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Evaluating associations between level of trauma care and outcomes of patients with specific severe injuries: A systematic review and meta-analysis

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BACKGROUND: Trauma networks have multiple designated levels of trauma care. This classification parallels concentration of major trauma care, creating innovations and improving outcome measures.

OBJECTIVES: The objective of this study is to assess associations of level of trauma care with patient outcomes for populations with specific severe injuries.

METHODS: A systematic literature search was conducted using six electronic databases up to April 19, 2022 (PROSPERO CRD42022327576). Studies comparing fatal, nonfatal clinical, or functional outcomes across different levels of trauma care for trauma populations with specific severe injuries or injured body region (Abbreviated Injury Scale score ≥3) were included. Two independent reviewers included studies, extracted data, and assessed quality. Unadjusted and adjusted pooled effect sizes were calculated with random-effects meta-analysis comparing Level I and Level II trauma centers.

RESULTS: Thirty-five studies (1,100,888 patients) were included, of which 25 studies (n = 443,095) used for meta-analysis, suggesting a survival benefit for the severely injured admitted to a Level I trauma center compared with a Level II trauma center (adjusted odds ratio [OR], 1.15; 95% confidence interval [CI], 1.06–1.25). Adjusted subgroup analysis on in-hospital mortality was done for patients with traumatic brain injuries (OR, 1.23; 95% CI, 1.01–1.50) and hemodynamically unstable patients (OR, 1.09; 95% CI, 0.98–1.22). Hospital and intensive care unit length of stay resulted in an unadjusted mean difference of −1.63 (95% CI, −2.89 to −0.36) and −0.21 (95% CI, −1.04 to 0.61), respectively, discharged home resulted in an unadjusted OR of 0.92 (95% CI, 0.78–1.09).

CONCLUSION: Severely injured patients admitted to a Level I trauma center have a survival benefit. Nonfatal outcomes were indicative for a longer stay, more intensive care, and more frequently posthospital recovery trajectories after being admitted to top levels of trauma care. Trauma networks with designated levels of trauma care are beneficial to the multidisciplinary character of trauma care. (*J Trauma Acute Care Surg.* 2023;94: 877–892. Copyright © 2023 The Author(s). Published by Wolters Kluwer Health, Inc.)

LEVEL OF EVIDENCE: Systematic review and meta-analysis; Level III.

KEY WORDS: Trauma centers; health care outcome assessment; critical care; wounds and injuries; multiple trauma.

Trauma is one of the leading causes of death worldwide. Injuries account for 8% of global mortality, taking the lives of nearly 4.5 million people around the world each year.[1] These deaths, represent a fraction of those injured each year and many trauma patients suffer from long-term morbidity.[2] In the pursuit of optimal care for trauma patients, regional trauma systems have been implemented worldwide, showing significant improvement in trauma outcomes.[3–7]

Regional trauma systems can be distinguished by inclusive and exclusive trauma networks. Within an exclusive trauma network, care is limited to several highly specialized hospitals, whereas all facilities within inclusive designated trauma networks participate in care for injured patients. Hospitals are commonly categorized by level based on criteria developed by professionals. These criteria sets are dependent on local public health care context. Higher-level facilities have more continuously available resources for the most severely injured patients, lower-level facilities are utilized for patients with minor injuries.[7,8]

When assessing outcomes across levels of trauma care, major trauma (MT) (Injury Severity Score [ISS] > 15) patients benefit from the highest level of trauma care.[9] However, defining MT based on an anatomical scoring system has restrictions. The ISS might underestimate the severity of injury for some trauma patients,[10,11] and MT populations are very heterogeneous. It would be of great interest zooming in on the beneficial effect of trauma center designation on patients with specific severe injuries.[12]

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This study aimed to provide an overview, including data synthesis, of clinical outcomes in subgroups of severely injured trauma populations across different levels of trauma care in trauma networks.

METHODS

This systematic review was reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA[13]) checklist (Supplemental Table 1, http://links.lww.com/TA/C851) and was registered in the International Prospective Register of Systematic Reviews (PROSPERO[14]) under identification number CRD42022327576 (submission date April 24, 2022; publication date June 9, 2022).

Search Strategy and Selection Criteria

On April 19, 2022 search engines Embase via embase.com, Medline ALL via Ovid, Web of science Core Collection, Cochrane Central registry of trials and Google scholar were used to identify publications examining trauma patient outcomes in relation to trauma center level comparison. Search terms were designed by an experienced biomedical information specialist (W.M.B.), and provided in Appendix A, Supplemental Table 2, http://links.lww.com/TA/C852. The search combined thesaurus terms and words and phrases in title and abstract in many variations for (a) emergency service or trauma ward; (b) tertiary center or academic hospital; (c) lower-level centers, such as secondary or primary health care with (d) outcomes, such as mortality and length of stay (LOS). Titles and abstracts of retrieved references were reviewed using the method as published by Bramer et al.[15] in EndNote[16] (version 20, The Endnote Team; Clarivate, Philadelphia, PA).

Studies comparing different levels of trauma care for traumatic injuries in relation to fatal and nonfatal clinical outcome measures were considered eligible for inclusion. Studies were included if they examined specific severe injuries or severely injured body regions (Maximum Abbreviated Injury Scale [MAIS] ≥ 3 or ISS > 15), of all causes, and the studied population was 14 years or older. Studies focusing on general (major) trauma populations, transferred patients, burn patients, pediatric patients, or patients with an isolated hip fracture were excluded, as well as studies addressing trauma system implementation, geography, volume-outcome, economic evaluation, prediction, or general public health issues. Nonavailable full-text articles, conference abstracts, forums,

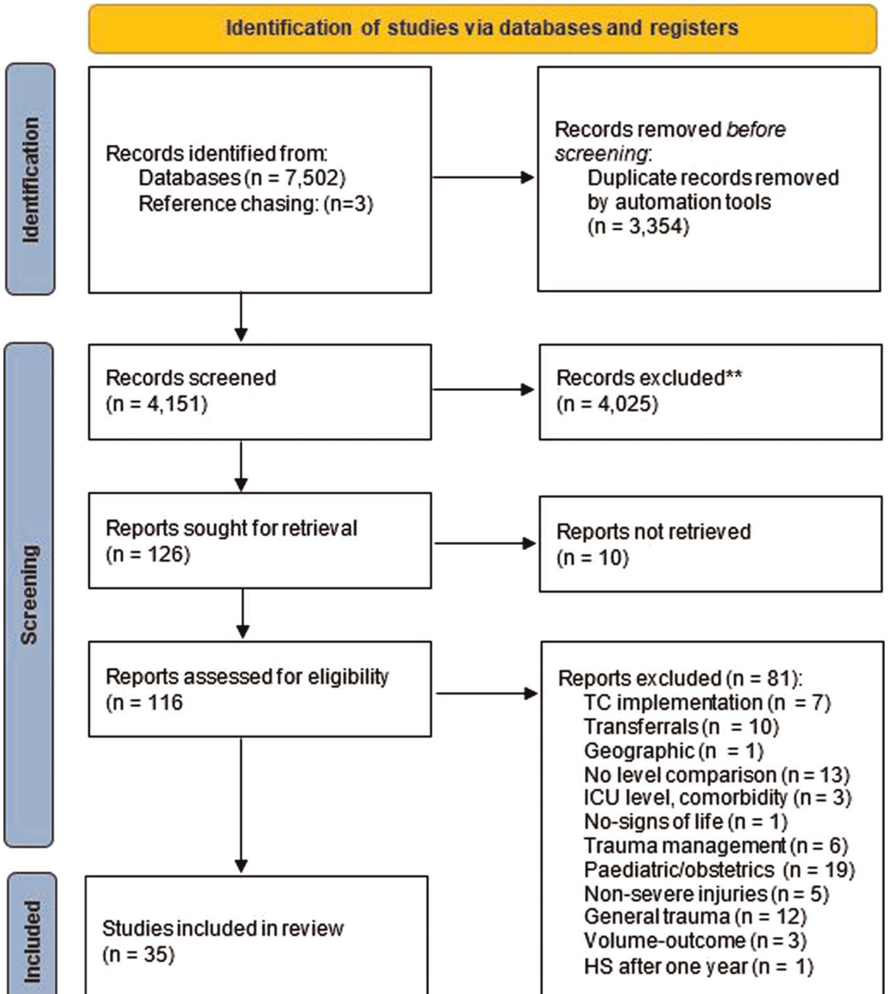

Figure 1. PRISMA 2020 flow diagram. The study selection flow diagram is depicted.

