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How effective is trauma simulation as an educational process for healthcare providers within the trauma networks? A systematic review

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A B S T R A C T

Background: Major trauma is a significant public health problem and a leading cause of death for several age groups. To address this issue, Major Trauma Networks were introduced in the UK from 2010, consisting of Major Trauma Centres (MTCs) and a network of linked Trauma Units (TUs).

Objective: The aim is to undertake a systematic review to examine how effective is trauma simulation as an educational process for healthcare providers within trauma networks.

Methods: The databases searched included Medline, Embase and Cinahl from 2010 to 2016. This time frame was chosen to reflect more contemporaneous research into simulation training since the advent of trauma networks in 2010 and the publication of national trauma guidelines (NICE). Seven observational studies were selected for narrative review. The screening and selection process followed the PRISMA guidance. The method used to assess the selected studies is based on the Scottish Intercollegiate Guidelines Network (SIGN) handbook.

Results: Overall, the studies showed benefits of simulation in trauma training, with some statistical evidence that non-technical skills and overall trauma team performance improved after simulation training, which appears to be effective. Although no studies found any specific correlation of simulation- based learning in trauma to wider effects such as patient outcomes, length of stay or morbidity. Some studies have found that time to diagnosis and treatment arising from improved non-technical trauma team skills from simulation, are a valid surrogate indicator of improved patient outcomes.

Conclusion: Overall, it is evident from this review that trauma simulation is an effective educational tool, which can aid trauma learning, develop team's non-technical skills and increase task completion, having a positive impact on the trauma network. Trauma units should therefore benefit from increased trauma simulation training and accessibility to repeated simulation based courses or workshops.

1. Background

The World Health Organisation (WHO) [1] recognises traumatic injury is a public health problem in both high income and low to middle income countries and Kehoe et al. reported trauma to be the leading cause of death in people between the ages of 25– 50 years and the second leading cause for those over 75 years [2].

International comparisons demonstrated that the United Kingdom (UK) were lagging behind other comparable high income countries in the treatment of trauma patients [3]. The NCEPOD concluded that more than 50% of UK patients with major trauma received sub-standard care [3]. In 2000, the Royal College of Surgeons of England [4] recommended that within each geographical region, there should be a network of Major Trauma Centres and Trauma Units to treat trauma patients with life-threatening conditions. Trauma Networks were then finally introduced across the UK in 2010, initially in London, and since then implemented in other parts England and Wales [5].

Each network has one Major Trauma Centre (MTC) and a number of Trauma Units (TUs). MTCs are equipped to treat severely injured patients 24 h a day. The supporting Trauma Units (TU) are responsible for managing patients with less severe injuries, including the assessment and transfer of those trauma patients requiring major trauma level one care [6]. Patients who trigger the major trauma triage tree will be conveyed to the nearest MTC by pre-hospital staff [7]. An evaluation of the London Trauma System by Cole et al. [8] reported significant improvement in the quality of care for trauma patients and an increase in the number of patients surviving following the implementation of the trauma network system [9]. In the original NCEPOD study, 18% of patients died, compared to 7% in the new Evaluation of the London Trauma System (ELoTS) report [10].

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Although there have been quality improvements as a result of the introduction of MTCs, the improvement is less evident in the TUs where there is disparity in trauma care. To obviate these clinical variations, it was recommended that further trauma training and multidisciplinary education are required to provide consistent trauma care in TUs [10,6]

While patients with obvious severe injuries are taken to MTC, TUs will receive infrequent major trauma patients, due either to major trauma patient's self-presentation to trauma units, or because of the evolution of pathophysiology, patients may not initially trigger the trauma activation criteria or because MTCs are overwhelmed. This results, consequentially, in the paucity of experience and lack of skills to manage the complex trauma patient.

The challenge facing the trauma networks is, how can healthcare providers develop and retain trauma skills, particularly within the UK TU environment, where exposure to complex trauma is significantly less?

1.1. Simulation in healthcare

Human errors, the quality of non-technical skills (NTS) in trauma resuscitations and cognitive mistakes are recognised as significant threats to patient safety [11]. These NTS include situational awareness, decision-making, communication, leadership and management of stress, fatigue and disturbance [12].

The National Health Service [13] has identified teamwork, situational awareness and communication skills as significant factors in adverse clinical events. Bergs et al. [14] for instance, estimated that 50% of communication errors occur in trauma team resuscitations; this, coupled with inefficient documentation, leads to errors and compromises patient safety.

