

## Simulation in undergraduate medical education: bridging the gap between theory and practice

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**OBJECTIVE** To evaluate the use of simulation-based teaching in the medical undergraduate curriculum in the context of management of medical emergencies, using a medium fidelity simulator.

**DESIGN** Small groups of medical students attended a simulation workshop on management of medical emergencies. The workshop was evaluated in a post-course questionnaire.

**SUBJECTS** All Year 4 medical students allocated to the resuscitation rotation during the first half of 2002.

**MAIN OUTCOME MEASURES** Student perceptions of learning outcomes, the value of the simulation in the undergraduate curriculum and their self-assessed improved mastery of workshop material.

**RESULTS** A total of 33 students attended the workshop and all completed questionnaires. Students rated the workshop highly and found it a valuable learning experience. In all, 21 (64%) students identified teamwork skills as key learning points; 11 (33%) felt they had learnt how to approach a problem better, particularly in terms of using a systematic approach, and 12 (36%) felt they had learnt how to apply their theoretical knowledge in a clinical setting better. All 33 students were positive about the use of simulation in their training; 14 students wrote that simulation should be used more or should be mandatory in training; 5 students commented positively on the realism of the learning experience and a further 5 said they valued the opportunity to learn new skills in a safe environment.

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**CONCLUSION** This study demonstrates that medical students value simulation-based learning highly. In particular, they value the opportunity to apply their theoretical knowledge in a safe and realistic setting, to develop teamwork skills and to develop a systematic approach to a problem. A medium fidelity simulator is a valuable educational tool in medical undergraduate education.

**KEYWORDS** education, medical, undergraduate/\*methods; clinical competence/\*standards; emergency medicine/\*standards; patient simulation; curriculum; questionnaires; attitude of health personnel.

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### INTRODUCTION

A major challenge for medical undergraduates is the application of theoretical knowledge to the management of acutely ill patients. Students must learn to be systematic in their approach to a problem, and develop skills appropriate to working with a clinical team. However, opportunities for students to develop these attributes are limited in undergraduate training. Can simulation help them achieve these goals?

Simulation-based workshops in crisis management are a popular and effective method of continuing medical education for medical specialists and trainees.<sup>1,2</sup> However, simulation is also widely used in undergraduate medical education. A recent, worldwide survey identified 158 simulation centres, many of which were involved in undergraduate education.<sup>3</sup>

Student opinion of simulation-based teaching using a high fidelity simulator (HPS) is generally enthusiastic.<sup>4,5</sup> However, evidence showing improved

## Key learning points

Medical students value simulation-based learning highly.

Simulation allows for the application of theoretical knowledge to practice.

Students can acquire new skills in a safe environment.

Simulation-based learning aids development of teamwork skills.

Students can develop a systematic approach to medical emergencies.

learning outcomes is limited and the financial cost is high.<sup>6</sup> Does simulation-based teaching warrant the expense and can a less expensive, medium fidelity simulator achieve the same results?

The aim of this study was to evaluate what students learnt from a simulation-based workshop using a medium fidelity simulator, and to seek student opinion on the value of simulation in the undergraduate curriculum.

## METHODS

The subjects in this study were 33 Year 4 medical students at Wellington School of Medicine, New Zealand, who were undertaking the resuscitation module in the first half of 2002. During this 4-week attachment, students spent time with an anaesthetist in the operating room, attended the emergency department, took part in tutorials and read a basic text on resuscitation. The aim of the module was to learn how to manage medical emergencies. Students attended a 3-hour workshop in the simulation centre as part of this module. The maximum class size for the workshop was 11 students.

Unlike traditional teaching methods, simulation encourages students to take an active role in management of an emergency situation. This can be stressful both in terms of participating in a realistically simulated emergency and performing in front of colleagues. Simulator 'death' can be particularly stressful and should be avoided, but it would be misleading if inappropriate actions resulted in a good

simulator outcome. The ethical issues of using simulation as a teaching tool were addressed in this workshop at 3 stages: in setting the scene, during the simulation and during feedback after the simulation.

To create a safe environment, students were told participation was not compulsory, and assured that their performance in the simulator was confidential and would not count in any way towards their course assessment. Students were reassured that they were not expected to perform beyond their ability as Year 4 medical students. Students worked in teams and chose their own roles within those teams, allowing less confident students to take a minor role in the simulation.

