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Identifying the severely injured benefitting from a specific level of trauma care in an inclusive network: A multicentre retrospective study

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A R T I C L E I N F O

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A B S T R A C T

Introduction: Defining major trauma (MT) with an Injury Severity Score (ISS) > 15 has limitations. This threshold is used for concentrating MT care in networks with multiple levels of trauma care.
Objective: This study aims to identify subgroups of severely injured patients benefiting on in-hospital mortality and non-fatal clinical outcome measures in an optimal level of trauma care.
Methods: A multicentre retrospective cohort study on data of the Dutch National Trauma Registry, region South West, from January 1, 2015 until December 31, 2019 was conducted. Patients ≥ 16 years admitted within 48 h after trauma transported with (H)EMS to a level I trauma centre (TC) or a non-level I trauma facility with a Maximum Abbreviated Injury Scale (MAIS) ≥ 3 were included. Patients with burns or patients of ≥ 65 years with an isolated hip fracture were excluded. Logistic regression models were used for comparing level I with non-level I. Subgroup analysis were done for MT patients (ISS > 15) and non-MT patients (ISS 9–14).
Results: A total of 7,493 records were included. In-hospital mortality of patients admitted to a non-level I trauma facility did not differ significantly from patients admitted to the level I TC (adjusted Odds Ratio (OR): 0.94; 95% confidence interval (CI) 0.68–1.30). This was also applicable for MT patients (OR: 1.06; 95% CI 0.73–1.53) and non-MT patients (OR: 1.30; 95% CI (0.56–3.03). Hospital and ICU LOS were significantly shorter for patients admitted to a non-level I trauma facilities, and patients admitted to a non-level I trauma facility were more likely to be discharged home. Findings were confirmed for MT and non-MT patients, per injured body region.
Conclusion: All levels of trauma care performed equally on in-hospital mortality among severely injured patients (MAIS ≥ 3), although patients admitted to the level I TC were more severely injured. Subgroups of patients by body region or ISS, with a survival benefit or more favorable clinical outcome measures were not identified. Subgroups analysis on clinical outcome measures across different levels of trauma care in an inclusive trauma network is too simplistic if subgroups are based on injuries in specific body region or ISS only.

Introduction

Since the implementation of trauma networks, care for the most severely injured patients is much more organized and in-hospital mortality has been reduced [1]. Severely injured patients treated in level I trauma centres (TC) have a survival benefit as compared to non-level I trauma facilities [2–6]. The Dutch trauma system consists of regionalized inclusive trauma networks, in which hospitals have designated levels of trauma care following specific criteria established by the Dutch Trauma Society. Level III facilities are intended for stable patients with isolated or minor injuries. Level II facilities are able to provide acute care for severely injured patients, if these patients are hemodynamically stable and do not require neurosurgical care. Level I TC's provide a fully equipped TC with twenty-four-seven availability of neurosurgery, and an Intensive Care Unit (ICU) with a minimum capacity of twelve beds, with one ICU bed available for acute trauma at all times. Level I TC's are intended for the most severely injured, also referred to as major trauma (MT) patients, and have to meet volume requirements of more than 240 MT patients per year. National regulations require that 90% of all MT patients must be primary admitted to level I TC's [2,7–9].

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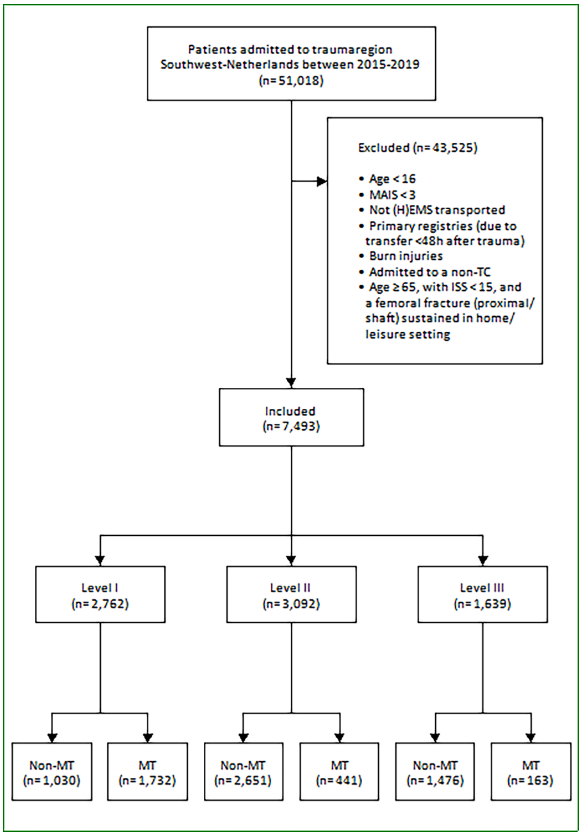

Fig. 1. Flowchart of patient record selection.

