Multidisciplinary operating room simulation-based team training to reduce treatment errors: a feasibility study in New Zealand hospitals

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ABSTRACT

AIMS: Communication failures in healthcare are frequent and linked to adverse events and treatment errors. Simulation-based team training has been proposed to address this. We aimed to explore the feasibility of a simulation-based course for all members of the operating room (OR) team, and to evaluate its effectiveness.

METHODS: Members of experienced OR teams were invited to participate in three simulated clinical events using an integrated surgical and anesthesia model. We collected information on costs, Behavioural Marker of Risk Index (BMRI) (a measure of team information sharing) and participants' educational gains.

RESULTS: We successfully recruited 20 full OR teams. Set up costs were NZ$50,000. Running costs per course were NZ$4,000, excluding staff. Most participants rated the course highly. BMRI improved significantly (P = 0.04) and thematic analysis identified educational gains for participants.

CONCLUSION: We demonstrated feasibility of multidisciplinary simulation-based training for surgeons, anesthetists, nurses and anaesthetic technicians. The course showed evidence of participant learning and we obtained useful information on cost. There is considerable potential to extend this type of team-based simulation to improve the performance of OR teams and increase safety for surgical patients.

Failures of teamwork are frequent in healthcare and may result in compromised patient care, inefficiency, and tensions among staff.[1-4] Salas et al[5] propose that three coordinating mechanisms are required for effective teamwork: mutual trust, closed-loop communication, and shared mental models (a shared understanding between members of the team of the situation, goals and plan). These shared mental models have been linked to improved team performance across many industries.[6] Two fundamental requirements for developing a shared mental model are effective communication and sharing of information between team members.[7] In healthcare, the use of checklists that promote the sharing of clinical information and construction of shared mental models has resulted in reduced surgical complications,[8-11] increased timely antibiotic administration,[12] and improved medical management.[13] Structured handovers also provide benefits that include fewer unexpected deaths[14] and adverse events.[15]

Simulation is increasingly used for teamwork training in healthcare. However, the primary target of these simulation-based initiatives is often a single professional discipline, which fails

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to fully address issues of communication between team-members from different disciplines. There are some published reports of multidisciplinary simulation-based team-training interventions for whole OR teams,[16-18] and such interventions have gained some traction in obstetrics[19,20] and emergency medicine.[21,22] However, whole OR simulation-based team training is not widely adopted. A recent review of multidisciplinary simulation-based team-training identified three common barriers: recruitment of participants; achievement of adequate fidelity; and cost.[16]

For voluntary educational initiatives, recruitment depends (among other things) on gaining the interest of all participants. For simulation-based education of OR teams, this requires simulations in which individuals from each discipline are engaged in meaningful and realistic activities. Some commercially available simulators are designed to engage anaesthetists,[23] while others are suitable for surgeons[24] but none combines the elements required to engage both at the same time, while also engaging theatre nurses and anaesthesia support staff.

This study is part of a wider body of work. Our ultimate goal is reducing treatment errors and improving patient safety through increasing our understanding of communication and teamwork in the OR and translating this into effective educational initiatives. The aim of this pilot study was to determine the feasibility and cost of developing and delivering a simulation-based course for surgical teams, and to evaluate its effectiveness.

Methods

This course is part of a wider research programme (Australia and New Zealand Clinical Trials Registry ID 12612001088831) to explore and improve teamwork and communication in the OR. We obtained approval from the Central Regional Ethics Committee, CEN/12/03/002.

Aims

We aimed to answer the following questions:

- Can we develop and run a simulation-based course for 20 general surgical OR teams?
- How much would such a course cost?
- Would the course be perceived by participants as a valuable learning experience?
- Would there be any evidence of learning by participants?

To do this we used a mixed methods approach.

A secondary objective was to obtain constructive feedback to guide further development of educational resources of this sort.

Course development and description

Research group

To ensure that our scenarios would be relevant to all disciplines we included representatives from surgery, anaesthesia, and nursing in the research group. This group, which included academics and clinical leaders from each disciplines, met monthly and contributed to each stage of course development and evaluation.

