Knowledge translation and teamwork interventions to optimize intraoperative processes of care and patient outcomes

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Thesis submitted to the University of Ottawa

in partial fulfillment of the requirements for the

M.Sc. degree in Epidemiology

School of Epidemiology and Public Health

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Abstract

The operating room (OR) is a high-risk environment that requires OR personnel to have up to date evidence-based technical and teamwork skills to maintain patient safety and consistent workflow. Despite anesthesiologists' significant role in surgical patient safety, there is practice variation and a lack of evidence translation among anesthesiologists. Our first review synthesized current evidence on Knowledge Translation Interventions (KTIs) in anesthesiology during the intraoperative period. We found that education was the most effective KTI followed by reminder and audit & feedback. The second systematic review synthesized the current evidence on teamwork interventions in the OR setting and identified which change strategies were used to target which teamwork behaviour barriers/enablers using the Theoretical Domains Framework. Our findings inform evidence to optimize practice standardization in anesthesia and enhance surgical patient safety. Both reviews identify future directions for knowledge translation research and provide guidance on designing more effective and reproducible teamwork interventions.

Acknowledgements

I want to extend my sincere gratitude to everyone who helped me along the way when I was preparing this thesis. Irina Podinic, Romanah Ahmed, Zaina Kahiel, and Mary Scott, who are my friends and fellow students, have never wavered in their encouragement and support of me. Throughout the entire process, their encouragement and friendship served as a source of solace and inspiration.

Additionally, I would like to express my gratitude to Dr. Cole Etherington, Dr. Sylvain Boet, and Dr. Justin Presseau who served as my supervisors, for their crucial advice and assistance. Their knowledge, wisdom, and support were crucial in helping me finish this thesis.

A special mention goes to all the screeners who helped with the review of my work. Their contributions and support were greatly appreciated and helped me achieve a higher level of quality in my work.

Finally, I would like to express my gratitude to my mom, sister, and husband for their emotional and motivational support throughout this journey. Their love and support were a constant source of strength and inspiration, and I am deeply grateful for their unwavering encouragement and understanding.

Thank you to everyone who has supported me in this incredible journey.

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Legend

Abbreviations

KT	Knowledge Translation
KTIs	Knowledge Translation Interventions
KTI	Knowledge Translation Intervention
TDIs	Teamwork Development Interventions
OR	Operating Room
RCT	Randomized Controlled Trial
RCTs	Randomized Controlled Trials
TDF	Theoretical Domains Framework
HCPs	Healthcare Professionals

Chapter 1: General Introduction

Optimization of processes of care in the operating room

The operating room (OR) is a multidisciplinary and increasingly complex interprofessional environment that sets it apart from many other fields. Due to the time-sensitive and high-risk procedures carried out in an OR, the risk of patient safety incidents and adverse clinical outcomes increases drastically when compared to other health care services. Therefore, the OR is a critical intervention setting to improve patient outcomes and prevent or reduce patient harm [1–3].

Global statistics indicate that a large proportion of adverse patient events resulting from medical errors occur during the perioperative care period (i.e., pre-operative, intra-operative, and post-operative care) [4,5]. It is estimated that more than 310 million major surgical procedures are performed globally each year, with over half of all surgical errors being preventable [4–8]. In the United States (US) alone, it has been estimated that 400,000 cases of preventable patient harm occur annually, with 100,000 resulting in patient death [9,10]. The cost of medical errors in the US is likely to be $20 billion annually, and surgical errors are often the leading cause of malpractice claims [10,11]. A study in 2004 reported an adverse event incidence rate of 7.5% amongst Canadian acute care hospital admissions out of which 36.9% are preventable and 20.8% results in death which is almost 38,480 deaths annually[12]. What is most interesting is that 51.4% of these adverse events in Canada are due to surgical procedures[12].

The causes of surgical patient adverse events have been found to include deficiencies in both technical and non-technical skills, such as communication breakdowns, practice variations, technical skill deficiencies, inefficient organizational structures, education and training deficiencies [4–6,13,14]. Therefore, targeting improvement in healthcare professionals' technical and non-technical skills in the OR can reduce the occurrence of preventable surgical errors [4,13–19]. Supporting OR healthcare professionals' technical skills and non-technical skills in accordance with new empirical advances is imperative to maintain a consistently high quality of patient care [14,20–23]. Non-technical skills have been described to encompass cognitive (decision making and situational awareness), social skills (leadership, communication and teamwork), and the individual mental and physical states (stress and fatigue) that may impact one's non-technical skill performance [1].

Figure 1. Visual representation of the relationship between technical and non-technical skills of OR care team and their impact on surgical patient outcomes.

Knowledge Translation Interventions (KTIs)

The term "knowledge translation" (KT) in healthcare refers to the process of taking evidence-based empirical knowledge and applying it in a clinical setting [24–27]. KTIs are a key component of this process, as they outline steps for transferring research evidence to the patient's bedside and making healthcare professionals aware of relevant knowledge, so that it can be effectively implemented in practice in a timely and efficient manner [24–27]. This approach is closely linked to evidence-based practice, which becomes challenging in the field of medicine due to the rapid pace of empirical advancements being produced and published [20,24,26–30]. To bridge the gap between research and practice, healthcare institutions have implemented KTIs, which can target individual healthcare professionals or entire organizations to promote efficient use of resources and bring about organizational change [24–27]. These interventions are unique pathways for disseminating evidence-based knowledge among healthcare professionals, with the potential to constantly update and improve clinical practice and patient outcomes [26].

KTIs have been sorted into ten intervention type categories by Sinuff et al. in their systematic review which evaluated KTIs in the critical care setting (see Table 1 for types and definitions). While this list is not exhaustive, it is a useful starting point when aiming to categorize KTIs. Some categories can be grouped together due to their similarity. For example, the categories "Clinical Practice Guidelines", "Protocol", and "Bundle/Checklist" were grouped together in the review by Sinuff et al. as they collectively represent standardizing clinical practice.

Table 1: Types of KTIs and their respective definitions.

KT Intervention Type	**Description**
Clinical Practice Guideline	"Clinical practice guidelines are "systematically developed statements to assist practitioner and patient decisions about appropriate health care for specific clinical circumstances". They define the role of specific diagnostic, prevention, and treatment modalities in the diagnosis, prevention, and management of patients. Guidelines contain one or more *recommendations* for specific elements of patient care, usually in the context of a specific clinical scenario. These recommendations are typically based on evidence from a rigorous systematic review and synthesis of the published medical literature."
Protocol	"Protocols are recommended pathways for care of a specific type of patient, or for a specific medical situation. These pathways typically include one or more specific goals and an algorithm or decision-tree containing specified diagnostic, preventive, and/or therapeutic elements of care designed to achieve the goal(s). This allows the clinician with choices for *automatic* management decisions (management decisions are made autonomously)."
Bundle/Checklist	"A bundle is a group of interventions related to a disease process that, when executed together, are purported to result in better outcomes than when implemented individually (IHI definition).

	Bundles typically have been developed from guidelines and/or protocols to guide multiple aspects of caring for a given type of patient or a given medical situation. Bundles incorporate specific directives to be executed at the point of care. In some cases, the study will specify that a checklist was used at the point of care, to implement the bundle. We will consider a **checklist** to be the same as a bundle. A checklist is a set of practices provided in a list that all need to be checked off at a given time at the point of care."
Person/ Team/ Organizational Change	"The KT Intervention is the person or team or a change to the organization of the ICU. These are a large and diverse group of interventions, which in one or multiple ways *alter the structures and processes* comprising the system of health care delivery. The study should specify that a specific person (i.e., pharmacist) was the intervention."
Education	"Education refers to the deliberate, systematic, and sustained effort to transmit knowledge or skills and any learning that results from the effort. Specifically, this must include any type of forum or session in which information is offered regarding the medical care (diagnostic, preventive, or therapeutic). The information is specific to changing the behaviour targeted by the study investigators. These may be individual or, more typically group sessions, formal or informal. The information can be provided via computers, and with an individual person as the target. Education includes the following 2 facets: 1. **Distribution of educational materials:** Distribution of published or printed recommendations for clinical care, including clinical practice guidelines, audio-visual materials, and electronic publications. Educational materials may be delivered in print or electronically. 2. **Educational meetings:** Participation of health care providers in conferences, lectures, workshops, or traineeships within or outside the providers' practice settings. "
Reminders	"Reminders are any interventions, provided verbally, on paper, or computerized, which are intended to prompt clinicians to recall information and remind them to perform a clinical action in keeping with the guidelines/protocols/bundles implemented in the study. If reminders were used, the Methods section should clearly specify that the study investigators used reminders as a trigger for the ICU clinician and they were provided about specific patient care actions."
Opinion Leaders/ Champions	"Local opinion leaders can be defined as health professionals nominated by their colleagues as 'educationally influential'. Opinion leaders generally include clinicians or non-clinicians in a leadership position or may be more generally respected member(s) of the local health care community. They openly take the position in support of the intervention being implemented. This support can be any combination

	of forms: written, verbal, computerized, or even just "leading by example". Opinion leaders are not necessarily elected into this position."
Academic Detailing	"Academic detailing refers to the provision of independent, evidence-based information about best prescribing practices by a health educator to physicians or health care providers on a one-on-one basis or in small groups. This is also known as "university or non-commercial-based educational outreach". The key elements of academic detailing include: 1. Process of face-to-face education of prescribers by trained health care professionals, typically pharmacists, physicians, or nurses. 2. Goal is to change prescribing of targeted drugs to be consistent with medical evidence, support patient safety, and to be cost-effective medication choices. 3. Key component of non-commercial or university-based academic detailing programs - they (academic detailers, management, staff, program developers, etc.) do not have any financial links to the pharmaceutical industry. *Academic detailing differs from 'Education'.* Academic detailing involves one-on-one conversation with a clinician *reluctant to adopt* the KT intervention (i.e., guideline recommendations, protocols, bundles) to address ongoing individual concerns and encourage him or her to change behavior through the provision of information or evidence. *Important here, is targeting clinicians reluctant to adopt the KT intervention (late or non-adopters).*"
Audit & Feedback	"*Audit* refers to the collection of any data regarding clinical performance of health care over a specified period of time. The data may describe processes or outcomes of care. When a summary of these data is communicated back to the clinicians (as a team, or individual), it is referred to as *feedback*. This performance is usually a rate, i.e., in a given clinical situation, the fraction of times for which the desired practice or intervention was actually done. The feedback may be written, oral, or electronic, and can include recommendations for improvement or action."