As in the Netherlands, MT is generally defined as an Injury Severity Score (ISS) > 15 [10,11]. Classifying MT based on ISS alone has limitations [12]. Defining MT with an anatomical sum score does not compensate for many possible combined injuries, and multiple lesions in the same body region. The new ISS (NISS) does compensate for the latter, however is not implemented as an quality indicator. Severely injured, major trauma, severe monotrauma (barytrauma), and polytraumatized patients can all have different injury patterns, with the same ISS. Other factors that determine severe injuries, such as physiological parameters, are also not part of the ISS.

The ISS has an evaluative character and is not readily available during on-scene acute care management [2]. Despite national guidelines of treating 90% of all MT patients in level I TC's, approximately one third of all MT patients are admitted to Dutch non-level I trauma facilities [9,13]. This addresses discrepancies of what is considered to be a MT by paramedics and physicians on-scene with following clinical acute care setting, compared with an anatomical sum score in retrospect. In addition, a recent Dutch study showed around 50% of trauma patients secondary transferred from a level II facility to a level I TC had an ISS ⟨ 15 [14]. The current definition of MT, possibly does not include all patients benefiting a specific level of trauma care. Either, severely injured patients without an ISS ⟩ 15 can benefit from level I TC care, or severely injured patients with an ISS > 15 do not necessary depend on level I TC care for a favorable outcome.

This calls for an evaluation of clinical outcome measures of the severely injured across different levels of trauma care from an inclusive trauma region perspective. This study aims to identify severely injured (Maximum Abbreviated Injury Scale (MAIS) ≥ 3) patients, with an ISS > 15 or not, benefiting on in-hospital mortality and non-fatal clinical outcome measures in an optimal level of trauma care.

Methods

Study design

A multicentre retrospective cohort study was reported in accordance with the STROBE statement [15]. Data from the Dutch National Trauma Registry (DNTR), [16] collected in trauma region Southwest Netherlands, was used. All hospitals in trauma region Southwest

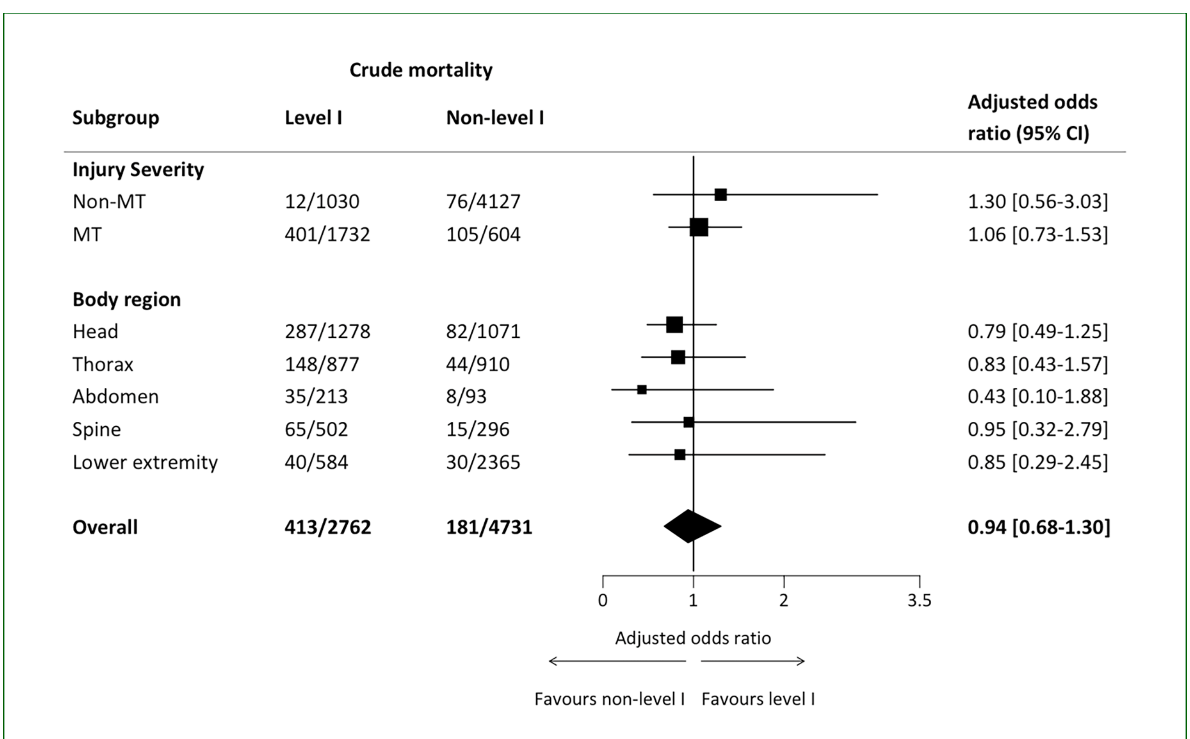

Fig. 2. Forest plot adjusted odds ratios of in-hospital mortality from patients admitted to non-level I trauma facilities versus the level I trauma centre.

Table 1
Baseline characteristics per level of trauma care overall, and per ISS category.

