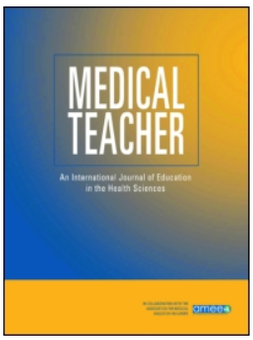

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Training in polytrauma management in medical curricula: A scoping review

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ABSTRACT

Introduction: Polytrauma (PT) is a leading cause of morbidity and mortality worldwide. However, it is unknown if PT teaching is taught or adequately included in undergraduate medical curricula. We conducted this scoping review to explore the literature on undergraduate PT training.

Methods: Using Arksey and O'Malley's five stage framework, a scoping review was conducted. Nine medical and educational databases, including PubMed, MEDLINE, Scopus, CINAHL, PsycINFO, and EMBASE were searched using keywords identified by the authors. Eligible studies were limited to the English language, with no set limitations on the year of publication. Studies reporting on PT teaching in undergraduate medical curricula were included.

Results: Nine studies were included. The articles were sub-categorised into three themes: current teaching of PT in medical curricula, trauma management courses and simulation-based trauma education. Four out of five studies on PT teaching in the curriculum were rated as inadequate by current or past students; on the other hand, three out of four trauma management/simulation courses were evaluated and all three were rated positively by students. Three trauma management courses compared students pre- and post-course scores on a written or practical test and reported significant improvement in post-course scores.

Conclusions: There is a relative paucity of literature on undergraduate PT training. There is a need for more research to explore how to deliver effective PT teaching to medical students.

KEYWORDS
Polytrauma; undergraduate; training; management; medical curricula; scoping review

Introduction

Polytrauma (PT)

PT is a modern medical term used in describing the medical condition of patients suffering from multiple severe traumatic injuries. To date, there is no internationally agreed definition of PT. The most recently updated definition suggests that trauma should include specific anatomical and physiological parameters to fit into the definition of PT. Anatomically, it is agreed that a patient with PT should have at least two body regions (systems) with Abbreviated Injury Scale (AIS) of more than two (Association for the Advancement of Automotive Medicine 2019). There is no international consensus on the physiological parameters of PT but it will most likely include tissue hypoxia and coagulopathy (Butcher and Balogh 2014). PT is a leading cause of morbidity and mortality in developed and developing countries (Matar 2007) and commonly affects young people within the 18–44 years age group (Kalsotra et al. 2016). Surgeons previously labelled the first few minutes of PT management as the 'golden hour', where the quality of medical care during this period will significantly increase or decrease the chances of injury related mortality and morbidity (Rogers et al. 2015).

Junior doctors in the emergency department are amongst the first to manage PT patients and provide them with initial resuscitation and care (Price and Hughes 1998; Carley and Driscoll 2001). Yates et al. conducted a study on the management of patients with major trauma presenting to 33 UK hospitals over a 2-year period and found that in 57% (826/1556) of cases of severe trauma (injury severity score $\geq$16) a senior house officer was in charge of the initial resuscitation (Yates et al. 1992). Training of surgical trainees, such as senior house officers, in the management of PT, is therefore, of clinical relevance, particularly when initial management during the 'golden hour' is correlated with clinical outcomes. At the postgraduate level many surgical trainees complete the Advanced Trauma Life Support (ATLS®) course, which provides training on early care of PT patients; however not all surgical trainees working in emergency departments or in acute surgical specialties have completed this training. A study by Graham and Sinclair (1996) found only 24% (28/119) of surgical trainees in acute surgical specialties in the West of Scotland had completed

Practice points

- Undergraduate PT education is poorly reported in the literature, and the small number of research articles identified in this scoping review confirms a lack of standardisation of training in PT.
- Medical students evaluated curricular trauma teaching as inadequate in four of five studies identified and evaluated trauma management courses, including simulation courses, in four out of four studies positively.
- More research is needed to determine design and components of effective PT teaching and evaluate long term impact on performance in the workplace.

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the ATLS®, while a study in the Republic of Ireland by Moholkar et al. (2004), across 26 hospitals providing acute trauma care, reported only 34% (167/488) were ATLS® trained (Graham and Sinclair 1996; Moholkar et al. 2004). Therefore, many surgical trainees, who take charge of the initial management of PT in their day-to-day clinical work may only have had training in PT in their undergraduate medical education.