The participants

We designed our intervention for a complete, general surgical OR team, comprising six participants: a specialist surgeon, a surgical trainee (at any stage in their surgical training), a specialist anaesthetist or a senior trainee in their last year of training, two OR nurses and an anaesthetic technician. We recruited members of established OR teams from each of two large tertiary hospitals in Auckland (20 teams in total). On each course day, we aimed to recruit participants who regularly worked together.

Needs assessment

To ensure relevance of the course to participants, we conducted nine focus groups involving 45 participants (surgeons, anaesthetists, nurses, anaesthetic technicians) from the participating hospitals. We asked participants about their experiences of teamwork and communication in the OR.

A large proportion of the participants' comments were related to problems with communication (ie, explicitness and checking that communication is successful) and 'shared mental models'[5] (ie, getting everyone on the same page).[25]

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Course objectives

Based on the needs assessment, the overarching objectives of the course were to improve communication and information sharing among members of the OR team.

The setting

The course was based at the Simulation Centre for Patient Safety (SCPS), University of Auckland. We created a realistic OR environment using: real drug ampoules and fluids with sterile syringes, needles and fluid giving sets as found in the clinical environment; artificial blood presented in packaging and identifiers as provided by the blood bank; equipment such as rapid infusion devices, fluid warmers, anaesthetic machine and surgical instruments similar to those used in our participants' hospitals; patient clinical notes and investigations available online. We designed the simulations so that the participants worked together on the case without prompts or input from faculty, as they would do in their normal working environment. A faculty nurse was available in the simulation room to assist only when requested to do so by the participants, for example by helping them to locate equipment, take blood, confirming (or not) the presence of a rash. We used audiovisual equipment and StudioCode© v4.5.1 software (Studiocode Business Group, Sydney, Australia) for recording and reviewing scenarios, and Laerdal 3G SimMan (Stavanger, Norway) and METI® HPS™ (Sarasota, FL, USA) manikins.

Development of the scenarios

Scenarios were developed from real cases encountered by members of the research group, and included problematic incidents described in the focus groups. We aimed to provide challenges to participants from all of the participating disciplines.

Two scenarios involved acute abdominal pathology: appendicitis complicated by sepsis and subsequent allergic reaction; and a stab wound with lacerated inferior vena cava (IVC) complicated by cardiovascular collapse. The third scenario involved a traumatic leg amputation following an explosion, complicated by lung barotrauma.

To explore sharing of information among OR teams, when participants were briefed on the clinical scenario, they each were given a unique additional item of information about the patient that was clinically relevant and important, plausible for that member to have sole knowledge of, and should ideally be shared with all team members. Examples of these items were: the patient was carrying an asthma inhaler; patient recently on long-haul flight and had calf pain 24 hours ago; metronidazole charted in ED but not yet administered.

Surgical models

We commissioned a special effects company (Main Reactor, Auckland New Zealand) to work with three consultant surgeons to manufacture life-like surgical models that integrated with both the METI and 3G SimMan manikins. We wanted surgeons to be able to operate on the models using surgical instruments and, when appropriate, we wanted the models to bleed realistically.

The abdominal model had a replaceable skin that could be cleansed with chlorhexidine, incised and retracted. Within the abdominal cavity there were a molded aorta, kidneys and psoas muscles and models of small and large bowel with mesentery and omentum, and IVC. The base of the appendix, the caecum, the IVC, and the skin could all be sutured as necessary. The models could be connected to a blood pump to produce bleeding consistent with an IVC laceration or bleeding from the femoral vessels. Blood could be suctioned and the abdomen washed out (Figure 1).

Recruitment of participants

Teams of six participants were recruited using a first-come first-enrolled approach. On any one study day, we aimed to recruit participants from the same hospital, who could have previously worked together.

Recruiting 20 teams implied recruiting the majority of specialist general surgeons in each institution, but not the majority of the anaesthetists, nurses, or anaesthetic technicians.

Structure of the Course Day

Familiarisation

We began each day with a 30-minute familiarisation exercise to the equipment and environment.

