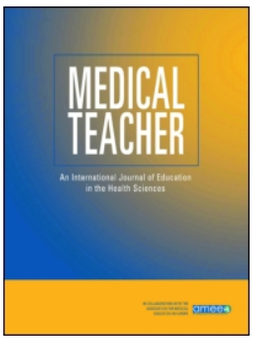

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A BEME systematic review of teaching interventions to equip medical students and residents in early recognition and prompt escalation of acute clinical deteriorations: BEME Guide No. 62

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BEME GUIDE

A BEME systematic review of teaching interventions to equip medical students and residents in early recognition and prompt escalation of acute clinical deteriorations: BEME Guide No. 62

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ABSTRACT

Background: Current educational interventions and teaching for acute deteriorations seem to address acute care learning in discreet segments. Technology enhanced and team training methodologies are in vogue though well studied in the nursing profession, teaching avenues for junior 'doctors in training' seem to be a lacuna.

Aims: The BEME systematic review was designed to (1) appraise the existing published evidence on educational interventions that are intended for 'doctors in training' to teach early recognition and prompt escalation in acute clinical deteriorations (2) to synthesise evidence & to evaluate educational effectiveness.

Methodology: The method applied was a descriptive, justification & clarification review. Databases searched included PubMed, PsycINFO, Science Direct and Scopus for original research and grey literature with no restrictions to year or language. Abstract review, full text decisions and data extraction were completed by two primary coders with final consensus by a third reviewer.

Results: 5592 titles and abstracts were chosen after removal of 905 duplications. After exclusion of 5555 studies, 37 full text articles were chosen for coding. 22 studies met final criteria of educational effectiveness, relevance to acute care. Educational platforms varied from didactics to blended learning approaches, small group teaching sessions, simulations, live & cadaveric tissue training, virtual environments and insitu team-based training. Translational outcomes with reduction in long term (up to 3–6 years) morbidity & mortality with financial savings were reported by 18% (4/22) studies. Interprofessional training were reported in 41% (9/22) of studies. Recent evidence demonstrated effectiveness of virtual environment and mobile game-based learning.

Conclusions: There were significant improvements in teaching initiatives with focus on observable behaviours and translational real patient outcomes. Serious game-based learning and virtual multi-user collaborative environments might enhance individual learners' cognitive deliberate practice. Acute care learning continuum with programmatic acute care portfolios could be a promise of the future.

KEYWORDS

Teaching interventions; acute deteriorations; acute/critical care; undergraduate and postgraduate training; trainee doctors (junior and senior house officers); medical education; health professions education; teaching effectiveness; teaching methods

Background

Acute deterioration can be defined '*as an evolving, (un)predictable and symptomatic process of worsening physiology towards critical illness*' (Lavoie et al. 2016). The patient with acute deterioration refers to a patient who moves from one clinical state to a worsening clinical state in a short period of time, dramatically increasing their individual risk of morbidity, including organ dysfunction, protracted hospital stay, disability or death (Jones et al. 2009).

Managing acutely deteriorating clinical situations requires the ability to process information rapidly in an intense atmosphere with multitude of inputs, roles and demands that require *situated cognition*. Situated cognition refers 'to activity, context and culture to solve problems' (Brown et al. 1989). Situated cognition as an attribute, once acquired, needs to be groomed and developed over the years of training so that healthcare professionals can process information in challenging clinical contexts in their senior

Practice points

- Acute care teaching and learning need to evolve as a programmatic portfolio-based initiative with continuity from early undergraduate clinical years to residency.
- Evaluations of effectiveness of teaching interventions should aim at long term improvements in system and patient outcomes.
- Performance expectations should be based on the context and situational circumstances.
- While high technology simulations are proven to be effective tools, individual cognitive deliberate practice and cognitive dexterity through serious game-based platforms and virtual environments could be a promise of the future.

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Supplemental data for this article can be accessed here.

years. This process requires *cognitive apprenticeship,* wherein the expert scaffolds the learning of the novice through graded responsibilities and learning opportunities (Collins et al. 1988; Dennen and Burner 2008). Curriculum developers strive to immerse the learners with progressively spiralling levels of knowledge, psychomotor & behavioural skills after ensuring that there is deliberate practise to achieve mastery in part task performance. This resonates with the *constructivist approach* of gradually introducing the unknown to the young 'doctors in training' after reinforcing prior clinical knowledge within the complexities of actual clinical situations (social learning theory, Bandura 1969).

The intent of medical and healthcare professions training is 'practice readiness' (GMC 2014a). Interns, house officers, foundational year trainees, residents and junior doctors are expected to manage patients who are acutely unwell and make the right assessments from the clinical cues and prompts received from the healthcare teams. It is known that when junior doctors commence independent work, the transitions were not seamless (Cave et al. 2009) and they were least prepared to make critical decisions in emergencies (Wall et al. 2006). There was an 8% increase in preventable mishaps with the induction period to clinical work for junior doctors, widely known as the 'killing season' and the 'black Wednesday' (Jen et al. 2009; Smith 2012). The inability to recognize acute illness and subsequent delay in prompt initiation of rescue measures, whilst awaiting senior assistance, thus is an area of concern.

It is known from published databases and acute care audits that 'one in four Intensive Care Unit (ICU) admissions were either without consultant intensivist supervision or did not receive formal review within 24 h after admission. In particular, the initial treatment was deemed to be delayed or inappropriate or both for those patients who died in ICU' (Adam and Odell 2005). Precious time is lost when there are significant delays in recognition of worrying clinical features (Hogan et al. 2012). This is more common if there were lapses in prompt escalation to staff with appropriate levels of experience and expertise (Gaskell et al. 2016).

Junior trainees' and nurses' pivotal role in recognising and responding to signs of patient deterioration in a timely manner is imperative for optimal patient outcomes (Purling and King 2012). In a systematic review on readiness of undergraduates in acute care, Tallentire et al. (2012) reported that graduates perceived themselves to be less prepared in managing acutely ill patients. In medical schools, acute care specialties such as emergency medicine, anaesthesiology and paediatrics establish domain-specific acute care teaching programs using didactic and simulation-based approaches to build the foundation for practice readiness. It is also not clear whether these training programs have translational outcomes by effectively preventing patient harm or minimising adverse events or malpractice claims. When it comes to curricular level of integrated approach to acute care training, with progression from foundational years to internship, there is limited published evidence.