In the US, Lucas et al., in their revision of the surgical clerkship and medical students' education in trauma, highlighted the need to develop a trauma core curriculum which should keep up with rapid developments in trauma care and the continuously changing trends in emergency medical systems (Lucas et al. 1986). In the UK, Taylor et al. made a recommendation to include structured teaching of trauma medicine within the undergraduate medical schools' curricula (Taylor and Johnston 1990). Carley and Driscoll recommended that trauma management training should actively begin at the undergraduate level (Carley and Driscoll 2001). We conducted a scoping review of the literature on undergraduate medical education in PT.

Scoping review

Scoping reviews are relatively new and there is no universal definition; most definitions, however, refer to 'mapping', a method that summarizes a range of existing evidence in order to convey the depth and breadth of a topic (Anderson et al. 2008; Levac et al. 2010). Scoping reviews do not include a formal assessment of the reviewed studies methodologies; instead, they usually provide an overview of the existing evidence base regardless of its quality (Peters et al. 2015). To ensure trustworthy scoping reviews' results, Zachary et al. emphasized on the importance of rigorous and transparent methods in their conduction (Zachary et al. 2018).

Arksey and O'Malley presented a five-stage framework as a methodological approach for conducting scoping reviews (Arksey and O'Malley 2005). Levac et al. published recommendations to clarify and enhance Arksey and O'Malley's scoping review framework (Levac et al. 2010).

The purpose of our scoping review is to explore the literature on training in PT in undergraduate medical curricula. We aim to highlight what is known from existing literature, identify the types of available evidence in PT management in medical curricula, examine how research was conducted on this topic, and identify and analyze gaps in the knowledge base.

Methods

In our scoping review, we applied the five systematic stage framework proposed by Arksey and O'Malley: (i) Identifying the research questions (ii) Searching for relevant studies, (iii) Selecting relevant studies, (iv) Charting the data, and (v) Collating, summarizing, and reporting the results (Arksey and O'Malley 2005). In addition, we considered Levac et al. recommendations to clarify and enhance each stage (Levac et al. 2010). We followed an explicit process to ensure that our search is replicable and to enhance the rigour of our review findings.

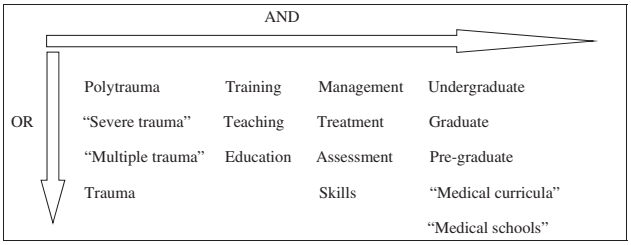

Figure 1. Illustration of literature search terms.

Stage 1, identifying research question(s)

Our research adopted one primary question in addition to two secondary questions:

Primary question:

- What is reported in the existing literature on training in PT in medical curricula?

Secondary questions:

- What teaching methods are used in PT education in medical curricula?
- What is the evidence of impact of PT training in medical curricula?

Stage 2, search for relevant studies

We refined our search strategy in consultation with an expert librarian at the National University of Ireland Galway. Eligible studies were limited to the English language, with no set limitations of the year of publication. Keywords/mesh terms, thesaurus and Boolean operators (AND/OR) were used to expand or narrow the search.

Keywords included: Polytrauma OR 'severe trauma' OR 'multiple trauma' OR trauma AND training OR teaching OR education AND management OR treatment OR assessment OR skills AND undergraduate OR graduate OR pre-graduate OR medical curricula OR medical schools (Figure 1).

Databases searched were the following: Pubmed, Medline, Scopus, Cinahl, PsycINFO, Cochrane, Embase, Education Resources Information Centre (ERIC), and Web of science. In addition, a hand-search of reference lists of included studies was conducted.

