In-house versus on-call trauma surgeon coverage: A systematic review and meta-analysis

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BACKGROUND: A rapid trauma response is essential to provide optimal care for severely injured patients. However, it is currently unclear if the presence of an in-house trauma surgeon affects this response during call and influences outcomes. This study compares in-hospital mortality and process-related outcomes of trauma patients treated by a 24/7 in-house versus an on-call trauma surgeon.

METHODS: PubMed/Medline, Embase, and CENTRAL databases were searched on the first of November 2020. All studies comparing patients treated by a 24/7 in-house versus an on-call trauma surgeon were considered eligible for inclusion. A meta-analysis of mortality rates including all severely injured patients (i.e., Injury Severity Score of ≥16) was performed. Random-effect models were used to pool mortality rates, reported as risk ratios. The main outcome measure was in-hospital mortality. Process-related outcomes were chosen as secondary outcome measures.

RESULTS: In total, 16 observational studies, combining 64,337 trauma patients, were included. The meta-analysis included 8 studies, comprising 7,490 severely injured patients. A significant reduction in mortality rate was found in patients treated in the 24/7 in-house trauma surgeon group compared with patients treated in the on-call trauma surgeon group (risk ratio, 0.86; 95% confidence interval, 0.78–0.95; p = 0.002; I^2 = 0%). In 10 of 16 studies, at least 1 process-related outcome improved after the in-house trauma surgeon policy was implemented.

CONCLUSION: A 24/7 in-house trauma surgeon policy is associated with reduced mortality rates for severely injured patients treated at level I trauma centers. In addition, presence of an in-house trauma surgeon during call may improve process-related outcomes. This review recommends implementation of a 24/7 in-house attending trauma surgeon at level I trauma centers. However, the final decision on attendance policy might depend on center and region-specific conditions. (*J Trauma Acute Care Surg.* 2021;91: 435–444. Copyright © 2021 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Systematic review/meta-analysis, level III.

KEY WORDS: Injury; trauma surgeon; attendance; level I; trauma center.

Injury remains a leading cause of death worldwide.[1–3] Over the last decades, the introduction of inclusive trauma systems successfully decreased trauma patients' mortality rates.[4–7] Additional centralization and differentiation of trauma care are suggested to further improve trauma patients' chances of survival.[5,8,9] Evaluating the effects of such developments on patient outcomes is essential because they are in general difficult to implement and could have consequences for other shackles within the chain of trauma care.

24/7 in-house presence of trauma surgeons in higher-level trauma centers is a development that needs evaluation because some opt that it could improve patient- and process-related outcomes.[10–12] This could be the result of trauma surgeons being more often and earlier present at the patients' bedside to make decisions regarding the initial trauma response and further treatment of trauma patients. The American College of Surgeons Committee on Trauma guidelines, however, still recommend a response time of 15 minutes for trauma surgeons in level I trauma centers, permitting them to reside on-call.[13,14]

Several level I trauma centers individually investigated the effects of the introduction of a 24/7 in-house policy for trauma surgeons,[10–12,15–23] as it is currently not obligatory and entails higher costs and more disutility. These studies reported potential benefits with regard to patient- and process-related outcomes. However, consensus regarding the 24/7 in-house policy has not been reached. A study that provides an overview of the individual studies that investigated these effects is currently lacking.

The aim of this study was to provide an overview of prior studies that investigated the effect of the presence of an in-house trauma surgeon (IHTS) compared with an on-call trauma surgeon (OCTS) on patient- and process-related outcomes. In addition, this study examines the potential effect of an IHTS on mortality by performing a meta-analysis. The results of this study could have implications for all (190) level I trauma centers in American and level I trauma centers in comparable trauma systems around the world.[24]

PATIENTS AND METHODS

Study Design

Ethical committee approval was not obligatory for this study. This systematic review and meta-analysis study was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-analysis Protocols (http://links.lww.com/TA/B991) guidelines and the Meta-analysis of Observational Studies in Epidemiology Guidelines (http://links.lww.com/TA/B992).[25–27]

Search Strategy and Inclusion Criteria

A syntax was created containing the following keywords: "trauma surgeon" and "on-call" or "in-house" and "outcomes" and their corresponding synonyms (Supplementary Table 1, http://links.lww.com/TA/B990). Search results were extracted from Medline, Embase, and CENTRAL databases on the first of November 2020. Thereafter, two reviewers (A.C.J.d.l.M. and R.D.L.) independently screened the articles. Published randomized controlled trials and observational studies were considered

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eligible for inclusion. In 1976, the American College of Surgeons Committee on Trauma published the original resource criteria for trauma center accreditation.[28] Therefore, we included all studies published from January 1976, and onward, comparing IHTS with OCTS attendance in any level trauma center and describing any patient- and process-related outcome. No language restrictions were applied, and articles published in languages other than English were assessed by a native speaker. Studies were excluded for the following reasons: no trauma patients, no determinant of interest, other study type (letters, surgical technique studies, no availability of full text article, biomechanical studies, reviews, and gray literature), no population of interest, or published before 1976. After screening of titles and abstracts, full texts of the remaining articles were retrieved. Eligibility assessment and final inclusion of articles were performed by two independent reviewers (A.C.J.d.l.M. and R.D.L.). A third independent reviewer was consulted in cases of discussion (M.v.H.). Reference screening and backward citation tracking was carried out to identify missed literature. A retrievable list of excluded references was assured.

