British Journal of Anaesthesia **114** (5): 794–800 (2015)
Advance Access publication 8 January 2015 · doi:10.1093/bja/aeu457

BJA

QUALITY AND PATIENT SAFETY

Learning through simulated independent practice leads to better future performance in a simulated crisis than learning through simulated supervised practice†

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Editor's key points

- Medical simulation offers learning opportunities without risk to patient care.
- Simulation scenarios reproduce physiological pertubations and critical incidents.
- Premature or simplistic resolution of a critical incident may limit solid learning.
- Failure, if coupled with supportive teaching, can impact positively on learning.

Background. Anaesthetists may fail to recognize and manage certain rare intraoperative events. Simulation has been shown to be an effective educational adjunct to typical operating room-based education to train for these events. It is yet unclear, however, why simulation has any benefit. We hypothesize that learners who are allowed to manage a scenario independently and allowed to fail, thus causing simulated morbidity, will consequently perform better when re-exposed to a similar scenario.

Methods. Using a randomized, controlled, observer-blinded design, 24 first-year residents were exposed to an oxygen pipeline contamination scenario, either where patient harm occurred (independent group, $n=12$) or where a simulated attending anaesthetist intervened to prevent harm (supervised group, $n=12$). Residents were brought back 6 months later and exposed to a different scenario (pipeline contamination) with the same end point. Participants' proper treatment, time to diagnosis, and non-technical skills (measured using the Anaesthetists' Non-Technical Skills Checklist, ANTS) were measured.

Results. No participants provided proper treatment in the initial exposure. In the repeat encounter 6 months later, 67% in the independent group *vs* 17% in the supervised group resumed adequate oxygen delivery ($P=0.013$). The independent group also had better ANTS scores [median (interquartile range): 42.3 (31.5–53.1) *vs* 31.3 (21.6–41), $P=0.015$]. There was no difference in time to treatment if proper management was provided [602 (490–820) *vs* 610 (420–800) s, $P=0.79$].

Conclusions. Allowing residents to practise independently in the simulation laboratory, and subsequently, allowing them to fail, can be an important part of simulation-based learning. This is not feasible in real clinical practice but appears to have improved resident performance in this study. The purposeful use of independent practice and its potentially negative outcomes thus sets simulation-based learning apart from traditional operating room learning.

Keywords: high-fidelity simulation; independent practice; medical education; medical error

Accepted for publication: 10 November 2014

The classic resident training paradigm of apprentice-based learning and traditional educational adjuncts (e.g. lectures and independent study) is under scrutiny in an era of working hour restrictions and decreased numbers or diversity of patient encounters.[1 2] Simulation has emerged as an important adjunct to modern clinical training, yet the key factors that distinguish simulation-based education from traditional operating room (OR) learning have not been fully elucidated. These factors are potentially important if senior doctors are to provide targeted and meaningful postgraduate education over a relatively short period of residency training.

Errors and near misses are ubiquitous in medicine,[3–5] cost billions of dollars annually,[6] and also have negative effects on practitioners.[7–13] Anaesthetists are not immune and may fail to recognize and manage certain rare, dangerous perioperative events properly.[14 15] While devastating, these

†This article is accompanied by Editorial Aev032.

errors can be important learning opportunities, prompting detailed recall[16 17] or encouraging self-reflection and study, or both, which may improve future practice.[18–20] In real clinical training, errors are ideally not allowed to occur or develop further as residents are supervised by senior faculty. However, these represent potential missed learning opportunities which, if engineered in the simulated environment, might lead to similar recall and self-reflection.

While some critics of simulated mortality believe it should almost never occur except in teaching specific, predefined objectives regarding the management of death (i.e. breaking bad news, terminating a resuscitative code),[21] there has been little convincing evidence that simulated mortality has a negative effect on practitioners. In the past, our group have shown that adding emotional fidelity and increasing stress during simulation improved future performance of advanced cardiovascular life support in a medical student cohort.[22] We posit that the stress of simulated mortality might act in a similar manner as a catalyst to improve learning and future performance in a cohort of anaesthesia residents.