		Overall Level I ($n = 2762$)	non-Level I ($n = 4731$)	p-value	ISS > 15 Level I ($n = 1732$)	non-Level I ($n = 604$)	p-value	ISS 9–14 Level I ($n = 1030$)	non-Level I ($n = 4127$)	p-value
Sex male		1967 (71.2)	2511 (53.1)	<0.001	1241 (71.7)	342 (56.6)	<0.001	726 (70.5)	2169 (52.6)	<0.001
Age		50 (21)	64.7 (18.9)	<0.001	51.3 (20.4)	67.9 (20.7)	<0.001	49 (21)	64 (9)	<0.001
Comorbidity	**Healthy**	1275 (47.8)	1396 (29.6)	<0.001	780 (47.4)	145 (24.2)	<0.001	495 (48.6)	1251 (30.4)	<0.001
	Mild	1112 (41.7)	2493 (52.9)		694 (42.2)	324 (54.0)		418 (41.0)	2169 (52.8)	
	Severe	224 (8.4)	746 (15.8)		145 (8.8)	113 (18.8)		79 (7.8)	633 (15.4)	
	Unstable	54 (2.0)	77 (1.6)		27 (1.6)	18 (3.0)		27 (2.7)	59 (1.4)	
SBP < 90		152 (5.8)	58 (1.3)	<0.001	135 (8.4)	19 (3.3)	<0.001	17 (1.7)	39 (1.0)	0.072
RR		18.9 (6.1)	16.9 (4.7)	<0.001	18 (16, 22)	18 (15, 21)	0.006	18 (15, 20)	16 (14, 18)	<0.001
BMR		4.6 (2.1)	5.9 (0.6)	<0.001	6 (1,6)	6 (6,6)	<0.001	6 (6,6)	6 (6,6)	<0.001
Transfer in		433 (15.7)	147 (3.1)	<0.001	279 (16.1)	12 (2.0)	<0.001	154 (15.0)	135 (3.3)	<0.001
ISS		20.8 (11.8)	11.4 (4.7)	<0.001	25 (18, 30)	19 (17, 25)	<0.001	10 (9, 13)	9 (9, 10)	<0.001
Injury	**Penetrating**	226 (8.2)	49 (1.0)	<0.001	109 (6.3)	6 (1.0)	<0.001	117 (11.4)	43 (1.0)	<0.001
	Blunt	2536 (91.8)	4682 (99.0)		1623 (93.7)	598 (99.0)		913 (88.6)	4084 (99.0)	
MAIS ≥ 3	**Head**	1278 (46.3)	1071 (22.6)	<0.001	982 (56.7)	317 (52.5)	0.073	296 (29)	754 (18.3)	<0.001
	Face	71 (2.6)	24 (0.5)	<0.001	62 (3.6)	10 (1.7)	0.019	9 (0.9)	14 (0.3)	0.021
	Neck	65 (2.4)	10 (0.2)	<0.001	43 (2.5)	4 (0.7)	0.006	22 (2.1)	6 (0.2)	<0.001
	Thorax	877 (31.8)	910 (19.2)	<0.001	715 (41.3)	211 (34.9)	0.006	162 (15.7)	699 (16.9)	0.352
	Abdomen	213 (7.7)	93 (2.0)	<0.001	182 (10.5)	53 (8.8)	<0.001	31 (3.0)	40 (1.0)	<0.001
	Spine	502 (18.2)	296 (6.3)	<0.001	332 (19.2)	53 (8.8)	<0.001	170 (16.5)	243 (5.9)	<0.001
	Arm	104 (1.3)	101 (2.1)	<0.001	38 (2.2)	4 (0.7)	0.015	66 (6.4)	65 (1.6)	<0.001
	Leg	584 (21.1)	2365 (50.0)	<0.001	311 (18.0)	105 (17.4)	0.752	273 (26.5)	2260 (54.8)	<0.001
	External	103 (3.7)	101 (2.1)	<0.001	82 (4.7)	38 (6.3)	0.135	21 (2.0)	63 (1.5)	0.245

Continuous variables are displayed as mean (SD;% missing) or median (((P25-P75;% missing), categorical variables are displayed as n (%;% missing). SBP, Systolic Blood Pressure; RR, Respiratory Rate; BMR, Best Motor Response; ISS, Injury Severity Score; MAIS, Maximum Abbreviated Injury Scale. Overall, comorbidity, SBP, RR, and BMR had missing value (1.5%, 7%, 37.5%, 16.5%, respectively), the other variables had no missing values.

Table 2
Clinical outcome measures per level of trauma care overall, and per ISS category.

