



Multidisciplinary Simulation-Based Team Training for Trauma Resuscitation: A Scoping Review

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OBJECTIVE: Simulation-based training as an educational intervention for healthcare providers has increased in use over the past 2 decades. The simulation community has called for standardized reporting of methodologies and outcomes. The purpose of this review was to (1) summarize existing data on the use of simulation-based team training for acute trauma resuscitation, and (2) describe differences in training methodologies, outcomes reporting, and gaps in the literature to inform research priorities.

DESIGN: We performed a scoping review of Ovid Medline, Embase, Cochrane Library, CINAHL, Web of Science, ERIC, and Google Scholar for studies evaluating simulation-based team training for acute trauma resuscitation. Full-text review was performed by 2 reviewers and variables related to study design, training methodology, outcomes reported, and impact of training were abstracted.

RESULTS: Forty-seven out of 3,911 screened studies met criteria for inclusion. Only 2 studies were randomized. The most frequent design was a pre-post study (64%). Eleven studies did not report their simulated scenario design. Interventions occurred most frequently in a laboratory-based setting (45%). Simulation-based training was associated with greater knowledge (n = 5/6), higher nontechnical skills (n = 12/13), greater number of resuscitation tasks completed (n = 10/13), and faster time to

resuscitation task completion (n = 11/11). No differences in patient outcomes were found (n = 3/3).

CONCLUSIONS: Simulation-based training for trauma resuscitation is associated with improved measures of teamwork, task performance and speed, knowledge, and provider satisfaction. Type of reported outcomes and training methodologies are variable. Standardized reporting of training methodology and outcomes is needed to address the impact of this intervention. (J Surg Ed 76:1669–1680. © 2019 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: Trauma resuscitation, Team, Simulation, Simulation-based training

COMPETENCIES: Patient Care, Medical Knowledge, Interpersonal and Communication Skills, Practice-Based Learning and Improvement, Systems-Based Practice

INTRODUCTION

Unintentional injury is the leading cause of mortality in children and young adults.¹ The highest incidence of mortality after trauma occurs in the first 24 hours,² suggesting the importance of early interventions for critically injured patients. Acute trauma resuscitation requires a multidisciplinary team of providers working together as a cohesive unit to provide timely and effective care. The Advanced Trauma Life Support (ATLS) course has historically not emphasized multidisciplinary team-based training.³ For this reason, many trauma

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providers develop role-related skills only during actual trauma patient resuscitations.

Simulation-based training methodology has been applied in many realms of medical education, offering the advantage of consequence-free preparation for high-stakes patient encounters with many demonstrated benefits. Patient simulators are components of Basic Life Support,⁴ Advanced Cardiovascular Life Support, ATLS and Trauma Resuscitation in Kids courses, and provide a realistic platform for the development of cognitive and procedural skills.⁵ The use of simulation has been associated with improved provider skills and patient outcomes.⁶ Procedural simulation has been shown to improve technical skills such as endotracheal intubation^{7,8} and central line placement.^{9,10} Simulation-based team training for pediatric medical resuscitation has been associated with lower mortality after cardiopulmonary arrest in pediatric inpatients.¹¹

Previous data suggests significant heterogeneity in simulation training methods, outcomes measured, and impact of training, leading to calls for standardization in reporting in simulation studies.^{6,21} We performed a scoping review of the literature to assess the current state of evidence supporting simulation-based team training for trauma resuscitation. Our purpose was to (1) summarize the existing evidence of the impact of simulation use on trauma team performance and trauma patient outcomes, and (2) identify differences in training methodology and outcomes reporting, with the goal of informing research priorities related to simulation-based training in trauma resuscitation.