In this study, we sought to test whether residents exposed to a simulated oxygen pipeline contamination would perform better in a second simulated exposure 6 months later, if during initial exposure, they were exposed to simulated mortality. We hypothesized that learners who were allowed to manage a scenario independently and allowed to fail, thus causing simulated morbidity, would consequently perform better when re-exposed to a similar scenario (as opposed to a group who could call an attending anaesthetist who was immediately available to assist).

Methods

Study design: phase 1

Study approval was obtained from the Mount Sinai Program for the Protection of Human Subjects. The study was given exemption from the need for written consent. The simulation curriculum is part of the integrative basic anaesthesia training programme at our institution. The experimental scenario (oxygen pipeline contamination) was otherwise hidden within the standard, identical 6 week simulation curriculum. All 24 incoming first-year anaesthesia residents were given the opportunity to opt out of the study voluntarily. All 24 residents agreed to participate in the study. The residents were informed that during the 6 weeks of simulation they would be observed for the research study, but were blinded as to which scenario was experimental.

The study was divided into two phases: the initial exposure phase (phase 1; hidden in the standard simulation curriculum); and the assessment phase (phase 2; 6 months later, not hidden). Before exposure to the scenario, every resident was given the Trait portion of the State–Trait Anxiety Inventory (STAI) to measure baseline anxiety levels.[23 24] All results were de-identified using identification numbers randomly generated for each resident. The initial exposure was given to all residents over the course of 2 days during the same week of training (week 4).

Scenario design

For the experimental scenario, participants were brought to the Mount Sinai Department of Anesthesiology Human Simulation Center for a combined 60 min simulation and debrief session. Participants were randomized, using a computer-generated binary group randomization program, to one of two groups, either the independent group or the supervised group. Both groups received the same starting scenario (see Supplementary material Appendix 1). The independent group would receive no help throughout the scenario (i.e. if they called for an attending anaesthetist, one would be 'busy' and .never arrive), whereas the supervised group would receive help from a simulated attending anesthetist when the patient's cardiopulmonary status began to deteriorate, whether or not they called for help (i.e. attending anaesthetist would state he wanted to check in and see how things were going).

The simulator used (CAE Human Patient Simulator, Saint-Laurent, Quebec, Canada) was programmed with the following baseline parameters: heart rate 121 beats min^{-1} in sinus rhythm, blood pressure 153/82 mm Hg, saturation 100% on 2 litres via nasal cannula, and respiratory rate 21 bpm. After being allowed to assess the situation, the surgeon would begin asking the team to provide anaesthesia as soon as possible because he was very busy. During the scenario, the patient proved extremely difficult to sedate for the procedure, and the surgeon insisted that the patient be given more sedation. Eventually, with escalating anaesthetic doses, the patient became apnoeic while the procedure commenced. Once apnoeic, the gas supply to the anaesthesia machine was manually switched from oxygen to nitrogen by a faculty member running the scenario remotely. Both groups were expected to diagnose and treat the apnoea using proper airway-management techniques. As the pipeline was contaminated, no intervention taken (including positive pressure ventilation with or without tracheal intubation) would improve the patient's status, and the patient monitoring would indicate oxygen desaturation. The oxygen concentration on both monitors accurately reflected the 0% oxygen that was being delivered to the patient.

The scenario then took one of two paths depending on the participant actions. In the independent group, the patient oxygen desaturation worsened and eventually progressed to cardiac arrest. Simulated patient death occurred unless one (or more) of three successful interventions was undertaken: (i) open the auxiliary oxygen tank on the anaesthesia machine and disconnect the machine from the pipeline; (ii) switch the anaesthesia machine to deliver air only; or (iii) ventilate the patient with a manual self-inflating resuscitative bag either connected to an auxiliary oxygen tank or room air. If help was called for, the participant was told their attending anaesthetist was unable to leave their other operating room because they were having 'issues'.