	Overall Level I ($n = 2762$)	non-Level I ($n = 4731$)	p-value
Mortality	413 (15.0)	181 (3.8)	<0.001
HLOS	8 (4, 15)	6 (4, 9)	<0.001
ICU	1186 (42.9)	828 (17.5)	<0.001
ICU LOS	4 (2, 11)	2 (2, 3)	<0.001
Discharged home	1338 (48.4)	2915 (61.6)	<0.001
	ISS > 15		
	Level I **($n = 1732$)**	**non-Level I** **($n = 604$)**	**p-value**
Mortality	401 (23.2)	105 (17.4)	0.003
HLOS	10 (4, 19)	7 (4, 12)	<0.001
ICU	1029 (59.4)	249 (41.2)	<0.001
ICU LOS	5 (2, 11)	3 (2, 5)	<0.001
Discharged home	582 (33.6)	262 (43.4)	<0.001
	ISS 9–14		
	Level I **($n = 1030$)**	**non-Level I** **($n = 4.127$)**	**p-value**
Mortality	12 (1.2)	76 (1.8)	0.133
HLOS	6 (3, 10)	5 (4, 9)	0.027
ICU	157 (15.2)	579 (14.0)	0.319
ICU LOS	3 (2, 4)	2 (1, 3)	0.006
Discharged home	756 (73.4)	2653 (64.3)	<0.001

Data are shown as median (P25-P75) or as n (%). LOS, Length Of Stay; ICU, Intensive Care Unit.

Netherlands participate in the DNTR and entail one level I TC, five level II and five Level III trauma facilities. Dutch TC level criteria requirements are similar to those of the American College of Surgeons Committee on Trauma (ACS-COT) [17]. All patients admitted to an emergency department (ED), within 48 h after trauma, following hospitalization or death in the ED, excluding dead on arrival, are included in the DNTR, and injuries are coded using AIS 2005 update 2008 [18]. All trauma patients, aged ≥ 16, with a maximum abbreviated injury scale (MAIS) ≥ 3, admitted to a level I TC, or level II, or III trauma facility, between January 1, 2015, and December 31, 2019, were included for this study. Initial transport to the ED was provided by (helicopter) emergency medical services ((H)EMS). If patients were transferred between hospitals within 48 h after trauma, the primary registry was excluded, to avoid patient doubling. Patients with burn injuries, or ≥ 65 years with an ISS < 15 and a proximal femoral or femoral shaft fracture incurred in a private setting, were excluded to avoid selection bias ().

Data collection included patient demographics (age, sex, comorbidities by the American Society of Anaesthesiologists physical status classification (ASA)), ED physiological parameters (best motor response (BMR), respiratory rate (RR), systolic blood pressure (SBP)), injury characteristics (ISS, MAIS per body region, type of injury (blunt or penetrating), cause of injury), and level of trauma care. A transfer variable was created, to adjust for potential selection bias. The primary outcome measure was in-hospital mortality, and secondary outcome measures were hospital length of stay (LOS), ICU length of stay (ICU LOS), and discharge home (yes/no).

The local Medical Research Ethics Committee exempted this study for the level I trauma centre (MEC-2022–0280). Following review of the protocol, they concluded that the study is not subject to the Medical Research Involving Human Subjects Act. Other hospital have not reviewed the protocol. Patient consent was not asked.

Statistical analysis

Statistical analyses were done using the R Project for Statistical Computing (version 4.0.3) [19].

First, a descriptive analysis was performed for level I versus non-level I regarding patient, injury and outcome characteristics. Patients were further divided into MT (ISS > 15) and non-MT (ISS 9–14) for subgroup analysis.

Shapiro-Wilk's test was used to test the normality of data. Parametric variables were tested with a Student's *t*-test for two groups and Analysis of Variance for multiple groups. Non-parametric variables were tested with the Mann-Whitney U test for two groups and the Kruskall-Wallis test for multiple groups, followed by a pairwise comparison with the Mann-Whitney U test as applicable. Descriptive figures were presented with means and standard deviations for parametric continuous data, median and first-third quartile for non-parametric continuous data, and numbers and percentages for categorical data. Missing values were

Table 3
Odds ratios and standardized mean differences of in-hospital mortality, hospital LOS, ICU LOS, and discharged home of patients admitted to non-level I trauma facilities versus level 1 TC.

