The impact of upper extremity injuries on polytrauma patients at a level 1 Trauma Center

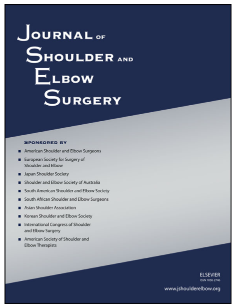
Zeelenberg, Miliaan L ; Den Hartog, Dennis ; Halvachizadeh, Sascha ; Pape, Hans-Christian ; Verhofstad, Michael H J ; Van Lieshout, Esther M M

Abstract: BACKGROUND Upper extremity injuries often lead to long-term problems in function and quality of life in patients. However, not much is known about this effect in polytrauma patients. This study aimed to describe the upper extremity injuries in polytrauma patients and to compare self-reported disability and quality of life in polytrauma patients with versus without upper extremity injuries. METHODS A retrospective cohort study was performed in adult patients with an injury severity score (ISS) of 16 or higher, admitted to Erasmus MC between January 1, 2007 and December 31, 2016. Patients were asked to complete the Disabilities of the Arm, Shoulder and Hand (DASH), Short Form-36 (SF-36), and EuroQol-5D (EQ-5D) questionnaires. Details on injuries, treatment, and clinical outcome were collected from the national trauma registry and medical files. Characteristics and self-reported outcomes of polytrauma patients, with versus without upper extremity injuries, were compared. RESULTS In a cohort of 3,469 trauma patients 1,246 (36.5%) suffered upper extremity injuries. Of these, 278 (22.0%) suffered severe injuries (AIS 3). Upper extremity injuries are associated with longer hospitalization (median 12 days versus 8 days, p<0.001), longer ICU stay (median 5 days versus 4 days, p=0.005), and lower mortality (14.6% versus 23.9%, p<0.001). In 598 patients who completed the questionnaires, no difference in physical component summary (47 versus 48, p=0.181) and mental component summary (54 versus 53, p=0.315) of the SF-36 and the Utility score (0.82 versus 0.85, p=0.101) and VAS score (80 versus 80, p=0.963) of the EQ-5D, was found. However, patients with upper extremity injuries showed a minor increase in disability in the DASH (9.2 versus 4.2, p=0.023). CONCLUSION Upper extremity injuries in polytrauma patients are associated with longer hospitalization, ICU stay, reduced mortality, and a minor increase in long-term disability.

DOI: https://doi.org/10.1016/j.jse.2021.10.005

Zeelenberg, Miliaan L; Den Hartog, Dennis; Halvachizadeh, Sascha; Pape, Hans-Christian; Verhofstad, Michael H J; Van Lieshout, Esther M M (2021). The impact of upper extremity injuries on polytrauma patients at a level 1 Trauma Center. Journal of Shoulder and Elbow Surgery:Epub ahead of print.
DOI: https://doi.org/10.1016/j.jse.2021.10.005

Journal Pre-proof



The impact of upper extremity injuries on polytrauma patients at a level 1 Trauma Center

Miliaan L. Zeelenberg, BSc, Dennis Den Hartog, MD PhD, Sascha Halvachizadeh, MD, Hans-Christian Pape, MD PhD, Michael H.J. Verhofstad, MD PhD, Esther M.M. Van Lieshout, PhD MSc

PII: S1058-2746(21)00754-0

DOI: https://doi.org/10.1016/j.jse.2021.10.005

Reference: YMSE 5764

To appear in: *Journal of Shoulder and Elbow Surgery*

Received Date: 17 June 2021

Revised Date: 17 September 2021

Accepted Date: 6 October 2021

Please cite this article as: Zeelenberg ML, Den Hartog D, Halvachizadeh S, Pape H-C, Verhofstad MHJ, Van Lieshout EMM, The impact of upper extremity injuries on polytrauma patients at a level 1 Trauma Center, *Journal of Shoulder and Elbow Surgery* (2021), doi: https://doi.org/10.1016/j.jse.2021.10.005.

The impact of upper extremity injuries on polytrauma patients at a level 1 Trauma Center

Miliaan L. Zeelenberg[1], BSc; Dennis Den Hartog[1], MD PhD; Sascha Halvachizadeh[2], MD; Hans-Christian Pape[2], MD PhD; Michael H.J. Verhofstad[1], MD PhD; Esther M.M. Van Lieshout[1], PhD MSc

[1]Trauma Research Unit, Department of Surgery, Erasmus MC, University Medical Center Rotterdam, Rotterdam, Netherlands

[2]Trauma Department, University Hospital Zürich, Zürich, Switzerland

Corresponding author:

Esther M.M. Van Lieshout, PhD, MSc

Trauma Research Unit Department of Surgery

Erasmus MC, University Medical Center Rotterdam

Rotterdam, The Netherlands

Phone: +31.10.7031050; Mail: e.vanlieshout@erasmusmc.nl

Disclaimers

Funding: No funding was disclosed by the author(s).
Conflicts of interest: The author(s), their immediate family, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

This study was approved by the Erasmus MC local medical ethics committee, “Medisch ethische toetsings commissie (METC)”, with study number: MEC-2018-1231

Abstract

Background: Upper extremity injuries often lead to long-term problems in function and quality of life in patients. However, not much is known about this effect in polytrauma patients. This study aimed to describe the upper extremity injuries in polytrauma patients and to compare self-reported disability and quality of life in polytrauma patients with versus without upper extremity injuries.

Methods: A retrospective cohort study was performed in adult patients with an injury severity score (ISS) of 16 or higher, admitted to Erasmus MC between January 1, 2007 and December 31, 2016. Patients were asked to complete the Disabilities of the Arm, Shoulder and Hand (DASH), Short Form-36 (SF-36), and EuroQol-5D (EQ-5D) questionnaires. Details on injuries, treatment, and clinical outcome were collected from the national trauma registry and medical files. Characteristics and self-reported outcomes of polytrauma patients, with versus without upper extremity injuries, were compared.

Results: In a cohort of 3,469 trauma patients 1,246 (36.5%) suffered upper extremity injuries**.** Of these, 278 (22.0%) suffered severe injuries (AIS≥3). Upper extremity injuries are associated with longer hospitalization (median 12 days versus 8 days, p<0.001), longer ICU stay (median 5 days versus 4 days, p=0.005), and lower mortality (14.6% versus 23.9%, p<0.001). In 598 patients who completed the questionnaires, no difference in physical component summary (47 versus 48, p=0.181) and mental component summary (54 versus 53, p=0.315) of the SF-36 and the Utility score (0.82 versus 0.85, p=0.101) and VAS score (80 versus 80, p=0.963) of the EQ-5D, was found. However, patients with upper extremity injuries showed a minor increase in disability in the DASH (9.2 versus 4.2, p=0.023).