Simulator death was avoided by prompts from the 'nurse', who wore a headset and could follow directions from the instructor. The nurse prompted students to initiate treatment when necessary and stopped them performing clinically inappropriate actions. For example, the nurse would prompt: 'Should I give the patient oxygen?' if students had failed to do this within a reasonable time, or: 'The doctors dilute the adrenaline in 10 ml and give it 1 ml at a time in this situation,' if students were about to administer an inappropriate dose. In addition, the instructor observed the scenario through 1-way glass and could vary the pace and complexity in response to student performance.

The discussion following the simulations aimed to be collegial and supportive, avoiding blame or humiliation, and focussing on behaviours rather than on individuals. Positive feedback was emphasised and critique was constructive. Students were encouraged to do most of the talking and to identify their own strengths, deficiencies and areas for improvement.

During the workshop, 4 cases were presented to the students: anaphylaxis, chest pain, coma of unknown cause, and major trauma. The instructor outlined the presenting problem and students were allowed several minutes to plan their response. Students managed their 'patient' in groups of 5–6, while their colleagues observed through audio-visual relay. A nurse helped the students with tasks such as connecting monitors, and locating medications. During the debriefing that followed each simulation, students reviewed their performance and clarified diagnostic and treatment pathways.

At the end of the workshop, all students completed an anonymous questionnaire rating aspects of the session on a scale of 1–5, using questions developed

and widely used by the Otago University Higher Education Development Centre. In addition, students scored their level of competency on the material before and after the session on a scale of 1–5, where 1 = beginner and 5 = master.

Open questions sought the students' views on the workshop, including key learning points, the most valuable aspects of the session and their opinion of simulation in undergraduate medical education.

We used a medium fidelity Laerdal SimMan patient simulator for the workshop (Laerdal, Stavenger, Norway). SimMan is a full-body manikin with a realistic upper airway, chest movement, variable cardiac and breath sounds and a palpable pulse. SimMan can be mask-ventilated, intubated, cannulated, given fluids and medications and defibrillated. In the event of a pneumothorax, needle thoracocentesis and chest drain insertion can be performed. Monitors display representations of blood pressure, ECG, oxygen saturation and expired carbon dioxide. The console operator can adjust clinical signs and monitor data as the scenario progresses.

This simulator differs from the more sophisticated and expensive HPS in several ways. The HPS is modelled to respond realistically to changing states or participant interventions such as failure to oxygenate or blood loss. In SimMan, the console operator keys in changes in parameters, with a limited facility for preprogrammed responses.

Unlike the Laerdal SimMan, the HPS lung model exchanges oxygen, carbon dioxide and anaesthetic agents, which can be measured with standard gas monitors. The HPS can be attached to a ventilator, and will generate realistic airway pressures, tidal

volumes and spirometry traces and can be connected to real monitors with appropriate alarm functions. This facility is limited in SimMan. Thus the Laerdal SimMan represents a major advance on the relatively inert resuscitation manikins, but is more limited than the HPS in what it can realistically simulate. However, the purchase cost of SimMan is less than 25% of that of the HPS, it is less expensive to maintain and requires considerably less operator training and time to prepare for clinical scenarios. This makes it a more feasible proposition for medical schools and instructors.

In analysing the data generated by the post-workshop questionnaire, descriptive statistics were used for student ratings. The Wilcoxin matched-pairs signed-rank test was used to determine the significance of the change in self-assessed competence ratings pre- and post-workshop. Written responses were coded into themes.

## RESULTS

Students rated the workshop highly and found it a valuable learning experience (Table 1). In particular, they felt comfortable working with the simulator, were encouraged to work as a team and felt the session helped integrate theory with practice.

Students felt their competency with the material increased following the workshop (Table 2). The mean increase in competency was 1.11 (SD 0.64), which was statistically significant ( $P < 0.0001$ ) using Wilcoxin matched-pairs signed-rank test.