METHODS

We performed a scoping review following the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-Scr) framework.¹² Search strategies were created and documented by a research librarian in the following bibliographic databases: Ovid Medline, Embase, Cochrane Library, CINAHL, Web of Science, and ERIC. The initial search was conducted on December 19, 2017 and repeated on May 9, 2018 to identify articles published during the initial screening process. A combination of subject headings (when available) and keywords were used for the concepts of simulation, resuscitation, and trauma (**Appendix**). No language, publication date, or other limits were applied. A search was conducted in Google Scholar to capture all relevant literature. Only a sample of the first 200 citations were collected from Google Scholar due to the lack of replicability of a Google Scholar search and proven sensitivity of the search engine's relevancy rankings.^{13,14} No additional efforts were conducted to obtain grey literature. Cited references of studies identified through the full text screening process were hand

searched, but no additional studies were included. Duplicates were removed according to methods described by Bramer et al.¹⁵ The resulting library was imported into Covidence online software (Vertitas Health Innovation Ltd, Melbourne, Australia, 2017), which was used for the title/abstract and full-text screening.

Inclusion and exclusion criteria were predefined, but iterative modifications were made during the screening process. We included all studies that examined simulation-based team training for acute trauma resuscitation. We excluded studies that evaluated only one simulation participant at a time (not team-based), were performed for medical resuscitation (nontrauma) training, were aimed at individual task-training (such as intubation) and were not performed in a simulated acute resuscitation setting. Studies examining video-game or computer-based simulation, editorials, reviews, validation studies, studies in which no simulation was used, and conference abstracts were also excluded. In keeping with the scoping review design, we used no inclusion or exclusion criteria based on simulation methodology or outcomes measured. Reported outcomes were categorized based on Kirkpatrick's model for evaluating training programs, which divides outcomes into 4 levels (reaction, learning, behavior, and results).⁶⁶ Three study members performed title and abstract screening. Two study members independently performed full-text screening. Any disagreements were settled by a fourth reviewer. Given the broad nature of this scoping review and expected significant heterogeneity of included articles, no formal quality assessment was performed.

RESULTS

Study Selection

Our database search strategies generated 6,249 total citations (**Fig. 1**). After removing duplicates, 3,911 studies underwent title and abstract screening. One recently published study that was not captured by our search was identified and included during the review process. A total of 405 studies underwent full-text screening, of which 358 were excluded (specific reasons for exclusion shown in **Fig. 1**).

Study Characteristics

Forty-seven studies met criteria to be included in this review. Year of publication ranged from 2001 to 2018 (**Table 1**). Thirty of the studies (64%) were from the United States, 6 (13%) from Canada, and the remaining from Denmark (4%), Israel (4%), Norway (4%), Sweden (4%), Australia (2%), Germany (2%), and Saudi Arabia (2%). The most frequently used study design was