Conclusion: Upper extremity injuries in polytrauma patients are associated with longer hospitalization, ICU stay, reduced mortality, and a minor increase in long-term disability.

Keywords: Polytrauma, Upper extremity, Quality of life, Disability, DASH

Level of evidence: Level III; Retrospective Cohort Comparison; Prognosis Study

While upper extremity fractures frequently occur as an isolated injury, 17-30% of polytrauma patients (Injury Severity Score (ISS) ≥16) have injuries of the upper extremities[4]. Studies show that there are distinct differences between polytrauma populations with or without upper extremity injuries, especially regarding early post-traumatic course. This includes longer hospital stay and higher surgical intervention frequency, leading to generally higher health care costs[4; 7].

Upper extremity injuries can have substantial impact on the ability to perform daily activities. As the ability to work is also (temporarily) affected, the societal burden can be high[6; 11; 20]. Polytrauma patients in general can be expected to have long hospital stay and often suffer long periods of unemployment or permanent disability[16; 19; 23-25]. In addition to this their cognitive and emotional function can suffer greatly. What proportion of these problems are caused by upper extremity injuries and to what extent additional injuries affect the recovery of the upper extremity injuries remains unclear. Studies in polytrauma patients with lower extremity injuries showed that lower extremity fractures can have significant impact on long term functional recovery and quality of life[5; 22; 24; 29]. For upper extremity trauma, however, the single study conducted on the influence of upper extremity injury on the long-term outcome of polytrauma patients treated in the 1980's and 1990's revealed no distinct difference in rehabilitation duration and long-term outcome measured by the Hannover Score for Polytrauma Outcome (HASPOC) and Short Form-12 (14).

As short-term mortality decreases due to better and more specialized care, long-term function and quality of life are becoming increasingly important in measuring polytrauma patient outcomes[12; 21]. This gives rise to the need for a recent and comprehensive overview of this diverse population and investigation of the long-term effects of additional upper extremity injuries in a polytrauma setting. More insight into the influence of specific injuries or combinations of injuries on patient recovery could provide a focus for future research on the improvement of treatment strategies in patients with multiple injuries.

The aim of this study was twofold; It aimed to give a detailed description of the complete polytrauma population in a recent cohort with main focus on the upper extremity injuries in polytrauma patients, admitted to a Level I trauma center. The secondary aim was to compare long-term self-reported disability and quality of life in polytrauma patients with versus without upper extremity injury.

Materials and Methods

Study design

After approval by the local medical research ethics committee a retrospective cohort study was conducted in patients admitted to Erasmus MC between January 1, 2007 and December 31, 2016. Patients were identified from the national trauma registry. The registry was searched for all patients with an ISS ≥16. Patients who had at least one registered Abbreviated Injury Scale (AIS) code for an upper extremity injury, were included as cases, all other patients served as controls. The AIS coding used was either the AIS 1990 (update 1998)[3], for patients admitted before January 1st 2015, or the AIS-2005 (update 2008)[10], for patients admitted January 1, 2015 and afterwards. Controls were all polytrauma patients without an AIS upper extremity injury code.

Data collection

Patient characteristics and details on injuries and admission were extracted from the national trauma registry, supplemented by the patients' medical files. This information included details on age, sex, date of admission, Glasgow coma scale before and during admission, hospital length of stay (HLOS), intensive care unit length of stay (ICU LOS), intubation time, and mortality. In addition to this, details on all traumatic injuries were collected and subdivided in the nine separate AIS regions (*i.e.*, upper extremity, head, face, neck, thorax, abdomen/pelvis, spine, lower extremity, and external). Upper extremity injuries were subdivided on AIS type of injury (*i.e.*, soft tissue, muscle/tendon/ligaments, nerves, vascular, joint and fracture). Soft tissue injuries was defined as injuries of the skin and subcutis. Upper extremity fractures were further subdivided based on fracture location (*i.e.*, clavicle, scapula, humerus, radius, ulna, carpus/metacarpus and finger).

Patients with age at trauma <18 year, unknown home address, severe cognitive disability or insufficient comprehension of Dutch or English language were excluded from the sub-study on quality of life (QoL) and functional outcome. All eligible patients received study information and a consent form at their home address and were invited to complete the Short Form-36 version 2 (SF-36-v2)[28], EuroQol-5D[27], and the Disabilities of the Arm, Shoulder, and Hand questionnaires (DASH)[26]. The SF-36 is a multipurpose, short-form health survey consisting of 36 questions, representing eight health domains that are combined into a physical and a mental component summary. Normalized scores ranging from zero to 100 points are derived for each domain, with lower scores indicating poorer quality of life. The EQ-5D is an instrument for measuring health-related quality of life, consisting of a utility score and a visual analog scale (EQ-VAS). The EQ-5D utility score (EQ-US) ranges from zero to one and is determined from five domains: mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. In addition, the EQ-VAS records the patient's rating of their quality of life state, which ranges from zero to 100. The Disabilities of the Arm, Shoulder and Hand (DASH) score is a 30-item, self-report questionnaire designed to measure physical function and symptoms in patients with any or several musculoskeletal disorders of the upper limb. Scores range from zero points (representing no disability) to 100 points (representing severe disability). When patients did not respond to the initial invitation by mail, at least, three attempts were made to contact them by telephone, before excluding them from the study.

Data analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 25.0 (IBM, Armonk, NY, USA). Variables were tested for normality using the Shapiro-Wilk test and were tested for homogeneity of variance using Levene's test. Statistical significance was assumed at a two-sided *P* value of <0.05.

Descriptive analysis was performed for the upper extremity injuries. Continuous variables are reported as median with percentiles (P_{25}-P_{75}) and categorical data are reported as frequencies with percentages. For the comparison of patients with versus without upper extremity, univariate analysis was done using the Mann-Whitney U-test for continuous data and Chi^2 test or Fisher's Exact test for categorical data, as applicable. Subgroup analyses were performed for patients with or without upper extremity fractures, specific fracture locations and patients with or without severe head injuries.