In response to the open questions, 31 of the students (94%) identified 1 or more key learning points

**Table 1 Student questionnaire. Response rate 33/33 (100%). Rating scale: 1 = very much, very effective or very often; 5 = not at all, not at all effective or seldom**

Question	Median	IQR	R
Did the instructor create a learning environment in which you felt comfortable?	1	1–2	1–3
How successful was the instructor in encouraging you to work as part of a team?	1	1–2	1–3
Did this session help you develop confidence to use what you learned in class in the clinical setting?	2	1–2	1–4
Was this session effective in helping you to integrate theory and practice?	1	1–2	1–3
Were the simulations a valuable learning experience?	1	1–2	1–3

IQR = interquartile range; R = range

**Table 2 Student questionnaire. Move in competency with material before and after simulation-based session. Response rate 32/33. Rating scale: 1 = beginner; 5 = master**

Move in competency	Frequency reported (%)
- 0.5	1 (3.13)
0	2 (6.25)
1	23 (71.88)
2	5 (15.63)
3	1 (3.13)

(Table 3). Thematic analysis of the written comments showed 21 students (64%) felt they had learnt more about working in a team (typified by the comments 'the importance of having a leader' and 'don't be afraid to lead'), the need for 'allocating jobs to be done within a team' ('defined roles lead to efficient and safe practice') and the importance of clarity in

communication. Students felt they had learnt how to implement a more systematic approach to a medical emergency in the initial assessment of the patient ('the ABC is the best starting point even if the diagnosis seems obvious' and 'reinforcement of ABCDE'). Students identified a difference between knowing what they should do and actually doing it in a realistically simulated medical emergency ('the theory and practice of medicine are 2 different things', '[putting] theory into practice is quite difficult', '[the workshop] reinforced what we'd read', '[the workshop] provided an opportunity to practise', and 'skills you read about are hard to put into practice in real life').

All 33 students gave written responses to the question 'What is your opinion on the use of the simulator in undergraduate medical education?' (Table 4). All students were very positive, with comments such as 'very valuable', 'fantastic', an 'excellent way of learning' and 'better than alternative methods'. Fourteen students felt simulation should be used more or that it was essential in their training. Five students remarked on the realism of the simulation, illustrated by the comments: '[It] gives some idea of

**Table 3 Key learning points. Students responding (31/33) to each theme. Written comments (total 60), number of comments and percentage of comments falling into each theme and subcategory**

Theme	Students responding <i>n</i> (%)	Written comments <i>n</i> (%)
Behavioural issues	21 (64)	29 (48)
Teamwork		15 (25)
Leadership		4 (7)
Task distribution		5 (8)
Communication		3 (5)
Effect of stress/managing stress		2 (3)
Approach to problem	11 (33)	12 (20)
Systematic approach to problem		6 (10)
Primary response		4 (7)
Secondary survey		1 (2)
Need to organise response		1 (2)
Need to think broadly re diagnosis		3 (5)
Need to know the basics		3 (5)
Learning to put theory into practice	12 (36)	12 (20)
Specific knowledge	7 (21)	10 (17)
Use of a medication		4 (7)
Management of specific problem		3 (5)
Use of oxygen delivery devices		3 (5)

**Table 4 Student opinion of simulation in their education**

	Student responses
Written comment groupings	<i>n</i> (%)
Very valuable learning tool	31 (94)
Should be more simulation workshops	14 (42)
Chance to learn in safe environment	5 (15)
Realism of experience	5 (15)

*n* = number of students giving a response in that theme. Some students' responses fell into more than 1 theme

an emergency situation' and 'makes it more real'. Five students commented on the value of learning practical skills in a safe environment, as typified by the comment that simulation provided a 'good opportunity to practise skills without hurting people'.

## DISCUSSION

In this study, undergraduates appeared to value simulation-based teaching very highly. In the workshop, students made all the clinical decisions, planned and administered treatment and arranged investigations and ongoing care. Students' comments confirmed that they valued the opportunity to manage a realistic medical emergency on their own and in a safe environment. They could apply their theoretical knowledge of resuscitation to practice, and develop a more systematic response to an emergency without causing patient harm. Because students worked on their 'patient' in teams, planned their roles in the team prior to the simulation, and reviewed the performance of their own team and those of their colleagues, they learnt important teamwork skills, as shown by the high percentage of students who nominated aspects of teamwork as key areas of learning. Despite the stress of performing in front of their peers, students found this a comfortable learning environment and wanted more simulation-based teaching in their medical course. Students felt their level of competency with the material improved following the workshop.

Simulation offers students a unique opportunity to learn through experience, aided by reflection and

feedback and the opportunity to practise. Simulation training is highly engaging, interactive and clearly relevant to practice. Students learn from each other in a safe, non-threatening environment. These attributes of simulation-based education are consistent with models of effective educational interventions.

