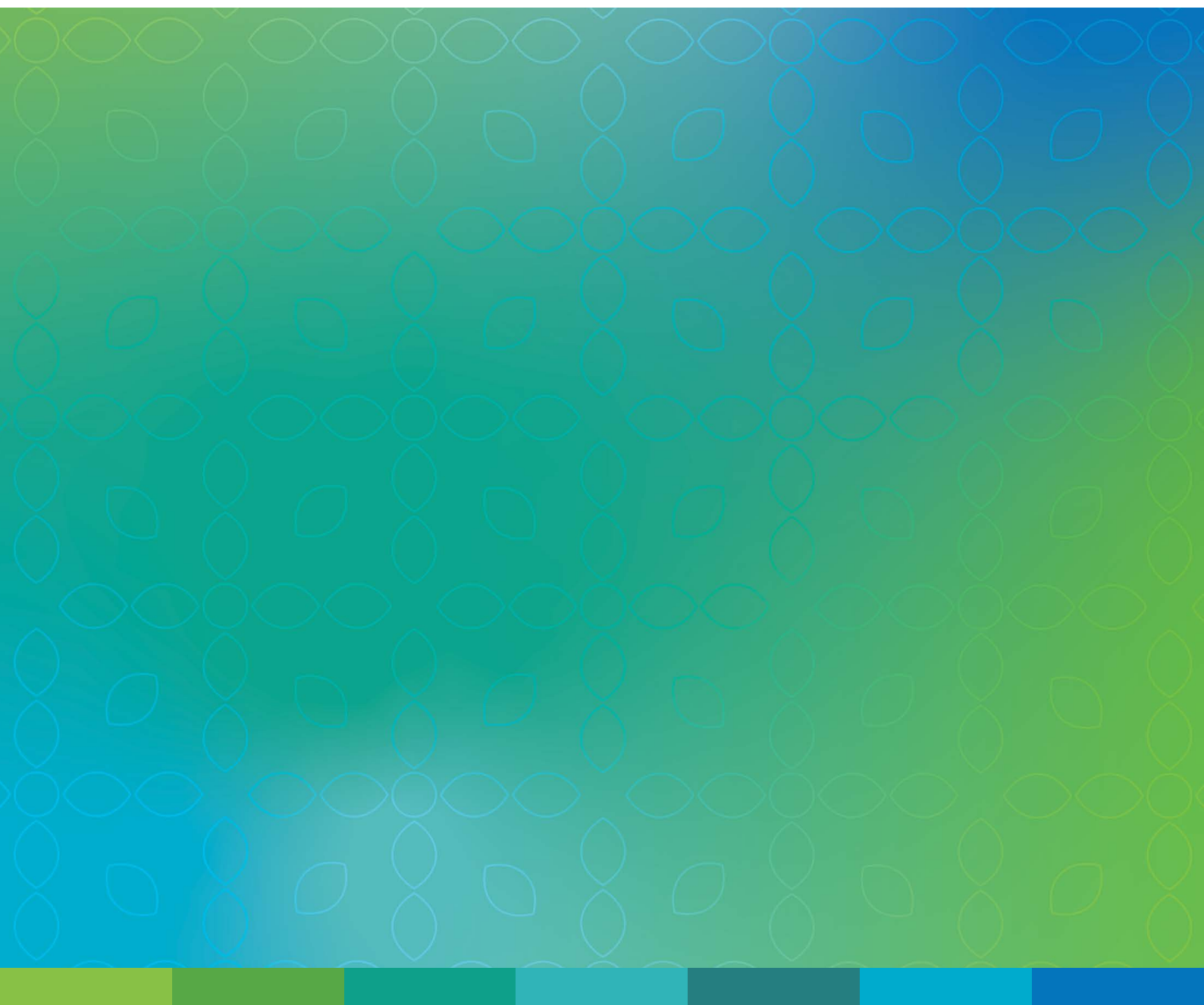




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Still more to do to improve perioperative safety and prevent patient harm

Above all else, the *raison d'être* of the perioperative nurse is to maintain surgical asepsis and patient safety. However, despite all current efforts, there is still an unacceptably high number of our patients experiencing preventable adverse events. A recent systematic review found that 20 per cent of surgical patients are harmed during their hospital stay, with 50 per cent of these harms judged as wholly preventable¹. This equates to approximately 200 000 Australian patients suffering injury or death each year because of unsafe and poor-quality surgical care.

The latest Australian Institute of Health and Welfare report draws attention to the epidemic of adverse events associated with surgery². The report highlights Australia's inferior performance on key performance indicators compared to other member countries of the Organisation for Economic Co-operation and Development (OECD). For example, our incidence of unintentionally retained surgical items is 63 per cent higher, deep venous thrombosis following hip and knee surgery is 86 per cent higher and post-operative pulmonary embolism is more than double (211 per cent higher).

One of the most significant preventable adverse events related to the quality of our perioperative care is surgical site infections (SSIs). In Australia, 3.6 per cent of patients experience an SSI, accounting for over one-quarter of all hospital-acquired infections (HAIs)³. These infections are associated with significant adverse post-operative outcomes for the patient, family and health service. They lead to extended hospital stays, higher readmission rates and increased health care costs, not to mention the emotional, physical and financial burden to patients⁴.

The most egregious preventable adverse events are called 'sentinel' events in Australia and 'never' events in many other countries. Sentinel events are a subset of adverse events that are 1) wholly preventable, 2) independent of a patient's overall health condition and 3) result in serious patient harm or death. Sentinel events indicate deficiencies in hospital systems and processes that represent compromised quality of care and patient safety. You will see that many of the listed sentinel events are related to perioperative care in acknowledgment of the high volume, high-risk environment.

Historically, states and territories interpreted and reported these events differently, requiring caution when interpreting the data (see Table 1). In 2019, the Sentinel Events Review Steering Committee was convened to revise the list and standardise reporting. The revised list (see box) contains ten events: five are as previously listed, three replace 'procedures involving the wrong patient or body part', and two are new, were not previously listed – 'use of physical or mechanical restraint resulting in serious harm or death' and 'use of an incorrectly positioned oro- or nasogastric tube resulting in serious harm or death'. Two events

Table 1: Australian sentinel event data 2015 to 2019

Selected sentinel event	2015	2016	2017	2018	2019
Procedures involving the wrong patient or body part resulting in death or major permanent loss of function	1	5	1	1	1
Suicide of a patient in an inpatient unit	30	28	20	24	17
Retained instruments or other material after surgery requiring re-operation or further surgical procedure	35	26	23	28	28
Intravascular gas embolism resulting in death or neurological damage	5	4	3	3	1
Haemolytic blood transfusion reaction resulting from ABO (blood group) incompatibility	1	2	0	2	0
Medication error leading to the death of a patient reasonably believed to be due to incorrect administration of drugs	14	7	10	16	12
Maternal death associated with pregnancy, birth or the puerperium	9	9	7	2	6
Infant discharged to the wrong family	0	0	0	1	0
Total	101	82	65	80	65

Revised sentinel event list 2020

1. Surgery or other invasive procedure performed on the wrong site resulting in serious harm or death
2. Surgery or other invasive procedure performed on the wrong patient resulting in serious harm or death
3. Wrong surgical or other invasive procedure performed on a patient resulting in serious harm or death
4. Unintended retention of a foreign object in a patient after surgery or other invasive procedure resulting in serious harm or death
5. Haemolytic blood transfusion reaction resulting from ABO incompatibility resulting in serious harm or death
6. Suspected suicide of a patient in an acute psychiatric unit or acute psychiatric ward
7. Medication error resulting in serious harm or death
8. Use of physical or mechanical restraint resulting in serious harm or death
9. Discharge or release of an infant or child to an unauthorised person
10. Use of an incorrectly positioned oro- or nasogastric tube resulting in serious harm or death

previously listed are not included in the revised list – ‘maternal death associated with pregnancy, birth or the puerperium’ and ‘intravascular gas embolism resulting in death or neurological damage’.

Many perioperative nurses have heard the saying, ‘the standard you walk past is the standard you accept’. This saying eloquently sums up the challenge of overcoming normalised deviance. Normalisation of deviance is a phenomenon where individuals and teams deviate from what is known to be an acceptable standard until the adopted way of practice becomes normalised (Figure 1). The Chernobyl nuclear accident and the NASA Challenger and Columbia Space Shuttle disasters are two infamous examples where incremental deviation from acceptable practice resulted in total catastrophe. In the perioperative environment, normalised deviance eventually leads to serious adverse events.

The safety of our patients is a collective responsibility that requires us to work together to create a safe

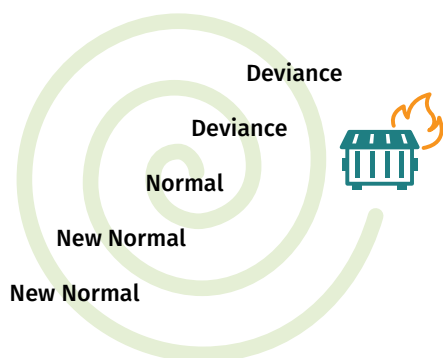


Figure 1: Development of normalised deviance

environment. Two programs that have frequently been used in other countries to promote teamwork and safety culture are TeamSTEPPS⁵ and CUSP⁶.

TeamSTEPPS (Team Strategies and Tools to Enhance Performance and Patient Safety)

TeamSTEPPS⁵ is an evidence-based program aimed at optimising performance among health care teams, enabling them to respond quickly and effectively to whatever situations arise. It was developed in the USA by the Agency for Healthcare

Research and Quality and the Department of Defense to improve collaboration and communication. The TeamSTEPPS program addresses four teachable–learnable skills: communication, leadership, situation monitoring and mutual support. TeamSTEPPS is freely available online, including individual modules related to the perioperative setting.

CUSP (Comprehensive Unit-based Safety Program)

The Comprehensive Unit-based Safety Program (CUSP)⁶ is a method that can help clinical teams make care safer by combining improved teamwork, clinical best practices and the science of safety. The Core CUSP toolkit gives clinical teams the training resources and tools to apply the CUSP method and build their capacity to address safety issues. A perioperative-specific toolkit is freely available online to help clinical teams adopt the CUSP method to make care safer. The toolkit is modular, and each module includes teaching materials, resources to support change, facilitator notes, presentation slides, tools and videos.

I encourage you to explore these and other similar programs to improve

teamwork and perioperative safety and welcome you to share your experiences with your colleagues here in the *Journal of Perioperative Nursing*.

References

1. Panagioti M, Khan K, Keers RN, Abuzour A, Phipps D, Kontopantelis E et al. Prevalence, severity, and nature of preventable patient harm across medical care settings: Systematic review and meta-analysis. *BMJ* 2019;366:l4185.
2. Australian Institute of Health and Welfare (AIHW). Australia's hospitals at a glance 2017–18. Canberra: AIHW; 2019.
3. Russo PL, Stewardson AJ, Cheng AC, Bucknall T, Mitchell BG. The prevalence of healthcare associated infections among adult inpatients at nineteen large Australian acute-care public hospitals: A point prevalence survey. *Antimicrobial Resistance & Infection Control* 2019;8(1):114.
4. Brown B, Tanner J, Padley W. 'This wound has spoilt everything': Emotional capital and the experience of surgical site infections. *Sociology of health & illness* 2014;36(8):1171–1187.
5. Agency for Healthcare Research and Quality (AHRQ). TeamSTEPPS [Internet]. Rockville, MD; 2014 [updated 2020 January; cited 2021 May 24]. Available from www.ahrq.gov/teamstepps/index.html.
6. Agency for Healthcare Research and Quality (AHRQ). CUSP Method [Internet]. Rockville, MD; 2012 [updated 2019 August; cited 2021 May 24]. Available from <https://www.ahrq.gov/hai/cusp/index.html>.

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Multidisciplinary simulation training for perioperative teams: An integrative review

Abstract

Background

The perioperative environment is a high-risk and complex area and the provision of safe, high-quality surgical care requires a multifaceted approach provided by multidisciplinary health care teams. However, it is reported that the multidisciplinary nature of perioperative teams can present barriers to patient safety through ineffective teamwork, ineffective collaboration and/or ineffective communication. Multidisciplinary simulation training creates realistic situations in safe environments to allow perioperative teams to improve teamwork and communication alongside the technical skills needed to manage emergency situations. This integrative review critically examines and reports the effects of multidisciplinary simulation training on perioperative teams and highlights the actual and potential advantages and disadvantages of such training.

Method

A structured integrative literature review process was undertaken yielding 14 key articles that were critically appraised and examined for emergent 'themes'.

Results

Multidisciplinary simulation training improved communication, teamwork, teamwork behaviours and teamwork attitudes between multidisciplinary perioperative team members. Overall, improvements in communication and teamwork correlated with improvements in perioperative patient safety. Despite the numerous benefits of multidisciplinary simulation training there are notable barriers to the implementation of such training programs. Multidisciplinary simulation training can be costly to set up and time consuming to facilitate. However, overall increases in patient safety offset the cost of simulation training and time-based barriers can be reduced by running simulation training in conjunction with existing education programs.

Conclusion

Multidisciplinary simulation training improved communication and teamwork among perioperative teams and this method of training is recommended overall within perioperative units. However, there were notable gaps within the literature, and further research involving multidisciplinary perioperative teams within Australian perioperative units should be conducted to gain a greater insight into the presence of multidisciplinary simulation training and the effects of such training.

Keywords: simulation training, multidisciplinary, interprofessional, interdisciplinary, perioperative, operating room, theatre

Introduction

Perioperative services are an essential part of health care, providing optimal health outcomes for patients through surgical and diagnostic procedures^{1,2}. Perioperative care can be a high-risk and complex process and the provision of safe, high-quality surgical care requires a multifaceted approach provided by multidisciplinary health care teams^{3–5}. Multidisciplinary perioperative teams consist of nurses, surgeons, anaesthetists and, depending on patient needs, may involve other health care professionals^{3,6,7}. During all stages of perioperative care, multidisciplinary teams are expected to work interdependently and collaboratively to meet the needs of the patient³. However, the multidisciplinary nature of perioperative teams can present specific barriers to patient safety – mainly through ineffective teamwork, collaboration and/or communication⁸. In perioperative emergency situations ineffective teamwork, collaboration and communication increases the likelihood of adverse health outcomes for the perioperative patient^{9,10}. Multidisciplinary simulation training has been identified as a method of training which can improve teamwork and communication within perioperative teams^{4,11}. The origins of simulation training can be traced back to the aviation industry, for the same reasons that it has been adopted in health care, and it is interesting to note that anaesthetists were the early adopters of this method of training^{12,13}. Simulated scenarios, often based on perioperative emergencies, are widely needed to allow the multidisciplinary perioperative team to learn, practice and improve the technical and non-technical skill required to manage perioperative emergencies¹⁴. With this in mind, the aim of this paper is to explore the

effectiveness of simulation training for multidisciplinary perioperative teams and identify potential gaps in practice through undertaking an integrative review of the research literature examining multidisciplinary simulation training in the perioperative setting.

Background

Multidisciplinary teams

Multidisciplinary perioperative teams consist of professionals from multiple disciplines such as surgeons, anaesthetists, anaesthetic technicians, theatre technicians and nurses^{3,6}. Unfortunately, the multidisciplinary nature of perioperative teams can present barriers to safe patient care, as a result of disciplinary ‘silos’, hierarchy and professional rivalries^{4,7,15}. These barriers are confounded by differences in clinical expertise, individual experiences and differing priorities for care⁹. Additionally, individual team members are continually changing due to rostering and transient workforces^{6,9}. All of these factors combined reduce team effectiveness and perioperative patient safety⁹.

Multidisciplinary simulation training

Multidisciplinary simulation training is a teaching technique whereby scenarios are created to represent realistic clinical situations to allow professionals to practice, learn, test or evaluate human actions, physical systems and processes⁶. Simulated scenarios are developed from relatively uncommon emergency events allowing perioperative teams to learn how to manage these events without causing harm to patients^{4,14,16,17}. Simulation training may occur within the environment in which the perioperative team would normally work or be conducted

in dedicated simulation centres¹⁸. However, for learning to be effective the environment in which simulation training takes place needs to reflect the clinical environment to provide participants with realistic and dynamic feedback^{19–21}.

Non-technical and technical skills

Perioperative care requires the use of both non-technical and technical skills to facilitate safe patient care, and failures in either have been associated with sentinel events within health care¹¹. Non-technical skills encompass interpersonal and cognitive aspects such as teamwork, collaboration, situational awareness, decision-making, problem-solving, task management, leadership and communication^{7,10,17,22,23}. Technical skills relate to the physical motor skills required to perform specific clinical tasks, for example, performing a surgical procedure or inserting an endotracheal tube^{12,17}. Technical skills also refer to the clinical knowledge needed to perform specific tasks related to patient care^{12,17}. Simulation training provides a platform in which technical skills rarely used in clinical practice can be practiced without causing patient harm^{12,17}.

Teamwork and communication are the non-technical skills focused on predominantly during multidisciplinary simulation training²¹. Effective communication within perioperative multidisciplinary teams is essential for collaboration, task management, leadership and teamwork^{10,15,24,25}. Social dynamics, heightened emotions in stressful situations and unclear messages all cause ineffective communication within multidisciplinary perioperative teams^{7,26}. This can be confounded by differences in communication training between the different disciplines within health care^{10,27}. Teamwork requires multidisciplinary

perioperative team members to work dynamically, interdependently and collaboratively while undertaking specific roles to achieve shared goals^{7,22,28}. All non-technical skills are interrelated, and inadequate levels of non-technical skills within multidisciplinary perioperative teams pose a significant risk to patient safety^{1, 11}.

Methods

Integrative review

A systematic process was used to conduct a detailed search of databases to identify current research literature related to perioperative simulation training. The review was integrative in that it drew upon, compared and contrasted both qualitative and quantitative studies (no mixed method studies were reported) to provide insight into multidisciplinary simulation training through the identification, summary and critique of themes^{29,30}.

Databases

To conduct a critical appraisal of the literature, a systematic search of the following electronic databases was conducted^{30–32}. Databases were searched with a linear approach beginning with PubMed, EBSCOhost and lastly Ovid. EBSCOhost was used to search CINAHL, Academic Search Ultimate, Australian/New Zealand Reference Centre Plus, Health Source: Nursing/Academic Edition, Medline and Medline Complete. Ovid was used to search UTAS Journal@Ovid, Joanna Briggs Institute EBP Database, Embase, Ovid Emcare and Ovid Medline all.

Key terms

To ensure a focused search of the literature, key terms were drawn from the research topic using the University of Tasmania’s

Table 1: Concept table

Group One		Group Two		Group Three
simulation training	AND	multidisciplinary	AND	peri*operative
		OR		OR
		interdisciplinary		operating room
		OR		OR
		interprofessional		theatre

concept table template. The key terms ‘simulation training’, ‘multidisciplinary’, ‘interprofessional’, ‘interdisciplinary’, ‘perioperative’, ‘operating room’ and ‘theatre’ were divided into three groups (Table 1). The asterisk truncation symbol was applied to retrieve all variables of the key term ‘perioperative’³⁰. Additionally, the following Medical Subject Headings (MeSH) terms were exploded and combined with major concepts within PubMed and Ovid³⁰. ‘Interdisciplinary studies’, ‘simulation training’ and ‘operating rooms’ MeSH terms were exploded and combined with major concepts within PubMed. ‘Simulation training’, ‘high fidelity simulation training’, ‘patient simulation’ and ‘operating room’ were selected as MeSH terms

and major concepts within Ovid and exploded. Key terms and MeSH terms were combined within group one, two and three with the Boolean operator OR, and each group were combined with the Boolean operator AND³².

Inclusion and exclusion criteria

Inclusion and exclusion criteria (Table 2) were set to focus the search strategy, producing literature closely aligned to the key terms^{30,32}. Articles were accepted if they included simulation-based training for multidisciplinary perioperative teams consisting of nurses, anaesthetists, surgeons and/or students from any of those disciplines. The location of simulation training could occur

Table 2: Inclusion criteria

Inclusion criteria	Exclusion criteria
Simulation-based team training	Simulation training conducted in emergency departments and intensive care units
Multidisciplinary team members from anaesthetic, surgical and perioperative nursing professions	Simulation training involving animal models, virtual reality and actors
Simulation-based training facilitated in situ or off-site	Abstracts
Full-text articles	Literature, narrative and integrative reviews
Articles publish after 2010	Historical papers
Articles written in English	Editorials
Primary research articles	

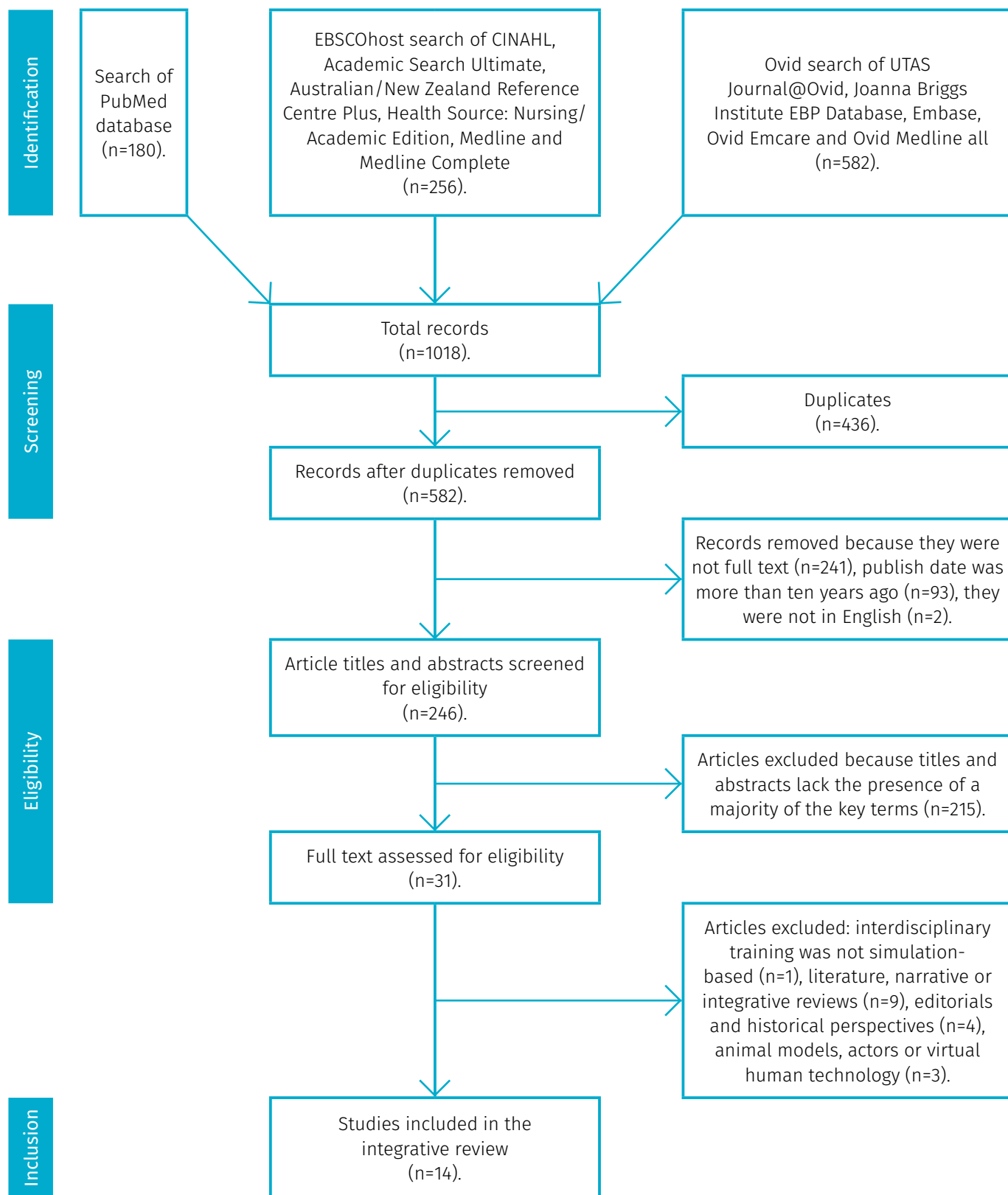


Figure 1: PRISMA flow diagram

in situ or be conducted off-site provided the training location emulated the perioperative setting. Articles were included if they were less than ten years old, were full text, written in English and primary research. Articles were excluded if they were abstracts only, literature, narrative and integrative reviews or were historical papers and editorials. Articles were excluded if simulation training involved animal models, virtual simulation or used actors as members of the multidisciplinary team.

Results

The search results are presented in a PRISMA flow diagram (Figure 1). A total of 1018 records were obtained and reduced to 582 when duplicate studies were removed. A further 241 records were removed because they were not full text, 93 records removed because they were older than ten years and two records removed because they were not in English. The titles and the abstracts of the remaining 246 records were assessed to ensure the papers included some measure of multidisciplinary simulation training within the perioperative setting. A further 215 records were excluded, and the remaining 31 articles read in full. One article was excluded because the interdisciplinary training was not simulation-based and nine articles were excluded because they were literature, narrative or integrative reviews. Four articles were excluded because they were editorials and historical perspectives and a further three articles excluded because they involved animal models, actors or virtual human technology.