Connell et al. (2016) performed a mixed methods systematic review of literature published between 2002 and 2014 on 'effectiveness of education in recognition and management of deteriorating patients. They reported positive impacts on learners, organisational systems and patient outcomes with a majority (>87%) being blended approaches with intermediate and high-fidelity simulations. The review had focused mainly on nursing education (15 out of 22 studies) and had included learners' self-reported perceptions of improvements in confidence & engagement. A systematic review done in 2007 that explored issues with teaching and training acute care skills showed that only 15 out of 374 studies (4%) demonstrated high quality evidence such as randomized controlled trials showing usefulness of educational interventions in undergraduate training (Smith et al. 2007). The study also highlighted that the evidence gathered in majority tend to stay on lower levels of evaluation of the Kirkpatrick's model such as 'reaction' or 'confidence/behaviour' and self-reported improvements (Kirkpatrick 1983). Not many studies show 'patient outcomes' (level 4) as the intended purpose of the studies or measured end points and hence a need to consider a systematic review of recent studies that evaluated that.

Early warning scores and review & report systems are well studied (Smith et al. 2014) and shown to have good results. The first responders' (nurses and healthcare assistants) training and educational effectiveness are well known (Liaw et al. 2011; James et al. 2010). Yet the 'bottle neck' of the system lies in how the junior doctors recognised & acknowledged the gravity of the situation when presented with vital information through monitoring, reviewing clinical and measured parameters. The chief concern is what happens after the 'doctors in training' are presented with vital information by the nursing teams. The lacuna is in their ability to eventually escalate it to their superiors or at the very least, initiated prompt measures to minimise further harm to patients. This aspect of acute care training in medical education is not well studied.

The emphasis of the present review was to focus on 'doctors in training' (undergraduates, transitional year trainees/non-trainees and postgraduates) by performing a full search with no restrictions to time and type of literature. The review was designed to explore educational interventions both within the medical profession and across interprofessional teaching avenues. In particular, efforts were made to appraise more recent revolutionary educational technology such as serious game-based learning (Connolly et al. 2012) & virtual environments (Pucher et al. 2014) and evaluate how effectively they improve the decision making and critical thinking abilities of junior doctors in recognising and responding to acute clinical deteriorations.

Review question(s)/objectives, type of review and keywords

The aims of the review were to: Identify and summarize published teaching interventions or acute care training programmes for undergraduate medical students and postgraduates to recognize and respond to clinical deterioration.

The review questions were:

1. What are the interventions designed for undergraduate medical students and residents to teach early recognition and/or prompt escalation of acute clinical deteriorations?

2. How effective are these teaching interventions in training them on early identification of clinical deteriorations?

Type of review: The type of review conducted was a systematic *descriptive, clarification and justification review*. When the authors set out with preliminary research question on 'whether virtual educational platforms help to improve early identification of clinical deterioration among junior doctors', a scoping review was conducted. By nature of scoping review methodology, rich information on the breadth and depth of the topic and the lack of publications evolved (Munn et al. 2018a). There were limited systematic evidence of literature summarising any of the existing platforms to teach this concept in medical education. There was also limited evidence to prove the educational effectiveness of these teaching platforms. Hence a systematic review methodology (Gough et al. 2012) that describes, summarises and clarifies the presence of educational interventions for the specific purpose of 'teaching to recognise clinical deteriorations' was instituted. The purpose was to include all published evidence with no restrictions to date, language or source. Next a clarification and justification review of educational effectiveness of the teaching intervention was performed (Munn et al. 2018b). This was to specifically synthesise evidence of higher order educational outcomes from the existing literature.

Stake holders: Medical educators, curriculum developers, quality and safety committees, postgraduate teaching audit committees, healthcare trainees, patients and healthcare teams.

Study selection criteria

The inclusion and exclusion criteria used are detailed in Table 1. Interprofessional and nursing educational studies that did not have medical students or junior doctors as team members or study participants were excluded.

Methods

Search strategy

The review was conducted according to the pre-approved protocol by the BEME International Collaborating Centre (BICC). Databases searched included PubMed, PsycINFO, Science Direct and Scopus for original research studies on teaching interventions for doctors-in-training with a focus on early recognition and prompt escalation of acute clinical deteriorations. Other resources searched include reference list of relevant papers, review articles, google scholar and grey literature.

Our search followed the PICO format (Santos et al. 2007): population, interventions, comparison and outcome.

1. Populations included medical undergraduates, house officers/interns, transitional year non-trainees, residents and senior residents.
2. Interventions included educational programs: small group teaching, interactive workshops, simulations of varying fidelity, curricular modules, live & cadaveric tissue-based training, virtual environment-based learning and multi-professional training.
3. The comparisons were either none or against no teaching intervention.
4. The outcome variables included Kirkpatrick's four-level of effectiveness: self-reported data, teachers' account of student/resident improvements, clinical supervisors' ratings and patients' clinical outcomes.

Reviews, viewpoints, opinions, editorials and commentaries were excluded. Studies that did not focus on medical trainees or had no relevance to acute deterioration or that merely described the design or validation of the program with no effectiveness data were excluded. Based on the inclusion and exclusion criteria, search terms were generated for each database. The detailed search strategies are shown in Supplementary Appendix 1.

Table 1. Study selection criteria.

Key features (PICO)	Inclusion criteria	Exclusion criteria
Study population	Undergraduate training House officers/interns Senior house officers Foundational year doctors Transitional year doctors Postgraduates Junior residents	Studies on training programs for non-medical and allied healthcare professionals that did not have an interprofessional component to include doctors in training
Teaching intervention	Educational programs Teaching methods Simulation and technology-based blended learning programs Multi professional training Acute care training methods Curricular modules that intend to provide training of acute care skills Cadaver & live tissue training In contact and virtual learning modules Small group teaching/training	Studies on 'review & report' and early warning scores without an educational intervention focus on doctors in training Studies with no acute care focus
Comparator/control	Not applicable	Not applicable
Outcomes/effectiveness data	Students' self-reports of confidence, better engagement, increased participation Future readiness data Teachers' account of student improvements Clinical supervisors' ratings Patient outcomes or clinical acute care improvement data suggesting better care Reduction in cost, preventable harm, morbidity & mortality indices etc	Studies quoting mere design & development of teaching intervention or the validation of the teaching methodology without reference to effectiveness/ learning outcomes