Results

A total of 3,469 polytrauma patients were included (Figure 1); 1,266 polytrauma patients with upper extremity injuries (cases) and 2,203 without upper extremity injuries (controls). After application of the exclusion criteria, 1,078 received the questionnaires. Of these, 598 (55.5%) patients completed the questionnaires.

Epidemiology of polytrauma patients

Table I shows that the 3,469 polytrauma patients had a median ISS of 25 (P_{25}-P_{75} 18-29). The median age was 48 (P_{25}-P_{75} 27-66) years and males formed 70.4% of the population. Cases showed a statistically significantly higher median ISS (26 versus 24, $p<0.001$). Other notable differences were the higher median hospital length of stay (12 versus 8 days, $p<0.001$) and ICU length of stay (5 versus 4 days, $p=0.005$) for the cases. They also showed a lower mortality rate (14.6% versus 23.9%, $p<0.001$) and had a higher Glasgow coma scale (GCS) score in both pre-hospital (14 versus 12, $p<0.001$) and Emergency Department (in-hospital) settings (14 versus 13, $p=0.008$). Patients with and without upper extremity injuries were similar with respect to age, gender, months to follow-up, and rates of ICU admission and intubation.

Table II shows a more detailed description of the types of injuries and the locations of fractures of the upper extremity. The 1,266 patients had sustained 2,344 injuries at the upper extremity. The two most common injuries were fractures (931/1,266 (73.5%) patients and 1,541/2,344 (65.7%) injuries) and soft tissue injuries (470 (37.1%) patients and 554 (23.5%) injuries). Of the 38% of patients with multiple upper extremity fractures, 14 had up to six fractures, with one patient sustaining up to 11 fractures. When the total of 1,541 upper extremity fractures is divided into anatomical regions, the most common locations were clavicle (350/931 (37.6%) patients and 364/1,541 (23.6%) fractures), scapula (260/931

(27.9%) patients and 274/1,541 (17.7%) fractures) and radius (243/931 (26.1%) patients and 266/1,541 (17.3%) fractures).

Table III shows the presence of any or severe injuries for the nine AIS body regions in patients with (cases) versus without upper extremity injuries (controls). A larger proportion of cases had injuries located to the face (608/1,266 (48%) versus 1,652/2,203 (37.1%), p<0.001), thorax (817/1,266 (64.5%) versus 734/2,203 (33.3%), p<0.001), spine (459/1,266 (36.3%) versus 504/1,266 (22.9%), p<0.001), and lower extremity (629/1,266 (49.7%) versus 526/2,203 (23.9%), p<0.001). Head injuries were significantly more prevalent in controls (888/1,266 (70.1%) versus 1,652/2,203 (75.0%), p=0.002). When comparing only severe injuries (AIS≥3) in the nine anatomical regions, a significantly lower proportion of controls suffered from severe head injuries (749/1,266 (59.2%) versus 1,544/2,203 (70.1%), p<0.001). Severe injuries of the thorax (690/1,266 (54.5%) versus 614/1,266 (27.9%), p<0.001), abdomen (153/1,266 (12.1%) versus 192/2,203 (8.7%), p=0.002) and lower extremities (293/1,266 (23.1%) versus 264/2,203 (12.0%), p<0.001) were more common in cases. Of the cases, 278 (22.0%) suffered from a severe injury of the upper extremity.

Disability of the upper extremity and health-related quality of life

Within the group of 598 patients who completed the questionnaires (Table IV), patients with upper extremity injuries (cases) had a higher median ISS (24 versus 21, p<0.001) than patients without upper extremity injuries (controls). The only other difference found between both groups was a shorter ICU length of stay (4 versus 6 days, p=0.033) in cases.

Comparison of the questionnaire results (Table IV) showed a statistically significantly higher level of disability, measured using the DASH score, in cases than in the control group (9.2 versus 4.2, p=0.001). No statistically significant difference between groups was found in quality of life, as measured by the SF-36 and EQ-5D. This included both the physical component summary (47 versus 48, p=0.181) and mental component summary (54 versus 53, p=0.315) of the SF-36 and the utility score (0.82 versus 0.85, p=0.101) and VAS score (80 versus 80, p=0.963) of the EQ-5D.

After performing subgroup analyses, patients with upper extremity fractures showed a statistically significantly higher median DASH score (10.0; P_{25}-P_{75}: 2.5-26.7) than patients without upper extremity fractures (5.8; P_{25}-P_{75}: 0.8-13.5; p=0.023; Figure 2A). Comparison of patients who sustained severe upper extremity injuries (AIS$\geq$3), with those suffering from less severe upper extremity injuries (AIS<3) showed no statistically significant differences in the median DASH (9.2, P_{25}-P_{75} 2.5-29 versus 8.3, P_{25}-P_{75} 1.7-24, p=0.251; Figure 2B). Patients suffering severe head injury (AIS$\geq$3) showed a significantly lower disability than patients with less severe head injury (5.1, P_{25}-P_{75}: 0-18, p=0.001 versus 9.6, P_{25}-P_{75}: 1.7-28; Figure 2C). Patients with multiple upper extremity fractures showed no significant increase in the DASH compared with patients with a single fracture (10, P_{25}-P_{75} 3.3-31 versus 9.0, P_{25}-P_{75} 1.7-23, p=0.238; Figure 2D). When comparing disability for polytrauma patients suffering fractures in a single upper extremity region, a significant difference (p=0.003, Kruskal-Wallis ANOVA; Figure 2E) was found among the six fracture locations. With radial (2.1, P_{25}-P_{75} 0-4.2) and ulnar fractures (5.8, P_{25}-P_{75} 1-10) showing remarkably lower long-term disability than clavicle (11, P_{25}-P_{75} 3.4-25), scapula (16, P_{25}-P_{75} 1.0-33), humerus (15, P_{25}-P_{75} 4.0-30) and hand fractures (13, P_{25}-P_{75} 3-31).