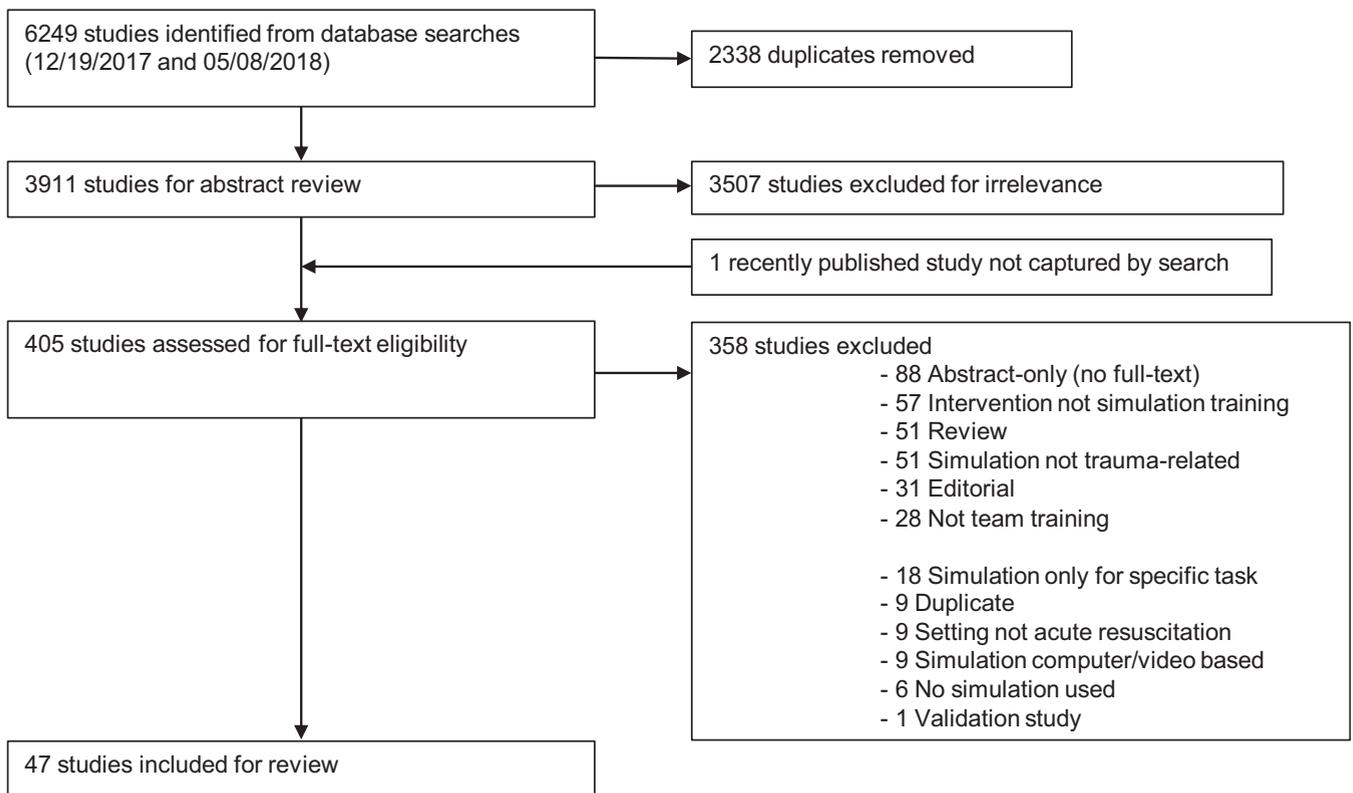


FIGURE 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram for study selection.

pre-post (64%). Only 2 studies (4%) were randomized. The remainder was either cohort, descriptive, or qualitative analyses. Half of studies (51%) did not document whether their simulations were intended to simulate adult or pediatric patients. The remainder of studies included pediatric (26%), adult (15%), and both adult and pediatric patients (9%). The number of participants ranged from 12 to 1,767. The number of simulations ranged from 8 to 88. Simulation location was most frequently in a laboratory setting (45%), followed by in situ (28%), both (11%), other (4%), and not reported (13%).

Simulation Participants and Scenario Design

Nurses were the most frequent participant (79%) in simulation training, followed by surgeons (62%) and emergency medicine physicians (40%). Twenty-two other specialties were represented in the included studies (Fig. 2). Resident participation in the simulation intervention was reported by 18 (38%) studies. Only 77% of studies provided detail of their simulated trauma scenarios (Fig. 3). The most frequently simulated scenario was blunt trauma (62%), followed by penetrating (36%), exposure/environmental (15%), mass casualty (11%), explosion (9%), and other (9%, child abuse, amputation, drowning, and earthquake).

Range of Outcomes Reported

Reported outcomes included data obtained from actual resuscitations in only 8 (17%) studies, with the remainder (83%) reporting data obtained only from simulated resuscitations (Fig. 4). The most frequently reported outcome was a feedback survey or focus group (62%), followed by measurements of task completion or use of a trauma resuscitation checklist (38%). Measurements of nontechnical skills such as teamwork, communication, or leadership were relatively common (34%). Time to resuscitation task completion or time to disposition from the emergency room was reported in 23% of studies. A written test was administered in 13%. Real trauma patient metrics and outcomes, such as hospital length of stay and mortality, were not commonly reported (6%).

Analyses of Team Performance – Teamwork, Leadership, and Communication

Among the analytic studies which examined objective measures of team performance (n = 21), the most frequently reported outcomes were nontechnical skills and number of tasks completed (both n = 13, Table 2). Most of these studies used a third-party observer who used a checklist to evaluate resuscitation performance. Twelve out of these 13 studies found objective measures of