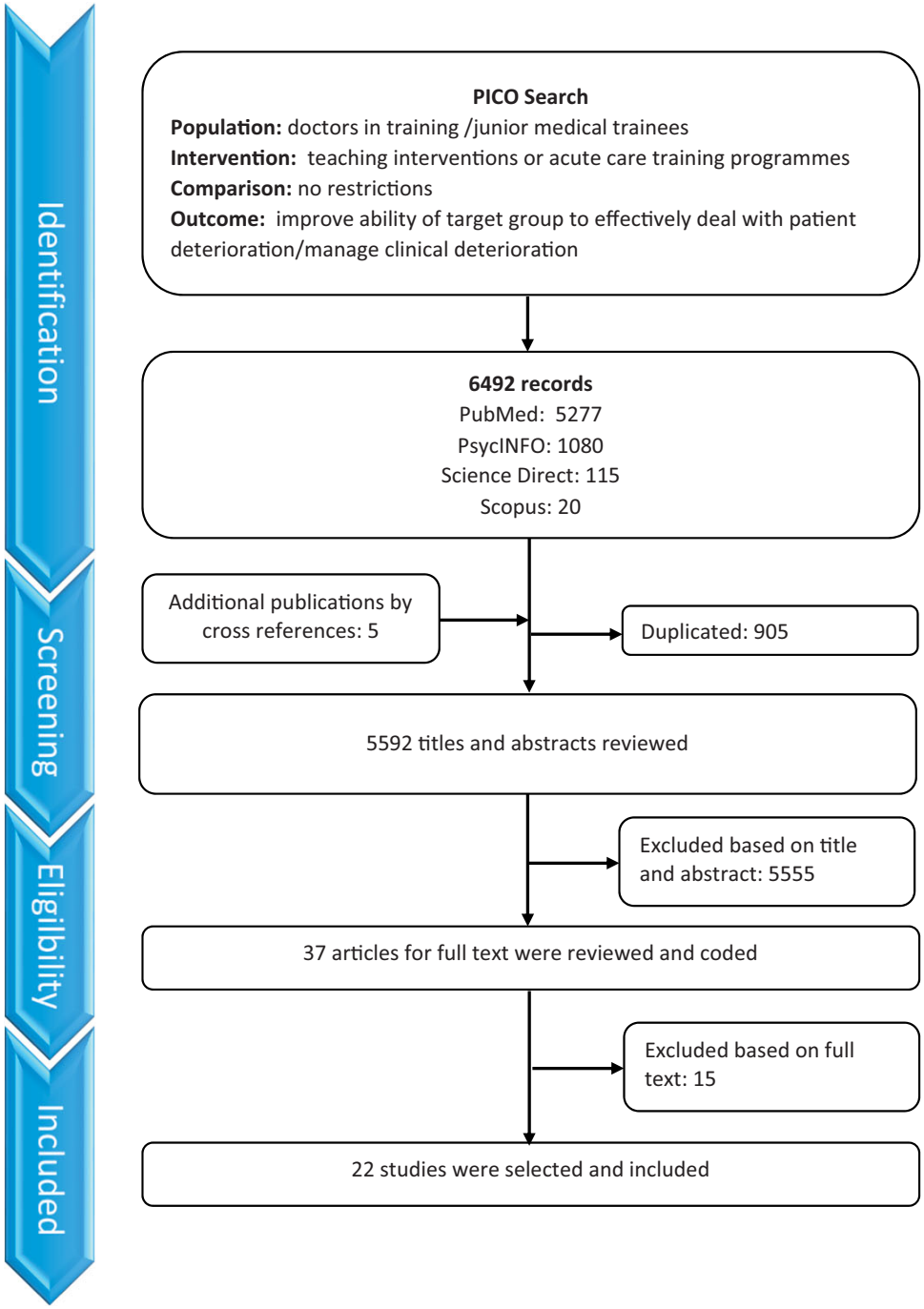

Figure 1. Prisma diagram for the study methodology.

Selection of included studies

Authors AB, CD and LL agreed on the search terms in January 2018. The search was widened with formal support from the university librarian without restriction on language or year of publications. The search showed 6492 records and after removing 905 duplications, 5592 titles and abstracts were considered for review. 5555 studies were excluded based on inadequate quality, poor relevance to acute care teaching and limited focus on teaching effectiveness to clinical deteriorations. Interventions that focussed mainly on bedside skills or basic foundational knowledge but not with an acute care focus were excluded. There was ample published literature on 'review & report' aspects of acute care in nursing and allied professions. However only those studies that reported the inclusion of junior doctors in their study methodology and outcomes were considered for the review.

The inter-rater reliability was achieved by pilot screening of the first 120 titles and abstracts independently by reviewers AB & CD. The congruence obtained was 87% between the reviewers. Where there were differences, it was resolved with weekly face to face sessions with third reviewer LL, through large screen displays on the chosen abstracts and final decisions were made. While review articles were excluded from data extraction, cross references from quoted reference of pertinent systematic reviews (Smith et al. 2007; Connell et al. 2016; Liaw et al. 2018) yielded rich information for the review. The preferred reporting items for systematic reviews and meta-analysis (PRISMA; Moher et al. 2009) flow diagram is shown in Figure 1.

Data extraction

The authors initially set out to perform data coding and extraction through cloud computing via Covidence

software (Melbourne, Australia). When nationwide workplace internet accessibility restrictions were levied in Singapore in response to malware threats and data breaches from July 2018 (Singhealth 2018), the authors had to abandon use of cloud computing and repopulated all data to Microsoft Excel-based (Microsoft corp. USA 2016) offline data processing. Periodic review meetings with large screen data display were convened for consensus on accepted abstracts and coding.

Data extraction form was adopted from the Cochrane systematic review coding sheet with modifications to suit educational studies (Supplementary Appendix 2). Thirty-seven full text articles were shortlisted for full-text review, coding and tabulation (Supplementary Appendix 3). Twenty-two studies where finalised for data analysis based on direct relationship to effectiveness data. All full text extractions were done by reviewers (AB, CD or LL) and after completion was cross checked by third reviewer (LL or CD) and final decisions on scoring and exclusion were made through consensus with face to face meetings among all three reviewers.

Studies were categorized according to (a) platform used for intervention (b) BEME collaborative's modified Kirkpatrick's four-level training model (Losco et al. 2017) and (c) timing of applying intervention in the curricula.

Quality assessment

Quality of included studies were assessed according to the quality indicators stated by Buckley et al. 2009; BEME guide No 11). Studies were categorized as high quality if the study had met 7 out of 11 indicators. Each study was individually appraised based on its relevance to focus on acute care teaching & learning and those that had limited or no focus to acute care were excluded from the final data synthesis after consensus of the team of coders.

Synthesis of evidence

The proposed mixed treatment comparator model (Sutton et al. 2009) in the BEME protocol could not be applied as there were heterogeneity in both the teaching methods (intervention) and the educational outcomes (end result). This review was set to map and scope all the existing information on educational interventions pertaining to acute care learning and more specifically to appraise effectiveness data on recognition & escalation of clinical deteriorations. Quantitative synthesis could not be performed due to heterogeneity in teaching interventions in terms of volume, frequency, timing and learner characteristics. Hence a *narrative synthesis* (Harden et al. 2004) with content analysis approach, wherein data, both quantitative & qualitative, was categorised into themes to identify dominant issues across studies (Pope et al. 2006). The method of narrative synthesis involves 'collating study findings into coherent textual narrative, with descriptions of the differences in characteristics' and where possible, capturing the validity and relevance to the context (Ryan and Consumers 2013; Campbell et al. 2018).