Figure 1: Leg model attached to 3G SimMan (left); abdominal model on METI HPS showing retracted skin, intestines, moulded aorta, and lacerated IVC with blood being suctioned (middle), and a team engaging in the simulation (right).

Presentation

We provided an overview of the evidence on communication failures in the OR; outlined the basic elements of effective teamwork and explained two communication tools: closed-loop communication[5] and structured call-out.[26]

Briefing

We provided participants with individualised case briefing notes before each of the three scenarios. All participants received the same description of the basic clinical details for the case, as well as a unique item of clinically relevant information.

Scenarios

Each team of six participants attended for one full day and took part in all three scenarios, each of approximately 40 minutes duration. The first and third scenarios (abdominal cases) were presented in random order to account for order effects.

Debriefing

After each scenario, participants took part in a structured 40-minute debrief, facilitated by trained debriefers from the research group comprising a surgeon, anaesthetist, and nurse or anesthetic technician. The debrief clarified the events, explored mechanisms of and barriers to sharing information, sought examples from their clinical experience and looked for application to subsequent clinical practice.

Data collection and analysis

Participation

We recorded participant demographics and difficulties in recruiting specific team members for each course day.

Cost

We estimated costs from invoices for consumables, facility costs, the model makers, and the cost of goods donated by sponsors of the project.

Participant perceptions of value of the course

Participants completed a questionnaire about the realism of the simulation and the models after each scenario. This included provision for comments.

At the conclusion of the course, participants completed a course evaluation asking if they found the course enjoyable, if they found it a useful learning experience, if they would recommend the course to their colleagues, and if they would change their practice as a result of the course. They answered each question on a 5-point Likert scale from “Disagree strongly” to “Agree strongly”. Written comments were invited.

Behavioural Marker of Risk Index (BMRI)

Team communication was measured using a simple tool to score observable team behaviours that have been shown to be predictive of adverse events. The BMRI tool measures six domains of behaviour in three phases of surgery. The domains are: briefing, information sharing, inquiry, contingency management, assertion, and vigilance (Table 1). The three phases are induction, intraoperative, and handoff.[27] In this work, only induction and intraoperative periods were scored as the simulations ended before handoff.

Observers and training

Two trained observers (LS and MC) rated all the first and third scenarios of each course day. The training included an introduction to behavioural studies and the BMRI-tool as well as orientation to the OR environment, as recommended by Carthey.[28] To ensure standardisation of observations, a series of exercises were performed before the recordings, whereby video clips of surgical cases were rated by

Table 1: Items used in scoring BMRI. Note inter-sub-team information sharing was not in the original tool.

Item	Description
Briefing	Situation/relevant background shared; patient, procedure, site/side identified; plans are stated; questions asked; ongoing monitoring and communication encouraged
Information sharing	Information is shared; intentions are stated; mutual respect is evident; social conversations are appropriate
Inquiry	Asks for input and other relevant information
Contingency management	Relevant risks are identified; backup plans are made and executed
Assertion	The members of the team speak up with their observations and recommendations during critical times
Vigilance	Tasks are prioritised; attention is focused; patient/equipment Monitoring is maintained; tunnel vision is avoided; red flags are identified

the trainers and observers and any discrepancies were discussed until consensus was reached. This process was repeated and within-group inter-rater agreement (RWG) was calculated at each step until acceptable agreement (RWG >0.8) was reached.

Statistical analysis

BMRI scores were calculated following the method of Mazzocco et al.[27] First, scores for each of the domains (excluding contingency management and assertion, as these do not occur often) in each of the phases were converted from a 0–4 (never observed-observed frequently) scale to a binary score (ie, 0–2 were converted to 1 and 3–4 were converted to 0). Averages of the binary scores were taken to calculate the BMRI score. Note that, as BMRI is an index of risk, lower scores are considered better as they reflect more frequently observed behaviours.

