Injury 54 (2023) 871–879

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

Comparing health status after major trauma across different levels of trauma care

J.C. Van Ditshuizen[a,b,*], L. De Munter[c], M.H.J. Verhofstad[a], K.W.W. Lansink[c,d,e], D. Den Hartog[a,b], E.M.M. Van Lieshout[a,1], M.A.C. De Jongh[c,d,1], BIOS-group[2], Dutch Trauma Registry Southwest[3]

[a] Trauma Research Unit, Department of Surgery, Erasmus MC, University Medical Center Rotterdam, The Netherlands
[b] Trauma Centre Southwest-Netherlands, Erasmus MC, University Medical Center Rotterdam, The Netherlands
[c] Department Trauma TopCare, Elisabeth-TweeSteden Hospital, Tilburg, The Netherlands
[d] Network Emergency Care Brabant, Brabant Trauma Registry, The Netherlands
[e] Department of Surgery, Elisabeth-TweeSteden Hospital, Tilburg, The Netherlands

A R T I C L E I N F O

Article history:
Accepted 2 January 2023

Keywords:
Trauma Registry
Major Trauma
EQ-5D-5L
Cognition
Level of Trauma Care

A B S T R A C T

Introduction: Mortality due to trauma has reduced the past decades. Trauma network implementations have been an important contributor to this achievement. Besides mortality, patient reported outcome parameters should be included in evaluation of trauma care. While concentrating major trauma care, hospitals are designated with a certain level of trauma care following specific criteria.
Objective: Comparing health status of major trauma patients after two years across different levels of trauma care in trauma networks.
Methods: Multicentre observational study comprising a secondary longitudinal multilevel analysis on prospective cohorts from two neighbouring trauma regions in the Netherlands. Inclusion criteria: patient aged $\geq$ 18 with an ISS $>$ 15 surviving their injuries at least one year after trauma. Health status was measured one and two years after trauma by EQ-5D-5 L, added with a sixth health dimension on cognition. Level I trauma centres were considered as reference in uni- and multivariate analysis.
Results: Respondents admitted to a level I trauma centre scored less favourable EQ-US and EQ-VAS in both years (0.81–0.81, 71–75) than respondents admitted to a level II (0.88–0.87, 78–85) or level III (0.89–0.88, 75–80) facility. Level II facilities scored significantly higher EQ-US and EQ-VAS in time for univariate analysis (β 0.095, 95% CI 0.038–0.153, $p = 0.001$, and β 7.887, 95% CI 3.035–12.740, $p = 0.002$), not in multivariate analysis (β 0.052, 95% CI -0.010–0.115, $p = 0.102$, and β 3.714, 95% CI -1.893–9.321, $p = 0.193$). Fewer limitations in mobility (OR 0.344, 95% CI 0.156–0.760), self-care (OR 0.219, 95% CI 0.077–0.618), and pain and discomfort (OR 0.421, 95% CI 0.214–0.831) remained significant for level II facilities in multivariate analysis, whereas significant differences with level III facilities disappeared.
Conclusion: Major trauma patients admitted to level I trauma centres reported a less favourable general health status and more limitations compared to level II and III facilities scoring populations norms one to two years after trauma. Differences on general health status and limitations in specific health domains disappeared in adjusted analysis. Well-coordinated trauma networks offer homogeneous results for all major trauma patients when they are distributed in different centres according to their need of care.

Introduction

The global trauma burden is substantial [1,2]. Health care and productivity costs are considerable, physical trauma can have a psychological impact, a large group reports social dysfunction and quality of life is below populations norms one year after major trauma [3–8]. In order to reduce that burden, many countries and regions have successfully implemented trauma systems the past decades [9]. Such trauma systems have been an important con-

* Corresponding author at: Erasmus MC, Trauma Centre Southwest Netherlands, P.O. box 2040, 3000 CA Rotterdam, The Netherlands
E-mail addresses: j.vanditshuizen@erasmusmc.nl, jvanditshuizen@gmail.com (J.C. Van Ditshuizen).
[1] Both authors contributed equally
[2] Group Authorship BIOS-group member found in Appendix section.
[3] Group Authorship Dutch Trauma Registry Southwest member found in Appendix section.

https://doi.org/10.1016/j.injury.2023.01.005

tributor to a reduction in mortality [10–12]. With a focus on concentrating major trauma care, management of prehospital and in-hospital trauma care, and volume-outcome associations are getting more attention recent years [13–15].

Focus in trauma outcome analysis has also shifted to non-fatal outcome with longitudinal analysis of large cohorts [16–18]. Studies relating health status or non-fatal clinical outcome measures to different levels of trauma care in a network are limitedly available or display inconsistencies in the body of evidence [19]. The only available study comparing patient reported outcome measures across different levels of trauma care in a trauma network, reported similar health status for major trauma patients admitted to level I and level II facilities [20].

Regionalised trauma care in the Netherlands is organised as an inclusive system. Trauma centres in the Netherlands have designated levels of care based on criteria established by the Dutch Trauma Society. Level I trauma centres deliver most extensive trauma care with immediate availability of specialists around the clock and are required to treat a minimum of 240 major trauma (Injury Severity Score (ISS) > 15) patients annually. Level II facilities are able to stabilize major trauma patients, but, do not have all neurosurgical facilities and other (damage control) resources immediately available. Patients with minor or isolated injuries should be admitted to a level III facility. Despite trauma networks, many major trauma patients are still admitted to a level II and level III facilities [21]. In level I trauma centres, major trauma populations might differ typically in composition of patient profiles from those admitted to level II and level III facilities. Especially for multivariable analysis of health status, it is relevant to gain knowledge on case mix by adjustment for the right variables. Local health care context, such as trauma networks with different levels trauma care facilities, can be an important factor in analysing quality of trauma care provided. This study aimed to determine health status of major trauma patients across different levels of trauma care at one and two years after trauma.

Methods

Following review of the protocol, the local Medical Research Ethics Committee concluded this study was not subject of the Medical Research Involving Human Subjects Act (MEC-2022–0136). Previous data collection in Southwest Netherlands was approved by the local Medical Ethics Committee (MEC-2017–041), and in Brabant by the local Medical Ethics Committee (NL50258.028.14) and registered at ClinicalTrials.gov (NTC02508675). Data are reported in line with strengthening the reporting of observational studies in epidemiology (STROBE) [22].

Study setting

This multicentre observational study comprised a secondary longitudinal multilevel analysis on data from prospective cohorts from two large neighbouring trauma regions in the Netherlands, Brabant and Southwest Netherlands. The combined trauma regions have 20 hospitals (two level I trauma centres), one dedicated Burn Centre, one dedicated Eye Hospital, six Emergency Medical Services (EMS), and the availability of Helicopter Emergency Medical Services (HEMS). Geographically, the catchment area is diverse with rural, remote, industrial, urban and touristic parts, inhabited by 5 million people.