Data Extraction

Study characteristics were extracted independently by two reviewers (A.C.J.d.l.M. and R.D.L.), using a predefined data extraction file: first author, year of publication, study design, country in which the study was conducted, trauma center level, number of patients, annual severely injured (i.e., Injury Severity Score [ISS], ≥16), patient volume per center (reported or calculated), other patient and trauma center characteristics, home-to-hospital times of the OCTS, and estimates of injury severity: ISS, Abbreviated Injury Scale, or Trauma Injury Severity Score. The following outcomes were extracted: in-hospital mortality,

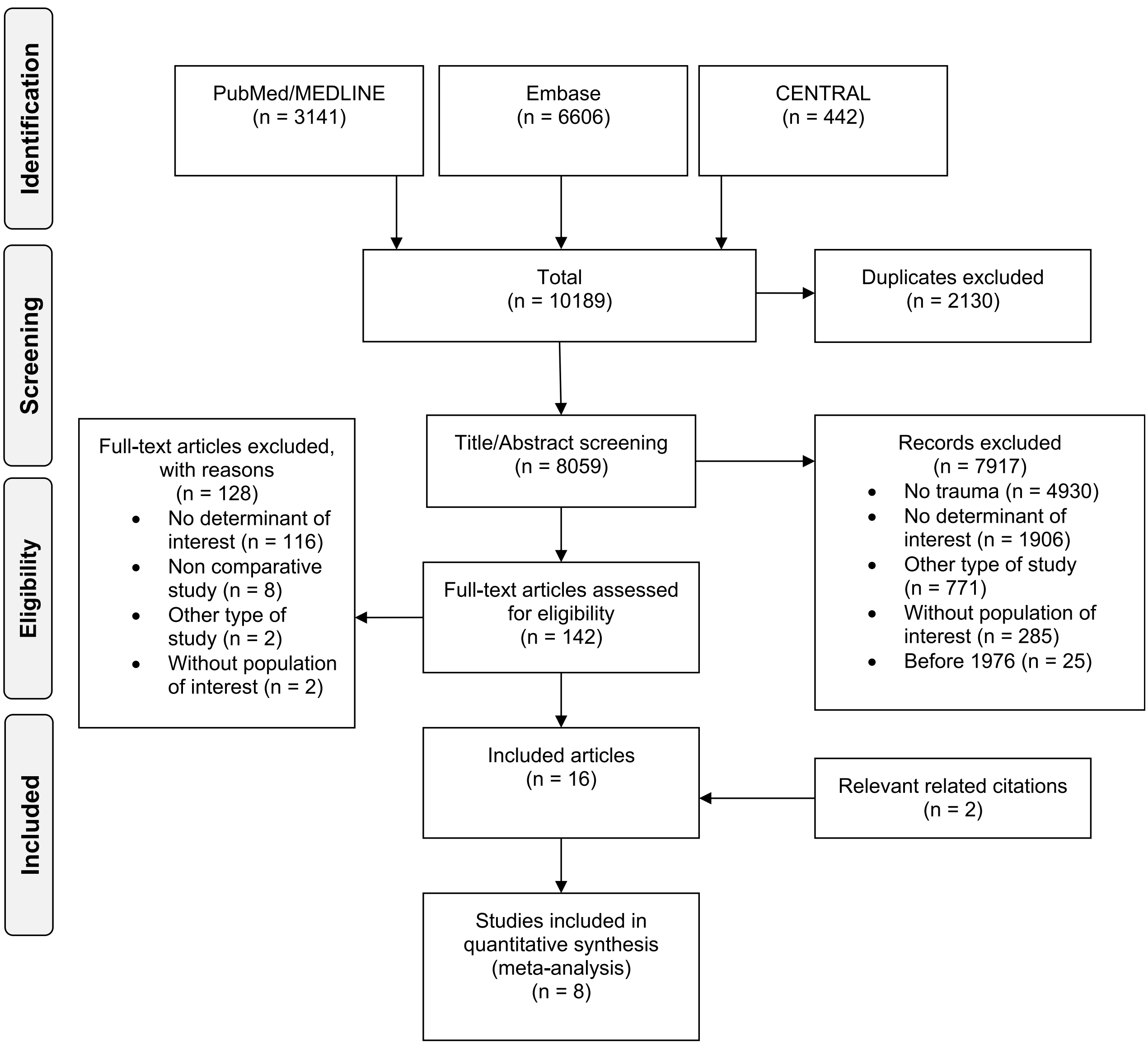

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-analysis 2009 Flow Diagram of search conducted on the first of November 2020.