Several studies report that simulation has been shown to develop motor skills, team work and communication [15], although in Issenberg et al. [16] systematic review of 109 papers, the authors maintain there is generally a lack of empirical evidence to support this contention; moreover, the studies published are generally weak and widely varying results were reported. Overall, rigour and quality of the papers required improvement but Issenberg et al. concluded high fidelity simulation is educationally valuable and complements clinical education.

Nevertheless, simulation training is a recommended method to help prevent human errors in patient care and an aid in decision making [17,18,11]. It is an established method for education and training for emergency care practitioners and is utilised as a model for accrediting such providers [19,20].

Given the need to establish effective methods of treatment at TU level, the aim of this systematic review is to address the question- how effective is trauma simulation as an educational process for healthcare providers within trauma networks?

2. Method

2.1. Design

The question is addressed and analysed using the PICO (Population, Intervention, Comparison and Outcome) framework. A 'comparison' has been omitted within the PICO table, because this is not a diagnostic review nor a randomised controlled trial (RCT) review [21] Table 1. The Preferred Reporting Items for Systematic Reviews and meta-analysis (PRISMA) statement was followed for the conduct and reporting of this review [25].

2.2. Search strategy

The search strategy aimed to find published studies limited to the English language. The initial timescale of the search was set originally from 2000 to 2016, but since the advent of trauma networks in 2010 and the publication of the national trauma guidelines (NICE) [22], on secondary consideration, the studies from 2000 to 2009 were removed. The rationale for amending the search years is intended to reflect more accurately the analysis of simulation in the new trauma network environment and to take account of significant technological changes in simulation and changes in teaching, learning and evaluation techniques relating to simulation in the years since 2010. Therefore, pre-set inclusion criteria for the search included reports using simulation as a learning aid, those in English, health professionals as learners, adult only resuscitations and those within trauma settings. Exclusions encompassed paediatrics, non-trauma simulations and papers published before 2010. The databases searched included Medline, Embase and Cinahl citing all relevant literature. An example Embase Search as shown in Appendix one

Table 1
Terms applied to search.

Population	Intervention	Outcome
Adults	Trauma	Simulation
Nurse	Emergency/Trauma	Simulation (patient, human or trauma)
Clinician	Emergency /Trauma nursing	Education
	Trauma teams	Nursing education

The key search terms used included *human simulation, trauma simulation, trauma education, nursing education, trauma, adult, emergency nursing.* Each database was searched using these terms or MeSH with boolean operators and fitting permutations. The specific search strategies were created by a health services librarian with expertise in systematic review searching.

3. Results

3.1. Study selection

The search discovered a total of 92 hits initially from the databases Embase 26, Medline 22 and CINAHL 44 including 1 hand search in Google Scholar. The author independently screened the titles and abstracts found from the search, against the inclusion criteria [25].

The articles that were removed included studies pre-2010, irrelevant studies, conference only abstracts and repeated results. In total eleven papers were fully read to assess suitability and criteria for quality.

Features sought for selected studies for final inclusion (full text screening) to ensure consistency included those with pre- and post-intervention design, simulation in clinical and non-clinical settings for trauma team members. Four papers were subsequently excluded that did not meet the inclusion criteria as they were not empirical studies [26–28]. The screening and selection process followed the PRISMA Checklist Fig. 1 [25].

Finally, seven articles were chosen to critique in this systematic review. A systematic narrative synthesis is provided with information presented in Table 2, to summarise and explain the characteristics and findings of the final included studies [25].

The methodology study design utilised is the Scottish Intercollegiate Guidelines Network (SIGN) model [23], the cohort checklist was deemed most appropriate due the selected studies being observational cohort and/or retrospective studies [24].

A narrative commentary was undertaken as there were insufficient studies and significant heterogeneity for a meta-analysis.

3.2. Overall description of the selected studies

The common thread in these studies is that they are, broadly, observational evaluations of the beneficial effects of non-technical skills (NTS) development on trauma team performance, demonstrated in