TABLE 1. Description of Study Design and Size for Included Studies

Author	Country	Year	Design	Simulated Patient Age	Participants (n)	Participant Profession	Simulations (n)	Simulation Location
Aceró et al. ²⁵	USA	2012	Pre-post	Adult	171	RN, S, A, E, PO, OR	52	Lab
Afzali & Viggers ²⁶	Denmark	2015	Descriptive	Adult	66	St	12	Other (military training facility)
Allen et al. ²⁷	USA	2016	Descriptive	-	-	RN, S, St, A, OR	-	Lab
Amiel et al. ²⁸	Israel	2015	Pre-post	-	60	RN, S, A, PO	-	both
Auerbach et al. ²⁹	USA	2014	Trend study	Pediatric	398	RN, S, A, E, PO, St, RT, OT, CC, Rad	22	<i>In situ</i>
Baker et al. ³⁰	USA	2015	Pre-post	Adult	48	St	24	Lab
Bayouth et al. ³¹	USA	2018	Pre-post	Pediatric	99	RN, E, RT, St	12	<i>In situ</i>
Berkenstadt et al. ³²	Israel	2003	Descriptive	Both	25	RN, S, A	-	Lab
Bonjour et al. ³³	USA	2016	Prospective cohort	-	-	RN, S, E, RT, Rad	60	-
Burke et al. ³⁴	USA	2017	Qualitative	Pediatric	55	RN, S, E, RT, Rad	-	<i>In situ</i>
Capella et al. ¹⁹	USA	2010	Pre-post	-	114	RN, S	-	Lab
Cheng et al. ³⁵	Canada	2010	Descriptive	Pediatric	66	RN, E, PO, RT	-	Lab
Couto et al. ³⁶	USA	2015	Retrospective/comparative	Pediatric	236	RN, E, PO, RT, EMT	88	both
Doumouras et al. ¹⁶	Canada	2014	Pre-post	-	19	RN, S	-	Lab
El-Gamal et al. ³⁷	Saudi Arabia	2017	Pre-post	-	34	St	-	Lab
Falcone et al. ²³	USA	2008	Cohort	Pediatric	160	RN, S, E, RT	46	Lab
Gillman et al. ³⁸	Canada	2016	Pre-post	-	109	RN, RT, PO	44	Lab
Hargestam et al. ³⁹	Sweden	2013	Descriptive	-	96	RN, S, A, OR	16	<i>In situ</i>
Harvey et al. ⁴⁰	Canada	2010	Randomized crossover study	-	13	S, E	26	Lab
Hoang et al. ⁴¹	USA	2016	Pre-post	-	-	RN, A, PO	-	Other (naval base)
Holcomb et al. ²⁰	USA	2002	Pre-post, cohort	-	30	RN, S, PO	60	Lab
Hunt et al. ⁴²	USA	2007	Pre-post	Pediatric	-	-	36	<i>In situ</i>
Hunt et al. ⁴³	USA	2006	Descriptive	Pediatric	-	-	35	<i>In situ</i>
Jakobsen et al. ⁴⁴	Norway	2018	Descriptive, Qualitative	-	310	St	-	Lab
Kellicut et al. ⁴⁵	USA	2014	Pre-post, Descriptive	-	220	RN, S, OR	-	<i>In situ</i>
Kim et al. ⁴⁶	USA	2012	Pre-post	Both	13	RN, PO, EMT	-	Lab
King et al. ⁴⁷	USA	2006	Descriptive	Adult	-	PO, St, OR	-	Other (team creates own ER, field OR, and ICU)
Knudson et al. ¹⁷	USA	2008	Randomized control trial	Both	18	S	-	Lab
Lehner et al. ⁴⁸	Germany	2017	Pre-post, descriptive	Pediatric	18	RN, S, A, E, CC	-	Lab
Marr et al. ⁴⁹	USA	2012	Pre-post	-	44	S, E	-	Lab
Marshall et al. ⁵⁰	USA	2001	Pre-post	-	12	S	-	Lab
Mikrogiannakis et al. ⁵¹	Canada	2008	Pre-post	Pediatric	37	S, A, E, CC, PO	-	-
Miller et al. ⁵²	USA	2012	Pre-post	-	-	RN, S, E, RT, OT	8	<i>In situ</i>
Murphy et al. ¹⁸	Australia	2018	Pre-post	Adult	324	RN, PO, Rad	-	-
Ostergaard et al. ⁵³	Denmark	2008	Descriptive	-	168	RN, S, A, PO, OT	-	<i>In situ</i>