In the supervised group, once the patient oxygen saturation fell below 80% an attending anaesthetist entered the room (whether help was called for or not), diagnosed the pipeline contamination with the resident, and dictated an effective treatment plan (i.e. switching from the hospital supply to an

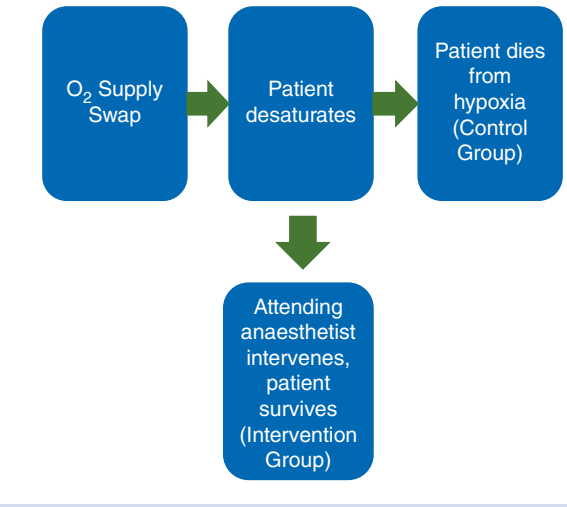

Fig 1 Phase 1 study design.

auxiliary oxygen source) if the resident had no valid suggestions. The patient then demonstrated complete resolution, the oxygen saturation increased to 100%, and the patient began breathing on their own (Fig. 1).

After the simulation, and regardless of the patient outcome, both groups received identical debriefings that did not focus on the patient outcome, but rather on how to identify and treat oxygen pipeline failure or contamination. The debrief was performed by the same individual in each case with a standardized lecture focusing on diagnosis and all proper treatment options for an oxygen pipeline failure or contamination (see Supplementary material Appendix 2).

A postsimulation State portion of the STAI was obtained from all residents.

Study design: phase 2

Phase 2 occurred 6 months later. No participant had extra simulation exposure in between phases 1 and 2. All residents returned to the simulation laboratory individually over the course of the same week and were told they were going to encounter one scenario.

The phase 2 scenario was identical for all residents. The scenario began by a confederate informing the resident that they were to proceed to the OR to relieve another anaesthetist. Upon entering the OR, the participants encountered a general anaesthetic already in progress for a planned robotic laparoscopy; the patient was receiving general anaesthesia with tracheal intubation, and they were draped and ready for surgery. Three confederates (all blinded to the study arm of the subject) were in the room: an anaesthetist, a surgeon, and a circulating nurse. Both groups were given the same standardized hand-off (Supplementary material Appendix 3).

After the brief history, the simulated attending anaesthetist left the room as the surgeon asked for the patient to be placed in the Trendelenburg position.

The simulator was programmed with the following baseline parameters: heart rate 86 beats min^{-1} in sinus rhythm, blood pressure 128/75 mm Hg, respiratory rate 18 bpm, and oxygen saturation of 100%. After receiving permission from the anaesthesia team to begin, the attending surgeon made an incision, at which point the oxygen pipeline contamination occurred and the timer was started. Once the robot was docked and the surgery commenced, the patient became increasingly hypoxaemic over a period of 2 min, eventually progressing to cardiac arrest and death. The patient was unresponsive to advanced cardiovascular life support protocols unless the proper diagnosis and treatment for an oxygen pipeline contamination was conducted as outlined for phase 1. The proper treatment options were considered as binary variables (i.e. yes/no). The scenario was terminated after 15 min regardless of outcome.

The resident's performance was assessed in terms of resuming adequate oxygen delivery and timing of treatment by two observers blinded to initial group placement using the Anaesthetists' Non-Technical Skills Score (ANTS).[25] The observers had been trained previously with the ANTS checklist and given ample time to familiarize themselves with all the aspects of the scoring system. Our ANTS training consists of a didactic presentation of ANTS and a 2 h online training programme repeated bi-annually. Our rater reliability data has been reported previously.[26] After the assessment phase, residents again completed the State portion of the STAI.