Qualitative analysis of debriefs

We recorded and transcribed the debriefs for qualitative analysis. One investigator (DM) undertook formal thematic analysis of the transcriptions according to the methodology of Braun and Clarke.[29] DM read all the transcriptions and then generated preliminary codes. The coded segments were then collated into themes using a table that linked theme headings to representative quotes. DM then reviewed the themes and sub-themes for distinctiveness and coherence, which led to some being merged, some being divided into separate themes, and some being removed. A second investigator (JW) reviewed nine transcriptions to independently consider the themes present in the data. DM and JW then discussed themes and sub-themes until consensus was reached on a coding framework.

Results

A total of 20 teams (120 professionals comprising 20 surgeons and 20 surgical trainees, 20 anaesthetists, 20 anaesthetic technicians, and 40 nurses) participated in the study between 15 October 2012 and 1 July 2013. Two study days were rescheduled because of surgeon unavailability. We were unable to recruit the full complement of participants from the study hospital on three days, and filled the gaps with participants from other hospitals in the region. The majority of participants were female (62.5%), but this varied by role (Table 2). Participants' self-reported experience in the OR ranged from less than 6 months to over 21 years and also varied by role (Table 2).

Cost

The set-up cost for the models, including the blood pump was approximately NZD$50,000. The costs per day are presented in Table 3. This does not include faculty salaries because of variable funding and staffing arrangements.

Participants' perceptions of value of the course

In the questionnaires administered after each scenario, when asked if the simulations and models were realistic, over 80% of participants agreed or strongly agreed (Figure 2). Also, 87.7% agreed or strongly agreed that the simulation was as challenging as a real case of similar nature, and 93.6% agreed or strongly agreed that they behaved as they would in real

Table 2: Participant demographics

Role	Gender (% Female)	Experience in the role in Operating Room (%)					
		0–12 months	1–2 years	3–7 years	8–12 years	13–20 years	21+ years
Specialist surgeons (n=20)	20%	0	0	10	40	35	15
Trainee surgeons (n=20)	75%	15	15	35	20	0	0
Anaesthetists (n=20)	65%	0	0	25	30	25	20
Nurses (n=40)	80%	0	22.5	45	12.5	15	5
Anaesthetic technicians (n=20)	55%	0	5	35	40	10	10
Overall	62.5%	2.5	10.83	32.50	25.83	16.67	9.17

Table 3: Approximate costs of each course day (exclusive of simulator models)

Simulation centre hire (per day)	$1,500
Consumables invoiced by simulation centre (average per day)	$550
Consumables donated (estimate per day)	$1,600
Model consumables (average per day)	$350
Total cost per day	**$4,000**

procedures. In free text comments many noted that the model and scenario realism were generally very good.

Representative quotes were:

"The patient was very real and it felt like real scenarios" (nurse)

"Both the surgical models and scenarios were realistic and generated the appropriate stress response" (surgeon)

Participants indicated low blood viscosity, insufficient bleeding from lacerated IVC, and breath sounds that were difficult to interpret as limitations to the realism of the models. Limitations to the realism of the environment included: lack of clinical help; limited equipment; and differences from usual practice (eg, diathermy could not be used, the endotracheal tube needed lubrication with silicon and updated laboratory results had to be requested by telephone).

In the end-of-course questionnaire almost all participants agreed or strongly agreed (98.3%) that the course was a useful learning experience (Figure 3). All but one participant would recommend the course to colleagues and 89.2% of participants indicated they would change their practice as a result of the course.

Eighty-four participants wrote responses in a free text field on the end of course questionnaire. No participants indicated the course was unsatisfactory, and many participants suggested expanding the scope to other specialties and providing more regular courses as illustrated by the following quotes:

"Please keep doing these as a means of promoting education and awareness" (anaesthetic technician)

"…could make this a course for theatre staff to attend on a yearly basis" (anaesthetist)

"this course should be compulsory as part of annual update" (nurse) "every theatre staff should be encouraged to attend" (surgeon).