Stage 3, selecting relevant studies

Two research team members (MJ, YF) assessed the studies identified by our search based on the following criteria:

Inclusion criteria: we searched all published articles related to trauma teaching in undergraduate medical curricula. We included studies reporting on trauma teaching delivered to medical students as part of their curriculum. Inclusion criteria were studies reporting trauma management in adults, written in the English language of which full-text was available. Exclusion criteria were articles which reported PT education in postgraduate education and articles which focused on paediatric trauma education.

Initial scanning of the titles and abstracts was conducted to determine the retrieval of potentially relevant full articles for review. After full-text screening references of included articles were screened to search for additional

articles. Any discrepancies between the two reviewers were resolved by discussing the articles and making a final decision. The bibliographic software of 'Endnote' and the Web application 'Rayyan' were used to collect and manage data.

Stage 4, charting the data

Data extraction from included studies was preceded by developing a data charting form to record characteristics of the included studies and determine the key information and variables to be extracted. This framework was developed and implemented by both reviewers.

Stage 5, collating, summarizing, and reporting the results

The included articles were collated, summarized and presented in the data charting form (Table 1). Emerging themes were identified by both reviewers, the included articles were sub-categorized and the findings discussed.

Results

Descriptive summary of articles included in scoping review

The initial search identified 692 potential articles (Figure 2). Following removal of duplicates, both reviewers (MJ, YF) independently screened titles and abstracts of the remaining 687 articles and 667 articles were excluded as they did not meet our inclusion criteria. The full texts of the selected 20 articles were read by the two reviewers and a further 12 articles were excluded. Reference lists of the selected eight articles were hand searched for any additional relevant studies; one article was selected and, following full-text review by both reviewers, it was added to the selected articles. The nine articles were categorized in curricular teaching on trauma management, trauma management courses and simulation-based trauma education.

Curricular teaching on trauma management

Five articles discussed the current teaching of PT in undergraduate medical curricula, four of which collected data from the administration of questionnaires (O'Dowd and Spencer 1992; Gabram et al. 2004; Mastoridis et al. 2011; Zonies et al. 2012; Waterford et al. 2015). In the UK O'Dowd and Spencer surveyed medical schools faculties (24 medical schools) engaged in teaching of orthopaedic and trauma surgery and Mastoridis et al. surveyed medical students from 16 medical schools on their curricular trauma education (O'Dowd and Spencer 1992; Mastoridis et al. 2011). Zonies et al. administered a questionnaire to 1502 medical students attending 77 medical schools in the world, located in high, high middle, low middle and low income countries, on trauma and burn education in their curricula (Zonies et al. 2012). Gabram et al. surveyed graduates from a single medical school in the US and Waterford et al. conducted a review of the curriculum in a single medical school, also in the US (Gabram et al. 2004; Waterford et al. 2015).

O'Dowd and Spencer reported on duration of trauma education and types of tuition being delivered in 24 U.K. medical schools; they reported an average of 5.6 weeks (range 3–12 weeks) of a course on trauma and orthopaedic teaching, with tuition being delivered in tutorials, on ward rounds and in outpatient clinics. The combination of subjects taught alongside orthopaedic and trauma surgery varied from none to a combination with 2 or 3 other disciplines such as rheumatology or accident and emergency medicine. Two-thirds of medical schools (16 out of 24) involved medical students in 'on-call' work for trauma cases. Zonies et al. surveyed 1502 medical students from 77 countries and also reported variability in the amount of time allocated to trauma training in the curriculum, ranging from less than 10 h to more than 2 months (Zonies et al. 2012). In addition, they reported most curricula delivered didactic teaching in core components but practical exposure was lacking. For example, only 36% had practical training in cervical spine stabilization, 52% in fluid resuscitation and 38% in external haemorrhage control. Mastoridis et al. did not report on duration of time on a course of trauma education but did report on tuition time; they found that 68% (34/50) and 18% (9/50) of final year students surveyed had received less than 5 h and no bedside teaching in trauma medicine respectively (Mastoridis et al. 2011). Waterford et al. examined the pre-clinical curriculum at Harvard Medical School and report on the amount of time devoted to the teaching of trauma education (Waterford et al. 2015). They found 6.5 h were spent on trauma education, a half hour lecture on orthopaedic fractures and a 6-h small group case-based discussion of a single case of musculoskeletal trauma. The authors found that core areas of trauma, such as traumatic brain injury, chest or abdominal trauma or head injury were not taught. Graham et al. surveyed graduates of a single medical school in the US on medical school electives in the surgical subspecialties (Graham and Sinclair 1996). Electives in trauma and burns were 2 weeks in duration. The authors did not provide details of the tuition or amount of time in classroom/bedside tutorials or doing practical training.

