeen te verminderen. In **Hoofdstuk VIII** wordt beschreven dat er sprake is van verminderde functionaliteit en verlaagde gezondheidsgerelateerde kwaliteit van leven na deze ingreep in vergelijking met een referentiepopulatie die deze ingreep niet onderging. Ondanks deze uitkomsten zouden bijna alle patiënten (90%) die deze ingreep ondergingen de ingreep aanbevelen aan anderen. In 69% van de patiënten verbeterde het lopen en in 76% was er sprake van minder pijn in vergelijking met de periode voor het vastzetten van het gewricht. Er werd op basis van deze resultaten geconcludeerd dat de bestaande functionele uitkomstmaten worden beïnvloed door bijkomende letsels en bijkomende procedures en dat het nodig is om nieuwe instrumenten te ontwikkelen die geschikt zijn voor ernstig gewonde patiënten met multipele en/of complexe letsels. **Hoofdstuk IX** beschrijft eenzelfde maar grotere populatie dan het vorige hoofdstuk en presenteert normatieve data met betrekking tot functionaliteit en gezondheidsgerelateerde kwaliteit van leven na operatief vastzetten van het onderste spronggewricht in het kader van pijnklachten na een breuk van het hielbeen. Gezondheidsgerelateerde kwaliteit van leven was lager in vergelijking met een referentiepopulatie. Roken, complicaties na de operatie, hoogenergetisch trauma en aanwezigheid van bijkomende letsels waren onafhankelijk geassocieerd met verminderde functionaliteit en lagere gezondheidsgerelateerde kwaliteit van leven.

Langetermijn patiënt-gerapporteerde uitkomsten na operatieve behandeling van een bepaald type enkelbreuk worden gepresenteerd in **Hoofdstuk X**. Deze uitkomsten tonen verminderde functionaliteit en lagere gezondheidsgerelateerde kwaliteit van leven in vergelijking met een niet-gewonde referentiepopulatie. Roken was geassocieerd met lagere gezondheidsgerelateerde kwaliteit van leven. Hoger BMI, diepe infectie na de operatie en lagere gezondheidsgerelateerde kwaliteit van leven waren geassocieerd met verminderde enkelfunctie. Deze studie benadrukt het belang van het verzamelen van zowel een regiospecifieke uitkomst (dus bijvoorbeeld enkelfunctie na een breuk van de enkel) als een algemene uitkomst (zoals gezondheidsgerelateerde kwaliteit van leven) in de evaluatie van uitkomsten na traumatisch letsel. Zo kan het onderzochte letsel in de juiste context worden geëvalueerd.

Deel III richt zich op het (proces van) meten van uitkomsten in traumapatiënten. Hoe variatie in het type trauma de uitkomsten na traumatische letsels van de ledematen beïnvloedt, werd onderzocht door middel van een systematisch literatuuronderzoek (**Hoofdstuk XI**). In de 21 geïncludeerde studies werden 32 verschillende uitkomstinstrumenten gebruikt (17 algemene instrumenten en 15 ledemaat-specifieke instrumenten). Op basis van de geïncludeerde studies werd een raamwerk gepresenteerd waarin traumatische letsels van de ledematen voorkomen in vier verschillende scenario's die alle geassocieerd zijn met een eigen, contextafhankelijke uitkomst: (1) Polytrauma met neurologisch letsel, (2) Polytrauma zonder neurologisch letsel, (3) Hoogenergetisch monotrauma, (4) Laagenergetisch monotrauma. We suggereren dat toekomstige studies tenminste twee typen patiënt-gerapporteerde uitkomsten meten: (1) gezondheidsgerelateerde kwaliteit van leven om globale functionaliteit te bepalen en (2) ledemaat-specifieke functionaliteit.