Critical analysis

Quality appraisal

To enhance the quality of this integrative review, the 14

studies chosen were assessed for quality, trustworthiness and relevance^{31–33}. The JBI Checklist for quasi-experimental studies (non-randomised experimental studies)³⁴ was applied to the non-randomised quantitative and mixed-method studies (see supplemental material). The Joanna Briggs Institute (JBI) Checklist for qualitative research³⁵ was applied to qualitative studies (see supplemental material). To calculate the percentage for the 14 chosen studies, each question within the relevant JBI checklist^{34,35} was assigned a score of one. Scores were totalled, divided by the number of questions in each tool and multiplied by 100 to calculate the percentage. Studies were considered to be of an appropriate quality if they scored 70 per cent or greater using the JBI checklists.

Theme identification

Critical analysis of the 14 primary studies required the identification of recurring and important themes and subthemes. Themes and subthemes were identified through an iterative approach involving reading and re-reading the primary studies, identifying themes and subthemes and determining the frequency with which these

themes and subthemes appeared in the primary studies Checklist for quasi-experimental studies (non-randomised experimental studies)³⁶. The final list of recurrent and repetitive themes and subthemes are identified in Table 3. Each theme and subtheme are expanded on in the discussion to examine the effect of multidisciplinary simulation training on perioperative teams.

Discussion

Critical analysis of the studies included in this review identified five themes: communication, teamwork, simulation fidelity, clinical change and barriers to program implementation.

Communication

Effective communication between multidisciplinary perioperative team members during emergency events is vital for safe perioperative patient care^{9,25,37}. Breakdowns in communication can be driven by professional hierarchies and lack of assertiveness, and is confounded by fatigue, interruptions and stressful high-risk situations⁹. Weller³⁸ identified that too much noise in the operating theatre also has a negative impact during

Table 3: Themes and subthemes

Themes	Subthemes
Communication	Debriefing
	Hierarchy and assertiveness
Teamwork	Non-technical skills
Simulation fidelity	In situ simulation vs off-site simulation
	Fidelity
Clinical change	Patient safety
Barriers to program implementation	Cost
	Time

emergency events. The disruptive effect of noise was also present in simulation training as Sørensen³⁹ identified that talking and laughing during simulation training reduced effective learning. Excessive noise needs to be reduced in perioperative environments as it distracts focus away from critical tasks and prevents effective communication between multidisciplinary perioperative team members^{38,40,41}.

Overall communication between multidisciplinary perioperative team members increased following simulation training^{38,39,42–45}. Furthermore, after undertaking multidisciplinary simulation training, perioperative teams were able to identify specific strategies for improving communication during emergency events^{38,44,45}. These strategies included using a whiteboard, avoiding acronyms and using common language to improve communication during an emergency^{38,44,45}. Additionally, closed loop communication was identified as an effective communication strategy^{38,44–46}. Closed loop communication creates a shared mental model through a process of information sharing, understanding and timely feedback³⁷. Effective communication leads to effective teamwork as it enhances leadership and task management. All of which are important non-technical skills required by multidisciplinary perioperative teams to manage emergency events.

An additional strategy for improving communication between multidisciplinary perioperative teams was direct communication^{38,45}. Direct communication involves using names to communicate directly with individual team members^{38,45}. The Surgical Safety Checklist⁴⁷ requires perioperative team member's roles and names to be identified prior to the start of surgery.

However, multidisciplinary teams members may change throughout the surgical case and face masks reduce the ability to recognise team members^{48–50}. Furthermore, only 30 per cent of names are recalled after team members are initially introduced^{48,49}. Briefings at the beginning of the day have been identified as a method of increasing name recall⁴⁵. Despite the issues just noted, simulation training is identified as an ideal way to 'get to know' the team members within the multidisciplinary team^{39,45,50}. Multidisciplinary perioperative team members also highlighted their appreciation for the opportunity to work in set teams during simulation training as it increased familiarity between team members and would therefore make direct communication easier⁵⁰. Effective communication leads to effective teamwork as it enhances leadership and task management. These are important non-technical skills required by multidisciplinary perioperative teams to manage emergency events.

Debriefing

An important forum for communication following multidisciplinary simulation training is debriefing after the simulation^{7,11,12}. If multidisciplinary perioperative teams are to meet learning objectives through simulation training they must reflect on their experience and test their understanding of knowledge gained⁵¹. This process is undertaken during debriefing and leads to a higher level of retention of key learning objectives through reflection, analysis, discussion and feedback^{7,11,51}. Multidisciplinary perioperative teams identified debriefing as the most positive and important part of learning following simulation training^{39,52}. Debriefing facilitated identification of patient care issues and reinforced

learning gained during simulation training, resulting in the transfer of new knowledge to the clinical setting^{39,53}. Debriefing also provided multidisciplinary team members with the opportunity to destress following simulation training^{51,52,54}.

Given the multiple functions of debriefing it is imperative that debriefing is facilitated by trained and experience staff^{51,55}. Properly facilitated debriefing sessions enable simulation participants to feel comfortable with being open and honest⁵³. Furthermore, Shapiro⁴⁶ emphasised the need for debriefing to be facilitated by staff who are aware of accreditation requirements as they used simulation training to ensure their office-based plastic surgery clinic met accreditation standards. This highlights the potential for multidisciplinary simulation training to be used to implement organisational changes to meet national standards and guidelines. However, accessing appropriately trained debriefing staff can be difficult and costly, presenting a potential barrier to the implementation of multidisciplinary simulation training^{38,52}.

Hierarchies and assertiveness

Traditional hierarchies within perioperative teams prevent open communication and have negative impacts on patient outcomes^{14,56}. Multidisciplinary team members identified the need to improve communication and teamwork and reduce hierarchies within the perioperative environment⁴⁵. Comments made after the simulation, showed simulation training gave perioperative team members more confidence to 'speak up'^{44,45, 53}. Interestingly, nurses and anaesthetists were more likely to identify the need to speak up than surgeons, demonstrating the existence of traditional hierarchies

within perioperative units^{53,57}. Although simulation training enabled multidisciplinary perioperative team members to feel more able to 'speak up', simulation training has not provided strategies for reducing professional hierarchies. In fact, reversing hierarchies by placing junior medical staff in leadership roles during simulation training has a negative impact on the experience of multidisciplinary simulation training³⁹. Involving students who may pursue a career in the perioperative field has been identified as a potential way of reducing professional hierarchies^{43,55}.

Teamwork

Non-technical skills

Effective teamwork among multidisciplinary perioperative teams requires individuals to work dynamically, interdependently and collaboratively while undertaking specific roles to achieve shared goals^{7,22,28}. Overall, there were improvements in teamwork, teamwork behaviours and teamwork attitudes following multidisciplinary simulation training of perioperative teams^{42,50,55,58-60}.

A range of rating systems were used to measure improvements in teamwork. Rating systems such as Behavioural Marker Risk Index (BMRI), Non-Technical Skills II (NOTECHS II), Non-Technical Skills for Surgeons (NOTSS) and Anaesthetist's Non-Technical Skills (ANTS) were used within the literature^{38,42,50,58}. Each rating system indicated improvements in teamwork by assessing non-technical skills such as leadership, management, problem solving, teamwork, cooperation, decision making, situational awareness and task management^{50,58}. Further to this, information sharing, briefing, contingency management, inquiry, assertion, inter-disciplinary information sharing and vigilance

are assessed in the BMRI rating system^{38,42}.

Rochlen⁵⁰ demonstrated overall improvements in NOTECHS II following simulation training. There were also improvements in NOTSS, ANTS and BMRI scores^{38,42,58}. Rochlen⁵⁰ found leadership and management improved the most following multidisciplinary simulation training, and proposed that this occurred due to the focus on communication during the debriefing process. Interestingly, communication and information sharing were identified as the individual components of the BMRI score which improved significantly as a result of simulation training³⁸. Further to this, debriefing was pivotal for multidisciplinary perioperative team members to identify the importance of information sharing³⁸. It is apparent that improvements in teamwork overall are dependent on improvements in non-technical skills^{38,42,50,58}. This demonstrates that non-technical skills are closely interrelated – communication and teamwork are not individual factors – and for perioperative teams to engage in effective teamwork they need to become proficient in a range of non-technical skills.

Effective teamwork between multidisciplinary perioperative team members requires individual disciplines to cooperate, work interdependently and collaboratively^{7,22,28}. This is evident by improvements in NOTSS scores which correlated with improvements in ANTS score but only when the scenarios were related to surgical complications⁵⁸. When the scenario was based on a difficult airway there were improvements in ANTS scores only⁵⁸. The surgeons did not contribute as much to this scenario demonstrating that simulation training needs to be appropriate to participant roles for learning to be effective^{39,50}. However, only one

surgical speciality was represented, and further research would be needed to assess if different surgical specialities demonstrate increases in NOTSS during a difficult airway scenario⁵⁸. Additionally, NOTSS and ANTS scores are representative of only two disciplines which make up a perioperative team. Further research would be required to examine if lessons learnt during simulation training involving one or two disciplines would transfer to the perioperative team as a whole.

Traditionally, multidisciplinary simulation training has not been taught at an undergraduate level, and it has been assumed that medical and nursing students will develop competence in communication and teamwork without formal training⁶¹. Unfortunately, this leads to the development of professional 'silos' and differences in communication training which creates ineffective communication between multidisciplinary team members^{7,10,27}. Multidisciplinary simulation training is an effective method of instilling consistent and optimal teamwork behaviours and attitudes in perioperative undergraduate students, interns and registrars^{43,52,55,60}. Instilling teamwork earlier in the careers of these students reduces professional hierarchies, increases collaboration between multidisciplinary teams and improves the overall culture thus fostering better communication and teamwork within multidisciplinary perioperative teams^{43,52,55,60}.

Simulation fidelity

Simulation training uses scenarios based on real clinical situations to allow multidisciplinary perioperative teams to practice and improve the non-technical and technical skills required to manage emergency situations without causing patient harm¹⁶.

Fidelity

The fidelity of a simulated scenario refers to the realism of a scenario, that is, the degree to which the simulated scenario correctly represents clinical events²⁰.

Simulation fidelity is identified as an important aspect of multidisciplinary simulation training to gain active engagement from perioperative teams^{45,46,50}. Greater engagement and 'buy in' from multidisciplinary teams occur once the perioperative team members determine that the scenarios are realistic and reflective of their clinical experiences^{45,46,50}.

There are several factors which influence the fidelity of simulated scenarios. Although, Shapiro⁴⁶, Rochlen⁵⁰ and Long⁴⁵ highlight the impact functional and psychological fidelity have on perioperative team members engagement with simulation training, physical fidelity is also important. Sørensen³⁹ found if perioperative team members wore their normal uniforms and full-scale mannequins or actors were used as patients, simulation fidelity was increased. However, some efforts at creating realistic situations during simulation training can be detrimental. Multidisciplinary team members found lists of telephone numbers to be disruptive and negatively impacted on the simulation experience³⁹. Maintaining traditional roles during simulation training was also deemed important for simulation fidelity³⁹; however, this could be problematic when challenging traditional hierarchies while undertaking simulation-based training, especially if traditional hierarchies are tied to traditional roles.

In situ vs off-site simulation

A further aspect of fidelity for simulation training is the physical setting in which a simulated

scenario takes place. Simulation training can be in situ simulation (ISS), which is facilitated within the perioperative unit in which the multidisciplinary teams work, or off-site simulation (OSS), which is in dedicated simulation centres^{18,21}. Conducting simulation training within the perioperative unit in which multidisciplinary team members work is believed to increase the authenticity and fidelity of the simulation training^{39,45,46,50}. In a study conducted by Sørensen³⁹, multidisciplinary perioperative team members believed ISS training would increase fidelity, therefore resulting in increased participant engagement. However, other factors became more important in relation to simulation participants' 'buy in', for example, multidisciplinary team members deemed authentic roles and realistic teamwork to be more important than simulation location. Improvements in teamwork, communication and safety climate within the multidisciplinary perioperative teams did not differ between ISS and OSS even though ISS was seen to be more authentic and realistic than OSS⁵⁹.

Conducting ISS training provides the opportunity for perioperative teams to identify latent safety threats within their clinical settings and identify changes which need to be made within organisations^{45,46,59}. Shapiro⁴⁶ used simulation training within their office-based plastic surgery clinic to not only improve the non-technical and technical skills of the staff but also test system issues within the office-based surgery. Furthermore, Shapiro⁴⁶ used simulation training to ensure their office-based plastic surgery practice complied with the accreditation standards for office-based practices within the United States.

Organisational changes can also be identified through simulation training. Slightly more organisational changes

were identified by multidisciplinary perioperative team members undertaking ISS than those who undertook OSS training⁵⁹. However, perioperative team members undertaking OSS found the location of training provided other unique learning opportunities³⁹. Their ability to adapt was challenged during OSS and adaptation during emergency events was seen as an important skill to possess. Furthermore, participants found that they were able to examine their routines from 'the outside' giving them a new perspective on their practices. Despite this advantage, perioperative team members identified being unfamiliar with the simulation environment as a drawback. Their focus shifted from improving essential non-technical skills to physical activities, such as searching for drugs and equipment, which they did not consider to be a priority or effective for learning³⁹.

Clinical change

Patient safety

Safe perioperative patient care is closely associated with effective communication and teamwork^{15,62,63}. Hinde⁶⁰ was able to show an improvement in safety climate following multidisciplinary simulation training due to improved teamwork, but stated that it was difficult to demonstrate a correlation between effective teamwork and improved safety culture and improved patient outcomes⁶⁰. This is contrary to the findings presented by Weller³⁸ and Weller⁴² who reported that an improvement in BMRI scores of 20 per cent correlated with a 14–16 per cent decrease in the likelihood of adverse events in the post-operative surgical patient^{38,42}. Doumouras⁵⁸ demonstrated that effective non-technical skills reduced the time to crisis resolution during surgical and anaesthetic emergencies.

This highlights the importance for multidisciplinary perioperative teams to undertake simulation training to increase perioperative patient safety.

Patient safety can be further improved through multidisciplinary simulation training as multidisciplinary teams test organisational systems, identify latent safety threats and test clinical practices⁶⁴. Following simulation training, Shapiro et al.⁴⁶ increased their multidisciplinary staff members' awareness of safety issues and identified processes which needed to be changed to increase patient safety⁴⁶. Similar results were demonstrated by Sørensen³⁹ and Sørensen⁵⁹ who reported that multidisciplinary perioperative team members were able to identify changes which needed to be made within their organisation to improve patient safety^{39,59}.

Barriers to program implementation

Cost

The development and implementation of simulation-based training programs can be costly²⁵. Reported costs within the literature include \$50 000 NZD for models and further costs of \$4000 NZD a day excluding staff wages paid during simulation training³⁸. Paige⁴³ estimated their costs to be \$9400 USD in total for the simulation session but they concede their cost estimates are low. Lost operating time, instructor training and instructor fees are not included in the estimates⁴³. Given the substantial costs of simulation training, improvements in teamwork, communication and patient safety, such as those reported by Weller³⁸ and Weller⁴², need to be demonstrated to gain support and funding from senior management and health care organisations^{38,42,44,45}.

This provides evidence of improved patient outcomes which correlates with decreased health care costs, which can be used to gain support and possible funding from senior management and/or alternative funding sources^{38,43–45}.

Time

A further barrier to implementing multidisciplinary simulation training is lack of time for facilitators to set up and run simulation training, and the lack of time to dedicate an entire operating theatre to simulation training⁴⁵. Study participants reported they lacked the required time to set up simulation equipment and course material⁴⁵. Furthermore, finding time between busy lists to set aside an operating theatre, resourcing facilitators and getting all team members together is challenging^{44,45}. Wongsirimeetee⁵² provided the schedule for simulation training months in advance to ensure they could secure nonclinical time for staff to participate in multidisciplinary simulation training. In contrast, Rochlen⁵⁰ designed their simulation training so that it could be conducted within one hour, making it easier to fit in with pre-existing weekly education and having minimal impact on operating times within the theatres. Integrating the multidisciplinary simulation training within existing education programs provides a way of negating the time-based barriers to implementation^{45,50}.

Further research

Despite the impact negative hierarchies can have on the effective functioning of multidisciplinary perioperative teams, hierarchies are not discussed in detail within the literature and neither is assertiveness. Furthermore, the ability for lessons learnt to be transferred to the perioperative team as a whole when one or two disciplines undertook simulation

training should be explored further. The largest gap in the literature, is the absence of Australian studies examining multidisciplinary simulation training for perioperative teams. It is unclear if simulation training is conducted regularly in Australian perioperative units and if there are positive or negative impacts on perioperative patient care. Further research involving multidisciplinary perioperative teams from Australian perioperative units should be conducted to gain a greater insight into multidisciplinary simulation training and the effects of such training before recommendations for practice changes can be made.

Conclusion and recommendations

Multidisciplinary simulation training undertaken by perioperative teams led to improvements in technical skills, non-technical skills and recognition of organisational changes, all of which improved perioperative patient safety. Individual non-technical skills such as communication were improved and techniques to improve communication were identified. Likewise, teamwork was also improved following simulation training. A high level of simulation fidelity is important for perioperative team members to engage in multidisciplinary simulation training and, initially, ISS was thought to be more beneficial than OSS training. However, clinical and organisational changes were identified in both settings. Despite the numerous benefits of multidisciplinary simulation training, barriers to the implementation of such training programs exist. Multidisciplinary simulation training is costly to set up and time-consuming to conduct.

There were gaps identified within in the literature following this

integrative review. Professional hierarchies and the lack of assertiveness within perioperative teams were not discussed in detail. There is also a lack of guidance on the frequency of simulation training and types of scenarios which should be used during simulation training. Lastly, none of the 14 primary studies used in this integrative review involve research conducted in Australia.

The perioperative environment is a dynamic and high-risk environment and requires multidisciplinary perioperative teams to engage in effective teamwork and communication. Although costly and time-consuming, simulation training improves both technical and non-technical skills within multidisciplinary perioperative teams increasing effective teamwork, communication and collaboration, and therefore improving perioperative patient safety. However, further research is required to discern the effects of multidisciplinary simulation training on Australian perioperative teams before further recommendations for clinical practice change can be made in the Australian context.

References

- World Health Organization (WHO). Patient safety [Internet]. Geneva: WHO; 2020 [cited 2020 September 28]. Available from: www.who.int/patientsafety/safesurgery/en/.
- Sutherland-Fraser S, Osborne S, Bryant K. Perioperative nursing. In: Hamlin L, Davies M, Richardson-Tench M, Sutherland-Fraser S, editors. *Perioperative Nursing: An Introductory Text*. Sydney: Elsevier; 2016, pp. 1–29.
- Gillespie BM, Davies M. The perioperative team and interdisciplinary collaboration. In: Hamlin L, Davies M, Richardson-Tench M, Sutherland-Fraser S, editors. *Perioperative Nursing: An Introductory Text*. Sydney: Elsevier; 2016, pp. 30–46.
- Wang R, Shi N, Bai J, Zheng Y, Zhao Y. Implementation and evaluation of an interprofessional simulation-based education program for undergraduate nursing students in operating room nursing education: A randomized controlled trial. *BMC Med Educ* 2015;15:115.
- Ozawa E, Mahboobi S. Teamwork in the operating room. In: Paige J, Sonesh S, Garbee D, Bananno L, editors. *Comprehensive Health Care Simulation: Interprofessional Team Training And Simulation*. Cham, Switzerland: Springer Nature Switzerland AG; 2020, pp. 249–260.
- Palaganas JC, Epps C, Raemer DB. A history of simulation-enhanced interprofessional education. *J Interprof Care* 2014;28(2):110–115.
- Komasawa N, Berg BW. Interprofessional simulation training for perioperative management team development and patient safety. *J Perioper Pract* 2016;26(11):250–253.
- Jowsey T, Beaver P, Long J, Civil I, Garden AL, Henderson K et al. Towards a safer culture: Implementing multidisciplinary simulation-based team training in New Zealand operating theatres – a framework analysis. *BMJ Open* 2019;9(10):e027122.
- Teunissen C, Burrell B, Maskill V. Effective surgical teams: An integrative literature review. *West J Nurs Res* 2020;42(1):61–75.
- Stephens T, Hunningher A, Mills H, Freeth D. An interprofessional training course in crises and human factors for perioperative teams. *J Interprof Care* 2016;30(5):685–688.
- Tan SB, Pena G, Altree M, Maddern GJ. Multidisciplinary team simulation for the operating theatre: A review of the literature. *ANZ J Surg*. 2014;84(7–8):515–522.
- Krage R, Erwtman M. State-of-the-art usage of simulation in anesthesia: Skills and teamwork. *Curr Opin Anaesthesiol* 2015;28(6):727–734.
- Zhang C, Thompson S, Miller C. A review of simulation-based interprofessional education. *Clin Simul Nurs* 2011;7(4):e117–e126.
- Coyle M, Martin D, McCutcheon K. Interprofessional simulation training in difficult airway management: A narrative review. *Br J Nurs* 2020;29(1):36–43.
- Weller J, Long JA, Beaver P, Cumin D, Frampton C, Garden AL et al. Evaluation of the effect of multidisciplinary simulation-based team training on patients, staff and organisations: Protocol for a stepped-wedge cluster-mixed methods study of a national, insurer-funded initiative for surgical teams in New Zealand public hospitals. *BMJ Open* 2020;10(2):e032997.
- Cain CL, Riess ML, Gettrust L, Novalija J. Malignant hyperthermia crisis: Optimizing patient outcomes through simulation and interdisciplinary collaboration. *AORN J* 2014;99(2):301–308.
- Myatra S, Kalkundre R, Divatia J. Optimizing education in difficult airway management: Meeting the challenge. *Curr Opin Anaesthesiol* 2017;30(6):748–754.
- Posner GD, Clark ML, Grant VJ. Simulation in the clinical setting: Towards a standard lexicon. *Adv Sim* 2017;2(1):1–5.
- Singh D, Kojima T, Gurnaney H, Deutsch ES. Do fellows and faculty share the same perception of simulation fidelity? A pilot study. *Simul Healthc* 2020(4):266.
- Sathya Kumar R, Steven M, Salman N, Jørgen E, Per H. Impact of simulation fidelity on student self-efficacy and perceived skill development in maritime training. *TransNav: International Journal on Marine Navigation and Safety of Sea Transportation*. 2019;13(3):663–669.
- Armenia S, Thangamathesvaran L, Caine AD, King N, Kunac A, Merchant AM. The role of high-fidelity team-based simulation in acute care settings: A systematic review. *Surgery* 2018;4(3):e136–e151.
- Masiello I. Why simulation-based team training has not been used effectively and what can be done about it. *Adv Health Sci Educ Theory Pract* 2012;17(2):279–288.
- Kasana R, Tachawan J, Pavinee S. Correlation of medical knowledge and non-technical skills assessment in anesthesia residents. *Siriraj Med J* 2020;72(6):483–487.
- Henderson A. *Communication for health care practice*. Victoria: Oxford University Press; 2019.
- Brunges M, Hughes TE. Using virtual human technology in perioperative team training simulations. *AORN J* 2020;111(6):617–626.
- Altabbaa G, Kaba A, Beran TN. Moving on from structured communication to collaboration: A communication schema for interprofessional teams. *J Healthc Commun* 2019;12(3/4):160–169.
- Foronda C, MacWilliams B, McArthur E. Interprofessional communication in health care: An integrative review. *Nurse Educ Pract* 2016;19:36–40.
- Peavey E, Cai H. A systems framework for understanding the environment's relation to clinical teamwork: A systematic literature review of empirical studies. *Environ Behav* 2020;52(7):726–760.
- Noble H, Smith J. Reviewing the literature: Choosing a review design. *Evid Based Nurs* 2018;21(2):39–41.
- Whitehead D. Critically searching and reviewing the literature. In: Whitehead D, Ferguson C, L'obiondo-Wood G, Haber J, editors. *Nursing and Midwifery Research Methods for Appraisal for Evidence-based Practice* 6th ed. Chatswood: Elsevier; 2020. pp. 55–80.
- Bowling A. *Research methods in health: Investigating health and health services*. Maidenhead: Open University Press; 2014.
- Gerrish K, Lathlean J. *The research process in nursing*. Chichester: John Wiley & Sons Inc.; 2015.