The quality of trauma education, as perceived by medical students was reported in some of these articles. In their survey, Mastoridis et al. included items on students' perceptions of trauma teaching in the curriculum: participating medical students confirmed their suspicions, whereby the mean score on a Likert-scale statement on agreement that teaching in trauma medicine was adequate indicated students did not agree with this statement (mean score 3.62, with scores $>$ 3.5 indicating disagreement). Zonies et al. reported that only 55% of students felt they were prepared to manage basic trauma care (Zonies et al. 2012). In addition, their comparison between countries revealed that undergraduate curricula in low and low middle income countries delivered more practical training than those in high middle and high income countries. Graham et al. evaluated the quality of surgical electives from the student perspective, whereby respondents were asked to rate the surgical electives in terms of meeting objectives of the six Accreditation Council for Graduate Medical Education core competencies (Bunnington and Williams 2003). Respondents rated the trauma and burns electives above average in achieving objectives in areas such as medical

Table 1. Data charting form.

Authors	Year	Country	Population and sample	Study design	Instrument used	Findings related to scoping review questions
Cuisinier A, Schilte C, Declety P, Picard J, Berger K, Bouzat P, Falcon D, Bosson JL, Payen JF, Albaladejo P	2015	France	19 Medical students during their 4th, 5th, or 6th year, Grenoble University Hospital/ France.	Pre-post interventional study	Trauma training course	Major trauma course led to improvement in student skills for major trauma management.
Gabram SGA, Hoenig J, Creech S, Minks KD, Gamelli RL	2004	USA	168 Graduates of Loyola University Chicago Stritch School of Medicine/ USA, (1999–2002).	Retrospective cohort study	Questionnaire	Trauma third year medical school elective met objectives in 5 of the 6 competencies set forth by the Accreditation Council for Graduate Medical Education (ACGME).
Hill DA	1993	Australia	41 4th year and 32 final year medical students, Royal Prince Alfred Hospital/Australia.	Pre-post interventional study	Trauma training course	Training course improved students' performance in managing traumatized patients
Hill KA, Johnson ED, Lutomia M, Puyana JC, Lee KK, Oduor PR, MacLeod JB	2018	Kenya	All final year medical students (61) of Egerton University Medical School/Kenya.	Pre-post interventional study	Trauma training course	Implementing TEAM course in Kenya was feasible. Demonstrated the course's effectiveness in this context as shown by knowledge acquisition.
Jakobsen RB, Gran SF, Grimsmo B, Arntzen K, Fosse E, Frich JC, Hjortdahl P	2018	Norway	310 Students and 16 facilitators from The Faculty of Medicine at the University of Oslo and the Department of Nursing at Oslo and Akershus University College of Applied Sciences/Norway.	Retrospective cohort study	Questionnaire	Inter-professional simulation-based emergency team training course was feasible to run. The course improved the students' team skills and received a favorable evaluation from both students and faculty.
Mastoridis S, Shanmugarajah K, Kneebone R	2011	UK	179 Medical students from 16 universities across the UK.	Cross-sectional	Questionnaire	Corroborated previous concerns that junior doctors are under-prepared for managing trauma patients. Supported the repeated calls made to include teaching of trauma in the undergraduate curriculum.
O'Dowd JK, Spencer JD	1992	UK	24 University orthopaedic and trauma surgery departments in the medical schools in Great Britain.	Cross-sectional	Questionnaire	There are major differences between these medical schools in the range of time spent in teaching trauma and delivering this teaching, and in teaching and assessment methods.
Waterford SD, Williams M, Siegert CJ, Fisichella PM, Lebenthal A	2015	USA	Preclinical curriculum of the Northeastern Medical School/USA.	Cross-sectional	Curricular review	Trauma education in the preclinical stage is almost absent. Preclinical curriculum might not be sufficient to expose medical students to the fundamentals of trauma management.
Zonies D, Maier R, Civil I, Eid A, Geisler B, Guerrero A, Mock C	2012	USA	774 Final year medical students from 77 countries.	Cross sectional	Questionnaire	Only half of the students felt prepared to manage traumatized patients and provide them with the basic care required safely.