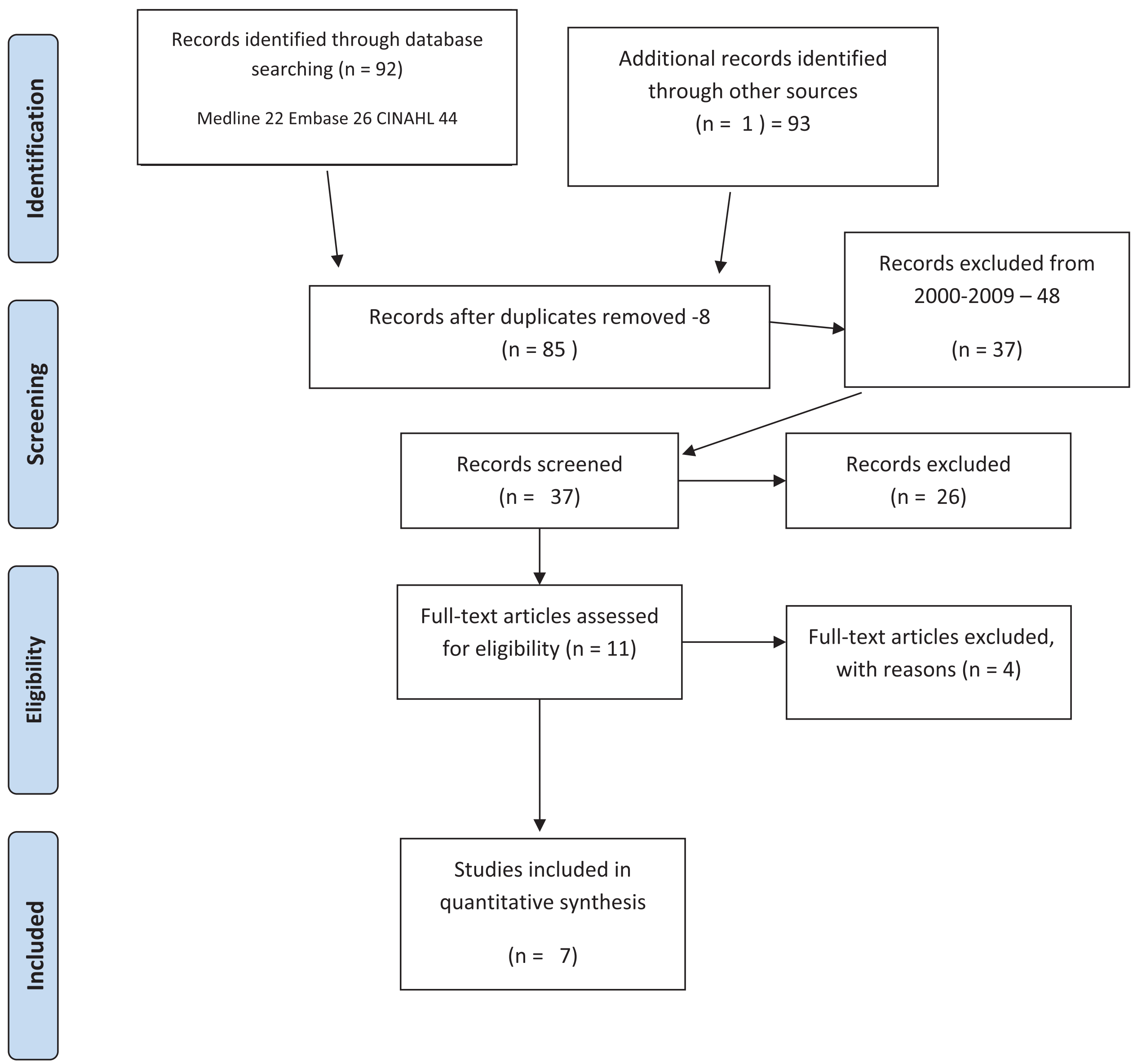

Fig. 1. PRISMA Flow Diagram to summarise study selection process [25].

virtual and real trauma settings, enhanced by prior preparation using simulation. Other learning modes, including traditional didactic methods are deployed, but the focus of interest in these studies is the relative effect of simulation and its sustainability as a strategy for improving better patient care through improved and measurable patient outcomes.

Most of the studies use pre- and post-observation methodologies and deploy evaluation instruments or previously accredited reference criteria to assess the effects they seek to demonstrate. NTS requirements and trauma team performance outputs are typically pre-determined and simulation and other learning interventions are described and implemented with the resultant outcomes reported.

3.3. Study Characteristics, design and methods of the studies

The seven selected studies [30–36], were all derived from peer-reviewed journals published between 2010 and 2015. Participants were all trauma team members or ED clinicians working in simulation or ED trauma settings, except for one involving pre-hospital nursing staff [33].

Four of the studies were set in the USA, one in Sweden, one in Central America, with one study from London, UK [35]. The range of participants was, where stated, 17–137 but several studies referenced the participation of trauma teams, stating their professional composition but not the number of staff participating. The time periods for the studies ranged from 5 days to two years and the settings were either in training spaces, simulation suites, in-situ clinical environments, actual trauma bays or combinations of these. All studies were cohort observational studies, mostly prospective with a pre/post intervention design and one was retrospective [30]. Interventions incorporated both didactic and simulation training with the purpose of demonstrating the beneficial impact of simulation training on trauma team performance and the acquisition and/or retention of technical and non-technical skills in the trauma team, and their effectiveness as an aid to patient safety and care.