Discussion

During the 10-year study period, 1,266 (36.5%) of 3,469 polytrauma patients sustained a total of 2,344 upper extremity injuries, with a maximum of 11 upper extremity injuries for a single patient. The largest proportion of these injuries involved, often multiple, fractures or soft tissue injuries. Patients with upper extremity injuries were admitted to the hospital and ICU for longer periods of time than patients without upper extremity injuries. This prevalence of upper extremity injuries in polytrauma patients is in line with previous research[4; 7]. In a study conducted by Bannerjee *et al* 39.7% of polytrauma patients sustained upper extremity injuries in a cohort of 24,885 patients[4]. In addition, Dowrick *et al* reported upper extremity injuries in 34% of a cohort of 1,051 patients[7]. Longer HLOS and ICU LOS for patients with upper extremity injuries were also found in previous research[4; 7]. A possible explanation for longer HLOS could be that adequate arm and hand mobility are needed for effective and independent self-care. Patients would need more care for longer periods of time before being moved to a home environment. The longer ICU LOS can partly be explained by the higher proportion of severe thoracic and abdominal trauma in patients with upper extremity injuries, causing an increased need for intensive supportive care and monitoring of vital functions.

Patients with upper extremity injuries had a lower prevalence of severe injuries of the head region than patients without upper extremity injuries. In addition to this, patients without upper extremity injuries also showed lower pre- and in-hospital GCS values. This makes isolated neurotrauma, a documented explanation for increased mortality[13], a likely reason for the increased mortality in patients without upper extremity injuries. Severe head injury also proved a significant predictor for lower long-term disability in polytrauma patients, when compared with patients with no or minor head injuries. Previous research suggests that although an association between traumatic brain injury and long-term loss-of-function of the extremities exists, an additional effect of upper extremity injuries seems absent[2]. Lower long-term disability after severe head injuries may be partly explained by higher mortality or resulting cognitive problems leading to difficulty in reacting to, or completing, questionnaires.

Part of the differences in the proportion of injuries per AIS region between the groups, can be explained on the basis of the calculation of the ISS. In order to achieve an ISS of 16 or higher, and thus being classified as polytrauma patient, patients without upper extremity injuries could only have sustained injuries in eight of the nine anatomical regions. This directly leads to a larger proportion and higher injury severity in the eight other regions. This fact makes it remarkable that a significantly higher proportion of upper extremity patients suffered injuries of the face, spine, lower extremities, thorax and abdomen. The ISS does, however, not account for multiple injuries in single AIS region, as it only uses the highest score per region in its calculation. It is therefore possible to have multiple injuries of the same severity in a region, possibly leading to increase disability, without this being reflected in the ISS score or maximum AIS per region.

This study found a statistically significantly higher self-reported DASH score for polytrauma patients with upper extremity injuries. No previous studies compared the DASH score in polytrauma patients with versus without upper extremity injuries. However, Ferree *et al*[8] found a score for the *Quick*-DASH, a shortened version of the DASH, of 17 (P_{25}-P_{75}: 0-31) in polytrauma patients with hand or finger injuries at 1-6 years post-trauma, a number in line with the findings of the current study. The minimal important change (MIC) for the DASH-score, the minimum difference in outcome score that is perceived as significant by an individual patient, varies between different upper extremity injuries. Examples are a MIC of 6.7 for humeral shaft fractures[15] or 10.8 in a cohort of diverse upper-extremity injuries[9]. The differences found between patients with and without upper extremity injuries in this study are smaller than these values, making the clinical relevance of these differences seem questionable. Additionally, no decrease was found in quality of life in the SF-36 and EQ-5D scores for polytrauma patients with upper extremity injuries when compared with polytrauma patients without upper extremity injuries. The increased overall disability, measured by the DASH, does not seem of sufficient magnitude to influence patient’s perception of their health or quality of life.

Only one previous study by Macke *et al*[14], compared long-term outcomes in polytrauma patients with and without upper extremity injuries. This study reported no differences between the groups in both the mental component summary (49.9 versus 50.5, p=0.9) and physical component summary (44.4 versus 43.1, p=0.2) of the SF-12, a shortened version of the SF-36, or the Hannover Score for Polytrauma outcome (62.0 versus 64.9, p=0.4). Only a significant influence of plexus injuries on long-term quality of life and function was reported. They included a population of patients treated between 1973 and 1990 and performed their follow-up between 2000 and 2003, a longer time-to-follow-up than the 5 to 9 years in the present study. In addition, these patients were treated in a different age of (early) fracture fixation and handling of traumatic fractures[17]. The current study provides a more up-to-date view of this population and both short-term and long-term outcomes.

Fractures were found to be an influential factor in the association between upper extremity injuries and higher disability, as patients with upper extremity fractures showed significantly higher DASH scores, compared with patients with other types of upper extremity injuries. This may be explained by the presence of fractures of specific complexity or region, an important predictor for complications[1]. Another explanation may be found in the trauma mechanism. The high energy needed to cause fractures may cause multiple fractures and injuries to other regions, further complicating a patient's recovery. This theory has not been tested yet and this study has insufficient numbers to further investigate the long-term effect of polytrauma on disability for specific fracture regions. Our study does suggest that some fractures, such as radial or ulnar fractures, are associated with lower long-term disability.

This study has several limitations. The retrospective design of this cohort study with a single follow-up moment does not allow to make any statements about recovery patterns. Also, there was no objective measurement of function. Polytrauma patients are a very diverse and heterogeneous patient population. While this study does provide robust numbers to compare more general subpopulations of patients, it is difficult to effectively compare specific injuries or injury patterns with each other. In addition, a substantial number could not be reached due to lack of a current address or contact details. In this study only 55.5% of patients invited completed the questionnaires. This may have introduced selection bias. This is, however, a recurring problem in long-term follow-up studies[18; 21]. We believe that through repeated invitation of patients, a substantial cohort with comparable baseline characteristics to the total population, was recruited and this cohort can provide accurate information.

As fracture location and severity heavily influences the risk of complications and long-term functional loss[1], future studies on upper extremity injuries in polytrauma patients should focus on specific injuries or combinations of injuries.

Conclusion

The prevalence of upper extremity injuries in polytrauma patients, in a level-1 trauma center is 36.5%, with fractures as most common type of injury. The clavicle, scapula and radius were most frequently affected. Upper extremity injuries in polytrauma patients are associated with longer hospitalization, ICU stay and a minor increase in long-term self-reported disability, when compared with polytrauma patients without upper extremity injuries. No significant change in long-term self-reported quality of life was found.