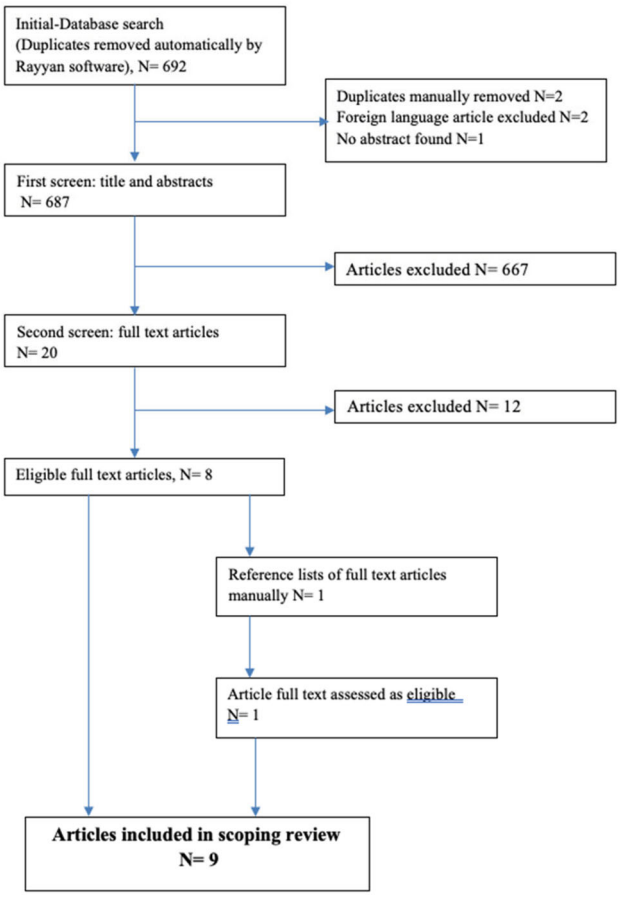

Figure 2. A flowchart demonstrating this scoping review's search results.

knowledge, patient care, making decisions, performing basic procedures, interpreting test results, understanding pain control and explaining test results and care plans. The trauma elective excelled in exposure to procedures and acute resuscitations (Graham and Sinclair 1996).

Trauma management courses (TMCs)

Three articles discussed the role and effectiveness of implementing TMCs at the undergraduate level. David Hill described a TMC developed to address 'perceived deficiencies of organized trauma content in many undergraduate surgical programmes': it aimed to provide a dedicated course on trauma care, rather than the fragmented, discipline-based teaching of trauma found in many medical curricula (Hill 1993). The model combined structured teaching in Year IV and a 15-week clinical clerkship in Year VI of the 6-year undergraduate curriculum in an Australian medical school. In Year IV students were taught basic knowledge and clinical skills; these were then expanded on in Year VI to a higher level of knowledge and clinical skills, with practice on resuscitation of simulated multi-trauma patients (Hill 1993). Classroom teaching consisted of a lecture followed by rotation, in small groups, through six stations where short tutorials were conducted by tutors (experienced trauma care clinicians). Topics covered included assessment and management of airway, chest injury and haemorrhagic shock.

Hill et al. studied the effect of implementing Trauma Evaluation and Management Course (TEAM) on final year medical students in Kenya (Hill et al. 2018). TEAM was developed by the American College of Surgeons and is adapted from the ATLS® course; its purpose is to provide teaching in trauma assessment and management to medical students. The authors modified TEAM content and structure to ensure it was effective and feasible in a low-income setting. The course was delivered by clinicians who were active in the management of trauma in Kenya (five instructors) and in Canada/US (two instructors). The structure of the course was similar to that described by David Hill in Australia, with large group teaching (lectures and videos) followed by students rotating in small groups through stations. In the case of Hill et al. the stations delivered case-based learning, radiology practice and essential procedure skills. Cuisinier et al. describe a TMC developed to improve theoretical knowledge, technical skills and behavioural abilities of medical students in the management of major trauma (Cuisinier et al. 2015). The course was delivered to fourth, fifth and sixth-year students during their emergency and intensive care unit (ICU) programmes in the undergraduate medical curriculum in a French medical school. The course consisted of three sessions: the first session was a 'poster fair,' where students viewed 10 posters with audio-guides; the second session consisted of workshops teaching technical skills, such as airway management and chest drainage; the final session was a simulation workshop using a high-fidelity manikin delivered by experienced clinicians in trauma care.