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TABLE 1 (continued)

Author	Country	Year	Design	Simulated Patient Age	Participants (n)	Participant Profession	Simulations (n)	Simulation Location
Patterson et al. ⁵⁴	USA	2013	Descriptive	Pediatric	218	RN, S, A, E, CC, RT, EMT	25	In situ
Peckler et al. ⁵⁵	USA	2012	Pre-post	-	41	RN, S, E, RT	-	-
Peters et al. ⁵⁶	USA	2018	Pre-post	-	82	RN	-	-
Siriratsivawong et al. ⁵⁷	USA	2016	Pre-post	Adult	123	RN, S, A, E, PO	-	Other (navy ship)
Steinmann et al. ⁵⁸	USA	2012	Pre-post	-	137	RN, S, E, RT, OT	57	In situ
Steinmann et al. ⁵⁹	USA	2011	Pre-post	-	137	RN, S, E, RT, OT	57	In situ
Subbarao et al. ⁶⁰	USA	2006	Pre-post	Both	67	RN, E, St, EMT, OT	-	-
Sullivan et al. ⁶¹	USA	2017	Pre-post	Adult	65	RN, S, E	26	Lab
Wallin et al. ⁶²	Sweden	2007	Pre-post	-	15	RN, St	-	Lab
Whitney et al. ⁶³	USA	2016	Pre-post	Pediatric	99	PO	-	Other (table-top)
Wisborg et al. ⁶⁴	Norway	2008	Pre-post	-	1767	RN, PO, OT	-	In situ
Ziesman et al. ⁶⁵	Canada	2013	Pre-post	-	29	RN, S, RT	-	Lab

Data not reported (-).

RN, registered nurse; S, surgery; A, anesthesia; E, emergency medicine; CC, critical care; PO, physician other; RT, respiratory; OT, other technician; St, student; Rad, radiology; OR, operating room.

teamwork, communication, or leadership to be significantly higher after simulation training. Only one study found no difference in nontechnical skills after the intervention.¹⁶

Analyses of Team Performance – Task Completion and Patient Outcomes

Simulation was associated with a higher number of resuscitation tasks completed in 77% of studies comparing this outcome. The remainder of studies (23%) found no difference in the number of resuscitation tasks completed, one of which was a randomized control trial which examined data from real trauma resuscitations.¹⁷ Trauma resuscitation process metrics (time to task completion and time to disposition) were significantly faster in studies that reported these outcomes (n = 11). One study found that time to critical operation was significantly faster after the intervention, but time to noncritical operation was significantly slower.¹⁸ Only 3 studies reported data on real patient outcomes.^{18,19,59} No significant differences in reported mortality or hospital length of stay were observed. In one study, emergency room length of stay was significantly longer in the overall cohort (all trauma patients) but significantly shorter for patients requiring critical operation.¹⁸

Trauma Resuscitation Knowledge

Studies which used a written examination to measure trauma resuscitation knowledge^{17,25,46,56,57,60} (n = 6) found that higher test scores were associated with the simulation intervention in 83% (n = 4 reported statistically significant differences). All 5 studies reporting higher test scores used a pre-post design in which the test was taken before and after the simulation intervention. One study did not find a significant difference in test scores in a randomized control trial which compared simulation-based team training to didactic-only education. This study design included only a post-test, however, so it could not be determined if trauma knowledge significantly changed in relation to the intervention.¹⁷

Simulation Participant Feedback

Subjective feedback from simulation participants was the most common outcome reported (n = 29). The content of the feedback surveys was variable, including questions about satisfaction with the simulation intervention, attitudes toward simulation training, confidence, perceived competence, perceived knowledge, and role understanding. Feedback was generally positive from study participants (Supplemental Table 1), with most studies concluding that simulation was a valuable educational tool for trauma resuscitation team training.