References

1. Allemann F, Heining S, Zelle B, Probst C, Pape HC. Risk factors for complications and adverse outcomes in polytrauma patients with associated upper extremity injuries. Patient Saf Surg 2019;13:7. 10.1186/s13037-019-0187-3

2. Andruszkow H, Probst C, Grun O, Krettek C, Hildebrand F. Does additional head trauma affect the long-term outcome after upper extremity trauma in multiple traumatized patients: is there an additional effect of traumatic brain injury? Clin Orthop Relat Res 2013;471:2899-2905. 10.1007/s11999-013-3031-6

3. Association for the Advancement of Automotive M. Abbreviated injury scale; 1990 revision: update 98: AAAM; 1998. ISBN13 (9780000002006)

4. Banerjee M, Bouillon B, Shafizadeh S, Paffrath T, Lefering R, Wafaisade A et al. Epidemiology of extremity injuries in multiple trauma patients. Injury 2013;44:1015-1021. doi: 10.1016/j.injury.2012.12.007.

5. Butcher JL, MacKenzie EJ, Cushing B, Jurkovich G, Morris J, Burgess A et al. Long-term outcomes after lower extremity trauma. J Trauma 1996;41:4-9.

6. Clay FJ, Newstead SV, Watson WL, McClure RJ. Determinants of return to work following non life threatening acute orthopaedic trauma: a prospective cohort study. J Rehabil Med 2010;42:162-169. 10.2340/16501977-0495

7. Dowrick AS, Gabbe BJ, Williamson OD. Does the presence of an upper extremity injury affect outcomes after major trauma? J Trauma 2005;58:1175-1178. 10.1097/01.TA.0000169930.79684.4E

8. Ferree S, van der Vliet QMJ, van Heijl M, Houwert RM, Leenen LPH, Hietbrink F. Fractures and dislocations of the hand in polytrauma patients: Incidence, injury pattern and functional outcome. Injury 2017;48:930-935. 10.1016/j.injury.2017.02.034

9. Franchignoni F, Vercelli S, Giordano A, Sartorio F, Bravini E, Ferriero G. Minimal clinically important difference of the disabilities of the arm, shoulder and hand outcome measure (DASH) and its shortened version (QuickDASH). J Orthop Sports Phys Ther 2014;44:30-39. 10.2519/jospt.2014.4893

10. Gennarelli TA, Wodzin E. Abbreviated injury scale 2005: update 2008: Russ Reeder; 2008. (ISBN No. 000000202X 9780000002020)

11. Gomberg BF, Gruen GS, Smith WR, Spott M. Outcomes in acute orthopaedic trauma: a review of 130,506 patients by age. Injury 1999;30:431-437.

12. Holcomb JB, Weiskopf R, Champion H, Gould SA, Sauer RM, Brasel K et al. Challenges to effective research in acute trauma resuscitation: consent and endpoints. Shock 2011;35:107-113. 10.1097/SHK.0b013e3181f7fd01

13. Lefering R, Paffrath T, Linker R, Bouillon B, Neugebauer EA, Deutsche Gesellschaft fur Unfallchirurgie/German Society for Trauma S. Head injury and outcome--what influence do concomitant injuries have? J Trauma 2008;65:1036-1043; discussion 1043-1034. 10.1097/TA.0b013e318184ee48

14. Macke C, Winkelmann M, Mommsen P, Probst C, Zelle B, Krettek C et al. Injuries to the upper extremities in polytrauma: limited effect on outcome more than ten years after injury - a

cohort study in 629 patients. Bone Joint J 2017;99-B:255-260. 10.1302/0301-620X.99B2.37999

15. Mahabier KC, Den Hartog D, Theyskens N, Verhofstad MHJ, Van Lieshout EMM, Investigators HT. Reliability, validity, responsiveness, and minimal important change of the Disabilities of the Arm, Shoulder and Hand and Constant-Murley scores in patients with a humeral shaft fracture. J Shoulder Elbow Surg 2017;26:e1-e12. 10.1016/j.jse.2016.07.072

16. Mkandawire NC, Boot DA, Braithwaite IJ, Patterson M. Musculoskeletal recovery 5 years after severe injury: long term problems are common. Injury 2002;33:111-115. 10.1016/S0020-1383(01)00047-X

17. Pape HC, Giannoudis P, Krettek C. The timing of fracture treatment in polytrauma patients: relevance of damage control orthopedic surgery. Am J Surg 2002;183:622-629. doi: 10.1016/s0002-9610(02)00865-6.

18. Pape HC, Zelle B, Lohse R, Stalp M, Hildebrand F, Krettek C et al. Evaluation and outcome of patients after polytrauma--can patients be recruited for long-term follow-up? Injury 2006;37:1197-1203. 10.1016/j.injury.2006.07.032

19. Pfeifer R, Lichte P, Zelle BA, Sittaro NA, Zilkens A, Kaneshige JR et al. Socio-economic outcome after blunt orthopaedic trauma: Implications on injury prevention. Patient Saf Surg 2011;5:9.] 10.1186/1754-9493-5-9

20. Polinder S, Iordens GI, Panneman MJ, Eygendaal D, Patka P, Den Hartog D et al. Trends in incidence and costs of injuries to the shoulder, arm and wrist in The Netherlands between 1986 and 2008. BMC Public Health 2013;13:531. 10.1186/1471-2458-13-531

21. Probst C, Pape HC, Hildebrand F, Regel G, Mahlke L, Giannoudis P et al. 30 years of polytrauma care: An analysis of the change in strategies and results of 4849 cases treated at a single institution. Injury 2009;40:77-83. 10.1016/j.injury.2008.10.004

22. Seekamp A, Regel G, Tscherne H. Rehabilitation and reintegration of multiply injured patients: an outcome study with special reference to multiple lower limb fractures. Injury 1996;27:133-138.

23. Soberg HL, Bautz-Holter E, Finset A, Roise O, Andelic N. Physical and mental health 10 years after multiple trauma: A prospective cohort study. J Trauma Acute Care Surg 2015;78:628-633. 10.1097/TA.0000000000000541

24. Soberg HL, Finset A, Roise O, Bautz-Holter E. The trajectory of physical and mental health from injury to 5 years after multiple trauma: a prospective, longitudinal cohort study. Arch Phys Med Rehabil 2012;93:765-774. 10.1016/j.apmr.2011.08.050

25. Soberg HL, Roise O, Bautz-Holter E, Finset A. Returning to work after severe multiple injuries: multidimensional functioning and the trajectory from injury to work at 5 years. J Trauma 2011;71:425-434. 10.1097/TA.0b013e3181eff54f

26. Veehof MM, Sleegers EJ, van Veldhoven NH, Schuurman AH, van Meeteren NL. Psychometric qualities of the Dutch language version of the Disabilities of the Arm, Shoulder, and Hand questionnaire (DASH-DLV). J Hand Ther 2002;15:347-354. 10.1016/S0894-1130(02)80006-0

27. Versteegh M, Vermeulen K, Evers M, de Wit GA, Prenger R, Stolk A. Dutch Tariff for the Five-Level Version of EQ-5D. Value Health 2016;19:343-352. 10.1016/j.jval.2016.01.003

28. Ware JE, Jr. SF-36 health survey update. Spine (Phila Pa 1976) 2000;25:3130-3139.

29. Zelle BA, Brown SR, Panzica M, Lohse R, Sittaro NA, Krettek C et al. The impact of injuries below the knee joint on the long-term functional outcome following polytrauma. Injury 2005;36:169-177. 10.1016/j.injury.2004.06.004

Figure and Table legends

Figure 1: Flowchart of included and excluded patients

PROM, Patient Reported Outcome Measure; UE, Upper extremity.