Note. Table recreated from Sinuff et al., 2013 [31].

KTIs for Anesthesiologists

Due to their engagement in every aspect of perioperative care (i.e., pre-, intra-, and post-operative), anesthesiologists are essential in perioperative medicine [32]. They have the capacity to influence patient outcomes at all three stages of surgical care—pre-, intra-, and post-operative care—and are in a unique position among healthcare professionals working in the OR to encourage collaboration and recognize potential hazards [32,33]. An integral part of the training of anesthesiologists focuses on non-technical skills and teamwork, potentially making them a key change agent to improve teamwork in the OR. The complex nature of anesthesiology and intraoperative care require optimal knowledge and application of up to date technical and non-technical skills which can only be achieved through adherence to evidence-based practices [34]. To

our knowledge, there has been no prior review that focuses on anesthesiologists and KTIs. Additionally, anesthesiologists' technical skills are very important because in certain surgical procedures the choice of anesthesia technique used can determine post-surgical patient outcomes[35]. However, current practice variations among different anesthesiologist practices are evidence for deficiencies in properly translating research evidence into clinical practice [2,34,36–40]. An example of practice variation amongst anesthesiologists is the variability in anesthetic care when it comes to utilization of regional anesthesia in surgeries[41]. Regional anesthesia has been found to be an effective operational anesthesia for surgical procedures especially in orthopedic surgeries[41]. However, it is still underutilized and the reasons for this have been found to be associated with either patient preferences or hospital factors or primarily due to the comfort and expertise of the operating anesthesiologist[42–45]. Therefore, effective translation of the growing research evidence for surgical anesthesia techniques and skills can improve clinical practice and patient surgical outcomes. This endeavor requires us to select the most effective and relevant KTIs for an organization's unique context and deficiencies. To this end, we need to first identify the different KTIs developed and evaluated thus far in the intraoperative context for anesthesiologists and then potentially choose the most effective strategy.

Knowledge translation strategies have been implemented in many clinical settings and their effectiveness has also been evaluated [22,24–27,29,30,34,36,40]. However, we currently lack a synthesis of the literature on intraoperative KTIs, and we cannot confidently generalize the findings on KTIs from other care contexts to the intraoperative context. This is because the intraoperative setting is very distinct, and the challenges and care pathways are more complex and unique in comparison to other clinical settings. As such it is highly likely that the process of translating knowledge from literature to the bed side in the intraoperative context is going to be impacted by unique barriers and enables. Due to these reasons, a synthesis of the growing body of literature evaluating KT strategies in anesthesiology and intraoperative medicine needs to be conducted. This will be a critical and necessary step towards the advancement of KT, and ultimately result in the improvement and standardization of anesthesiologists' technical and non-technical skills required in surgical practice.

Teamwork development interventions (TDIs)

Suboptimal teamwork practices in surgical care have been found to increase the odds of adverse postoperative patient outcomes [2]. Members of a healthcare team need to collaborate with each other in order to provide optimal health care to their patients [4,13–16,46–48]. Teamwork as a non-technical skill is very important in all healthcare settings, but it becomes especially challenging in the OR setting due to the involvement of multiple distinct professions each having their own specific roles and responsibilities during the care process [4,13,16,49]. In this scenario, deficiencies in teamwork processes such as communication between intra-operative team members can have detrimental impacts on the patients' safety and surgical outcomes [4,13,16]. An example of this would be wrong-site surgeries due to breakdowns in communication chains [4,13].

To improve healthcare professionals' performance of teamwork behaviours, many TDIs have been developed and implemented in various healthcare settings [50,51]. In particular, the past two decades have shown a drastic increase in teamwork intervention research [52,53]. These interventions can range from checklist aids to help streamline communication processes, to training programs focusing on skills such as leadership, situation-awareness, and coordination

[50,51]. Due to this increased interest and the potential for reducing preventable patient harm in the OR setting, it is worth delving and conducting an in-depth analysis of the TDI literature [1–3].

Previous empirical studies and reviews have found evidence that suggests an association between teamwork processes and improved patient safety and clinical outcomes in multiple healthcare settings especially acute care settings such as the OR [4,7,16–19,48,50,51]. However, the evidence on the impact of TDIs on patient outcomes is inconclusive due to the inconsistency in findings [19]. This suggest a need to investigate factors that might be impacting the effectiveness of these interventions. One possible explanation for the ineffectiveness of existing TDIs could be deficiencies in the processes employed when designing the intervention [16].

Teamwork is a set of behaviours and as such an intraoperative TDI is essentially an intervention aiming to facilitate behaviour change amongst OR personnel. The effectiveness of an intervention aiming at changing behaviour partly depends on the extent to which it addresses the known enablers/barriers to behaviour change in addition to the implementation barriers/enablers [54–56]. Implementation science best practices propose that prior to designing an intervention, one should gather evidence regarding the context specific barriers and enablers that may impact the uptake of an intervention and use this to inform intervention design.[57] In the context of TDIs for the OR care setting, a preliminary assessment of barriers/enablers of effective teamwork can help to identify which factors need to be addressed by the TDI and these may vary amongst different hospitals. Figure 2 outlines the steps that can be taken to design an evidence based TDI.

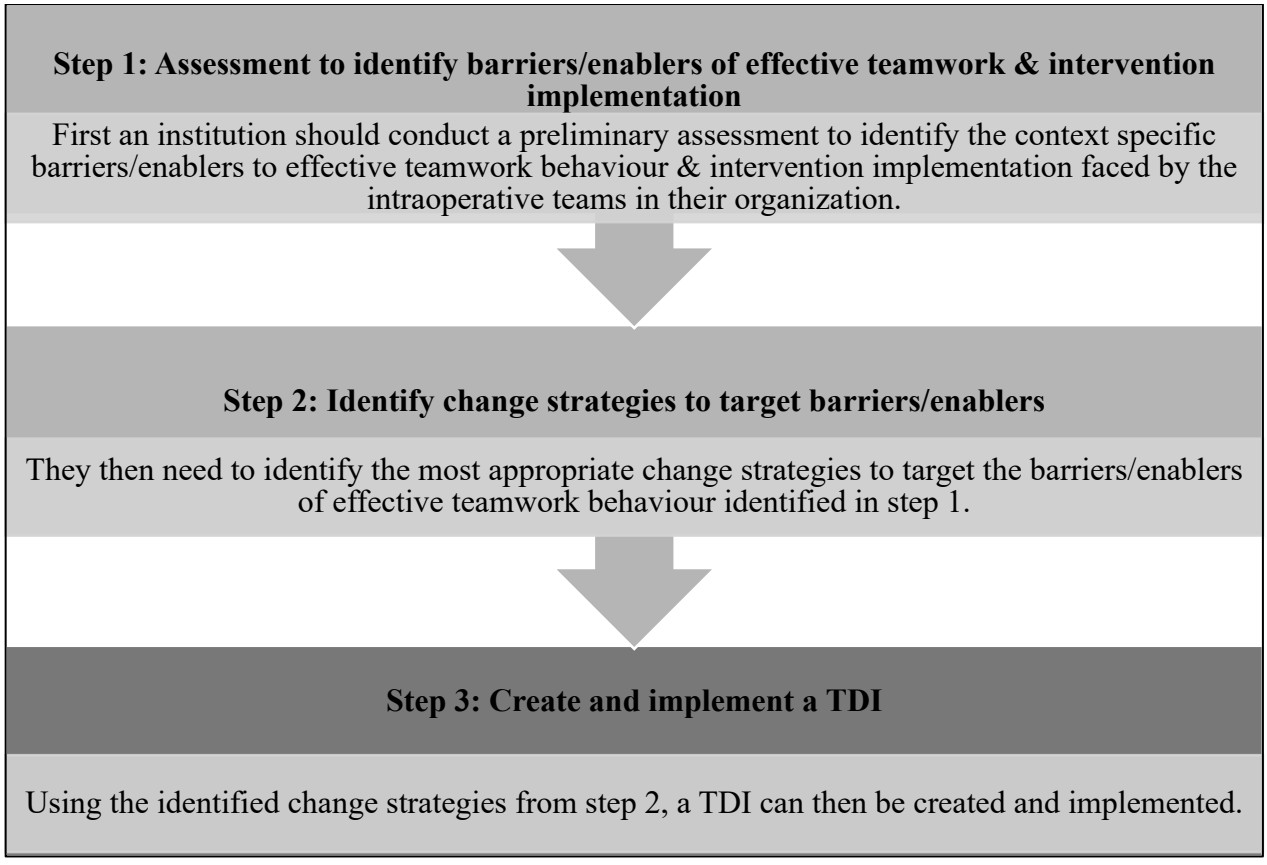

Figure 2. Outlines a basic overview of the steps that should be taken when designing an evidence-based TDI as recommended by the best practices in implementation science [57].
To improve future intraoperative TDI design, we need to target OR context specific barriers and enablers for behaviour change to facilitate the desired behaviour change in teamwork practices[54,55]. Current reviews can be used to determine which intervention to choose based on the healthcare setting it is to be implemented in. However, there is a gap in evidence when trying to target certain barriers/enablers to teamwork that are likely to vary amongst different healthcare organizations and departments [52,53,55]. Due to the extensive existing body of TDI literature in healthcare, it is beneficial to investigate the kinds of change strategies used by these TDIs to target which barriers/enablers to effective teamwork behaviour in the OR. We have coined the term "change strategies" to define the individual components that come together to form an intervention for example, a teamwork intervention including didactic lectures, simulation training, and coaching sessions is made up of three component change strategies. This systematic synthesis and analysis of the existing literature in TDIs will inform future endeavours regarding the design of new TDIs that sufficiently address barriers/enablers of effective teamwork in the OR care setting.