3.4. Limitations and bias

None of the studies were randomised, controlled and blinded at the same time, indicating moderate to high bias. All studies were single centred, Hagiwara et al. [33] was the smallest study with only n = 17 participants and no control group. Briggs et al. [30] sample size was

Table 2
Description of the selected studies [23].

Study	Type & location	Cohort & selection	Intervention	Primary end points	Perfor. measure	Eval. Tools	Results
Briggs et al. [30]	Retrospective cohort study: Stratus Centre for Medical Simulation Boston, Mass. USA	20 trauma teams members undertook 2 separate high fidelity simulated trauma scenarios	Introduction to the principles of crisis resource management followed by simulated trauma scenarios	TT NTS were assessed using T-NOTECHS. NOTSS was used for assessing TL NTS. Clinical performance measures included adherence to trauma guidelines & time to performing critical tasks.	NTS scores & time to completion of critical tasks- ETT & Chest tube placement. And correlation of TL & TT scores	NOTSS, T-NOTECHS & local checklist	Correlation demonstrated between TL & TM cognitive skills ($p < 0.05$) & critical task performance. NTS skills decision making (correlation coefficient 0.775) & situational awareness (correlation coefficient 0.785). NTS performance declined as scenarios progressed ($p < 0.0001$).
Capella et al. [31]	Observation intervention study with pre-training/post-training design. Level 1 TC, Carilion Clinic, Roanoke, Va. USA	1) Convenience sample (n = 33) of trauma resuscitations evaluated 2) team training incl. didactic and sim sessions undertaken 3) another sample (n = 40) of actual trauma resuscitations evaluated.	Didactic and Simulation training	mprovement in teamwork NTS as described in TEAMSTEPPS; correlation with time to completion of critical tasks.Correlation with ICU, hospital LOS, complication & mortality rates and times from arrival to FAST and time in ED.	Age, gender, ISS, ICU LOS, Hosp. LOS,% no complications, % alive at discharge,% predicted to survive using TRISS, time to FAST, CT, ETT & OR, time in ED	TEAMSTEPPS with simulation; TPOT	Performance improved across all domains ($p < 0.001$). Performance times from arrival to CT, ETT & OR decreased significantly after training. ICU & hospital LOS, mortality & complication rates, times from arrival to FAST & time in the ED were not significantly different between pre & post training groups
Miller et al. [32]	Observation Study pre/post intervention. Department of Emergency Medicine Albuquerque New Mexico USA	Convenience sample of 39 trauma activations across four phases, pre-training, during, post and decay	1) Didactic phase -lecture 2) In-situ sim intervention. 8-week period of once-weekly simulations. With graduated difficulty, highlighting increasing importance of teamwork/ communication.	Teamwork, communication skill, situational awareness, decision-making, performance, allocation, role clarity, responsibility and patient friendliness	1)pre intervention didactic-only intervention2) in-situ sim phase, real trauma cases scored; 3)decay phase4)following discontinuation of in-situ sims	Clinical Team Skills (CTS) scale	NTS scores for 11 of 14 measures improved from baseline to didactic phase, mean and median scores of all CTS scale measures were greatest during the in-situ phase. Improved communication & teamwork seen in-situ phrase only. Benefits lost if programs cease.
Hagiwara et al. [33]	Observation study pre/post intervention. Health studies, Armed Forces Care for Defence Medicine, Sweden	17 ambulance nurse students evaluated in 2 simulated trauma cases. 1) theory 2) pre-test sim 3) post-test sim	Low/ high fidelity sim used in skill stations. Plus simulated exercises - moulage patients/ HFS mannequins	Progression of students' clinical competence following training as detailed in performance measures and evaluation tool	Ability to observe, gather data, structured patient history; evaluate patient's medical status. Initial treatment; decision making, communication and general safety during procedures.	GRSAPCC	Increase in over-all results in post-test, mean difference from pre-test of 1.2. Improvements were in situational awareness, patient assessment & decision-making.
Pringle et al. [34]	Observational pre/post intervention study School of Medicine, Managua, Nicaragua	33 participants in a 5-day trauma course. Selection criteria not specified but participants selected from highly qualified groups	Didactic & simulation components included 18 lectures, 3 procedure labs, &4 live simulation cases. On days 1 & 5, participants underwent pre- and post-training evaluations	Simulation case scores based on completion of simulation trauma tasks, time to complete primary survey completion & cervical spine immobilization. Outcome of written tests post intervention.	Exam paper on trauma knowledge. Completion checklists tailored for each simulation case. Simulation mode not specified, except described as low-tech	Locally validated questions & checklists based on ATLS	Exam scores 26%, mean increase 15% ($p < 0.001$); simulation scores improved by 75%, mean increase of 29% ($p < 0.001$). Completion of primary survey/ cervical spine immobilization improved 56% to 97% and 81% to 94%. Time to completion of primary survey /cervical spine immobilization reduced by 56% & 47% in post-training simulations
Pucher et al. [35]	Observational prospective study. Major Trauma Centre St Mary's Hospital, London UK	50 real trauma calls observed over 6-month period; purposive sample over 24/7 by clinician observers trained in T-NOTECHS	No intervention. Observational study of in-situ trauma calls assessing trauma management performance and using T-NOTECHS to assess NTS	Observation from time of TT activation to final disposition defined as transfer to CT, to OR; to interventional radiology; TT stepdown after stabilization or death	Completion and timing primary and secondary assessments, X ray, FAST. NTS assessed using T-NOTECHS. Delays, errors adverse events noted. Demographic and injury data recorded.	T-NOTECHS	Trauma calls with T-NOTECHS scores below median had greater time to disposition (35 min (IQR 23–53) compared to T-NOTECH scores above the median, 20 min (IQR 16–25, $p < 0.46$). No significant correlation with incidence of delays or LOS.Morbidity and mortality not assessed as endpoints because of low incidence.