	In-hospital mortality OR (95% CI) Unadjusted	p-value	OR (95% CI) Adjusted	p-value	Hospital LOS SMD (95% CI) Unadjusted	p-value	SMD (95% CI) Adjusted	p-value
Overall	0.23 (0.19–0.27)	<0.001	0.94 (0.68–1.30)	0.709	−5.03 (−5.49–4.56)	<0.001	−2.87 (−3.48–2.26)	<0.001
ISS 9–14	1.59 (0.86–2.94)	0.137	1.30 (0.56–3.03)	0.546	−1.45 (−1.89–1.01)	<0.001	−1.93 (−2.43–1.44)	<0.001
ISS > 15	0.70 (0.55–0.89)	0.003	1.06 (0.73–1.53)	0.766	−5.22 (−6.58–3.86)	<0.001	−3.42 (−5.00–1.84)	<0.001
Head	0.29 (0.22–0.37)	<0.001	0.79 (0.49–1.25)	0.311	−6.23 (−7.26–5.19)	<0.001	−2.09 (−3.43–0.76)	0.002
Thorax	0.25 (0.18–0.36)	<0.001	0.83 (0.43–1.57)	0.558	−5.89 (−7.04–4.73)	<0.001	−1.60 (−3.13–0.07)	0.041
Abdomen	0.48 (0.21–1.08)	0.075	0.43 (0.10–1.88)	0.264	−6.31 (−9.83–2.80)	<0.001	−3.66 (−7.80–0.47)	0.083
Spine	0.36 (0.20–0.64)	<0.001	0.95 (0.32–2.79)	0.925	−7.25 (−9.16–5.33)	<0.001	−4.45 (−6.80–2.11)	<0.001
Upper extremity	0.24 (0.03–2.04)	0.191	26.21 (0.00-inf)	0.491	−7.84 (−11.58–4.11)	<0.001	−7.08 (−11.36–2.81)	0.001
Lower extremity	0.17 (0.11–0.28)	<0.001	0.85 (0.29–2.45)	0.758	−9.44 (−10.23–8.65)	<0.001	−6.30 (−7.32–5.28)	<0.001
	Discharge home				**ICU LOS**			
Overall	1.71 (1.56–1.88)	<0.001	1.38 (1.18–1.61)	<0.001	−4.76 (−5.45–4.06)	<0.001	−2.04 (−2.98–1.10)	<0.001
ISS 9–14	0.65 (0.56–0.76)	<0.001	1.07 (0.88–1.31)	0.494	−1.35 (−2.07–0.64)	<0.001	−0.69 (−1.54–0.16)	0.112
ISS > 15	1.51 (1.25–1.83)	<0.001	1.97 (1.50–2.58)	<0.001	−4.41 (−5.68–3.14)	<0.001	−2.75 (−4.18–1.32)	<0.001
Head	2.92 (2.47–3.46)	<0.001	1.73 (1.31–2.27)	<0.001	−5.61 (−7.27–3.95)	<0.001	−3.57 (−5.43–1.70)	<0.001
Thorax	2.47 (2.04–2.99)	<0.001	1.50 (1.08–2.08)	0.015	−5.45 (−6.49–4.42)	<0.001	−2.20 (−3.67–0.74)	0.003
Abdomen	2.27 (1.34–3.87)	0.003	3.11 (1.41–6.85)	0.005	−4.40 (−7.21–1.58)	0.003	−1.58 (−5.15–1.99)	0.387
Spine	1.61 (1.21–2.16)	0.001	1.12 (0.71–1.77)	0.622	−6.14 (−10.55–1.72)	0.007	−3.49 (−8.50–1.51)	0.173
Upper extremity	0.95 (0.49–1.83)	0.877	0.29 (0.10–0.84)	0.022	−6.80 (−13.53–0.07)	0.058	−2.05 (−9.45–5.34)	0.593
Lower extremity	1.14 (0.95–1.37)	0.158	0.99 (0.72–1.36)	0.946	−6.79 (−8.51–5.08)	<0.001	−2.09 (−4.80–0.63)	0.133

Level I is the reference in all analyses. Adjusted analyses were run with age, sex, comorbidity, best motor response, systolic blood pressure, and respiratory rate. CI, Confidence Interval; OR, Odds Ratio; SMR, Standardized Mean Differences.

reported when appropriate.

Second, covariates RR, SBP, BMR, and ASA were imputed with multilevel multiple imputation dependent on mechanism of missingness with the mice package [20].

Unadjusted and adjusted analyses were performed using a fixed effects logistic regression model for in-hospital mortality and discharge home (yes/no), and a fixed effects linear regression model for hospital LOS and ICU LOS. Levels of trauma care were divided into level I TC and non-level I trauma facility, with the level I TC being the reference category. Level of trauma care, transfer, type of injury, ISS, BMR, RR, SBP, ASA, age, and sex were set as independent variables for all analyses. RR and BMR were log transformed, ISS was modelled with a spline function with 3 knots, and an interaction term age*sex was added in accordance with the TARN and TRISS model [21]. For each outcome measures subgroup analyses were performed for MT (ISS > 15) and non-MT (ISS 9–14) patients per injured body region.

Results

Study characteristics

A total of 7493 patient records were included, of which 2762 patients were admitted to the level I TC, 3092 patients to a level II, and 1638 patients to a level III facility (). Patients admitted to the level I TC were younger, more often male, and had less comorbidities than patients admitted to a non-level I trauma facility (Continuous variables are displayed as mean (SD;% missing) or median (((P25-P75;% missing), categorical variables are displayed as n (%;% missing)). A larger part of the level I patients were secondarily admitted after transfer from other hospitals (n = 433, 15.7%), as opposed to patients admitted to a non-level I trauma facility (n = 147, 3.1%).

Patients admitted to the level I TC, were more severely injured than patients admitted to a non-level I trauma facility (ISS respectively 17 (13–26),11.4 (4.7))), and were more likely to suffer from penetrating injuries (n = 226, 8.2%; n = 49, 1.0%), respectively). Overall, 2336 MT patients were included; 1732 (74.1%) were admitted to the level I TC and 604 (25.8%) to a non-level I facility (Continuous variables are displayed as mean (SD;% missing) or median (((P25-P75;% missing), categorical variables are displayed as n (%;% missing)). The proportion non-MT patients (n = 5157) differed across levels of trauma care as well; 1030 (20.0%) were admitted to the level I TC and 4127 (80.0%) to a non-level I facilty.