Data of the Brabant cohort were extracted from a larger cohort (Brabant Injury Outcome Surveillance, BIOS) [23]. This cohort included all acute (within 48 h after trauma) hospitalised adult (≥18years) major trauma (ISS > 15) patients who survived to discharge. Patients were followed throughout six follow up moments from 1 week up to 24 months. The Southwest cohort included all acute (within 48 h after trauma) hospitalised adult (≥18years) major trauma (ISS > 15) patients from the Dutch National Trauma Registry (DNTR) [24], and invited participants one year and two years after trauma [7]. The inclusion period of the Brabant cohort ran from August 1, 2015 to July 31, 2016, the inclusion period for the Southwest cohort was January 1, 2016 to December 31, 2016 (Fig. 1). All persons or legal proxies gave written consent, before participating. Non-response bias was reduced to a minimum by sending reminders and allowing legal sequelae to help incapacitated persons.

Demographics and clinical variables

For descriptive characteristics of the cohorts and useful predictors of health status, age, sex, level of trauma care, cause of trauma, type of injury (blunt or penetrating), Revised Trauma Score (RTS) [25] at ED, Hospital Length of Stay (LOS), ICU admitted, mechanical ventilation, all injuries coded with the Abbreviated Injury Scale 2008 [26] (AIS08), derived Injury Severity Score [27,28] (ISS08), as well as the number of fractures were extracted from the DNTR. Both trauma regions have a 100% participation rate in the DNTR.

From AIS08 coded injuries a Prehospital Trauma Triage Protocol (PTTP) variable was created. In the Netherlands, specific injuries are mentioned in a national protocol for prehospital trauma care for (H)EMS, whether a patient should be allocated to a level I trauma centre or a non-level I trauma centre. The following injury codes are specifically mentioned in the PTTP; ‘flail chest’, ‘cervical, thoracic, lumbar cord contusion’, ‘brachial plexus’, ‘pelvic instability’, ‘penetrating head, thoracic or abdominal injuries’, ‘two or more fractures of tibia, humerus or femur’, and ‘hypothermia ≤ 33 Celsius’. For hypothermia, AIS08 codes have a cut-off point of 32 °Celsius or 34 °Celsius, the latter was chosen. PTTP was dichotomised in ‘yes’ and ‘no’. PTTP is also based on vital signs, which are represented In the RTS as a covariate.

Comorbidities present before trauma were surveyed with a modified version of the Cumulative Illness Rating Scale (CIRS), which is validated as an indicator of health status [29]. First available reported comorbidities were used for analysis. Educational level was categorized in ‘low’ (no diploma, primary school, or secondary vocational education), ‘middle’ (senior secondary or general vocational education, or university preparatory education), and ‘high’ (university of applied science or academic).

Outcome

Health status was measured by EuroQol-5D (EQ-5D) [30], which is a valid instrument for measuring health-related quality of life [31–33]. Five health dimensions are scored on a Likert scale: ‘mobility’, ‘self-care’, ‘daily activities’, ‘pain or discomfort’, and ‘anxiety or depression’. Each scored health dimension adds a utility score to a summary EuroQol utility score (EQ-US, range −0.33–1.00, higher scores represent better health status). The second part of the EQ-5D is the EuroQol visual analogue scale (EQ-VAS). The EQ-VAS represents an overall health state and is scored from ‘worst imaginable’ to ‘best imaginable’ health state (0–100).

The Brabant cohort used EQ-5D-3 L, and the Southwest cohort used the 5 L version. In the 3 L version all health dimensions are scored on a 3 point Likert scale (‘no problems’, ‘moderate problems’, ‘severe problems’), and for the 5 L version answer options on a 5 point Likert scale are ‘no problems’, ‘slight problems’, ‘moderate’, ‘severe’, and ‘unable’. An EQ-5D-5 L Index Value Calculator [34] was developed by the EuroQol Group and used to convert EQ-US based on EQ-5D-3 L to EQ-5D-5 L, based on the Dutch value set.

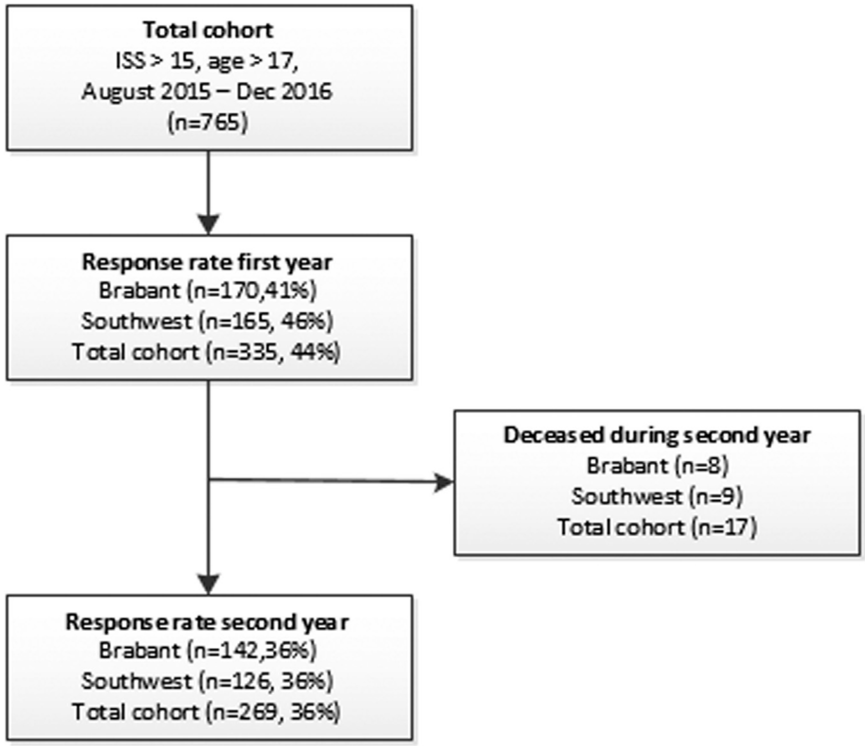

Fig. 1. Study flow chart.

Since EQ-5D does not capture cognitive functioning, an extra question was added and considered as a sixth health dimension with the same alteration of the above mentioned 3 L and 5 L answer-options as used in EQ-5D [35–37].

All health dimensions of EQ-5D-3 L and EQ-5D-5 L and cognition were dichotomised in 'no limitations' ('no problems') and 'limitations' (from 'moderate to severe' for EQ-5D-3 L and 'slight problems' to 'unable' for the EQ-5D-5 L).