(*continued on next page*)

Table 2 (*continued*)

Study	Type & location	Cohort & selection	Intervention	Primary end points	Perfor. measure	Eval. Tools	Results
Steinemann et al. [36]	Observational prospective study: Queens Medical Centre Honolulu, Hawaii USA	137 TT members. 244 real life and 33 blunt trauma resuscitations observed before and after training	Pre-training vs. post-training performance. HPS-based, in situ team training curriculum.	Times to critical clinical task completion, total time in the ED and T-NOTECH teamwork ratings	Task completion -trauma survey, vital signs, physical exam, FAST, chest X-ray, time in the ED, number /type of procedures performed, unavoidable delays to patient transfer	T-NOTECHS, subsequently validated in Steinemann et al. 2012	Improved T-NOTECH scores. (Means pre,15.9, post,19.5p < 0.001) Improved speed / clinical tasks. In observed real resuscitations post training, improved- mean teamwork scores from the pre-to post-training resuscitations. 76% increase in task completion and mean overall ED resuscitation time reduced by 16%

Key to the selected studies-Table 2:
Perfor = Performance
Eval = Evaluation
ATLS = Advanced Trauma Life Support Course TT/TL = Trauma team/leader; TTT = Trauma Team training; MTC = Major Trauma Centre; MDT = multi-disciplinary team; NTS = Non-technical skills; ICU = Intensive Care Unit; ETT = Endo-tracheal tube; CT = computerised tomography scan; FAST = Focused Assessment with Sonography in Trauma; (TR) ISS= (Trauma and) Injury Severity Score; LOS = length of stay; ED/ER = Emergency Department/Room; OR = Operating Room; OOH = Out of hours; ISTS = In-situ trauma simulation; HFS = High fidelity simulators; GRSAPCC = Global Rating Scale for Assessment of Paramedic Clinical Competence; T-NOTECHS = modified nontechnical skills scale for trauma; NOTSS = Non-technical skills for surgeon's scale TPOT = Trauma team performance observation tool; CTS = Clinical Teamwork Scale; TEAMSTEPPS = Team Strategies and Tools to Enhance Performance and Patient Safety; TRISS = Trauma Injury Severity Scale.

n = 20, the authors additionally disclosed some of the data was not published. Pringle et al. [34] also consisted of a small study sample n = 33, and the candidates (all leaders or educationalists) were deliberately chosen by the stakeholders to ensure 'top down' trauma change management, therefore this has potential selection bias [24].

Capella et al. [31] data was obtained retrospectively from the trauma registry, which may indicate a lack of complete data. And Miller et al. [32] convenience sample only assessed day traumas, so a 24hr picture was not represented. Overall, Pucher et al. [35] and Steinmann et al. [36] were the most robust studies in terms of participants, design features, performance measures, risk of bias, evaluation and outcomes.