Overall, the most frequent injured body regions (MAIS ≥ 3) were lower extremities (n = 2949, 39.4%), head (n = 2349, 31.3%), thorax (n = 1787, 23.8%), and spine (n = 798, 10.6%) (Continuous variables are displayed as mean (SD;% missing) or median (((P25-P75;% missing), categorical variables are displayed as n (%;% missing)). Similar, in non-level I trauma facilities the most frequent affected body region was lower extremities n = 2365, 50%), head (n = 1071, 22.6%), thorax (n = 910, 19.2%)), and spine (n = 296, 6.3%). The most frequent injured body region of patients admitted to the level I TC were, head (n = 1278, 46.3%), thorax (n = 877, 31.8%), lower extremities (n = 584, 21.1%), and spine (n = 502, 18.18%).

Outcomes

In-hospital mortality

In-hospital mortality differed across levels of trauma care; level I n = 413, 15.0%; non-level I trauma facility n = 181, 3.8% (p < 0.001,). Univariate analysis showed a lower mortality for non-level I trauma facilities than the level I TC (OR 0.23 (95% CI 0.19–0.27), p < 0.0001, Level I is the reference in all analyses. Adjusted analyses were run with age, sex, comorbidity, best motor response, systolic blood pressure, and respiratory rate. CI, Confidence Interval; OR, Odds Ratio; SMR, Standardized Mean Differences). After adjusting for confounders, no difference in in-hospital mortality was found (OR 0.94 (95% CI 0.68–1.30), p = 0.709, Level I is the reference in all analyses. Adjusted analyses were run with age, sex, comorbidity, best motor response, systolic blood pressure, and respiratory rate. CI, Confidence Interval; OR, Odds Ratio; SMR, Standardized Mean Differences,). In the multivariate analysis MT patients showed no difference in in-hospital mortality (OR 1.06 (95% CI 0.73–1.53), p = 0.7663, Level I is the reference in all analyses. Adjusted analyses were run with age, sex, comorbidity, best motor response, systolic blood pressure, and respiratory rate. CI, Confidence Interval; OR, Odds Ratio; SMR, Standardized Mean Differences,). Among non-MT patients, there was no significant difference for adjusted in-hospital mortality (OR: 1.30 (95% CI 0.56–3.03), p = 0.546, Level I is the reference in all analyses. Adjusted analyses were run with age, sex, comorbidity, best motor response, systolic blood pressure, and respiratory rate. CI, Confidence Interval; OR, Odds Ratio; SMR, Standardized Mean

Differences,). With regard to body regions, the biggest difference in overall crude in-hospital mortality was found in patients with severe head injuries (level I $n = 287$, 22.5%; level II $n = 53$, 7.6%; level III $n = 29$, 7.8%;). Univariate analysis showed a lower in-hospital mortality in patients admitted to non-level I trauma facilities for all body regions, which was significant for patients injured to the head, thorax, spine, and lower extremities (Level I is the reference in all analyses. Adjusted analyses were run with age, sex, comorbidity, best motor response, systolic blood pressure, and respiratory rate. CI, Confidence Interval; OR, Odds Ratio; SMR, Standardized Mean Differences). In multivariable analyses all body regions showed no significant in-hospital mortality difference between non-level I trauma facilities and the level I TC (Level I is the reference in all analyses. Adjusted analyses were run with age, sex, comorbidity, best motor response, systolic blood pressure, and respiratory rate. CI, Confidence Interval; OR, Odds Ratio; SMR, Standardized Mean Differences,).

Hospital LOS

MT patients had a significant shorter hospital LOS in level II and III facilities (6.0 (4.0–9.0)) than in the level I TC (9.5 (4.0, 19.0), $p<0.001$,). Comparing the level I TC with non-level trauma facilities resulted in an unadjusted SMD (95% CI) of −5.22 (−6.58–3.86, $p<0.001$), and an adjusted SMD (95% CI) of −3.42 (−5.00–1.84, $p<0.001$, Level I is the reference in all analyses. Adjusted analyses were run with age, sex, comorbidity, best motor response, systolic blood pressure, and respiratory rate. CI, Confidence Interval; OR, Odds Ratio; SMR, Standardized Mean Differences). For non-MT patients, multivariable analyses showed a significant shorter hospital LOS in non-level I trauma facilities (SMD (95% CI) −1.93 (−2.431.44), $p<0.001$, Level I is the reference in all analyses. Adjusted analyses were run with age, sex, comorbidity, best motor response, systolic blood pressure, and respiratory rate. CI, Confidence Interval; OR, Odds Ratio; SMR, Standardized Mean Differences). When comparing hospital LOS per injured body region across different levels of trauma care, patients admitted to non-level I trauma facilities were shorter hospitalized in all analyses (, Level I is the reference in all analyses. Adjusted analyses were run with age, sex, comorbidity, best motor response, systolic blood pressure, and respiratory rate. CI, Confidence Interval; OR, Odds Ratio; SMR, Standardized Mean Differences,).