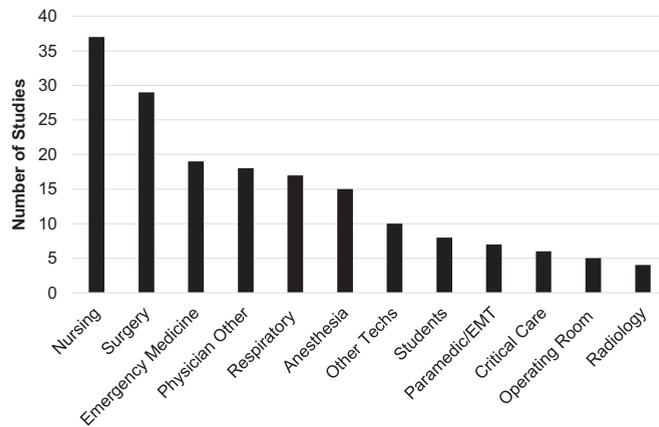


FIGURE 2. Frequency of profession participation in intervention for included studies. Participants not mutually exclusive. Pediatric and adult specialties are included in same category. ‘Physician Other’: orthopedics, otolaryngology, gynecology and obstetrics, oral surgery, general medical officers, family physicians, and physicians without named specialty. Not shown: Medic ($n = 3$), pharmacy ($n = 2$), child life ($n = 2$), social work ($n = 1$), and blood bank ($n = 1$).

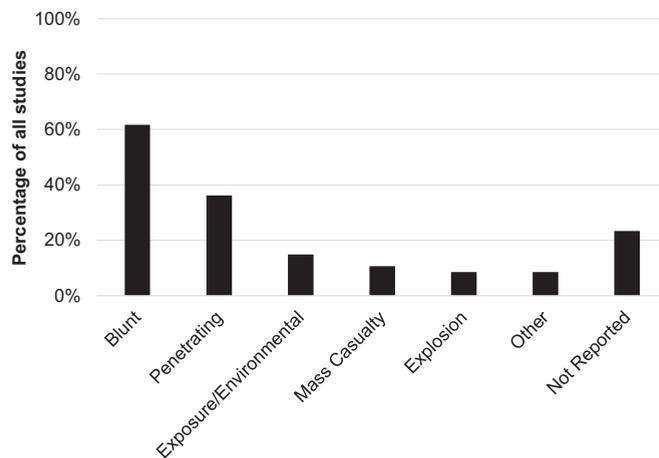


FIGURE 3. Frequency of injury mechanisms reported in simulated trauma scenarios. $N = 36$ (77%) studies reported injury mechanism. Mechanisms not mutually exclusive. ‘Other’ includes child abuse, amputation, drowning, and earthquake.

DISCUSSION

This scoping review of simulation team training for trauma resuscitation examined 47 studies from the last 20 years. We found considerable heterogeneity in elements of study design, including identity and number of participants, simulation setting, and outcomes reported. Only 2 studies were randomized, and under-reporting of research methodology was frequent. Measures of team performance such as teamwork, number of resuscitation tasks completed, time to task completion, and overall time to disposition improved in most studies that examined these as outcomes. The impact of simulation training on patient outcomes was rarely studied and no significant differences were observed.

Simulation training offers the benefit of practicing high-stakes skills needed to resuscitate a trauma patient. Post-simulation debriefing allows for feedback

directed at improving team and individual skills. Ideal use of simulation may result in higher quality resuscitation. No consensus measurement of trauma team performance or no proven “ideal” use of simulation exists. Use of patient outcomes to define team performance can be misleading, particularly in the adult population in which comorbid conditions can confound many outcome measures. Several studies examining trauma team performance have used resuscitation checklists, based on ATLS protocol, and time to task completion as surrogate measures of resuscitation quality.¹⁹⁻²³ The implication is that a high quality resuscitation requires rapid performance of critical resuscitation tasks. Most studies in our review found simulation training to improve the number of tasks completed and time to task completion. The main conclusion based on these studies is that simulation training improves trauma team performance.