Data analysis

Statistical analyses were done with Statistical Package for Social Sciences version 25.0 (SPSS, Chicago, IL). Normality of continuous variables was tested using the Shapiro-Wilk test (p-value < 0.05 was considered significant). All continuous variables were non-normally distributed. Descriptive statistics are presented as median with 25th and 75th percentiles (P_{25}-P_{75}) for continuous variables and number (percentage,%) for categorical variables.

A Mann-Whitney-test was used for comparing two groups. A Kruskal-Wallis-test was used for multiple groups. For categorical variables a χ^2-test or Fisher's exact test was used, as applicable. All statistical tests were two-sided. A p-value of <0.05 was considered significant.

Linear mixed models with random intercepts for subject and trauma region were performed with level of trauma care as covariate and EQ-US and EQ-VAS as outcome measures (univariate, unadjusted). Linear mixed models were also used in multivariable analysis with EQ-US and EQ-VAS as outcome variables, and independent variable level of trauma care combined with age, sex, comorbidities, educational level, PTTP, mechanical ventilation, ISS, RTS at the ED, and time. Estimates per covariate were reported with 95% confidence interval (CI) and p-value. Logistic mixed models were performed with the same procedure (univariate and multivariable with the same covariates) on all dichotomised (limitations 'yes' and 'no') health dimensions of EQ-5D and cognition as outcome measures. The following reference categories were taken: sex (male), level of trauma care (level I), comorbidities (none), educational level (high), measurement (year 1). Odds ratio's with 95% CI and significance level were reported per independent variable.

Results

This study included 765 major trauma patients, of which 377 (49%) responded at either one year and/or two years after trauma (Fig. 1). One year after trauma 335 (44%) responded, and 269 (36%) responded at two years after trauma. Two third ($n = 230$) responded at both time points.

Descriptive analysis

Table 1 displays that respondents were significantly older (55 years, P_{25}-P_{75} 40–68, $p = 0.034$), had a longer hospital LOS (11 days, P_{25}-P_{75} 9–19, $p = 0.022$) and were more frequently ICU admitted ($n = 242$, 64%, $p = 0.024$) than non-respondents (50 years, P_{25}-P_{75} 31–66; LOS 9, P_{25}-P_{75} 4–18; $n = 218$ (56%), respectively). One of the 12 included patients with penetrating injuries responded. Trauma settings differed significantly between respondents and non-respondents; a smaller percentage sustained their injuries due to violence (2%), traffic (36%) or were self-inflicted (3%) in the responding group than non-respondents (4%, 41%, and 5% respectively), and a larger percentage had work (9%) or sports (8%) related injuries in the responding group than non-respondents (6% and 3%, respectively).

Respondents to a level I centre were younger (53, P_{25}-P_{75} 36–66) than respondents admitted to a level II (64, P_{25}-P_{75} 51–75) or a level III centre (58, P_{25}-P_{75} 41–74) (Table 2). The percentage responding females was lower in level I trauma centres than level II and III facilities (49% and 39%, respectively). Respondents admitted to a level I centre were more severely injured (ISS 21, P_{25}-P_{75} 17–26) than respondents admitted to a level II (18, P_{25}-P_{75} 17–21) or level III (ISS 20, P_{25}-P_{75} 17–23) facility. Respondents admitted to the ED of a level II or a level III facility, had an equal RTS (7.84,

Table 1
Characteristics of the total cohort one year after non-fatal trauma and epidemiological comparison between respondents at one or two years post trauma and non-respondents.

		Total cohort missing (n)	Total cohort (n = 765)	Respondents missing (n)	Respondents* (n = 377)	Non-respondents missing (n)	Non-Respondents (n = 388)	*p-value*
Age at arrival ED (year)		–	53 (36–68)	–	55 (40–68)	–	50 (31–66)	0.034
Females		–	257 (33.6%)	–	118 (30.4%)	–	139 (36.9%)	0.059
Level of trauma care	I	–	533 (69.7%)	–	267 (70.8%)	–	266 (68.6%)	0.299
	II	–	186 (24.3%)	–	84 (22.3%)	–	102 (26.3%)	
	III	–	45 (5.9%)	–	26 (6.9%)	–	19 (4.9%)	
ISS		–	20 (17–25)	–	20 (17–25)	–	20 (17–25)	0.452
Hospital LOS (days)		3	10 (5–18)	2	11 (9–19)	1	9 (4–18)	0.022
Admission ICU		–	460 (60.1%)	–	242 (64.2%)	–	218 (56.2%)	0.024
Mechanical ventilation		–	194 (25.4%)	–	100 (26.5%)	–	94 (24.2%)	0.465
Number of fractures		4	2 (1–4)	3	2 (1–4)	1	2 (1–4)	0.128
Penetrating injury		36	12 (1.6%)	16	1 (0.3%)	20	11 (2.8%)	0.004
Cause	**violence**	22	23 (3.0%)	5	6 (1.6%)	17	17 (4.4%)	0.007
	traffic		311 (40.7%)		153 (35.8%)		158 (40.7%)	
	work		58 (7.6%)		34 (9.0%)		24 (6.2%)	
	home/leisure		273 (35.7%)		135 (35.8%)		138 (35.6%)	
	sports		42 (5.5%)		31 (8.2%)		11 (2.8%)	
	self-inflicted		28 (3.7%)		10 (2.7%)		18 (4.6%)	

Data are shown as median (P_{25}-P_{75}) or as n (%). *Respondents either at one year, two years or at both measurements. ED, Emergency Department; ISS, Injury Severity Score; LOS, Length Of Stay; ICU, Intensive Care Unit.

Table 2
Characteristics and epidemiological comparison between respondents for different levels of trauma care.

		Level I missing (n)	Level I (n = 267)	Level II Missing (n)	Level II (n = 84)	Level III missing (n)	Level III (n = 26)	*p-value*
Age at arrival ED (year)		–	53 (36–66)	–	64 (51–75)	–	58 (41–74)	< 0.001
Female		–	88 (33%)	–	41 (49%)	–	10 (39%)	0.031
ISS		–	21 (17–26)	–	18 (17–21)	–	20 (17–23)	< 0.001
PTTP level I injuries		–	106 (40%)	2	23 (27%)	–	7 (27%)	0.093
RTS ED		85	7.84 (6.90–7.84)	13	7.84 (7.84–7.84)	6	7.84 (7.84–7.84)	< 0.001
Mechanical ventilation		–	97 (36%)	–	3 (4%)	–	0 (0%)	< 0.001
Educational level	**High**	7	55 (21%)	2	19 (23%)	1	6 (23%)	0.663
	Low		92 (35%)		22 (26%)		7 (27%)	
	Middle		113 (42%)		41 (49%)		12 (46%)	
Comorbidity	**None**	–	131 (49%)	–	43 (51%)	–	14 (54%)	0.058
	1		88 (33%)		20 (24%)		3 (12%)	
	> 1		48 (18%)		21 (25%)		9 (35%)	
Response time	**1 year**	35	374 (366–391)	8	370 (363–392)	4	389 (371–414)	0.013
	2 years	72	737 (726–753)	28	733 (722–747)	10	762 (739–796)	0.002

Data are ashown as median (P_{25}-P_{75}) or as n (%). ED, Emergency Department; ISS, Injury Severity Score; PTTP, Prehospital Trauma Triage Protocol; RTS, Revised Trauma Score.