33. Joanna Briggs Institute. Critical appraisal tools. Adelaide: Joanna Briggs Institute; 2020.
34. Joanna Briggs Institute. Checklist for quasi-experimental studies (non-randomised experimental studies). Adelaide: Joanna Briggs Institute; 2020.
35. Joanna Briggs Institute. Checklist for qualitative research. Adelaide: Joanna Briggs Institute; 2020.
36. Neville S, Whitehead D. Analysing data in qualitative research. In: Whitehead D, Ferguson C, LoBiondo-Wood G, Haber J, editors. *Nursing and Midwifery Research Methods for Appraisal for Evidence-based Practice* 6th ed. Chatswood: Elsevier; 2020. pp. 136–155.
37. Diaz MCG, Dawson K. Impact of simulation-based closed-loop communication training on medical errors in a pediatric emergency department. *Am J Med Qual* 2020 Dec;35(6):474–478.
38. Weller J, Cumin D, Torrie J, Boyd M, Civil ID, Madell D et al. Multidisciplinary operating room simulation-based team training to reduce treatment errors: A feasibility study in New Zealand hospitals. *NZ Med J* 2015;128(1418):40–51.
39. Sørensen JL, Navne LE, Emdal HM, Ottesen B, Albrechtsen CK, Pedersen BW et al. Clarifying the learning experiences of health care professionals with in situ and off-site simulation-based medical education: A qualitative study. *BMJ Open* 2015;5(10):e008345.
40. Mohammed HME-HS, Badawy SSI, Hussien AIH, Gorgy AAF. Assessment of noise pollution and its effect on patients undergoing surgeries under regional anesthesia, is it time to incorporate noise monitoring to anesthesia monitors: An observational cohort study. *Ain-Shams J Anesthesiol* 2020;12(1):1–9.
41. Smith P, Gibbs J. 'Below ten thousand': An effective behavioural noise reduction strategy? *JPN* 2016;29(3):29–32.
42. Weller J, Cumin D, Civil ID, Torrie J, Garden A, MacCormick A et al. Improved scores for observed teamwork in the clinical environment following a multidisciplinary operating room simulation intervention. *NZ Med J* 2016;129(1439):59–67.
43. Paige JT, Garbee DD, Kozmenko V, Yu Q, Kozmenko L, Yang T et al. Getting a head start: High-fidelity, simulation-based operating room team training of interprofessional students. *J Am Coll Surg* 2014;218(1):140–149.
44. Weller J, Civil I, Torrie J, Cumin D, Garden A, Corter A et al. Can team training make surgery safer? Lessons for national implementation of a simulation-based programme. *NZ Med J* 2016;129(1443):917.
45. Long JA, Jowsey T, Henderson KM, Merry AF, Weller JM. Sustaining multidisciplinary team training in New Zealand hospitals: A qualitative study of a national simulation-based initiative. *NZ Med J* 2020;133(1516):1021.
46. Shapiro FE, Pawlowski JB, Rosenberg NM, Xiaoxia L, Feinstein DM, Urman RD. The use of in-situ simulation to improve safety in the plastic surgery office: A feasibility study. *ePlasty* 2014;14:620.
47. World Health Organization (WHO). WHO Surgical Safety Checklist Implementation [Internet]. Geneva: WHO;2020 [cited 2020 September 28]. Available from: www.who.int/patientsafety/safesurgery/checklist_implementation/en/.
48. Gorman S, Cox T, Hart RS, Marais L, Wallis S, Ryan J et al. Who's who? Championing the '#TheatreCapChallenge'. *J Perioper Pract* 2019;29(6):16671.
49. Burton ZA, Guerreiro F, Turner M, Hackett R. Mad as a hatter? Evaluating doctors' recall of names in theatres and attitudes towards adopting #theatrechallenge. *Br J Anaesth* 2018;121(4):9846.
50. Rochlen LR, Malloy KM, Chang H, Kim S, Guichard L, Cassidy R et al. Pilot one-hour multidisciplinary team training simulation intervention in the operating room improves team nontechnical skills. *J Educ Perioper Med* 2019;21(2):e624.
51. Kim Y-J, Yoo J-H. The utilization of debriefing for simulation in health care: A literature review. *Nurse Educ Pract* 2020 Feb;43.
52. Wongsirimeteekul P, Mai CL, Petrusa E, Minehart R, Hemingway M, Pian-Smith M et al. Identifying and managing intraoperative arrhythmia: A multidisciplinary operating room team simulation case. *MedEdPORTAL* 2018 Feb;14:10688.
53. Arriaga AF, Gawande AA, Raemer DB, Jones DB, Smink DS, Weinstock P et al. Pilot testing of a model for insurer-driven, large-scale multicenter simulation training for operating room teams. *Ann Surg* 2014;259(3):40310.
54. Tosterud R, Kjølberg K, Kongshaug AV, Haugom JV. Exploration of two different structures for debriefing in simulation: The influence of the structure on the facilitator role. *Simul Gaming* 2020;51(2):24357.
55. Leithead J, Garbee DD, Yu Q, Rusnak VV, Kiselow VJ, Zhu L et al. Examining interprofessional learning perceptions among students in a simulation-based operating room team training experience. *J Interprof Care* 2019;33(1):2631.
56. Bould MD, Sutherland S, Sydor DT, Naik V, Friedman Z. Residents' reluctance to challenge negative hierarchy in the operating room: A qualitative study. *Can J Anaes* 2015;62(6):57686.
57. Broom J, Broom A. Fear and hierarchy: Critical influences on antibiotic decision-making in the operating theatre. *J Hosp Infect* 2017;99(2):1246.
58. Doumouras AG, Hamidi M, Lung K, Tarola CL, Tsao MW, Scott JW et al. Non-technical skills of surgeons and anaesthetists in simulated operating theatre crises. *Br J Surg* 2017;104(8):102836.
59. Sørensen JL, van der Vleuten C, Rosthøj S, Østergaard D, LeBlanc V, Johansen M et al. Simulation-based multiprofessional obstetric anaesthesia training conducted in situ versus off-site leads to similar individual and team outcomes: A randomised educational trial. *BMJ Open* 2015;5(10):e008344.
60. Hinde T, Gale T, Anderson I, Roberts M, Sice P. A study to assess the influence of interprofessional point of care simulation training on safety culture in the operating theatre environment of a university teaching hospital. *J Interprof Care* 2016;30(2):2513.
61. Murphy M, Curtis K, McCloughen A. What is the impact of multidisciplinary team simulation training on team performance and efficiency of patient care? An integrative review. *AENJ* 2016;19(1):4453.
62. Cumin D, Boyd MJ, Webster CS, Weller JM. A systematic review of simulation for multidisciplinary team training in operating rooms. *Simul Healthc* 2013;8(3):1719.
63. Rydenfält C, Borell J, Erlingsdottir G. What do doctors mean when they talk about teamwork? Possible implications for interprofessional care. *J Interprof Care* 2019;33(6):71423.
64. Lie SA, Wong LT, Chee M, Chong SY. Process-oriented in situ simulation is a valuable tool to rapidly ensure operating room preparedness for COVID-19 outbreak. *Simul Healthc* 2020;15(4):22533.

Multidisciplinary simulation training for perioperative teams: An integrative review

Supplemental material: Summary of study findings

Author, date, title, country	Participants	Outcome measures / method	Reliability / validity of measures	Findings/conclusions	Limitations
Arriaga et al. (2014) ¹ , Pilot testing of a model for insurer-driven, large-scale multicentre simulation training for operating room teams, USA	n = 221	Participant perceptions; realism of the scenario, quality of debriefing and scenario relevance to clinical practice. Post-test survey questions scored on a five-point Likert scale and one free-text open-ended question.	Not specified	Participant evaluation of simulation scenarios and debriefing: 94% found simulation to be realistic 95% found the simulation challenging 95% found the simulation appropriate for their level of training 98.2% of participants felt they could be open and honest during debriefing 98.1% of participants strongly agreed debriefing was of high quality 96.3% of participants will use lessons learnt from simulation training in clinical practice 92.6% felt simulation training would improve patient safety Free text question leading results: improved personal communication and assertiveness.	Unclear if the intervention will demonstrate changes in practice or improved patient outcomes.
Paige et al. (2014) ² , Getting a head start: high-fidelity, simulation-based operating room team training of interprofessional students, USA	n = 66	Feasibility and effectiveness of high-fidelity simulation training for interprofessional operating room students. Pre- and post-training questionnaires including 15-item Likert-type questions. Observers evaluated teams using Operating Room Teamwork Assessment Scales (ORTAS). Open-ended questions analysed using Miles and Huberman qualitative methods.	Paired t-test with Bonferroni adjustment. One-way ANOVA.	Statistically significant increases of $p < 0.001$ were found in 11 of the 15 items compared between scenarios one and two. Observer-rated performance scores showed statistically significant increases from scenarios one and two for all three comparisons $p < 0.001$. Observer-rated role scores showed statistically significant increases between scenarios one and two $p < 0.001$ and $p = 0.001$. Team-based behaviour scores were statistically significant for comparison between observer and participants $p = 0.039$. Themes identified: simulation-based training benefits, debriefing impact, enhanced communication and scenario realism. Themes identified: least beneficial aspects of simulation-based training, lack of time and feeling unprepared.	Small sample size. Multisource ratings were based on roles rather than individual performance. Three scenarios had more participants from one discipline.
Shapiro et al (2014) ³ , The use of in-situ simulation to improve safety in the plastic surgery office: A feasibility study, USA	n = 16	In situ simulation used to assess the ability to manage medical emergencies and increase awareness of safety issues. AHRQ Medical Office Survey on Patient Safety administered before and after simulation training. Debriefing with open-ended questions in follow up survey.	McNemar or Stuart-Maxwell test performed. Fisher's exact test. Statistical tests 2-sided with type 1 error of 0.05. $p < 0.05$ considered statistically significant	Statistical significance was found in three of the 18 categories in the abbreviated AHRQ Medical Office Survey. Debriefing identified crisis resource management principles and system-based issues. Follow-up surveys identified five improvements: BLS/ALS algorithms to be reviewed, algorithms to be placed in the operating room, code cart to be regularly reviewed, simulation exercises to be repeated, team communication to be practiced regularly.	No limitations identified by authors.

Author, date, title, country	Participants	Outcome measures / method	Reliability / validity of measures	Findings/conclusions	Limitations
Sørensen et al. (2015) ⁴ , Clarifying the learning experiences of healthcare professionals with in situ and off-site simulation-based medical education: a qualitative study, Denmark	n = 25	Influence of setting on the experiences of learning for health care professionals undertaking simulation training. Focus group discussion.	Transcripts coded by two moderators. Principle researcher interpreted the data, three authors validated the data.	Theme 1: The value participants put on in situ simulation training being a priority for their learning decreased during the course of the study. Theme 2: Participants involved in off-site simulation training felt that it challenged them to adapt to changes. Theme 3: Participants felt realistic roles were more important than location. Theme 4: Positive and negative factors were not related to location. Theme 5: Regardless of location, teamwork skills, communication and interprofessional communication improved due to simulation training. Theme 6: Organisational changes were suggested after simulation training at both in situ and off-site simulation training.	Participants were known to each other which may have affected the accuracy of results. Heterogeneity of groups may have influenced results. Composition of focus groups may not have represented clinical working groups.
Sørensen et al. (2015) ⁵ , Simulation-based multiprofessional obstetric anaesthesia training conducted in situ versus off-site leads to similar individual and team outcomes: A randomised educational trial, Denmark	n = 100	Examine the effect of in situ simulations (ISS) versus off-site simulation (OSS) on team performance, participants perceptions of simulation, organisational impact, stress, patient safety attitude, motivation and knowledge. 40-item multiple-choice question (MCO). 33-item Safety Attitudes Questionnaire (SAQ). Salivary cortisol levels and Stress-Trait Anxiety Inventory (STAI) and cognitive appraisal (CA). 22-item Intrinsic Motivation Inventory (IMI). Evaluation questionnaire. Team Emergency Assessment Measure (TEAM). Open ended questions and debriefing and evaluation.	95% confidence interval calculated with generalised estimating equations. Kruskal-Wallis rank-sum test. P values adjusted using the Benjamini-Hochberg method. Mean outcomes compared with linear ANCOVA model and inferences based on GEE. Linear mixed methods models. Two-sided p values < 0.05 considered significant.	MCO: no statistical difference between ISS and OSS. SAQ: no statistical difference between ISS and OSS. Salivary Cortisol, STAI and CA: mean change from baseline to the peak was similar in both ISS and OSS for both scenarios. IMI: no statistically significant difference found between ISS and OSS. Evaluation questionnaire: no difference between ISS and OSS for 20 questions. Two questions on the fidelity and authenticity were scored higher for ISS than OSS. TEAM: no statistical difference was found between ISS and OSS. Organisational outcomes: more ideas for organisational change were identified by ISS participants. ISS and OSS groups scored equally concerning simulations inspiring participants to make changes to guidelines and practices.	No follow-up testing of team performance or knowledge or long-term retention. Teams had previous simulation experience.

Author, date, title, country	Participants	Outcome measures / method	Reliability / validity of measures	Findings/conclusions	Limitations
Weller et al. (2015) ⁶ , Multidisciplinary operating room simulation-based team training to reduce treatment errors: A feasibility study in New Zealand hospitals, New Zealand	n = 120	Primary objective: development and running of a simulation course, calculating course costs, perceived learning experience by participants, is there evidence of learning. Secondary objective: obtain feedback to guide future development of similar education resources. Post-course evaluation using a 5-point Likert scale and written responses. Behavioural Marker of Risk Index (BMRI) scored for induction and intra-operative phases.	Inter-rater agreement reached. Mazzocco et al. method used to calculate BMRI scores. Braun and Clarke methodology used for thematic analysis of transcribed debriefings. Two authors used to reach consensus on themes.	Cost: set-up costs \$50 000, per day \$4000. Participant's perceptions: 80% found simulations and model realistic 87.7% agreed or strongly agreed simulations were as challenging as an actual case 93.6% agreed or strongly agreed that their behaviour was the same in the simulation as it would be in a real case. Free text answers indicated that model and scenario realism was very good. Some aspects of the models were shown to be limitations of the realism. Some aspects of the environment added to the limitations of the realism of the scenario training. End of course questionnaire: 98.3% agreed or strongly agreed the course was a useful learning experience. 89.2% of participants indicated that they would change their practice. BMRI scores improved from the first to the last scenario, $p=0.04$. Themes identified in qualitative analysis: promoting team orientation, establishing a coordinated team, appreciation of the importance of information sharing.	Long term follow-up data not collected. Potential bias because participants were volunteers.
Hinde et al. (2016) ⁷ , A study to assess the influence of interprofessional point of care simulation training on safety culture in the operating theatre environment of a university teaching hospital, UK	n = 84	Pre- and post-intervention comparison of operating theatre teamwork, climate and safety scores. The Safety Attitude Questionnaire – Operating Room (SAQ-OR) survey instrument Teamwork and Safety Climate survey instrument with language modified for the UK setting.	Scores compared using paired sample t-test. Effect size measured with Cohen's d.	Of the 84 participants, only 72 remained at the trust six months later. Only 46 (64%) of the 72 participants completed the SAQ-OR six months after the intervention. Outcome measures: - Safety Climate – pre/post intervention mean 65.8 vs 73.9 $p<0.001$ Cohen's d 0.604. - Teamwork Climate – pre/post intervention mean 73.6 vs 78.9 $p=0.013$ Cohen's d 0.382. Participants reports: 90% had increased awareness 85% had increased confidence in dealing with critical incidences 100% felt in situ simulation was a valuable learning experience 81% supported simulation training being conducted six-monthly.	Modest sample size. Improved patient outcomes cannot be directly shown with study results.

Author, date, title, country	Participants	Outcome measures / method	Reliability / validity of measures	Findings/conclusions	Limitations
Weller et al. (2016) ⁹ , Can team training make surgery safer? Lessons for national implementation of a simulation-based programme, New Zealand	n = 49	What are the perceived challenges of implementing change? What are the motivators for implementing change? How was the change implemented in the clinical practices following MORSim? Semi-structured interviews.	One researcher conducted, transcribed and analysed the interviews. Crosschecking conducted by a second researcher to refine themes.	Theme: Lessons learnt and changes in clinical practice. • Positive practice changes 73% of participants. • No change in practice 9% of participants. • New knowledge gained from MORSim 94% of participants. Theme: Changes in other's work styles. • No changes observed in other's work practices 65% of participants. Theme: Effect on patient management • Improved processes had improved patient management 25% of participants. Theme: Shared learning with staff members • Positive shared learning 65% of participants. Theme: Barriers to change in clinical practice • Participants perceived one or more barriers existed to prevent change in practice 81%.	Bias may have been introduced by the framing of questions by the interviewer. Interviewees may have reported positively on their communication and teamwork skills. Study limited to two centres.
Weller et al. (2016) ⁹ , Improved scores for observed teamwork in the clinical environment following a multidisciplinary operating room simulation intervention, New Zealand	437 surgical cases observed.	Observing changes to communication behaviours and teamwork in clinical practice following participation in MORSim. Behavioural Marker Risk Index (BMRI) measured at three phases of surgery before and after MORSim participation.	Acceptable inter-rater agreement reached. Calibration session held to maintain inter-rater agreement. Pre- and post-test scores compared using ANOVA. To test for effect, a logistic regression model was used. Significance set at $p < 0.05$. Bonferroni correction used during secondary analysis.	Extended BMRI decreased by more than 20% following MORSim compared to before MORSim. Statistically significant improvement in extended BMRI for induction $p = 0.005$ and intra-operative $p < 0.001$ phases. Individual domains of vigilance, information sharing, interdisciplinary information sharing, intra-operative briefing, briefing, information sharing, and interdisciplinary information sharing were more frequently observed after MORSim for all three phases.	Unable to blind raters. Simulation occurring in the clinical setting introducing variables which could not be controlled. No use of a control group. Voluntary participation could have introduced bias.

Author, date, title, country	Participants	Outcome measures / method	Reliability / validity of measures	Findings/conclusions	Limitations
Doumouras et al. (2017) ¹⁰ , Non-technical skills of surgeons and anaesthetists in simulated operating theatre crisis, UK	n = 26	Primary outcome measure: time to crisis resolution. Secondary outcome: non-technical skills (NTS) score of anaesthetists and surgeons using Anaesthetist Non-Technical Skill (ANTS) and Non-Technical Skill for Surgeons (NOTSS) rating systems.	Student t-tests. Inter-rating reliability assessed with intraclass correlation absolute mixed-effect statistic. Linear mixed-effects regression models with 95% confidence intervals. Statistical significance was set at $p < 0.05$.	NOTSS scores higher for haemorrhage scenario than difficult airway scenario 14.34(2.07) vs 12.15(2.07) $p < 0.001$. ANTS scores did not differ between scenarios 13.04(2.62) vs 12.99(2.62) $p = 0.895$. NOTSS and ANTS scores were higher before compared to during the crisis 13.62(2.57) vs 12.78(3.00) $p = 0.031$ and 13.75(2.22) vs 12.28(2.78) $p < 0.001$. Higher NOTSS score before and during was associated with a faster crisis resolution (34.69 seconds $p = 0.001$). Increased ANTS scores were associated with faster crisis resolution (32.09 seconds $p = 0.009$). NTS declined during the crisis for both the anaesthetist and surgeons evident by NOTSS scores 0.74 points lower during crisis ($p = 0.008$) and ANTS scores 1.38 points lower during the crisis ($p < 0.001$). NOTSS scores were also significantly lower during the difficult airway scenario 2.09 points lower ($p < 0.001$). NOTSS scores were found to influence ANTS scores during the haemorrhage scenario and vice versa. A 1-point increase in NOTSS scores increased ANTS score by 0.30 ($p = 0.005$). A 1-point increase in ANTS scores increased NOTSS score by 0.21 ($p = 0.0012$). ANTS scores had the greatest influence on the predictor of crisis resolution. 1-point increase decreased crisis duration by 53.50 seconds ($p < 0.001$).	Interpretation of results was more complex due to the use of a sensitivity analysis using a time-to-event hazard ratio model; therefore, results may be less meaningful. Only two potential scenarios were used during the simulation. The study is based on simulated crisis events. The contributions of scrub technicians and theatre nurses during the scenarios were not analysed.
Wongsirimeetee et al. (2018) ¹¹ , Identifying and managing intraoperative arrhythmia: a multidisciplinary operating room team simulation case, USA	n = 91	The primary goal was for the participants to develop crisis management and clinical practice skills. Post-intervention evaluation using a seven-point Likert scale and free text.	Not specified	Participant evaluation: 94% agreed or strongly agreed working as an interprofessional team was important 96% agreed or strongly agreed the simulation exercise was applicable to their own practice 88% agreed the simulation improved their teamwork skills. Free text answers indicate that participants' practice will change, communication is vital for effective teamwork, and new knowledge was gained, as a result of the simulation training.	Small sample size. Intervention implemented for operating room staff only.

Author, date, title, country	Participants	Outcome measures / method	Reliability / validity of measures	Findings/conclusions	Limitations
Leithead et al. (2019) ¹² , Examining interprofessional learning perceptions among students in a simulation-based operating room team training experience, USA	n = 152	Examine the impact of high-fidelity interprofessional simulation training on students from different professions within the operating room. A 15-item questionnaire using a six-point Likert-type interprofessional teamwork (IPT), Readiness for Interprofessional Learning Scale (RIPLS) using a five-point Likert Teamwork Assessment Scale (TAS) with six-point Likert scale and two three-item subscales.	Student t-test. ANOVA analysis. p-value <0.05 statistically significant Effect size calculated with Cohen's d. Post-hoc pairwise analysis of pre-post score differences with Tukey's Studentised Range Distribution.	The response rate was over 80%. IPT scores were statistically significant for all professions $p < 0.001$. RIPLS overall scores were statistically significant $p < 0.001$. Nurse anaesthetist improvement scores $p = 0.003$ and medical students $p = 0.042$. The mean IPT difference between the professions was statistically significant $p < 0.001$, whereas the mean RIPLS differences were not $p = 0.491$. Pairwise comparison of the mean differences between professions on the IPT survey showed statistical significance between a nurse anaesthetist and medical students – mean difference 0.62, 95% confidence level 0.34 to 1.01, effect size 0.91 – and undergraduate nursing student and nurse anaesthesia student – mean difference 0.62, 95% confidence level 0.24 to 1.00, effect size 0.79.	Greater number of medical students in some groups. Student differences over four years may have influenced results. General Linear Model analysis may have been a more appropriate statistical technique. Small sample size. Statistical significance for mean RIPLS scores was small and may not reflect the clinical significance. RIPLS was not implemented until 2012-2013.
Rochlen et al. (2019) ¹³ , Pilot one-hour multidisciplinary team training simulation intervention in the operating room improves teams non-technical skills, USA	n = 31	Hypothesis 1: Simulation training will improve non-technical skills. Hypothesis 2: Self-Reflection Survey scores will improve during the intervention and at the 2-week follow up. Non-Technical Skills II (NOTECHS II) tool Self-Reflection Survey (SRS)	Generalised Estimating Equations. Statistical significance set at $p = < 0.05$. Confidence interval set at 95%.	NOTECHS II scores increased from simulation one to simulation two and simulation two to post-intervention. All scores were higher for post-intervention than scenario one. No scores were statistically significant. Changes in scores between scenarios two and one with 95% CI were not statistically significant. All SRS scores compared to pre-intervention increased with statistical significance. Mean SRS scores immediately after intervention 0.57 $p = 0.0175$, at the end of the day 0.81 $p = 0.0150$, at the two-week follow up 0.49 $p = 0.0426$ The type of profession affected SRS scores.	Small sample size. Study conducted at a single centre. False positive correlations due to team familiarity. Raters and participants were not blinded to interventions or control group.
Long et al. (2020) ¹⁴ , Sustaining multidisciplinary team training in New Zealand hospitals: a qualitative study of a national simulation-based initiative, New Zealand	n = 27	Explore perspectives on the long-term sustainability of the NetworkZ programme. Semi-structured interviews. Codes deductively developed into themes aligned to Roger's Diffusion of Innovation Theory's five main factors.	Coding conducted by author one and reviewed by author two.	Theme 1: Relative advantage – multidisciplinary, delivered in situ, the relevance of communication and teamwork, realism of scenarios and generalisability to another setting. Theme 2: NetworkZ aligned with personal beliefs of the importance of teamwork. Theme 3: Complexity of course delivery – complexity reflected in the reduced time available to set up the program and multiple roles required of the instructors. Theme 4: Observability of programme impact – improved teamwork, improved teamwork behaviour, improved communication, reduced hierarchy, improved confidence to speak, identification of latent safety threats.	Potential bias due to vested interest by researchers. Generalisability is untested.