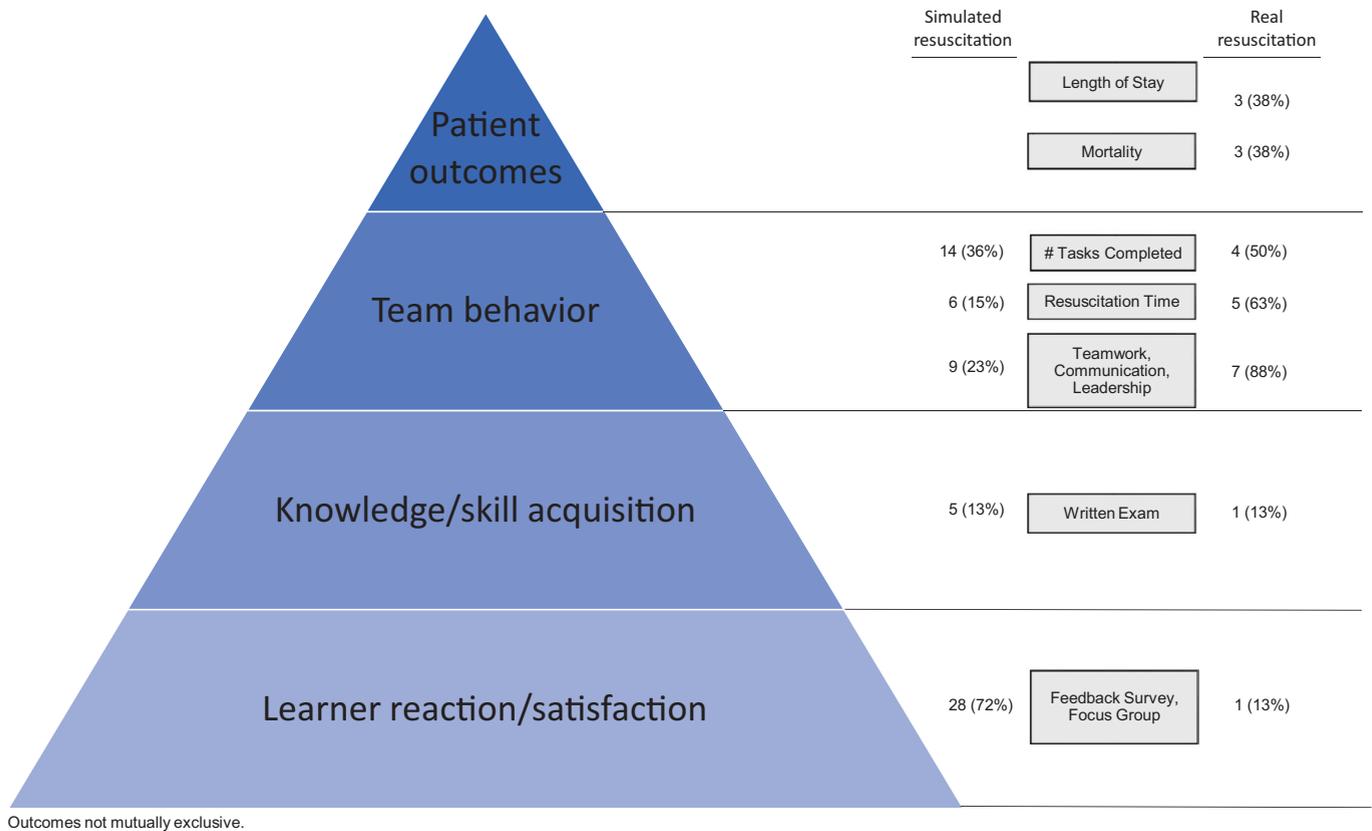


FIGURE 4. Kirkpatrick⁶⁶ model of measured outcomes after simulation intervention. Outcomes not mutually exclusive.

The lack of association with simulation-based training and improved patient outcomes is a major gap in the literature. Only 3 studies in this review reported actual trauma patient outcome data, finding no difference in complications, length of stay, or mortality. Although the use of simulation is supported by high provider satisfaction scores and improved teamwork measures, it has yet to be determined if simulated resuscitation training translates into any benefit to trauma patients. Many of the studies identified by this review were exploratory and most analytic studies used a pre-post design without a control group. At worst, the existing data suggest that simulation has no effect on trauma patient outcomes. This may be a manifestation of the myriad factors that contribute to trauma patient outcomes and the current state of modernized trauma care in which ATLS is ubiquitous and trauma resuscitation highly standardized (especially at trauma centers). Centers that have tested simulation training may be the very centers least likely to benefit from its implementation. Perhaps simulated resuscitation training would be more beneficial at smaller centers with lower trauma volume and less resources. Future studies testing the effects of simulation training for trauma resuscitation should apply a more rigorous research design (with an emphasis on prospective

studies with a true control group or randomized treatment groups) and strongly consider evaluating a variety of patient outcomes and metrics (such as time in the emergency department, time to critical procedures, volume of blood products transfused, disposition from the emergency department, and disposition from the hospital). Perhaps the patient benefit from simulation should not simply be measured by survival alone.