P_{25}-P_{75} 7.84–7.84), which was lower based on P_{25}-P_{75} for respondents admitted to a level I trauma centre (7.84, P_{25}-P_{75} 6.90–7.84). A larger part of the respondents was mechanically ventilated in a level I trauma centre (36%) than in a level II (4%) or level III (0%) facility.

Health status: EQ-US and EQ-VAS

The crude median EQ-US was 0.83 (P_{25}-P_{75} 0.71–0.81) at one year after trauma and 0.82 (P_{25}-P_{75} 0.71–1.00) at two years after trauma (Fig. 2). For respondents who completed the questionnaire at both time points, an increase was reported from 0.83 (P_{25}-P_{75} 0.71–1.00) to 0.84 (P_{25}-P_{75} 0.72–1.00) (Supplemental Figure S1). Respondents admitted to a level I trauma centre scored lower on crude EQ-US in both years (0.81–0.81) than respondents admitted to a level II (0.88–0.87) or level III (0.89–0.88) facility.

The crude median EQ-VAS increased from 73 (P_{25}-P_{75} 60–82) in the first year to 77 (P_{25}-P_{75} 65–88) in the second year after trauma, for the total cohort. When looking at complete cases only, crude medians did not differ and P_{25}-P_{75} were 60–85 and 65–89, respectively (Supplemental Figure S1). Respondents admitted to a level I trauma centre scored lower on crude EQ-VAS in both years (71–75) than respondents admitted to a level II (78–85) or a level III (75–80) facility.

Health dimensions and cognition

Limitations with mobility were experienced by 49% (n = 164) of the respondents at one year after trauma, and by 47% (n = 126) at two years after trauma (Fig. 3). Limitations in self-care were reported by 18% (n = 61) of the respondents at 1 year after trauma and by 22% (n = 59) of the respondents at 2 years after trauma. Limitations in daily activities were reported by 55% (n = 181) of the respondents after one year and after two years by 57% (n = 152) of the respondents. Pain and discomfort were reported by 63% (n = 210) of the respondents one year after trauma and by 60% (n = 161) of the respondents after two years. Of the respondents 36% (n = 119) reported limitations due to anxiety and depression after one year, which was 38% (n = 100) two years after trauma. Cognitive limitations were reported by 48% (n = 156) of the respondents one year after trauma, which was 50% (n = 134) after two years. Overall, a larger part of the respondents admitted to a level I trauma centre reported limitations than respondents admitted to a level II or a level III facility (Fig. 3). In general, respondents reported in both years less limitations in year two on

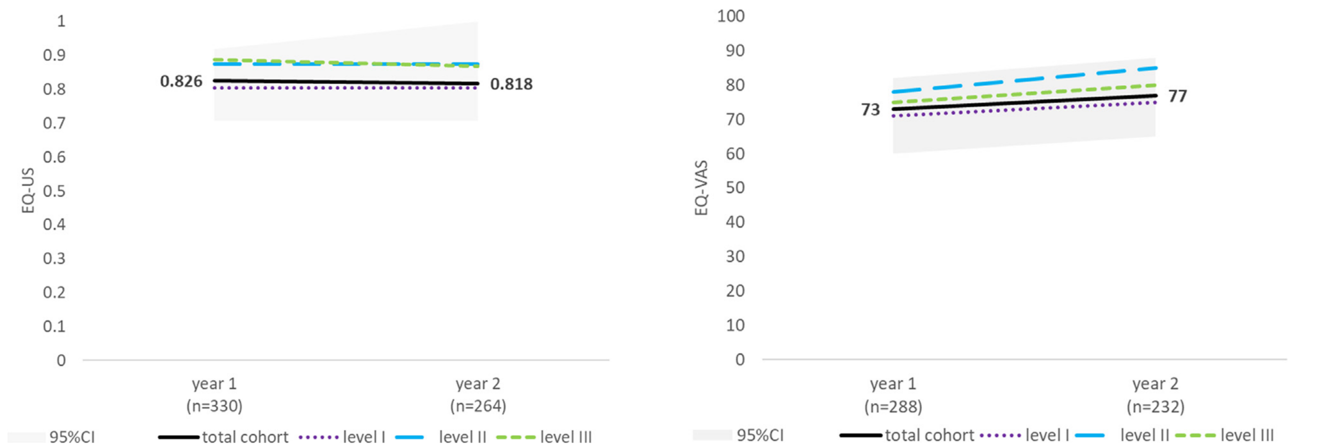

Fig. 2. EQ-US and EQ-VAS at one and two years after major trauma for the total cohort. Missing values EQ-US: year 1 n = 8 (2%), year 2 n = 5 (2%). Missing values EQ-VAS: year 1 n = 50 (15%), year 2 n = 37 (14%).