All the studies deployed different trauma team members throughout the study groups, this was recognised in several studies as a potential limitation [32,36], however by contrast, trauma teams are not static and changed on a daily basis, thereby reducing any potential heterogeneity within studies. Senior residents were employed at set times throughout the year, and arguably this seniority in the trauma team might affect results [31,30], but then again, junior residents do represent a relatively homogenous group balancing any further bias.

A summary of limitations is discussed in Table 3; study size, in all cases precluded assessment of the effect of improved NTS and critical task performance on wider system outcomes such as LOS and mortality (as included in Table 3).

Further, potential risk of bias is summarised in Table 4 below. As seen in the table, studies demonstrated moderate to high risk of bias generally with risk of selection bias common to all. Confounders were only addressed fully in one, but overall the majority of studies were adequately conducted and reported. The use of validated tools to aid observation of NTS and video-taping helped to reduce inter-rater reliability (IRR) divergence and therefore detection bias.

3.5. Assessors

The other main form of evaluation was through the use of trained assessors. None of the assessors in these papers were blinded to the exposure and so risk of detection bias is generally evident as in all observational studies [29]. Although arguably, it is not possible to blind assessors. The training of the assessors is an important criterion in assessing the direction and degree of risk of bias but is only described in four of the papers [31,32,35,36]. The degree and extent of training varied from educators, clinical nurse trauma specialists, ATLS trained physicians, ATNC trained nurses, and medical students with training on the T-NOTECHS. Pucher *et al's* [35] assessor was trained in not only ethnography but simulation as well. In only one study [36], team members were blinded to the clinical outcomes of the study; overall, the assessors were not blinded in any of the other reported studies.

3.6. Heterogeneity

There was significant heterogeneity in study methods in these studies; the evaluation tools deployed, the degree of NTS tuition given to participants and the study parameters all varied widely. However, the core quantitative assessments common to most, were focused on statistical analysis of the relationship between improved trauma team and team leader performance (such as the time to completion of essential tasks in the trauma room, completion of the primary survey and the time taken to episode completion) following simulation training in NTS factors such as team-working, leadership, assessment, situational awareness, communication and decision-making.

3.7. Statistical summary of the findings

All studies found statistical improvement in performance after simulation training and there was a general trend in the studies to find significant increase in values relating to the more concrete cognitive NTS skills, which include assessment, decision-making, and situational

Table 3
Limitations of the studies.

Limitations						
Briggs et al. [30]	Capella et al. [31]	Hagiwara et al. [33]	Miller et al. [32]	Pringle et al. [34]	Pucher et al. [35]	Steinemann et al. [36]
Some data not published	Retrospective data from trauma registry	Small study	Only observed trauma calls in the day-only 9–4 Mon to Thurs	Small study- participants chosen by key stakeholders	Observer availability	Possible heterogeneity in using different team members
Potential assessor bias and training	Limited references	Potential assessor bias No control group Assessors not blinded	Limited references	Non validated written tests Exam papers ratified locally	Only one rater out of hours	

Table 4
Cochrane risk of bias tool [37].

Study	Type of bias	Level of risk	Notes
Briggs *et al* [30]	Selection	High	Team characteristics unspecified
	Detection	Mod-High	Comparability of values in NOTSS & T-NOTECHS instruments Used two tools to reduce single source bias **Overall: adequate study**
Capella *et al* [31]	Selection Performance Detection	Mod-High Mod-High Mod-High	Unblinded assessors and team aware Assessment criteria not described No training assessment criteria No explanation of assessment tool **Overall: unreliable study**
Hagiwara *et al* [33]	Selection	High	Self-selecting participants with wide range of experience
	Detection	Mod-High	Unblinded assessors **Overall: method satisfactory but study size suggests unreliability**
Miller *et al* [32]	Performance Detection	Mod-High Mod-High	Local assessors training unspecified Inability to distinguish leadership effect **Overall: adequate study/well designed**
Pringle *et al* [34]	Selection	High	Selection criteria not specified
	Performance	Mod	Participants chosen by key stakeholders Non-validated written tests but ATLS based **Overall: adequate study but small study size**
Steinemann *et al* [36]	Detection	Low-Moderate	Potential for observer bias TTM-Blinded to clinical endpoints **Overall: well conducted study**
Pucher *et al* [35]	Selection	Low	Good sample size/purposive sample. Analyses for confounders **Overall: well conducted study**

awareness as opposed to the "softer" NTS social skills of communication, interaction and coping with stress. In general, the studies under review demonstrated that NTS and overall trauma team performance improved after simulation training. A description of all endpoints of interest are explored in the discussion section.