TABLE 1. Characteristics of Included Studies Comparing In-house Versus On-call Trauma Surgeon (n = 16 Studies)

Study	Year	Country	Nature (All Retrospective)	No. Patients	Type of Trauma	Type of Center (No. Centers)	Annual Trauma Center Volume (ISS, ≥16) (No. Patients)	Trauma Severity (ISS) Inclusion Categories	Age, Mean (SD), y		Sex (% Male)		Adjusted for
									OCTS	IHTS	OCTS	IHTS	
Arbabi et al.[37]	2003	USA	Multicenter cohort	1,104	Blunt, penetrating	UA level I (10)	NR	≥16	NA		NA		GCS, ISS, SBP, age, institutional volume
Claridge et al.[15]	2011	USA	Before-after	518	Splenic injury	Regional level I (1)	NR	NA	Overall, 34 (1)		Overall, 67		NA
Cornwell et al.[12]	2003	USA	Before-after	4,753	All trauma	UA level I (1)	168*	1–15, ≥16	30.9	31.6	84.6	81.3	ISS, SBP, AIS
Cox et al.[16]	2014	USA	Before-after	10,099	All trauma, trauma alert red patients	UA level I (1)	NR	NA	44.0 (19.4)	45.0 (19.7)	65.7	63.9	Age, ISS, sex, and TRISS
Demarest et al.[39]	1999	USA	Multicenter cohort	2,833	All trauma	UA level I (2)	OCTS center, 656* IHTS center, 1206*	≥16	33.9 (16.6)	40.0 (18.9)	NA		NA
Durham et al.[17]	2005	USA	Before-after	8,626	All trauma	UA level I (1)	410**	1–75, 1–8, 9–15, 16–24, 25–40, 41–49, 50–74	36.9 (16.3)	37.7 (17.5)	NA		NA
Fulda et al.[18]	2002	USA	Before-after	4,278	All trauma	UA level I (1)	280*	All, ≥16	36.73 (19.6)	33.47 (19.3)	75.0	72.7	ISS, RTS
Havermans et al.[19]	2019	The Netherlands	Before-after	3,714	All Trauma	UA level I (1)	268*	≥16	Median (IQR), 46 (28–61)	Median (IQR), 51 (33–66)	63.1	63.7	ISS, GCS, SBP, age and severe neurotrauma
Helling et al.[20]	2003	USA	Before-after	766	All trauma	UA level I (1)	NR	≥16, >25	NA		NA		NA
Khetarpal et al.[40]	1999	USA	Multicenter cohort	1,776	All trauma	UA level I (2)	OCTS center, 384* IHTS center, 464 *	≥16	Center 1, 31 ± 16	Center 2, 33 ± 16	NA		NA
Luchette et al.[21]	1997	USA	Before-after	1,043	All trauma	UA level I (1)	NR	1–15, ≥16	36.1	36.0	74	71	ISS, RTS, and GCS for time subgroup
Mains et al.[10]	2009	USA	Before-after	15,297	All trauma	Regional level I (1)	488*	1–15, 16–24, ≥25	NA		61.3	62.1	Transfers-in, mechanism of injury, ISS, age, and head injury
Offner et al.[22]	2003	USA	Before-after	1,071	All trauma	Regional level I (1)	433*	1–15, 16–24, ≥25	37.1 (1)	39 (1)	NA		Age, ISS, mechanism of injury
Rogers et al.[23]	1993	USA	Before-after	4,164	All trauma	UA level I (1)	NR	NA	34 (1.9)	33 (1.5)	71	80	Transport time, ISS, RTS
Thompson et al.[38]	1992	USA	Before-after	3,689	Severe thoracoabdominal trauma, severe head injury	Regional level II (1)	NR	≥16		Overall median (IQR), 32.1 (2–104)	NA		ISS, TS, age, time to surgery
van der Vliet et al.[11]	2019	The Netherlands	Before-after	606	All trauma	UA level I (1)	NR	≥25	Median (IQR), 47 (26–66)	Median (IQR), 50 (26–69)	70	65	NA, although comparable groups

*Calculated by authors using original data from article.
**Estimated by authors using original data from article.
AIS, Abbreviated Injury Scale; GCS, Glasgow Coma Scale; IQR, interquartile range; NA, not applicable; NR, not reported; RTS, Revised Trauma Score; SBP, systolic blood pressure; TRISS, Trauma Injury Severity Score; TS, trauma score; UA, university affiliated; USA, United States of America.

emergency department length of stay (ED-LOS), intensive care unit length of stay (ICU-LOS), hospital length of stay (hospital LOS), time to operating room (OR), and time to computed tomography (CT) imaging.

Assessment of Study Quality

The Risk of Bias in Nonrandomized Studies of Interventions I quality assessment tool was used by two reviewers (A.C.J.d.l.M. and R.D.L.) to assess the quality of the included studies. This is a validated tool to assure the methodological quality of observational studies.[29,30] A third independent reviewer was consulted in cases of discussion (M.v.H.).