References

1. Arriaga AF, Gawande AA, Raemer DB, Jones DB, Smink DS, Weinstock P et al. Pilot testing of a model for insurer-driven, large-scale multicenter simulation training for operating room teams. *Ann Surg* 2014;259(3):40310.
2. Paige JT, Garbee DD, Kozmenko V, Yu Q, Kozmenko L, Yang T et al. Getting a head start: High-fidelity, simulation-based operating room team training of interprofessional students. *J Am Coll Surg* 2014;218(1):140–149.
3. Shapiro FE, Pawlowski JB, Rosenberg NM, Xiaoxia L, Feinstein DM, Urman RD. The use of in-situ simulation to improve safety in the plastic surgery office: A feasibility study. *ePlasty* 2014;14:620.
4. Sørensen JL, Navne LE, Emdal HM, Ottesen B, Albrechtsen CK, Pedersen BW et al. Clarifying the learning experiences of health care professionals with in situ and off-site simulation-based medical education: A qualitative study. *BMJ Open* 2015;5(10):e008345.
5. Sørensen JL, van der Vleuten C, Rosthøj S, Østergaard D, LeBlanc V, Johansen M et al. Simulation-based multiprofessional obstetric anaesthesia training conducted in situ versus off-site leads to similar individual and team outcomes: A randomised educational trial. *BMJ Open* 2015;5(10):e008344.
6. Weller J, Cumin D, Torrie J, Boyd M, Civil ID, Madell D et al. Multidisciplinary operating room simulation-based team training to reduce treatment errors: A feasibility study in New Zealand hospitals. *NZ Med J* 2015;128(1418):40–51.
7. Hinde T, Gale T, Anderson I, Roberts M, Sice P. A study to assess the influence of interprofessional point of care simulation training on safety culture in the operating theatre environment of a university teaching hospital. *J Interprof Care* 2016;30(2):2513.
8. Weller J, Civil I, Torrie J, Cumin D, Garden A, Corter A et al. Can team training make surgery safer? Lessons for national implementation of a simulation-based programme. *NZ Med J* 2016;129(1443):917.
9. Weller J, Cumin D, Civil ID, Torrie J, Garden A, MacCormick A et al. Improved scores for observed teamwork in the clinical environment following a multidisciplinary operating room simulation intervention. *NZ Med J* 2016;129(1439):59–67.
10. Doumouras AG, Hamidi M, Lung K, Tarola CL, Tsao MW, Scott JW et al. Non-technical skills of surgeons and anaesthetists in simulated operating theatre crises. *Br J Surg* 2017;104(8):102836.
11. Wongsirimeteekul P, Mai CL, Petrusa E, Minehart R, Hemingway M, Pian-Smith M et al. Identifying and managing intraoperative arrhythmia: A multidisciplinary operating room team simulation case. *MedEdPORTAL* 2018 Feb;14:10688.
12. Leithead J, Garbee DD, Yu Q, Rusnak VV, Kislov VJ, Zhu L et al. Examining interprofessional learning perceptions among students in a simulation-based operating room team training experience. *J Interprof Care* 2019;33(1):2631.
13. Rochlen LR, Malloy KM, Chang H, Kim S, Guichard L, Cassidy R et al. Pilot one-hour multidisciplinary team training simulation intervention in the operating room improves team nontechnical skills. *J Educ Perioper Med* 2019;21(2):e624.
14. Long JA, Jowsey T, Henderson KM, Merry AF, Weller JM. Sustaining multidisciplinary team training in New Zealand hospitals: A qualitative study of a national simulation-based initiative. *NZ Med J* 2020;133(1516):1021.

Multidisciplinary simulation training for perioperative teams: An integrative review

Supplemental material: Application of Joanna Briggs Institute (JBI) Critical appraisal checklist for quasi-experimental studies to the ten quantitative studies

Checklist item	Study									
	Paige et al. (2014)	Arriaga et al. (2014)	Shapiro et al. (2014)	Sørensen et al. (2015)	Weller et al. (2015)	Hinde et al. (2016)	Weller et al. (2016)	Doumouras et al. (2017)	Leithead et al. (2019)	Rochlen et al. (2019)
Is it clear in the study, what is the cause and what is the effect?	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Were the participants included in any comparisons similar?	✓	✓	✓	✓	✓	✗	✗	✓	✗	✗
Were the participants included in any comparisons receiving similar treatment/care, other than the exposure of intervention of interest?	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Was there a control group?	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
Were there multiple measurements of the outcome, both before and after the intervention/exposure?	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analysed?	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Were the outcomes of participants included in any comparisons measured in the same way?	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Were outcomes measured in a reliable way?	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Was appropriate statistical analysis used?	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Percentage	89%	89%	89%	89%	89%	78%	78%	89%	78%	78%

Multidisciplinary simulation training for perioperative teams: An integrative review
Supplemental material: Application of Joanna Briggs Institute (JBI) Critical appraisal checklist for qualitative research to the four qualitative studies

Checklist item	Study			
	Sørensen et al. (2015)	Weller et al. (2016)	Wongsirimeetekul et al. (2018)	Long et al. (2020)
Is there congruity between the stated philosophical perspective and the research methodology?	✓	✓	✓	✓
Is there congruity between the research methodology and the research question or objectives?	✓	✓	✓	✓
Is there congruity between the research methodology and the methods used to collect data?	✓	✓	✓	✓
Is there congruity between the research methodology and the representation and analysis of data?	✓	✓	✓	✓
Is there congruity between the research methodology and the interpretation of results?	✓	✓	✓	✓
Is there a statement locating the researcher culturally or theoretically?	✓	✓	✓	✓
Is the influence of the researcher on the research, and vice versa, addressed?	✓	✓	✓	✓
Are participants and their voices, adequately represented?	✓	✓	✗	✓
Is the research ethical according to current criteria or, for recent studies, is there evidence of ethical approval by an appropriate body?	✓	✓	✓	✓
Do the conclusions drawn in the research report flow from the analysis, or interpretation, of the data?	✓	✓	✓	✓
Percentage	100%	100%	90%	100%

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Determining the attitude of operating room nurses to radiation exposure: A descriptive study

Abstract

Objective

This study aims to determine the attitude of operating room nurses to radiation exposure.

Methods

This descriptive study was conducted with 70 nurses working in the operating room of two university hospitals belonging to a university in Istanbul. Descriptive statistical analyses were performed using IBM SPSS 23. The protocol of the study was registered in clinicaltrials.gov (NCT04703933).

Results

There was a significant relationship between radiation protection training and the use of protective equipment ($p < 0.05$).

Conclusions

It was found that the nurses working in the operating room had insufficient radiation protection training and there was a positive relationship between radiation protection training and protection behaviour. Seminars should be organised to increase the level of knowledge of nurses about radiation protection practices.

Keywords: radiation protection, radiation, operating room nursing, attitude

Introduction

Operating rooms are dynamic places where advanced technology is used. Operating room personnel face many biological, physical and infectious risk factors. One of these risk factors is ionizing radiation¹. Medical imaging techniques used as diagnostic devices, such as X-ray imaging, computed tomography (CT) and fluoroscopy, lead to patients and medical staff being exposed to radiation^{2,3}.

Radiation is used in many applications in operating rooms and long-term exposure to radiation

may occur. Radiation exposure occurs when all or part of the body absorbs penetrating ionizing radiation from an external radiation source. Radiation exposure also occurs after internal contamination, i.e. when a radionuclide is ingested, inhaled or absorbed into the blood stream⁴.

Radiation can cause serious adverse effects on hematopoietic, immune, reproductive, circulatory, respiratory, musculoskeletal, endocrine, nervous, digestive, and urinary systems^{5,6}. The negative effects of radiation exposure generally fall into two categories: deterministic effects or probabilistic

effects⁷. Although the deterministic effects are directly related to cell death, they occur as a result of exposure of cells to radiation. Deterministic effects may result in infertility, cataract, leukaemia, skin burns and death. Probabilistic effects are associated with the accumulation of absorbed radiation in tissues and may occur even at the lowest dose. Probabilistic effects include genetic disorders and cancer formation^{3,5,6}.

The use of protective equipment plays a significant role in reducing radiation exposure. The use of masks ensures protection from respiratory hazards, the use of protective clothing ensures that the radioactive substance does not damage the skin and hair, and the use of personal dosimeters ensures the management of the duration of stay in an area with high radiation levels and the monitoring of accumulated doses⁸.

The chance of radiation exposure is very high for operating room nurses⁹; therefore, nurses should have sufficient information about radiation and protection from radiation¹⁰. This study was carried out to determine the attitude of operating room nurses to radiation exposure.

Materials and methods

Study design

A descriptive study. The protocol of the study was registered in clinicaltrials.gov (NCT04703933).

Population and sample

This research was conducted in two university hospitals belonging to a university in Istanbul. The sample of the study consisted of 70 volunteer operating room nurses.

Instruments

The data were collected with a data collection form created by the researchers and based on

Table 1: Nurses' demographic characteristics (N=70)

Variables		n	%
Age	18–25	21	30.0%
	26–35	31	44.3%
	36–45	17	24.3%
	46 years or more	1	1.4%
Gender	Female	60	85.7%
	Male	10	14.3%
Marital status	Married	32	45.7%
	Single	38	54.3%
Educational status	Vocational high school of health	9	12.9%
	Associate degree	6	8.6%
	Bachelor's degree	40	57.1%
	Postgraduate degree	15	21.4%
Professional experience	1–5 years	33	47.1%
	6–10 years	17	24.3%
	11–15 years	8	11.4%
	16–20 years	7	10.0%
	21 years or more	5	7.1%
Operating room experience	1–5 years	43	61.4%
	6–10 years	17	24.3%
	1–15 years	5	7.1%
	16–20 years	3	4.3%
	21 years or more	2	2.9%
Role	Scrub nurse	22	31.4%
	Circulating nurse	11	15.7%
	Scrub and circulating nurse	37	52.9%
Hours worked each week	Less than 40 hours	2	2.9%
	40–49 hours	38	54.3%
	50–59 hours	26	37.1%
	60 hours or more	4	5.7%

the relevant literature¹¹. The data collection form consisted of a total of 18 questions regarding radiation exposure, such as the number of professional working years, the number of years working in the operating room, the nursing role, the tasks involved, the exposure

to radiation technology, the use of protective measures when exposed to radiation technology, the use of personal dosimeter and radiation level measurements in the operating room. Demographic data, such as age, gender, and educational status, were also collected. Pilot implementation

Table 2: Nurses' exposure to radiation and radiation protection used (N=70)

Variables		n	%
Exposure to radiation technology in the last year	Yes	52	74.3%
	No	18	25.7%
Frequency of exposure to radiation technology	More than once a day	12	17.1%
	More than once a week	30	42.9%
	Once a week	5	7.1%
	Once a month	6	8.6%
	None	17	24.3%
Protective equipment use with radiation technology	Yes	57	81.4%
	No	13	18.6%
Items of protective equipment used with radiation technology	Protective eyewear and gloves	20	28.6%
	Thyroid shield	44	62.9%
	Lead apron	54	77.1%
Radiation protection training received	Yes	35	50.0%
	No	35	50.0%
Presence of radiation hazard warning signs in the work area	Yes	46	65.7%
	No	24	34.3%
Dosimeter use	Yes	25	35.7%
	No	45	64.3%
Operating room radiation levels measured	Yes	30	42.9%
	No	40	57.1%
Care taken when using radiation technology	Yes	48	68.6%
	No	22	31.4%

was carried out with ten operating room nurses before starting the research.

Ethical review statement

Necessary permissions were obtained from the Istanbul University Cerrahpasa Ethics Committee (255651) before starting the research.

Data analysis

The research data were evaluated using IBM SPSS 23 (Statistical Package for Social Sciences for Windows, Version 23.00, Armork NY) program. In

the analysis of the data, frequency and percentage among descriptive statistical methods were used. Kolmogorov-Smirnov Goodness of Fit Test was used for normality analysis of the data obtained. The chi-square test was used to evaluate normally distributed data. Significance level was accepted as $p < 0.05$.

Results

Since the study was conducted in two hospitals belonging to the same university, the radiation protections measures applied and the results

obtained at the two hospitals were not different from each other.

Demographic characteristics of the nurses are shown in Table 1 – 44.3 per cent were between the ages of 26 and 35, 85.7 per cent were female, and 57.1 per cent had a bachelor's degree. Approximately half the nurses had one to five years of professional experience and 61.4 per cent had one to five years of operating room experience.

Nurses' exposure to radiation is shown in Table 2 – 74.3 per cent of the nurses were exposed to radiation in the last year, 42.9 per cent were exposed to radiation technology more than once a week, 81.4 per cent of the nurses used protective equipment when using radiation technology, 28.6 per cent used protective eyewear and gloves, 62.9 per cent used thyroid shields, and 77.1 per cent used lead aprons. It was found that half of the nurses participating in the study received radiation protection training, 65.7 per cent stated that there were radiation danger signs in the operating rooms where they worked, and 57.1 per cent stated that radiation level measurements were not performed where they worked. It was determined that 64.3 per cent of the nurses did not use a dosimeter and 31.4 per cent of the operating room personnel did not take the necessary care when using radiation technology.

Table 3 shows the relationship between radiation protection training and radiation protection attitudes in the nurses. It was determined that 94.3 per cent of the nurses who received radiation protection training used protective equipment ($p < 0.05$). The rates of use of protective eyewear and gloves, thyroid shields, lead aprons, and dosimeters as protective equipment were 51.4 per cent, 80 per cent, 91.4 per cent and 65.7 per cent, respectively ($p < 0.05$).

Table 3: The relationship between nurses receiving radiation protection training and radiation protection used (N=70)

Characteristics Yes (%)		Radiation protection training		
		Yes (%)	No (%)	p
Protective equipment use	Yes	94.3	68.6	0.006
	No	5.7	31.4	
Protective eyewear and glove use	Yes	51.4	5.7	0.000
	No	48.5	94.3	
Thyroid shield use	Yes	80	45.7	0.003
	No	20	54.3	
Lead apron use	Yes	91.4	62.9	0.005
	No	8.6	37.1	
Dosimeter use	Yes	65.7	5.7	0.000
	No	34.3	94.3	
Care taken when using radiation technology	Yes	91.4	45.7	0.000
	No	8.6	54.3	

It was found that those who received radiation protection training took the necessary care when using radiation technology, had radiation danger signs in the operating rooms where they worked, and radiation level measurements were performed ($p < 0.05$).

Discussion

Approximately seven million health workers worldwide are exposed to occupational radiation¹³. The Turkish Atomic Energy Authority (TAEK) regulates the safe use of sources of ionizing radiation and radiation protection in Turkey. The TAEK regulations follow the ALARA (as low as reasonably achievable) principle of radiation safety which recommends three protective measures – time, distance and armouring¹². That is, reducing time of exposure, maximising distance between the radiation source and personnel, and putting a shield between the radiation source and personnel. Radiation technology is used in many applications in Turkish

operating rooms, and operating room personnel are exposed to the negative effects of radiation. Therefore, attitude towards ionizing radiation plays an important role in protection from radiation and safe application of radiation technology. This study aimed to determine the attitude of operating room nurses to radiation exposure.

Previous studies have reported a positive relationship between attitudes to radiation protection and knowledge level^{9,14,15,16,17}. It is observed in the literature that the majority of nurses know the harmful effects of radiation but do not pay attention to protection measures^{3,18,19}. The literature also states that nurses have insufficient information about radiation and protection from radiation, and the vast majority of them are exposed to radiation^{1,20,21}. The current study determined that half of the nurses received radiation protection training and the majority of the nurses who received protection training paid attention to the use of radiation technology.

Radiation protection training given to nurses included the use of radiation technology, protective equipment and radiation signs.

The use of personal dosimeters ensures the management of the duration of stay in an area with high radiation levels and the monitoring of accumulated doses⁸. Studies by Alavi et al²² and Güden et al²³ found that the majority of the participants used personal dosimeters^{22,23}. In contrast, this study found that the majority of nurses did not use personal dosimeters.

The use of protective equipment is essential for radiation protection. Güden et al²³ reported that the majority of personnel did not use protective lead aprons²³. Yasak and Vural²⁴ stated that the majority of personnel did not use protective equipment, although lead aprons were available in the operating rooms²⁴. In contrast, the current study found that the majority of operating room nurses used protective equipment and the protective equipment that was used most often were lead aprons followed by thyroid shields.

Conclusion and recommendations

It is seen that the majority of operating room nurses are exposed to radiation, the training received for radiation protection is insufficient, the majority of operating room nurses take care to use protective equipment but do not use personal dosimeters. For this reason, it is recommended that training programs and seminars be provided for nurses to protect themselves from radiation.

References

1. Vural F, Fil S, Çiftçi S, Dura AA, Yıldırım F, Patan R. Ameliyathanelerde radyasyon güvenliği; çalışan personelin bilgi, tutum ve davranışları [Radiation safety in operating units; knowledge, attitude and behaviors of operating room staffs]. *Balikesir Sağlık Bilimleri Dergisi [Balikesir Health Sciences Journal]* 2012;1(3):131–136.
2. Çeçen G, Oçmen S, Bulut G, Çolak M, Yıldız M. Eğitim hastanesi ortopedi ameliyathanesi'nde flouroskopi kullanımı ve radyasyondan korunma [Fluoroscopy usage in orthopedics surgery room of a training hospital and radiological protection]. *Kartal Eğitim ve Araştırma Hastanesi Tıp Dergisi [Kartal Training Research Hospital Medical Journal]* 2003;14(3):156–158.
3. Yıldız EM, Kandemir Y, Demirci K, Özcan M. Level of information about radiation among medical staff working in operating rooms with fluoroscopy. *Turkish Medical Student Journal (TMSJ)* 2015;20(30):31–35.
4. US Department of Health & Human Services (HHS), Radiation Emergency Medical Management (REMM). Radiation exposure – animations [Internet]. Washington: HHS; [cited 2021 February 03]. Available from www.remm.nlm.gov/exposureimage_top1.htm.
5. Popanda O, Marquardt JU, Chang-Claude J, Schmezer P. Genetic variation in normal tissue toxicity induced by ionizing radiation. *Mutation Research* 2009;667(1–2):58–69. DOI: doi.org/10.1016/j.mrfmmm.2008.10.014.
6. Clement CH, Stewart FA, Akleyev AV, Hauer-Jensen M, Hendry JH, Kleiman NJ et al. ICRP publication 118: ICRP statement on tissue reactions and early and late effects of radiation in normal tissues and organs – threshold doses for tissue reactions in a radiation protection context. *Annals of the ICRP*. 2012;41(1–2):1–322. DOI: doi.org/10.1016/j.icrp.2012.02.001.
7. Canham CD, Williams RB, Schiffman S, Weinberg EP, Giordano BD. Cumulative radiation exposure to patients undergoing arthroscopic hip preservation surgery and occupational radiation exposure to the surgical team. *Arthroscopy* 2015;31(7):1261–1268. DOI: doi.org/10.1016/j.arthro.2015.01.017.
8. Centers for Disease Control and Prevention (CDC). ALARA – As Low As Reasonably Achievable [Internet]. Atlanta: CDC; 2015 [cited 2020 December 03]. Available from: www.cdc.gov/nceh/radiation/alara.html.
9. Jeong KW, Jang HJ. Relationship between knowledge and performance of radiation protection among nurses who work in operating room. *Advanced Science and Technology Letters* 2015;116:65–69.
10. Yusuf SD, Umar I, Tarfa UF, Mundi AA. assessment of knowledge and attitude of nurses in a specialist hospital towards ionizing radiation at Maiduguri, Borno State, Nigeria. *Asian Nurs Res* 2020;3(1):42–51.
11. Kang SG, Lee EN. Knowledge of radiation protection and the recognition and performance of radiation protection behavior among perioperative nurses. *Journal of Muscle and Joint Health* 2013;20(3):247–257.
12. Mudun A. radiation safety of intraoperative gamma probe in breast cancer. *The Journal of Breast Health*. 2009;5(3):116.
13. World Health Organization (WHO). Ionizing radiation [Internet]. Geneva: WHO; [cited 2020 November 17]. Available from www.who.int/ionizing_radiation/about/med_exposure/en/index.html.
14. Kim JH, Ko SJ, Kang SS, Choi SY, Kim CS. Analysis of radiation/radioactivity-related knowledge, perception and behaviors of radiological technologists. *Journal of Radiological Science and Technology* 2011;34(2):123–129.
15. Kang SG, Lee EN. Knowledge of radiation protection and the recognition and performance of radiation protection behavior among perioperative nurses. *Journal of Muscle and Joint Health*. 2013;20(3):247–257. DOI: doi.org/10.5953/JMJH.2013.20.3.247.
16. Lee HM. Radiation protection knowledge, attitudes and behavior of operating room nurses. Doctoral dissertation, Master thesis. Chuncheon: Hallym University; 2013.
17. Yoon J, Yoon YS. A survey about the knowledge, attitudes and behavior for radiation safety management of operating room nurse and dental hygienists. *J Dent Hyg Sci* 2014;14(2):230–239.
18. Rassin M, Granat P, Berger M, Silner D. Attitude and knowledge of physicians and nurses about ionizing radiation. *J Radiol Nurs* 2005;24(2):26–30. DOI: doi.org/10.1016/j.jradnu.2005.04.001.
19. Anim-Sampong S, Opoku SY, Addo P, Botwe BH. Nurses knowledge of ionizing radiation and radiation protection during mobile radiodiagnostic examinations. *Educational Research* 2015;6(3):39–49.
20. Alotaibi M, Saeed R. Radiology nurses awareness of radiation. *J Radiol Nurs* 2006;25(1):7–12. DOI: doi.org/10.1016/j.jradnu.2005.12.001.
21. Maliro FMJ. Ionizing radiation protection awareness among nurses working at Queen Elizabeth Central Hospital Malawi [Internet]. PhD thesis. Johannesburg: University of Johannesburg; 2011 [cited 2020 November 17]. Available from https://ujcontent.uj.ac.za/vital/access/manager/Repository/uj:8758?site_name=GlobalView.
22. Alavi SS, Dabbagh ST, Abbasi M, Mehrdad R. Medical radiation workers' knowledge, attitude, and practice to protect themselves against ionizing radiation in Tehran Province, Iran. *J Educ Health Promot* 2017;6:58.
23. Güden EA, Oksüz K, Balci E, Tuna R, Borlu A, Cetinkara K. Radyoloji Çalışanlarının Radyasyon Güvenliğine İlişkin Bilgi, Tutum ve Davranışı [Knowledge, attitude and behavior of radiology workers regarding radiation safety]. *Sağlıkta Performans Ve Kalite Dergisi [Journal of Performance and Quality in Health]* 2012;3:29–47.
24. Yasak K, Vural F. Assessment of the Environmental and physical ergonomic conditions of ORs in Turkey. *AORN J* 2019;110(5):517–523. DOI: doi.org/10.1002/aorn.12841.

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COVID-19 changes to Post Anaesthesia Care Unit nursing practices

Abstract

The pandemic year of 2020 brought unparalleled and swift changes to health care processes within Australia. All registered nurses in the Post Anaesthesia Care Unit (PACU) of a regional tertiary referral hospital had to make changes to routine personal protective equipment (PPE) practice to accommodate a safer environment for both staff and patients. Changes to PPE practices included the addition of heat moisture exchange (HME) filters to laryngeal mask airways (LMAs), and the use of Level 3 surgical masks during aerosolising procedures such as extubation and nebulisation. Changes were also made to the structured handover from anaesthetic nurse to the PACU to increase compliance with PPE practice.

Identified problem

COVID-19 is an infectious airway disease, spread primarily through droplets of saliva or discharge from the nose¹. The COVID-19 pandemic required extensive policies and procedures to be created and implemented within the perioperative unit for patients who were suspected or confirmed COVID-19 cases. However, data suggests asymptomatic or mild infections account for 80 per cent of cases, and asymptomatic patients are likely to journey through the operating theatre without implementation of the personal protective equipment (PPE) precautions recommended for airborne particles².

The perioperative environment was identified as a high-risk environment for aerosolising procedures¹. Routine practice within the perioperative unit includes manual ventilation, intubation, extubation, suctioning and nebulisation which all produce small particles of fluid from the patient's airways that can flow through the air, spread widely and settle on surfaces in the environment¹.

The Post Anaesthesia Care Unit (PACU) in this report has 18 bed spaces and, on average, it accommodates 290 elective and emergency surgical patients a week. The 18 bed spaces are divided into three bays of six beds; when at capacity in stage one PACU, there is a minimum of 12 people, both staff and patients, within each bay. It was therefore identified that this workspace, with less than 1.5 metres between each bed space, does not allow staff and patients to maintain the physical distancing of at least 1.5 metres that is advised to reduce the spread of COVID-19³. Additionally, when compared to operating theatres, the PACU has no high efficiency particulate air (HEPA) filter, which would remove small (0.1–1 micron) airborne particles⁴.

PPE is used to safeguard health care workers and patients. Prior to the pandemic, routine PPE worn by staff in the PACU during care of non-infectious patients from admission to discharge included surgical scrubs, fabric or disposable surgical hats, gloves and safety goggles⁵. Traditionally, the heat moisture exchange (HME) anaesthetic filters used intra-operatively were

removed from the laryngeal mask airways (LMAs) on transfer from the operating theatre (OT), and patients were received in the PACU with no HME filter on the airway. Coughing during extubation from an LMA within the PACU is common and without the HME filter in place or a HEPA filter within the unit fluid particles from the patient's airway can be expelled directly into the PACU environment, spreading to both staff and other patients and remaining in the environment². It was identified that COVID-19 particles are smaller than five micron and the HME filters are verified to particles smaller than two micron⁶. Additionally, COVID-19 particles can stay in the air for several hours and fomites can remain active on plastic surfaces within the environment for 72 hours^{1,5,6}. Due to this, changes to routine PPE practices within the PACU had to be made to safeguard both staff and patients during the COVID-19 pandemic.