4. Discussion

4.1. Hawthorne effect and performance

Three studies [35,36,31] did discuss the Hawthorne effect, in which, performance whilst being observed, tends to be superior to routine performance [38]. The Hawthorne effect has been under much debate over the decades. If the putative Hawthorne effect does exist, studies could become biased and pose significant implications for research

[39].

Steinemann's study [36] highlighted that the result of improved teamwork T-NOTECH scores may be attributed to the Hawthorne effect. However, it was noted that there is no incentive for the trauma teams to express better team working apart from enhancing patient care. The authors believe that improved clinical performance was secondary to the team members attaining experience during the time of their simulated scenarios, which is plausible. In Pucher et al. [35], the authors remarked that observers are regularly present in the trauma room for educational purposes, therefore any Hawthorne inspired change in behaviours is unlikely. This is evident in many of the London MTCs, where researchers or junior clinicians are present to gain clinical exposure day to day. This observational practice therefore has become a normal part of the trauma teams' daily work, which suggests it has little effect on behaviours.

Moreover, in Capella et al. [31] the resident clinical assessors were familiar with the environment and additionally worked within the trauma teams, thus, it was said, their familiarity minimised the Hawthorne effect. This is perhaps debatable and begs the questions that if the assessors were also part of the trauma team, they may well contribute to assessor bias. Although equally, the observer assessor requires a knowledge and understanding of the trauma process to comment sensibly on what has transpired [27].

Additionally, team personalities were signified as a potential confounding factor. Miller et al. [32] noted that whilst a single personality (leader) can have an effect on the team, the authors believe that the overriding culture of the team has more of an impact on communication and interactions.

In a contemporary study on the effect of nurse team leaders within major trauma resuscitations, Clements et al. [40] noted in their results, significant improvement in communication and accuracy of documentation and a decrease in negative elements of communication and leadership in trauma resuscitations, such as "intimidating personality", as it was phrased in their pre and post-test surveys. Nonetheless, personality types and correlation of trauma team leadership skills should be thoroughly explored in future studies.

4.2. Sustainability

Other significant factors that the studies highlighted are sustainability and retention of simulation skills, and their transfer into clinical practice. Retention of knowledge and skills can be linked to the amount of exposure to trauma care; if skills are not used frequently, they may be lost [41]. Miller et al. [32] found teamwork improved during the ISTS programme, but this was not sustained once the study ceased. Equally, Steinemann et al. [36] and Pringle et al. [34] echoed the question regarding sustainability and retention post programmes suggesting the necessity for refresher training. The difficulty in maintaining skills post training is supported by Rabøl et al. [42] and is known from patient safety interventions. The findings of these studies all emphasise the importance of continuous professional development linked to simulation based training.

4.3. Team performance and clinical outcomes

Observing trauma simulations and fast-moving real-life trauma calls is an intricate process coupled with the complex nature of trauma team working and their NTS in the contemporary trauma world, so what are the consequences of this training for patient outcomes? Can simulation training be easily transferable into the clinical setting? How can this relate to our trauma network training and current clinical practice?

One of the more important aspects of assessing the effectiveness of trauma team training is evaluating its impact on patient care and outcomes [43]. Wayne et al. [44] demonstrated that clinicians who had simulation training are more likely to adhere to clinical guidelines, prompting patient safety and evidence based practice, although data on patient outcomes according to Teteris et al. [45] are less clear.

Team performance and NTS showed significant statistical improvement in six of the studies [30,31,33,32,34,36] including, evaluating the ability to transfer learning into the clinical environment. Although one study found complications in maintaining this [30]. Four studies [31,35,36,34] all demonstrated statistically significant results in task completion and NTS skills, including disposition to definitive care and completion of the primary survey. Steinemann et al. [36] maintain that the completion of clinical tasks in the primary trauma survey appears to be a valid clinical measure which impacts on positive patient outcomes.

From analysing the chosen papers in this systematic review, it is evident the studies showed positive results in terms of team performance, acquisition or development of NTS and task completion/ task performance. However, study results in relation to wider considerations such as, patient outcomes (for instance mortality/morbidity, complications, LOS) are much less certain.

4.4. Patient outcomes

Three studies [36,35,31] set out to evaluate the wider patient outcomes such as mortality/morbidity, complications and LOS. All three studies showed no significant differences in these clinical endpoints and this result could be associated with the plethora of clinical variables within the complexity of trauma care or in fact that improved teamwork might have little effect on mortality. The consensus view was that there were so many factors affecting patient outcomes, that the impact on them by simulation training could not be detected in small studies such as those under review. Therefore, larger cohort studies are recommended to evaluate the effect on patient outcomes of timely trauma team interventions enhanced by training in NTS. Interestingly, Draycott's et al. [46] larger and related study on obstetric teams did show such an improvement in clinical outcomes. Nevertheless, Teteris et al. [45] and Aebersold and Tschannen [47] believes there is a paucity of empirical evidence of the direct impact of simulation on patient outcomes.