Results

Context of studies & attributes

More than 50% of the studies were reported from USA (12/22), 7 from Europe (4/22 UK, 3/22 Sweden), 2 from Canada and 1 from Australia. There were no explicit documentations of conceptual frameworks for the educational interventions stated other than constructivist approach on layering of prior learning. The search for use of cognitive aids as an educational tool revealed one study quoting its use for resuscitation training (Cruetzfeld et al. 2010).

Outcomes

The outcomes of the review were justified under the two headings: design and implementation of educational interventions & evaluation of learning outcomes. The first outcome refers to the actual design, construct and conduct of the educational intervention and the context of the learners in which it was studied. The second outcome on evaluation chiefly related to the extent of educational effectiveness and the impact that it had on the learners, the environment and eventually on real world practice and patient care improvements (Supplementary Table 2).

Design & implementation of educational outcomes

The type of educational interventions/platforms

The educational *platforms* varied from low technology, small group interactive workshops to standardised patient volunteers with augmented realism and engagement to use of combinations of high technology full-scale simulations to wide area virtual environments. The actual teaching or educational *environments* varied mostly from lecture/didactic settings, small group discussions, clinical postings, simulation centres or virtual rooms, insitu simulations and mock codes (Supplementary Table 3). Combinations of didactics with hands on training in simulated educational contexts were used when multidisciplinary, multi-professional learning was planned. One study (Stephan and Stephan 2013) reported live tissue training with anaesthetised ferrets to create realism and higher levels of authenticity for learning acute care skills and retention/transferability to acute care management.

Lead time for planned interventions

The actual timing of interventions in the curriculum varied among the studies. Pre-posting formal training was achieved through planned simulation sessions 2–3 weeks before MICU rotations (Schroedl et al. 2012) while a Moodle based Web- SP was studied in medical undergraduates at the start of internal medicine postings (Botezatu et al. 2010). Educational interventions within clinical postings included outpatient sessions (Cooke et al. 2008: family medicine critical care training), integrated small group learning (Levinson et al. 2017: PBL + Simulated learning exercises) and elective surgery posting (Paige et al. 2014: Virtual OR full-scale simulation).

Workplace-based periodic training included mock codes or regular insitu training sessions: paediatric mock codes (Cappelle and Paul 1996; Sam et al. 2012), weekly ACLS

interprofessional rounds (Dagnone et al. 2008), hybrid SP simulation (Egenberg et al. 2017), interprofessional operation theatre simulation (IP-OT sim; Hinde et al 2016); paediatric Medical Emergency Teams (MET) with weekly simulation training (Theilen et al. 2017) and Immediate Life Support (ILS) implementations (Spearpoint et al. 2009). One-off teaching events included annual combat training in military medicine for undergraduates (Wide Area Virtual Environments-WAVE; Stephan 2013) and Acute Life-Threatening Events Recognition and Treatment (ALERT; Smith and Poplett 2004) course for junior practitioners. Data on timing of interventions were not available for rest of the studies (Cooke et al. 2008; Creutzfeldt et al. 2010; Evans et al. 2015; Caylor et al. 2015; Hinde et al. 2016). No study reported the best sequence of teaching interventions (which teaching method to apply first) when a blended approach was adopted.

Repeated intervention vs one-time teaching points

Most of the studies had single time point interventions followed by outcomes data measured post intervention. One study (Spearpoint et al. 2009) evaluated the effect of continuing multiprofessional educational intervention over a six-year period with ongoing training and data collection. Hinde et al. (2016) studied two sets of operation theatre simulation with crisis scenarios given 6 months apart and the effect on safety and team dynamics.

The duration of educational interventions

Time on task varied with the setting. Multiprofessional training was largely full day events (ranging from half day, 2 days and weekly training for a year or two) with the actual crisis management goals achieved through 4–5 h of simulation time with high technology simulators and chiefly supplemented with didactic resources to improve knowledge, skills and expected behavioural changes (Supplementary Table 3). Specific cohort-based simulations such as undergraduate training and residency training were mostly short sessions that were less than 4 h each. When multisession multiprofessional trainings were in place, these were blended approach with active performance sessions of up to 5 h interspersed with didactic teaching.

Evaluation of outcomes

Strength of study intervention

Four of the studies were randomised controlled trials (Reyes et al. 2016: undergraduate first clinical year internal medicine clerkship; Schroedl et al. 2012: Resident Pre-MICU simulation; Botezatu et al. 2010: WEB-SP, undergraduate virtual patient simulation in internal medicine; Stephan 2013: live tissues vs simulation training) and one study was non-randomised (Mullon et al. 2009: Residents' additional 1 month in ICU with skills training). Rest of the studies were chiefly prospective before & after data showing the effects of educational interventions or quasi experimental in nature. Many of these studies were hospital-wide all staff training measures where possibility of control group allocations was limited.

Evaluation of effectiveness of educational interventions

The review showed that majority of studies evaluated multiple levels of outcomes. The BEME collaborative's modified Kirkpatrick levels of outcomes were applied (Losco et al. 2017). Studies that merely evaluated level 1(participations) with evaluation of aesthetics of teaching methods and quality of instructions were not considered for final data extraction (15 of 37 studies were excluded). The outcomes studied included level 2a and above:

- Level 2a: self-rated changes in attitudes & perceptions
- Level 2b: changes in knowledge & skills
- Level 3: observed (supervisor/faculty) actual changes in applying new knowledge, skills or acute care attributes
- Level 4a: translational outcomes through organisational & system enhancements
- Level 4b: improvements in patient outcomes such as reduced harm, morbidity & mortality data and better quality of life

For the purpose of data collation, where multiple levels of outcome were quoted in same study, tabulation was based on the highest level of effectiveness quoted in the study. Nearly half of the studies (45% Level 2a – 3/22; Level 2b 7/22) were on self-perceived improvements in confidence, engagement, readiness/clinical autonomy, preparedness and reduction in anxiety while about one third (36% Level 3: 8/22) showed supervisor or clinical assessor reported improvements in applied knowledge, skills, diagnosis, management, clinical reasoning, critical thinking, reflective practice with reduction in observed misjudgements. Four studies (18%) demonstrated the highest level of outcomes with translational actual patient benefits from reduction in complications, morbidity and mortality or reduced incidences of cardiac arrests and improved overall cost savings (Level 4a: Egenberg et al. 2017; Level 4b: Mullon et al. 2009; Spearpoint et al. 2009; Theilen et al. 2017).