Proposed solution

PPE for airborne precautions and strict adherence to infection control policy and procedure were in place for patients who were suspected or confirmed to have COVID-19; however, measures for asymptomatic COVID-19 patients needed to be implemented. To protect both patients and staff from asymptomatic COVID-19 carriers, changes to routine PPE use within the PACU were introduced. HME filters were left on patient's LMA during transfer from the OT to the PACU and Level 3 masks became routine PPE for staff caring for a patient with an airway in place or when performing aerosolising procedures. Level 3 surgical masks are used for droplet and contact precautions, and in relation to COVID-19 they are used when in contact with or during direct care of a person who is confirmed or suspected of having COVID-19^{6,7,8}. The anaesthetic team also worked toward decreasing the use of re-usable LMA's

within the OT and, when appropriate, using single-use airways to reduce the risk of cross-contamination from faulty sterilisation. Additionally, the structure of the ISBAR (Identification, Situation, Background, Assessment and Request or Recommendation) nursing handover between anaesthetics and PACU was refined to improve PPE change compliance.

Implementation strategies and opportunities for improvement

This project was a collaboration between medical and nursing staff within the perioperative unit. Communication regarding implementation of this project occurred during staff meetings and in emails between PACU and anaesthetic team leaders. A change of practice was instigated by the anaesthetic department (medical and nursing), to ensure HME filters were left on patient LMAs during transport from the OT to the PACU. Additionally, single-use LMA stock levels were increased by the stores department, and the use of re-usable LMAs by anaesthetic staff was discouraged. However, nation-wide stock shortages at the beginning of COVID-19 did not facilitate this change to single-use airways.

Most staff members, both medical and nursing, embraced the changes in routine PPE practice without issue; however, a small subset of staff showed a consistent aversion to implementing the changes. After a general staff meeting where the reason for the changes to PPE practice were discussed, compliance did improve. Additionally, since the project was carried out in a university teaching hospital, the regular changeover of medical staff meant that HME filters could be routinely left off LMAs when patients were

transferred to the PACU. If compliance was seen to be decreasing a general email was sent to both medical and nursing anaesthetic staff to ensure they are aware of practice changes and the importance of compliance to safeguard both patients and colleagues.

Project successes

Prior to the patient arriving in the PACU, the PACU team leader receives verbal phone handover about the patient from an anaesthetic nurse. Before this project, the anaesthetic to PACU nursing handover routinely consisted of theatre number and patient name; after this project, the handover now contains the patient's airway status which is a prompt to ensure the HME filter is left in place on transfer. Including this in the handover allows for the receiving PACU nurse to be appropriately allocated and Level 3 surgical mask to be donned prior to the patient's arrival. The Level 3 surgical mask remains in use until the high aerosol risk procedure is completed.

This project also included the introduction of an anaesthetic to PACU handover 'cheat sheet' which was placed near the phone in every theatre. The sheet summarises key points for a succinct ISBAR structured handover, including operating room number, patient name, operation performed, anaesthetic given, airway status / HME filter present, and any intra-operative issues and/or patient alerts. Lanyard-sized 'cheat sheet' cards were also made for anaesthetic nurses.

Recommendations

These relatively minor changes to routine PPE and handover within the perioperative department are recommended to help protect both patients and staff from acquiring and spreading infectious airway diseases, such as COVID-19.

References

1. Australian Society of Anaesthetists (ASA). Anaesthesia and caring for patients during the COVID-19 outbreak [Internet]. Sydney: ASA; 2020 [cited 2020 October 24]. Available from: https://asapublicaccess.s3.ap-southeast-2.amazonaws.com/website/ASA_airway_management.pdf.
2. World Health Organization (WHO). Coronavirus disease (COVID-19) Situation report – 46 [Internet]. Geneva: WHO; 2020 [cited 2020 November 16]. Available from: <https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200306>.
3. Department of Health. Physical distancing for coronavirus (COVID-19) [Internet]. Canberra: Australian Government; 2020 [updated 2020 September 23; cited 2020 November 15]. Available from: www.health.gov.au/news/health-alerts/novel-coronavirus-2019-ncov-health-alert/how-to-protect-yourself-and-others-from-coronavirus-covid-19/physical-distancing-for-coronavirus-covid-19.
4. United States Environmental Protection Agency (EPA). Air cleaners, HVAC filters, and coronavirus (COVID-19) [Internet]. Washington: EPA; 2020 [cited 2021 January 13]. Available from: www.epa.gov/coronavirus/air-cleaners-hvac-filters-and-coronavirus-covid-19.
5. Gupta N, Sachdev A, Bansal A, Sood A, Sharan T, Patki V. Personal protective equipment during COVID-19 epidemic. *J Pediatr Crit Care* 2020;7(7):22–30. DOI: 10.4103/JPCC.JPCC_75_20.
6. Koo C, Lee SY, Chung SH, Ryu J. Deep vs. awake extubation and LMA removal in terms of airway complications in pediatric patients undergoing anesthesia: a systemic review and meta-analysis. *J Clin Med* 2018;7(10):353. DOI: 10.3390/jcm7100353
7. Zucco L, Levy N, Ketchandji D, Aziz M, Ramachandran SK. An update on the perioperative considerations for COVID-19 severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2). *APSF Newsletter* 2020;35(2). Available from: www.apsf.org/article/an-update-on-the-perioperative-considerations-for-covid-19-severe-acute-respiratory-syndrome-coronavirus-2-sars-cov-2.
8. Department of Health. Guidance on use of personal protective equipment (PPE) in hospitals during the covid-19 outbreak [Internet]. Canberra: Australian Government; 2020 [updated 2020 November 12; cited 2020 November 16]. Available from: www.health.gov.au/resources/publications/guidance-on-the-use-of-personal-protective-equipment-ppe-in-hospitals-during-the-covid-19-outbreak.

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Ergoophthalmological risks associated with dry eye in the operating room

Abstract

Dry eye disease is one of the most common pathologies of the ocular surface. In parallel with increased screen exposure, environmental changes and modern life in recent years, the prevalence and severity of dry eye have been increasing. Ergoophthalmology is the study of visual ergonomic conditions. It is concerned with injuries to the eyes caused by occupational factors and uses a multidisciplinary approach to understand the causes of occupational vision-related and ocular diseases and to prevent and manage these conditions. Vision-related risks in the operating room are critical for patients and health care providers. There are many predisposing factors in the operating room environment – air conditioning, constant humidity, constant room temperature, intense lighting, surgical smoke, anaesthetic gases and the use of irritant chemicals and biological aerosols. In addition, surgery itself is a critical task requiring long-term mental effort and concentration which can also predispose operating room staff to dry eye disease. In this review, we discuss occupational and environmental ergoophthalmological risk factors for dry eye disease in the operating room.

Keywords: dry eye, ergoophthalmology, operation room, health workers

Introduction

Dry eye disease is one of the most common ocular morbidities. It is a multifactorial, chronic pathology of the ocular surface and tear film, characterised by tear film instability and visual disturbances and potentially results in injury to the ocular surface. In the majority of cases, it is accompanied by increased osmolarity of the tear film with increased evaporation and ocular surface inflammation¹.

The prevalence of dry eye disease varies between five to 50 per cent in adults worldwide and may increase up to 75 per cent in postmenopausal women aged above 50 years. While it is seen in only 2.7 per cent of young adults aged between 18 and 45 years², recent studies have emphasised the increased prevalence of dry eye among young adults aged between 18 and 34 years due to the increased use of digital screens^{3,4}. Although

advanced age and female sex are the main known risk factors, occupational activities and environmental factors have been shown to be closely associated with increased prevalence and severity of dry eye disease². Occupational activities include reading, driving and screen use which all require maximal mental effort. Environmental factors, where blinking is inhibited involuntarily due to the evaporative and irritant effects on the ocular surface, include low humidity, cold air, artificial indoor heating and air conditioning, air pollutants such as dust and smoke, liquid or gas chemicals such as ozone and formaldehyde, biological agents such as demodex, pollen and fungi, and cigarette smoke^{5,6}. Several studies have demonstrated that poor indoor air quality in modern office buildings, low relative humidity, high room temperature, high air flow, scents and other chemical pollutants are the main causes of

ocular symptoms⁷⁻⁹. These symptoms initially cause oxidative stress and injury to the ocular surface resulting in itching, burning and lacrimation. Patients present with pain, foreign body sensation and, in later stages, blurred vision as the trigeminal nerves are affected^{10,11}. In an epidemiological study, Azuma et al.¹² examined the relationship between indoor air quality and building-related symptoms of office workers and found a significant correlation between low ambient humidity and eye irritation. In another study, the incidence of ocular diseases and eye fatigue were significantly higher among office workers¹³. Considering their use of computers for long hours, occupational activities with a high level of visual burden and their working environment, office personnel and cabin attendants are considered a high-risk group¹⁴. In addition, dry eye has been associated with anxiety and depression, decreased effective working time and productivity and limited psychological, physical and social functioning, particularly among office workers¹⁵⁻¹⁷. A limited number of studies has also demonstrated that the risk of dry eye disease is higher by 56 per cent in operating room staff and laboratory technicians than the general population¹⁸⁻²⁰.

To the best of our knowledge, there is no research examining dry eye disease in operating room staff. Additionally, there is no standard for prevention or management of dry eye disease in national and international reports of occupational health practices for operating room staff. In previous studies regarding ergonomic principles of surgery, musculoskeletal disorders and fatigue are the most common occupational diseases or injuries caused by non-ergonomic factors^{21,22}; however, Anshel²³ commented on the relationship between musculoskeletal disorders

and visual performance – that the eyes commanded the body's action and adapted to the viewing environment when vision was poor or unsatisfactory. Therefore, the use of intense lighting, ventilation filters, irritant chemicals and surgical laser, and the presence of surgical smoke, anaesthetic gases and biological aerosols in the hospital setting, as well as advanced medical technology, call for ergoophthalmological studies. In this review, we discuss occupational and environmental ergoophthalmological risk factors of dry eye disease among operating room staff.

The effects of evaporation and blinking

The proposed vicious cycle of the pathology of dry eye disease is tear film instability, leading to hyperosmolarity and inflammation of the ocular surface²⁴. Accordingly, the disease is classified into two main categories: hyperevaporation related to meibomian gland dysfunction (MGD) which is characterised by excessive evaporation of the tear film, and aqueous deficiency caused by reduced aqueous production from the lacrimal glands²⁵. Aqueous deficiency occurs in about 10 per cent of cases of ocular symptoms related to dry eye disease, while hyperevaporative or mixed type is seen in more than 80 per cent of cases²⁶.

It has been well documented that evaporation plays a key role in the onset and maintenance of dry eye disease and is the main cause of hyperosmolarity and ocular surface damage; thereby, leading to the loss of epithelial and goblet cells directly or through inflammation²⁴. Tear film osmolarity is the indicator of the balance between the tear production, evaporation, drainage and absorption^{27,28}. As a result, tear film osmolarity is primarily affected

by the body's hydration, tear film lipid layer, palpebral fissure width, frequency of eye blinking, tear film stability and environmental factors.

Previous studies have suggested that the blink reflex is the main mechanism of an intact ocular surface and tear film osmolarity^{2,29}. Blinking occurs on a voluntary basis or through motor innervation or reflex in healthy individuals. The blink reflex is the rapid closing of the eyelid which is evoked in response to ocular, acoustic, trigeminal or visual stimuli, as well as external stimuli such as motor movements³⁰. Blinking spreads, mixes and distributes the tear film components onto the ocular surface and secretion of lipids from the meibomian glands is stimulated through the muscle movement during eye blinking. Several studies have supported the potential link between incomplete blinking, MGD and development of evaporative dry eye disease. In a study investigating the impact of blinking on tear film parameters, ocular surface characteristics and dry eye symptomology, incomplete blinking was associated with a two-fold increased risk of dry eye disease³¹. In addition, reduced blink rate and incomplete blinking during a visual display terminal task were associated with decreased tear film stability and dry eye disease-related symptoms. This can be attributed to decreased secretion of the meibomian glands and reduced quality of the meibomian lipids and the tear film lipid layer becomes thickened^{32,33}.

Ergoophthalmological risk factors in the operating room

In recent years, a serious concern has been raised about the harmful effects of occupational and environmental factors on dry eye disease. In the operating room

these factors include the burden of surgical procedures, the use of constant temperature and humidity, high-efficiency particulate air (HEPA) filters, operating room lighting panels, surgical laser and electrocautery instruments, chemical antiseptics, disinfectants and sterilising agents. In addition, operating rooms are likely to contain anaesthetic gases, surgical smoke, ambient particle load, and microbial agents.

Surgical procedure

Surgery is the cornerstone of treatment in many cases. Although there is no standard duration for surgical procedures, it has been found to vary between 42 and 504 minutes in previous studies³⁴. Surgery, itself, is a critical task which requires long-term mental effort and concentration and is associated with reduced frequency of eye blinking and increased evaporation – both potential precipitating factors for the development of dry eye disease. It is well established that reduced frequency of eye blinking during visual tasks requiring long-term mental effort and concentration is associated with increased evaporation of the tear film^{14,19}. Previous studies have also shown that there is a significant inverse relationship between the frequency of eye blinking and tasks requiring long-term mental effort³⁰. The frequency of eye blinking is involuntarily inhibited resulting in increased evaporation during cognitive, mental or visual tasks. To illustrate, the frequency of blinking is reduced to six to ten times per minute while using a computer screen but ranges from 15 to 20 times per minute in standard room temperature and humidity (i.e. 22 °C and 40 per cent humidity) in healthy individuals, although this rate may vary in each individual depending on the personal behavior patterns and

environmental factors^{5,35}. Similarly, occupations and tasks which require high visual and cognitive demands have been proven to be the most common occupational risks for increased dry eye symptoms, underlining the relationship between the increased incidence of dry eye disease and occupational activities requiring a high level of cognitive and visual skills^{10,30}.

Physical environment of the operating room

The quality of the environment is affected by several components such as ambient temperature, humidity, air conditioning, air flow, lighting and noise. It has been well established in many studies that the ambient air of the operating room is contaminated by pollutants including dust particles loaded with bacteria, textile fibers, respiratory aerosols and surgical smoke, thereby leading to the increased rate of surgical site infections and threatening the health of health care workers³⁶⁻³⁸. In accordance with patient and health care worker safety, the cleanroom standards for the operating room using constant room temperature, constant humidity, appropriate air conditioning and air flow and have been implemented for many years to keep contaminants and particles outside the room^{39,40}.

According to the [European] DIN 1946-4 standard, operating rooms, corridors, sterile goods storage, pre- and post-operative recovery rooms, surgical hand washing units and the surroundings, anaesthesia units and units for the processing of medical devices require the highest hygiene requirements and are defined as cleanrooms (Class I) with no viable microorganisms. Patient rooms, emergency wards, laboratories and radiography units are Class II rooms with no viable microorganisms. For cleanrooms, the particle size should

not exceed 0.5 µm and the particle count per cubic meter (m³) or cubic foot (ft³) is the determinant for classification^{37,41}.

Ventilation systems specifically designed to keep the number of microorganisms and particles within the defined range are indispensable to minimising contamination and providing clean air during surgery in the operating room. In accordance with the cleanroom standards, air pollutants such as air particles, microorganisms, dust and electrocautery smoke are eliminated by air filter systems^{42,43}. Currently, traditional or laminar flow diffusers are frequently used in the operating room setting^{40,44,45}.

Based on the criterion of a particle size of 0.5 µm per unit, laminar flow is provided at a degree of primary turbulence of less than five per cent and 0.24 m/sec. In contrast to corridors and other closed rooms, the air flow of the operating room is maintained with positive pressure. In addition, at least 15 total air exchange per hour is maintained using special filters for bacterial particles larger than 0.3 µm^{37,46}. Thanks to the scavenging effect of positive pressure and laminar air flow, the highest protection against particle contamination is ensured. The recommended air filtration and recirculation system in the operating room and intensive care units has two filter beds: the first has 30 per cent efficiency and the second has 90 per cent efficiency. Air particles are removed using special filters with 99.97 per cent efficiency for particles larger than 0.3 µm. Scavenging systems, which are used for anaesthetic gas disposal from the operating room, are the fourth major component of the air filtration systems. These systems are external to the air filtration and vacuum systems and are specifically designed to collect gases and

vapours vented from the breathing circuit and remove them from the operating room^{43,47}. Despite the highest level of protection against particle contamination thanks to the scavenging effect of positive pressure and laminar air flow, the increased air circulation, constant humidity and constant temperature increase the precorneal air exchange, eventually leading to excessive ocular evaporation⁵. Similarly, high horizontal or downward air velocity around the head region enhances the evaporation rate of the tear film, accelerates a temperature decrease, particularly in the cornea, and results in irritation of the ocular surface⁷.

In accordance with operating room standards, the room air should be maintained at 21 to 24 °C and the humidity should be maintained at 30 to 60 per cent to minimise static electricity discharges⁴³. Previous studies show that low ambient humidity (particularly less than 40 per cent) and air flow provided by the air conditioning and ventilation systems and fan coil units had adverse effects on the ocular structures including irritation, burning and hyperaemia. Also, unfavorable environmental factors such as temperature, humidity and air flow resulted in increased severity of ocular symptoms such as itching, redness, pain and decreased visual acuity^{48,49,50}. In low-humidity environments, tear film instability increased and the ocular surface became more vulnerable⁷.

Operating room lighting fixtures consist of a single- or multiple-light head assembly attached to a suspension arm. They can be mounted at a fixed point on the ceiling or wall. Sterilisable handles allow the surgeon to adjust the position of the light easily. Surgical lights are designed to enable optimal visualisation of the surgical site. The surgical lighting requirements

vary depending on the type, brand and model of the lighting system. The illuminance of a surgical light head is measured in lux and should not exceed 160 000 lux⁵¹. In general, standard lighting uses 100 lux illuminance for general lighting of the operating room and 50 000 to 100 000 lux illuminance for the operating table. Surgical lamps can be classified into two main types as conventional (incandescent) and light-emitting diode (LED)^{52,53}. There is no study investigating the effect of high-intensity lighting on the operating room staff in the literature; however, eye fatigue was reported in 59.6 per cent of cleanroom microscope workers^{54,55}. Altogether, these findings indicate that, similar to artificial air conditioners, wind, continuous air flow conditioning and ventilation systems, constant temperature and humidity may increase the rate of evaporative dry eye disease among operating room staff. Considering the high level of illuminance in the operating room, surgical lighting should be considered an ergophthalmological risk factor.

Chemical irritants (antiseptics, disinfectants and sterilising agents)

Surgical asepsis, also referred to as aseptic technique, is the mainstay of safe surgery. The most frequently used chemicals for aseptic technique in the operating room include phenol and phenol derivatives (hexachlorophene), chlorine and chlorine derivatives (hypochlorite), iodine and iodine derivatives (iodophor, povidone-iodine), aldehydes (formaldehyde, glutaraldehyde), alcohols (ethyl alcohol, isopropyl alcohol), ammonium compounds (chlorhexidine) and hydrogen peroxide⁵⁶. Previous studies examined the irritating effects of

these chemicals on the cornea and ocular surface^{57,58}. In a study, acute exposure to chemicals such as ozone, volatile organic compounds, cigarette smoke, nitrogen oxide and combustion products caused irritation of the ocular surface, while chronic exposure was associated with nerve and muscle injury²⁴.

The corneal epithelium is extremely sensitive to chemicals or heat and produces the blink reflex in response to these stimuli. Long-term exposure to such stimuli results in irregularity and edema of the corneal epithelium, thereby leading to prolonged tear break-up time, tear film instability and decreased visual acuity. Formaldehyde is the most potent air pollutant for eye tissues^{59,60}. Additionally, stress and injury to the ocular tissues caused by persistent trigeminal stimulation induced by chemicals through the olfactory tract have been shown to be associated with more frequent itching, burning and lacrimation. Besides formaldehyde, acetaldehyde, acetic acid, ammonia, butanol, formic acid, glutaraldehyde and hydrogen peroxide, many other compounds that are used less frequently have irritating effects on the ocular surface⁶⁰. Previous studies reported that peracetic acid showed a wide range of local effects from mild ocular irritation to irreversible tissue damage, depending on the duration and intensity of exposure^{61,62}. Sporicidal agents containing hydrogen peroxide, peracetic acid and acetic acid for cleaning and disinfection were also associated with eye irritation symptoms in 44 per cent of hospital cleaning staff and the severity of these symptoms increased with prolonged exposure^{63,64}. In another study, eye irritation was the most common adverse event related to the antimicrobial pesticide exposure⁶⁵. Furthermore, glutaraldehyde,

orthophthaldehyde, peracetic acid, hydrogen peroxide, hypochlorous acid, hypochlorite and formaldehyde, which are frequently used for disinfection in the health care setting, were confirmed to be associated with eye irritation symptoms⁶⁶. The current evidence identifies antiseptics, disinfectants and sterilising agents as the main chemical risks which threaten the lives of health care workers⁶⁷. Based on these findings, antiseptics, disinfectants and sterilising agents, either in liquid or gas form, are all a threat for the development of dry eye disease.

Surgical laser and surgical smoke

Surgical smoke is the gaseous by-product caused by thermal tissue destruction during electrosurgery, ultrasonic scalpel dissection and laser tissue ablation or coagulation⁶⁸.

As with cigarette smoke, surgical smoke contains potentially hazardous substances including toluene, polyaromatic hydrocarbons, carbon monoxide, furfural, formaldehyde, decane, benzene, acrylonitrile, acrolein, acetylene and acetaldehyde as well as dead and living cellular materials and viruses⁶⁹.

In a study, Sisler et al.⁷⁰ collected 36 surgical smoke samples in real-time in cell culture media using an electrocautery device to cut and coagulate human breast tissue. A field emission scanning electron microscope was then used to characterise airborne particles collected in the cell medium. The authors detected 17 different volatile organic compounds in all samples. Acetaldehyde, ethanol and isopropyl alcohol were the most frequently detected substances in each sample and were present in high concentrations. The main hazardous

effects of chemicals produced by surgical smoke are irritation to the eye and upper respiratory tract⁷¹.

In another study, Ilce et al.⁷² examined the problems related to surgical smoke exposure in 81 nurses and physicians working in the operating room and reported that the most common complaints were headache, watering of the eyes, cough, sore throat, bad odors absorbed in the hair and nausea. In addition, several studies showed that surgical smoke contained a mixture of chemical and biological contaminants, posing a potential hazard for both patients and operating room staff^{71,73,74}. Furthermore, downward air flow from the ceiling to the floor (i.e. positive pressure) in the operating room dissipated surgical smoke into the surrounding environment, exposing all surgical personnel to it⁷⁵.

In biomedical applications, laser produces a narrow beam of light with a high level of energy concentrated in a very small area. It is widely used for the removal of vascular tumors, as a scalpel to make the opening incision, to collect incisional and excisional biopsy materials, to cauterise vascular lesions, to cut gingiva and oral mucosa, in coagulation and soft tissue curettage, to treat tumors, and in endoscopic procedures⁷⁶. However, it is not safe for patients and operating room staff due to the radiant intensity it has and potential surgical smoke it produces^{77,78}.

Corneal and retinal injury related to laser exposure have been described in the literature and transient or permanent loss of vision may occur. In a previous study, exposure to laser beam caused ocular symptoms such as excessive watering of the eyes or foreign body sensation and decreased visual acuity and blurred vision⁷⁹.

Conclusion and recommendations

In conclusion, dry eye disease is a multifactorial disease of the ocular surface characterised by tear film instability which adversely affects visual functions and quality of life of patients. In the majority of cases, it is caused by excessive evaporation of the tear film and persistent ocular irritation. Besides individual risk factors, in recent years environmental factors and occupations, tasks and habits which require high visual and cognitive demands have been associated with reduced blink rate, ocular symptoms and dry eye disease. Operating rooms are complex, isolated workplaces where different specialties are blended, cutting-edge technology is employed, air quality must be controlled and high standards of cleanliness is required. The nature of surgery, itself, as a critical task requiring long-term mental effort and concentration, often involving prolonged and non-stop working hours, particularly in major surgeries; artificial indoor air conditioning systems, constant humidity, constant room temperature and intense lighting; use of antiseptics, disinfectants and sterilising and sporicidal agents; and, in certain situations, the presence of surgical laser light and surgical smoke should all be considered ergoophthalmological risk factors of dry eye disease among the operating room staff.

References

1. Nelson JD, Craig JP, Akpek EK, Azar DT, Belmonte C, Bron AJ et al. Tear Film & Ocular Surface Society (TFOS) Dry Eye Workshop (DEWS) II Introduction. *Ocul Surf* 2017;15(3):269–275. DOI: 10.1016/j.jtos.2017.05.005.