Figure 2: Long-term function measured using the DASH score

The analysis is stratified for (A) presence or absence of upper extremity (UE) fractures, (B) presence of absence of severe UE injuries (AIS ≥3), (C) presence or absence of severe head injuries (AIS ≥3), (D) single versus multiple UE fractures, or (E) different UE fractures. Data are shown as box-whisker plots, in which the box indicates median and the 1st and 3rd quartile, and the whiskers indicate the minimum and maximum observed value.

[a]Mann-Whitney U-test, [b]Kruskal-Wallis ANOVA.

AIS, Abbreviated injury scale; DASH, Disabilities of the Arm, Shoulder and Hand; UE, Upper Extremity.

Table I: Population characteristics for the total study population and stratified by presence or absence of upper extremity injuries

Data are shown as [a]median (P_{25}-P_{75}) or as [b]number (%) and were analyzed using a [c]Mann-Whitney U-test, [d]Pearson Chi-squared or [e]Fisher's exact test.

GCS, Glasgow Coma Scale; ICU, Intensive Care Unit; ISS, Injury Severity Score; LOS, Length Of Stay; UE, Upper Extremity.

Table II: General type of upper extremity injury and location of upper extremity fractures

Data are shown as number (%).

[*] Patients suffered up to 11 individual fractures.

[#] NFS includes 1 patient with the classification hand fracture.

NFS, Not further specified; UE, Upper Extremity.

Table III: Overview of the location and severity of injuries for the nine anatomical regions

Data are shown as number (%) and were analyzed using a [a]Pearson Chi-squared or [b]Fisher's exact test.

AIS, Abbreviated injury scale; UE, Upper Extremity.

Table IV: Patient characteristics and PROM results

Data are shown as [a]median (P_{25}-P_{75}) or as [b]number (%) and were analyzed using a [c]Mann-Whitney U-test or [d]Fisher's exact test.

DASH, Disabilities of the Arm, Shoulder and Hand; EQ-5D, EuroQol-5D GCS, Glasgow Coma Scale; ICU, Intensive Care Unit; ISS, Injury Severity Score; LOS, Length Of Stay; MCS, Mental Component Score; PCS, Physical Component Score; SF-36, Short Form-36; UE, Upper Extremity; VAS, Visual Analog Scale.

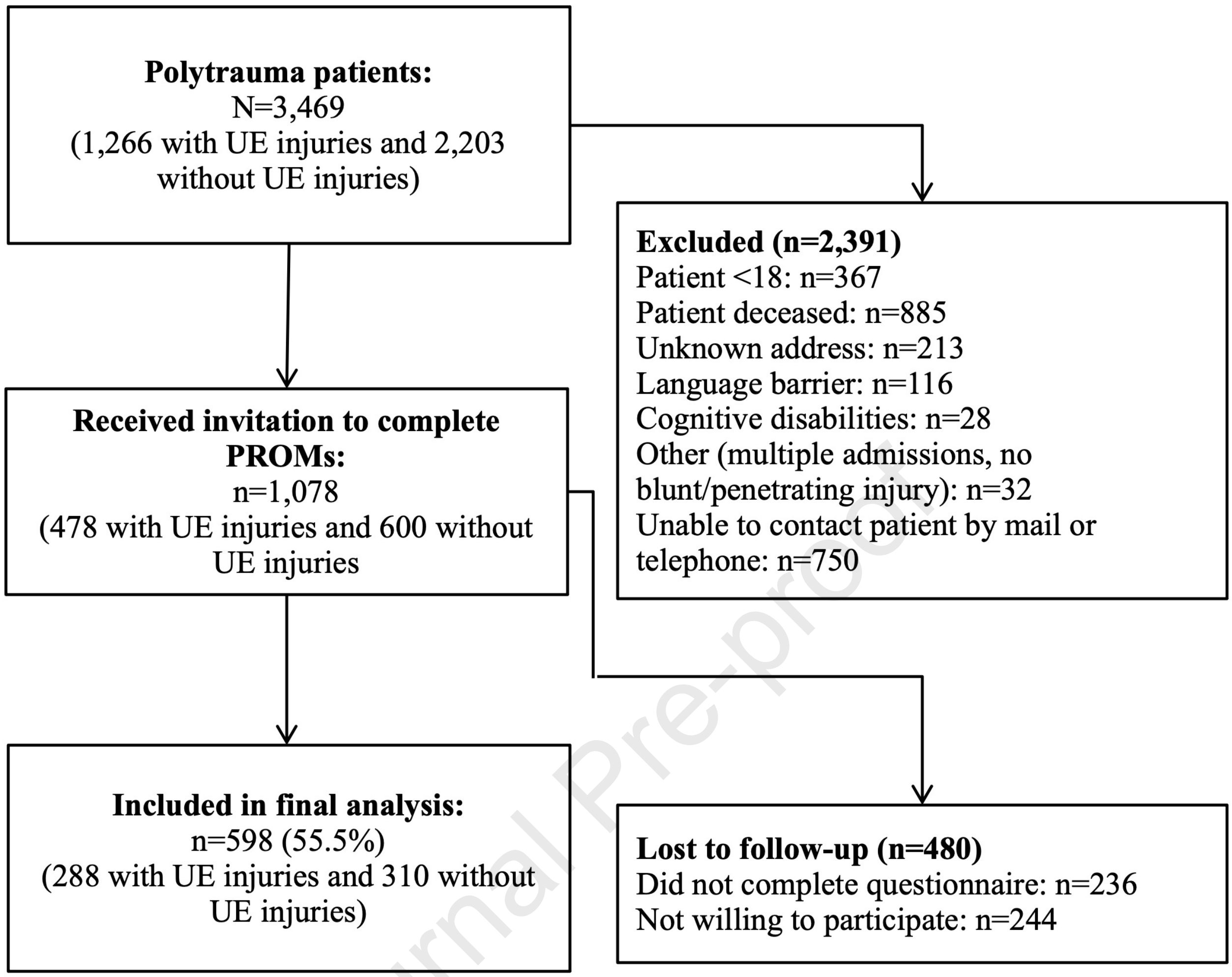
Characteristic	Total population (N=3,469)	Patients with UE injuries (N=1,266)	Patients without UE injuries (N=2,203)	P-value
ISS[a]	25 (18-29)	26 (20-34)	24 (17-26)	**<0.001[c]**
Age (years)[a]	48 (27-66)	47 (28-63)	48 (26-67)	0.394[c]
Male gender[b]	2,442 (70.4%)	888 (70.1%)	1,544 (70.5%)	0.805[d]
Time to follow-up (months)[a]	81 (54-111)	82 (56-111)	81 (54-111)	0.329[c]
GCS pre-hospital[a]	13 (6-15)	14 (7-15)	12 (5-15)	**<0.001[c]**
GCS in-hospital[a]	13 (3-15)	14 (3-15)	13 (3-15)	**0.006[c]**
Penetrating injury[b]	188 (5.5%)	53 (4.2%)	135 (6.3%)	**0.008[e]**
Hospital LOS (days)[a]	9 (4-19)	12 (5-23)	8 (3-17)	**<0.001[c]**
ICU admission[b]	1,949 (56.2%)	739 (58.4%)	1,210 (55%)	0.051[e]
ICU LOS (days)[a]	4 (2-10)	5 (2-15)	4 (2-10)	**0.005[c]**
Intubation [b]	1,409 (72.7%)	517 (73.4%)	893 (73.8%)	0.872[d]
Intubation time (days)[a]	4 (2-9)	3 (1-10)	4 (2-9)	0.303[c]
Mortality[b]	712 (20.5%)	185 (14.6%)	527 (23.9%)	**<0.001[e]**