TABLE 1. Characteristics and Key Findings of Included Articles

Author, Year	Level Comparison	Study Design	Country	Data Source	Period	Inclusion	Exclusion	Sample Size	ISS (Mean, Median, Min)	Outcome	Overall Key Findings
Traumatic Brain Injury											
Alkhoury et al., 2011[22]	Level I vs. II (ACS)	RCS	United States	NTDB	2001–2006	Isolated TBI, ED GCS score < 9	Incomplete records	31,736	(GCS score 3–4:74%)	Mortality, HLOS, ICU LOS, MVD, DD, major CR	Mortality crude: Level I = II. DD home: Level I > II. HLOS, ICU LOS, MVD, CR DVT: Level I > II.
Brown et al., 2010[50]	Level I vs. Level II (ACS)	RCS	United States	NTDB	2002–2006	ED GCS score ≤ 12, survived to discharge	Incomplete FIM scores	25,170	GCS score ≤ 8: LI: 21 (13) LII: 21 (13) GCS score 9–12: LI: 15 (12) LII: 14 (11)	HLOS, FIM (FI, IE)	FI, IE, HLOS severe TBI: Level I > II. FI, IE, HLOS moderate TBI: Level I = II.
Chalouhi et al., 2019[26]	Level I vs. Level II (PTSF)	RCS	United States	PTOS	2002–2017	Age ≥18 y, TBI GCS score < 9, craniotomy, craniectomy	-	3,980	LI: 29.5 (10.2 LII: 29.6 (9.5)	Mortality, HLOS, ICU LOS, FIM at discharge	Mortality: Level I < II. FIM, HLOS, ICU LOS: Level I > Level II.
Deng et al., 2019[29]	Level I ACS vs. Level II ACS vs. other (level unknown and unranked)	RCS	United States	NTDB (NSP)	2003–2012	Age ≥18 y, TBI firearm injured	Missing data outcome variables	8,148	77% ISS > 15 10% ISS missing	Mortality, HLOS, ICU LOS, CR, DD	Mortality, HLOS, ICU LOS, CR: Level I = II. DD home: Level I > II.
DuBose et al., 2008[30]	Level I vs. Level II (ACS)	RCS	United States	NTDB	5-year period	Isolated TBI MAIS ≥3, Other injury MAIS <3	DOA	16,035	LI: 20.6 (9.9) LII: 20.9 (9.7)	Mortality, HLOS, ICU LOS, MVD, CR, FIM	Mortality, CR: Level I < Level II. HLOS, ICU LOS: level I > II. MVD, FIM: level I = II.
Gupta et al., 2020[33]	Level I vs. Level III (ACS)	RCS	United States	TR Medical charts	2012–2014	Age ≥18 y, TBI GCS score ≥ 13, CT diagnosed minor injuries	Open skull fracture, intubation, HU, bleeding diathesis history, MAIS >2 other than head	191	LI: 16 (10–17) LIII: 10 (9–13)	Mortality, HLOS, ICU LOS, CR, need for TBI interventions	Mortality crude, CR, ICU LOS, need for TBI interventions: Level I = III. HLOS: level I > II.
Haas et al., 2008[54]	Level I (ACS or state/ regional) vs. nondesignated TC	PCS	United States	NSCOT	7/2001–11/2002	Age 18–84 y, TBI MAIS ≥3, pupillary abnormality, CT midline shift, English/Spanish-speaking, US residents	No vital signs and death <30 m, presentation ≥24 h, age ≥65 y and isolated hip fracture, major burns, isolated gunshot head, incarcerated, homeless	766	TC: 30.9 (17.0) Non-TC: 23.6 (9.6)	Mortality, ICU admission	Mortality in patients receiving early operative intervention: level I < non-TC.
Kaufman et al., 2018[53]	Level I/II vs. neurosurgery capable nondesignated TC	RCS	United States	State ED Database, State Inpatient Database	2011–2012	TBI or neck MAIS ≥3, MAIS ≤2 other	Late effects or complications of injury	62,198	TC: 14 (10–17) Non-TC: 14 (10–16)	Mortality, DD	Mortality: TC = neurosurgery capable non-TC. DD home: TC > neurosurgery capable non-TC.
Plurad et al., 2021[45]	Level I vs. Level II (ACS)	RCS	United States	TQP-PUF	2017	Age 16–90 y, TBI MAIS ≥3, MAIS <3 other	Transfers	39,764	LI: 16.6 (6.7) LII: 15.4 (7.1)	Mortality, HLOS, ICU LOS, DD, procedures performed, CR.	Mortality: Level I = level II. HLOS, ICU LOS, DD: level I > level II.

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TABLE 1. (Continued)

Author, Year	Level Comparison	Study Design	Country	Data Source	Period	Inclusion	Exclusion	Sample Size	ISS (Mean, Median, Min)	Outcome	Overall Key Findings
Yeates et al., 2020[49]	Level I vs. II (ACS)	RCS	United States	TQIP	2010–2016	Age ≥18 y, TBI MAIS >3	Death <24 h, nonsurvivable TBI (MAIS = 6)	204,895	LI: 17 (12) LII: 17 (12)	Mortality, HLOS, ICU LOS, VTE rate, chemo prophylaxis initiation time	Mortality crude, HLOS, ICU LOS: level I = level II.
Spinal Injuries											
Baron et al., 2021[23]	Level I vs. II (ACS)	RCS	United States	TQIP	2013–2015	Spinal trauma	Transfer, missing data on ACS level MAIS spine = 6, death/discharge <24 h, MAIS >2 other than head	21,580	LI: MAIS ≥3 65% LII: MAIS ≥3 64%	Mortality, HLOS, ICU LOS, CR	Mortality, HLOS: Level I = II. ICU LOS: Level I > II. CR: Level I < Level II.
Macias et al., 2009[41]	Level I + II vs. non-TC	RCS	United States	State hospital discharge files MEDPAR	2001	Age ≥16 y, SCI with or without fracture	Late effects or complications due to medical/surgical care, foreign bodies, poisoning, external causes	4,121	TC: 19.1 (0.3) non-TC: 14.7 (0.2)	Mortality, paralysis rate	Mortality: Level I = II.
Williamson et al., 2021[37]	Level I vs. II + III + IV (ACS)	RCS	United States	NTDB	2011–2014	Age ≥18 y, SCI with fracture	Concurrant TBI, self-reported multiple race, missing data on surgery/transfer/ACS level, ISS < 2, ED-SBP < 40, Invalid records	10,844	LI: 25 (16–33) LII + III + IV: 21 (14–29)	Mortality, HLOS, ICU LOS, MVD, DD	Mortality, MVD: Level 1 = Level II + III + IV. HLOS, ICU LOS, DD: Level I > level II + III + IV
Thoracic injuries											
Ahmed et al., 2019[21]	Level I + II (ACS) vs. III + IV (ACS) + unranked institutions	RCS	United States	NTDB	2012–2014	Age ≥65 y, thoracic MAIS >0 after GLF	No signs of life	15,256	High level: 9 (5–13) low level: 9 (5–12)	Mortality, HLOS	Mortality, HLOS: TC level high = low.
Bukur et al., 2012[25]	Level I vs. II vs. III + IV (ACS)	RCS	United States	NTDB	5-year period	Patients receiving thoracotomy	Missing time to procedure, Thoracotomy <1 h, Missing data on ACS level	2,367	LI: 31.3 (18.9) LII: 30.9 (19.2) LIII/IV: 32.0 (21.8)	Mortality, HLOS, ICU LOS, MVD	Mortality, HLOS, ICU LOS, MVD: level I = II = III + IV.
Checchi et al., 2020[27]	Level I vs. II vs. other (ACS + non-ACS state designated)	RCS	United States	NTDB	2013–2016	Age ≥16 y, Penetrating injuries	Transfers	68,727	MAIS ≥3 16 (10–25)	Mortality	Mortality: level I = II.
Choi et al., 2021[28]	Level I + II + III vs. IV + unranked (ACS)	RCS	United States	NEDS	2016	Age ≥18 y, rib fractures	Missing data on ACS level, transfers, death at ED	504,085	TC: 7.7 (0.3) non-TC: 3.8 (0.6)	ED mortality, ED DD, mortality, HLOS, SSRF, DD	Mortality: level I + II + III = IV + unranked. HLOS, DD: level I + II + III > IV + unranked
Oliver et al., 2019[55]	Level I vs. non–Level I (state designated)	RCS	United States	NTDB	2014–2015	Patients receiving thoracotomy < 24 h	Missing time of thoracotomy, missing DD	3,183	LI: 25 (16–38) non-LI: 25 (16–36)	Mortality (in-hospital survival)	Mortality: level I < II.