At the completion of phase 2, all residents were also given an objective survey to measure several factors, including scenario memorability, an assessment of their own performance, and self-study.

This study was approved by Jeffrey H. Silverstein, chair of the institutional review board at Mount Sinai Medical Center (HS#12-00339, GCO#12-0659(0001)(01)AN).

Statistical analysis

Data were entered into an Excel spreadsheet (Microsoft Corp., Redmond, WA, USA) and transferred to an SAS file (SAS Institute Inc., Cary, NC, USA) for data description and analysis. Descriptive data are presented as *n* (percentage), median with interquartile range, or mean (SD). Rater's scores on the ANTS scale were averaged. For simple group comparison, the χ^2 test or Fisher's exact test was used for categorical variables, and Student's paired *t*-test or Wilcoxon's rank sum test was used for continuous variables, as appropriate. Time to proper treatment was analysed using log-rank analysis. All statistical analyses were performed using SAS 9.2 (SAS Institute Inc.) with a 0.05 two-sided significance level. Sample size estimation was not performed, but rather a convenience sample of all first-year residents was used as the study cohort, given the limitations of possible participants.

Results

The groups were demographically well matched. No resident in either group had simulation exposure between phases, nor did any experience a real pipeline contamination during that time (Table 1).

In both groups, 12 residents (100%) failed to provide proper treatment independently during phase 1. During phase 2, proper management of the pipeline contamination was observed in 67% (n=8) of the independent group participants *vs* 17% (n=2) of the supervised group (P=0.013). If proper treatment was provided, there was no significant difference in the time to proper treatment between groups [602 (interquartile range 490–820) s to treatment in the independent group *vs* 610 (420–800) s in the supervised group, P=0.79].

Residents in the independent group had higher ANTS scores during the second exposure than did the supervised group [42.3 (31.5–53.1) in the independent group *vs* 31.3 (21.6–41) in the supervised group, P=0.015, intraclass correlation coefficient=0.98]. Subgroup analysis showed a statistically significant improvement in situational awareness and decision making in the independent group (Table 2).

The Trait portions of the STAI were similar between groups at baseline. However, there was a statistically significant difference in State scores between the groups' after the initial exposure, with the independent group having higher STAI scores. In contrast, after the phase 2 scenario, state anxiety levels were similar between groups (Table 3).

In the survey given after phase 2, residents were asked to rate several factors regarding the initial scenario concerning memory, an assessment of their own performance, and self-study. Regarding memory of the scenario, in the independent group 50% of the participants thought the pipeline swap scenario was most memorable in comparison to only 8% of the unsupervised group. In the 50% reporting the pipeline contamination as most memorable, all residents cited patient death as the reason for memorability. This was similar to unpublished historical data for our centre, where 52% of 72 previous residents thought the pipeline contamination was the most memorable scenario. In the one participant from the supervised group citing the pipeline scenario as most memorable, the reason for the memory was cited as 'confusion' and 'knowing I could not save the patient without help'.

Regarding critical assessment of their own performance, when asked if they would have figured out the source of the critical event in the initial exposure on their own in time to help the patient, none of the participants in the independent group said 'yes', two said they 'weren't sure', and 10 said 'no'. This was in contrast to the supervised group, in which five of the participants said 'yes', five said they 'weren't sure', and two said 'no'.

Regarding increased self-study after the scenario, when asked if extra reading occurred related to the outcome of their patient after the initial scenario, the independent group had seven participants (58%) reading more on the topic *vs* one participant (8%) in the supervised group.

All participants were given access to a staff psychologist who supports resident physicians in coping with stress and other psychological disorders. None of the participants sought counselling as a result of this study.