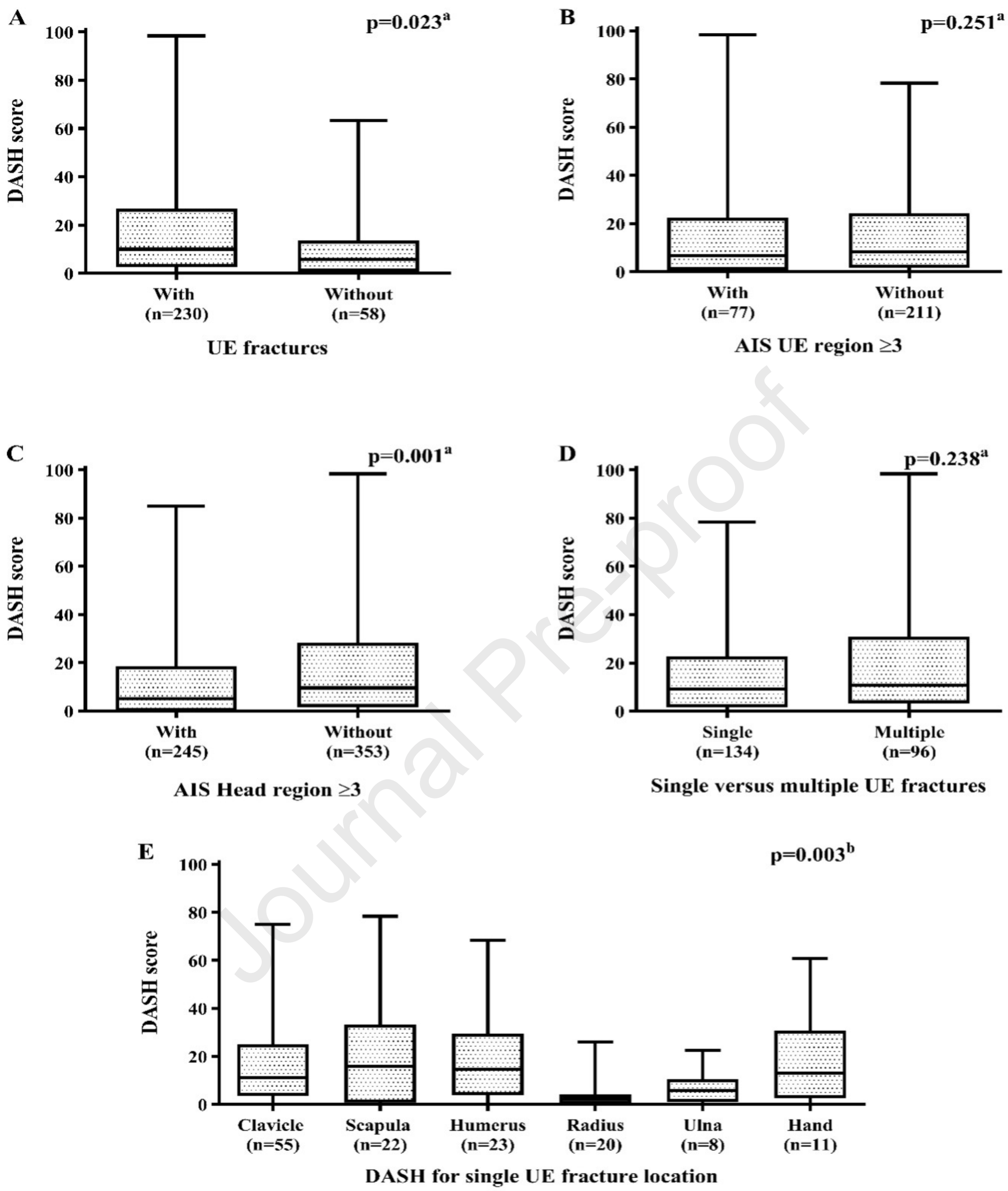
Type of injury	**N injuries (N=2,344)**	**N patients (N=1,266)**	**N patients with 1 up to 6+ injuries**					
			1	**2**	**3**	**4**	**5**	**6+***
Soft tissue	552 (23.5%)	470 (37.1%)	398 (84.7%)	66	2	4		
Muscle/tendon/ligaments	46 (2.0%)	34 (2.7%)	25 (73.5%)	8			1	
Nerves	22 (0.9%)	21 (1.7%)	20 (95.2%)	1				
Vascular	24 (1.0%)	21 (1.7%)	18 (85.7%)	3				
Joint	159 6.8%)	148 (11.7%)	138 (93.2%)	9	1			
Fracture	1,541 (65.7%)	931 (73.5%)	577 (62.0%)	222	69	37	12	14