ICU LOS

The level I TC had more ICU-admitted patients ($n = 1186$, 42.9%) than non-level I trauma facilities ($n = 828$, 17.5%) facilities (). Patients admitted to the ICU in non-level I trauma facilities had a shorter ICU LOS, remaining significant in multivariable analysis (SMD (95% CI) −2.04 (−2.98—1.10), $p<0.001$, Table 3). The ICU admission rate of MT patients in the level I TC was higher ($n = 1029$, 59.4%) than in non-level I trauma facilities ($n = 1029$, 59.4%, $p<0.001$,). MT patients showed a significant shorter ICU LOS in level II and III facilities in adjusted analysis (SMD (95% CI) −2.75 (−4.18—1.32), $p<0.001$ (Level I is the reference in all analyses. Adjusted analyses were run with age, sex, comorbidity, best motor response, systolic blood pressure, and respiratory rate. CI, Confidence Interval; OR, Odds Ratio; SMR, Standardized Mean Differences). Multivariable analysis for non-MT patients resulted in a non-significantly different ICU LOS across level of trauma care (SMD (95% CI) −0.69 (−1.54–0.16), $p = 0.112$, Level I is the reference in all analyses. Adjusted analyses were run with age, sex, comorbidity, best motor response, systolic blood pressure, and respiratory rate. CI, Confidence Interval; OR, Odds Ratio; SMR, Standardized Mean Differences). When comparing ICU LOS per injured body region across the different levels of trauma care, patients admitted to non-level I trauma facilities were indicative for a shorter ICU LOS in all analysis and was significantly shorter for patients with head (adjusted SMD (95% CI) −3.57 (−5.43–1.70), $p<0.001$) or thoracic (SMD (95% CI) −2.20 (−3.67–0.74), $p = 0.003$) injuries, in adjusted analysis (Table 2, Table 3).

Discharge home

Overall, patients admitted to a level II or a level III facility were significantly more often discharged home ($n = 2915$, 61.6%) than in level I ($n = 1338$, 48.8%, $p<0.001$,). This was similar for MT patients (non-level I $n = 262$, 43.4%; level I $n = 583$, 33.6%, $p<0.001$,), remaining significant throughout multivariable analysis (OR (95% CI) 1.97 (1.50–2.58), $p<0.001$, Level I is the reference in all analyses. Adjusted analyses were run with age, sex, comorbidity, best motor response, systolic blood pressure, and respiratory rate. CI, Confidence Interval; OR, Odds Ratio; SMR, Standardized Mean Differences). Non-MT patients admitted to the level I TC were more often discharged home ($n = 756$, 73.4%) than patients admitted to non-level I trauma facilities ($n = 2653$, 64.3%, $p<0.001$,). In multivariate analysis this difference disappeared (OR (95% CI) 1.07 (0.88–1.31), $p = 0.494$, Table 3). Patients with head, thorax, or abdominal injuries had a higher chance to be discharged home when admitted to a non-level I trauma facility in multivariate analysis (respectively OR (95% CI) 1.73 (1.31–2.27), $p<0.001$; OR (95% CI) 1.50 (1.08–2.08), $p = 0.015$; OR (95% CI) 3.11 (1.41–6.85), $p = 0.005$). For patients with injured upper extremities multivariate analysis showed they were more likely to return home when admitted to the level I TC (OR (95% CI) 0.29 (0.10–0.84), $p = 0.022$). The proportion of patients discharged home with spinal or lower extremity injuries did not differ across levels of trauma care in multivariate analysis.

Discussion

This study aimed to identify severely injured patients benefiting on in-hospital mortality and non-fatal clinical outcome measures in an optimal level of trauma care. Level I TC's perform equally as non-level I trauma facilities, when looking at in-hospital mortality among severely injured patients (MAIS ≥ 3), even though patients admitted to level I TC's were more severely injured. Patients admitted to a non-level I trauma facility had a shorter hospital and ICU stay, and were more likely to be discharged home. These results were consistent across level of trauma care for MT patients (ISS > 15) and non-MT patients (ISS 9–14), as well as for analyses per injured body region. Compared to other body regions, there was a high difference in the number of head trauma, and associated in-hospital mortality, of this population in the level I TC compared to non-level I trauma facilities. It seems reasonable this was due to the regional function of the level I TC as a neuro-surgical centre around the clock.

Previously reported survival benefits for MT patients admitted to a level I TC,[2–4,22,23] did not match our current findings. Studies reporting similar performance of level I and level II facilities are not uncommon. Such results have been described in general MT populations and geriatric trauma patients, as well as in more specific populations, such as trauma patients with severe thoracic injuries, elderly with thoracic injuries, severe traumatic brain injuries, severe traumatic abdominal injuries, severe traumatic pelvic injuries and traumatic spine injuries [24–36]. In addition, a recent study comparing clinical outcomes between level I and II TC's of patients with combined burn injuries and other physical trauma, a group known to have high rates of morbidity and mortality, found no in-hospital mortality difference [37].

