TRAINING AND EDUCATIONAL PAPER

Comparison of three simulation-based training methods for management of medical emergencies

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Education; Emergency treatment; Guidelines; Resuscitation; Training

Summary Trainee medical officers (TMOs) participated in a study comparing three methods of simulation-based training to treat medical emergencies occurring in a hospital setting. The methods were:

Group 1: Computer screen-based training (CSBT), scripted presentations on medical emergencies and practice on simple part-task trainers.

Group 2: As above but with some practice on whole-body patient simulators.

Group 3: As above plus some practice using patient simulators in 'full-mission' simulation.

All groups had the same total teaching time. Participants (n = 61) had an initial (pre-training) assessment by written tests, self assessment and simulations of medical emergencies (‘VT’ and ‘HYPOglycaemia’). Participants were tested again post-training using similar simulations to the initial scenario and a new scenario (‘ANAphylaxis’). Trained ‘experts’, blinded to the teaching group of participants, watched video-CDs of the simulations to assess participants’ performance.

All groups demonstrated increased knowledge and confidence (pre-training scores compared to post-training) but no differences could be detected between the three groups. In simulated emergencies, post-training scores were also improved. There was no difference between groups in the ‘HYPO’ scenario but in the ‘VT’ scenario there was moderate evidence that Group 3 was superior. In the ‘ANA’ scenario, Group 3 had far better test scores, especially in behavioural items.

There did not appear to be any significant advantage of using whole body manikins over CSBT and simple part-task trainers. Full-mission simulation training helped
Introduction

Medicine has a long history of attempting resuscitation of seriously ill and unconscious patients but standardised application of proven techniques in resuscitation is relatively recent. Unfortunately, there has been ‘...general disappointment in skills acquisition and retention after conventional resuscitation training...’ that led the International Liaison Committee on Resuscitation (ILCOR) to make specific recommendations on ways to improve ‘Education in Resuscitation’. One major change suggested was from instructor-directed, task orientated training to scenario-based training using simulators and including team skills. Whilst it was expected this would be beneficial the need for scrutiny and evaluation of changes in course content and delivery was identified.

Clinical skills used in acute care have, like most medical skills, generally been acquired through extended clinical experience. To reduce patient risk of unwanted outcome associated with training the Institute of Medicine and others have also recommended increased use of simulation to create learning environments. The range of simulation technologies that can be used in medical education is outlined in Table 1 but there is no information on the relative effectiveness of each. Training 'in context' should help theory building assist knowledge retention (learning) but providing authentic training using patient simulators in full-mission simulation is an expensive undertaking so is not readily accessible for basic training. In contrast, computer screen-based training (CSBT) offers inexpensive scalability but does not include actual performance of technical skills.

Supervisors of training need to know that their budgets are being spent effectively so we decided to investigate the comparative effectiveness of some different simulation-based acute care training methods. The methods we used were developed from the published recommendations for education about resuscitation so the results of this study would be useful information for all involved in teaching resuscitation. The main question we sought to answer was whether full-mission simulation would provide better training than predominantly CSBT.

Methods

This study was designed to test the hypothesis that the same duration of training, whatever the technology, would result in the same outcomes (the null hypothesis). Trainee medical officers (TMOs) working at all metropolitan teaching hospitals in Adelaide (South Australia) were invited to participate in this project. The ethics committees of each of the teaching hospitals included approved the study. Participants gave written consent and were then allocated randomly to one of three ‘training’ groups. The teaching received by each group is outlined in Table 2. All participants had a ‘pre-training’ assessment on entering the study, the same total duration of teaching and then a ‘post-training’ (exit) assessment (see below).

Pre-training assessment

TMOs knowledge of acute care was tested first using MCQs. Confidence of trainees in performing a number of skills was assessed using a 16 item Skills Confidence Questionnaire (SCQ). Each TMO then participated in two ‘Pre-training’ test scenarios (Table 3) that used whole-body patient simulators in a realistic clinical setting.