Rockne et al., 2021[46]	Level I vs. II (ACS)	RCS	United States	TQIP	2010–2015	Age ≥18 y, rib fractures with SSRF	—	14,046	LI: 22 (14–29) LII: 19 (14–27)	Mortality, HLOS, ICU LOS, MVD, respiratory CR, DD	Mortality, CR: level I = II. HLOS, DD: Level I > II. ICU LOS, MVD: level I < II.
Abdominal injuries											
Harbrecht et al., 2004[34]	Level I vs. II (PTSF)	RCS	United States	PTOS	1998–2000	Age ≥16 y, Patients with splenic injuries	Death at ED, penetrating injuries	2,138	LI: 26.0 (0.4) LII: 26.2 (0.5)	Mortality, HLOS, ICU LOS, operative/ nonoperative (success/failed) management	Mortality crude: Level I = II. HLOS, ICU LOS: Level I > II.
Helling et al., 1997[35]	Level I vs. II (Missouri state designated)	PCS	United States	Hospital records Patient charts	1987–1992	Patients with liver injuries	Death before liver CT or laparotomy, TBI MAIS ≥2, transfer <24 h	300	LI: 22 (14.2) LII: 20 (10.3)	Mortality, HLOS, ICU LOS, time to OR	Mortality crude, HLOS: Level I = II. ICU LOS: level I < II.
Hotaling et al., 2012[38]	Level I vs. II vs. III + IV	RCS	United States	NTDB	2002–2007	Patients with renal injuries converted to AAST grades	Patients with AIS codes mapped >1 AAST grades	6,290	LI: 22.0 (20) LII: 20.1 (21) LIII-IV: 19.5 (23)	Mortality, HLOS, ICU LOS, DD, successful initial management, nephrectomy rates	Mortality crude: level I = II. HLOS, ICU LOS: level I > II. DD: level I < II. Conservative therapy: level I > II / III + IV. Definite initial therapy: level I > II / III + IV.
Lewis et al., 2021[52]	Level I vs. II (ACS)	RCS	United States	TQIP	2013–2016	Age ≥16 y, blunt liver injuries (MAIS ≥3)	Penetrating injuries, transfer in, MAIS ≥3 other than liver, death <72 h, no LMWH administered for VTE prophylaxis	2,825	≥9 40% ISS > 15	Mortality, HLOS, ICU LOS, CR	Mortality, MVD: level I = II. HLOS, ICU LOS, CR: level I < II.
Sheehan et al., 2020[47]	Level I vs. II (ACS)	RCS	United States	TQIP	2010–2016	Age ≥18 y, penetrating abdominal aortic injury	—	378	LI: 26.0 (9) LII: 25.0 (5)	Mortality, HLOS, ICU LOS, MVD, time to hemorrhage control, type of operation, blood product transfusion, CR	Mortality, HLOS, ICU LOS, MVD, CR: Level I = II
Tignanelli et al., 2018[48]	Level I vs. II (ACS)	RCS	United States	TQIP	2011–2016	Age ≥16 y, blunt liver injuries (MAIS ≥3)	No signs of live at ED, transfer	454	≥5 82% ISS > 15	Mortality, HLOS, ICU LOS, death <48 h, management strategy, CR, failure to rescue	Mortality: Level I < II. HLOS, CR: level I = II. ICU-LOS: level I > II.
Hemodynamically unstable											
Dufresne et al., 2017[31]	Level I vs. II vs. III vs. IV (ACS)	RCS	Canada	Quebec TR	1998–2014	Age ≥16 y, SBP < 90, surgical care or death without <6 h, torso injury (MAIS ≥4)	TBI MAIS >3	922	>15	Mortality, surgical delay, CR, HLOS	Mortality: level I < II/III/IV. CR, HLOS: level I > II.

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TABLE 1. (Continued)

Author, Year	Level Comparison	Study Design	Country	Data Source	Period	Inclusion	Exclusion	Sample Size	ISS (Mean, Median, Min)	Outcome	Overall Key Findings
Haas et al., 2008[54]	Level I (ACS or state) vs. nondesignated TC	PCS	United States	NSCOT	7/2001–11/2002	Age 18–84 y, penetrating injury (MAIS ≥3), SBP < 90, English/ Spanish-speaking, US residents	No vital signs and death within 30 m, presentation ≥24 h age ≥65 y and isolated hip fracture, major burns, isolated gun shot head, incarcerated, homeless	565	TC: 19.1 (22.0) non-TC: 17.9 (15.2)	Mortality, ICU admission	Mortality in patients receiving early operative intervention: level I < non-TC.
Hamidi et al., 2019[51]	Level I vs. II (ACS)	RCS	United States	TQIP	2013–2014	Age ≥18 y, MTP, transfusion ≥10 units pRBC <24 h	Transfer in, DOA	2,776	LI: 29 (19–41) LII: 27 (18–38)	Mortality, HLOS, ICU/MV free LOS, blood transfusion, CR	Mortality, HLOS: Level I < II. CR: Level I > II
Herrera-Escobar et al., 2018[36]	Level I vs. II (ACS)	RCS	United States	NTDB	2007–2012	Age 18–64 y, ISS > 15, SBP < 90	Transfer, DOA, Patients with burns, missing data on ED SBP / injury mechanism	13,846	LI: 27 (22–38) LII: 27 (22–38)	Mortality <24 h, mortality, ICU admission, MV requirement	Mortality 4–7 h postadmission: Level I < II.
Plurad et al., 2021[45]	Level I vs. II (ACS)	RCS	United States	TQP-PUF	2017	Age ≥14 y, SBP < 90		7,264	LI: 19.3 (15) LII: 16.7 (14)	Mortality, HLOS, ICU LOS	Mortality, ICU LOS: Level I = II. HLOS: level I > II.
Penetrating torso injuries											
Grigorian et al., 2019[32]	Level I vs. Level II (ACS)	RCS	United States	TQIP	2010–2016	Patients with gunshot injuries	Patients with severe/critical/ MAIS = 6 of head/ neck/extremities, missing data on ACS level, Transfer	17,965	LI: 14 (9–24) LII: 14 (9–22)	Mortality, HLOS, ICU LOS, MVD, blood products transfusion, thoracotomy, time to surgical intervention, CR	Mortality: Level I < II. HLOS, MVD: level I = II. ICU LOS, CR: Level I > II.
Lower-extremity injuries											
Bouzat et al., 2013[24]	Level I vs. Level II	RCS	France	Trenau	2009	Patients with pelvic injuries (MAIS ≥3)	Patients with Isolated acetabular fractures	65	LI: 30 (13–75) LII: 22 (9–59)	Mortality, TRISS	Mortality crude: level I < II. Mortality O/E: Level I = II.
Jakob et al., 2021[39]	Level I vs. Level II (ACS)	RCS	United States	TQIP	2013–2016	Age ≥18 y, pelvic fracture (MAIS ≥3), Primary admission	Penetrating injuries death <72 h, MAIS ≥3 other than pelvic, Angiography >24 h, Unknown or VTE prophylaxis other than UH/LMWH	3,906	≥9 26% ISS >15	Mortality, HLOS, ICU LOS, CR	Mortality, HLOS: Level I = II. ICU-LOS, CR: Level I < II
Khoury et al., 2016[40]	Level I vs. II	PCS	Israel	NTR, EMS, ED, hospital records, survey	—	Age ≥18 y, femoral shaft fracture (AO/OTA 32 group)	Age ≥65 y patients with pathological fractures Discharged without signing IC	238	≥9 52% ISS > 15	Mortality, HLOS >11 days, ICU admission, CR, DD	Mortality crude, CR: Level I > II. HLOS >11 d, DD: Level I = II.

Morshed et al., 2015[42]	Level I vs. IV + other	RCS	United States	NSCOT	2001–2002	Age 18–84 y, Pelvic/Acetabular inury, Other MAIS ≥3, English speaking, US residents	No vital signs and death within 30 m, presentation ≥24 h age ≥65 y and isolated hip fracture, major burns, homeless, incarcerated	2,644	LI: 11.3 (14.7) Non-TC: 22.5 (22.3) LI: 22.3 (44.8) Non-TC: 21.0 (25.0) (weighted)	Mortality, death <90 days, SF-36 and MFA after 1 year	Mortality: Level I = nontrauma centers. SF-36, MFA 1 y: Level I > non-TC.
Oliphant et al., 2018[43]	Level I vs. II (ACS)	RCS	United States	MTQIP	2011–2017	Age ≥16, ISS ≥ 5, (partially unstable) pelvic ring fracture	Penetrating injuries No signs of life ED transfer missing critical data	1,220	≥5 71% ISS > 15	Mortality, death <48 h, HLOS, ICU LOS, initial management, orthopedic strategy, CR, failure to rescue	Mortality: Level I < II. HLOS, ICU LOS, CR: Level I = II.