Outcomes

In-hospital mortality was chosen as the primary outcome. The following process-related outcomes were chosen as secondary outcomes: ED-LOS, ICU-LOS, hospital LOS, time to OR, and time to CT.

Statistical Analysis

Continuous variables were presented as a mean value with SD or range. The Cochrane Handbook for Systematic Reviews of Interventions was consulted to determine the mean and SD if sufficient data were available.[31] Categorical variables were extracted as absolute number and percentage. The total annual trauma center volume was calculated from study cohorts that included all severely injured patients in a specific time frame or estimated by multiplying the annual amount of patients by two in studies that solely reported the number of severely injured patients treated during off-hours (i.e., nights and weekends). A meta-analysis including all severely injured patients (i.e., ISS, ≥16) was performed to examine the relationship

TABLE 2. Mortality Rates of the Included Studies (n = 16 Studies)

Study	ISS	Subgroups	Mortality, n (%) OCTS	Mortality, n (%) IHTS	OR
Arbabi et al.[37]	≥16	Blunt	NR (15.8)	NR (16.6)	IHTS vs. OCTS 1.2 (0.5–3.0)*
		Penetrating	NR (6.8)	NR (9.4)	1.7 (0.6–4.5)*
Claridge et al.[15]	NR	—	10 (16.4)	26 (9.5)	—
Cornwell et al.[12]	All	—	96 (4.5)	82 (3.4)	OCTS vs. IHTS 0.69 (NR)
	≥16	—	88 (20.3)	74 (18.1)	—
Cox et al.[16]	All	—	NR (5.9)	NR (5.3)	OCTS vs. IHTS 0.87 (0.69–1.09)
	Trauma alert red patients		NR (20.7)	NR (18.2)	—
Demarest et al.[39]	≥16	—	8 (25.5)	11 (34.4)	—
Durham et al.[17]	All	—	99 (9.6)	94 (9.6)	—
	≥16		76 (21.3)	69 (20.0)	
Fulda et al.[18]	All	—	87 (26.1)	46 (22.5)	—
	≥16	—	74 (38.7)	38 (30.4)	IHTS vs. OCTS 1.45 (0.90–2.34)
Havermans et al.[19]	All	—	90 (7.0)	101 (4.2)	OCTS vs. IHTS 0.63 (0.42–0.95)*
	≥16	—	81 (26.0)	95 (19.2)	0.67 (0.48–0.94)
Helling et al.[20]	All	—	146 (25)	42 (23)	—
	≥16	—	96 (37.9)	35 (31.8)	
Khetarpal et al.[40]	≥16	—	NR (14.0)	NR (13.0)	—
Luchette et al.[21]	All	—	62 (11.4)	46 (9.4)	—
Mains et al.[10]	All	—	243 (3.82)	248 (3.12)	OCTS vs. IHTS 0.81 (0.66–0.99)*
	≥16		192 (14.83)	200 (11.41)	0.74 (0.58–0.94)*
Offner et al.[22]	All	—	NR (2.6)	NR (3.0)	—
	1–15		NR (0)	NR (0.3)	
	16–24		NR (9.6)	NR (5.2)	
	≥25		NR (26)	NR (26)	
Rogers et al.[23]	Severely injured	—	(37)	(39)	—
Thompson et al.[38]	AIS ≥3	Severe thoracoabdominal injury	Survival (n), 0.808 (80)	Survival (n), 0.767 (56)	—
	≥16	Severe head injury	Survival (n), 0.627 (47)	Survival (n), 0.529 (37)	
van der Vliet et al.[11]	>24	—	52 (24)	107 (27)	—

*Adjusted outcomes.
OR, odds ratio; NR, not reported.