Theory-Informed Evaluation of Interventional Design

All interventions are faced with implementation challenges (i.e., barriers/enablers) and there is an increasing shift towards the use of theoretical approaches to identify and address these challenges during the intervention design phase in the field of implementation science.[58] For our case where we are aiming to analyse already designed and implemented TDIs, the literature suggests the use of evaluation frameworks to guide this process.[58] One such evaluation framework that can be used to retrospectively determine factors an intervention targeted and how successful it was at doing so is the Theoretical Domains Framework (TDF).[58] The TDF is a theoretical framework that has been developed and validated by a team of behavioural scientists and implementation science researchers.[56] It is a framework for identifying barriers/enablers of behaviour change which can then be used to inform the design of interventions aiming to change behaviour.[56,59] The TDF includes 14 domains derived from 84 theoretical constructs and 33 theories of behavior and behavior change which are presented in Table 2 below.[56]

Table 2. The 14 domains of the TDF with their respective definitions and constructs as described in version 2 of the TDF by Cane *et al.*, (2012).

TDF Domain (Version 2)	Domain definition	Constructs
Knowledge	"An awareness of the existence of something"	• Knowledge (including knowledge of condition/scientific rationale) • Procedural knowledge • Knowledge of task environment

Skills	"An ability or proficiency acquired through practice"	• Skills • Skills development • Competence • Ability • Interpersonal skills • Practice • Skill assessment
Social/professional role & identity	"A coherent set of behaviours and displayed personal qualities of an individual in a social or work setting"	• Professional identity • Professional role • Social identity • Identity • Professional boundaries • Professional confidence • Group identity • Leadership • Organisational commitment
Beliefs about capabilities	"Acceptance of the truth, reality or validity about an ability, talent or facility that a person can put to constructive use"	• Self-confidence • Perceived competence • Self-efficacy • Perceived behavioural control • Beliefs • Self-esteem • Empowerment • Professional confidence
Optimism	"The confidence that things will happen for the best or that desired goals will be attained"	• Optimism • Pessimism • Unrealistic optimism • Identity
Beliefs about consequences	"Acceptance of the truth, reality, or validity about outcomes of a behaviour in a given situation"	• Beliefs • Outcome expectancies • Characteristics of outcome expectancies • Anticipated regret • Consequents
Reinforcement	"Increasing the probability of a response by arranging a dependent relationship, or contingency, between the response and a given stimulus"	• Rewards (proximal/distal, valued/not valued, probable/improbable) • Incentives • Punishment • Consequents • Reinforcement • Contingencies • Sanctions

Intentions	"A conscious decision to perform a behaviour or a resolve to act in a certain way"	• Stability of intentions • Stages of change model • Transtheoretical model and stages of change
Goals	"Mental representations of outcomes or end states that an individual wants to achieve"	• Goals (distal/proximal) • Goal priority • Goal/target setting • Goals (autonomous/controlled) • Action planning • Implementation intention
Memory, attention, and decision processes	"The ability to retain information, focus selectively on aspects of the environment and choose between two or more alternatives"	• Memory • Attention • Attention control • Decision making • Cognitive overload/ tiredness
Environmental context and resources	"Any circumstance of a person's situation or environment that discourages or encourages the development of skills and abilities, independence, social competence and adaptive behaviour"	• Environmental stressors • Resources/material resources • Organisational culture/climate • Salient events/critical incidents • Person × environment interaction • Barriers and facilitators
Social influences	"Those interpersonal processes that can cause individuals to change their thoughts, feelings, or behaviours"	• Social pressure • Social norms • Group conformity • Social comparisons • Group norms • Social support • Power • Intergroup conflict • Alienation • Group identity • Modelling
Emotion	"A complex reaction pattern, involving experiential, behavioural, and physiological elements, by which the individual attempts	• Fear • Anxiety • Affect • Stress • Depression • Positive/negative affect

	to deal with a personally significant matter or event"	• Burn-out
Behavioural regulation	"Anything aimed at managing or changing objectively observed or measured actions"	• Self-monitoring • Breaking habit • Action planning

Note. Table recreated from *Cane et al.*, 2012 [59].

The TDF has been utilized in many healthcare contexts to help guide the process of identifying specific barriers and enablers to behaviour change and using this to design interventions that can overcome these barriers/enablers.[55,60–63] A top-down approach to intervention design when using TDF, involves investigating which of the 14 barriers/enablers depicted in the TDF domains are applicable to the intervention being designed. Conversely, a bottom-up approach can also be utilized by investigating an already designed intervention to identify which of the 14 barriers/enablers depicted in the TDF domains are being targeted by the intervention. This approach of working backwards by retrospectively identifying the factors targeted by an intervention whose design was not informed by theory, has been utilized in a previous study on improving quality of care for patients at risk of osteoporosis [64].

Thesis Rationale

The OR care setting is a high risk and fast-paced environment that requires OR personnel to be knowledgeable and up to date with relevant evidence-based technical skills and have excellent teamwork capabilities to ensure a smooth and safe workflow in the intraoperative phase. Anesthesiologists play a key role in patient safety, in particular from a teamwork perspective in the entire perioperative phase. Anesthesiologists also have a history of demonstrating variations in medical practice across professionals, as well as a knowledge-practice gap, and as such they can benefit from KTIs that can standardize their medical practice. Therefore, to improve patient safety and outcomes for surgical patients in the OR, this dissertation aimed to conduct two systematic reviews: 1) Explore KTIs to identify what KTIs are most effective to standardize anesthesiologists' intraoperative practice, and 2) delve into the literature for TDIs and how they can be optimally designed to improve teamwork capabilities of OR personnel.

Thesis Outline and Objectives

The main objective of this thesis is to improve patient safety and outcomes for surgical patient in the intraoperative care setting. This has been addressed by conducting two systematic reviews that explore the standardization of medical practice amongst anesthesiologists in the OR and improving teamwork practices amongst all the personnel working together in an OR.

This is a manuscript-based thesis that is divided into 4 chapters:

Chapter 1: In this chapter, we provide an introduction of the key concepts related to our research, the research problem, and the significance of our research.

Chapter 2: In this chapter, we present the manuscript of a quantitative systematic review and meta-analysis that addresses the following objectives:

> **Objective 1:** Identify the KTIs that involve anesthesiologists as a target audience and the intraoperative care context.
>
> **Objective 2:** Synthesize the effectiveness of these KTIs meta-analytically within the context of anesthesiology during the intraoperative period.

Chapter 3: In this chapter we present the manuscript of a qualitative systematic review that addresses the following objectives:

> **Objective 1:** What are the types of TDIs that have been evaluated empirically in the intraoperative care setting?
>
> **Objective 2:** Amongst these TDIs, which change strategies were used to target which teamwork behaviour barriers/enablers using the TDF?

Chapter 4: In this chapter we discuss and compare the findings between our two reviews as well as the considerations and implications for future research and strengths and limitations.

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Chapter 2:

Title: Knowledge translation interventions in intraoperative anesthesiology: A systematic review and meta-analysis of randomized controlled trials.

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Funding:
Dr. Boet was supported by The Ottawa Hospital Anesthesia Alternate Funds Association and the Faculty of Medicine, University of Ottawa with a Tier 2 Clinical Research Chair. The DistillerSR licenses were funded by the Department of Anesthesiology and Pain Medicine, The Ottawa Hospital.

Conflict of interest:
None

Acknowledgements:
We would like to thank Dr. Tasnim Sinuff for her advice and early review of the study protocol prior to the commencement of the review.

ABSTRACT

Purpose

Documented practice variations among anesthesiologists suggest an opportunity to improve translation of research evidence into informed clinical decisions. Thus, we aimed to synthesize current evidence on Knowledge Translation Interventions (KTIs) in anesthesiology during the intraoperative period.

Source

Literature searches were conducted in MEDLINE, EMBASE, CINAHL, ERIC, and Cochrane CENTRAL from inception to 21st April, 2021. We included randomized controlled trials (RCTs) that empirically evaluated the effectiveness of KTIs in anesthesiology during the intraoperative period. We excluded studies reporting self-assessment outcomes only. Abstract screening was conducted using humans and artificial intelligence as a pair. Full-text screening and risk of bias assessment were conducted in duplicates. Outcomes relating to changes in providers' processes of care, patient outcomes, and cost of care were extracted if available.

Principal Findings

Thirty-five RCTs met our inclusion criteria and 26 were meta-analytically analysed. Processes of care improved when using the following KTI types: Education (RR [95% CI]: 2.69 [1.48 to 4.89], P=0.001; SMD [95% CI]: 1.69 [0.52 to 2.65], P=0.005), Reminders (SMD [95% CI]: 1.94 [0.65 to 3.23], P=0.003), and Audit & Feedback (SMD [95% CI]: 0.78 [0.26 to 1.29], P=0.003). For the KTI type Reminders, enough studies had evaluated patient related outcomes for a meta-analysis, and no improvement in patient outcomes was observed (RR [95% CI]: 1.00 [0.99 to 1.00], P=0.35).

Conclusion

Education which included simulations, didactic sessions, or workshops, was the most effective KT strategy followed by Reminder and Audit & Feedback respectively for anesthesiologists in the intraoperative care context.

INTRODUCTION

Rationale

Over 310 million major surgical procedures occur globally each year and the postoperative mortality is projected to reach 12 million death per year globally.[1] In addition to surgical mortality, high rates of surgical morbidity due to adverse events are also a cause for concern however, around half of all surgical errors have been identified as preventable.[1–4] Practice variation is one of the main causes of the preventable harm experienced by surgical patients,[5–8] and may in part reflect the challenges faced by healthcare professionals in translating results from an increasingly large volume of published medical studies into informed clinical decisions.[9] Practice variations can be the result of differences in patient preferences, hospital factors and provider comfort and expertise[10]. Other barriers to the adoption of evidence-informed practice include controversies in the literature,[11,12] fear of iatrogenic complications,[13] and lack of time to filter relevant information.[13,14]

Optimizing healthcare professionals' adherence to evidence-based practices ensures quality patient care, improved patient outcomes, and effective use of healthcare resources.[15–18] This is especially important in anesthesiology during the intraoperative period, given its fundamental role in surgical patient outcomes[17,19–21] and the documented wide variation in anesthesiologists' practice.[22–27]

To promote the systematic and effective transfer of research evidence to the bedside of surgical patients, it is necessary to understand the state of knowledge translation (KT) specific to the intraoperative period. While the effectiveness of KT strategies has been studied in other clinical areas,[9,24–27] these findings may not necessarily be generalizable to the intraoperative context given its unique characteristics (e.g., high-risk, rapidly changing patient conditions, interprofessional setting, sophisticated diagnostic and management strategies delivered concurrently by multidisciplinary teams). This systematic review and meta-analysis therefore aimed to synthesise the effectiveness of KT interventions and best practice implementation strategies within the context of anesthesiology during the intraoperative period.