Evidence of participant learning

BMRI

There was no difference in BMRI between scenarios. There was a significant improvement in BMRI from the first to the

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Figure 2: Participant perceptions of the model and course realism

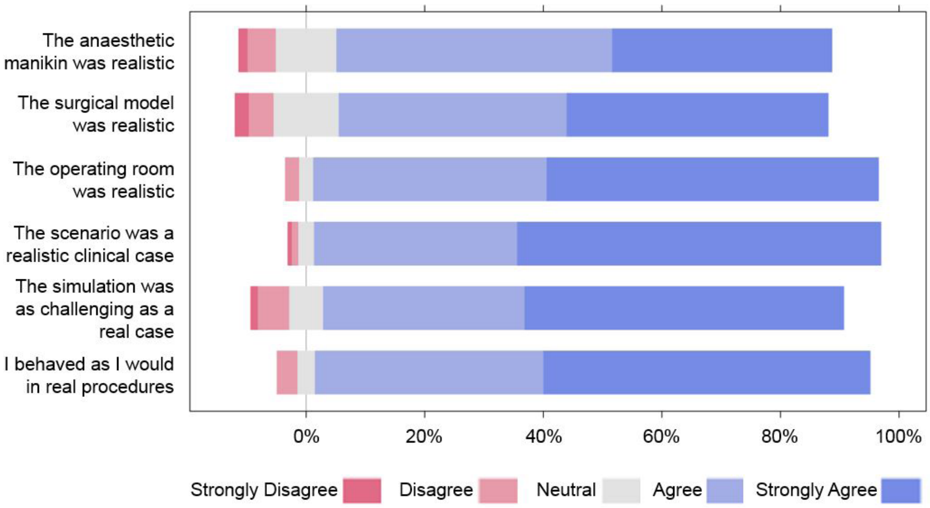

Figure 3: Participant responses to the end-of-day questionnaire.