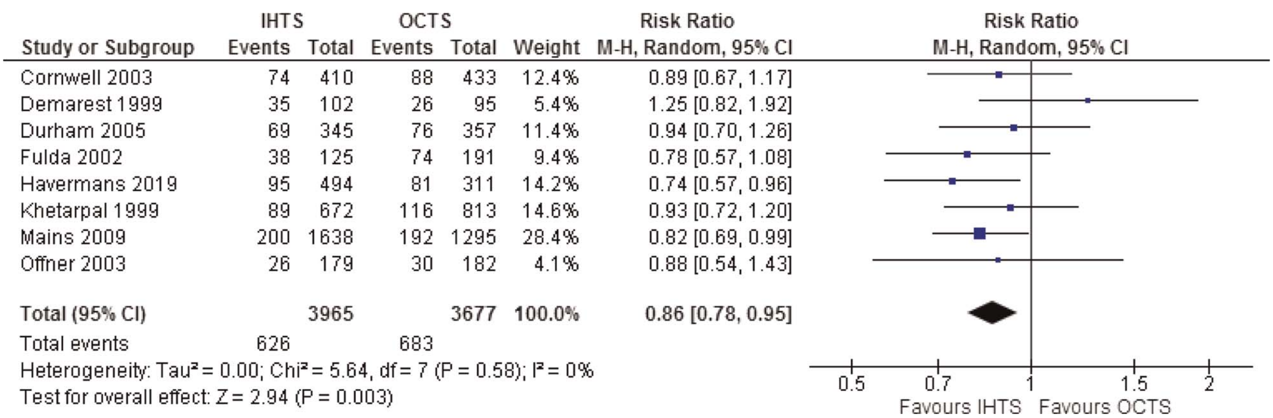

Figure 2. Mortality rate forest plot of the in-house versus on-call trauma surgeon in level I trauma centers (ISS, ≥16; all types of trauma) (n = 8 studies).

between an IHTS and in-hospital mortality. Studies that compared daytime (i.e., in-house) versus nighttime (i.e., on-call) were not included in the meta-analysis because these time frames were not considered comparable. In-hospital mortality was pooled using the Mantel-Haenszel method and presented as a risk difference or risk ratio with a 95% conference interval.[32] Random-effect models were used to provide an estimate of the average treatment effect, assuming that the true treatment effect differed between studies.[33] The assessment of statistical heterogeneity was performed by visual inspection of the forest plot and by the I^2 and χ^2 statistics. The significance level of treatment effects was evaluated by using the overall effect Z test. The Cochrane Handbook for Systematic Reviews of Interventions was consulted for interpretation of effect estimates.[31] Significance was defined as a p value of below 0.05. Visual inspection of Funnel plots, and Begg's and Egger's tests were performed to assess potential publication bias. Analysis was executed with the Review Manager (RevMan, version 5.3.5),[34] the R software environment (version 3.6.1),[35] and Stata (version 13.1).[36]

Sensitivity Analyses

Sensitivity analyses of the primary outcome were performed including studies performed in the United States, studies published in the two most recent decades (i.e., post-2000), studies with an obligatory response time of <15 minutes for the OCTS, studies with a 24/7 in-house senior resident in general surgery in the OCTSs group, studies with a low to moderate risk of bias, and studies conducted in low-volume level I trauma centers (i.e., <650 severely injured patients [i.e., ISS, ≥16] annually).

RESULTS

Included Studies

A total of 7,430 studies were identified and screened on title and abstract after duplicate exclusion. Fourteen of 142 studies that were screened on full text met the inclusion criteria. After checking citations and references, two additional articles were added. In total, 16 articles were included in this systematic review, and eight studies in the meta-analysis. The exclusion flow diagram and the electronic database search are reported in Figure 1 and Supplementary Table 1 (http://links.lww.com/TA/B990), respectively.

Quality Assessment

The overall risk of bias was found to be moderate in 13[10–12,15–17,19–23,37,38] and serious in 3[18,39,40] of the 16 included studies (Supplementary Fig. 1, http://links.lww.com/TA/B990; Supplementary Fig. 2, http://links.lww.com/TA/B990).

Study Characteristics

The majority of studies (14 of 16 studies) were performed in the United States,[10,12,15–18,20–23,37–40] and 2 studies were conducted in the Netherlands.[11,19] Fourteen of the included studies were conducted in American and Dutch level I trauma centers.[10,11,15–23,37,39,40] Of these studies, 12 were performed in university-affiliated trauma centers[11,12,16–21,23,37,39,40] and 3 in regional level I trauma centers.[10,15,22] In one university-affiliated American study, level I designation was attained after the implementation of the IHTS.[12] One study was performed at a regional American level II trauma center.[38] Annual severely injured trauma patient volume ranged from 168 to 1,206.

TABLE 3. Sensitivity Analyses of Mortality in the Included Meta-analysis Studies (n = 9 Studies)

		Mortality			
Studies	**n**	**RD (95% CI)**	**RR (95% CI)**	***p***	**I^2**
All studies	8	−0.02 (−0.04 to −0.01)	0.86 (0.78–0.95)	0.003	0%
USA	7	−0.02 (−0.04 to −0.00)	0.89 (0.80–0.98)	0.03	0%
Post-2000	6	−0.03 (−0.05 to −0.01)	0.83 (0.74–0.93)	<0.001	0%
OCTS response time of <15 min	5	−0.02 (−0.04 to −0.00)	0.88 (0.78–0.99)	0.03	0%
Senior resident in-house for OCTS	5	−0.02 (−0.04 to −0.00)	0.88 (0.78–0.99)	0.03	0%
Studies with low to moderate risk of bias	5	−0.03 (−0.05 to −0.01)	0.81 (0.70–0.93)	0.003	0%
Studies conducted in relatively low annual volume of trauma patients	7	−0.03 (−0.04 to 0.01)	0.85 (0.76–0.93)	0.001	0%

RD, risk difference; RR, relative risk; USA, United States of America.