METHODS

This systematic review was registered with PROSPERO (CRD42015020551), conducted in accordance with the Cochrane Collaboration principles for systematic reviews [28] and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[29]

Information sources & Search strategy
The electronic databases MEDLINE (via Ovid), EMBASE (via Ovid), CINAHL (via EBSCO), ERIC (via Ovid), and the Cochrane Central Register of Controlled Trial (via Ovid) were searched from inception to 21st April 2021. We used specific search strategies for identifying KT literature that were previously developed by McKibbon and Lokker.[30] A MEDLINE comprehensive search strategy was formulated by an experienced health sciences information specialist (AD), which was informed by the KT specific search strategy, recently published KT literature, and input from the research team. The final search strategy was peer- reviewed by another information specialist according to the Peer Review of Electronic Search Strategies (PRESS) guidelines.[31] The MEDLINE search strategy (Appendix C) was then adapted to the syntax and subject headings of all the other databases. When updating the search on 21st April 2021, another information specialist (LS) adapted the original MEDLINE search strategy to the syntax and subject headings of all other databases. A specific widely used search filter for RCTs was incorporated at this stage to increase the sensitivity of our search strategy and reduce the time and resources needed to screen the additional articles.[32] There were no restrictions on publication status, language, year, or study location. Studies published in languages other than English were excluded at the screening stage. Sources of grey literature were not included in the search strategy.

Selection of sources of evidence
To be eligible for inclusion, studies had to: 1) be a randomized controlled trial (e.g., parallel group, crossover, cluster, factorial designs); 2) include at least one anesthesiologist among participants; and 3) empirically evaluate the effectiveness of a KT intervention aimed at improving adherence to evidence-based practices in anesthesiology. The intervention also had to be implemented in the intraoperative period (it could be extended to pre and/or post operative period as long as it included the intraoperative period), with the control group receiving no KTI (control) or another type of KTI (comparator). Eligible study outcomes for inclusion had to reflect at least one component of the Triple Aim Initiative (TAI) for improving healthcare.

TAI was developed by Donald Berwick and colleagues at Institute for Healthcare Improvement (IHI),[33] and is comprised of three domains: improving the individual experience of care, improving the health of populations, and reducing per capita costs of care.[33] We have selected TAI because it includes patient-centered clinical outcomes. Patient-centered outcomes are required when considering potentially low-cost interventions that also improve clinical practices with a clear benefit for patients. In this review, we categorized the outcomes of KTI studies into one or more of the three TAI categories.[33]

Self-assessment outcomes were excluded as evidence shows that healthcare professionals are poor at summative self-assessment and this introduces the potential for self-reporting bias.[34] All reviews, editorials, commentaries, notes, letters and opinions were excluded.

The final literature search results were merged and uploaded to Distiller Systematic Review (DistillerSR) software (Evidence Partners, Ottawa, Canada), an online collaborative platform for carrying out study selection and data extraction. Screening questions and forms were developed a priori, and pilot tested on DistillerSR using the first 20 references until a kappa interrater reliability score of at least 80% was achieved amongst the pairs of screeners. All reviewers received training and guidance regarding the use of DistillerSR and the screening forms for each screening stage.

The Artificial Intelligence feature of DistillerSR software was used in addition to human screeners for abstract screening for feasibility. The accuracy of the AI tool for this topic area was previously established by our research group through a diagnostic test accuracy study.[35] DistillerSR's Artificial Intelligence tool called DistillerAI was trained using a test set of 300 citations established through human screening and consensus. The AI assigned a score to all abstracts in the test set. These scores indicated the likelihood of the AI to include an article. The DistillerAI tool allows user-defined thresholds to be used where a range between 0-1 is specified and an article is excluded, included, or marked as unsure depending on which range the corresponding score falls within. Scores were compared to the human screeners' decisions. When comparing human abstract screening to DistillerAI abstract screening results, although specificity (i.e., the proportion of negatives that were correctly identified as negative) varied, sensitivity (i.e., the proportion of positives that were correctly identified as positive) was consistently high (100%) for every threshold setting. None of the threshold settings resulted in any false negatives (i.e., an article is excluded when it should have been included) but occasionally had false positives (i.e., an article is included when it should have been excluded).[35]

Another recent paper evaluated the DistillerAI tool and recommended two strategies for screening when using this tool: modified screening approach (i.e., replace duplicate screening by two humans with a dual screening approach where one screener is a human and the other the AI tool); stopping approach (i.e., after having humans screen a specified amount of articles in duplicates, the remaining articles are screened by the AI only and human screening is stopped).[36] We opted for a modified screening approach strategy where the first set of 300 articles were screened by a pair of human screeners and since we found the DistillerAI tool to be highly accurate through the preliminary study, we used the AI screening tool as a second screener paired with a primary human screener for the rest of the citation abstracts. The tool was set to using a conservative threshold approach where the AI tool was programmed to not rate an article if it deemed it to be ambiguous (i.e., between 0.1 and 0.9) thus preventing the occurrence of false negatives. If the AI rated an article as ≤0.1 then it was excluded and if rated as 0.9≥ then it was included. AI not rating an article was analogous to when a pair of human screeners disagree, and a human reviewer intervened to reach consensus.

Citations included by DistillerAI and the human screener at this point moved on to the next screening stage (abstract screening by two humans). A pair of trained human screeners then screened the full texts of the resulting included citations independently and in duplicate.

Citations were excluded at this stage if they were excluded by both reviewers. All conflicts were resolved by consensus or involvement of a third reviewer, if necessary, at the end of each human screening stage.

Data extraction

A data extraction form (Appendix C) was developed a priori in DistillerSR and pilot tested on a sample of studies. Two independent reviewers extracted the information detailed in the data extraction form. Any discrepancies or disagreements were resolved by consensus or the involvement of a third reviewer. During data extraction, the type of KTI in each study was categorised in to one of the ten KTI types identified and defined by Sinuff et al. in their systematic review.[37] The ten KTI types identified and defined by Sinuff et al. are as follows: clinical practice guidelines, protocols, bundle/checklists, person/ team/ organizational change, education, reminders, academic detailing, audit and feedback, and opinion leaders/champion.[37]

Quality assessment

Risk of bias of randomized controlled trials was assessed independently and in duplicate by two reviewers using the revised Cochrane risk of bias tool for randomized trials (RoB 2).[38] Disagreements were resolved by consensus or involvement of a third reviewer. The Cochrane risk of bias tool considers the following domains: sequence generation, allocation concealment, blinding (of participants, personnel, and outcome assessors), incomplete outcome data, selective outcome reporting, and other sources of bias for the RCTs.[28,38] Each item was described as a 'low', 'high', or 'some concerns" for risk of bias.[38] The risk of bias within studies were presented graphically using the excel tools developed by the RoB 2 development team for parallel group RCTs, cluster RCTs, and crossover RCTs.[38]

Data synthesis
Study characteristics were summarized as frequencies and percentages for categorical characteristics. Individual study characteristics were summarized qualitatively in a table containing the following fields: primary author, study design, country, funding source, clinical setting, provider characteristics, KTI type(s), study specific results & conclusions. The primary outcomes of each study were categorized according to the Triple Aim Initiative (TAI) categories and type of outcomes (i.e., dichotomous, continuous, counts/rates, ordinal, time-to-event).

We carried out a meta-analysis for each type of knowledge translation intervention and type of outcome (process of care/patient outcomes/cost of care) evaluated by at least 2 studies. We extracted data relating to only primary outcomes from each study. We extracted dichotomous, continuous, counts/rates, ordinal or time-to-event process of care measures, patient outcomes or cost of care outcomes separately. If multiple primary outcome process measures of the same variable type (e.g., two dichotomous variables) were reported by a study we chose the most clinically relevant outcome, and if needed the outcome evaluated by a validated measuring scale. For cluster RCTs, we adjusted the sample size using the ICC reported in the study itself following the guidelines recommended in the Cochrane Handbook for systematic reviews.[28] For crossover randomized controlled trials, we used the data from the first parallel group comparison prior to occurrence of any crossover as we cannot be certain that there was no spill-over effect of

the pre-crossover treatment on the groups' performance in post-crossover treatment due to the nature of KT interventions. For three-arm RCTs, we extracted data for only the KTI of interest and the control group.

For dichotomous outcomes, we extracted raw unadjusted data and, for continuous, data we extracted means and standard deviations (SD), and we converted median (interquartile range) to mean (SD) using the methods recommended in the Cochrane handbook for systematic reviews.[28] Ordinal data were treated as continuous data in meta-analysis. Counts/rates and time-to-event data were assessed as dichotomous outcomes when appropriate and possible (i.e., if individual level data were available). Where time-to-event outcomes were measured as continuous variables, we summarized them in a separate meta-analysis as a sensitivity analysis. We summarized dichotomous process measures as risk ratio (RR) using raw unadjusted data extracted from each study. Continuous process measures were summarized as standardized mean differences (SMD). We excluded dichotomous outcomes from our analysis if raw-unadjusted data could not be obtained. In the instance that a trial had reported dichotomous, continuous, and time-to-event outcomes then we included all three outcomes separately in their respective meta-analysis. Therefore, results from a trial could appear in the meta-analysis for dichotomous outcomes and also appear in the meta-analysis for continuous outcomes.

All meta-analyses were conducted using random effects generic inverse variance models. For dichotomous and continuous process measures respectively, a RR>1 and SMD>0 represented an improvement in process measures. Sensitivity analysis was conducted by stratifying the results according to different outcome measures i.e., dichotomous, continuous, or time-to-event and by category of outcomes i.e., improvement in process of care, or patient outcomes. Publication bias was assessed by visually inspecting funnel plots for dichotomous and continuous process measures stratified by process of care or patient outcomes. Heterogeneity was assessed using I^2 values and all meta-analysis were carried out using Review Manager (Version 5.3, The Cochrane Collaboration, Copenhagen, Denmark).

RESULTS

Study selection

Our search strategy yielded a total of 11,685 studies (Figure 1). After removal of duplicates, 8,955 studies were assessed for eligibility using their title and abstract and 65 studies were included at the abstract screening stage. Out of the 65 studies that underwent full-text screening, 35 RCTs were included in our review for qualitative analysis and 26 RCTs were included for quantitative analysis.