Ervaringen met het routinematig verzamelen van langetermijn patiënt-gerapporteerde uitkomsten in de Nederlandse traumaregistratie worden beschreven en gekarakteriseerd in **Hoofdstuk XII**. In deze prospectieve studie laten we zien dat het routinematig verzamelen van gezondheidsgerelateerde kwaliteit van leven een jaar na trauma haalbaar is. Het responspercentage was 75% (1315/1753 van de benaderbare patiënten). De gemeten gezondheidsgerelateerde kwaliteit van leven in dit cohort was lager dan in de Nederlandse referentiepopulatie.

Deze thesis concludeert dat uitkomstevaluatie in traumapatiënten inadequaat is wanneer er geen rekening wordt gehouden met het mechanisme van trauma, bijkomende letsels en algeheel functioneren en wanneer er alleen gebruik wordt gemaakt van bestaande vragenlijsten.

Als er meer nadruk op het gebruik van PROMs als uitkomstmaat blijft worden gelegd, bijvoorbeeld bij het vaststellen van vergoedingen voor bepaalde behandelingen, is er meer kennis nodig over het evalueren van patiënt-gerapporteerde uitkomsten in de heterogene traumapopulatie.

Review committee

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Dr. Heng, Marilyn, I am so glad you decided to try working with 'a Dutchie' at the Orthopaedic Trauma department. Thank you so much for providing me with this opportunity; it has been an amazing experience. I truly admire your dedication to orthopaedic surgery as well as research. You are by far the most brilliant orthopeadic surgeon I've ever met. And I love how you manage to combine orthopaedics with boots, bottles of whiskey and lots of cookies. We will keep in touch.

Dr. Hietbrink, Falco, wat ontzettend fijn om jou mijn copromotor te mogen noemen. Jouw adviezen, ideeën en opmerkingen zijn altijd zó doordacht en spot on. En dat ook nog binnen een tijdsframe van een paar uur. Jouw betrokkenheid en nauwkeurigheid zijn ongekend.
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Abhiram Bhashyam, Abhi, from a ride to Raynham to defending our theses together. Who would ever have imagined that? I am so fortunate you offered me that ride. Our collaboration has been very fruitful and most of all, a lot of fun, and I am certain we will keep on working together. I look forward to learning even more from you. So proud we did this! You are a one in a million.

Lukas van Spengler, 'BAAS!', ik mis onze dagelijkse gesprekken. Staand in de deuropening hebben we heel wat besproken. Het is mooi om te zien hoe consciëntieus jij álles aanpakt. Veel dank dat je op elk plan of idee dat ik aan je voorstelde (en dat waren er nogal wat) serieus inging. Ik geloof dat ik jou vaker om geld heb gevraagd dan mijn ouders...

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En papa, de vertraging in de laatste fase van het schrijven van dit proefschrift is je allang vergeven. Ik ben zo vreselijk blij dat je het resultaat nu in je handen hebt.

Curriculum vitae auctoris

Quirine Maria Jacoba van der Vliet was born on December 26, 1991 in Purmerend, the Netherlands. She grew up in Ilpendam, a village just north of Amsterdam. Attending high school in Amsterdam, she graduated cum laude from the Barlaeus Gymnasium. In 2009, Quirine started her medical education at the University of Utrecht.

In 2015, she worked as a graduate research assistant (extracurricular internship) at the Massachusetts General Hospital, Boston, United States, Orthopaedic Spine and Oncology Department, supervised by dr. J.H. Schwab.

Quirine developed an interest in medical research during her first surgical internship in 2012. She has been working on various research projects since. After obtaining her medical degree in 2016, Quirine moved to Boston. As a PhD cadidate, she worked at the Harvard Orthopaedic Trauma Initative guided by dr. M. Heng. Upon returning to the Netherlands in 2017, Quirine continued working on her PhD at he University Medical Center Utrecht until 2018 (supervised by prof. dr. L.P.H. Leenen).

Currently, Quirine works as a surgical resident (not in training) at the Diakonessenhuis Utrecht under supervision of dr. Th. van Dalen.
Quirine lives with Bram in Utrecht.