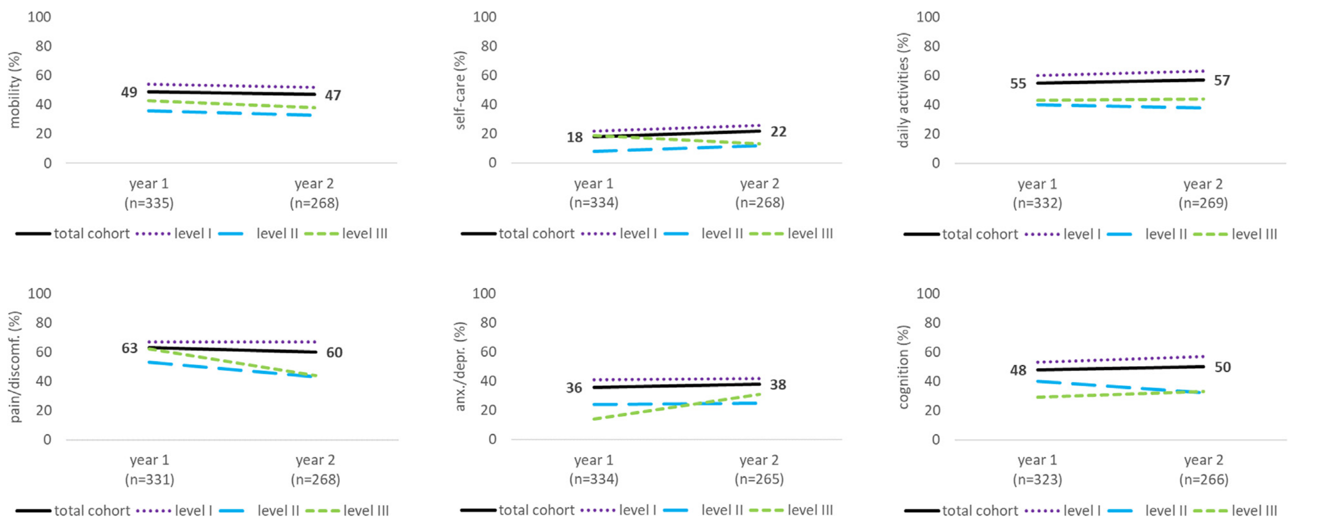

Fig. 3. Limitations in all health dimensions of the EQ-5D and cognition one and two years after major trauma. Missing values mobility: year 1 n = 3 (1%), year 2 n = 1 (0%). Missing values self-care: year 1 n = 4 (1%), year 2 n = 1 (0%). Missing values daily activities: year 1 n = 6 (2%), year 2 n = 0 (0%). Missing values pain/discomfort: year 1 n = 7 (2%), year 2 n = 1 (0%). Missing values anxiety/depression: year 1 n = 4 (1%), year 2 n = 4 (1%). Missing values cognition: year 1 n = 15 (4%), year 2 n = 3 (1%).

all health dimension of the EQ-5D and cognition for all levels of trauma care (Supplemental Figure S2).

EQ-US

Univariate analysis resulted in a statistically significant higher EQ-US over time (β 0.095, 95% CI 0.038–0.153, p = 0.001) for level II facilities than for level I trauma centres (Table 3). EQ-US in level III facilities did not differ from level I trauma centres in univariate analysis, over time (β 0.058, 95% CI −0.037–0.154, p = 0.228).

Multivariable analysis of EQ-US revealed no statistically significant differences over time in level II (β 0.052, 95% CI −0.010–0.115, p = 0.102) and level III (β 0.010, 95% CI −0.089–0.108, p = 0.844) facilities, relative to level I trauma centres.

EQ-VAS

Univariate analysis resulted in a statistically significant higher EQ-VAS over time in level II (β 7.887, 95% CI 3.035–12.740, p = 0.002) and level III (β 7.986, 95% CI 0.374–15.598, p = 0.040) facilities, relative to level I trauma centres (Table 3).

Multivariable analysis of EQ-VAS revealed no statistically significant differences over time in level II (β 3.714, 95% CI −1.893–9.321, p = 0.193) and level III (β 4.837, 95% CI −3.571–13.246, p = 0.258) facilities, relative to level I trauma centres.

Health dimensions and cognition

Univariable analysis displayed statistically significant fewer limitations in patients admitted to a level II facility, than major trauma patients admitted to a level I trauma centre, in all health dimensions of the EQ-5D and cognition (Table 3) over time; Mobility (OR 0.430, 95% CI 0.243–0.762), self-care (OR 0.369, 95% CI 0.177–0.767), daily activities (OR 0.380, 95% CI 0.225–0.642), pain and discomfort (OR 0.442, 95% CI 0.267–0.731), anxiety and depression (OR 0.438, 95% CI 0.255–0.753), cognition (OR 0.459, 95% CI 0.262–0.8025).

Multivariable analysis resulted in statistically significant differences over time between level II and level I trauma centres for mobility (OR 0.344, 95% CI 0.156–0.760), self-care (OR 0.219, 95% CI 0.077–0.618), and pain and discomfort (OR 0.421, 95% CI 0.214–0.831). No statistically significant differences over time were found for daily activities (OR 0.584, 95%CI 0.294–1.160), anxiety and depression (OR 0.570, 95%CI 0.275–1.178), and cognition (OR 0.714, 95%CI 0.338–1.506).

Table 3
Univariate (unadjusted) and multivariable (adjusted) linear mixed models for EQ-US and EQ-VAS and multivariable logistic mixed models for all health dimensions of the EQ-5D-5 L and cognition, focusing on level of trauma care.

Linear Mixed Models		Unadjusted*		Adjusted°	
	level	β (95% CI)	*p-value*	β (95% CI)	*p-value*
EQ-US	II	0.095 (0.038–0.153)	***0.001***	0.052 (−0.010–0.115)	0.102
	III	0.058 (−0.037–0.154)	0.228	0.010 (−0.089–0.108)	0.844
EQ-VAS	II	7.887 (3.035–12.740)	***0.002***	3.714 (−1.893–9.321)	0.193
	III	7.986 (0.374–15.598)	***0.040***	4.837 (−3.571–13.246)	0.258

Logistic Mixed Models		Unadjusted*		Adjusted°	
Limitations	level	OR (95% CI)	*p-value*	OR (95% CI)	*p-value*
Mobility	II	0.430 (0.243–0.762)	***0.004***	0.344 (0.156–0.760)	***0.008***
	III	0.589 (0.227–1.531)	0.277	0.511 (0.143–1.830)	0.302
Self-care	II	0.368 (0.177–0.767)	***0.008***	0.219 (0.077–0.618)	***0.004***
	III	0.679 (0.222–2.075)	0.497	0.466 (0.086–2.515)	0.374
Daily activities	II	0.380 (0.225–0.642)	***0.000***	0.584 (0.294–1.160)	0.124
	III	0.455 (0.188–1.106)	0.082	0.722 (0.235–2.212)	0.567
Pain	II	0.442 (0.267–0.731)	***0.002***	0.421 (0.214–0.831)	***0.013***
	III	0.564 (0.241–1.320)	0.186	0.567 (0.189–1.704)	0.311
Anxiety	II	0.438 (0.255–0.753)	***0.003***	0.570 (0.275–1.178)	0.129
	III	0.387 (0.148–1.012)	0.053	0.626 (0.189–2.070)	0.441
Cognition	II	0.459 (0.262–0.802)	***0.006***	0.714 (0.338–1.506)	0.375
	III	0.339 (0.128–0.897)	***0.029***	0.618 (0.179–2.134)	0.446

* Unadjusted: univariate model including level of trauma care. °Adjusted: multivariable model adjusting for age, sex, ISS, PTTP, RTS at ED, Mechanical Ventilation, level of trauma care, educational level, comorbidity and time. β, linear regression coefficients; OR, Odds Ratio; CI, Confidence Interval. In unadjusted and adjusted models for all outcome measures level I trauma centres are the reference category.