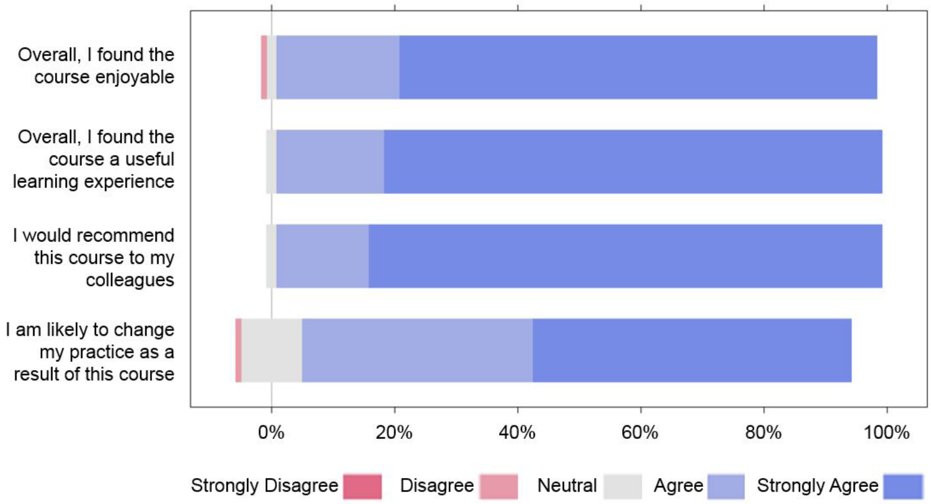

Figure 4: Boxplot of BMRI scores from the first to the third scenario

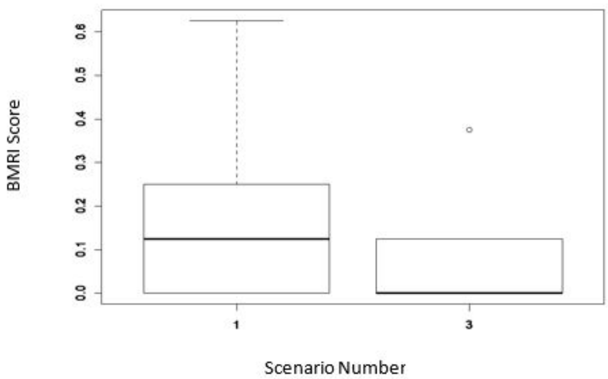

Table 4: Promoting a team orientation: illustrative participant quotes

Discouraging professional silos and hierarchies	*"Establishing the culture to actually have everybody contribute to the situation and not feel that there is a hierarchal situation where one's information is not necessarily relevant [is important]."* (ST) *"We all work in our own little areas …. anaesthetic, nursing, surgical, and we communicate very well within those little areas, and it is very important that we do the cross-pollination or cross-communication to make sure that we get that overview of the whole picture"* (SS)
Supporting team continuity	*"I've known [name] since I was a former medical student. So I feel like I could … pipe up with something a little bit more than I might with some of these brand new bosses that I've known for two weeks, and don't know how they might respond to me."* (ST)
Debriefing after complex cases	*"If there has been an absolute disaster, you know, a clinical disaster… some emotional support and emotional debrief is necessary in those circumstances."* (A)

SS=Specialist Surgeon, ST=Surgical Trainee, A=Anaesthetist

Table 5: Establishing a coordinated team: illustrative participant quotes

Clearly defining job roles	*"I think there's room for having even more defined roles in theatre like, you know, whose job it is to put the TED [thromboembolism-deterrent] stockings on."* (SS)
Use of team coordinators	*"As long as you all agree that what we need to do is a laparotomy, then getting the steps done to get to a point where you can incise the abdomen, doesn't have to be a surgical, or for that matter, anaesthetic, job. It's just an organisational job."* (A)

SS=Specialist Surgeon, A=Anaesthetist

last scenario (0.15 v 0.056; p=0.04; Figure 4). The domain that contributed the most to the improvement was briefing.

Qualitative analysis of debriefs

Analysis of the debrief transcripts identified the following three themes arising from the experiences of course participants: promoting a team orientation; establishing a coordinated team; and appreciation of the importance of information sharing.

Promoting a team orientation

Participants discussed the importance of setting aside professional boundaries to work towards a common goal. They suggested more stable team membership and debriefing after complex cases could promote team values of cooperation and mutual support (Table 4). Some comments were prompted by discovering that team members had different information about the simulated cases.

Establishing a coordinated team

Participants highlighted the importance of a team that functions well as a unit. They suggested this could be encouraged by clearly defining roles and establishing a team coordinator (Table 5).

Appreciation of the importance of information sharing

Many participants discussed the use of pauses in surgery as opportunities to share information, and included pre-operation team briefings, formal time-outs immediately before surgical incision, and 'call-outs' during critical events when the case became confusing or difficult to manage.

Participants suggested that all OR team members should contribute thoughts and opinions to help with patient management, and their recommendations included: putting hierarchy or anxiety aside to articulate uncertainty rather than continuing in silence; being assertive and explicit regardless of your position in the team; and inviting contributions from others. Closed-loop communication, avoiding acronyms, and using a whiteboard could help share information. Participants also identified directing communication by using people's names as important, which

Table 6: Appreciation of the importance of information sharing: illustrative participant quotes

Sharing information through briefings and prompted pauses	*"If the opportunity is there then it is great to have a briefing as a team beforehand, which may be possible in a trauma situation, you know if … you've got ten minutes before they're coming up to theatre."* (A) *"On induction [she] just went into severe bronchospasm …stating the obvious, like, we're not doing the surgery ...the anaesthetists everyone rolled their eyes as if that was obvious, but the nurses were like, Oh, okay good. We'll un-scrub and help then."* (SS)
Timing of timeouts	*"But in trauma, having [timeout] before the patient goes to sleep is quite good… You unmask a whole lot of things when you start giving a patient drugs and there isn't a lot of time to stop and think after that, you really have to have thought through your options before that."* (A) *"You can [have] time out once you get stability though, can't you - I think it's important about antibiotics, DVT and those other things being done."* (SS)
Articulating uncertainty	*"I got the impression during my anaesthetic training [that] to admit any uncertainty or indecision or let anyone else chip in, that was sort of a sign of weakness... and it's really nice to perhaps be given a template whereby you can maintain a leadership role whilst admitting uncertainty, indecisiveness, inviting input without… abdicating leadership."* (A)
Increasing assertiveness and explicitness	*"When you're a junior, or when you're a nurse, you should always remember that your opinion counts, because - you don't want to talk up - you might offend someone."* (A)
Inviting contributions	*"It's important to make sure that everybody in the room not only does share what they know but is made to feel like what they know is important. It doesn't matter if you're the porter or the scrub nurse, whoever you are in the room, that you are confident to share what you know."* (ST)
Avoiding acronyms and abbreviations	*"But then I realized... do people have different ideas of 'triples'? Cause my 'triples' is Amoxicillin, Gentamicin and Metronidazole… maybe I should have asked exactly what triples are."* (ST)
Directing communication to specific people	*"And it's not like, "Oh, someone get me this and someone get me that" it's "[Name] can you go and get this" and "[Name] can you go and get me that", so your name is said first, so you know that people are talking to you."* (N)
Establishing the right amount of communication	*"Too much noise is bad as too little information …we should have good default procedures so that you don't have to talk a lot …it should just be routine procedures."* (SS)