Table 1 Subject characteristics. Values are *n* (percentage) or mean (range)

	Independent group	Supervised group
Subjects	12	12
Age (yr)	29 (28–31)	28.5 (28–30)
Males	6 (50%)	9 (75%)
Resident yr 1	12 (100%)	12 (100%)
Previous simulation experience	9 (75%)	9 (75%)
Simulation exposure between phases	0 (0%)	0 (0%)

Table 2 Outcome measures for participant cohorts. Values are *n* (percentage) or mean (range). ANTS, Anaesthetists' Non-Technical Skills Checklist

	Independent group	Supervised group	*P*-value
Proper treatment provided	8/12 (67%)	2/12 (17%)	0.013
Phase 2 ANTS scores (total)	42.3 (31.5–53.1)	31.3 (21.6–41)	0.015
Phase 2 ANTS scores (task management)	11.7 (9.3–14.1)	10.4 (7.9–13.3)	0.67
Phase 2 ANTS scores (team working)	14.6 (11.5–17.7)	13.9 (10.1–17)	0.84
Phase 2 ANTS scores (situational awareness)	6.9 (4.8–9)	3.6 (2.4–4.8)	0.036
Phase 2 ANTS scores (decision making)	8.5 (7.3–10.5)	3.7 (1.3–6.1)	0.021
Time to proper treatment (if provided)	602 (490–820)	610 (420–800)	0.79

Discussion

Human simulation has become an important part of medical education and is a useful adjunct to traditional OR

Table 3 State–Trait Anxiety Index scores. Values are mean (SD)

	Independent group	Supervised group	*P*-value
Baseline (Trait portion)	35.2 (5.0)	33.7 (7.1)	0.56
After initial exposure (State portion)	54 (11.0)	43.9 (8.5)	0.019
After repeat exposure (State portion)	44.9 (5.5)	45.1 (12.3)	0.97

experiences.[27] Although considered to be a teaching technique that improves skills and increases retention of material,[28] to date few have investigated why simulation might be effective, with distinct advantages over the apprentice model. In the present study, we attempted to compare a simulation-based encounter of a rare and critical event with a similar encounter, had it occurred in the real OR (where patient harm could not be intentionally allowed). The difference in the two environments we sought to focus on was the level of supervision that occurred, allowing for patient mortality. We found that residents were more likely to manage a difficult simulation scenario effectively if their initial encounter occurred while practising independently and experiencing failure in the form of patient death.

The reasons why our experimental group showed improved performance 6 months after their initial encounter are likely to be multifactorial. In this study, we documented an increase in self-directed reading in the independent group, increased memorability of the scenario (possibly as a result of the impact of patient death), and potentially, more accurate self-reflection regarding the participants' abilities to manage a similar scenario independently. Given all of the variables involved, it is impossible to attribute the improvement directly to the simulated death, but there are several reasonable explanations for the improved performance in the group who experienced simulated death. In this group, the high stress responses prompted increased reading outside the simulator laboratory, which should improve future performance. Also, the stress levels in both groups were not significantly different in the follow-up simulation. The equivalent stress levels could be attributed to stress inoculation from the original simulated mortality and subsequent better performance on repeated exposure to mortality. Lastly, the subjects in the simulated mortality group did have the opportunity to participate directly in the original mortality; this could lead them to feel more empowered and engaged in the learning, which may improve future performance. While we recognize it as a limitation that this study could not tell which of these reasons explains exactly why exposure to simulated mortality improves future performance, we would argue that any of them would suffice because they all stem directly from experiencing the original simulated death.

Anecdotally, many physicians state that the most memorable patient experiences are the ones where something went wrong. It is critical that practitioners learn from their mistakes and use them as catalysts for self-directed learning and reflection to prevent potential future mistakes. The simulator laboratory is a unique place, where mistakes can be allowed deliberately, and subsequently, used to improve medical education. Poor patient outcomes could not be morally, ethically, or legally allowed to happen. In human simulation laboratories, the same constraints do not exist. Simulated morbidity and mortality can easily be recreated and specifically tailored to teach certain lessons without causing real patient harm. This is emphasized at the beginning of each simulation course we provide, and we believe that the safety and comfort in knowing that no patient was genuinely harmed makes the environment stressful without being unsafe, as some have argued.[29 30] We also believe this is one of the reasons why learning in the simulator laboratory can be considered potentially advantageous to traditional OR learning.