2. Stapleton F, Alves M, Bunya VY, Jalbert I, Lekhanont K, Malet F et al. Tear Film & Ocular Surface Society (TFOS) Dry Eye Workshop (DEWS) II Epidemiology report. *Ocul Surf* 2017;15(3):334–365. DOI: 10.1016/j.jtos.2017.05.003.
3. Patil SD, Trivedi HR, Parekh NV, Jignesh J. Evaluation of dry eye in computer users. *Int J Community Med Public Health* 2016;3(12):3403–3407. DOI: 10.18203/2394-6040.ijcmph20164264.
4. Farrand KF, Fridman M, Stillman IÖ, Schaumburg DA. Prevalence of diagnosed dry eye disease in the United States among adults aged 18 years and older. *Am J Ophthalmol* 2017;182:90–98. DOI: 10.1016/j.ajo.2017.06.033.
5. Akyol N. Modern life and dry eye. *Turkiye Klinikleri J Ophthalmol – Special Topics*, 2013;6(3):30–35.
6. Sullivan DA, Rocha EM, Aragona P, Clayton JA, Ding J, Golebiowski B et al. Tear Film & Ocular Surface Society (TFOS) Dry Eye Workshop (DEWS) II Sex, gender, and hormones report. *Ocul Surf* 2017;15(3):284–333. DOI: 10.1016/j.jtos.2017.04.001.
7. Wolkoff P. External eye symptoms in indoor environments. *Indoor Air* 2017;27(2):246–260. DOI: 10.1111/ina.12322.
8. Salimifard P, Rim D, Gomes C, Kremer P, Freihaut JD. Resuspension of biological particles from indoor surfaces: Effects of humidity and air swirl. *Sci Total Environ* 2017;583:241–247.
9. Coles-Brennan C, Sulley A, Young G. Management of digital eye strain. *Clin Exp Optom*, 2019;102(1):18–29. DOI: 10.1111/cxo.12798
10. Belmonte C, Nichols JJ, Cox SM, Brock JA, Begley CG, Bereiter DA et al. Tear Film & Ocular Surface Society (TFOS) Dry Eye Workshop (DEWS) II Pain and sensation report. *Ocul Surf* 2017;15(3):404–437. DOI: 10.1016/j.jtos.2017.05.002.
11. Koh S, Tung CI, Inoue Y, Jhanji V. Effects of tear film dynamics on quality of vision. *Br J Ophthalmol* 2018;102(12):1615–1620. DOI: 10.1136/bjophthalmol-2018-312333.
12. Azuma K, Ikeda K, Kagi N, Yanagi U, Osawa H. Physicochemical risk factors for building-related symptoms in air-conditioned office buildings: Ambient particles and combined exposure to indoor air pollutants. *Sci Total Environ* 2018;616:1649–1655.
13. Van Tilborg MM, Murphy PJ, Evans KS. Impact of dry eye symptoms and daily activities in a modern office. *Optom Vis Sci* 2017;94(6):688–693. DOI: 10.1097/OPX.0000000000001086.
14. Wolkoff P. The mystery of dry indoor air – an overview. *Environ Int* 2018;121(2):1058–1065. DOI: 10.1016/j.envint.2018.10.053
15. Nichols KK, Foulks GN, Bron AJ, Glasgow BJ, Doğru M, Tsubota K et al. The international workshop on meibomian gland dysfunction: Executive summary. *Investigative Ophthalmology Vis Sci* 2011;52:1922–1929.
16. Tiskaoglu NS, Yazıcı A, Karlıdere T, Sari E, Oguz EY, Musaoglu M, et al. Dry eye disease in patients with newly diagnosed depressive disorder. *Curr Eye Res* 2017;42(5):672–676. DOI: 10.1080/02713683.2016.1236966
17. Rouen PA, White ML. Dry eye disease: Prevalence, assessment, and management. *Home Healthc Now* 2018;36(2):74–83. DOI: 10.1097/NHH.0000000000000652.
18. Smedbold HT, Ahlen C, Norbäck D, Hilt B. Sign of eye irritation in female hospital workers and the indoor environment. *Indoor Air* 2001;11(4):223–231.
19. Castellanos-González JA, Torres-Martínez V, Martínez-Ruiz A, Fuentes-Orozco C, Rendón-Félix J, Irusteta-Jiménez L et al. Prevalence of dry eye syndrome in residents of surgical specialties. *BMC Ophthalmol* 2016;16:108. DOI: 10.1186/s12886-016-0292-3.
20. Reyhan AH, Bilgin B. Yoğun bakım hemşirelerinde nöbet sonrası gözyaşı bulgularının değerlendirilmesi [Assessment of tear film parameters after working overnight in intensive care nurses]. *Kırıkkale Üni Tıp Fak Derg [Kırıkkale University Faculty of Medicine Journal]*, 2018;20(3):280–286.
21. Janki S, Mulder EEAP, Jzermans JNM, Tran TCK. Ergonomics in the operating room. *Surg Endosc* 2017;31(6):2457–2466.
22. Gutierrez-Diez MC, Benito-Gonzalez MA, Sancibrian R, Gandarillas-Gonzalez MA, Redondo-Figuero C, Manuel-Palazuelos JC. A study of the prevalence of musculoskeletal disorders in surgeons performing minimally invasive surgery. *Int J Occup Saf Ergon* 2018;24(1):111–117.
23. Anshel JR. Visual ergonomics in the workplace. *AAOHN Journal* 2007;55:415–420.
24. Bron AJ, De Paiva CS, Chauhan SK, Bonini S, Gabison EE, Jain S et al. Tear Film & Ocular Surface Society (TFOS) Dry Eye Workshop (DEWS) II Pathophysiology report. *Ocul Surf* 2017;15(3):438–510.
25. Messmer EM. The pathophysiology, diagnosis and treatment of dry eye disease. *Dtsch Arztebl Int* 2015;112(5):71–81.
26. Arita R, Fukuoka S, Morishige N. New insights into the lipid layer of the tear film and meibomian glands. *Eye Contact Lens* 2017;43(6):335–339.
27. Yeh TN, Graham AD, Lin MC. Relationships among tear film stability, osmolarity and dryness symptoms. *Optom Vis Sci* 2015;92(9): 264–272. DOI: 10.1097/OPX.0000000000000649.
28. Willcox MDP, Argüeso P, Georgiev GA, Holopainen JM, Laurie GW, Millar TJ et al. Tear Film & Ocular Surface Society (TFOS) Dry Eye Workshop (DEWS) II Tear film report. *Ocul Surf* 2017;15(3):366–403.
29. Gümüş K. The epidemiology and pathophysiology of dry eye disease. *MN Oftalmoloji*, 2018;25:5–11
30. Wolkoff P, Karcher T, Horst M. Problems of the ‘outer eyes’ in the office environment – an ergophthalmologic approach. *JOEM* 2012;54(5):621–631.
31. Wang MT, Tien L, Han A, Lee JM, Kim D, Markoulli M et al. Impact of blinking on ocular surface and tear film parameters. *Ocul Surf* 2018;16(4):424–429.
32. Portello JK, Rosenfield M, Chu CA. Blink rate, incomplete blinks and computer vision syndrome. *Optom Vis Sci* 2013;90(5):482–487.
33. Hirota M, Uozato H, Kawamorita T, Shibata Y, Yamamoto S. Effect of incomplete blinking on tear film stability. *Optom Vis Sci* 2013;90(7):650–657.
34. Eijkemans MJC, Houdenhoven M, Nguyen T, Boersma E, Steyerberg EW, Kazemier G. Predicting the unpredictable: A new prediction model for operating room times using individual characteristics and the surgeon’s estimate. *Anesthesiology* 2010;112(1):41–49. DOI: 10.1097/ALN.0b013e3181c294c2.
35. Alex A, Edwards A, Hays JD, Kerkstra M, Shih A, de Paiva CS et al. Factors predicting the ocular surface response to desiccating environmental stress. *Invest Ophthalmol Vis Sci* 2013;54(5):3325–32. DOI: 10.1167/iovs.12-11322.
36. Noguchi C, Koseki H, Horiuchi H, Yonekura A, Tomita M, Higuchi T et al. Factors contributing to airborne particle dispersal in the operating room. *BMC Surg* 2017;17(1):78–92.
37. Friedrich L, Boeckelmann I. Hygienische Abnahmeprüfungen raumlufttechnischer Anlagen unter Ruhebedingungen nach DIN 1946-4:1999-03 – eine retrospektive Auswertung [Hygienic inspections of ventilation systems under resting conditions (According to DIN 1946-4:1999-03) – a retrospective assessment]. *Zentralbl Chir [Central sheet for Surgery]* 2018;143(6):617–624. DOI: 10.1055/s-0043-120916.
38. McHugh SM, Hill AD, Humphreys H. Laminar airflow and the prevention of surgical site infection: More harm than good? *Surgeon* 2015;13(1):52–58. DOI: 10.1016/j.surge.2014.10.003.
39. Pada S, Perl TM. Operating room myths: What is the evidence for common practices. *Curr Opin Infect Dis* 2015;28(4):369–374. DOI: 10.1097/QCO.0000000000000177.

40. Bischoff P, Kubilay NZ, Allegranzi B, Egger M, Gastmeier P. Effect of laminar airflow ventilation on surgical site infections: A systematic review and meta-analysis. *Lancet Infect Dis* 2017;17(5):553–561. DOI: 10.1016/S1473-3099(17)30059-2.
41. American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). Interpretation IC 170-2013-1 of ANSI/ASHRAE/ASHE Standard 170-2013 Ventilation of Health Care Facilities [Internet]. Peachtree Corners, GA: ASHRAE; 2014 [cited 2021 January 02]. Available from: www.ashrae.org/technical-resources/standards-and-guidelines/standards-interpretations/interpretations-for-standard-170-2013.
42. International Organization for Standardization (ISO). ISO 14644-1:2015 Cleanrooms and associated controlled environments — Part 1: Classification of air cleanliness by particle concentration [Internet]. Geneva: ISO; 2015 [cited 2021 January 02]. Available from: www.iso.org/standard/53394.html.
43. Katz JD. Control of the environment in the operating room. *Anesth Analg* 2017;125(4):1214–1218.
44. Centers for Disease Control and Prevention (CDC). Environmental Infection Control Guidelines: Guidelines for Environmental Infection Control in Health-Care Facilities (2003) [Internet]. Atlanta: CDC; 2003 [cited 2021 January 02]. Available from: www.cdc.gov/infectioncontrol/guidelines/environmental/index.html.
45. Pasquarella C, Barchitta M, D'Alessandro D, Cristina ML, Mura I, Nobile M et al. Heating, ventilation and air conditioning (HVAC) system, microbial air contamination and surgical site infection in hip and knee arthroplasties: The GISIO-Siti Ischia study. *Ann Ig* 2018;30(5):22–35.
46. Alsved M, Civilis A, Ekolind P, Tammelin A, Andersson AE, Jakobsson J et al. Temperature-controlled airflow ventilation in operating rooms compared with laminar airflow and turbulent mixed airflow. *J Hosp Infect*, 2018;98(2):181–190.
47. Totaro M, Costa AL, Casini B, Profeti S, Gallo A, Frendo L et al. Microbiological air quality in heating, ventilation and air conditioning systems of surgical and intensive care areas: The application of a disinfection procedure for dehumidification devices. *Pathogens*, 2019;8(1):1–8.
48. Abusharha AA, Pearce EI, Fagehi R. Effect of ambient temperature on the human tear film. *Eye Contact Lens* 2016;42(5):308–312. DOI: 10.1097/ICL.0000000000000210.
49. Alves M, Novaes P, Morraye MA, Reinach PS, Rocha EM. Is dry eye an environmental disease? *Arq Bras Oftalmol* 2014;77(3):193–200.
50. Zhang X, Vimalin MJ, Qu Y, He X, Ou S, Bu J et al. Dry eye management: Targeting the ocular surface microenvironment. *Int J Mol Sci* 2017;18(7):1398. DOI: 10.3390/ijms18071398.
51. Curlin J, Herman CK. Current State of Surgical Lighting. *Surg J (NY)* 2020;6(2):87–97.
52. Lim SR, Kang D, Ogunseitan OA, Schoenung JM. Potential environmental impacts from the metals in incandescent, compact fluorescent lamp (CFL), and light-emitting diode (LED) bulbs. *Environ Sci Technol* 2011;45(1):320–327.
53. Hawesa BK, Brunyé TT, Mahoney CR, Sullivan JM, All CD. Effects of four workplace lighting technologies on perception, cognition and affective state. *Int J Ind Ergon* 2012;42(1):122–128.
54. Pachito DV, Eckeli AL, Desouky AS, Corbett MA, Partonen T, Rajaratnam SM et al. Workplace lighting for improving alertness and mood in daytime workers. *Cochrane Database Syst Rev* 2018;3, CD012243.
55. Lin KH, Su CC, Chen YY, Chu PC. The effects of lighting problems on eye symptoms among cleanroom microscope workers. *Int J Environ Res Public Health* 2019;16(1):101. DOI: 10.3390/ijerph16010101.
56. Vazquez-Ferreiro P, Carrera Hueso FJ, Alvarez LB, Diaz-Rey M, Martinez-Casal X, Ramón Barrios MA. Evaluation of formaldehyde as an ocular irritant: A systematic review and meta-analysis. *Cutan Ocul Toxicol* 2019;38(2):169–175. DOI: 10.1080/15569527.2018.1561709.
57. Jung SJ, Mehta JS, Tong L. Effects of environment pollution on the ocular surface. *Ocul Surf* 2018;16(2):198–205.
58. Slaughter RJ, Watts M, Vale JA, Grieve JR, Schep LJ. The clinical toxicology of sodium hypochlorite. *Clin Toxicol* 2019;57(5):303–311. DOI: 10.1080/15563650.2018.1543889.
59. Lai LJ, Hsu WH, Wu AM, Wu JH. Ocular injury by transient formaldehyde exposure in a rabbit eye model. *PLoS One* 2019;8(6):e66649. DOI: 10.1371/journal.pone.0066649.
60. Vitoux MA, Kessal K, Baudouin C, Laprèvote O, Parsadaniantz S, Achard S et al. Formaldehyde gas exposure increases inflammation in an in vitro model of dry eye. *Toxicol Sci* 2018;165(1):108–117.
61. Pacenti M, Dugheri S, Boccalon P, Arcangeli G, Dolara P, Cupelli V. Air monitoring and assessment of occupational exposure to peracetic acid in a hospital environment. *Ind Health* 2010;48(2):217–221.
62. Pechacek N, Osorio M, Caudill J, Peterson B. Evaluation of the toxicity data for peracetic acid in deriving occupational exposure limits: A minireview. *Toxicol Lett* 2015;233(1):45–57.
63. Hawley B, Casey M, Virji MA, Cummings KJ, Johnson A, Cox-Ganser J. Respiratory symptoms in hospital cleaning staff exposed to a product containing hydrogen peroxide, peracetic acid and acetic acid. *Ann Work Expo Health* 2017;62(1):28–40.
64. Pougnet R, Lucas D, Durand-Moreau Q, Dewitte JD, Loddé B. Occupational bronchial disease caused by peracetic acid-hydrogen peroxide mixture: Discussion about reactive airways dysfunction syndrome. *Occup Med* 2019;69(8):635–636. DOI: 10.1093/occmed/kqz130.
65. Casey ML, Hawley B, Edwards N, Cox-Ganser JM, Cummings KJ. Occupational health risks associated with the use of germicides in health care. *Am J Infect Control* 2016;44:85–89.
66. Weber DJ, Consoli SA, Rutala WA. Occupational health risks associated with the use of germicides in health care. *Am J Infect Control* 2016;44:85–89.
67. Walters GI, Burge PS, Moore VC, Thomas MO, Robertson AS. Occupational asthma caused by peracetic acid-hydrogen peroxide mixture. *Occup Med* 2019;69(4):294–297.
68. Fencl JL. Guideline implementation: Surgical smoke safety. *AORN J* 2017;105(5):488–497.
69. Okoshi K, Kobayashi K, Kinoshita K, Tomizawa Y, Hasegawa S, Sakai Y. Health risks associated with exposure to surgical smoke for surgeons and operation room personnel. *Surg Today* 2015;45(8):957–65.
70. Sisler J, Shaffer J, Soo J, LeBouf R, Harper M, Qian Y. In vitro toxicological evaluation of surgical smoke from human tissue. *J Occup Med Toxicol* 2018;13:1–12.
71. York Y, Autry M. Surgical smoke: Putting the pieces together to become smoke-free. *AORN J* 2018;107(6):692–703. DOI: 10.1002/aorn.12149.
72. Ilce A, Yuzden GE, Yavuz van Giersbergen M. The examination of problems experienced by nurses and doctors associated with exposure to surgical smoke and the necessary precautions. *J Clin Nurs* 2017;26(11–12):1555–1561.
73. Choi SH, Kwon TG, Chung SK, Kim TH. Surgical smoke may be a biohazard to surgeons performing laparoscopic surgery. *Surg Endosc* 2014;28(8):2374–2380.
74. Bree K, Barnhill S, Rundell W. The dangers of electrosurgical smoke to operating room personnel: A review. *Workplace Health Saf* 2017;65(11):517–526.

75. Tseng HS, Liu SP, Uang SN, Yang LR, Lee SC, Liu YJ et al. Cancer risk of incremental exposure to polycyclic aromatic hydrocarbons in electrocautery smoke for mastectomy personnel. *World J Surg Oncol* 2014;12:11–31.
76. Azadgoli B, Baker RY. Laser applications in surgery. *Ann Transl Med* 2016;4(23):452.
77. Eder SP. Guideline implementation: Energy-generating devices, part 1 – electrosurgery. *AORN J* 2017;105(3):300–310.
78. Burlingame BL. Guideline implementation: Energy-generating devices, part 2 – lasers. *AORN J* 2017;105(4). 392–401.
79. Castelluccio D. Implementing AORN recommended practices for laser safety. *AORN J* 2012;95(5):612–624.

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Capnography monitoring in the Post Anaesthesia Care Unit (PACU)

Abstract

Problem identification

Capnography monitoring has been identified as a valuable monitoring tool to assist in the early detection of respiratory adverse events in post-operative patients in the PACU who are receiving supplemental oxygen. This integrated review of literature aims to identify the usefulness of implementing capnography monitoring in the PACU as standard practice to ensure safe patient outcomes.

Literature search

A search was undertaken of Scopus, Cumulative Index Nursing and Allied Health Literature (CINAHL) Complete, Health Source: Nursing and Academic Edition, Clinical Key, PubMed and MEDLINE Complete electronic databases. Articles (n=12) were selected for this review including a randomised control trial (RCT), quality improvement projects, a prospective observation study, a prospective cross-sectional study, an evidence summary and a systematic review and meta-analysis study.

Data evaluation synthesis

The main indicators for the use of capnography in the PACU included patients on assisted oxygen, patients receiving opioid analgesia, patients with obstructive sleep apnoea and paediatric patients. All articles related to capnography presented complimentary findings regarding the usefulness of capnography monitoring and its implementation in the PACU.

Implications for perioperative nursing practice or research

Capnography is effective in identifying compromised ventilation in post-operative patients who are receiving supplemental oxygen in the PACU, compared to the use of pulse oximetry alone. The literature recommends the combined use of pulse oximetry and capnography in the post-operative period to provide clinicians with a complete assessment of a patients ventilatory status. Nursing education is indicated to improve respiratory assessments and monitoring skills of PACU nurses combined with further research to ensure the effective implementation of capnography in the PACU.

Keywords: capnography, end tidal carbon dioxide (ETCO₂), hypoxaemia, PACU, paediatrics, respiratory depression, sleep apnoea

Introduction

Capnography is a method for monitoring the partial pressure of carbon dioxide in the blood and end tidal capnography measures the partial pressure of carbon dioxide at the end of an exhaled breath¹, i.e. end tidal carbon dioxide (ETCO₂). This observation is non-invasive and occurs through a gas sampling line attached to a mask or nasal prongs in the spontaneously breathing patient². The significance of capnography is its ability to determine the effectiveness of ventilation in patients exposed to supplemental oxygen³.

Patients in the Post Anaesthesia Care Unit (PACU) are at high risk of adverse respiratory events due the effects of sedation, the use of opioid analgesia and other anaesthetic agents⁴. Respiratory depression, also referred to as hypoventilation, is slow and ineffective breathing which can lead to increasing carbon dioxide levels in the blood (hypercapnia) and low blood oxygen levels (hypoxaemia)¹. Very early signs of malignant hyperthermia are also heralded by an exponential increase in ETCO₂ levels; therefore capnography may assist in faster detection of this life-threatening event⁵.

The suite of standard observations in Australian PACUs includes level of consciousness, blood pressure, oxygen saturation, heart rate, respiratory rate, temperature, comfort level, urine output, wound dressing and drain output, Bromage scores, and dermatome levels, if applicable⁶. While currently not mandated, electrocardiogram (ECG) is standard for many PACU units and is growing in popularity⁷.

The use of assisted oxygen is known to mask the signs of inadequate or deteriorating respiratory function, and this has resulted in tragic patient outcomes⁸. Oxygen

saturation is currently observed using pulse oximetry which is beneficial for identifying hypoxaemia but of limited use when a patient is exposed to supplemental oxygen as pulse oximetry cannot accurately and rapidly detect a patient with compromised ventilation¹.

Capnography can identify variations in ETCO₂, respiratory rate, breathing pauses and cessation of breathing (apnoea), providing clinicians with real time information regarding a patient's ventilatory status^{1,2}. Capnography has not been broadly adopted as part of standard monitoring practice in PACUs, despite a growing body of research justifying its adoption for post-operative patients on supplemental oxygen¹. Capnography would be a valuable tool in addition to the existing suite of standard observations to enable early nursing intervention and the prevention of respiratory adverse events⁹.

This review has evaluated and synthesised the relevant literature and will discuss capnography use in the PACU, the implications for perioperative nursing and finally the translation of knowledge concerning this valuable monitoring tool.

Problem identification

The use of assisted oxygen may mask a deterioration in respiratory function⁸. While pulse oximetry is a valuable part of observations performed by nurses in the PACU, this tool alone cannot detect compromised ventilation with sufficient accuracy in patients who are receiving supplemental oxygen¹. Patients recovering on supplemental oxygen may decline rapidly due to ineffective ventilation long before a coincidental drop in blood oxygen saturation is reflected by pulse oximetry¹⁰.

In the operating theatre, the use of capnography has become a standard practice to monitor the continuous ventilation of intubated patients^{11,12}. While capnography monitoring has become increasingly used in critical care areas, to assist with the early detection of respiratory events, it has not been broadly implemented as standard practice for monitoring in the PACU¹⁰. This review aims to identify the usefulness of implementing capnography monitoring in the PACU as standard practice to ensure safer patient outcomes.

Literature search

Design

This review adopts the method outlined by Whittemore and Knafl for conducting an integrative review¹³. This method includes five stages – problem identification, literature search, data evaluation, data analysis and presentation – providing an exhaustive review of the literature for inclusion in this review¹³.

Literature search methods

A search of the literature was undertaken electronically using databases including EBSCOhost (including Cumulative Index Nursing and Allied Health Literature (CINAHL Complete), Health Source: Nursing and Academic Edition, Clinical Key, PubMed and MEDLINE Complete. Medical subject headings (MeSH) terms, parentheses, truncation and Boolean operators were used included Capnography" OR "End tidal carbon dioxide" OR "ETCO₂" OR "Capnometry" AND "Monitoring" AND "Post Anaesthesia Care Unit" OR "PACU" OR "Recovery" OR "Postoperative.

Delimiters regarding peer-reviewed articles only and year of publication were set, with articles accepted

from 2015 to 2020, in order to ensure only relevant, timely and quality articles were used in this literature review. Articles were excluded if the full-text was not written in English, due to language constraints of the authors. Primary sources of literature were prioritised for the purpose of allowing direct interpretation of results. Editorials, conference abstracts and opinion papers were excluded due to inability to directly analyse the quality of the research included.

This search criteria identified 25 articles excluding duplicates, which were reviewed against the inclusion and exclusion criteria to determine applicability. Initially 12 articles were selected including a randomised control trial (RCT), quality improvement projects, a prospective observation study, a prospective cross-sectional study, an evidence summary and a systematic review and meta-analysis study.

A review of the reference lists was also completed in search of other relevant articles for inclusion in the review. Four additional pieces of literature were included in this paper, one provided information on writing an integrated review, two provided further background information on monitoring, and one explored the risks of assisted oxygen.

Data evaluation and synthesis

The final 16 articles were read and examined to identify background information and indications for the use of capnography. Indications included patients on assisted oxygen, patients receiving opioid analgesia, patients with obstructive sleep apnoea (OSA) and paediatric patients. These four indications have been used as subthemes to facilitate this review.

Results: Studying the performance of capnography in the PACU

The Australian and New Zealand College of Anaesthetists (ANZCA) PS04 Statement on the Post Anaesthesia Care Unit states that capnography monitoring must be applied to patients with an endotracheal tube and must be available if a patient is intubated or requires intubation in the PACU⁶. There are currently no recommendations for the use of capnography as standard monitoring in the PACU although respiratory events are frequent and capnography would be beneficial to ensure the safety of post-operative patients².