Omission of reporting elements of research methodology has been shown to occur frequently in studies examining simulation training in the healthcare setting.⁶ The findings of our review were consistent with this observation. Half of studies failed to report if adult or pediatric trauma patients were simulated. Over 20% did not provide any information of their simulation scenarios. Insufficient reporting of study design limits external validity and the ability to compare studies. One solution to the problem of under-reporting may include adherence to universal reporting criteria, as suggested by Cheng et al.²⁴ Specifically, the guidelines suggested by Cheng's consensus panel include reporting key methodical factors that are unique to simulation interventions such as the simulation equipment used, location and components of the simulation environment, a detailed description of the simulation scenarios, and explaining the

TABLE 2. Summary of Team Performance and Patient Outcomes in Analytic Studies

Author	Year	Comparison Group	Outcome Setting	Teamwork	Tasks Complete	Task Completion Time	Disposition Time	Mortality
Acerio et al.	2012	Same	Simulation		Increased	Faster		
Amiel et al.	2015	Same	Simulation	Increased	Increased			
Auerbach et al.	2014	Same	Simulation	Increased	Increased			
Baker et al.	2015	Same	Simulation	Increased				
Capella et al.	2010	Same	Real	Increased		Faster	Faster	ND
Doumouras et al.	2014	Same	Simulation	ND				
Falcone et al.	2008	Early cohort	Simulation		Increased	Faster		
Gillman et al.	2016	Same	Simulation	Increased	ND			
Hoang et al.	2016	Same	Simulation		Increased		Faster	
Holcomb et al.	2002	Same	Simulation		Increased	Faster		
Hunt et al.	2007	Same	Simulation		Increased			
Knudson et al.	2008	Didactic	Real	Increased	ND			
Marr et al.	2012	Same	Real	Increased		Faster	Faster	
Marshall et al.	2001	Same	Simulation	Increased	Increased			
Mikrogianakis et al.	2008	Same	Simulation		ND			
Miller et al.	2012	Same	Real	Increased				
Murphy et al.	2018	Same	Real				Faster*	ND
Siriratsivawong et al.	2016	Same	Simulation		Increased		Faster	
Steinmann et al.	2011	Same	Real	Increased	Increased		Faster	ND
Sullivan et al.	2017	Same	Simulation	Increased				
Wallin et al.	2007	Same	Simulation	Increased				

Outcomes left blank were not reported. ND = no difference.

*Time to operating room was faster for patients with critical injuries, but slower for patients with noncritical injuries.

feedback or debriefing methods utilized. Journals which accept articles on simulation training should also consider recruiting reviewers with experience in simulation training or medical education. An emphasis on standardized reporting and study design may allow for future meta-analyses to better measure the impact of simulation training for trauma resuscitation.

This scoping review was limited by the search strategies used. We did not include studies from the grey literature, unpublished data, or conference abstracts. We performed a second database search after the initial screening to identify if any additional eligible articles had been published, but a risk of publication bias was evident in this review. Our search strategy was broad, and we did not limit articles based on publication date or language. This review was also limited by the lack of a formal quality assessment.

In summary, this scoping review found that simulation for acute trauma resuscitation team training is associated with improved provider confidence and knowledge, objective measures of teamwork and communication, number of resuscitation tasks completed, and time to task completion. The risk of bias was high in most publications, related to a preference for pre-post study design and nonrandomized group assignment. Omission of reporting of simulation design elements also occurred frequently. These results suggest that

more rigorous, higher quality studies are needed to address the benefit of simulation training for trauma resuscitation teams.

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SUPPLEMENTARY INFORMATION

Supplementary material associated with this article can be found in the online version at doi:[10.1016/j.jsurg.2019.05.002](https://doi.org/10.1016/j.jsurg.2019.05.002).