Study characteristics

Characteristics of the 35 included RCTs are summarized in Table 1. We included 25 parallel group RCTs, [39–63] three RCTs with repeated measures, [64–66] three cluster RCTs, [67–69] and four crossover RCTs. [70–73] Two trials were conducted over the entire perioperative care period (including the intraoperative period), [42,68] 15 in an actual operating room, [39–41,45,47,49,52,54,56,58,61,63,67,69,70] 17 in a simulated operating room, [43,44,48,50,51,53,55,57,59,60,62,64–66,71–73] and one in a non-operating room virtual simulation of a clinical task. [46] Seventeen studies took place in the United States, [39,41,42,47,50,52–54,56,59,61–63,70–73] ten in Canada, [40,43,44,48,49,51,64,65,68,69] two in the Netherlands, [67,68] and one in each of the following countries: Australia, [66] New Zealand, [45] Germany, [57] Rwanda, [55] Italy, [46] India[58] and France. [60] Additional information on participant and study characteristics for each individual study is provided in Table 3. The most common funding source was from industry (n=16), [41,44,47,50,55,57,61–65,67,68,70,71,73] followed by a combination of government and industry grants (n=6). [45,48,51,54,59,69] Three studies received no funding, [46,52,66] three studies received funding from the government only, [43,49,56] and seven studies did not report a funding source. [39,40,42,53,58,60,72]

KT interventions

Thirty-five different knowledge translation interventions were identified (30 single KT strategy, and 5 combinations of KT strategies). "Reminder" (n=11[31.4%]) and "Education" (n=11[31.4%]) were the most studied type of KTIs followed by "Audit & Feedback" (n=4[11.4%]), and "Bundle/Checklist" (n=4[11.4%]). 4 different combinations of KTIs were evaluated amongst five studies out of which "Education + Audit & Feedback" was studied in two studies compared to one study only for the other combinations (Table 1).

Types of outcomes assessed

The primary outcomes are summarized in Table 4 according to their type of outcome, TAI category (i.e., improving the patient experience of care (process of care or patient outcomes), improving the health of populations, and reducing the cost of care). The primary outcomes of most included studies involved a change in processes of care (i.e., "improving the patient experience of care" category). Studies were excluded from meta-analysis because they did not report the primary outcome measure(s) in enough detail, or they were the only study in the subgroup. Included studies used 23 continuous process measures, 15 dichotomous, eight time-to-event treated as continuous, three time-to-event treated as dichotomous, two rate and one ordinal outcome. Out of these, 33 outcome measures were eligible for meta-analysis. Table 4 describes in further detail the reason why each outcome was excluded from meta-analysis. Therefore, meta-analysis was conducted for the following KTIs: Education, Reminder, Checklist/Bundle (RR for dichotomous & SMD for continuous), and Audit & Feedback (SMD).

Impact of KT interventions on change in processes of care & clinical outcomes
We included four unique single KTIs with at least two process measures per KTI type (Table 4). Dichotomous process measures related to "process of care", improved when using Educational KTIs (RR [95% CI]: 2.69 [1.48 to 4.89], p=0.001). Continuous process measures related to "process of care", improved using Educational KTIs (SMD [95% CI]: 1.69 [0.52 to 2.65], p=0.005), Reminder KTIs (SMD [95% CI]: 1.94 [0.65 to 3.23], p=0.003), and Audit & Feedback KTIs (SMD [95% CI]: 0.78 [0.26 to 1.29], p=0.003).

Improvement in the dichotomous outcomes with reminder or checklist/bundle KTIs was not statistically significant (RR [95% CI]): 1.38 [0.97 to 1.96], p=0.07 and 1.97 [0.86 to 4.50], p=0.11 respectively). Similarly, the pooled improvement in the continuous outcomes when using checklist/bundle was also not statistically significant (SMD [95% CI]: 1.51 (-1.91 to 4.93], p=0.39). Heterogeneity in our meta-analysis varied from none to considerable in both dichotomous and continuous outcomes related to a change in "process of care" as shown by the I^2 values in Table 4. Change in "patient outcomes" was evaluated by more than two studies using the KTI type Reminder only and it was not associated with an improvement in dichotomous patient outcomes (RR [95% CI]: 1.00 [0.99 to 1.00]), p=0.35).

Five time-to-event outcomes were reported as continuous. It is not appropriate to measure time-to-event variables as continuous and therefore, we excluded these from our main continuous process measure analysis and conducted a separate meta-analysis for these. Three studies evaluated Educational KTIs using time-to-event outcomes reported as continuous measures and no association with improvement in outcomes was observed in our meta-analysis (SMD [95% CI]: 0.43 [-0.42 to 1.28]. p=0.32). Two studies evaluated Reminder using time-to-event outcomes reported as continuous and no association with improvement in outcomes was observed in our meta-analysis (SMD [95% CI]: 0.95 [-0.22 to 2.11], p=0.11).

Publication bias
We visually inspected the funnel plots to evaluate publication bias (Figure 15 to 24). Publication bias may have been present for the effect of continuous process measures relating to change in "process of care" outcomes when evaluating education as a KTI (i.e., large studies with small effect sizes). We did not have enough studies included in other subgroup meta-analysis to make a judgement about publication bias however, there was a trend of individual effects being closer to the overall effect, in a horizontal line rather than being scattered and there were more large studies with small effects than smaller sized studies.

Risk of bias assessment
Risk of bias within studies was appraised via the revised Cochrane tool for assessing the risk of bias in RCTs (RoB 2) summarized in Figures 2, 3, & 4 for parallel group RCTs, crossover RCTs, and cluster RCTs respectively.[38] For the 28 parallel group RCTs, there was a low risk of bias for four domains (randomization process, deviations from intended interventions, missing outcome data, and selection of the reported results), and high risk or some concerns in the domain 'measurement of the outcome' (Figure 2). Amongst the four crossover studies, apart from the domains 'randomization process' and 'selection of the reported results', all other domains had some studies with some concerns or a high risk of bias. Lastly, for the cluster RCTs, there was a

low risk of bias in three domains (timing of identification or recruitment of participants, missing outcome data, and selection of reported results) and some concerns or a high for some studies in the other domains. In summary, 20 studies were overall at low risk, 5 studies with some concerns, and 10 studies at high risk of bias.

DISCUSSION

In this systematic review, we found 35 studies that tested the effectiveness of KTIs on the clinical practice of anesthesiologists during the intraoperative period. These included studies evaluated 35 different knowledge translation interventions.[37] We found that "Education" and "Reminders" were the two most common type of KTI designed for anesthesia in the intraoperative setting. Existing literature to date demonstrates that implementation of KTIs that incorporate "Education", "Reminders", or "Audit & feedback" as KT strategies, is associated with improvements in processes of care amongst anesthesiologists in the intraoperative period. There is limited data with regards to the impact of these KT strategies on patient outcomes, with the exception of "Reminders" as a KT strategy which was not associated with improvements in patient outcomes.

We found no association between clinical outcomes and the KT strategy "Reminders"; however, an association was apparent between the processes of care outcomes and KTIs. Previous reviews on KTIs in other healthcare settings have also reported limited evidence for the impact of KTIs on patient-centered outcomes, clinical or otherwise.[74–76] This may be because a single category of KT strategy may not be enough to impact patient outcomes or because it is challenging to choose an outcome directly linked to the KTI choosing relevant outcome measures. Most included KTIs aimed to achieve a change in clinical practice and indirectly clinical outcomes and thus a direct measure of the interventions' effectiveness would be to evaluate a change in clinical practice (i.e., process of care). We can argue that the follow-up period was perhaps not adequate to see a significant positive change in clinical outcomes, but it may have been adequate to measure immediate changes in clinical practice post KTI implementation. Sample size can also be a factor here as small sample sizes can make it difficult to detect the small improvements that occurred in clinical outcomes due to the nature of these outcomes. For example, mortality often requires a long-follow up period to evaluate.

Variation in outcomes may also be due, at least in part, to the lack of preliminary analysis of barriers and facilitators to inform intervention development, as has been noted in other settings.[76] Although one of the trials used the Theoretical Domains Framework and conducted a survey prior to KTI development and implementation to inform the design of the intervention, another strategy (i.e., substitution with an alternative instead of cessation of previous clinical practices) was ultimately found to be more successful in bringing about the desired change rather than the KTI itself.[68] As preliminary analysis of barriers and facilitators for behavior change was not part of any of the other included trials in this review, it will also be necessary for future KTI studies to consider this component of intervention design and implementation. This may enhance the effectiveness of KTI strategies, or at least enable iterative development of KTIs.

Based on the current body of literature and our meta-analysis, Educational KTIs were the most studied and effective KT strategy in improving processes of care amongst anesthesiologists in the intraoperative care setting. The educational interventions in the included trials utilized simulated OR and actual ORs as well as didactic sessions. There is a need to conduct more trials to compare the differences and effectiveness of these different educational KTI strategies.

A strength of this systematic review is that we followed established guidelines for conducting reviews and conducted a thorough search of the published literature using a previously validated search strategy designed specifically for identifying KT literature by McKibbon and Lokker.[30] Another strength is that we have conducted a meta-analysis to quantitatively determine the most effective KTI design and included a sensitivity analysis by exploring the effect by type of outcome data (dichotomous vs. continuous vs. time-to-event outcomes), and process of care outcomes vs. clinical outcomes.

There are several limitations of this review. First, we included RCTs only. As such, it is likely that we may have excluded some moderate and high-quality observational studies that would have provided additional evidence for the effectiveness of the KTIs included in this review and may have also evaluated types of KTIs not included in this review. Secondly, some important details about the implementation of the interventions, study participants or clinical setting may not have been reported by the study. Most of the included studies were positive studies alluding to publication bias. Lastly, we excluded non-English publications and most included trials were conducted in North America and were single centre studies, reducing the generalizability of the findings.

Conclusion

In conclusion, “Education” which included simulations, didactic sessions, or workshops, was the most effective KT strategy followed by “Reminder” and “Audit & feedback” respectively among RCTs in anesthesiology during the intraoperative period. We identified Educational KTIs as the most common and most effective type of KTI and future trials should compare head-to-head different types of Educational KTIs and should also explore the effectiveness of single category versus bundle KTIs.