Three studies analysed the use and effectiveness of capnography monitoring in the PACU environment. A prospective observational study was conducted by Chung et al. to determine the usefulness of capnography in the PACU for early detection and intervention in comparison to the standard PACU monitoring². PACU nurses adopted standard monitoring while capnography monitoring was undertaken by researchers². The capnography detected respiratory adverse events 8.3 to 11 minutes earlier than standard monitoring in 75 per cent of cases². Chung et al. concluded that the addition of capnography to standard PACU monitoring would be valuable in the early detection of respiratory adverse events². A systematic review and meta-analysis conducted by Lam et al. identified an increase in ETCO₂ to be a valuable indicator and early warning sign for respiratory depression¹. Data revealed that a group monitored with continuous capnography identified 8.6 per cent more episodes of post-operative respiratory depression than those

observed in the group with pulse oximetry (11.5% compared to 2.8%; $P<.00001$)¹. Lam et al. also found capnography provided an accuracy six times greater than pulse oximetry alone in the detection of respiratory depression ($P<.00001$)¹. Similarly, a quality improvement project conducted by Latham et al. in a large hospital PACU identified that the early detection of respiratory complications was 28 times more likely with capnography than pulse oximetry⁴.

Capnography can also provide early identification of patients at risk of respiratory events prior to discharge from the PACU, allowing for transfer to an area of higher-level care or for increased supervision on lower acuity units². A prospective cross-sectional study was conducted by Zito et al. to determine if the confidence of nurses was increased with the use of ETCO₂ in the discharge of patients from the PACU¹⁴. The confidence of nurses regarding patient readiness for discharge differed before and after the assessment of ETCO₂, suggesting ETCO₂ has an important role as a monitoring tool to ensure safe discharge from the PACU to lower acuity nursing areas, such as the surgical wards¹⁴.

The apparent opportunity to improve the safety of post-operative patients in relation to respiratory events using capnography is well documented². The four main areas of focus for the use of capnography in the PACU identified in the literature include patients receiving assisted oxygen, patients receiving opioid analgesia, patients with OSA and paediatric patients. It is well accepted that patients in these categories are at heightened risk of compromised ventilation while recovering from general anaesthetic.

The ability of supplemental oxygen to mask underlying respiratory function

While not a specific case study related to the PACU, a coronial communique⁸ reminds readers that supplemental oxygen may mask the signs of poor or deteriorating respiratory function as it elevates oxygenation and therefore pulse oximetry readings which would otherwise be falling if the patient were breathing room air⁸. The use of capnography in cases where supplemental oxygen is being used would allow faster, more accurate detection of alterations in respiratory function³.

Opioid analgesia

Patients in the PACU are at risk of respiratory depression and hypoxaemia which is further compounded by the need for analgesia for post-operative pain management¹⁵. Carlisle states that opioid-related adverse events can be prevented in the perioperative setting through the improvement of monitoring practices¹⁰. One observational study and two quality improvement projects were identified in the literature relating to the use of capnography in the PACU for patients receiving opioid analgesia^{3,10,12}

A prospective observational study conducted by Jungquist et al. included orthopaedic patients in the PACU wearing three types of electronic monitoring – pulse oximetry, capnography and minute ventilation. The study aimed to examine the effectiveness of these devices in identifying respiratory adverse events in patients³. All patients had supplemental oxygen and 48 out of 60 patients wore all three types of monitoring³. Findings revealed that 50 per cent (n=24) of patients displayed signs of opioid induced respiratory

depression (OIRD), detected as hypoventilation through unchanged oxygen saturation, increased ETCO₂ and decreased minute ventilation³. Jungquist et al. concluded that while capnography and minute ventilation were effective in the PACU for identifying patients with respiratory compromise, analysing oxygen saturation alone (in patients with assisted oxygen) is more reactive which may compromise intervention response times and expose patients to an increased risk of subsequent adverse events³. Jungquist et al. concluded that a proactive approach rather than a reactive approach is beneficial to identify patients at risk of OIRD³.

Carlisle conducted a quality improvement project that involved the implementation of capnography as standard monitoring in the PACU to reduce the risk of OIRD with 71 per cent (n=174) of patients displaying at least one risk factor for OIRD¹⁰. Nursing education concerning OIRD risk assessment and capnography was implemented and twelve months after its implementation a significant rise in the frequency of capnography monitoring in high risk OIRD patients was observed¹⁰. Carlisle concluded that the implementation resulted in an improvement in the number of high-risk patients receiving capnometry monitoring and a decrease in the number of OIRD cases¹⁰.

Another quality improvement project was conducted by Oswald et al. to improve the monitoring of high-risk patients and patients receiving opioids in the PACU through the use of capnography¹². Capnography identified 44 per cent (n=14) of patients had high ETCO₂ and 48 per cent (n=16) of patients had a low respiratory rate (< 10 bpm). Capnography identified respiratory depression earlier than

pulse oximetry oxygen saturation observations in 100 per cent (n=33) of patients¹².

Obstructive sleep apnoea (OSA)

OSA is the obstruction of the upper airway during sleep⁹. It is a sleep disorder that is caused by the relaxation of the pharyngeal muscles resulting in decreased airflow⁹. While this condition is increasing in prevalence, 80 per cent of surgical patients continue to be undiagnosed at the time of surgery due to poor understanding of symptoms⁹. In turn, this increases the risk of post-operative respiratory adverse events resulting in partial or complete airway obstruction⁴. Capnography monitoring of post-operative patients with OSA has been implemented in two quality improvement projects found in the literature with further recommendations for use supported by a best practice evidence summary.

A quality improvement project conducted by Scully et al. included patients with OSA, 36 per cent of which were preoperatively identified as high risk of OSA⁹. An OSA screening tool was implemented as well as a nursing education package that focused on capnography. Capnography was subsequently used on 76 per cent (n=241) of OSA patients, allowing nurses to easily detect hypoventilation and intervene accordingly⁹. Respiratory complications relating to OSA occurred in 10.8 per cent (n=34) of patients who required high level care⁹. Scully et al. concluded that the implementation of capnography in the PACU resulted in an improvement in the respiratory assessment skills of nurses and a coextensive decrease in respiratory complications for OSA patients⁹. Similarly, a quality improvement project conducted by Latham et al. included patients screened for OSA,

with the implementation of an OSA screening tool and capnography in the PACU after nursing education⁴. It was found that 67 per cent (n=41) of post-operative patients were identified as high risk for OSA with 76 per cent (n=31) of these patients having no previous diagnosis of OSA⁴. The conclusion drawn by Latham et al. was that capnography monitoring effectively identified patients at risk of respiratory complications, allowing for early nursing interventions to ensure safe patient care⁴.

The use of capnography for monitoring post-operative patients at risk of OSA in the PACU has been recommended as best practice by the 2019 Joanna Briggs Institute (JBI) evidence summary to prevent respiratory adverse events¹⁶. Education for health care providers on capnography monitoring for post-operative patients and the interpretation of capnography findings, used in conjunction with clinical observation and assessment, is also recommended as best practice¹⁶.

Paediatric patients

In the PACU, hypoventilation and apnoea are the most common respiratory events that occur among paediatric patients¹⁵. Two studies completed by Langan et al. reviewed hypoventilation and capnography monitoring in children in the PACU after analgesia^{11,15}.

A randomised control trial conducted by Langan et al. included 201 children, with 98 patients in the control group and 103 in the intervention group. PACU nurses were randomly allocated to be able to see the capnography monitor with the intervention group and not see the monitor with the control group¹¹. Standard monitoring including pulse

oximetry was applied and 94 per cent of patients received supplemental oxygen¹¹. The results found decreased rates of hypoventilation and apnoea over time between the children in the intervention group (with capnography) and the children in the control group (with pulse oximetry)¹¹. The results were related to a higher rate of identification of respiratory issues and improved effectiveness of interventions by nursing staff¹¹. Decreased rates of slow breathing over time were found in the control group compared to the intervention group and no difference in hypoxaemia was found over time between the two groups¹¹. Langan et al. concludes that capnography identified most of the respiratory events among children in the PACU, resulting in fewer adverse events due to improved nursing interventions¹¹.

A prospective cross-sectional study conducted by Langan et al. included 194 children randomly selected with capnography monitors concealed from the view of PACU nurses¹⁵. Standard monitoring including pulse oximetry was applied and 86.5 per cent of patients received supplemental oxygen¹⁵. Capnography detected hypoventilation or apnoea in 45.5 per cent (95% CI 38.5%, 52.5%) of patients and oxygen desaturations in 19 per cent (95% CI 13%, 24%) of patients, with interventions in 9 per cent (95% CI 5%, 13%) of patients¹⁵. Hypoventilation or apnoea was observed as more likely to occur in patients who received narcotic medication and supplemental oxygen¹⁵. Langan et al. concluded that capnography as part of standard monitoring could improve the detection of respiratory depression and improve the safety of patients in the PACU¹⁵.

Implications for perioperative nursing practice or research

This review examined the limited available literature regarding the effective use of capnography monitoring in the PACU to ensure safe patient outcomes. The articles obtained for the review were mainly quality improvement projects and prospective studies from the USA and Canada, and one Australian coronial communique. Jungquist et al. suggests that the limited types of studies conducted to date may have been driven by ethical considerations relating to experimental approaches to care of PACU patients³. Differences may also be present in the capnography thresholds from the studies conducted overseas potentially skewing the results and final outcomes.

The majority of studies identified in this review draw from analysis of the comparative effectiveness of capnography across classes of treatment where capnography has been identified as beneficial and best practice. This includes patients having supplemental oxygen, those receiving opioid analgesia, patients with OSA and paediatric patients. Some studies have noted the effectiveness of capnography monitoring compared to pulse oximetry alone in identifying compromised ventilation justifying the expanded adoption across the PACU environment for all patients where supplemental oxygen is applied. The empirical results indicate with sufficient clarity that capnography presents ventilatory data faster and with superior accuracy to pulse oximetry allowing for rapid response and improved patient outcomes. Ventilation changes will also be detected even

with the use of assisted oxygen, allowing respiratory deterioration to be more easily detected in the cohort³. The combined use of pulse oximetry and capnography in the post-operative period would provide clinicians with a complete assessment of a patient's ventilatory status to improve patient safety and prevent respiratory adverse events¹². Such recommendations are well supported in the data and the study outcomes with nursing education indicated to improve the assessment skills of PACU nurses combined with further research to ensure the effective implementation of capnography in the PACU.

Knowledge translation

PACU nurses are a vital part of the perioperative team, ensuring the safety and care of the post-operative patient. As adverse respiratory events are frequent, the value of capnography monitoring in the PACU is clear and highly recommended as best practice in the reviewed literature. Although not currently standard practice in Australian PACUs, the use of capnography monitoring is unlimited and encouraged for use in all patients receiving supplemental oxygen as well as patients who have been administered opioid analgesia, patients with OSA or patients from the paediatric population. Further education among the nursing profession is suggested to improve the analysis, interpretation and response to capnography measures resulting in improved respiratory assessments and monitoring skills of PACU nurses.

Conclusion and recommendations

Capnography is an underutilised tool for monitoring and responding to events of compromised ventilation in the PACU. To date, mandatory use

of capnography or its adoption as part of the best practice suite of standard observations has not been implemented except for intubated patients. Research in this study area suggests that the accuracy and sensitivity of ETCO₂ capnography in identifying ineffective ventilation should support its adoption more broadly across PACU environments to complement pulse oximetry readings for patients on supplemental oxygen.

All 12 studies that were specifically related to capnography demonstrated that ETCO₂ monitoring could highlight an adverse respiratory event several minutes faster than pulse oximetry alone. This is because a coincident drop in blood oxygen saturation may not be logged by pulse oximetry observations for some time after an event of compromised ventilation, by which time the drop in oxygen saturation may be rapid, severe and fatal. The research has demonstrated that adoption of capnography monitoring is likely to result in more rapid and life-saving interventions for patients receiving supplemental oxygen.

The body of evidence available emanates from three main study areas where the risk of compromised ventilation is perceived to be higher – patients receiving opioid analgesia, patients presenting with OSA and patients from the paediatric population. It is however suggested that broader adoption of capnography for all patients receiving supplemental oxygen in the PACU would likely be supported by further research in this area. A number of studies have also emphasised the importance of nursing education in monitoring and interpreting capnography results. This point should not be understated and is critical to such an initiative.

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References

1. Lam T, Nagappa M, Wong J, Singh M, Wong D, Chung F. Continuous pulse oximetry and capnography monitoring for post-operative respiratory depression and adverse events: A systematic review and meta-analysis. *Anesth Analg* 2017;125(6):2019–2029.
2. Chung F, Wong J, Mestek M, Niebel K, Lichtenthal P. Characterisation of respiratory compromise and the potential clinical utility of capnography in the post-anesthesia care unit: A blinded observational trial. *J Clinical Monitoring and Computing* 2019;34(2020):541–551.
3. Jungquist C, Chandola V, Spulecki C, Nguyen K, Crescenzi P, Tekeste D et al. Identifying patients experiencing opioid induced respiratory depression during recovery from anesthesia: The application of electronic monitoring devices. *Worldviews Evid-based Nurs* 2019;16(3):186–194.
4. Latham K, Bird T, Burke J. Implementing microstream end tidal CO₂ in the PACU. *J Perianesthesia Nurs* 2018;33(1):23–27.
5. Hopkins P, Girard T, Dalay S, Jenkins B, Thacker A, Patteril M et al. Malignant hyperthermia 2020 Guideline from the Association of Anaesthetists. *Anaesthesia*. 2021;76:655–664.
6. Australian and New Zealand College of Anaesthetists (ANZCA). PS04 Statement on the Post Anaesthesia Care Unit [Internet]. Melbourne: ANZCA; 2020 [cited 7 May 2021]. Available from: www.anzca.edu.au/4e793bd3-6f6a-46b0-9058-1a425392d0ea.
7. Foran P. ECG for all patients in the PACU: Some say why? I say why not? *JPN* 2020;33(2):36–38.
8. Young C. Case #1: Not going to plan. *Clinical Communiqué* 2017;4(1):2.
9. Scully K, Rickerby J, Dunn J. Implementation science: Incorporating obstructive sleep apnoea screening and capnography into everyday practice. *J Perianesthesia Nurs* 2020;35(2020):7–16.

10. Carlisle H. Promoting the use of capnography in acute care settings: An evidence-based practice project. *J Perianesthesia Nurs* 2015;30(3):201–208.
11. Langan M, Li F, Lichtor J. The impact of capnography monitoring among children and adolescents in the postanesthesia care unit: A randomised control trial. *Paediatr Anaesth* 2017;27:285–393.
12. Oswald L, Zeuske T, Pfeffer J. Implementing capnography in the PACU and beyond. *J Perianesthesia Nurs* 2016;31(5):392–396.
13. Whittemore R, Knafl K. The integrative review: Updated methodology. *J Adv Nurs* 2005;52(5):546–553.
14. Zito A, Berardinelli A, Butler R, Morrison S, Albert N. Association of end-tidal carbon dioxide monitoring with nurses' confidence in patient readiness for postanesthesia discharge. *J Perianesthesia Nurs* 2019;34(5):971–977.
15. Langan M, Li F, Lichtor J. Respiratory depression detected by capnography among children in the postanesthesia care unit: A cross-sectional study. *J Paediatric Anaesthesia* 2016;26:1010–1017.
16. Sivapuram M. Joanna Briggs Institute evidence summary obstructive sleep apnoea risk: Post-operative capnography monitoring. Clinical Guideline 2019.

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Identifying barriers to patient advocacy in the promotion of a safety culture: An integrative review

Abstract

Problem identification

Promoting patient safety, through patient advocacy, is an important part of the perioperative nurse role. However, identified barriers to effective patient advocacy have also reflected deficits in the characteristics of safety culture. This integrative review aims to highlight these barriers and discuss strategies for promoting patient safety within the perioperative context by presenting links between patient advocacy and safety culture.

Literature search

An electronic search of the databases, EBSCOhost, Academic search ultimate, Cumulative Index Nursing and Allied Health Literature (CINAHL), Healthsource, MEDLINE and PubMed, was undertaken and yielded ten articles for inclusion. Primary research included in this review consisted of five qualitative studies, three quantitative studies and two case studies. Further literature was used to provide background into this subject and guidance on writing this paper.

Data evaluation synthesis

The selected research was critically appraised for methodological quality using JBI critical appraisal checklists for case reports, qualitative and prevalence research. A data extraction table was used to record, group, compare and inform the integrative process of thematic analysis and data synthesis, generating themes that emerged through the selected literature.

Implications for practice

Synthesised findings will highlight the importance of patient advocacy by the perioperative nurse to increase patient safety. This review of the literature will present barriers to patient advocacy and discuss the suggestion that the key to greater patient safety may be an organisational commitment to enhance patient advocacy by perioperative nurses allowing them to speak up on behalf of their patients.

Keywords: patient safety, safety culture, patient advocacy, perioperative nursing

Introduction

Patients put their trust in the health care system to provide high-quality, safe care that will meet their needs and expectations¹. Acceptance of accountability for practice and acknowledgement of the nurse's role in protecting a patient's autonomy and right to care that is of high quality, and both clinically and culturally safe, is paramount². This could not be more important than in the perioperative context, where patients are exposed to the vulnerabilities associated with undergoing anaesthesia when they are temporarily unable to act on their own behalf³.

In the words of Virginia Henderson, a famous nursing theorist, when defining patient advocacy in nursing

the nurse is temporarily the consciousness of the unconscious, the love of life for the suicidal, the leg of the amputee, the eyes of the newly blind, a means of locomotion for the infant, knowledge and confidence for the young mother, and a 'mouthpiece' for those too weak or withdrawn to speak⁴ p.63.

The objectives of this review are to understand the relationship between patient advocacy and safety culture in the perioperative context; to present the perioperative nurse role in patient advocacy; discuss some of the barriers to patient advocacy, including hierarchy in the perioperative environment and fear of blame; and identify strategies to overcome these barriers, including flattening the hierarchy, open-communication and non-punitive approaches to risk reporting.

Problem identification

Patient advocacy in the perioperative context has been widely researched over the last two decades. Results

have shown that perioperative nurses view their role as a protector from harm and a human rights activist³. Patient advocacy provides nurses with the opportunity to exercise their professional, moral and ethical perspective, promoting empowerment and professional satisfaction⁵. Barriers to perioperative nurse advocacy, such as hierarchy and communication constraints, have been well described in discussion papers reflecting on clinical practice⁶⁻⁸. These papers also highlight the relationship between advocacy and the concept of safety culture⁶⁻⁸. As recognised by the Australian Commission on Safety and Quality in Health Care (ACSQHC), safety culture is a key element in the collaborative delivery of high-quality, safe care and is demonstrated through organisational attitudes that shape the behaviours of clinicians and leaders⁹. Despite this, the role of patient advocate has been impeded; therefore, identifying and overcoming the barriers to patient advocacy by perioperative nurses is vital for patient safety³.

Literature search

Search strategy

An electronic database search of the literature was conducted. Included in the search were, PubMed and, via EBSCOhost, Academic search ultimate, Cumulative Index Nursing and Allied Health Literature (CINAHL) complete, Healthsource: nursing/academic edition, MEDLINE, and MEDLINE complete.

Key terms used in the search were 'patient', 'advocacy', 'perioperative', 'operating room', 'nurs*', 'patient advocacy' and 'safety culture'. The PubMed MeSH and PubMed search builder were utilised to include medical subject headings (MeSH) terms in the search. MeSH terms were, 'patient safety'[Mesh],

'Perioperative Care/ethics'[Mesh], 'Perioperative Care/legislation and jurisprudence'[Mesh], 'Perioperative Care/organisation and administration'[Mesh]. Boolean phrases, AND and OR were applied to narrow the search terms and the truncation '*' applied to include plurals of key terms.

Inclusion and exclusion criteria

To access the most up-to-date primary research and scholarly, peer-reviewed literature, the search results were limited to the years 2015 to 2020 and articles from peer-reviewed journals only. Included articles referenced the key terms and were in English due to language constraints of the authors. Exclusion criteria included research not related to nursing, patient advocacy or safety culture; secondary sources of research; protocols; guidelines and research not transferrable to the perioperative context.

Data evaluation synthesis

Data extraction and evaluation

Data extraction included the author, date of publication, origin of the study, population and sampling method, study design, level of evidence, key findings and limitations. In agreement with Whitemore and Knafl, the diversity in research design of the included studies indicated the appropriateness for the application of quality appraisal tools¹⁰. Reliability and validity of the selected research was determined using the levels of evidence as described by Jirojwong, Johnson and Welch from level I, the highest, to level VII, the lowest¹¹. The selected research was critically appraised for 'methodological quality' using the JBI critical

appraisal checklists for case reports, qualitative and prevalence research¹². Each checklist had between eight and ten questions that was allocated a score, 'yes', 'unclear', 'no', 'not applicable', which was interpreted by the author with a rating of low-, moderate- or high-quality research.

Data analysis and synthesis

As suggested by Whittemore and Knafl, the integrative review method was followed to analyse and

synthesise the data through thematic analysis¹⁰. Data reduction initially involved grouping the research by study design. The data extraction table, used to record extracted data to be later used for comparison, is included as supplemental material. Data display was achieved through the applied table by grouping similar data. Comparison of the grouped data was used to generate themes and connections. The themes and connections were integrated for

discussion and synthesised for verification and to draw conclusions.

Descriptive findings

As indicated in the PRISMA flow diagram (Figure 1), the search strategy identified 347 articles and four articles were identified through a search of the reference lists in the selected literature, as recommended by Liberati et al¹³. After duplicates were removed from the total 351 articles, 163

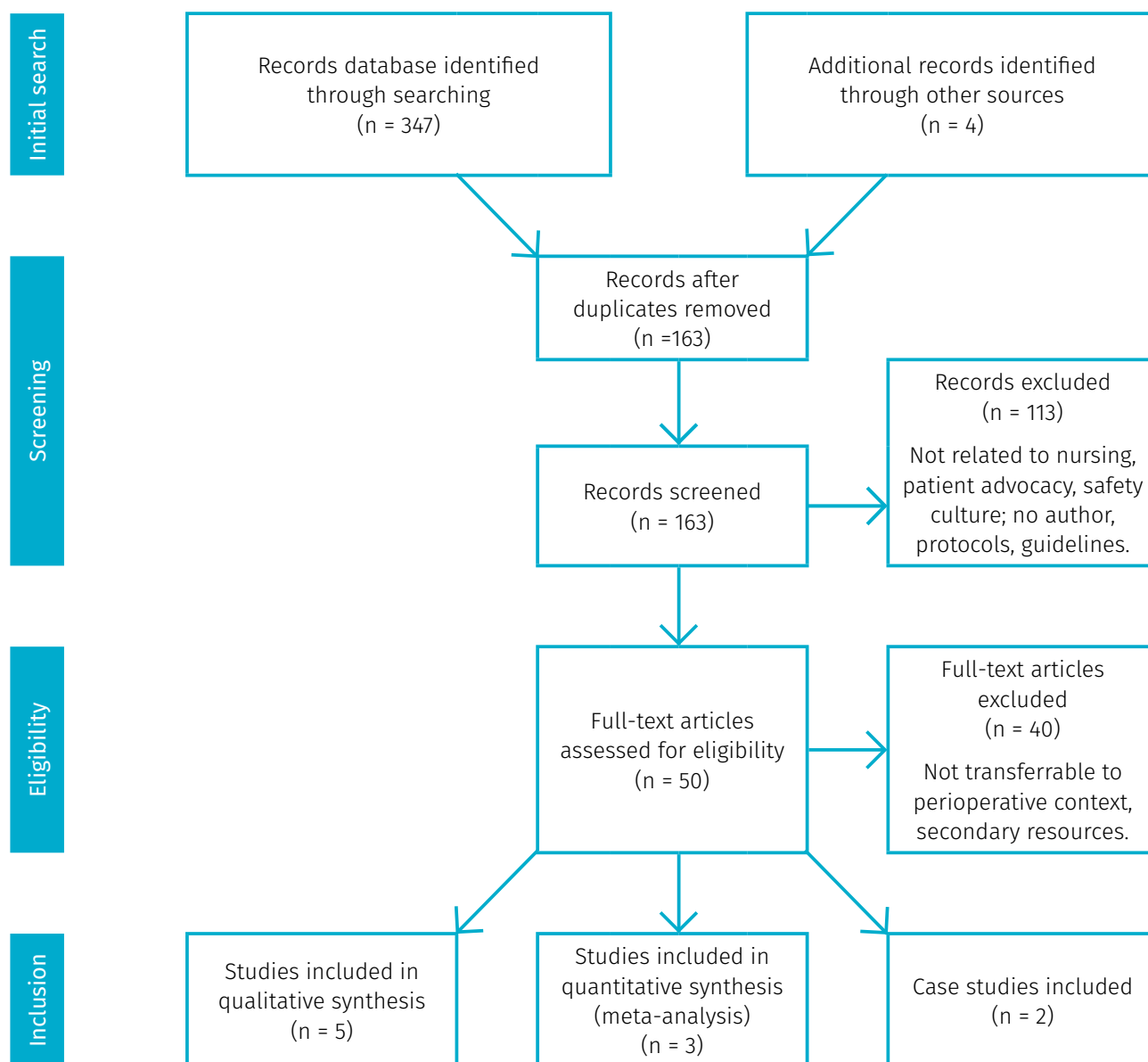


Figure 1: PRISMA flow diagram of papers for inclusion

remained. Of the 163 articles, 113 articles were excluded after titles and abstracts were screened against the inclusion and exclusion criteria. The 50 remaining full-text articles were screened for relevance to the review aims resulting in 40 articles being excluded. The majority of the excluded full-text articles were found to be relevant to patient advocacy and safety culture; however, based on the recommendations of Jirojwong et al.¹¹ and Joanna Briggs Institute (JBI)¹² they were excluded as they were determined by the author to be low-level discussion papers or low-quality case reports where reliability and validity of the results could not be determined. Three full-text articles were also found to be relevant to the review aims but were excluded as they were review articles. A total of ten primary research articles were selected for inclusion. The origin of selected articles were the USA ($n=7$), Sweden ($n=1$), Australia ($n=1$) and Canada ($n=1$).