In-hospital mortality is addressed as mortality, unless stated otherwise. ACS, American College of Surgeons; Retrospective Cohort Study; NTDB, National Trauma Data Bank; TBI, traumatic brain injury; ED, emergency department; GCS, Glasgow Coma Scale; MVD, Mechanical Ventilation duration; DD, discharge destination; CR, complication rate; DVT, deep venous thrombosis; FIM, functional independence measure; GLF, ground level fall; FI, functional independence; IE, independent expression; PTOS, Pennsylvania Trauma Outcome Study; NSP, National Sample Program; DOA, dead on arrival; TR, Trauma Registry; CT, computed tomography; HU, Hemodynamically Unstable; TC, trauma center; NSCOT, National Study on Costs and Outcomes of Trauma; TQP-PUF, Trauma Quality Program Participant Use File; TQIP, Trauma Quality Improvement Program; VTE, Venous Thromboembolic Event; MEDPAR, Medicare Provider Analysis and Review; SCI, Spinal Cord Injury; NEDS, National Emergency Department Sample; SSRF, surgical stabilization of rib fractures; PTSF, Pennsylvania Trauma System Foundation; AAST, The American Association for the Surgery of Trauma; LMWH, low molecular weight heparin; UH, unfractionated heparin; SBP, Systolic Blood Pressure; MTP, Massive Transfusion Protocol; pRBC, packed red blood cell; TRISS, Trauma Revised Injury Severity Score; O/E, Observed Expected; MTQIP, Michigan Trauma Quality Improvement Program; PCS, Prospective Cohort Study; NTR, National Trauma Registry; EMS, Emergency Medical Services; AO/OTA, Arbeitsgemeinschaft für Osteosynthesefragen/Orthopedic Trauma Association; IC, informed consent; SF-36, Short Form-36; MFA, Musculoskeletal Function Assessment.

panel discussion, or experience talk were also excluded. Two reviewers (J.C.V.D. and C.A.S.) screened titles and abstracts for eligibility. Full-text documents were retrieved and independently screened by two reviewers (J.C.V.D. and L.A.R.). Disagreements were resolved by consensus or by consulting a third reviewer (C.A.S.). Finally, all references of the full-text inclusions were screened for additional potential inclusions.

Data Extraction and Quality Assessment

Two reviewers (J.C.V.D. and L.A.R.) independently extracted characteristics on each included study: year of publication, type of trauma center level comparison, study design, country, study period, data source, sample size, inclusion and exclusion criteria, severity of injured population, population characteristics, study outcome measures, and key findings.

Quality assessment was performed by two reviewers (J.C.V.D. and L.A.R.) for each included study. Studies were scored using the Newcastle-Ottawa Scale (NOS),[17] creating international standardized comparability. In addition, a quality assessment tool, based on existing literature, was created to assess quality, generalizability, and risk of bias of the included studies.[18]

For data synthesis J.C.V.D. and L.A.R. collected data independently. The primary outcome parameter was in-hospital mortality. Secondary outcome parameters included hospital LOS (HLOS), intensive care unit (ICU) LOS and discharge destination with or without, home health.

Disagreements on characteristics of studies, quality assessment, or data extraction, were resolved through discussion, or by consulting a third reviewer (C.A.S.).

Data Analysis

Data were analyzed using the R Software Environment (version 4.1.1, The R Foundation for Statistical Computing, Vienna Austria).

To examine the association between trauma center level and clinical outcomes for traumatic injuries, a meta-analysis was performed. Subgroup analyses were performed for severely injured patients with injuries in a specific body region, patients with penetrating injuries, or hemodynamically unstable patients if three or more studies were found on specific injuries.

The main focus was a comparison of Level I (highest level) and non–Level I trauma care. If level distinction was not numerical, the highest level of care was used to compare with lower levels of trauma care. Tertiary, academic trauma care and MT centers were considered the equivalent of Level I, if a study was conducted outside the United States. When studies compared multiple levels, all individual comparisons were included in the meta-analysis. When studies merged levels in their comparison, results were only included in qualitative analysis.

For unadjusted meta-analysis crude numbers and adjusted odds ratios (ORs) with 95% confidence intervals (95% CIs) were extracted for binary/categorical outcome measures and means with standard deviation (SD) and absolute numbers for continuous outcome measures. For adjusted meta-analysis, adjusted OR with 95% CI were extracted. The Mantel-Haenszel method was used to provide a pooled unadjusted OR, the inverse variance method provided a pooled adjusted OR and the mean difference (MD) with 95% CI was used as summary statistic for unadjusted

TABLE 2. Quality Assessment and NOS of Included Studies

Study, year, subgroup	Clear in- and exlusion criteria	Nation- or region wide	Registry based	AIS/ICD revision reported	Definition TC level	2 TC levels separated	Age ≥ 16	Overall ISS	ISS per level	Baseline per level	Mortality per level (crude)	Mortality per level (adj.)	HLOS per level (crude)	HLOS per level (adj.)	ICU LOS per level (crude)
Head															
Alkhoury, 2011[22]	+	+	+	+	+	+	-	-	-	+	+	-	+	-	+
Brown, 2010[50]	+	+	+	+	+	+	-	-	+	+	-	-	+	-	-
Chalouhi, 2019[26]	+	+	+	-	+	+	+	-	+	+	+	+	+	+	+
Deng, 2019[29]	+	+	+	+	+	+	+	+	-	-	+	+	-	+	-
DuBose, 2008[30]	+	+	+	-	+	+	-	+	+	+	+	+	+	-	+
Gupta, 2020[33]	+	-	+	-	+	+	+	-	+	+	+	-	+	-	+
Haas, 2018[54]	+	+	+	+	+	-	+	-	+	+	+	+	-	-	-
Kaufman, 2018[53]	+	+	+	+	+	-	-	-	+	+	+	+	-	-	-
Plurad, TBI, 2021[45]	+	+	+	-	+	+	+	+	+	+	+	+	+	-	+
Yeates, 2020[49]	+	+	+	-	+	+	+	-	+	+	+	-	+	-	+
Spinal injuries															
Baron, 2021[23]	+	+	+	-	+	+	-	-	-	+	+	+	+	+	+
Macias, 2009[41]	+	+	+	+	+	-	+	-	+	+	+	+	-	-	-
Williamson, 2021[37]	+	+	+	+	+	-	+	-	+	+	+	-	+	-	+
Thoracic injuries															
Ahmed, 2019[21]	+	+	+	+	+	-	+	+	+	+	+	+	+	-	-
Bukur, 2012[25]	+	+	+	+	+	+	-	-	+	+	+	+	+	-	+
Checchi, 2020[27]	+	+	+	+	+	+	+	+	-	-	+	+	-	-	-
Choi, 2021[28]	+	+	+	+	+	-	+	-	+	+	+	+	+	-	-
Oliver, 2019[55]	+	+	+	+	-	-	-	-	+	+	+	+	-	-	-
Rockney, 2021[46]	+	+	+	+	+	+	+	-	+	+	+	+	+	-	+
Abdominal injuries															
Harbrecht, 2004[34]	+	+	+	+	+	+	+	+	+	+	+	-	+	-	+
Helling, 1997[35]	+	-	-	-	+	+	-	-	+	+	+	-	+	-	+
Hotaling, 2012[38]	+	+	+	+	+	+	-	-	+	+	+	-	+	-	+
Lewis, 2021[52]	+	+	+	-	+	+	+	-	-	+	+	+	+	-	+
Sheehan, 2020[47]	+	+	+	+	+	+	+	-	+	+	+	+	+	-	+
Tignanelli, 2018[48]	+	+	+	+	+	+	+	-	-	+	-	+	-	+	-
Hemodynamically unstable															
Dufresne, 2017[31]	+	+	+	-	+	+	+	-	-	+	+	+	+	+	-
Haas, 2018[54]	+	+	+	+	+	-	+	-	+	+	+	+	-	-	-
Hamidi, 2019[51]	+	+	+	-	+	+	+	+	+	+	+	+	+	-	-
Herrera-Escobar, 2018[36]	+	+	+	-	+	+	+	-	+	+	+	+	-	-	-
Plurad, HU, 2021[44]	+	+	+	-	+	+	-	+	+	+	+	+	+	-	+
Torso penetrating injuries															
Grigorian, 2019[32]	+	+	+	+	+	+	-	-	+	+	+	+	+	-	+
Pelvic injuries & femoral shaft fractures															
Bouzat, 2013[24]	+	-	+	-	+	+	-	-	+	+	+	-	-	-	-
Jakob, 2021[39]	+	+	+	+	+	+	+	-	-	+	+	+	+	-	+
Khoury, 2016[40]	+	+	+	-	+	+	+	-	-	+	+	-	-	-	-
Morshed, 2015[42]	+	+	+	+	+	-	+	-	+	+	+	+	-	-	-
Oliphant, 2018[43]	+	+	+	+	+	+	+	-	-	+	-	+	-	+	-
Total + (%)	100	92	97	61	97	75	67	22	72	94	92	72	64	17	50

AIS, Abbreviated Injury Scale ICD, International Classification of Diseases; TC, Trauma Center; ISS, Injury Severity Score; adj., adjusted; HLOS, Hospital Length of Stay; ICU LOS, Intensive Care Unit Length of Stay; OR, Odds Ratio; CI, Confidence Interval; NOS, New Ottawa Scale; na, not applicable.