Type of UE fracture#	**N fractures[b] (N=1,541)**	**N patients[b] (N=931)**	**N patients with 1 up to 6 injuries**					
			1	**2**	**3**	**4**	**5**	**6**
Clavicle	364 (23.6%)	350 (37.6%)	336 (93.3%)	14				
Scapula	274 (17.7%)	260 (27.9%)	246 (89.8%)	14				
Humerus	183 (11.9%)	175 (18.8%)	168 (91.8%)	6	1			
Radius	266 (17.3%)	243 (26.1%)	220 (82.7%)	23				
Ulna	215 (14.0%)	196 (21.1%)	178 (82.8%)	17	1			
Carpus/metacarpus	178 (11.6%)	116 (12.5%)	82 (46.1%)	21	4	4	4	1
Finger	58 (3.8%)	45 (4.8%)	38 (65.6%)	3	2	2		
NFS#	3 (0.2%)	3 (0.3%)	3 (100.0%)					

Body region	**Patients with UE injuries (N=1,266)**	**Patients without UE injuries (N=2,203)**	**P-value**
Any injury (AIS ≥ 1)			
Upper extremity	1,266 (100.0%)	N.A.	N.A.
Head	888 (70.1%)	1,652 (75.0%)	**0.002[b]**
Face	608 (48.0%)	818 (37.1%)	**<0.001[b]**
Neck	53 (4.2%)	68 (3.1%)	0.102[b]
Thorax	817 (64.5%)	734 (33.3%)	**<0.001[b]**
Abdomen	323 (25.5%)	335 (15.2%)	**<0.001[b]**
Spine	459 (36.3%)	504 (22.9%)	**<0.001[b]**
Lower extremity	629 (49.7%)	526 (23.9%)	**<0.001[b]**
External	88 (7.0%)	158 (7.2%)	0.895[a]
Severe injury (AIS ≥ 3)			
Upper extremity	278 (22.0%)	N.A.	N.A.
Head	749 (59.2%)	1,544 (70.1%)	**<0.001[b]**
Face	47 (3.7%)	78 (3.5%)	0.778[b]
Neck	14 (1.1%)	28 (1.3%)	0.749[b]
Thorax	690 (54.5%)	614 (27.9%)	**<0.001[b]**
Abdomen	153 (12.1%)	192 (8.7%)	**0.002[b]**
Spine	215 (17.0%)	323 (14.7%)	0.072[b]
Lower extremity	293 (23.1%)	264 (12.0%)	**<0.001[b]**
External	10 (0.8%)	33 (1.5%)	0.080[b]

Characteristic	Total population (N=598)	Patients with UE injuries (N=288)	Patients without UE injuries (N=310)	P-value
ISS[a]	22 (18-29)	24 (19-33)	21 (17-26)	**<0.001**[c]
Age (years)[a]	51 (37-62)	52 (37-62)	51 (37-62)	0.782[c]
Male gender[b]	422 (70.6%)	206 (71.5%)	216 (69.7%)	0.654[d]
Time to follow-up (months)	75 (50-102)	74 (50-103)	75 (49-101)	0.773[c]
GCS pre-hospital[a]	14 (9-15)	14 (9-15)	14 (9-15)	0.386[c]
GCS in-hospital[a]	14 (9-15)	14 (10-15)	14 (9-15)	0.741[c]
Penetrating injury[b]	10 (1.7 %)	6 (2.1%)	4 (1.3%)	0.533[d]
ICU admission[b]	304 (50.8%)	154 (53.5%)	150 (48.4%)	0.221[d]
ICU LOS (days)[a]	5 (2-12)	4 (2-9)	6 (3-15)	**0.033**[c]
Hospital LOS (days)[a]	13 (7-23)	13 (7-23)	13 (7-23)	0.750[c]
Intubation[b]	195 (66.1%)	93 (64.1%)	102 (68.0%)	0.539[d]
Intubation time (days)[a]	5 (2-12)	3 (1-9)	6 (2-14)	0.006[c]
Injury to dominant side	N.A.	142 (49.3%)	N.A.	-
DASH score[a]	6.7 (0.83-23)	9.2 (1.7-25)	4.2 (0-21)	**0.001**[c]
EQ-5D Utility score[a]	0.84 (0.70-0.93)	0.82 (0.70-0.82)	0.85 (0.70-0.95)	0.101[c]
EQ-5D VAS[a]	80 (70-90)	80 (70-90)	80 (70-90)	0.963[c]
SF-36 PCS[a]	48 (38-54)	47 (38-53)	48 (38-55)	0.181[c]
SF-36 MCS[a]	54 (44-58)	54 (44-59)	53 (44-58)	0.315[c]


Polytrauma patients:
N=3,469
(1,266 with UE injuries and 2,203 without UE injuries)
Excluded (n=2,391)
Patient <18: n=367
Patient deceased: n=885
Unknown address: n=213
Language barrier: n=116
Cognitive disabilities: n=28
Other (multiple admissions, no blunt/penetrating injury): n=32
Unable to contact patient by mail or telephone: n=750
Received invitation to complete PROMs:
n=1,078
(478 with UE injuries and 600 without UE injuries
Included in final analysis:
n=598 (55.5%)
(288 with UE injuries and 310 without UE injuries)
Lost to follow-up (n=480)
Did not complete questionnaire: n=236
Not willing to participate: n=244


A
p=0.023a
DASH score
100
80
60
40
20
0
With
(n=230)
Without
(n=58)
UE fractures
B
p=0.251a
DASH score
With
(n=77)
Without
(n=211)
AIS UE region ≥3
C
p=0.001a
DASH score
With
(n=245)
Without
(n=353)
AIS Head region ≥3
D
p=0.238a
DASH score
Single
(n=134)
Multiple
(n=96)
Single versus multiple UE fractures
E
p=0.003b
DASH score
Clavicle
(n=55)
Scapula
(n=22)
Humerus
(n=23)
Radius
(n=20)
Ulna
(n=8)
Hand
(n=11)
DASH for single UE fracture location