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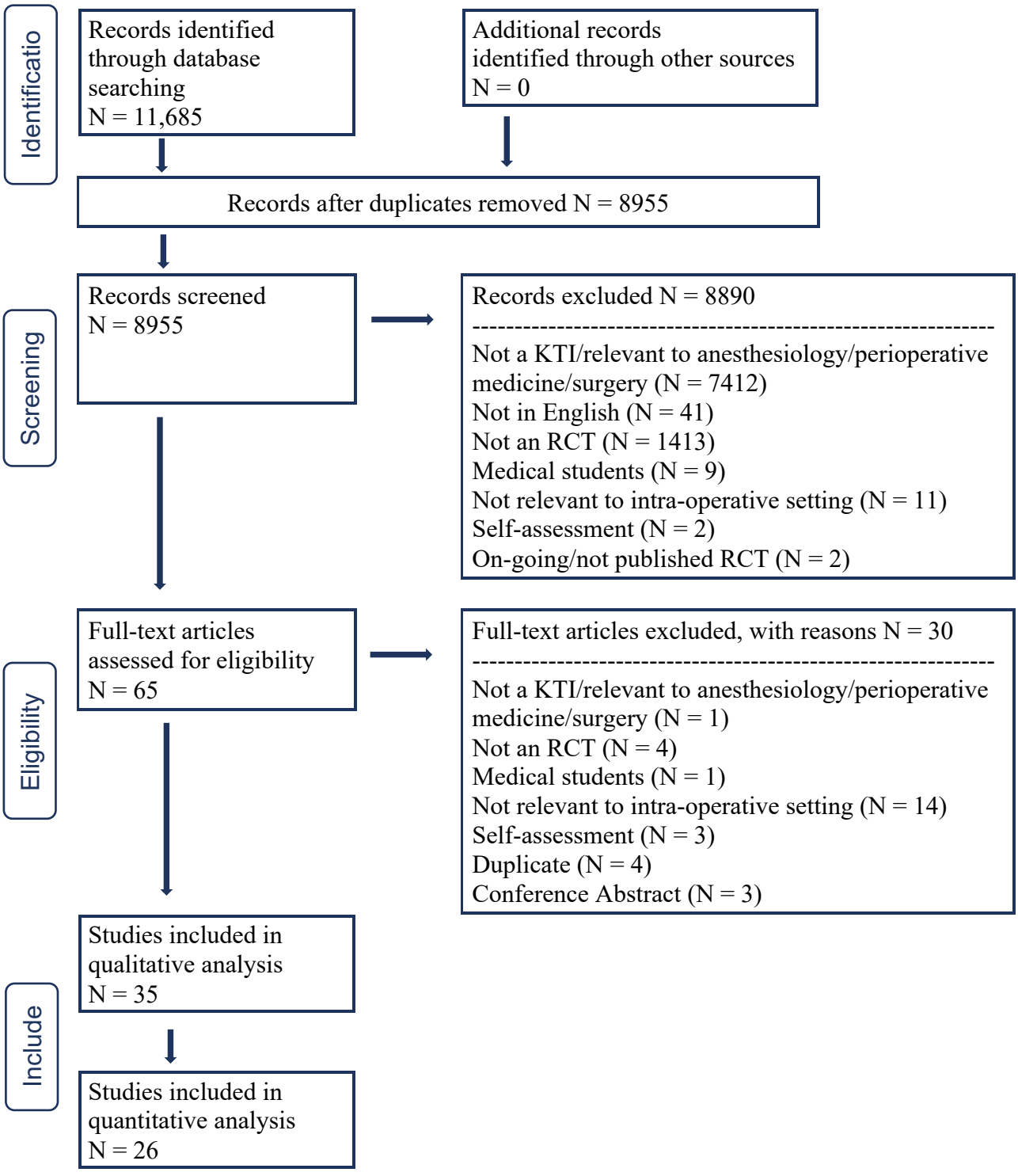
Table 1 Summary of study characteristics of included studies (n=35).

Study descriptors	***No. of studies*** N=35	***References***
Study design		
Randomized Controlled Trial (RCT)	25 (71.4)	[39–63]
RCT - multicenter repeated measures	1 (2.9)	[66]
Cluster RCT	3 (8.6)	[67–69]
RCT - repeated measures	2 (5.7)	[64,65]
Cross-over RCT	4 (11.4)	[70–73]
Clinical setting		
Perioperative	2 (5.7)	[42,68]
Operating Room	15 (42.9)	[39–41,45,47,49,52,54,56,58,61,63,67,69,70]
Simulated operating room	17 (48.6)	[43,44,48,50,51,53,55,57,59,60,62,64–66,71–73]
Non-operating room virtual simulation of clinical task	1 (2.9)	[46]
Study country		
United States	17 (48.6)	[39,41,42,47,50,52–54,56,59,61–63,70–73]
Australia	1 (2.9)	[66]
Canada	10 (25.7)	[40,43,44,48,49,51,64,65,68,69]
The Netherlands	2 (5.7)	[67,68]
New Zealand	1 (2.9)	[45]
Germany	1 (2.9)	[57]
Rwanda	1 (2.9)	[55]
Italy	1 (2.9)	[46]
India	1 (2.9)	[58]
France	1 (2.9)	[60]
Sources of funding		
Funding from government & industry	6 (17.1)	[45,48,51,54,59,69]
None	3 (8.6)	[46,52,66]
Funding from industry	16 (45.7)	[41,44,47,50,55,57,61–65,67,68,70,71,73]
Funding from government	3 (8.6)	[43,49,56]
Not reported	7 (20.0)	[39,40,42,53,58,60,72]
Types of Knowledge Translation Interventions: single or multifaceted		
Reminder	11 (31.4)	[41,42,47–49,52,54,60–62,67]
Bundle/Checklist	4 (11.4)	[53,59,66,73]
Education	11 (31.4)	[40,44,46,50,51,55,56,58,63,71,72]
Audit & Feedback	4 (11.4)	[39,64,65,69]
Education + Audit & Feedback	2 (5.7)	[43,68]
Education + Bundle/Checklist	1 (2.9)	[70]
Education + Reminder	1 (2.9)	[57]
Bundle/Checklist + Reminder + Organizational change	1 (2.9)	[45]

Table 2 Meta-analysis: Effects of Knowledge Translation Interventions stratified by process measures or patient outcomes from included Randomized Controlled Trials (n=26). (Process measure = Change in process of care; Patient outcomes = clinical outcomes)

Type of Knowledge Translation Intervention	***No. of studies***	***Effect measure***	***P value***	***I^2 (%)***
Patient experience: Change in processes of care				
Dichotomous process measures		*RR (95% CI)*		
Education	3	2.69 (1.48 to 4.89)	0.001	0
Reminder	2	1.38 (0.97 to 1.96)	0.07	87
Checklist/Bundle	2	1.97 (0.86 to 4.50)	0.11	89
Continuous process measures		*Standardized Mean Difference (95% CI)*		
Education	9	1.69 (0.52 to 2.85)	0.005	94
Reminder	2	1.94 (0.65 to 3.23)	0.003	80
Checklist/Bundle	2	1.51 (-1.91, 4.93)	0.39	96
Audit & Feedback	3	0.78 (0.26 to 1.29)	0.003	47
Time-to-event process measures		*Standardized Mean Difference (95% CI)*		
Education	3	0.43 (-0.42 to 1.28)	0.32	66
Reminder	2	0.95 (-0.22 to 2.11)	0.11	87
Patient experience: Change in patient outcomes				
Dichotomous process measures		*RR (95% CI)*		
Reminder	5	1.00 (0.99 to 1.00)	0.35	6

Figure 1 PRISMA flow diagram summarizing study selection procedure.



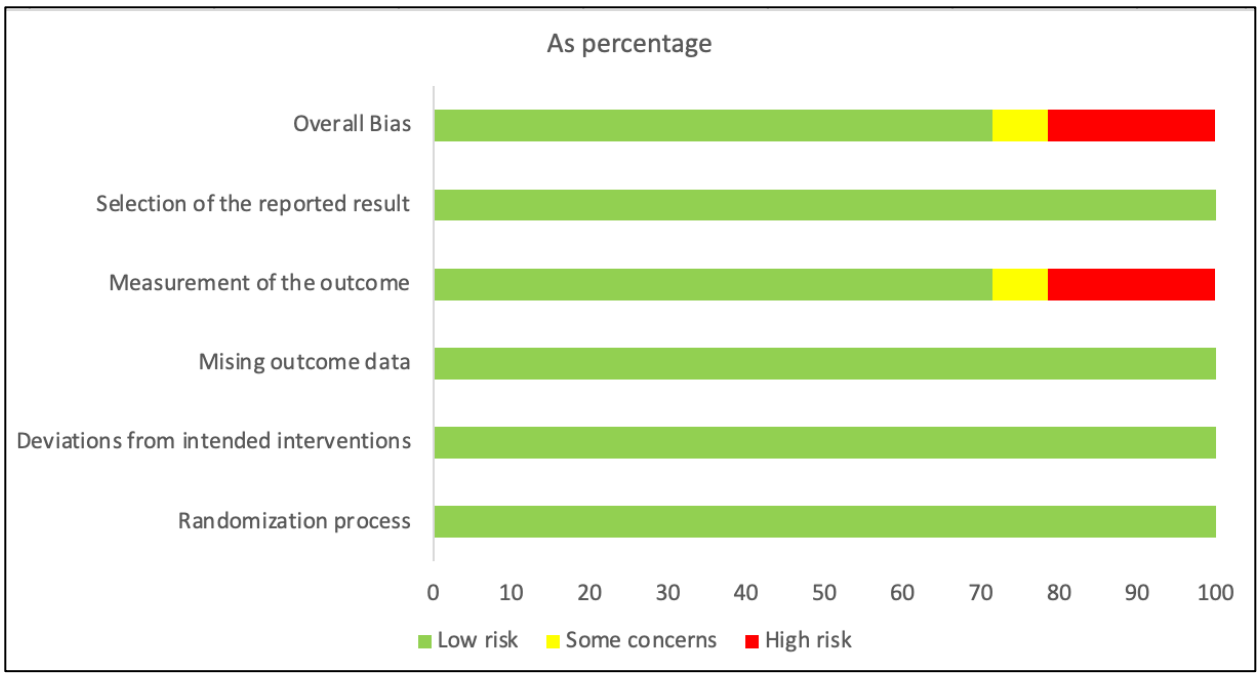


Figure 2 Risk of bias summary of parallel group RCTs. Green = low risk; yellow = some concerns; red = high risk. D1=Randomization process; D2=Deviations from intended interventions; D3=Missing outcome data; D4=Measurement of the outcome; D5=Selection of the reported result.