A=Anaesthetist, SS=Specialist Surgeon, ST = Surgical Trainee, N=Nurse

prompted discussions about knowing names. Participants also noted too much communicating during critical periods could potentially be distracting (Table 6).

Discussion

We succeeded in recruiting 20 full OR teams to a full-day simulation course. Almost all our participants from each of the disciplines found the simulations realistic. Participants rated the course highly in terms educational value and we showed evidence of learning by participants through a significant improvement in BMRI scores for communication and information sharing over the course of the day. In addition, the qualitative analysis of the debriefs following simulations suggested participants learnt about team orientation, team co-ordination, the importance of a sharing information between team members and strategies to achieve this.

Despite having senior clinical leaders on the project team, recruitment was not always easy. This could partly be ascribed to our strict protocol for participant eligibility and numbers and more flexibility might facilitate recruitment. This course was free to participants, which may have influenced attendance. The course was outside any organisational or continuing professional development requirements. Embedding such courses in organisational structures could be required for widespread implementation.

While participants generally considered the simulations to be of sufficient realism to engage, they did identify some limitations to the realism. These may be overcome by better familiarisation and framing of expectations, conducting more frequent simulations, or conducting the scenarios in-situ at the participants' usual place of work.

While development costs were considerable, ongoing costs of NZD$4,000 per day (plus staff time) are in line with other established simulation-based courses in our institution. At a minimum we estimate it would require two instructors and two simulation technicians to run this course but there is scope to increase the number of participants per course. This study was funded through grants and product donations from industry. Funding ongoing training may require innovative solutions working with quality and safety committees, colleges, district health boards and medical insurance organisations. For example an insurance-driven funding model has been piloted by the Harvard Surgical Safety Collaborative.[18]

We have shown that all but two of the 120 participants agreed that the course was a valuable learning experience. The scale of the improvement in BMRI scores would, according to Mazzocco,[27] translate to a 16% reduction in adverse events (from an odds ratio of 1.24 to 1.04). The potential for cost-savings would more than justify the costs of the course. Furthermore, our analysis of the debriefs showed insightful reflections on information sharing amongst team members. Participants recognised instances where information was not shared, identified barriers to such information sharing, and discussed strategies to improve information sharing in clinical practice.

We think the strengths of the course were: establishing a multidisciplinary research team; undertaking a preliminary needs assessment; reasonably realistic surgical models which could engage surgeons in technical tasks; building in challenges for all members of the team; creating a highly realistic simulation environment; and finally, minimal faculty input during the scenarios ensured communication was almost exclusively within the team of participants. There are a number of limitations in this study. We report only experiences on the course day, and do not evaluate retention of learning or transfer of learning to clinical practice. In future work we plan to explore the impact of the course on participants' knowledge and attitudes over time, and on their subsequent clinical practice.

There is potential for bias in our participants, who were all volunteers, and results may not reflect other groups of participants. The course was run at a purpose-built simulation centre and potential to run similar courses in situ will be the focus of future work.

Conclusions

We demonstrated feasibility of multidisciplinary simulation-based training for surgeons, anesthetists, nurses and anaesthetic technicians. The course was rated highly by participants, we showed evidence of participant learning and improved BMRI scores. There is considerable potential to extend this type of team-based simulation to improve the performance of OR teams and increase safety for surgical patients.

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