Duration of sustained education effects

The duration of reported retention and educational effectiveness was variable. Most of the studies reported *immediate post intervention data* on confidence, engagement, knowledge testing and skills improvements (Cappelle and Paul 1996; Cooke et al. 2008; Dagnone et al. 2008; Botezatu et al. 2010; Schroedl et al. 2012; Stephan 2013; Goolsby et al. 2014; Paige et al. 2014; Caylor et al. 2015; Evans et al. 2015; Butcher et al. 2015; Hogg and Miller 2016; Levinson et al. 2017). When outcomes data on continuing improvement on patient morbidity were recorded, then studies reported follow up for 6 months to 6 years.

In undergraduate training, one study (Creutzfeldt et al. 2010) reassessed CPR skills retention 6 months after virtual training and another study (Reyes et al. 2016) reported follow up for 2 years on durability of sustained skills and transfer to outcomes. These outcomes were assessed through simulation 2 years later while training was imparted during first clinical year internal medicine clerkship using small group interactive workshops. For transitional year trainees, retention for up to 12 months was reported through 1-day ALERT courses (Smith and Poplett 2004).

In postgraduate residency, sustained outcomes were reported through team training initiatives: obstetric emergencies with reduction of obstetric transfusions for 2 years (Egenberg et al. 2017); insitu operation theatre simulations with 6–12 months self-reported sustained safety and climate culture (Hinde et al. 2016); paediatric PMET + weekly multiprofessional simulations showing 3 years process improvements with reduced paediatric ICU admission severity, mortality and eventual cost savings (Theilen et al. 2017). Hospital-wide insitu training implementation such as Immediate Life Support (ILS) showed sustained improvements in pre-arrest management for up to 6 years for organisational behavioural outcomes and patient outcomes (Spearpoint et al. 2009).

Discussion

The systematic review identified 22 studies that evaluated teaching interventions for undergraduate medical students and junior doctors. The focus was to appraise the design, implementation and educational effectiveness of these teaching interventions in acute care learning. The review showed that in comparison to previous systematic reviews (Smith et al. 2007; Connell et al. 2016) there are improvements in the use of blended learning approaches and teaching methods to enhance acquisition and retention of acute care knowledge, skills and behaviours. The platforms used have evolved from merely didactic sessions to small group active learning sessions with emphasis on learner engagement. Game-based learning platforms (Evans et al. 2015) and technology enabled learning platforms that facilitate asynchronous guided learning initiatives have been successfully implemented with evidence of effectiveness (Creutzfeldt et al. 2010; Caylor et al. 2015). These included combinations of didactic and active methods, multiprofessional team training initiatives and enhancements in educational technology (Botezatu et al. 2010) such as multiuser virtual environments and use of timely feedback with active participation of the faculty. Asynchronous learning (Moller 1998) refers to technology enabled learning, where the learners could log in at various time frames and access learning resources in their own time and participate in 'offline' discussions at their own pace. While this offers individual progress with less pressure of time, imparting faculty inputs and structured support may not be timely and immediate. The review showed that synchronous learning with active web-based faculty feedback has been effective in learner engagement and shown better retention of acute care content and application when the teams of interprofessional participants collaborated in game-based platforms (Caylor et al. 2015).

The systematic review identified enhancements in teaching & learning methodology, improvements in educational platforms with highlight on areas of focus and scope for progress. These could be broadly considered under implications for higher levels of translational outcomes, considerations to the concept of acute care thinking in varying depths, duration and sequencing of the teaching interventions for optimal educational effect etc. Further insight into gaps in existing literature in acute care teaching & learning with practical suggestions for future research directions are provided below.

Translational outcomes

Level 2 educational outcomes that included perceptions and mostly self-reported improvements were shown in half of the studies. Data and research evidence have shown that learners tend to overestimate their educational effectiveness. It is proven that self-reported outcomes are not robust resources for making strong conclusions about educational effectiveness (Baxter and Norman 2011). Fewer studies show Kirkpatrick level 3–4 stages of observed practice improvements, organisational behavioural changes and actual improved patient outcomes. There are consistencies in improvement of pre-arrest recognition and prevention of catastrophes (Smith et al. 2002) with overall sustained reduction in morbidity, mortality and financial savings when training systems used a combination of teaching interventions, regular updates, periodic certifications and more importantly, invested protected time in training (Spearpoint et al. 2009; Egenberg et al. 2017; Theilen et al. 2017). These interventions relate to teaching methods that provide contextual information that juxta pose (situated cognition) relevant specific knowledge, skills and acute care aptitudes for managing clinical deteriorations (Chaiklin 2003; Novak et al. 1999).

Depth of acute care critical thinking

Acute care training modules commonly include *deliberate practice* for psychomotor skills, and team training through high technology simulations (Bond et al. 2006). Educational technology has evolved and there are scores of educational platforms that are aimed at engaging the digital natives. These included SEPTRIS, a mobile-based game for Sepsis (Evans et al. 2015); MMVW: Massively Multiuser Virtual World for multiuser avatar-based interprofessional emergency medicine training of virtual CPR (Creutzfeldt et al. 2010); WAVE: Wide Area Virtual World, a military mixed-reality combat training module (Goolsby et al. 2014), Second-Life Avatar-based virtual TeamSTEPPS (Caylor et al. 2015) and WEB SP: Moodle-based virtual patient simulator (Botezatu et al. 2010). These platforms allow educators to provide layering of information in a staged spiral manner aligning to the 'constructivist approach' where new information reaffirms and enhances existing knowledge. This approach enhances learning of relevant specific and supporting information when the educational activity stimulates the learners to seek and absorb information around the area of the teaching focus, known as the Vygotsky's zone of proximal development (ZPD: Chaiklin 2003). It is known that advanced learners acquire relevant specific complex information and engage in critical processing when presented with knowledge (Just in Time Teaching, JiTT) after an immersive experience (Novak et al. 1999). The feedback given during and immediately after the virtual scenarios help to improve the construct of 'cognitive apprenticeship' where thinking is allowed, nurtured and refined contextually (Collins et al. 1988). The learners are given the 'psychological safety' and safe learning environment to learn, unlearn and relearn at their own pace with faculty feedback and support.