Table 1 Simulation tools and approaches used in simulation-based medical education

<table>
<thead>
<tr>
<th>Tool or Approach</th>
</tr>
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<tbody>
<tr>
<td>Low-tech/part-task simulators</td>
</tr>
<tr>
<td>Simulated/standardised patients</td>
</tr>
<tr>
<td>Computer screen-based simulators</td>
</tr>
<tr>
<td>Complex task trainers</td>
</tr>
<tr>
<td>Realistic patient simulators</td>
</tr>
<tr>
<td>- Instructor driven</td>
</tr>
<tr>
<td>- Model driven</td>
</tr>
</tbody>
</table>


a Interns (postgraduate year 1/PGY1) and resident medical officers (postgraduate year 2/PGY2) are collectively known as trainee medical officers (TMOs).

b Copies of all materials used (e.g. MCQs and SCQ are available from the authors.)
Table 2  Outline of teaching methods provided for the three groups of trainee medical officers

<table>
<thead>
<tr>
<th>Group</th>
<th>Teaching Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 (n=20)</td>
<td>Self-directed, computer screen-based simulation (CSBT) resuscitation training, scripted presentation of emergency care material including cardiac arrest and discussion and some practice on simple trainers</td>
</tr>
<tr>
<td>Group 2 (n=21)</td>
<td>Some CSBT, some scripted presentations of emergency care material and training in emergency care through scenarios using whole-body manikins with an ECG generator</td>
</tr>
<tr>
<td>Group 3 (n=20)</td>
<td>Some CSBT resuscitation training, some scripted presentation of emergency care material and training in emergency care using a range of manikins including full-mission clinical simulation using a computer-controlled, high-fidelity human patient simulator</td>
</tr>
</tbody>
</table>

The teaching

Computer screen-based teaching

All groups received computer screen-based training (CSBT) provided by the ‘ResusSim®—In Hospital’ programme (www.laerdal.com). This resuscitation training programme presents a number of medical emergencies in which each treatment to be given by the doctor or nurse is chosen from pull-down menus. The program has sounds for added realism and provides an individualised debriefing at the end of each scenario.

Practise on basic CPR trainers

The basic CPR trainers used included Basic Buddy® (www.enasco.com), Little Anne® (www.laerdal.com) Laerdal or CPR Pal® (www.ambu.com). When Group 1 were practising on these models they were also shown pictures of the actual clinical equipment (e.g. defibrillators) that would be used in particular situations and when and how to use it explained.

Simple scenario training

The simple scenario training for Groups 2 and 3 used the Resusc-Ane® CPR-D (www.laerdal.com). A number of ‘cardiac arrest’ scenarios were presented and actual clinical equipment was used.

Full-mission clinical simulation

Full mission simulation was used only by Group 3. Two computer-controlled patient simulators, the ALS Skillmaster® manikin with HeartSim4000® and SimMan UPS® (www.laerdal.com) were used in realistic clinical settings. The sophisticated features of the ‘SimMan UPS’ meant scenarios could be staged to include some ambiguity or ‘grey areas’ designed to encourage active learning through problem-solving and to provide multiple opportunities for performance assessment.

Table 3  Outline of the test scenarios

The two baseline (entry) tests

(i) VT-pre: A 64-year-old male patient (ALS SkillMaster manikin) developed pulseless VT very soon after arrival in the Emergency Department (ED). Prompt cardioversion led to restoration of sinus rhythm
(ii) HYPO-pre: An elderly man (SimMan UPS®) is confused on arrival in the ED and quickly becomes unconscious. Jaw support is required as well as diagnosis and treatment. The medication brought with the patient and a MedicAlert® bracelet should quickly lead to blood sugar analysis and treatment with IV glucose

The three post-training (exit) tests

(1) VT-post: A 58-year-old male (Megacode Kelly® and ECG generator) on the post-surgical ward requires assessment of chest pain after long-standing surgical pain. He developed VT but remained conscious (with a pulse) although he became unconscious (and pulseless) if there was much delay in using the defibrillator. This was similar to VT-pre but used a patient simulator that had not been encountered before
(2) HYPO-post: An 88-year-old female (SimMan UPS®) presented to ED with a laceration to the left hand sustained whilst making breakfast. Soon afterwards she became confused and then unconscious. Jaw support was required as well as diagnosis and treatment. This scenario was very similar to HYPO-pre
(3) ANAphylaxis: A distressed 24-year-old female (SimMan UPS®) was admitted to ED with shortness of breath developing after ant bites. She had a history of asthma and has been hospitalised for treatment of this in the past. Today she had taken her asthma medication according to her ‘asthma plan’ but without relief. On examination she had obvious welts across her chest and hypotension. She responded to appropriate treatment with adrenaline but deteriorated if this was delayed. This was a totally new scenario that had little in common with the others
Post-training assessment

Trainees undertook a post-knowledge test and completed the SCQ again, as well as a questionnaire on perceived value of training. The questionnaire included items exploring changes in both skills competence and confidence. All trainees then participated in three scenarios. Two were similar to the baseline test scenarios and one was on a whole-body patient simulator that none of the participants had seen before. The third scenario was a new condition (anaphylaxis) that had not been taught by us. We chose anaphylaxis (ANA) for this assessment because an earlier study reported that the diagnosis of this condition was usually made late in hospital and treatment was typically unstructured.8,9 The post-training assessment was scheduled 3 weeks after the last training but was occasionally longer than this due to trainees’ other commitments.