Univariable analysis displayed statistically significant less cognitive limitations (OR 0.339, 95% CI 0.128–0.897) in patients admitted to a level III facility than their counterparts admitted to a level I trauma centre over time. They did not score statistically significant different over time on mobility (OR 0.589 (0.227–1.531), 95% CI), self-care (OR 0.679, 95%CI 0.222–2.075), daily activities (OR 0.455, 0.188–1.106), pain and discomfort (OR 0.564, 95%CI 0.241–1.320), and anxiety and depression (OR 0.387, 95%CI 0.148–1.012).

Multivariable analysis did not result in statistically significant differences between level III and level I trauma centres in all health dimensions of the EQ-5D and cognition over time; Mobility (OR 0.511, 95%CI 0.143–1.830), self-care (OR 0.466, 95%CI 0.086–2.515), daily activities (OR 0.722, 95%CI 0.235–2.212), pain and discomfort (OR 0.567, 95%CI 0.189–1.704), anxiety and depression (OR 0.626, 95%CI 0.189–2.070), cognition (OR 0.618, 95%CI 0.179–2.134).

Discussion

Two large Dutch major trauma cohorts of neighbouring inclusive trauma networks were merged for this study. A response rate of 44% ($n = 335$) was obtained one year after trauma, and 36% ($n = 269$) two years after trauma. Respondents scored an EQ-US of 0.83 and 0.82 at one and two years after trauma, respectively. This is below the population norm of 0.88 [36]. One and two years after trauma, respondents admitted to level II (EQ-US 0.88–0.87 resp.) and level III (EQ-US 0.89–0.87 resp.) facilities scored similar to abovementioned population norms. Major trauma patients admitted to level I trauma centres reported a lower general health status at one and two years after trauma (EQ-US 0.81–0.81 resp.). Differences in general health status of major trauma patients admitted to level I trauma centres and level II facilities disappeared, after adjusting for age, sex, ISS, PTTP, RTS, mechanical ventilation, level of trauma care, educational level, comorbidity, and time. Similar, major trauma patients admitted to level I trauma centres reported more limitations in all health domains of the EQ-5D and cognition, than major trauma patients admitted to level II facilities. With adjusted analysis this difference disappeared for health domains daily activities, anxiety, and cognition, while differences in health domains mobility, self-care, and pain remained. General health status or limitations in specific health domains of major trauma patients admitted to level III facilities did not differ significantly from level I trauma centres in all crude and adjusted analysis. "Composition of trauma populations admitted to different levels of trauma care differ. Responders of major trauma patients admitted to level I trauma centres were younger and had more severe injuries due to high impact trauma, whereas responders of non-level I trauma centres were older and had less severe injuries due to low energy trauma." Overall, major trauma care appears to be of high quality, independently of level of trauma care.

Angerpointer et al. [20]. published similar results comparing level I and level II facilities in a certified trauma network in southern Germany. Crude analysis displayed higher EQ-US and EQ-VAS up to 2 years after trauma for level II facilities. After adjusting for injury severity, revised injury severity classification II [38], and functional capacity index [39], no significant difference was present for general health status. Level I (mean EQ-US ≈ 0.65–0.69) and II (mean EQ-US ≈ 0.75–0.78) facilities scored lower one and two years after trauma than the German reference population (EQ-US 0.90). This deviates from the present study; non-level I trauma centres score similar, and level I trauma centres score lower than the Dutch reference population.

When analysing health status of major trauma patients across different levels of trauma care, an ISS > 15 cut-off point is questionable. First, this threshold is internationally accepted, but mortality based [40] and with limitations [41,42]. Severely injured can also be defined by an ISS < 15, deviating physiological parameters, a long clinical length of stay, or trauma team activation for instance. Second, health status of severely injured patients with an ISS < 15 can be very much affected. Injuries like amputations, multiple long bone fractures, or complex panfacial fractures result in an ISS < 15, but can heavily impact daily life and recovery trajectories. Third, patients at risk for impaired health status can be identified by symptoms of anxiety or depression, acute stress disorder, post-traumatic stress disorder, neuroticism, and trait anxiety, and in general not on sociodemographics or clinical outcome measures [43]. Fourth, level I trauma centres might not have reached their optimal volume of major trauma patients for an ideal exposure/skills and ownership/coordination ratio [44]. When analysing health status of severely injured patients on a broader spectrum of patient profiles, an optimal learning/feedback curve in contemporary major trauma care might developed. Regionalization of major trauma care has created a high level of trauma care in all trauma facilities. Merging trauma centres on a supraregional scale could be the next step for trauma care in the Netherlands.

Limitations

Many major trauma patients are prehospitally undertriaged and over time scattered with small volumes over level II and III facilities [45]. Major trauma profiles are heterogeneous and when considered in such small proportions possibly not a reliable comparison with volumes of regional level I trauma centres. Even though we merged two large trauma regions, sample sizes of respondents in level I trauma centres were well above 100 per centre, this was 6 per centre for level II and level III facilities. With level I trauma centres having many injury patterns across their major trauma population, and non-level I trauma centres having very small incidences of specific injury patterns, chances are that not all injury profiles are represented throughout each level of trauma care. Especially major trauma patients admitted to level III facilities had very few respondents, resulting in non-significant findings a priori. Merging multiple major trauma cohorts can create a dataset with all patient profiles fully represented, and increases power and the use of statistical tools for longitudinal subgroup and multilevel analysis.

Due to combining health dimensions of the 3 L and the 5 L version of the EQ-5D, we did not compensate for ceiling effect, thereby ignoring internal validity issues by combining two cohorts. The ceiling effect has been reported to be around 4% lower for the 5 L version. The ceiling effect in the Dutch population has been reported to be low for both EQ-5D versions.

With a response rate of 44% one year after trauma and response rate of 36% two year after trauma, this study is prone to non-response bias. Non-response bias was reduced to a minimum by sending reminders and allowing legal sequelae to help incapacitated persons, however it seems reasonable to expect some overestimation of health status by a lower response rate under incapacitated persons and younger persons (Table 1) still recovering. Complete case analysis displays an increase of EQ-US between year one and year two after trauma, and the percentage of respondents experiencing limitations decreases between year one and year two after trauma. When looking at all responses, EQ-US displays a decrease and several health dimensions display an increase of experienced limitations. An overestimation of health status one year after trauma and an underestimation of health status after two years is probable.

Strenghts

Two large major trauma cohorts have been merged, creating a representative Dutch cohort. Analyses were done with pre-injury demographics, on scene prehospital trauma triage protocol, emergency department vital signs, clinical parameters and injury coding. With regionalized trauma care being a complex and team performance, all phases in acute trauma care are represented.