continuous outcome measures. Studies were pooled using a random-effects meta-analysis. Random effects were used to compensate for heterogeneity, thereby addressing differences in study periods, regional/geographical characteristics, and trauma populations. Heterogeneity between studies was assessed using both the I^2 and the X^2 statistics. I^2 values were used to interpret the amount

ICU LOS per level (adj.)	Discharge home per level (crude)	Discharge home per level (adj.)	OR's with 95% CI	All confounders reported	Adjusted for injury severity	Adjusted for demographics	Adjusted for comorbidity	Adjusted for transfer	Conflict of interest declared	Funding identified	NOS selection (4*)	NOS comparability (2*)	NOS outcome (3*)	NOS total (9*)
-	+	-	na	na	na	na	na	na	-	-	3*	0*	3*	6*
-	-	-	+	+	+	+	+	-	-	-	4*	2*	3*	9*
+	-	-	+	+	+	+	-	-	+	-	4*	2*	3*	9*
+	+	+	+	+	+	+	+	-	+	-	4*	2*	3*	9*
-	-	-	+	+	+	+	-	-	-	+	4*	2*	3*	9*
-	-	-	na	na	na	na	na	na	+	+	4*	0*	3*	7*
-	-	-	+	+	+	+	+	+	+	+	3*	2*	3*	8*
-	-	+	+	+	+	+	+	-	+	+	4*	2*	3*	9*
-	+	-	+	+	+	+	+	na	+	+	4*	2*	3*	9*
-	-	-	na	na	na	na	na	na	-	-	4*	2*	3*	9*
+	-	-	+	+	+	+	-	na	+	-	4*	2*	3*	9*
-	-	-	+	+	+	+	+	-	-	+	4*	2*	3*	9*
-	+	-	na	na	na	na	na	na	+	-	4*	2*	3*	9*
-	-	-	+	+	+	+	+	-	+	+	4*	2*	3*	9*
-	-	-	+	+	+	+	+	-	-	-	4*	2*	3*	9*
-	-	-	+	+	+	+	-	na	+	+	4*	2*	3*	7*
-	+	-	+	-	+	-	-	na	+	-	4*	2*	3*	9*
-	-	-	+	+	+	+	+	-	-	-	3*	2*	3*	8*
-	+	-	+	+	+	-	+	-	-	+	4*	2*	3*	9*
-	-	-	na	na	na	na	na	na	+	-	4*	2*	3*	7*
-	-	-	na	na	na	na	na	na	-	-	4*	0*	3*	7*
-	+	-	na	na	na	na	na	na	-	-	3*	2*	3*	8*
-	-	-	+	+	+	+	-	-	+	+	4*	2*	3*	9*
-	-	-	+	+	+	+	-	-	+	+	4*	2*	3*	9*
+	-	-	-	+	+	+	-	-	+	+	4*	2*	3*	9*
-	-	-	+	+	+	+	+	na	+	+	4*	2*	3*	9*
-	-	-	+	+	+	+	+	+	+	+	3*	2*	3*	8*
-	-	-	+	+	+	+	-	na	+	+	4*	2*	3*	9*
-	-	-	na	na	na	na	na	na	+	+	4*	2*	3*	9*
-	-	-	+	+	+	+	+	na	+	+	4*	2*	3*	9*
-	-	-	+	+	+	+	+	na	+	+	4*	2*	3*	9*
-	-	-	na	na	na	na	na	na	+	-	4*	1*	3*	8*
-	-	-	+	+	+	+	+	na	+	+	4*	2*	3*	9*
-	-	-	na	na	na	na	na	na	+	+	2*	0*	3*	5*
-	-	-	+	+	+	+	+	-	+	+	3*	2*	3*	8*
+	-	-	-	+	+	+	-	+	+	+	4*	2*	3*	9*
14	19	6	94	97	100	94	72	61	72	61				

of heterogeneity: 30% to 60% possible moderate, 50% to 90% possible substantial and 75% to 100% considerable.[19] Funnel plots were used to detect publication bias.[20]

As a comparative measure of effect for unadjusted OR, the number needed to treat for an additional beneficial outcome (NNTB) was calculated.

RESULTS

Search

The study selection PRISMA flow diagram is depicted in Figure 1. The initial search identified 7,502 records. After removing duplicates, 4,151 records were screened on title and abstract, resulting in 122 potentially eligible studies. After full-text screening 32 studies were included.[21–52] Three additional studies were identified using reference chasing,[53–55] resulting in 35 included studies for the systematic review; 10 studies on traumatic brain injuries (TBIs),[22,26,29,30,33,45,49,50,53,54] six studies on thoracic injuries,[21,25,27,28,46,55] six studies on abdominal injuries,[34,35,38,47,48,52] three studies on spinal cord injuries,[23,37,41] five studies on lower-extremity injuries,[24,39,40,42,43] and five studies on hemodynamically unstable patients.[31,36,44,51,54]

Study Characteristics

The included studies comprised a total of 1,100,888 patients with a minimum age of 14 years (Table 1). Most (n = 32, 91%) studies were retrospective cohorts,[21–34,36,37,39,41–53,55] three (9%) studies were prospective cohorts.[35,40,54] The majority (n = 32, 91%) were United States based,[21–23,25–30,32–39,41–55] one study was conducted in France,[24] one in Israel,[40] and one study in Canada.[31] A total of 26 (74%) studies[22–27,29–32,34–36,38–40,43–52] compared Level I with Level II trauma centers. Other studies compared Level I with unranked,[54,55] Level I with IV and unranked,[42] Level I/II with III/IV,[21,41] Level I/II with unranked,[53] Level I with III,[33] Level I with II/III/IV,[37] Level I/II/III with unranked.[28]

Quality Assessment

Included studies had clear inclusion and exclusion criteria (n = 35, 100%), distinct trauma center level definitions (n = 34, 97%), were registry based (n = 34, 97%), were national or regional (n = 32, 91%), and reported ISS per level (n = 25, 71%) (Table 2). A minimum age of 16 years or 18 years was used as inclusion criterion in 66% (n = 23) of the studies and 61% (n = 21) reported the Abbreviated Injury Scale or International Classification of Diseases revision used for coding injuries. Crude in-hospital mortality per level was reported in 91% (n = 32) of the included studies and 63% (n = 23) reported adjusted in-hospital mortality. A fair amount of these studies, reported confounders used in adjusted analysis (n = 23, 66%); 69% (n = 24) of studies adjusted analysis for injury severity, 69% (n = 24) for demographics, 43% (n = 15) for comorbidity, and 6% (n = 2) for transfers (54% [n = 19] of studies excluded transfers). Quality assessment and NOS[17] scores were comparable, studies scoring low on the NOS, scored low on quality assessment as well (69% [n = 24] had a perfect score).

In-Hospital Mortality - Systematic Review

Of all 34 studies reporting in-hospital mortality,[21–49,51–55] 11 studies (32%)[24,26,30–32,36,43,48,51,54,55] found Level I trauma centers are associated with lower in-hospital mortality versus non–Level I trauma centers (Table 1). Of these 11 studies, nine studies (82%)[24,26,30–32,36,43,48,51] compared Level I with Level II trauma centers. A total of 22 studies (65%)[21–23,25,27–29,33–35,37–39,41,42,44,46,47,49,52,53] reported no difference in in-hospital mortality across different levels of trauma care (Table 1). Of these 22 studies, 17 studies (77%)[22,23,25,27,29,34,35,38,39,41,44–47,49,52,55] compared Level I with Level II trauma centers. One study found Level I trauma centers to be associated with higher in-hospital mortality rates compared with Level II.[40]

Meta-Analysis—Unadjusted

Of 34 studies reporting in-hospital mortality, 22 studies (65%)[22–27,29–31,34–36,38–40,44–47,49,51,52] were included in the