Performance of trainees in both ‘Pre-’ and ‘Post-training’ scenarios was recorded on video for subsequent (off-line) scoring by experts who were medical staff working in acute care disciplines. The volunteer assessors attended a training session where a video of a ‘good’ and ‘bad’ (specially staged) performances were shown and discussed along with the rating instrument. The domains to be considered were discussed in relation to the videos and a number of additional hypothetical situations. Sets of videos were written to a video-CD so that assessors could easily navigate and view the files on a PC. The ‘experts’ rated the performance of the trainees in managing simulated crises using a checklist that included items for applied knowledge of medical management and clinical behaviour. An overall (global) score was also given. The reviewers worked independently and were blinded to the trainees’ level of training and the allocated simulation training group.

Statistical analysis

Statistical analyses were performed to test two null hypotheses:

(i) There is no difference between Groups 1 and 2, and
(ii) Group 3 scores do not differ from those of Groups 1 and 2.

MCQ and SCQ scores obtained after training were examined by analysis of covariance, pre-training scores being used as the covariate. Assessors’ ratings of the video recordings of performances were analysed using mixed effects linear models with assessor as a random factor. For data from the VT and HYPO scenarios, scores from the post-intervention assessment were analysed using scores from the pre-intervention assessment as a covariate. Initial analyses examined the ‘overall score’ in the domains of Knowledge and Medical Management, Behaviour, and Overall Performance. Specific items within each domain were analysed only if there was evidence that interventions had differentially affected overall scores for that domain.

The null hypothesis of no group differences was rejected if the two-tailed p-value was less than 0.05.

Results

Of the 64 trainees who entered the programme, 53 were interns (first postgraduate year or PGY1) and 11 were resident medical officers (RMO or PGY2) and most (49/64) came from the hospital where the simulation facility is located. TMOs from many other hospitals said they wanted to participate but were put off by the travelling that would be required and did not enrol. There were three TMOs who enrolled in the project but did not attend all sessions and 20 who gave consent but then withdrew before the first session. There was no suggestion that the allocated group had any impact on commencement or completion with most (n = 16 or 70%) citing clinical workload for their actions.

Knowledge test (MCQ) scores improved significantly (<0.001) following teaching in all groups and there was no difference detected between groups. There was also overall improvement in self-evaluated ‘confidence’ (SCQ) scores (p < 0.001). The trainees were performing clinical duties throughout the study so improvement is not necessarily attributable to teaching received in the study.

Scores in the VT-post and HYPO-post scenarios were significantly greater than in the corresponding pre-intervention scenarios. Whilst there was no difference between groups in the management of hypoglycaemia (HYPO-post), Group 3 showed significantly higher scores (p = 0.047) in the VT-post scenario (Table 4). Group 3 performed significantly better than the other groups in the ANAphylaxis scenario (p = 0.012).

These results provide evidence that full-mission simulation training improved scores in the ANAphylaxis scenario more than either CSBT or low-fidelity training and this was especially in relation to ‘behaviour’ (Question 2) and in overall performance. The scores for the specific components of behaviour were analysed, to see if only certain aspects of behaviour might be affected (see Table 5) but Group 3 scored better in all areas. The difference was quite small in item 10 (manages conflict)
but there was little ‘conflict’ to manage during the scenario.

### Discussion

In this study, all groups demonstrated improved knowledge of acute care of medical emergencies and relevant clinical skills and behaviour. This may not have been only from teaching received in this study because trainees were learning from many sources. Participants made many positive comments about the training that suggested to us that it was this acute care teaching that specifically improved confidence. Improved confidence has frequently been reported following simulation training but confidence is not a good predictor of competence. Improved confidence has frequently been reported following simulation training but confidence is not a good predictor of competence. Improved confidence has frequently been reported following simulation training but confidence is not a good predictor of competence.10 Confidence does reduce doctor stress which is important for new medical graduates involved with management of medical emergencies.11

Medical knowledge (which improved during our training) is very important but what is done with it determines patient outcome.11 and we believe

### Table 4

Comparison of three simulation-based training methods for management of medical emergencies