Gruen et al. [48] and Kirby [49] evaluated trauma performance studies focussing on morbidity and mortality rates including reporting missed injuries and reporting adverse events. But due to the retrospective nature of these studies, data error or data omission could suggest limitations. What is more, this data does not capture individual patient care or team performances, which are linked to effective patient management and the reduction of errors. However, Gruen et al. [50] recommends a shift in focus from mortality to non-mortality outcomes, from single measures of MTC and TU performance to measures more suitable to monitoring the performance of systems of trauma care spanning the entirety of the patient journey. This would produce wider, more accurate and meaningful data.

The National Peer Review Programme (NPRP) in the UK [51] has developed the Trauma Quality Improvement Network System (TQuINS), which records the level of compliance of MTCs, TUs and the trauma care pathway for patients and the services involved. The aims are to improve care for patients involved in trauma; improve the quality and effectiveness of care, to provide development and learning for all involved and to encourage the dissemination of good practice.

The outcomes of the NPRP include the confirmation of the characteristics of services, access to published reports regarding the quality of these and educational quality indicators. Key guidance documents include trauma competencies and the necessity for trauma training which incorporates trauma simulation and courses at an accredited level to meet the measurable TQuINS educational quality standards [51].

5. Summary of evidence

5.1. Limitations and strengths of the review

All studies considered for the review, except perhaps [35], had some methodological limitations, relating to the role of simulation in trauma team training. It was and remains an emergent field of study, characterised largely by observational studies, which have known limitations in relation to degree of risk of bias and subjectivity. Unpublished studies were not searched, which could result in a risk of publication bias. Strengths of this review include critiquing a contemporary topic and evaluating recent research within the last five years.

5.2. Implications for clinical practice and recommendations

There are demonstrable benefits from these studies, despite the acknowledged risk of bias. Nevertheless, none, except Pucher et al. [35] and perhaps Steinemann et al. [36] can be regarded as definitive in terms of their measured impact, because of their overall quality and low risk of bias compared with the other studies.

From this review recommendation for clinical practice, include:

- Overall increased access to trauma training for all healthcare professionals (in MTS, TUs and EDs).
- Trauma units should benefit from increased trauma simulation training and accessibility to simulation based courses or workshops on a rotational basis.
- Repetition of trauma simulation courses and local in-situ low fidelity simulation to retain skills in the TUs.
- Simulation courses should be incorporated into mandatory emergency medicine, trauma and nursing curricula.
- Further research, MTCs acting in concert should consider a multicentre study to demonstrate the links between simulation based-training and improved patient outcome.

A raft of ancillary initiatives at regional and local level would also support the sustainability of skills in the management of the trauma patient. The TQuINS peer review programme [51] points the way towards linking resources to quality of care and provides an opportunity for reviewing trauma training courses to recommend and encourage the use of simulation.

6. Conclusion

Trauma care has come a long way since the implementation of the trauma networks in 2010 and this review has aimed to track the developing literature over the last five years relating to the effectiveness of simulation in trauma team training.

From these, albeit, limited studies it is evident that trauma simulation is an effective educational tool, which can aid trauma learning, develop team's NTS, increase task completion and indirectly have a positive impact on patient outcomes.

The strategic vision and resources at the trauma network level are essential to support and sustain repeated simulated trauma team training. This in turn will have an encouraging effect on clinical outcomes for trauma patients in TUs and continuing care for trauma patients in MTCs.

7. Conflict of interest

No conflict of interest.

8. Ethical statement

No ethical approval required.

Appendix one

Embase

Database	Embase	
Year	< 1996 to 2016 Week 15 >	
1	exp simulation/(188867)	
2	trauma.tw. (164827)	
3	1 and 2 (9 4 7)	
4	(simulat* adj3 (patient or trauma or human)).tw. (7374)	
5	3 or 4 (8126)	
6	exp emergency nursing/(4661)	
7	exp nurse/(100228)	
8	exp nursing education/(38445)	
9	trauma.tw. (164827)	
10	6 or 7 or 8 (136128)	
11	9 and 10 (1548)	
12	trauma adj5 (nurse or nurses or nursing)).tw. (5 2 6)	
13	5 and 12 (29)	
14	limit 13 to (english language and yr = "2000 -Current") (26)	
15	hand removed 2000–2010 (3)	Total 23

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