Prior to this study, it was unclear what students were learning from simulation workshops. It appears that the students in this workshop valued the development of generic skills, such as applying a systematic approach to a problem and learning to work with a team, more than they valued the acquiring of items of knowledge or component technical skills specific to the 4 cases presented. These attributes of systematic problem solving and teamwork are hard to address by other methods and simulation may fill a gap in current undergraduate programmes.

It is hardly surprising that studies have shown that simulation-based learning is valued highly by students.<sup>4,5</sup> This was confirmed by our study, suggesting that the positive attributes of simulation-based education apply across different centres and curricula. Euliano<sup>7</sup> demonstrated the value of high fidelity simulation in teaching small groups of undergraduates applied respiratory and cardiovascular physiology and pharmacology as an alternative to laboratory experience. Morgan *et al.*<sup>8,9</sup> showed positive evaluations using simulation to teach basic anaesthesia skills to medical undergraduates. Gordon *et al.*<sup>5</sup> also showed positive evaluations for a simulation-based course on the management of medical emergencies. In the 2 studies conducted by Morgan *et al.*,<sup>8,9</sup> students worked individually. In the study by Gordon *et al.*,<sup>5</sup> they were able to seek guidance from a teacher during the simulation exercise.

The present study differs from other studies in several ways. Students worked in teams and each team managed the clinical problem on its own. The workshop content was aligned with the core objectives of the undergraduate curriculum, which, in New Zealand, does not include anaesthesia. Students were asked to identify what they had learnt from the simulation workshop and to assess their competency before and after the workshop.

Previous studies used a high fidelity simulator, capable of simulating the more complex anaesthesia environment. Although the HPS would still be of value as a model on which to learn respiratory and cardiovascular physiology, the medical students in

the present study demonstrated a similarly high degree of satisfaction in using a much less expensive medium fidelity simulator, which may be adequate for recreating clinical situations outside the operating room. This makes simulation-based training a much more feasible proposition for undergraduate education.

To justify the expense of simulation, it would be desirable to demonstrate that students performed better after a simulation workshop than after an alternative teaching intervention. The paucity of randomised, controlled trials in the medical education literature attests to the problems of conducting them.<sup>10</sup> For example, despite the long history of problem-based learning for medical undergraduates, there is little evidence in support of its effectiveness in improving learning outcomes.<sup>11</sup> It is, therefore, unsurprising that simulation-based teaching lacks evidence of improved learning outcomes.

One randomised, controlled trial compared simulation-based teaching with an alternative teaching method. Morgan *et al.*<sup>9</sup> found no improvement in test outcomes when comparing a simulation workshop and video viewing, where the content concerned basic anaesthesia skills for undergraduates. The main outcome measure was the score in an itemised checklist of required actions in the simulator at the end of the workshop. In addition, scores in a written test administered 2–30 days after the teaching were compared between groups. It has been argued that simulation may be of value in assisting in retention of learning,<sup>12</sup> an area which could not be tested in this study. The assessment may have been testing little more than the ability to memorise a list of required actions.

Perhaps the outcomes we should be measuring from simulation-based learning are higher levels of performance, including the ability to apply knowledge in a clinical context, to engage in an effective process of problem solving and to work effectively within a team. The present study indicated that these are areas in which students did learn from the simulation experience.

Given the paucity of evidence from randomised, controlled trials, can we state that simulation is worth the cost? Simulation-based teaching is expensive in terms of faculty time. The workshops in this study required an instructor, a 'nurse' and a console operator. On the other hand, the less expensive simulator used in this study is only a fraction of the cost of the high fidelity simulator, is

much easier to learn how to operate and may well be as effective for undergraduate training. With lower acquisition costs, many more centres are likely to purchase simulators for undergraduate education. Indeed, more than 22 Laerdal SimMan simulators were distributed in Australasia in 2002 and more than 63 were distributed in the UK (personal communication, Laerdal marketing manager).

Simulation-based teaching scores highly on theoretical grounds. Students are actively engaged. New knowledge is acquired in a clinical context, which may aid subsequent retrieval. The relevance of the learning is immediately obvious to students. The limited evaluation data available is positive. On balance, it seems that simulation-based teaching may well justify its cost.

This study was limited to student opinion and student self-assessment. A randomised, controlled trial with adequate numbers and appropriate outcome measures could provide objective evidence to support the additional cost of simulation. This study suggests that appropriate outcome measures should include the development of teamwork skills and a systematic approach to the management of medical emergencies.

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