Sequence of educational interventions

The review showed there are long term educational benefits (beyond 6 months) of introducing educational interventions in four studies (Smith et al. 2002; Hinde et al. 2016; Egenberg et al. 2017; Theilen et al. 2017). It is not clear from literature on what is the timing of acute care teaching, i.e., *the lead time before actual clinical practice* that the training must be provided for time and resource-efficient outcomes to be obtained. Smith et al. (2002) showed that when house officers had received 1-day multiprofessional course within the previous 12 months, they had higher acute care knowledge retention scores compared to their peers who had received it more than 2 years before. Though their study evaluated knowledge retention, further research is needed in exploring: (1) *practice readiness* through applied acute care skills and (2) the best timing for acute care teaching interventions (lead time before actual practice readiness) targeting interns and transitional year trainees.

Conventional teaching curricula focus on pre-reading with planned pre-test evaluating base knowledge acquisitions followed by active hands-on interactive teaching that may or may not be supplemented with structured debriefing and group discussions. Evolving educational practices quote active learning sessions with concise contextual information during the session or immediately after (Smith and Poplett 2004). It is not clear from literature on what is the ideal sequence of the intervention for optimum learning and retention- didactic before active sessions or during/after with just-in-time information (Simkins and Maier 2010) and if knowledge acquired is equitable to practice readiness. One of the authors completed a randomised controlled study (Thampi et al. 2020) that shows evidence of usefulness (long term knowledge & skills retention) of introduction of the active approach through simulation-based learning first before the didactic sessions.

Implications for practice for medical educators & stake holders

A summary of chief implications in medical education and proposed solutions for stake holders in improving it are outlined in Table 2 and stratified by stage of learning such as undergraduates, interns, transitional year junior doctors & residents. The study informs *the educators* of the limitations of current focus on *group and team training* of healthcare professionals. There are assumptions that individual proficiency in acute care management develops optimally among junior doctors who are to make the right decisions to continue the chain of command and appropriate action. The emerging platforms such as game-based virtual learning with active faculty inputs could be the lead for enhancing the quality of care in acute deteriorations as they are deemed to be just-in-time with *feedforward* instead being a feedback (Molloy 2010; Mulliner and Tucker 2017).

The review informs medical educators of the range of educational interventions, in isolation and in groups of teaching activities that are applied in varying educational environments. These would help the *curriculum developers* to choose efficiently from what could be well resource matched in all contexts be it a well-equipped versatile university teaching hospital or be it a resource limited setting in an area-of-need district service in the suburban establishments.

Gaps in literature

Focus on transitional years' acute care training

Undergraduate medical education worldwide is well structured and benchmarked to global standards competencies clearly articulated in postgraduate education (ACGME: Singh et al. 2005; CANMEDS: Frank and Danoff 2007; GMC 2014b). These standards are set to be meticulously achieved through modular, semester or year-based progressions, high-stake assessments like licensure exams or through progress testing and portfolio-based assessments. The review showed that structured interventions and educational initiatives are in plenty in these fixed mandatory training systems of undergraduate and postgraduate years. Yet, the concept of acute care education is variable in medical education, with the interns, pre residency junior doctors and transitional year medical officers receiving less training for *on-the-ground thinking* and acute care related critical decision making (Smith et al. 2002; Spearpoint et al. 2009).

Even in simulated team training of emergency situations there are inconsistencies in uniformity of learning that occurred. There is evidence showing that there are significant differences between *leader and follower roles*. Meurling et al. (2013) showed that leader roles in simulation scenarios resulted in increased concentration, better communication and postulated the need for better training strategies *if leader roles are to be expected of every participant* of simulation training. Current simulation-based teaching programs impart training to medical students in groups and only one in five students have the opportunity for leader roles during the session. Clinical practice as house officers and junior doctors requires them to function as leaders. This is true when they are presented with first-hand information in the chain of response (recognition, reporting & responding) by the nursing support staff in deteriorating patients and must respond in a time sensitive manner for optimal patient outcomes.

A programmatic approach: acute care learning journey

The review showed that the existing curricular teaching interventions are mostly brief segments of acute care learning such as short courses or modules that address a phase of medical education and training. There is limited published literature on programmatic approach to acute care learning wherein longitudinal acute care content that are introduced in the early years are consolidated over the years with documentation of progression in acute care specific knowledge and skills.

It is proven that portfolio-based curricular approaches improved personal responsibility for one's own learning and supported continuing professional development among postgraduates (Tochel et al. 2009). Among undergraduate learners, portfolios have resulted in 'improvement in student knowledge and understanding, greater self-awareness and encouragement of reflection' and the ability to learn independently (Buckley et al. 2009). Use of

Table 2. Implications for educators and stakeholders.

Level of training/feature	Issue	Proposed solution	Comments
Undergraduate	Scattered training avenues; limited acute care learning continuity	Programmatic acute care portfolio/dossier	Allows for continuity and layering of new acute care knowledge
Internship	Fewer published focussed training programs Longer lead time before practice	Practice readiness refreshers sessions for knowledge, skills, team-based learning	Minimising the large gaps and induction period calamities
Transitional years/non-trainee junior doctors	Fewer formal training avenue other than BLS/ALS	Specific focus on individual competencies for acute care readiness	Pillars of the system, first responders in decision making, have maximum impact on outcome and minimising harm
Residency	Varying levels of progressions to acute care expertise	EPA guided acute care training progressions in continuum from undergraduate training	First nodal point in chain of command for concrete decision and differential diagnosis and management pitfalls
Stake holders (curriculum developers, educational leads, hospital and health authorities)	No acute care training continuum	Acute care training mandates needed Portfolio based training progressions	Could minimise large gaps and help distribute curricular time and resources, enhance layering of new information
	Cognitive aids training minimal	Should be integrated in all acute care training sessions	Cheaper, effective, repeatable, less resource intensive
	Resource limitations/curricular time	Virtual & web-based learning reduce faculty time Off-curricular own learning time	Feedback and faculty input need to be layered to enhance engagement and educational effectiveness
	Educational Expectations and demands mismatched to context	Context and situational circumstance matched expectations needed	Direct import of overseas practice requirements, standards and assessments may not fit institute socio-cultural dynamics

portfolio or programmatic dossiers of 'acute care training' can be proposed as practice requirements for all junior doctors' as prerequisites or mandate before handling patients independently. These acute care dossiers could document the full range of completed activities from computer-based simulated/standardised patients, part-task training, course certifications, full-scale simulations, deliberate cognitive training avenues and interprofessional team training. Future research could focus on educational interventions that provide a *continuous learning journey in acute care training* from undergraduate clinical year to internship and transitional years before they have full specialty roles as a resident (Hirsh et al. 2007).