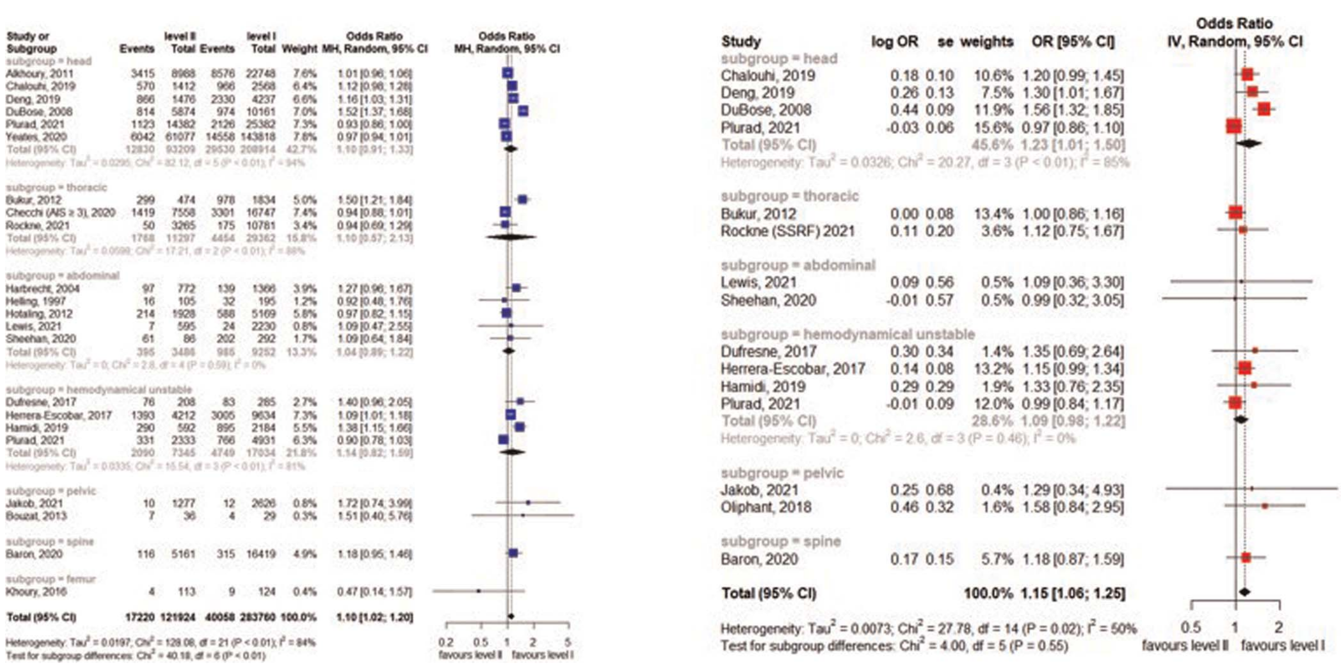

Figure 2. Meta-analysis for unadjusted (left) and adjusted (right) in-hospital mortality in severely injured trauma populations for Level I versus Level II trauma centers.

unadjusted meta-analysis on in-hospital mortality, comparing Level I and Level II trauma centers, comprising a total of 405,684 trauma patients (Fig. 2). The overall pooled unadjusted OR (95% CI) was 1.10 (1.02–1.20), I^2 = 84% (Fig. 2). Subgroup analysis was possible for TBI (OR, 1.10; 95% CI, 0.91–1.33),[22,26,29,30,45,49] thoracic injuries (OR, 1.10; 95% CI, 0.57–2.13),[25,27,46] abdominal injuries (OR, 1.04; 95% CI, 0.89–1.22),[34,35,38,47,52] and hemodynamically unstable patients (OR, 1.14; 95% CI, 0.82–1.59).[31,36,44,51] Overall and for subgroups, heterogeneity was strong (I^2, 81–94%). There was no suggestion of publication bias (Fig. 4).

Meta-Analysis—Adjusted

Adjusted meta-analysis on in-hospital mortality comparing Level I and Level II trauma centers, included 15 (44%) studies[23,25,26,29–31,36,39,43–47,51,52] (n = 135,861) with a pooled adjusted OR (95% CI) of 1.15 (1.06–1.25) (I^2 = 50%) (Fig. 2). Subgroup analysis was possible for TBI (OR, 1.23; 95% CI, 1.01–1.50)[26,29,30,45] and hemodynamically unstable patients (OR, 1.09; 95% CI, 0.98–1.22).[31,36,44,51] Overall and for subgroups, heterogeneity was strong (I^2, 50–85%). There appeared to be no publication bias (Fig. 4).

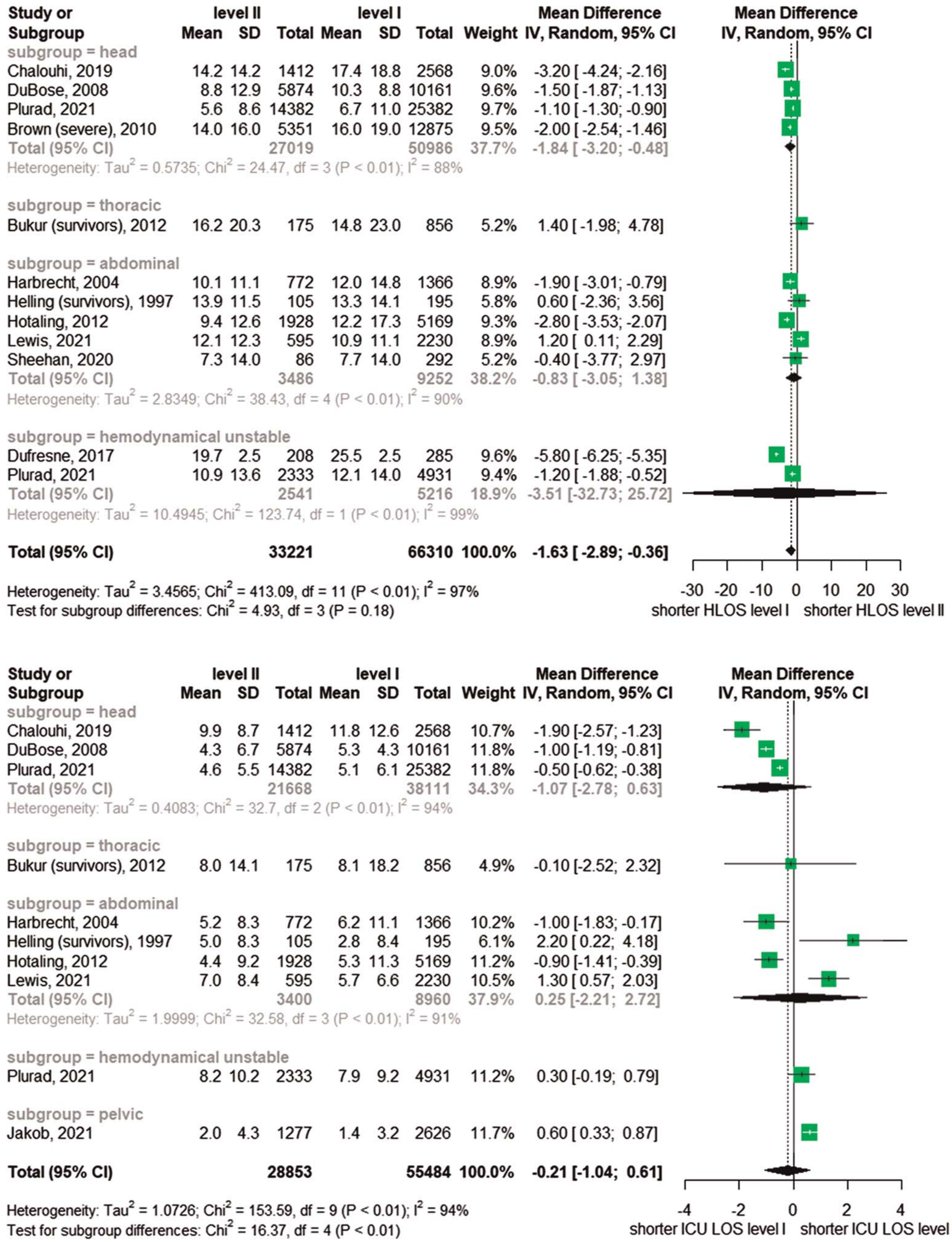

Figure 3. Meta-analysis unadjusted HLOS (upper) and ICU LOS (lower) in severely injured trauma populations for Level I versus Level II trauma centers.

Hospital LOS—Systematic Review

Of all studies, 26 studies (74%)[21–23,25–35,37–39,43–52] reported on HLOS comparing higher with lower level trauma centers, of which 19 studies (73%)[22,23,25,26,30–32,34,35,38,39,44–47,49–52] compared Level I with Level II trauma centers (Table 1). A total of 13 studies (50%)[22,26,28,30,31,33,34,37,38,44–46,50] found lower level trauma centers associated with shorter HLOS than at higher levels, 11 studies (42%)[21,23,25,29,32,35,39,43,47–49] reported no significant difference, and 2 studies (11%)[51,52] found a significant difference in HLOS in favor of Level I trauma centers.

Meta-Analysis

Twelve studies (46%),[26,30,31,34,35,38,44,45,47,50,52] comparing Level I and Level II trauma centers, reported a mean (SD) HLOS, comprising a total of 99,531 trauma patients, resulting in an overall pooled unadjusted MD of −1.63 (95% CI, −2.89 to −0.36; $I^2 = 97\%$; $\chi^{2-} = 4.93$; $p < 0.18$) (Fig. 3). Subgroup analysis was possible for TBI patients (MD, −1.84; 95% CI, −3.20 to −0.48),[26,30,45,50] and patients with abdominal injuries (MD, −0.83; 95% CI, −3.05 to 1.38).[34,35,38,47,52] Overall and for subgroups, heterogeneity was strong (I^2, 60–97%). There was an indication of possible publication bias (Fig. 4). As a side note, three of the included studies[25,29,35] based HLOS solely on survivors.