Conclusion

Major trauma patients admitted to level I trauma centres reported a less favourable general health status and more limitations in all health dimension of the EQ-5D at one and two years after trauma than major trauma patients admitted to level II or level III facilities. After adjusting, health status of respondents one to two years after trauma did not differ significantly between levels of trauma care. Level II admitted major trauma patients reported less limitations in mobility, self-care and pain/discomfort than major trauma patients admitted to level I trauma centres. Differences are most probably present due to more severely injured patients with high energy trauma admitted to level I trauma centres, and older low energy major trauma patients admitted to non-level I trauma centres. A well-coordinated trauma network can offer homogeneous results to all major trauma patients when they are distributed in different centers according to their need of care.

Patient and public involvement

Patients were informed on the reporting and dissemination plans of our research.

Disclaimer

The views expressed in the submitted article are of the authors and not of the represented institutions.

Author agreement

All authors and author group contributors approved the final version. All authors and author group contributors warrant that the article is the authors' original work, hasn't received prior publication, and isn't under consideration for publication elsewhere.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Funding

None.

Appendix

Group Authorship BIOS-group

A. van der Veen, MD, PhD, Department of Surgery, Catharina Ziekenhuis, Eindhoven, The Netherlands
C. Stevens, MD, Department of Surgery, Ziekenhuis Bernhoven, Uden, The Netherlands
D. Vos, MD, PhD, Department of Surgery, Amphia, Breda, The Netherlands
F. van Eijck, MD, Department of Surgery, Bravis Ziekenhuis, Roosendaal, The Netherlands
E. van Geffen, MD, Department of Surgery, Jeroen Bosch Ziekenhuis, 's-Hertogenbosch, The Netherlands
P. van Eerten, MD, Department of Surgery, Maxima Medisch Centrum, Veldhoven, The Netherlands
W. Haagh, MD, Department of Surgery, St. Anna Ziekenhuis, Geldrop, The Netherlands
J.B. Sintenie, MD, Department of Surgery, Elkerliek Ziekenhuis, Helmond, The Netherlands
L. Poelhekke, MD, Department of Surgery, Maasziekenhuis Pantein, Beugen, The Netherlands

Group Authorship Dutch Trauma Registry Southwest:

N.M.R. Soesman, MD, Department of Surgery, Francisus Gasthuis & Vlietland, Rotterdam, The Netherlands.
T.S.C. Jakma, MD, Department of Surgery, Albert Schweitzer Hospital, Dordrecht, The Netherlands.
M. Waleboer, MD, Department of Surgery, Admiraal de Ruyter Hospital, Goes, The Netherlands.
M. Staarink, MD, Department of Surgery, Het Van Weel-Bethesda Hospital, Dirksland, The Netherlands.
M.M.M. Bruijninckx, MD, Department of Surgery, IJsselland Hospital, Capelle aan den IJssel, The Netherlands.
A.Y.M.V.P. Cardon, MD, Department of Surgery, ZorgSaam Zeeuws-Vlaanderen Hospital, Terneuzen, The Netherlands.
P.T. den Hoed, MD, PhD, Department of Surgery, Ikazia Hospital, Rotterdam, The Netherlands.
G.R. Roukema, MD, Department of Surgery, Maasstad Hospital, Rotterdam, The Netherlands.
C.H. van der Vlies, MD, PhD, Burn Center, Maasstad Hospital, Rotterdam, The Netherlands.
N.W.L. Schep, MD, PhD, Department of Surgery, Spijkenisse Medisch Centrum Hospital, Rotterdam, The Netherlands
L. van de Schoot, MD, Department of Surgery, Beatrixhospital, Gorinchem, The Netherlands

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.injury.2023.01.005.