<table>
<thead>
<tr>
<th></th>
<th>Mean (S.D.)</th>
<th>p-Valuesb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group 1</td>
<td>Group 2</td>
</tr>
<tr>
<td>VT scenario (change scores)a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge and MM</td>
<td>0.20 (1.44)</td>
<td>0.45 (1.57)</td>
</tr>
<tr>
<td>Behaviour</td>
<td>0.16 (1.46)</td>
<td>0.41 (1.33)</td>
</tr>
<tr>
<td>Overall</td>
<td>0.15 (1.60)</td>
<td>0.36 (1.40)</td>
</tr>
<tr>
<td>HYPO scenario (change scores)a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge and MM</td>
<td>1.00 (1.48)</td>
<td>1.45 (1.71)</td>
</tr>
<tr>
<td>Behaviour</td>
<td>0.90 (1.58)</td>
<td>0.86 (1.96)</td>
</tr>
<tr>
<td>Overall</td>
<td>0.95 (1.47)</td>
<td>1.23 (1.88)</td>
</tr>
<tr>
<td>ANAnaphylaxis Scenario (scores)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge and MM</td>
<td>4.19 (1.50)</td>
<td>4.36 (1.71)</td>
</tr>
<tr>
<td>Behaviour</td>
<td>4.43 (1.21)</td>
<td>4.45 (1.44)</td>
</tr>
<tr>
<td>Overall</td>
<td>4.29 (1.38)</td>
<td>4.64 (1.43)</td>
</tr>
</tbody>
</table>

a 'Post-training’ score minus ‘pre-training’ score.

b p values for the Group 1 vs. Group 2 comparison were all greater than 0.3.

### Table 5

Analysis of specific components of Section 2 of the expert evaluators’ checklist which relates to the behaviour of trainees during the ANAnaphylaxis scenario

<table>
<thead>
<tr>
<th>Item</th>
<th>Specific component of behaviour</th>
<th>Mean score</th>
<th>Significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Acquisition of all available information</td>
<td>3.19</td>
<td>3.50</td>
</tr>
<tr>
<td>2.2</td>
<td>Anticipates and plans</td>
<td>3.00</td>
<td>3.23</td>
</tr>
<tr>
<td>2.3</td>
<td>Calls for help appropriately</td>
<td>3.10</td>
<td>2.95</td>
</tr>
<tr>
<td>2.4</td>
<td>Re-evaluates situation</td>
<td>3.00</td>
<td>3.55</td>
</tr>
<tr>
<td>2.5</td>
<td>Utilises team resources effectively</td>
<td>3.33</td>
<td>3.59</td>
</tr>
<tr>
<td>2.6</td>
<td>Allocates attention wisely</td>
<td>3.10</td>
<td>3.50</td>
</tr>
<tr>
<td>2.7</td>
<td>Prioritizes</td>
<td>3.19</td>
<td>3.41</td>
</tr>
<tr>
<td>2.8</td>
<td>Concise, directed instructions, closes communication loop</td>
<td>3.05</td>
<td>3.68</td>
</tr>
<tr>
<td>2.9</td>
<td>Communicates problem clearly to team listens to team</td>
<td>3.38</td>
<td>3.55</td>
</tr>
<tr>
<td>2.10</td>
<td>Manages conflict</td>
<td>3.21</td>
<td>3.53</td>
</tr>
</tbody>
</table>

* p < 0.05, Group 3 vs. Groups 1 and 2.

** p < 0.01, Group 3 vs. Groups 1 and 2.

# p < 0.05, Group 1 vs. Group 2.

Overall and in most parts there is evidence of superior performance of Group 3.
observed performance in a physical simulation is a better indicator of clinical expertise than written tests. In the post-training assessment using simulation the major difference between the groups was in the TMOs that had had most simulation training (Group 3), were rated most highly in their management of the "new" challenge. Although we had not taught management of anaphylaxis to any participant, those who had received full-mission simulation training appeared best able to manage the situation. The group was also better able to manage an emergency they had encountered before but occurring in a new 'patient' seen for the first time. This is very important because they will face many new challenges and it will never be possible for trainees to learn and practise managing every possible clinical emergency. Clearly the best training outcome is when trainees have moved beyond simply applying rule-based treatment when undertaking emergency care of an acutely ill patient and can prioritise and solve problem even under pressure.11

Ideally we would have had several experts to assess each trainee but we did not have the resources to provide that. However, all our assessors undertook a benchmark training exercise and assessing performance using trained assessors and checklist scoring of simulation has been reported to be acceptably reliable.10,12 We also note that in the "manages conflict" item similar scores would be expected in all three groups because there was very little conflict and this was the case.