ICU LOS—Systematic Review

Of all studies, 21 studies (60%)[22,23,25,26,29,30,32–35,37–39,43–49,52] reported ICU LOS comparing higher and lower level trauma centers (Table 1). A total of 10 studies (48%)[22,23,26,30,32,34,37,38,45,48] found lower level trauma centers associated with shorter ICU LOS compared with higher levels, seven studies (33%)[25,29,33,43,44,47,49] reported no significant differences in ICU LOS between higher and lower level trauma centers, and four studies (19%)[35,39,46,52] found a significant lower ICU LOS in Level I trauma centers.

Meta-Analysis

Ten studies (43%),[25,26,30,34,35,38,39,44,45,52] comparing Level I and Level II trauma centers, reported a mean (SD) ICU LOS, comprising a total of 84,337 trauma patients, resulting in an overall pooled unadjusted MD (95% CI) of −0.21 (−1.04–0.61) ($I^2 = 94\%$, $\chi^{2-} = 16.37$, $p < 0.01$) (Fig. 3). Subgroup analysis was possible for TBI (MD, −1.07; 95% CI, −2.78 to 0.63)[26,30,45] and patients with abdominal injuries (MD, 0.25; 95% CI, −2.21 to 2.72).[34,35,38,52] Overall and for subgroups, heterogeneity was strong (I^2, 91–94%). There was an indication of possible publication bias (Fig. 4). As a side note, three of the included studies[25,29,35] based ICU LOS solely on survivors.

Mechanical Ventilation Duration—Systematic Review

Mechanical ventilation duration was reported by eight studies,[22,25,30,32,37,46,47,52] comparing higher with lower level trauma centers, of which seven studies[22,25,30,32,46,47,52] compared Level I with Level II trauma centers (Table 1); five studies[25,30,32,47,52] found no significant differences, two studies[22,37] reported longer, and one study[46] found shorter mechanical ventilation duration in Level I trauma centers.

Complications—Systematic Review

Complications of any kind were reported by 16 studies (46%),[22,23,29–33,37,39,40,43,46–48,51,52] comparing higher with lower level trauma centers (Table 1); seven studies[22,29,31,33,40,47,48] found no significant differences between Level I and non–Level I trauma centers, and five studies[39,43,46,51,52] reported no differences,

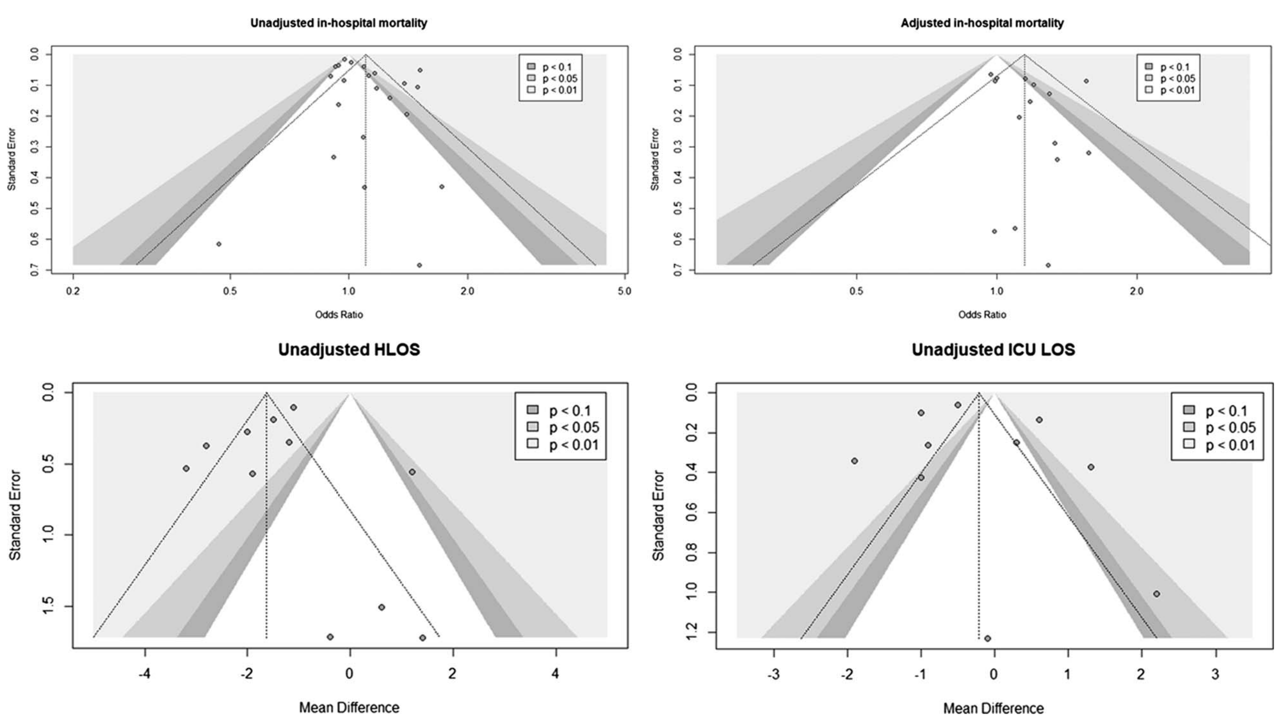

Figure 4. Funnel plots on publication bias: Upper left unadjusted in-hospital mortality, upper right adjusted in-hospital mortality, lower left unadjusted HLOS, lower right unadjusted ICU LOS.

except for a higher rate in Level I trauma centers of acute respiratory distress syndrome, a ventilator assisted pneumonia,[52] and pulmonary embolism.[46] Lower complication rates of any kind in Level I trauma centers were found in two studies,[23,30] and one study[32] found higher complication rates of any kind but similar rates of acute respiratory distress syndrome and DVT in Level I trauma centers.

Discharge Destination Home (With or Without Home Health)—Systematic Review

Of all included studies, nine studies[22,28,29,37,38,40,45,46,53] (26%) reported discharge destination home comparing higher- and lower-level trauma centers (Table 1); six studies[22,28,29,45,46,53] (67%) found higher level trauma centers to be associated with a larger percentage of patients discharged home, two studies[37,40] (22%) reported no significant difference, and one study[38] (11%) associated lower-level trauma centers with a larger percentage of patients discharged to home.

Meta-Analysis

Of the nine studies reporting discharge destination home, six studies (67%) were included in the unadjusted meta-analysis, comparing Level I and Level II trauma centers, comprising a total of 98,950 patients (Fig. 5). The overall pooled unadjusted OR (95% CI) was 0.92 (0.78–1.09) (I^2 = 84%) (Fig. 2). Subgroup analysis was possible for TBI (OR [95% CI] 0.86 [0.58–1.27]). Heterogeneity was strong; overall I^2 was 84% and for TBI I^2 was 90%. There was no suggestion of publication bias (Fig. 5).

Functional Outcome Measures Systematic Review

Three TBI studies[26,30,50] compared the functional independence measure between Level I and Level II trauma centers (Table 1); two studies[26,50] found Level I trauma centers to be associated with better functioning, whereas one study[30] found no differences. Health related quality of life, measured after 1 year by Short Form-36[56] and the Musculoskeletal Function Assessment,[57] was associated with better functioning after being admitted