The Australian TMC assessed students' learning by conducting a pre-course multiple choice question (MCQ) test and a post-course MCQ test. Students in both years performed significantly better in the post-course MCQ (for example, year VI students pre-course mean (SD) of 18 (3) increased to post-course mean (SD) of 24 (2), $p < 0.001$). Hill also reports that the MCQ test was employed formatively, with immediate marking after the test and provision of feedback to students. Assessment of the TEAM course in Kenya, similar to the TMC in Australia, consisted of a pre-course and post-course MCQ test; mean post-course score was significantly higher than mean pre-test score (pre-course mean score of 57% increasing to post-course score of 72%, $p < 0.001$). Cuisinier et al. assessed students' ability to provide first line care of simulated major trauma cases, with a before and after test. Mean post-course scores on the assessment and management of simulated major trauma cases increased by 47% compared with pre-course scores ($p < 0.01$). The TEAM course in Kenya collected narrative evaluations and reported the course was positively evaluated; in particular, students liked the inter-active components, such as small group case-based discussions and skills practice (Hill et al. 2018). Time constraints were noted and students expressed the need for more time, in particular, for small group teaching and skills practice. Students who completed the TMC in Grenoble University Hospital expressed a high level of satisfaction with the course (Cuisinier et al. 2015).

Simulation-based teaching

Use of simulation to teach technical and non-technical skills in initial assessment and management of trauma patients was described in four articles, three of which have been described in the above section on TMCs (Hill 1993; Cuisinier et al. 2015; Hill et al. 2018). The final article

reported on a simulation course adapted for students from a graduate training course in trauma management, 'Better and Systematic Team Training' (BEST), which was part of the curriculum for all final year medical students at the University of Oslo (Jakobsen et al. 2018). The learning focus was on development of team skills, using high-fidelity manikins, with a strong focus on inter-professional education (IPE) where medical students worked in teams with nursing students and students in nursing anaesthesia in managing trauma simulations. Students completed the course in 1 day, rotating in teams through four 60-min sessions, comprising a 20-min recorded simulation, followed by debriefing, and four 30-min interactive lectures. Facilitators had experience in teaching and delivering trauma and emergency care; they also completed a workshop on the BEST principles of simulation and debriefing.

Student learning from the student-BEST course was captured using qualitative (student free-text comments) and quantitative data from Likert scale questionnaires, where a score of 1 indicated 'strongly disagree' and 5 'strongly agree' (Jakobsen et al. 2018). Medical students agreed that their communication skills were improved by learning the 'closed loop' technique (mean (SD), 4.8 (0.5)), it was useful to document continuously, (mean (SD), 4.4 (0.8)), they learned something useful about how to take leadership in a team (mean (SD), 4.2 (0.8)), they learned that it was difficult for the leader to keep track of everything (mean (SD), 4.5 (0.6)), they learned something useful about teamwork (mean (SD), 4.8 (0.4)) and they were more positive about teamwork in the future (mean (SD). Medical students agreed that team members from different health professions were important (mean (SD) 4.8 (0.5). Qualitative data analysis yielded 5 themes, emotional activation and learning outcomes with 4 themes: insight and stress management, understanding the leadership role, insight into teamwork and skills in team communication (Jakobsen et al. 2018). Emotional activation was both positive and negative, using terms such as 'exciting,' 'fun,' 'scary' and 'demanding.' Jakobsen et al. reported that students rated learning about trauma management in a simulation setting more useful compared with traditional lectures on trauma topics (mean score (SD) of 4.8 (0.4)).