Enhancing cognitive deliberate practice

While full scale simulations have reported data showing collective acute care and soft skills training modules with individual psychomotor skills and knowledge improvements, there is paucity of information on what teaching initiatives are in place for 'cognitive deliberate practice' for the individual on the ground (Creutzfeldt et al. 2010). Basic and advanced life support courses (BLS, ALS) are mandated by many institutions as minimum requirements for healthcare practitioners (Greenfield et al. 2015). Yet, recognition and prompt management of acute deteriorations seem to require a higher order cognitive training, '*cognitive deliberate practice*', than merely certifying on tick-list based skills defined by these programmes. The Stanford university cognitive aids (2016) illustrate how common mishaps are analysed in a more detailed intuitive way (Goldhaber-Fiebert and Howard 2013). These stepwise approaches advocate: addressing the chief issues, initiating most relevant management, collective decision making on chief differentials and deciding the best course of action. The cognitive aids initiative (Harrison et al. 2006; Marshall 2013) dates to 1992 when Gaba et al. (1992) proposed to avert preventable catastrophes by simple measures like flash cards enabling practitioners to think critically yet act practically and not miss the big picture in what is called the "elephant in the room". Cognitive aid assisted simulation and acute care training seems to have enhanced the safety of airway management and reduction in catastrophes (Vortex cognitive aid: Chrimes 2016). The use of cognitive aids as an educational intervention should be encouraged at the curricular level when core content is designed and at the modular level when training is imparted at the individual and team level.

Resource limited educational environments

The review showed that the data on educational effectiveness are chiefly from North America, Australia and Western Europe with very little information on what effective educational systems or best practices are in place for resource limited countries with different cultural backgrounds. Even within the developed countries, educational resources (staff, technology, facility, time) can be variable with differences in student learning attributes, teaching environments (e.g. University teaching hospital vs district service hospitals) and staff support. Expectations in learner's performance and degree of acute care practice readiness might hence need to be matched to the context and situational considerations such as *what & how it is taught, how much, for how long and in what depth and with what level of guidance* in assisted reflection. While most of these settings cannot have the affordances of technology enabled learning, card-based serious gaming and use of cognitive aids can be explored. Both card and board games have proven to be effective learning methods that allow repetitive practice with engagement and facilitate individual and peer assisted learning (Barclay et al. 2011; Abdulmajed et al. 2015).

Ambiguity in terminology and issues with educational platforms

'Fidelity' vs technology?

The review identified varying educational platforms with a full spectrum of fidelity (Supplementary Table 2). Yet, it is

not clear what creates the educational impact/outcomes, whether it was the fidelity or was it how active interventions were planned in the curriculum to achieve this impact. Connell et al. (2016) review on educational interventions for training readiness for clinical deteriorations suggested positive inclinations towards medium and high-fidelity simulations. What is not clear is whether it was the nature of high-technology or its realism in creating learning experiences that made it effective.

The concept of fidelity vs technology as terminology has been questioned. Hamstra et al. (2014) recommended *abandoning the term 'fidelity'* and revising it with concepts of physical resemblance and functional task alignment with a focus on instructional goal and applied context. Fidelity or high engineering has been proven to not always be associated with better educational benefits compared to simpler interventions (Kneebone 2005; De Giovanni et al. 2009). Future synthesis of evidence in this area would have to consider the studies that quote context and the functional '*educational fidelity*' of the tool (simulator) rather than simply stratifying them by structural appearances or technological specifications as high fidelity. It would also then be apt to consider how the educational intervention was well 'planted' in the acute care curriculum that it provided timely, optimal, contextual cognitive load for the young trainee.

Virtual simulations: confusions

Virtual simulation is fraught with confusion in terminology. Liaw et al. (2018) showed that there was heterogeneity in how the platforms were described and outcomes were measured and reported. Virtual simulation or virtual reality or virtual world simulation with or without contextual environment (augmented vs virtual) were different from computer-based two-dimensional fixed case scenarios or voice over presentations. Non interactive two-dimensional screen-based platforms tend to offer knowledge enhancements while time-based interactive and immersive platforms tend to provide graded increments in complexity and critical decision making and create rich learning experiences. Further classifying virtual simulations into *screen-based (cold)* simulations, immersive screen based *interactive (hot)* simulations and *wearable technology-based (hop-on)* simulations and educational interventions might help in synthesising evidence in the future.

Strengths and limitations

Strengths

The lead reviewer was given formal training through *Practical Skills for Reviewing Evidence in Health Professions Education* (PASREV) courses at AMEE 2017 with panel of faculty support for protocol development and further follow up with educational mentoring for the review. The scoping review was reviewed by the BEME team and amendments were made to improve the breadth and depth of the research to span all possible literature for this topic with removal of restrictions for year and language.

The presence of university library support guided the systematic search with refinements to the outcome of full text chosen. Use of Cochrane based coding checklist helped with the robustness of data extraction. Any conflict, indecision and doubts with choice of articles were discussed weekly, face-to-face for the first 2 months of extraction with a third coder LL, who had prior experience with systematic reviews. The team composition was carefully chosen to have triangulations from head of postgraduate medical boards, head of medical education who was a quality assurance expert from curriculum review committee and ministry of health. The nursing faculty in the team had rich experience in systematic reviews and interprofessional & team based acute care training and research.

The study identified the spectrum of teaching interventions that range from didactic lectures, small group sessions, individual learner-based and team-based active sessions, classroom based, simulation based, live tissues training and virtual & game-based learning platforms. A review of this breadth was needed to appraise the current (till 2018) proven literature on what effectively helps with acute care teaching, learning, retention and practice improvements. Most of the published literature seem to focus either on undergraduate training or postgraduate residency. This review had specific focus to address the unstructured or not well streamlined phase of medical education namely the internship, transitional years and junior non-trainee doctors.

Limitations

The review was set to explore all teaching interventions that focus on acute care deteriorations. These included technological variations, curricular differences, interventions with varying duration and time & sequence of application in the curriculum. Owing to this heterogeneity, it was difficult to synthesise information on educational outcomes that could compare the full spectrum of educational platforms applied.

Quality of studies appraisals (Buckley et al. 2009; BEME guide No 11) showed all studies were of high quality with scores more than 7 out of 11. When the degree and extent of *acute relevance* of a study was looked into (acute care knowledge, skills, behaviours and systems improvements) the authors noted that prospective acute care effectiveness studies should consider both these criteria (Kirkpatrick levels of outcomes & Acute care relevance) and state it transparently in the methodology. This can guide the educators to choose appropriate teaching methodology that score high on education outcomes while having a better relevance to acute care per se.