Quality assessment

The ten included articles were assessed for quality according to Jirojwong et al.¹¹ and JBI¹². The three quantitative studies were found to be level III-3 cross-sectional studies and were critically appraised across nine criteria for prevalence research to be of moderate quality. Quality was reduced by low response rates and description of sampling methods. The five level VI qualitative studies included four that consisted of semi-structured interviews and focus groups, and one with an etic approach that was observational with informal interviews. All qualitative studies included field notes or journaling, coding and thematic analysis. The five qualitative studies were critically appraised across ten criteria for qualitative research and found to be of high quality. Of the two level IV case studies, one was

critically appraised against eight criteria and one against six of the eight criteria, due to no applicability to the study. Both were found to be of high quality.

Results

The analysis of the data was mapped through comparison for similarities in the methodology, aims and findings of the selected research. Through this iterative process the overarching theme to emerge linking perioperative patient advocacy and safety culture, was 'perioperative nurse role in patient advocacy'. Subthemes generated under barriers to perioperative advocacy were 'hierarchy in the perioperative environment' and 'fear of blame'.

Discussion

Perioperative nurse role in patient advocacy

Four qualitative studies researched the perspective of perioperative nurses as patient advocates¹⁴⁻¹⁷. Two qualitative studies found that perioperative nurses viewed their patients as vulnerable and that attentiveness to patients' needs and expectations builds trust and promotes advocacy^{14,15}. Through the collective experiences of preoperative nurses, and end-users of preoperative care, Malley et al. found that there is often a gap between patient expectation and specialist knowledge that can negatively impact transitions of care¹⁴. This study found that patients coming in for surgery expected that all the information pertaining to their care would be available when they arrived¹⁴. When gaps in information occur, distrust and fear builds, and patient outcomes are negatively impacted¹⁴. This research revealed that nurses perceived themselves as important in filling these gaps to

build trust, and that by gathering all the necessary information nurses put themselves in a position to protect their patients from harm¹⁴. Echoing these sentiments, Ingvarsdottir et al. reiterated the importance of these findings, explaining that while there was limited time preoperatively to spend with patients, perioperative nurses identified this as being very important to filling the gaps in information and building patient trust¹⁵.

Sundqvist et al. highlighted that, despite the limited time perioperative nurses have with a conscious patient during transition to the operative phase, trust building was still achievable through acts of advocacy that promote psychosocial support, integrity and autonomy¹⁶. For example, in one study a nurse was observed to be conscious of meeting the patient's needs in addressing the patient by name, checking for comfort, assisting with transfer onto the theatre table, talking the patient through steps in the process and pulling the blinds down to cover the window into the theatre¹⁶. During the phase of anaesthesia, where the patient was unaware, members of the theatre team were also seen to protect the patient through constant surveillance, collaborative interactions, acts of information-sharing at different points in the patient's transition through the perioperative environment and challenging each other on decisions in patient care¹⁶.

The findings of challenging decisions and surveillance for patient protection are also consistent with a qualitative study by Bacon that researched the nurse experience of 'failure-to-rescue' (FTR) post-operatively¹⁷. Although the concept of FTR is not specific to the perioperative context, the results are generalisable through application to current Australian standards

in recognising the deteriorating patient¹⁸. It was found that the participants in this study viewed their role as patient protectors through patient surveillance in relation to their abilities to escalate care¹⁷. This was linked to patient advocacy, as the study highlighted both the importance and the difficulties in speaking up on behalf of the patient when deterioration is detected¹⁷. Through rich description, it was also found that junior nurses, in particular, have difficulty in knowing when or how intensely to pursue escalations of care when they have concerns for a patient's welfare¹⁷. FTR, even with experienced nurses in the PACU and despite efforts to advocate and escalate care for their patients, has resulted in adverse events¹⁹.

Barriers to perioperative advocacy

Hierarchy in the perioperative environment

Rich data from two qualitative studies found that the ability to escalate care is often associated with fear^{15,20}. In a phenomenological study, the lived experience of participants described the view of being 'unpopular' for speaking up in the best interest of patients¹⁵. A grounded theory study found that culture in the perioperative environment was characterised by a 'steep hierarchy' that played a central role in the functioning and mood of the environment²⁰. Although this study was of surgical resident doctors working in the operating suite, it was relevant in its insight into the culture of the perioperative milieu²⁰. The experience of participants was described as avoiding conflict with both nurses and consultant doctors, suppressing feelings or using questioning, either indirect or direct, to challenge decisions²⁰. This is consistent with the findings of

Rainer and Schneider that suggest that nurses feel subordinate to doctors, hindering their ability to speak up²¹. In support of this notion, one case study described a nurse raising concern with a surgeon over the viability of a written consent and, despite the nurse's concern, the surgeon insisting the patient still be transferred to the operating suite²². Feeling pressured by the conflict between their professional obligations to the patient and the perspectives of the surgeon, the nurse transferred the patient to the theatre; however, the nurse did escalate her concerns to the manager²². The manager pursued the nurse's concerns with the surgeon, thus supporting the nurse and flattening the hierarchy, and the patient's surgery was subsequently postponed until a valid consent was obtained²².

Fear of blame

Fear of blame was a common barrier to risk reporting within the selected literature^{15,20,23–25}. The data from one quantitative study showed that 59 out of 352 participants revealed they had not reported a patient safety concern, with 33 of those citing the reason as fear of blame²⁴. In the same study, data revealed that even though 94.8 per cent of participants believed their facility was supportive of risk reporting, 37 per cent did not report an unsafe practice they had seen²⁴. One qualitative study also found that low rates of reporting risks to patient safety was due to a lack of opportunity for formal, open discussion and a fear of documented risk reports being used to leverage individual blame¹⁵.

Links to safety culture

Fan et al. hypothesised that surgical site infection rates were linked to the concept of safety culture²⁵. This research used a survey with

twelve dimensions of safety culture that examined perceptions of open communication, feedback, risk reporting processes and approaches, management of and support for patient safety, and teamwork²⁵. Findings ($r = -0.90$; CI 95% = $[-0.45, 0.99]$) revealed that poor organisational commitment to safety leads to low perceptions of safety culture by staff in the workplace, which in turn leads to higher rates of surgical site infections²⁵.

In a quality improvement case study, Lozito et al. had identified an increase in patient harm from surgical error and 'near-miss' events that were often not being reported²³. It was identified through a staff survey, that open communication and non-punitive approaches to risk reporting needed improvement²³. In this study the implementation strategy included education for safety culture, standardising the reporting process and debriefing following reporting to promote open discussion and reflective learning²³. This study showed that implementing strategies to improve organisational commitment to patient safety improved 'near-miss' reporting, with statistically significant results ($p < 0.05$)²³. Lozito et al. showed that an organisational commitment to safety, through improved communication strategies, resulted in a 15 to 20 per cent increase in staff satisfaction with aspects of safety culture – open communication, feedback, 'non-punitive' approaches to risk reporting and education²³.

These findings are supported by a quantitative study that explored how safety culture influences team behaviour. The study found a statistically significant correlation between patient advocacy in 'speaking up' and a positive safety culture ($p = 0.000$)²¹. This study showed that a safety culture which is supportive of questioning, risk

reporting and the ability to challenge on behalf of patient safety issues, reduced 'moral distress' experienced by nurses through promoting their ability to 'speak up' thus advocating for the safety of their patients²¹.

Implications for perioperative nursing practice or research

The aim of this integrative review was to understand the relationship between patient advocacy and safety culture, and identify strategies to promote patient advocacy and patient safety within the perioperative context. The included literature recognises the perioperative nurse role as a protector of patients from harm. The research highlights the complexities of the perioperative team environment and identifies hierarchical structures as a barrier to advocating for patient safety. Open communication and non-punitive approaches to risk reporting, were recognised as key characteristics of safety culture, greatly influencing the perioperative climate. For perioperative leaders, the findings of this review will provide context to the recently devised ACSQHC safety culture measurement toolkits, aimed at improving patient safety within Australian health care organisations⁹.

Knowledge translation

1. Perioperative nurses view patients within the perioperative environment as vulnerable, and themselves as protectors from harm. Through acts of advocacy, nurses execute their responsibility and moral compass to promote the rights of their patients and to provide the highest standard of safe patient care.
2. Nurses fearing to 'speak up' on behalf of their patients, when

there is a perceived hierarchy and lack of support from clinical leaders, negatively impacts communication and promotes a poor safety culture.

3. Flattening the hierarchy through open communication strategies and non-punitive approaches to risk reporting were identified as promoting a positive safety culture that better supports patient advocacy.

Limitations

The results of this integrative review are limited by the low number of primary research articles found through the search strategy, with only one study being Australian. Generalisability and transferability of the results may be biased by only six of the included studies being specific to the perioperative context. Of those, only four could be related directly to Australian perioperative nursing practice.

Conclusion

This integrative review explored the perceptions of the perioperative nurse role in patient advocacy as protector from harm. Synthesised findings of the selected literature highlight that team culture can be a barrier to advocating for patient safety when it is hierarchical and promotes communication that is closed and punitive.

The ability of perioperative nurses to speak up on behalf of their patients is paramount in the operating suite where patients are vulnerable and often unable to speak for themselves. This advocacy sits close to the heart of perioperative nursing and perioperative nurses see this task as very important.

As limited literature was available on patient advocacy and safer patient outcomes, further research

into these important links may be warranted.

The literature in this review revealed that strategies by organisational leaders to promote supportive, open communication, free from fear, have the potential to strengthen the ability of perioperative nurses as patient advocates, ultimately improving patient safety outcomes.

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References

1. Australian Commission on Safety and Quality in Health Care (ACSQHC). The state of patient safety and quality in Australian hospitals 2019 [Internet]. Sydney: ACSQHC; 2019 [cited 2020 October 5]. Available from: www.safetyandquality.gov.au/sites/default/files/2019-07/the-state-of-patient-safety-and-quality-in-australian-hospitals-2019.pdf.
2. Battie R, Steelman V. Accountability in nursing practice: Why it is important for patient safety. *JPN* 2016;29(4):11–14.
3. Munday J, Kynoch K, Hines S. Nurses' experiences of advocacy in the perioperative department: A systematic review. *JBHI Database System Rev Implement Rep* 2015;13(8):146–189. DOI: 10.11124/jbisrir-2015-2121.
4. Henderson, V. The nature of nursing. *AJN* 1964; 64(8):62–68.
5. Sundqvist A-S, Holmefur M, Nilsson U, Carlsson A. Perioperative patient advocacy: An integrative review. *J Perianesth Nurse* 2016;31(5):422–433. DOI: 10.1016/j.jopan.2014.12.001.
6. McClelland G, Smith MB. Just a routine operation: A critical discussion. *J Perioper Pract* 2016;26(5):114–117. DOI: 10.1177/175045891602600504.

7. Clark C, Kenski, D. Promoting civility in the OR: An ethical imperative. *AORN J* 2017;105(1):60–66. DOI: 10.1016/j.aorn.2016.10.019.
8. Crook C. Advocacy: How far would you go to protect your patients? *AORN J* 2016;103(5):522–526. DOI: 10.1016/j.aorn.2016.03.009.
9. Australian Commission on Safety and Quality in Health Care (ACSQHC). Patient safety culture [Internet]. Sydney: ACSQHC; 2019 [cited 2020 October 5]. Available from: www.safetyandquality.gov.au/our-work/indicators-measurement-and-reporting/patient-safety-culture.
10. Whitemore R, Knafl K. The integrative review: Updated methodology. *J Adv Nurs* 2005;52(5):546–553.
11. Jirojwong S, Johnson M, Welch, editors. *Research Methods in Nursing and Midwifery: Pathways to Evidence-based Practice*. 2nd ed. Melbourne: Oxford university press; 2014.
12. Joanna Briggs Institute (JBI). Critical appraisal tools [Internet]. Adelaide: JBI; 2020 [cited 2020 September 19]. Available from: <https://joannabriggs.org/critical-appraisal-tools>.
13. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JPA, et. al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: Explanation and elaboration. *PLoS Med* 2009; 6(7): e1000100. DOI: 10.1371/journal.pmed.10000100.
14. Malley A, Kenner C, Kim T, Blakeney B. The role of the nurse and the preoperative assessment in patient transitions. *AORN J* 2015;102(2):181e1–181e9. DOI: 10.1016/j.aorn.2015.06.004.
15. Ingvarsdottir E, Halldorsdottir S. Enhancing patient safety in the operating theatre: From the perspective of the experienced operating theatre nurses. *Scan J Caring Sci* 2017;32(2):951–960. DOI: 10.1111/scs.12532.
16. Sundqvist A-S, Holmefur M, Nilsson U, Carlsson A. Promoting person-centred care in the perioperative setting through patient advocacy: An observational study. *J Clin Nurs* 2018;27(11–12):2403–2415. DOI: 10.1111/jocn.14181.
17. Bacon C. Nurses' experiences with patients who die from failure to rescue after surgery. *J Nurs Scholarsh* 2017;49(3):303–311. DOI: 10.1111/jnu.12294.
18. Australian Commission on Safety and Quality in Health Care (ACSQHC). Recognising and responding to acute deterioration standard [Internet]. Sydney: ACSQHC; 2017 [cited 2020 September 30]. Available from: www.safetyandquality.gov.au/standards/nsqhs-standards/recognising-and-responding-acute-deterioration-standard.
19. State Coroners Court of New South Wales (NSW). In: Coroners Court of New South Wales, editor [Internet]. Sydney: State Coroners Court; 2019 [cited 6 May 2021]. Available from: www.coroners.nsw.gov.au/coroners-court/coronial-findings-search.html?searchtext=p.%201-31.&searchYear=2019.
20. Bould D, Sutherland S, Sydor D, Naik V, Friedman Z. Residents' reluctance to challenge negative hierarchy in the operating room: A qualitative study. *J Can Anesth* 2015;62(6):576–586. DOI: 10.1007/s12630-015-0364-5.
21. Rainer J, Schneider J. Testing a model of speaking up in nursing. *JONA* 2020;50(6):349–354. DOI: 10.1097/NNA.0000000000000896.
22. Gilbert J, Gillespie B. Surgical consent and the importance of a substitute decision-maker: A case study. *JPN* 2017;30(1):15–19.
23. Lozito M, Whiteman K, Swanson-Bearman, Barkhymer M. Good catch campaign: Improving the perioperative culture of safety. *AORN J* 2018;107(6):705–714. DOI:10.1002/aorn.12148.
24. Cole D, Bersick E, Skarbek A, Cummins K, Dugan K, Grantoza R. The courage to speak out: A study describing nurses' attitudes to report unsafe practices in patient care. *J Nurs Manag* 2019;27:1176–1181. DOI: 10.1111/jonm.12789.
25. Fan C, Pawlik T, Daniels T, Vernon V, Banks K, Westby P et al. Association of safety culture with surgical site infection outcomes. *J Am Coll Surg* 2016; 222(2):122–128. DOI: 10.1016/j.jamcollsurg.2015.11.008.

Identifying barriers to patient advocacy in the promotion of a safety culture: An integrative review

Supplemental material: Data extraction matrix

Author/date/country	Population/sampling	Study design	Level of evidence and appraisal score	Aim and key findings	Limitations
Sundqvist S et al. 2017 Sweden		Qualitative • Descriptive observational – etic approach • Informal interviews – emic approach • Field notes • Content analysis framed by findings from previous integrative review	10/10 JBI-high VI-low	Aim: To support findings of a previous integrative review for perioperative nurse role in patient advocacy through experience of a registered nurse anaesthetist (RNA). Findings substantiated previous integrative review. Acts of patient advocacy: constant surveillance, anticipation and being prepared, multidisciplinary approaches to preparing patient and ensuring safety, safety checking equipment, speaking up when things are not right. Observed delivering holistic approaches to care: psychosocial support (physical touch), being attentive (eye contact, using name, promoting autonomy through offering choice), ensuring integrity (closing blinds), involving the patient (talking through each step in the preparation process). Collaboration with team for information sharing to plan for care.	Transferability: experience of registered nurse anaesthetists not consistent with Australian nursing.
Bacon C. 2017 USA	n=14 nurses (5 OR, 1 PACU, 5 ICU, 1 EDU, 2 surgical ward) Purposive, Snowball sampling	Qualitative • Phenomenology semi-structured interviews – open-ended questioning 30–90 minutes, recording, transcribed verbatim • Journaling • Phone follow-up to validate findings • Thick description	10/10 JBI- High VI- low	Aim: Explore lived experience of nurses in ‘failure to rescue’ (FTR). Precipitating factors: not consistent with research relating to errors, resources, or patient surveillance. ‘Typical day’. Nurse perspective: all but one, not preventable, not consistent with medical review data – preventable. Nurse role in preventing FTR: view role as a protector through surveillance and escalating care. Experience highlighted nurse responsibility to prepare for the unexpected to make sure things are all right.	Recollection of events. Inconsistent timeframes of the FTR experienced. Validity: 50% of the participants validated the interpretation of responses bias.
Malley A, Kim T. 2015 USA	n=24 nurses Purposive sampling	Qualitative • Focus groups • Semi-structured, open-ended questions • Field notes • Thick description	9/10 JBI- High VI-Low	Aim: Understand nurse perception of preoperative nurse role and identify contribution to transition in care through the perioperative journey. Preoperative assessment forms a baseline for transition points, opportunity to gain holistic view of the patient and identify potential risk factors for patient safety. Communication factors: • gaps between patient and consultant understanding of expectations and needs during treatment are common • multiple modes of information sharing leads to incomplete information • differing perspectives between disciplines of what information is needed. Preoperative nurses required to fill the gap through follow-up. Preoperative nurses consider themselves to be central in trust building and patient advocacy – understanding vulnerability of the patients, identifying patient preferences, family situations, other health issues. Patient expectation of overall outcomes: patients have preconceived idea of what health professionals and facilities should know about them – when gap is not filled, distrust and poor outcomes may result.	Transferability: no demographic data for experience level of the participants in the specialty, higher proportion of end-user nurses. Bias: interview nurse known to some participants and pre-knowledge of the environment.

Author/date/ country	Population/ sampling	Study design	Level of evidence and appraisal score	Aim and key findings	Limitations
Ingvarsdottir E, Halldorsdottir S. 2017 USA	n=11 participants Purposive sampling	Qualitative • Phenomenological study • Open-ended, in-depth interviews transcribed verbatim • Research diary	8/10 JBI- High VI- low	Aim: Explore ways to enhance patient safety through understanding the experiences of the OT nurse Overarching theme: OT nurse balancing constant risk management and preventing patients from harm. Central factors to enhancing patient safety: awareness of patient vulnerabilities and trust building in the OT – respect, attentiveness. Limited time with conscious patient, considered valuable. Navigating task and patient care: communication, teamwork, coordination, preparation. Difficulties in communication and teamwork, consistent theme – misleading incomplete or inaccessible information. Protocols that are generic, not designed for context, cause confusion. The theme for preventing harm: risk reporting – documentation, follow-up, open-discussion, reflection. Limited feedback, follow-up following critical events was evident. Documentation was reported as lacking. Confusion noted about defining an adverse event. OT culture impacting safety: seen as stressful – distractions, multitasking, time-pressures, understaffing. Importance placed on ‘speaking-up’, overall view described ‘... being unpopular’. Everyone has a role and work within it to achieve common goal in patient care outcomes. Overall view – patient safety requires competence in both technical and non-technical skills.	Trustworthiness and confirmability: the lead researcher was known to five participants and extensive experience on the area of research. Trustworthiness and dependability: no thick description, generalised narratives.
Bould Det al. 2015 Canada	n=44 anaesthetic residents	Qualitative • Grounded theory • Semi-structured interviews – open-ended questioning, recorded, transcribed verbatim • Thick description	10/10 JBI-High VI Rigorous, low level study	Aim: To understand impact of hierarchy on resident doctors to challenge decision-making in the OT. Culture of the OT: ‘steep hierarchy’, central to functioning of the OT. Gender influences position in hierarchy, women less dominant, less respected as authoritative. Hierarchical attitude universal across all disciplines in the OT.	Gender bias for gender related experiences: more female than male participants. Bias: no sampling method. Transferability and generalisability: experiences of resident doctors not consistent with perioperative nursing.
Rainer J, Schneider J. 2020 USA	n=303 Convenience sampling	Quantitative • Cross-sectional, SAQ-Likert-scale surveys • Subscales – team climate, safety climate, MDS – ‘moral distress’ • Spearman correlations Mann-Whitney testing	7/7 JBI- Mod III-3- Mod	Aim: Explore influence of workplace cultures on speaking up. Correlation found: strong safety culture and speaking up ($r=0.81$, $p=0.000$) and low levels of ‘moral distress’ ($r=-0.56$, $p=0.000$). ‘Team work’ climate relates to support for questioning and reporting safety issues and handling of disagreement in workplace. ‘Safety climate’ relates to organisational commitment to safety, reflective learning, reporting processes. ‘Moral distress’ relates to patient advocacy and collegial support.	Generalisability: authors acknowledge participant self-selection bias in limiting demographic diversity of sample population.
Gilbert J, Gillespie B. 2017 Australia	2 cases	Case study	6/6 JBI- Mod IV- Low	Aim: Explore principles of informed consent in OT. Case 1: Elderly patient – associated complications of treatment not duly disclosed, injury sustained, poor patient outcome, doctor sued for negligence. Case 2: Informed consent when patient/carer cognitively impaired – perioperative nurse advocated for patient, doctor intimidating and demanded surgery continue, support from nurse leader helped nurse advocate for patient, surgery postponed, informed consent obtained via substitute decision-maker.	

Author/date/ country	Population/ sampling	Study design	Level of evidence and appraisal score	Aim and key findings	Limitations
Lozito M et al. 2018 USA	n=123 3–300 near misses=1 adverse event Retrospective data – 85 documented risks.	Case study – quality improvement project • Pre-/post- implementation testing • AHRQH staff survey • Chi-square testing for statistical analysis	7/8 JBI- High IV- low	Aim: Improve the culture of safety in perioperative department by implementing 'Good Catch Campaign'. Site was seeing increase in WSPE – low number of near misses reported. 'Good catch' – any event that could potentiate patient harm. Safety culture measurement tool – identify barriers to reporting – 2012, 2014 and 2015 = poor communication, fear of intimidation and legal implications. Implementation strategy – education, standardise reporting, debriefing. Data presentation – team meetings and posters. Post-implementation analysis: $p=0.05$, indicating increase in 'good catches' reported. AHRQH survey: 15–20% increased satisfaction for communication, feedback, non-punitive responses and education.	Generalisability: a single, small hospital. No survey distribution disclosure.
Cole A et al. 2019 USA	Convenience sampling n=362 registered nurses – 96% acute care setting. Power analysis= CI-95%	Quantitative • Descriptive • Likert-scale questionnaire	8/9 JBI- High III-3- Mod	Aim: Identify factors influencing reporting unsafe practice. Results: • 75.4% reported practices that could result in patient harm. • 63.3% reported unsafe practices of another nurse. • 59 participants did not report a patient safety concern, 33 because of fear of blame, 21 did not think it would be acted on. • Experience of repercussions following reporting: self 'no' – 72.7%, another nurse 'no' – 82.6%. • Reprisal after reporting a doctor: 'no' – 77.4%. • 37.6% did not report a witnessed unsafe practice. • 76.5% did not report a known breach in patient safety by a nurse supervisor. • 94.8% agreed the facility encouraged reports of unsafe practice. • 95.3% reported knowing the process of reporting.	Confirmability: correlations are assumed through the frequency data. 86% of the participants were from a 'magnet hospital' Transferability and generalisability: educational and certification prerequisites not applicable to Australia, not specific to perioperative area.
Fan C et al. 2016 USA	Seven hospitals	Quantitative • Cross-sectional • Combine data post colon surgery SSI rates/ HSOPS 5-point Likert scale • Pearson's r correlation • Correlation coefficient (r): 1=negative, 0=nil and +1=positive correlation, CI 95%	4/9 JBI- Mod III-3- Mod	Hypothesis: Safety culture central to SSI. Aim: Test association between SSI and safety culture. Results: perceptions of safety culture against the 12 dimensions – wide variation, 16–92% satisfaction. SSI rates 30% across the sites. Correlated data: low perception of safety culture showed higher incidence of SSI rates ($r=-0.90$; CI 95% = $[-0.45, -0.99]$). Nine of twelve dimensions linked to SSI infection that centred around communication, organisational support for safety, responses to error and risk reporting.	Bias: response rate of 43%. Validity: incomplete patient data – unknown confounding variables to surgical site infection rates. No accurate number of surveys. No sampling strategy. No clear aim described.