References

[1] Polinder S, Haagsma JA, Toet H, Van Beeck E. Epidemiological burden of minor, major and fatal trauma in a national injury pyramid. Br J Surg 2012;99:114–21.
[2] Global Burden of Disease 2013 DALYs and HALE CollaboratorsGlobal, regional, and national disability-adjusted life years (DALYs) for 306 diseases and injuries and healthy life expectancy (HALE) for 188 countries, 1990-2013: quantifying the epidemiological transition. Lancet 2015;386:2145–91.
[3] Polinder S, Haagsma JA, Panneman M, Scholten A, Brugmans M, van Beeck EF. The economic burden of injury: health care and productivity costs of injuries in the Netherlands. Accid Anal Prev 2016;93:92–100.
[4] van Delft-Schreurs CCHM, van Bergen JJ, de Jongh MAC, van de Sande P, Verhofstad MHJ, de Vries J. Quality of life in severely injured patients depends on psychosocial factors rather than on severity or type of injury. Injury 2014;45:320–6.
[5] Visser E, Gosens T, Den Oudsten BL, De Vries J. The course, prediction, and treatment of acute and posttraumatic stress in trauma patients: a systematic review. J Trauma Acute Care Surg 2017;82(6):1158–83.
[6] Herrera-Escobar JP, Rivero R, Apoj M, Geada A, Villanyi M, Blake D, et al. Long-term social dysfunction after trauma: what is the prevalence, risk factors, and associated outcomes? Surgery 2019;166(3):392–7.
[7] van Ditshuizen JC, van Lieshout EMM, van Beeck EF, Verhofstad MHJ, den Hartog D, Dutch Trauma Registry S. Health-related quality of life and return to work 1 year after major trauma from a network perspective. Eur J Trauma Emerg Surg 2021.
[8] Ringburg AN, Polinder S, van Ierland MC, Steyerberg EW, van Lieshout EM, Patka P, et al. Prevalence and prognostic factors of disability after major trauma. J Trauma 2011;70:916–22.
[9] National Academy of S, National Research Council Committee on T, National Academy of S National research council committee on S. accidental death and disability. The Neglected Disease of Modern Society; 1966.
[10] Nathens AB, Jurkovich GJ, Rivara FP, Maier RV. Effectiveness of state trauma systems in reducing injury-related mortality: a national evaluation. J Trauma 2000;48(1):25–30 discussion -1.
[11] Celso B, Tepas J, Langland-Orban B, Pracht E, Papa L, Lottenberg L, et al. A systematic review and meta-analysis comparing outcome of severely injured patients treated in trauma centers following the establishment of trauma systems. J Trauma 2006;60:371–8.
[12] Lansink KW, Gunning AC, Spijkers AT, Leenen LP. Evaluation of trauma care in a mature level I trauma center in the Netherlands: outcomes in a Dutch mature level I trauma center. World J Surg 2013;37:2353–9.
[13] van Rein EAJ, van der Sluijs R, Raaijmaakers AMR, Leenen LPH, van Heijl M. Compliance to prehospital trauma triage protocols worldwide: a systematic review. Injury 2018;49(8):1373–80.
[14] de la Mar ACJ, Lokerman RD, Waalwijk JF, Ochen Y, van der Vliet QMJ, Hietbrink F, et al. In-house versus on-call trauma surgeon coverage: a systematic review and meta-analysis. J Trauma Acute Care Surg 2021;91(2): 435–444.
[15] Sewalt CA, Wiegers EJA, Venema E, Lecky FE, Schuit SCE, Den Hartog D, et al. The volume-outcome relationship in severely injured patients: a systematic review and meta-analysis. J Trauma Acute Care Surg 2018;85:810–19.
[16] Kruithof N, Polinder S, de Munter L, van de Ree CLP, Lansink KW, de Jongh MAC, et al. Health status and psychological outcome after trauma; a prospective multicenter cohort study. Prevalence, recovery patterns and determinants of non-fatal outcome after trauma. In Press; 2020. p. 38–59. Chapter 3.
[17] Havermans RJM, de Jongh MAC, de Munter L, Lansink KWW. Longitudinal analysis of health status the first year after trauma in severely injured patients. Scand J Trauma Resusc Emerg Med 2020;28(1):29.
[18] de Munter L, Polinder S, van de Ree CLP, Kruithof N, Lansink KWW, Steyerberg EW, et al. Predicting health status in the first year after trauma. Br J Surg 2019;106:701–10.
[19] Van Ditshuizen JC, Van Den Driessche CRL, Sewalt CA, Van Lieshout EMM, Verhofstad MHJ, Den Hartog D. The association between level of trauma care and clinical outcome measures: a systematic review and meta-analysis. J Trauma Acute Care Surg 2020;89(4):801–12.
[20] Angerpointner K, Ernstberger A, Bosch K, Zeman F, Koller M, Kerschbaum M. Quality of life after multiple trauma: results from a patient cohort treated in a certified trauma network. Eur J Trauma Emerg Surg 2019.
[21] Sturms LM, Driessen MLS. Dutch trauma system performance: are injured patients treated at the right place? Injury 2021.
[22] von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies. Int J Surg 2014;12(12):1495–9.
[23] de Jongh MAC, Kruithof N, Gosens T, van de Ree CL, de Munter L, Brouwers L, et al. Prevalence, recovery patterns and predictors of quality of life and costs after non-fatal injury: the Brabant Injury Outcome Surveillance (BIOS) study. Inj Prev 2017;23:59.
[24] Driessen MLS, Sturms LM, Bloemers FW, Ten Duis HJ, Edwards MJR, den Hartog D, et al. The Dutch nationwide trauma registry: the value of capturing all acute trauma admissions. Injury 2020.
[25] Champion HR, Sacco WJ, Copes WS, Gann DS, Gennarelli TA, Flanagan ME. A revision of the Trauma Score. J Trauma 1989;29(5):623–9.
[26] Association for the Advancement of Automotive MedicineThe abbreviated injury scale 2005 revision. update 2008:2008 Des Plaines, IL: AAAM; 2008.
[27] Baker SP, O'Neill B. The injury severity score: an update. J Trauma 1976;16:882–5.
[28] Baker SP, O'Neill B, Haddon W, Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma 1974;14:187–96.
[29] Salvi F, Miller MD, Grilli A, Giorgi R, Towers AL, Morichi V, et al. A manual of guidelines to score the modified cumulative illness rating scale and its validation in acute hospitalized elderly patients. J Am Geriatr Soc 2008;56(10):1926–31.
[30] EuroQolGEuroQol–a new facility for the measurement of health-related quality of life. Health Policy (New York) 1990;16(3):199–208.
[31] Herdman M, Gudex C, Lloyd A, Janssen M, Kind P, Parkin D, et al. Development and preliminary testing of the new five-level version of EQ-5D (EQ-5D-5L). Qual Life Res 2011;20:1727–36.
[32] Janssen MF, Pickard AS, Golicki D, Gudex C, Niewada M, Scalone L, et al. Measurement properties of the EQ-5D-5L compared to the EQ-5D-3L across eight patient groups: a multi-country study. Qual Life Res 2013;22: 1717–1727.
[33] Van Beeck EF, Larsen CF, Lyons RA, Meerding WJ, Mulder S, Essink-Bot ML. Guidelines for the conduction of follow-up studies measuring injury-related disability. J Trauma 2007;62:534–50.
[34] van Hout B, Janssen MF, Feng YS, Kohlmann T, Busschbach J, Golicki D, et al. Interim scoring for the EQ-5D-5L: mapping the EQ-5D-5L to EQ-5D-3L value sets. Value Health 2012;15(5):708–15.
[35] Geraerds A, Bonsel GJ, Janssen MF, de Jongh MA, Spronk I, Polinder S, et al. The added value of the EQ-5D with a cognition dimension in injury patients with and without traumatic brain injury. Qual Life Res 2019;28(7): 1931–1939.
[36] Hoeymans N, van Lindert H, Westert GP. The Health Status of the Dutch population as assessed by the EQ-6D. Qual Life Res 2005;14: 655–663.
[37] Krabbe PF, Stouthard ME, Essink-Bot ML, Bonsel GJ. The effect of adding a cognitive dimension to the EuroQol multiattribute health-status classification system. J Clin Epidemiol 1999;52(4):293–301.
[38] Lefering R, Huber-Wagner S, Nienaber U, Maegele M, Bouillon B. Update of the trauma risk adjustment model of the TraumaRegister DGU: the revised injury severity classification, version II. Crit Care 2014;18(5):476.
[39] MacKenzie EJ, Damiano A, Miller T, Luchter S. The development of the functional capacity index. J Trauma 1996;41(5):799–807.
[40] Champion HR, Copes WS, Sacco WJ, Lawnick MM, Keast SL, Bain LWJ, et al. The major trauma outcome study: establishing national norms for trauma care. J Trauma 1990;30:1356–65.
[41] Cook A, Weddle J, Baker S, Hosmer D, Glance L, Friedman L, et al. A comparison of the injury severity score and the trauma mortality prediction model. J Trauma Acute Care Surg 2014;76(1):47–52.
[42] Aharonson-Daniel L, Giveon A, Stein M, Israel Trauma G, Peleg K. Different

AIS triplets: different mortality predictions in identical ISS and NISS. J Trauma 2006;61(3):711–17.
[43] Visser E, Oudsten BLD, Gosens T, Lodder P, De Vries J. Psychological risk factors that characterize the trajectories of quality of life after a physical trauma: a longitudinal study using latent class analysis. Qual Life Res 2021;30(5):1317–35.
[44] Hietbrink F, Houwert RM, van Wessem KJP, Simmermacher RKJ, Govaert GAM, de Jong MB, et al. The evolution of trauma care in the Netherlands over 20 years. Eur J Trauma Emerg Surg 2020;46(2):329–35.
[45] Sturms LM, Driessen MLS, van Klaveren D, Ten Duis HJ, Kommer GJ, Bloemers FW, et al. Dutch trauma system performance: are injured patients treated at the right place? Injury 2021.