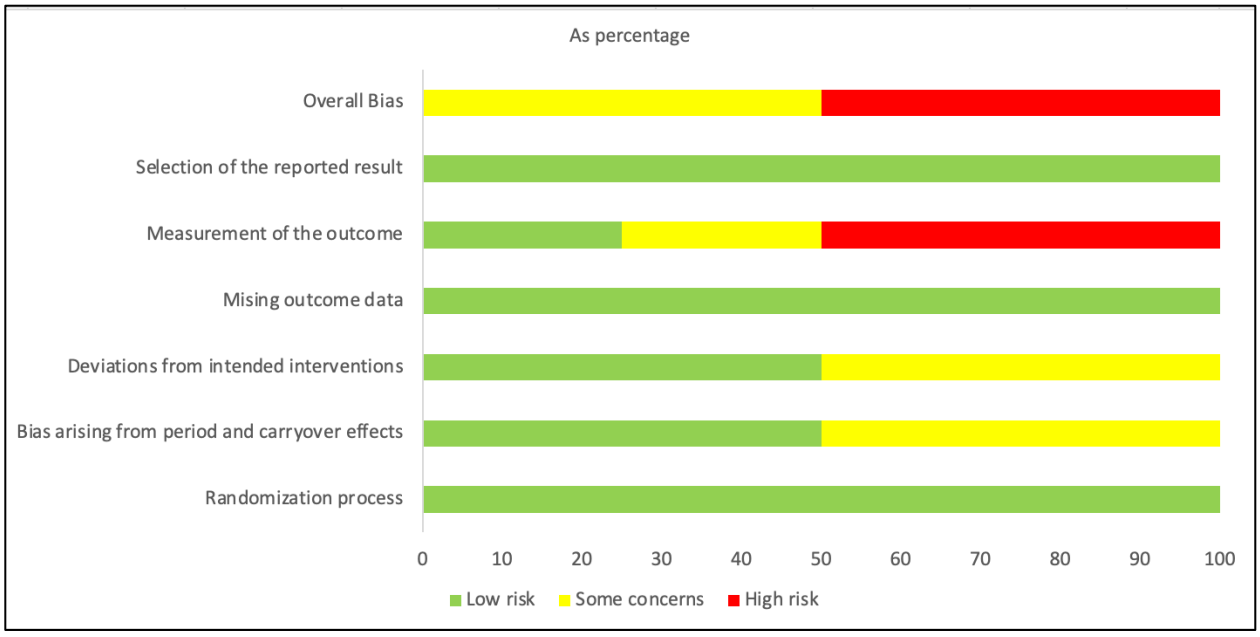


Figure 3 Risk of bias summary of crossover RCTs. Green = low risk; yellow = some concerns; red = high risk. D1=Randomization process; D2=Deviations from intended interventions; D3=Missing outcome data; D4=Measurement of the outcome; D5=Selection of the reported result.

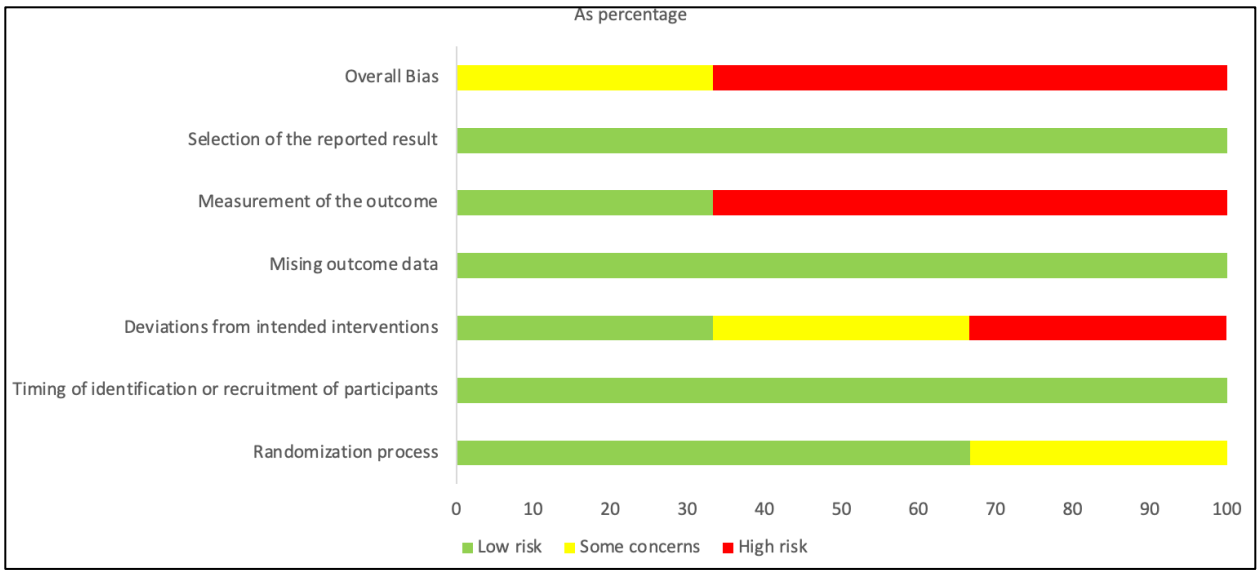


Figure 4 Risk of bias summary of cluster RCTs (n=3). Green = low risk; yellow = some concerns; red = high risk. D1=Randomization process; D2=Deviations from intended interventions; D3=Missing outcome data; D4=Measurement of the outcome; D5=Selection of the reported result.

Table 3 Description of participant and study characteristics at the individual study level (n=35).

Primary author (Year)	*Study design Country Funding*	*Clinical setting*	*Provider characteristics*	*Knowledge translation intervention*	*Risk of bias assessment*
KTI Type: Education					
Naik et al. (2001)[40]	Parallel group RCT Canada Funding source not reported	Intraoperative setting	First-year anesthesiology residents and first- and second-year internal medicine residents	Simple extraoperative model used to teach fiber- optic bronchoscopic manipulation skills	Low
Bruppacher et al. (2010)[44]	Parallel group RCT Canada Funding from industry	Simulated cardiac operating room: weaning from cardiopulmonary bypass (CPB)	Residents and fellows in anesthesiology, postgraduate year 4 or higher	High-fidelity simulation-based training	High
Park et al. (2010)[71]	Crossover RCT United States Funding from industry	Simulated operating room; hypoxemic & hypotensive events	Anesthesiology residents	High-fidelity simulation training	Some concerns
Rakoff et al. (2018)[58]	Parallel group RCT India Funding source not reported	Operating room; Elective adult and pediatric cardiac and thoracic surgeries	Surgeons, anesthesiologists, nurses, and perfusionists.	Customized training on surgical safety checklist (SSCL)	Low
Ambardekar et al. (2019)[72]	Crossover RCT United States Funding source not reported	Simulated pediatric operating room; hypoxemia and dysrhythmia management	Anesthesiology residents	Pediatric anesthesia simulation-based curriculum	Some concerns
Linganna et al. (2020)[63]	Parallel group RCT United States Funding from industry	Intraoperative transesophageal echocardiography	Anesthesiology residents	Echoeducator is a smartphone-accessible application that educates through image-based multiple-choice questions	Low
Giglioli et al. (2012)[46]	Parallel group RCT; Italy None	Non-OR virtual simulated Fibre optic intubation	First-year anesthesiology residents	Virtual Fiberoptic Intubation Simulator	Low
Goldberg et al. (2015)[50]	Parallel group RCT; United States	Simulated intraoperative setting; oxygen pipeline contamination scenario	Anesthesiology resident; Resident year 1	Simulated independent practice i.e., Manage a scenario independently without	Low

	Funding from industry			intervention from an attending physician during a simulation scenario	
You-Ten et al. (2015)[51]	Parallel group RCT; Canada Funding from government & industry	Simulated intraoperative setting - American Society of Anesthesiologist' difficult airway algorithm	Postgraduate year two (PGY2) anesthesia residents	Hands-on cricothyrotomy training	Low
Skelton et al. (2016)[55]	Parallel group RCT; Rwanda Funding from industry	Simulated OR; providing anesthesia for elective or urgent caesarean deliveries	Anesthesia technicians and residents	ANTS training: teaching session using a low-cost high psychological fidelity simulation model with debriefing	Low
Lim et al. (2016)[56]	Parallel group RCT United States Funding from government	Epidural anesthesia in obstetric anesthesiology subspecialty	Post-Graduate Year 2 (PGY-2) anesthesiology residents	Mental imagery (MI) training	High
KTI Type: Reminder					
Zanetti et al. (2003)[41]	Parallel group RCT United States Funding from industry	Intraoperative redosing of prophylactic antibiotics; prolonged cardiac operations.	Anesthesiologists	Automated intraoperative alert	Low
Kheterpal et al. (2007)[42]	Parallel group RCT United States Funding source not reported	Perioperative setting; adult and pediatric patients undergoing scheduled elective surgery	Residents & certified registered nurse anesthetist (CRNA)	Automated electronic reminders via alphanumeric paging and e-mail	Low
Freundlich et al. (2013)[47]	Parallel group RCT; United States Funding from industry	Operating Room – intraoperative setting; surgeries in adult, cardiovascular and children's hospital ors	Resident/Certified Registered Nurse-Anesthetist, & Anesthesiology Attending Physician	Anesthesia information management systems – automated electronic alerts to promote compliance with start time documentation requirements	Some concerns
Görges et al. (2013)[48]	Parallel group RCT Canada Funding from government & industry	Simulated operating room: Critical respiratory-related events	Anesthesiologists & anesthesiology trainees (fellows and residents)	Clinical expert system	High