TABLE 4. Process-Related Outcomes of Included Studies Comparing In-house Versus On-call Trauma Surgeon (All Included Patients) (n = 16 Studies)

Study	ED-LOS	ICU-LOS	Hospital LOS	Time to OR	Time to CT
Arbabi et al.[37]		ND	ND		
Claridge et al.[15]					
Cornwell et al.[12]		ND			
Cox et al.[16]				ND	
Demarest et al.[39]	ND	ND	ND	ND	
Durham et al.[17]		ND	ND	ND	
Fulda et al.[18]	ND	ND	ND	ND	ND
Havermans et al.[19]					
Helling et al.[20]	ND		ND	ND	ND
Khetarpal et al.[40]					
Luchette et al.[21]		ND			
Mains et al.[10]			ND		
Offner et al.[22]		ND			
Rogers et al.[23]					
Thompson et al.[38]				ND	ND
van der Vliet et al.[11]			ND		ND

Dark gray indicates positive effect for IHTS ($p < 0.05$); light gray, negative effect for IHTS ($p < 0.05$); ND, no measured difference IHTS versus OCTS ($p > 0.05$); and white, not reported.

A total of 67,679 patients were included, ranging from 518 to 15,297 per study (Table 1). Thirteen studies enrolled patients suffering from all types of injury.[10–12,16–23,39,40] Two articles included patients with splenic and severe thoracoabdominal injuries.[15,38] The remaining article reviewed independent cohorts consisting of blunt and penetrating injuries in different hospitals.[37] The majority of articles (12 of 16 studies) reported outcomes of severely injured patients (ISS, ≥16).[10,12,16–20,22,37–40] Six studies reported a significant ISS difference between study groups (Supplementary Table 2, http://links.lww.com/TA/B990);[10,16,22,23,39,40] four of these studies adjusted their outcomes for ISS (Supplementary Table 2, http://links.lww.com/TA/B990).[10,16,22,23]

The majority of the included studies (12 of 16 studies) compared outcomes before implementation of the IHTS with outcomes after implementation of the IHTS in a single center.[10–12,15–23] Three studies compared two different trauma centers (i.e., an OCTS center vs. an IHTS center) in a concurrent period.[37,39,40] One study compared in-house periods (7:00 AM to 6:00 PM) with on-call periods (6:01 PM to 06:59 AM).[38] Response times of the OCTS varied between 10,[39] 15,[16,20–22,37] 20,[11] and 30 minutes.[19,23,40] In 11 of 16 articles, a senior resident in general surgery was present in the hospital in the OCTS group (Supplementary Table 3, http://links.lww.com/TA/B990).[10–12,15–17,20–23,40] Six studies specifically reported the prevalence of penetrating and blunt injuries, which did not significantly differ between the OCTS and IHTS group (Supplementary Table 4, http://links.lww.com/TA/B990).[10,17,20,37,39,40]

Primary Outcome

Two of 16 studies reported a significantly reduced mortality rate in the IHTS group (Table 2).[10,12] Eight studies were included in the meta-analysis.[10,12,17–19,22,39,40] These studies included all severely injured patients (i.e., ISS, ≥16), who suffered from any type of injury and were treated at level I trauma centers. The meta-analysis showed that the IHTS was associated with reduced mortality rates compared with an OCTS (risk ratio, 0.86; 95% confidence interval (CI), 0.78–0.95; p = 0.003; I^2 = 0%) (Fig. 2). The Funnel plot showed no visual asymmetry (Supplementary Fig. 3, http://links.lww.com/TA/B990). The Egger's linear regression test (p = 0.31) and the Begg's rank correlation test (0.40) revealed no indication of publication bias.

Sensitivity Analyses

Table 3 shows the results of the performed sensitivity analyses. Seven of the eight studies included in the meta-analysis were performed in the U.S.[10,12,17,18,22,39,40] The overall pooled effect showed a significant reduction in mortality for an IHTS compared with an OCTS in these studies (risk ratio, 0.88; 95% CI, 0.80–0.98; p = 0.03; I^2 = 0%) (Supplementary Fig. 4, http://links.lww.com/TA/B990). The overall pooled effect showed a significant lower risk in mortality for an IHTS in the six studies that were published in the two most recent decades (i.e., post-2000) (risk ratio, 0.83; 95% CI, 0.74–0.93; $p < 0.001$; I^2 = 0%) (Supplementary Fig. 5, http://links.lww.com/TA/B990).[10,12,17–19,22] Six studies were included to compare an IHTS with a rapidly available OCTS (i.e., an OCTS with an obligatory response time of less than 15 minutes).[10,12,17,18,22,39] The overall pooled effect showed a significant reduction in mortality for an IHTS in these studies (risk ratio, 0.88; 95% CI, 0.78–0.99; p = 0.03; I^2 = 0%) (Supplementary Fig. 6, http://links.lww.com/TA/B990). Five studies were included to compare an IHTS with an OCTS that shared call with a 24/7 in-house senior resident in general surgery.[10,12,17,22,40] The overall pooled effect showed significant reduction in mortality for an IHTS in these studies (risk ratio, 0.88; 95% CI, 0.78–0.99; p = 0.01; I^2 = 0%) (Supplementary Fig. 7, http://links.lww.com/TA/B990). In the sensitivity analysis that included the five articles that were not classified as severe risk of bias, the overall pooled effect showed a significant lower risk of mortality for an IHTS (risk ratio, 0.81; 95% CI, 0.70–0.93; p = 0.003; I^2 = 0%) (Supplementary Fig. 8, http://links.lww.com/TA/B990).[10,12,17,19,22] Seven studies were performed in low-volume trauma centers (<650 severely injured patients annually).[10,12,17–19,22,40] In these studies, the overall pooled effect showed a significant reduction in mortality for an IHTS (risk ratio, 0.85; 95% CI, 0.76–0.93; p = 0.001; I^2 = 0%) (Supplementary Fig. 9, http://links.lww.com/TA/B990).