Simulation allows emergency care to be included in a structured training programme for TMOs and should lead to more competent health professionals13 than relying on opportunistic teaching in clinical practice. However, we only tested participants in three situations and a larger number of scenarios would be needed to truly assess actual clinical competence.14,15 There have been several surveys of skills required by junior medical staff and their preparedness for clinical work. Most medical schools examine knowledge well but clinical skills and behaviour are examined less rigorously.16

The gap between what has been learnt at medical school and what is needed to function as a junior doctor has been identified before17,18 and some trainees need special help.19 There is currently no system to identify such individuals but a structured simulation-based programme can both assist identification of training needs and then provide training for the intervention. The main hospital where this study was conducted has now introduced regular simulation training for TMOs with these being some of the objectives of the programme.

Ideally trainees would receive regular formative feedback from their supervisors but anecdotally this is not common. High workload pressure has a deleterious effect on the ability and willingness of trainers and trainees to engage in debriefing even though clinical experience of resuscitation without feedback improves confidence but not skill.20 Trainees themselves are not necessarily good at assessing their own performance and recognising the need for additional learning.21 Participation in simulated cardiac arrest calls does increase the perceived need of residents for more knowledge before supervising a call,22 but competence is not predicted by either clinical experience or confidence.20

Summation assessment of students or trainees requires a standard to be set (benchmark performance) so that a pass–fail decision can be made.23 ILCOR has identified that any deficiencies in care can have a major adverse impact on outcome4 so any standard other than perfection must be set arbitrarily in assessing resuscitation. For this reason we compared rated performance of the groups rather than attempting to identify what proportion had reached a particular standard of care.

We did not observe any appreciable difference between the performance of Groups 1 and 2 so using a whole body manikin is not necessarily better than a smaller, simpler part-task trainer. We have described the simulation training for Group 3 as "full-mission" but this is not to say that the Sim-Man simulator is necessarily a high-fidelity patient simulator but that the setting included all the elements needed to create an authentic clinical environment. In many aspects this is probably more important than whether the simulator is "model" or "instructor-driven". General principles for using simulators in teaching have been described23,24 but buying a patient simulator is not a trivial exercise. Technology alone is not a solution25 and even an expensive simulator is only as good as the educational programme which it is embedded in23,24 and faculty development is essential.6

Ultimately, investigating whether such training actually makes a difference to patient outcome will be difficult.26 However, if trainees are unable to demonstrate good performance in a simulator then it is unlikely that they will be better when treating patients and trainees who demonstrate unsafe behaviour in a simulation cannot be relied on to perform effectively in the real clinical situation. Weller et al.27 have reported that simulation training improves practice among specialists and is an effective form of continuing medical education and there have been occasional reports of simulator training improving medical outcomes.6

Eaton and Cottrell28 reported that structured teaching methods enhance skill acquisition but
not problem-solving abilities and different teaching methods are needed for professionals to achieve clinical competence. In this study all groups improved their knowledge and skills to manage medical emergencies but physical simulation and debriefing appeared to generate better problem-solving skills than the CSBT programme ResusSim® with automated debriefing. CSBT is less demanding than physical simulation and the menus listing treatment choices may provide triggers for recall that are generally not present. Also, CSBT is typically undertaken individually but effective interdisciplinary communication and careful allocation of available resources are vital in managing medical emergencies.29,30 Whether this can ever be achieved using CSBT based on another learning structure needs further investigation.31 Whatever the simulation training, it must be compatible with local clinical practice or it is unlikely to be retained32 and a generic artificial reality in a CSBT programme may not reflect local conditions closely enough.

We originally planned to complete this study in one year but many TMOs could not find the time to attend because of their workload and the time commitment that was needed. The work schedules of the TMOs that did enrol made it difficult for them to commit to attending a session more than a few days ahead and scheduled sessions were often postponed by the TMO at very short notice because of workload. The impact of reduced hours legislation on clinical work undertaken by trainee medical staff (in anaesthesia) has been documented33 so that traditional time-based training can no longer be relied on to achieve training objectives. Alternate training methods need to be considered to ensure competence but ‘lack of time’ has already been identified as a barrier to simulation-based education.34 This is compounded if participants have to travel off-site to receive training so eventually staffing levels will have to take account of scheduled teaching.

Conclusion

This study of acquisition of clinical skills needed for acute care taught using different simulation training technologies indicated that full-mission simulation using physical patient simulators appeared to be the most useful training method. All training methods were associated with improved knowledge and skills but full-mission simulation helped develop the ability to recognise when skills learnt to manage one type of medical emergency can be applied to manage another emergency not previously encountered. It is hoped this observation can be confirmed because it would make a compelling case for investment in simulation training.

Conflict of interest

No author has any conflict of interest to declare.

Acknowledgements

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