Studies reporting similar performance of level I and non-level I trauma facilities are USA originated and included American College of Surgeons Committee on Trauma (ACS-COT) verified TC's. The Dutch TC level criteria requirements are quite similar to those of ACS-COT, making Dutch and American studies comparable [8,17]. A plausible explanation for the current results and above mentioned studies reporting similar performance of level I and non-level I trauma facilities, is that the difference between level I and level II trauma care has reduced since the trauma networks were implemented 30 years ago [35]. Medical advances, intensive collaboration between hospitals and better prehospital triage in trauma regions have accelerated quality of care in the Netherlands and led to a mature trauma system, in terms of in-hospital mortality rates and efficiency in the trauma chain construct such as type of surgeon and the availability of HEMS [2,38].

Another point of consideration is the definition of MT based on an anatomical sum score, this is a general criterion. As mentioned, the ISS has limitations. Also, it does not include physiological parameters, or trauma mechanism, and it does not take multiple injuries in the same body region into account (NISS could serve as an alternative, but is still anatomy based). For example, TBI patients with or without rapid neurological deterioration can have the same ISS, but require different treatment. The first patient might require acute neurosurgery and extensive care, thus admittance to a level I TC, whereas the latter could be safely managed with (initial) conservative treatment in a level II facility. This was illustrated by a recent study including traumatic brain injury (TBI) patients with an acute subdural haematoma comparing surgical evacuation with initial conservative treatment. That study reported that acute surgical evacuation was not associated with better functional outcome [39].

Adding physiological parameters as introduced with the Berlin polytrauma definition, can be of additive value for classification of patients with multiple severe injuries and a high mortality risk [40–42]. This definition does not include patients with severe isolated injuries (SII, MAIS $\geq$4), which makes up for 50% of the MT population in the Netherlands and is considered a high risk entity as well [43]. Both MT patients following the BPD and MT patients with severe isolated injuries are part of the MT population defined with ISS>15. Both MT groups have different injury patterns and can result in a different physiological response. In that sense, the greater part of a ISS > 15 threshold for major trauma patients seems well defined (a combination of SII and BPD). It would be of great value for policy makers to create an overview of which specific combination of severe injuries and what specific isolated severe injuries create a high risk patient profile.

Demetriades *et a*l. examined patients with specific, isolated severe injuries and found a survival benefit for patients admitted to an ACS level I TC as compared to level II TC's [44]. Based on this study, one could argue that a large proportion of overtriage is needed for a small group of patients with specific severe injuries to have a benefit of trauma care by being admitted to a level I TC.

By identifying patient profiles in need of a specific level of trauma care, contemporary trauma care could be more efficient and cost-effective, while improving clinical outcomes and quality of life. Additional research should focus on identifying which severely injured patients require a specific level of trauma care, in order to optimize the current trauma care network chain. Combining predictive parameters for ISS > 15 or alternative classification parameters in the prehospital and clinical setting, will improve our knowledge of which trauma patients are admitted to the appropriate trauma facility for optimal care. Complementary, this way the quality indicator, how it is presented now, will be able to evolve following contemporary trauma care.

Limitations

First, the retrospective design is limited with several biases. Second, patients admitted to the level I TC were younger, had less comorbidities, poorer ED physiological parameters, higher injury severity scores, and were more likely to be secondary admitted than patients admitted to a non-level I trauma facility. Although we adjusted for these confounders, unmeasured confounding such as time from injury to treatment, presence of the systemic inflammatory response syndrome[46], undiagnosed comorbidities, or the presence of obesity[47], cannot be excluded. Third, another important limitation is statistical power. Even though the overall sample size consists of 7493 patient records, sample sizes of some subgroups were small, especially subgroups in non-level I trauma facilities. Fourth, field triage criteria that can adequately predict MT (ISS > 15) do not yet exist [2]. Instead, paramedics and physicians use on scene vital parameters, guidelines, and maybe even more importantly instinct and experience to determine which patients require level I trauma care, for which we could not adjust.

Strengths

A strength is the use of a large dataset from a trauma region in which all hospitals participate in trauma registration. The dataset contained most relevant clinical parameters for predicting in-hospital mortality [45] and there were hardly any missing data, which allowed multivariable analysis. By adjusting for transfers and excluding elderly patients with isolated hip fractures, selection bias was minimized. Second, looking at MT populations and non-MT populations, per injured body region, has given a broad overview of clinical outcome measures across levels of trauma care based on anatomically coded injuries.

Conclusion

This study found that a level I TC performed equally as non-level I trauma facilities comparing in-hospital mortality among severely injured patients, while patients admitted to the level I TC were more severely injured. Hospital and ICU length of stay were significantly shorter for patients admitted to non-level I trauma facilities and patients admitted to non-level I trauma facilities were more likely to be discharged home, subgroup analysis confirmed these findings for MT and non-MT patients and as well for the subgroups per injured body region. Subgroups analysis on clinical outcome measures across different levels of trauma care in an inclusive trauma network is too simplistic if subgroups are based on injuries in specific body region or ISS only, (Fig. 1, Fig. 2,Table 1).

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. Artificial intelligence was not used for writing the article.

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.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.injury.2023.111208.

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