Process-Related Outcomes

All 16 included studies reported process-related outcomes. An overview of process-related outcomes is provided in Table 4. In four of nine studies, the ED-LOS was significantly shorter in the IHTS group than in the OCTS group,[11,12,16,17] while two studies found a significantly shorter ED-LOS in the OCTS group.[15,22] In 4 of 12 studies, the ICU-LOS was significantly shorter in the IHTS group,[10,15,16,19] and in 1 study significantly shorter in the OCTS group.[20] Three of 13 articles reported a significantly reduced hospital LOS for the IHTS group,[12,16,19] while 1 study found a significantly shorter LOS in the OCTS group.[22] A significantly shorter time to OR was found in the IHTS group in 5 of 12 studies.[11,12,15,21,23] One study reported a significantly shorter time to CT imaging in the IHTS group, compared with the OCTS group.[38] Process-related outcome data are depicted in Supplementary Table 5 (http://links.lww.com/TA/B990) and 6 (http://links.lww.com/TA/B990).

DISCUSSION

This is the first systematic review that provides an overview of studies that compared the outcomes of patients who were treated by an IHTS with those of patients who were treated by an OCTS. A total of 16 studies, consisting of 64,337 patients, were included. The meta-analysis, including the severely injured patients of eight different studies, showed a significant association between the presence of an IHTS and decreased mortality rate in severely injured patients (risk ratio, 0.86). In addition, sensitivity analyses of the following groups showed similar lifesaving associations for an IHTS: studies conducted in the United States, recent studies (i.e., published post-2000), studies with an obligatory OCTS response time of <15 minutes, studies with an in-house senior resident in general surgery in the OCTS group, studies with low to moderate risk of bias, and studies conducted in low-volume level I trauma centers. In addition, the majority of studies report that an IHTS is found to improve at least one process-related outcome.[10–12,15–17,19–21,23,40]

Several factors contributed to the strength of this study. First, the latest searching and quality assessment methods were used: an extensive systematic search was conducted, an independently performed exclusion process was executed by two authors, and the most recent Risk of Bias in Nonrandomized Studies of Interventions I quality assessment tool was used.[29] Second, all articles included in the meta-analysis described outcomes for a comparable population: all severely injured trauma patients (ISS, ≥16) who were treated at level I trauma centers. Third, all included studies were conducted in either the United States or the Netherlands: high-income countries with comparable inclusive trauma systems.[41]

This review suffers from certain limitations. First, all included studies were retrospective observational studies. However, recent literature shows that the absence of randomized controlled trials does not automatically affect the result and validity of a meta-analysis.[42–44] Second, the majority of included studies had a before-after design. These studies inherently suffer from temporal confounders that might have affected their outcomes. Third, the trauma centers' annual patient volume was calculated or estimated. However, this was based on specific study cohort data, reported in the included articles. Fourth, the performed quality assessment indicated that overall quality of the studies was moderate, follow-up times were in a substantial number of cases not reported, and selection bias or bias due to missing data was present in a considerable number of studies. Fifth, additional bias might be present because of study heterogeneity as a result of the following reasons. A substantial number of the included studies did not report adjusted mortality outcomes. Therefore, a meta-analysis of adjusted outcomes could not be conducted. In four of five studies in which the ISS significantly differed between IHTS and OCTS group, the IHTS group contained more severely injured patients.[16,22,23,39,40] Consequently, the positive association between an IHTS policy and decreased mortality is potentially stronger than was portrayed in our study. Moreover, the presence and level of additional surgical physicians (residents or fellows in general surgery) differed between studies. However, the sensitivity analysis of the IHTS compared with the OCTS combined with a 24/7 in-house senior resident in general surgery shows similar lifesaving associations to our primary analysis. Included studies did not describe alterations in the presence of other emergency care providers during initial trauma response between IHTS and OCTS group. Furthermore, two studies reported concurrent changes with the implementation of the IHTS (e.g., renovation of the trauma room).[12,19] The authors considered that the implementation of the IHTS was, however, the most important component of their trauma center modification. All other included studies did not report any concurrent changes. In addition, the obligatory OCTS response times differed between the studies included in the meta-analysis. However, the sensitivity analysis of an OCTS with an obligatory response time of only 15 minutes shows similar results, suggesting that the IHTS may even outperform an OCTS with a short response time. Comparing center specific obligatory response times is argumentative, as experience teaches that actual home-to-OR times are center- and surgeon-dependent and it is unknown in how many cases the OCTS was in fact in-house. Despite that the aforementioned factors may have contributed to bias due to heterogeneity, study heterogeneity was found to be low (0%) in the meta-analysis of the primary outcome.