Intentionally exposing practitioners to bad outcomes has some implications that need to be investigated further. It could be argued that it is ethically immoral to put providers into these situations intentionally for the sake of learning. A justification for allowing such stressful experiences is that all practitioners will inevitably experience bad outcomes, and shielding them 'from this, simply defers the necessity for them to come to terms with this issue'.[31] Furthermore, psychological risk to the learner has yet to be elucidated as more than merely theoretical. In fact, some data have shown that learners do not mind experiencing simulated death and think their peers should be allowed to experience it.[32]

The present investigation has some limitations. First, as with many simulation studies, the sample size was small. Although there was statistical significance in major outcome measures, the limited number of participants could predispose to population bias. Also, there can be questions about generalizability, given that all residents were junior practitioners at the beginning of residency and there were no senior residents. It is important to note, however, that the literature demonstrates that even senior supervising anaesthetists do not always provide optimal care in the case of an oxygen pipeline contamination.[3 4]

Another possible limitation is that the positive results may have only been from exposure to repeated simulations and may not translate into improved patient outcomes in the OR. In order to reduce this possibility, we did seek to increase fidelity in the simulation laboratory as much as possible. The entire simulation occurred in a fully stocked mock operating room. Also, the pipeline contamination occurred after a completely different beginning during phase 2 compared with phase 1 in order to hide the experimental situation. If the positive results were merely attributed to repeated exposure and not to increased learning in one group, it would be expected that both groups would perform in a similar manner when re-exposed to the pipeline contamination, because both groups had similar scenarios in the past, at least inasmuch as they were simulation based. Also, we used only one scenario where failure occurred, and it is unclear whether similar memorability from failure would have occurred with a similarly stressful but more common intraoperative event (e.g. severe bronchospasm).

Although the groups were similar at baseline, it is impossible to control for contamination of the groups as far as knowledge base. We did not poll residents to find out whether they talked to each other before arrival about what to expect. There is a chance that certain residents came in expecting the pipeline contamination and only performed well because they researched what to do. If this were the case, one would expect both groups to perform better in phase 2. We did not observe this phenomenon.

We sought to determine whether allowing anaesthesia residents to practise independently, and ultimately, to cause

simulated morbidity or mortality, would improve long-term retention of material in comparison to a more accurate representation of the clinical environment (i.e. an available senior supervising anaesthetist). We found that allowing learners to fail and experience an adverse simulated patient outcome led to increased scenario memorability, and ultimately, better performance when re-exposed to a similar scenario. This is consistent with our hypothesis that permissive failure may be what fosters learning in the simulated arena compared with the real clinical arena. However, it may also be that simply managing a case independently is what led to these findings, irrespective of simulated patient outcome. While more research is certainly warranted, this investigation suggests that independent practice and poor patient outcomes safely engineered in the simulation laboratory may improve future performance and responses to rare and critical events.

Supplementary material

Supplementary material is available at *British Journal of Anaesthesia* online.

Authors' contributions

A.G., A.L., and S.D. contributed substantially to all aspects of the manuscript, including conception and design, acquisition, analysis, and interpretation of data, and drafting the article. E.S. contributed substantially to the study conception and design, interpretation of data, and drafting the article. S.S. contributed substantially to the acquisition of data and drafting the article. D.K. contributed substantially to the acquisition of data. H.M.L. contributed substantially to the analysis and interpretation of data and drafting the article.

Declaration of interest

None declared.

Funding

Icahn School of Medicine at Mount Sinai Hospital.

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Handling editor: P. S. Myles