The review showed mostly studies with positive outcomes and educational benefits. Scientific journals and academic forums should strive to avoid the risks of publication bias (Higgins and Altman 2008) as this tends to perpetrate reporting biases from authors (Sterne et al. 2008). Transparent reporting of negative outcomes would help in judicious resource allocation (faculty time and financial) for appropriate educational platforms that demonstrate evidence-based effectiveness, especially so, for resource limited settings. About a third of studies quoted sampling from voluntary participation in the newer educational interventions, while most of the multidisciplinary educational programs involved full cohort or whole fraternity implementations. This could have

Table 3. Research implications.

Research aspect	Issue	Solution	Comment
Terminology	Fidelity vs technology Virtual simulation variability	Labelling by educational effectiveness not technology Virtual simulation: hot cold & hop-on simulations	Revising and standardising terminology will help in accurate synthesis of research data
Methodology	New Educational interventions are mostly a sample of cohort Group interventions are based on full cohort outcomes (team training) Mostly lower order educational outcomes studies	More experimental studies with more participation of entire cohort Needs more robust studies with observable outcomes in learner and patients than mere self-reported improvements in confidence, satisfaction and engagement	Will help in understanding effectiveness and planning educational resources efficiently
Grouping & comparison	Majority compare with no interventions	Needs appropriate planning with ethical considerations	Remains to be a major limitation for educational study when a curricular level promising intervention is introduced
Analysis & synthesis	Heterogeneity in duration of interventions, timing, volume, type and single vs repeat interventions	Major concern when quantitative synthesis of data is performed	Curricula, institutions, countries seem to vary widely on this
	Kirkpatrick levels vs acute care relevance	Acute care relevance scoring needs to be designed & applied to select specifically studies addressing acute care aptitudes	The evidence synthesis for acute care training need to appraise both high order educational outcomes with higher acute care relevance scores
Publication	Chiefly published on positive outcomes	Need to encourage studies with no difference or poorer outcomes to be published	Repeating same errors in resource poor settings will mean larger proportion of healthcare education resource allocations are wasted
Areas of lacunae	Sequence of training: didactic before or after active teaching unknown	Very little information on the ideal sequence or relevance of just in time acute care information	Better retention of applied knowledge and practice readiness skills
	Individual cognitive training lacking	Need for focus towards on-the-ground cognitive deliberate practice	While group and team training are common, individual readiness needs to be improved
	Assessable acute care attributes	No framework for assessment of the acute care attributes	Need for establishing acute care EPA and rubrics for measuring knowledge and applied skills

added to further heterogeneity when effectiveness data was synthesised and compared.

The authors set out to synthesise evidence using the mixed treatment comparison modelling (MTC) as heterogeneity was expected. The model considers two aspects where treatment and its effect size are measured, which in this review would be teaching intervention and educational outcomes. The assumption for deploying this method is that either there would be homogeneity in educational interventions (test) or homogeneity in the educational outcomes (results). The review showed that there were varying types of educational structures, durations, platforms, volume of intervention, varying types and scale of effects studied. Neither was there homogeneity in the results obtained nor homogeneity in treatment, and hence, both models of MTC were not applicable. Future studies, during the design phase, could consider standardising the educational intervention or the effect size for achieving high quality synthesis of evidence that can inform educators and curriculum developers.

Implications for future research

Implications for research in acute care learning are outlined under terminology, methodology, issues with comparators, analysis & synthesis with highlight on areas of lacunae (Table 3).

Future educational research could look into areas highlighted such as acute teaching and training framework, assessment rubrics for its effectiveness in acute care, ideal sequence for educational interventions (active sessions before didactics or vice versa), planning studies that have both higher order educational effectiveness and having a higher acute care relevance score. The core terminology on how educational intervention such as simulation and virtual platforms are described need to be standardised. For uniformity in comparison, the issue of 'adequate volume or dose' of the educational intervention and how its quantified needs to be addressed. This heterogeneity seems to be primary concern when synthesising data quantitatively to ascertain effectiveness. Groups or study arms are not always comparable owing to the limitation that newer technology is uniformly deployed across the student cohort and comparators are not ethically possible for research data generation.

Evaluating the effectiveness of an acute care continuum through a portfolio or dossier could be promising. More robust studies that capture *learner analytics data* on novel virtual and game-based learning platforms might be a solution for individual cognitive dexterity training and individual preparedness.

Conclusions

The review showed that majority of educational interventions studied seem to be on self-reported improvements in confidence, knowledge and self-efficacy related outcomes with four studies focussing on *translational long-term system and patient benefits*. There were large gaps and dearth of data when it comes to training and education for the transitional year trainees, interns and house officers who are the vital workforce in recognition and immediate management of in-hospital acute deteriorations.

Whilst group therapy with 'team of doctors' being trained in high-technology simulations might appear promising, *individualised repetitive cognitive deliberate practice* with feedback/feedforward might be needed to improve pattern recognition and prompt escalation of acute clinical deteriorations by doctors in training. The aim is to equip the junior doctors to handle situations individually with enhanced critical decision making in clinical practice. The introduction of serious game-based learning and virtual environments might bridge this lacuna and could be a promise of the future.

Future curricular reforms could focus on *programmatic acute care portfolios* and dossiers that guide the acute care learning journey from foundational and early clinical years to residency until full accreditation as a specialist. There is lack of data on educational interventions that are in vogue in resource limited regions and hence generalisability of effectiveness data would depend on context, resources and level of supervision that the system is able to afford.

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The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

Glossary

Acute deterioration: Patients who move from one clinical state to a worsening clinical state in a short period of time which dramatically increases their individual risk of morbidity, including organ dysfunction, protracted hospital stay, disability or death.

Teaching intervention: Any educational program or module or teaching methods that are intended to improve the process of imparting acute care knowledge.

Educational Effectiveness: The degree to which intervention is successful in producing a desired result or success. Lower levels of effectiveness data refer to self-reported confidence improvements, participant satisfaction and engagement. Higher level includes clinical practice standard improvements, workplace reviews of better quality of trainee doctors: 360-degree reports and ratings/ impressions of clinical supervisors. Highest of them includes patient management indices such as reduced morbidity and mortality data, better patient satisfaction scores of confidences in junior practicing doctors, overall reductions of preventable errors or reduced events.

Medical students: Includes undergraduate medical students, house officers and interns who are yet to obtain their qualifications as a medical doctor.

Residents, postgraduates, trainees: Are terms used interchangeably in various educational systems. These are doctors who are in structured training program and have not yet obtained specialist qualifications or certification for independent unsupervised specialty practice from the respective medical boards.

Transitional years, senior house officers, medical officers, non-trainees: Are doctors who have obtained their undergraduate medical degree and work as junior medical doctors and have not entered specialty track or a formal structured program of training into specialist accreditation.

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