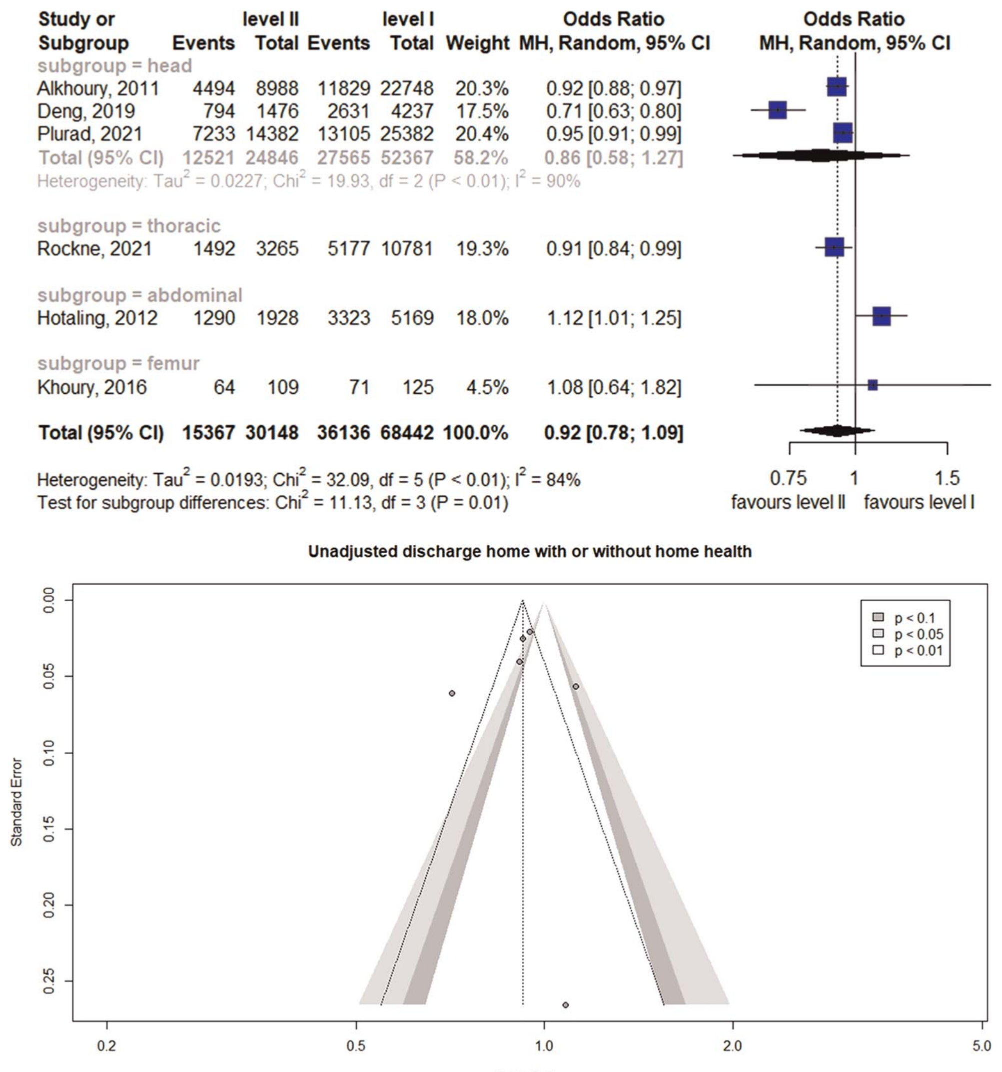

Figure 5. Meta-analysis unadjusted discharge home with or without home health (upper) and funnel plot on publication bias (lower) in severely injured trauma populations for Level I versus Level II trauma centers.

to a Level I trauma center than to a non–Level I trauma center (Level IV + other).[42]

DISCUSSION

In an attempt to analyze MT care in networks, this study assessed the association of patients with specific severe injuries admitted to a specific level of trauma care and (non)fatal outcome measures. This systematic review included 35 studies with a total population of 1,100,888 trauma patients. The results of 25 studies (n = 443,095) that compared Level I with Level II trauma centers suggest a survival benefit for the severely injured admitted to a Level I trauma center (unadjusted OR, 1.1; NNTB, 84; adjusted OR, 1.15; NNTB, 57). A few subgroup analyses for adjusted in-hospital mortality could be done: Patients with TBI have a survival benefit when admitted to a Level I trauma center (OR, 1.23; 95% CI, 1.01–1.50), and there was an indicative survival benefit for hemodynamically unstable patients and patients with penetrating injuries when admitted to a Level I trauma center (OR, 1.09; 95% CI, 0.95–1.22; OR, 1.04; 95% CI, 0.78–1.38, respectively (Supplemental Fig. 1, http://links.lww.com/TA/C853, and 2, http://links.lww.com/TA/C854). Overall, there was an unadjusted nonsignificant tendency for shorter HLOS and longer ICU in Level I trauma centers, mechanical ventilation duration was similar between Level I and Level II trauma centers, and a larger part of patients admitted to Level II trauma centers were discharged home, which could be addressed to differences on population level.

Even though nonmajor but severely injured patients (ISS 9–14) were included in this study, results were similar to previous reviews for general MT populations.[9,58] All studies and subgroups combined in the present study could be considered a general severely injured trauma population as well.

Various (excluded) studies around the same theme are worth mentioning: no survival benefit for combined burn and MT patients in either Level I or II trauma centers,[59] survival benefit in Level I trauma centers for patients with severe specific injuries,[12,60] level I and II trauma centers with low mortality rates prevent and treat complications better in the severely injured,[54,61] and patients admitted to level I trauma centers with severe lower extremity injuries have a higher chance of limb salvage.[62] Several studies analyzed specific age groups in association to level of trauma care, the largest groups being pediatrics and geriatrics. Most pediatric studies compare severely injured children admitted to pediatric, adult and mixed trauma centers, indicating benefits of a regionalized pediatric (major) trauma center.[63–66] Studies on severely injured (very) elderly indicate beneficial care in higher level trauma centers, despite many geriatric trauma patients being admitted to lower level trauma centers as a stable older trauma patient with lower energy injury mechanisms.[67–69] Comparing top levels of trauma care indicates no differences between centers.[68–71]

In the present study, a level of care association with outcomes has been studied from a subgroup perspective mostly based on injured body region. When looking at case mix differences between levels of trauma, what is considered as severely injured is under debate. A minimum of MAIS 3 was considered severe, but when looking at a subgroup with specific injured body regions one can imagine a lot of detail is lost. Severe is a catch-all term, while MAIS 3–5 or ISS >15 and ISS >24 are quite differential, not to speak of a differentiation of specific injured organs or a combination of injuries in different body regions. It might very well be that studies finding no differences between levels of trauma care are biased because of a certain overtriage (admit-all-term) in the context of concentration of the severely injured. If overtriage makes sure that a small group of critical injured patients associated with high mortality rates are admitted as fast as possible to Level I trauma centers, a beneficial true effect for small groups might statistically remain unnoticed in standard analysis on a population level. In addition, compliance to field triage protocols by emergency medical services might not be optimal. By reducing undertriage and overtriage, the quality of health care has still much to be gained. However, on-scene triage is good enough to result in a beneficial effect in the trauma networks included in the current study.

Limitations

An overall strong heterogeneity seems logical considering the multidisciplinary character of trauma care when combining all subgroups. Statistically, homogeneity might be more favorable, especially when looking at subgroups. Therefore, results should be carefully interpreted. Studies per subgroup were limited in all outcomes, especially in adjusted analysis. Looking at (adjusted) outcome measures, in-hospital mortality was best represented. Hospital, ICU, and mechanical ventilation duration displayed inconsistencies of summary measure, were missing, and if not, adjusted values were scarce. When adjustments were done, physiological biomarkers were seldom available or used. Complications rates were often reported, however overall and specific complications were not interchangeable between studies. Discharge destination and functional outcome measures were least represented for individual levels of trauma care, making it difficult to create a robust nonfatal overview.

The three included studies not originating from the United States, where conducted in France, Israel, and Canada. These studies all compared numeric designated levels of trauma care, and where considered to be the same as the numeric levels of trauma care in the United States. It is difficult to address what influential elements of trauma management like level criteria, hospital volume, local (field) protocols, and activation of helicopter emergency medical services have on the included studies. Local health care context can be of great importance in the light of time to admission (geo-spatial elements), transfers, and maturation of trauma networks. Generalizability of the current results to other care systems or middle-low income countries is questionable, the studies for that account are too homogeneous.

No randomized trials could be identified (probably due to ethical issues) creating resulting in methodological limitations. Finally, the search was restricted to English written publications, creating a language bias. An additional search on all languages resulted in 53 extra studies, potentially resulting in one missing study proportionally to an English restricted search only, making publication bias negligible.

Strength

Severely injured patients were represented on a broad injury spectrum. All studies comparing any level of trauma care were included, and as many nonfatal outcomes as possible were studied. All but one study were based on data from the 21st century, creating an thorough overview of contemporary trauma networks with a clinical focus. This framework does right to the multidisciplinary approach and chain of trauma care.

CONCLUSION

Level of trauma care is associated with in-hospital mortality when specific severely injured trauma populations are combined; Level I trauma center resources add most to a survival benefit compared with non–Level I trauma centers, also in severely injured non-MT populations. Unadjusted nonfatal clinical outcomes were indicative for a longer stay, more intensive care, and a greater need for posthospital recovery trajectories after being admitted to top levels of trauma care, which could be addressed to differences on a population level. Functional outcome measures were underreported. Trauma networks with designated levels of trauma care are beneficial to the multidisciplinary character of trauma care.

AUTHORSHIP

J.C.V.D. developed the study protocol, participated in the literature search, study selection, data collection, meta-analysis, data interpretation, and drafting the article. L.A.R. participated in the literature search, study selection, data collection, data interpretation, and drafting the article. C.A.S. developed the study protocol, participated in the literature search, data interpretation, and critical revision of the article. W.M.B. developed and assisted in the literature search strategy, and critical revision of the article. D.D.H., E.M.M.V.L. and M.H.J.V. participated in data interpretation and critically revised the article. All authors approved the final version.

DISCLOSURE

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