Discussion

Our findings reveal a relative lack of research on education in PT in undergraduate medical training. In the studies included in our review, we found variability in the amount of time spent in the curriculum on trauma education and in the combination of trauma education with other surgical subspecialties. In some cases, there was little time in the curriculum devoted to trauma education (Mastoridis et al. 2011; Zonies et al. 2012; Waterford et al. 2015). There is limited evidence on the learning achieved from trauma education. Only the TMCs assessed students' learning, reporting significant improvement in post-course scores on a written or practical test (Hill 1993; Cuisinier et al. 2015; Hill et al. 2018). Delivery of trauma education through traditional clinical clerkships, where tuition takes place in the workplace with or without some classroom teaching, was viewed by students in four of the five articles on trauma teaching in the curriculum as inadequate (O'Dowd and Spencer 1992; Mastoridis et al. 2011; Zonies et al. 2012; Waterford et al. 2015). Two of the three articles on TMC evaluated students' perceptions of the TMC and both reported a high level of satisfaction from students, with some requesting more time for trauma education (Cuisinier et al. 2015; Hill et al. 2018). The BEST course described by Jakobsen was the only study to deliver IPE in trauma training and the only course which focused on learning of non-technical skills in trauma management (Jakobsen et al. 2018). Compared to traditional lectures, students who completed the simulation trauma IPE course rated their learning of trauma management more useful.

Trauma and Emergency medicine has been recognized as the 23rd specialty by the American Board of Medical Examiners since 1979 (Jagoda et al. 1999). This specialty had very small beginnings about 50 years ago and its development continued to evolve mainly in UK, USA, and later in Australia, Europe and other parts of the world (Williams 2018). Trauma was the cause of death in 4.48 million deaths in 2017 and is one of the top 10 causes of death worldwide (GBD 2017, Causes of Death Collaborators). A comparison of curricular time spent on trauma education relevant to the burden of disease from trauma may be a useful exercise for curricula committees in medical schools. At the very least this exercise will highlight the time allocated to trauma education in the undergraduate curriculum.

Many medical schools have adapted an integrated curricular design where basic sciences are taught in the context of relevance to clinical medicine (Quintero et al. 2016). Purposeful trauma management courses, such as TMCs, in an integrated curriculum, would be expected to build on elements of trauma education delivered in other years and modules of the curriculum, reflecting both horizontal and vertical integration. It is unclear from our review if the authors of the TMC and simulation trauma courses considered curricular integration in their course design. We agree with Borggreve et al. that the focus should be on creating effective trauma educational programmes that are integrated into the curriculum (Borggreve et al. 2017).

Simulation is increasingly used and recommended in healthcare education (Motola et al. 2013; Jakobsen et al. 2018). It has a number of advantages over other teaching modalities and learning in the real-life clinical environment: these include patient safety, opportunities for repeated practice of skills and the teaching of both technical and non-technical skills (Motola et al. 2013; Borggreve et al. 2017; Jakobsen et al. 2018). Non-technical skills, such as communication skills, teamwork, situational awareness, decision making and task management can be applied, practiced and experienced in high-fidelity simulation; this hands-on learning in managing trauma patients rarely takes place in real-world trauma cases, where the urgency of medical care and patient safety take priority over teaching. Lack of effective communication skills and leadership have been found to be a factor in fatal medical events; by comparison effective communication and leadership skills are associated with shorter time in reaching a correct diagnosis and an increase in completed clinical tasks in emergencies (Doumouras et al. 2017). A review of literature of simulation-based trauma education (SBTE) for medical students reported three out of four studies which assessed student

learning reported significantly higher scores in the intervention group (SBTE) compared with a control or in the post-course assessment compared with pre-course assessment and recommended its implementation in the medical curriculum (Borggreve et al. 2017). We are in agreement that simulation should be implemented in medical education in general, and in trauma education in particular.

There is a lack of standardisation of trauma education in undergraduate medical curricula (Taylor and Johnston 1990; Carley and Driscoll 2001). Questions, such as, when to teach trauma management in the curriculum, how much time should be devoted to trauma teaching, what are the desired outcomes of trauma training and what teaching modalities should be used in trauma education are not answered at this time. This may be contributing to the varying amount of time spent in trauma education in medical curricula, the timing of trauma teaching in the curricula and the different learning objectives of trauma courses in undergraduate curricula, as reported in this review.