Future studies could overcome these limitations by investigating the IHTS policy in high-quality prospective cohort studies including comparable centers with a comparable case mix or adjusting for differences between patient groups or performing meta-analyses using individual patient data. Solely adjusting for ISS, for example, is limited to adequately compare two groups of patients, as it correlates differently with mortality within certain injury types (e.g., penetrating vs. blunt). Furthermore, future research should differentiate between direct (i.e., involved in the patient treatment) and indirect treatment effects (e.g., affecting the decision-making of other physicians), to quantify both effects of the IHTS on patient outcomes. This study suggests that improved process-related outcomes might account for such an indirect treatment effect, positively affecting patient outcomes. Unfortunately, a meta-analysis of process-related outcomes could not be conducted because of a lack of data. Additional research is needed to investigate these effects.

This study could have implications for clinical practice. Our findings suggest that implementation of the IHTS leads to a decreased mortality rate compared with the OCTS, even if call is shared with in-house senior residents. As opposed to these findings, literature shows that trauma patients treated by novice surgeons have similar mortality rates as those who were treated by experienced trauma surgeons.[45] Research should point out whether a certain level of expertise among residents does suffice for the initial trauma response and further treatment, until the OCTS arrives at the hospital. A favorable additional effect of the in-house policy might be that trauma surgeons become more accessible for residents. Therefore, residents may also consult the IHTS more often to discuss treatment decisions regarding (deteriorating) hospitalized trauma patients.

This study suggests that a trauma surgeon should be available 24/7 for the treatment of severely injured patients. Organization of the resuscitation process and thus the potential impact of the IHTS already starts at the announcement and runs throughout the whole trauma chain. Team readiness, leadership and communication skills, logistical oversight, and rapid surgical decision-making may add to the prevention of potential delay. These qualities of the IHTS reflect on both the reduced mortality rate and the improved process-related outcomes. In contrast, OCTSs are inherently delayed because of additional home-to-hospital time. Center-specific prevalence of certain trauma mechanisms (e.g., penetrating trauma) should not prevent implementation of an IHTS. The two included articles that reported on these injury mechanism subgroups suggest that there is no difference in mortality rate between the OCTS and the IHTS.[20,37] While literature shows benefits from an expedited trauma response only for treating penetrating injuries,[46–48] our study suggests improved outcomes for all severely injured patients after implementing an IHTS. Trauma centers should examine if implementation of an IHTS is feasible considering a centers' patient volume and its additional costs. Our results endorse the importance of implementation of an IHTS in all volume type level I trauma centers. Finally, the costs might be locally decisive. Multiple studies reported a reduction in patient costs after introducing an IHTS as a result of enhanced process-related outcomes.[21,49,50] However, other studies described larger salary expenses in case of an IHTS, although without adjusting for potential reduced process-related costs.[51–55] Future research should investigate the cost-effectiveness of an IHTS.

CONCLUSION

This study provides an overview of the best available evidence regarding the effect of the IHTS on patient- and process-related outcomes, compared with the OCTS. In addition, a meta-analysis demonstrates a significant association between the IHTS and a reduced mortality rate in severely injured patients. Also, this study found that the introduction of the IHTS may improve process-related outcomes. Therefore, we recommend the implementation of a 24/7 in-house trauma surgeon in level I trauma centers, to optimize chances of survival and enhance process-related outcomes. However, the decision on attendance policy might depend on local conditions and trauma population characteristics, as feasibility and cost-effectiveness of the IHTS require further investigation.

AUTHORSHIP

M.v.H. is the principal investigator; he had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. A.C.J.d.l.M., R.D.L., and M.v.H. contributed in the literature search. A.C.J.d.l.M., R.D.L., and M.v.H. contributed in the study design. A.C.J.d.l.M., R.D.L., and M.v.H. contributed in the data collection. A.C.J.d.l.M. and R.D.L. contributed in the data analysis and interpretation. A.C.J.d.l.M. contributed in the drafting of the first version of the article. A.C.J.d.l.M. contributed in the statistical analysis. A.C.J.d.l.M. and R.D.L. contributed in the administrative, technical, or material support. M.v.H. contributed in the study supervision. All authors have been actively involved in the drafting and critical revision of the article, and each provided final approval of the version to be drafted.

DISCLOSURE

The authors declare no conflicts of interest.

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