Findings from studies reporting TMC interventions with undergraduate medical students also reported improvements in clinical and cognitive skills, which are in agreement with the TMC studies in this review (Hill 1993; Ali et al. 2002, 2003, 2004; Ali 2003; Cuisinier et al. 2015; Delgado-Reyes et al. 2016; Hill et al. 2018). Ali and colleagues conducted a number of experimental studies, with before and after assessments of medical students who completed the intervention (TEAM), in a number of countries and reported improvement in students' knowledge and skills (Ali et al. 2002, 2004, 2005). This is similar to the findings reported by Hill et al. on TEAM in an undergraduate medical curriculum (Hill et al. 2018).

The impact of TMCs in medical curricula, reported to date, focuses on short-term evaluations, in particular on student evaluation and short-term learning. These are at level 1 (reaction of students to training) and level 2 (learning) of Kirkpatrick's 4 level model in evaluating training programmes (Kirkpatrick 1996). Evidence of retention of learning over time and at level 3 (behaviour or performance in the clinical workplace) and level 4 (results, such as improved patient safety and patient outcomes) are lacking at the undergraduate level. Others highlighted the same points and shared similar concerns when they discussed the effectiveness of implementing TMCs into the undergraduate surgical curricula (Lum and Subramaniam 2016; Hill et al. 2018).

Cherry and Ali call for further research "to validate long-term retention of knowledge and skills, provide reliable methods to evaluate teaching effectiveness and performance and to demonstrate improvement in patient safety and overall quality of care" from SBTE (Cherry and Ali 2008). There is some evidence from postgraduate training, that trauma skills learned through simulation, lead to improvements in performance in trauma management on-the-job (Knudson et al. 2008). More research is needed to determine if learning, including performance, of medical students in SBTE leads to better performance in trauma management on-the-job of junior doctors.

Limitations

Although our scoping review is on training in 'PT' management in medical curricula, the term PT is not used by authors reporting on undergraduate trauma management training. Instead, most articles used terms such as 'severe trauma', 'multiple trauma', or 'trauma'. This may reflect the absence of an internationally agreed definition of PT. However, we selected the term PT to draw attention to the need for undergraduate training in managing a life-threatening condition. We did not conduct a hand-search of key journals and only articles in English were included which means there could be relevant articles which are not included in this review. We acknowledge that our findings of a relative paucity of literature on PT teaching in medical curricula are not synonymous with a lack of coverage of this topic. It was beyond the scope of this review to include other approaches to assess curricular content, such as reviewing of the curricular maps of individual medical schools or interrogation of national accreditation bodies' learning objectives for undergraduate medical training.

Conclusions

Our scoping review highlights a relative paucity of literature on PT training in undergraduate medical curricula. Furthermore, the evaluation of PT teaching is limited and whether it can improve students' performance as junior doctors is unknown at this time. Increased attention from the medical education community and research on PT training at the undergraduate stage will help answer these unknowns and provide guidance on the provision of effective PT teaching to medical students.

Glossary

Abbreviated Injury Scale (AIS): 'Anatomically-based injury severity scoring system that classifies each injury by body region on a 6 point scale. AIS is the system used to determine the Injury Severity Score (ISS) of the multiply injured patient. AIS classifications:

- AIS 1 – Minor
- AIS 2 – Moderate
- AIS 3 – Serious
- AIS 4 – Severe
- AIS 5 – Critical
- AIS 6 – Maximal (currently untreatable)' (NSW Institute of Trauma and Injury Management (ITIM), 2020).

Injury Severity Score (ISS): ISS assesses the combined effects of the multiply injured patient and is based on the Abbreviated Injury Scale (AIS). ISS is an internationally recognised scoring system which correlates with mortality, morbidity and other measures of severity.

ISS is calculated as the sum of the squares of the highest AIS code in each of the three most severely injured ISS body regions. These body regions are:

- Head or neck
- Face
- Chest
- Abdominal or pelvic contents
- Extremities or pelvic girdle
- External

ISS range from 1 to 75. If an injury is assigned an AIS of 6, the ISS score is automatically assigned 75' (NSW Institute of Trauma and Injury Management (ITIM), 2020).

Disclosure statement

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