Kappen et al. (2014)[67]	Cluster RCT The Netherlands; Funding from industry	General anesthesia for elective, noncardiac surgery	Anesthesiologists	Prediction model for postoperative nausea and vomiting (PONV)	Some concerns
Zaouter et al. (2014)[49]	Parallel group RCT Canada Funding from government	Operating room; orthopedic patients undergoing spinal analgesia with propofol sedation	Anesthesiologists	Decision support systems	Low
Panjasawatwong et al. (2015)[52]	Parallel group RCT; United States None	Operating room; noncardiac surgery	Attending anesthesiologists or experienced certified registered nurse anesthetists	Supplemental decision support alert for critically low systolic blood pressure (SBP)	Low
Mccormick et al. (2016)[54]	Parallel group RCT USA Funding from industry & government	Intraoperative; double low events in noncardiac surgery	Anesthesiologists	Intraoperative alerts for double-low events over 33 months	Low
Donze et al. (2019)[60]	Parallel group RCT France Funding source not reported	Simulated cardiac arrest scenarios	Anaesthesia residents in their first to fifth postgraduate year and consultant anaesthesiologists	"Read & do" Digital cognitive aid	High
Sessler et al. (2019)[61]	Parallel group RCT United States Funding from industry	Adults having noncardiac surgery with volatile anesthesia and Bispectral Index monitoring	During a surgery the in-room clinician and the attending anesthesiologist	Digital Triple low alerts	High
Shear et al. (2018)[62]	Parallel group RCT United States Funding from industry	Simulated operating room; malignant hyperthermia complicated by hyperkalemia and ventricular fibrillation	Anesthesia residents in clinical anesthesia years 2 and 3	Dynamic electronic cognitive aid with embedded clinical decision support	Low
KTI Type: Audit & Feedback					
Savoldelli et al. (2006)[64]	Three-arm, repeated-measures RCT Canada	Simulated Operating Room; 2 cardiac arrest scenarios	Anesthesiology residents; Postgrad years 1, 2, & 4	2 types of debriefing process during simulation-based education: oral feedback or video assisted oral feedback	Low

	Funding from industry				
Berman et al. (1998)[39]	Parallel group RCT United States Funding source not reported	Neurosurgical anesthesia	Anesthesiology residents	Drug and Supply Cost Feedback System	Low
Boet et al. (2018)[69]	Cluster RCT Canada Funding from government & industry	Anesthesiologists' intraoperative temperature management	Anesthesiologists	Targeted audit and feedback	High
Boet et al. (2013)[65]	Repeated measures RCT Canada Funding from industry	Simulated intraoperative cardiac arrests	Anesthesiologists, surgeons, & nurses	Interprofessional within-team debriefing	Low
KTI Type: Checklist/Bundle					
Wetmore et al. (2016)[53]	Parallel group RCT; United States Funding source not reported	Simulated Operating Room–intra-operative setting; elective monitored anesthesia care case; repeat breast biopsy under local anesthesia	Anesthesiology residents; CA-1,2,3	Pre-Anesthetic Induction Patient Safety (PIPS) Checklist	Low
Marshall et al. (2016)[66]	Multicentre repeated measures RCT Australia None	Simulated intraoperative setting; anaphylaxis crises	Senior trainee (an anaesthetic fellow), a junior trainee and anaesthetic nurse, trainee, and anaesthetic nurse	Linear cognitive aid; and a branched cognitive aid	Low
Acar et al. (2019)[59]	Parallel group RCT United States Funding from government & industry	In-situ simulation, evacuation of a patient under general anesthesia from the operating room (OR)	Anesthesiologist, Nurse anesthetist	Standardized Checklist	High
Grigg et al. (2017)[73]	Crossover RCT United States Funding from industry	Simulated operating room anesthesia administration scenarios	Anesthesia providers	Anesthesia Medication Template (AMT)	High
KTI Type: Education + Checklist					

Blike et al. (2000)[70]	Cross-over RCT United States Funding from industry	Emergency cesarian delivery	Anesthesia residents, Certified Registered Nurse anesthetists, attending anesthesiologists	Computer-based highly interactive electronic checklist; didactic lecture	High
KTI Type: Education + Audit & Feedback					
Morgan et al. (2009)[43]	Parallel group RCT Canada Funding from federal grant	Simulated Operating Room; laparoscopic cholecystectomy; urgent laparotomy for large bowel obstruction	Certified Anaesthetists with FRCPC	Simulation-based debriefing	Low
KTI Type: Bundle + Reminder + Organizational Change					
Merry et al. (2011)[45]	Parallel group RCT New Zealand Funding from government & Industry	Operating theatres in the adult anaesthetic departments	Anesthesiologists	New patented multimodal system designed to reduce errors in the recording and administration of drugs in anaesthesia.	Low
KTI Type: Education + Reminder					
St.Pierre et al. (2017)[57]	Parallel group RCT Germany Funding from industry	Simulated operating room; intraoperative myocardial infarction in a simulation of caesarean delivery under spinal anaesthesia.	Anesthetic trainees, Consultants, & anesthetic nurses	Electronic cognitive aid + Standardised educational intervention	Some concerns
KTI Type: Education + Audit & Feedback					
Voorn et al. (2017)[68]	Cluster RCT The Netherlands. Funding from industry	Perioperative blood management techniques for hip and knee arthroplasty	Orthopedic surgeons & Anesthesiologists	Multifaceted de-implementation strategy for low value care	High

KTI= Knowledge Translation Intervention; RCT = Randomized Controlled Trial; ORs = Operating Rooms; CA = Clinical Anesthesia; ANTS = Anesthesiology residents' non-technical skills

Table 4 Categorization of included studies' primary outcomes into the respective Triple Aim Initiatives (TAI), type of outcome measure and inclusion or exclusion from meta-analysis with reasoning (n=35).

	Primary outcome(s)	***Triple Aim initiative category***	***Type of outcome***	***Included in meta-analysis (yes/no) with reasoning if no***
Grigg et al. (2017)	Odds of dosing medication error	Process of care	Dichotomous	No; Only 1 study in subgroup
	Time to locate and administer medication	Process of care	Time-to-event	No; Not enough information provided
Berman et al. (1998)	Average anesthesia-related cost for the studied procedures	Cost of care	Continuous	No; Only 1 study in subgroup
Blike et al. (2000)	Detection rate for each fault	Process of care	Rate treated as dichotomous	Yes
Naik et al. (2001)	Global Rating Scale (GRS) assessment scores	Process of care	Continuous	Yes
	Checklist	Process of care	Continuous	No; Chose GRS a validated scale over this
	Time to complete task	Process of care	Time-to-event treated as continuous	Yes
	Successful intubation	Process of care	Dichotomous	Yes
	Overall pass rating	Process of care	Dichotomous	No; Deemed as not directly evaluating KTI
Zanetti et al. (2003)	Intraoperative redosing	Process of care	Dichotomous	Yes
	Surgical site infection	Patient outcome	Dichotomous	Yes
Savoldelli et al. (2006)	Pre-test to post-test change in total Anesthesiology residents' non-technical skills (ANTS) score	Process of care	Continuous	Yes

Kheterpal et al. (2007)	Compliance rate	Process of care	Rate treated as dichotomous	Yes
Morgan et al. (2009)	Performance checklist	Process of care	continuous	No; Chose GRS a validated scale over this
	Global Rating Scale of Performance (GRS)	Process of care	continuous	Yes
Bruppacher et al. (2010)	Anesthesiologists' Nontechnical Skills Global Rating Scale	Process of care	Continuous	Yes
	Checklist of expected clinical actions.	Process of care	Continuous	No; Chose GRS a validated scale over this
Park et al. (2010)	Task completion rate	Process of care	Ordinal treated as continuous	Yes
Merry et al. (2011)	Composite of errors in the recording and administration of intravenous drugs	Process of care	Rate	No; Only 1 study in subgroup
	lapses in responding to an intermittent visual stimulus	Process of care	Ordinal	No; Only 1 study in subgroup
Giglioli et al. (2012)	Checklist score	Process of care	Ordinal treated as continuous	No; Chose GRS a validated scale over this
	Global rating assessment scores	Process of care	Ordinal treated as continuous	Yes
Freundlich et al. (2013)	Compliance rate	Process of care	Rate treated as dichotomous	No; Not enough information provided
Görges et al. (2013)	Time to diagnosis	Process of care	Time-to-event treated as continuous	Yes
	Time to treatment	Process of care	Time-to-event treated as continuous	No; Less clinically relevant
Boet et al. (2013)	The Effect of Test Phase and Debriefing Type on Total TEAM Score	Process of care	Ordinal treated as continuous	Yes
Kappen et al. (2014)	The incidence of PONV	Patient outcome	Dichotomous	Yes

Zaouter et al. (2014)	Reduction in the number of critical events detected	Patient outcome	Continuous	No; Only 1 study in subgroup
	Reduction in the time it took to detect and, if necessary, treat them.	Process of care	Time-to-event treated as continuous	Yes
Goldberg et al. (2015)	Participants' proper treatment	Process of care	Dichotomous	Yes
	Time to diagnosis	Process of care	Continuous	Yes
	Non-technical skills (measured using the Anaesthetists' Non-Technical Skills Checklist, ANTS)	Process of care	Time-to-event treated as continuous	Yes
You-Ten et al. (2015)	Major deviation from the ASA-DAA	Process of care	Count treated as dichotomous	Yes
Panjasawatwong et al. (2015)	How many had their SBP brought back to 80mmHG	Process of care	Time-to-event treated as dichotomous	Yes
Wetmore et al. (2016)	Performance evaluated using a scoring checklist	Process of care	Continuous	Yes
McCormick et al. (2016)	All-cause 90-day mortality	Patient outcome	Time-to-event treated as dichotomous	Yes
Marshall et al. (2016)	Team overall behavioural performance	Process of care	Ordinal treated as continuous	No; Not enough information provided
Skelton et al. (2016)	Overall ANTS score (maximum, 16).	Process of care	Ordinal treated as continuous	Yes
Lim et al. (2016)	Technical achievement	Process of care	Continuous	Yes
	Duration to task completion	Process of care	Time-to-event treated as continuous	Yes

St.Pierre et al. (2017)	The time interval from the first diagnosis of "STEMI" until the cardiac catheterization lab was contacted	Process of care	Time-to-event treated as continuous	No; Only 1 study in subgroup
Voorn et al. (2017)	Use of blood salvage	Process of care	Dichotomous	No; Only 1 study in subgroup
	Use of erythropoietin	Process of care	Dichotomous	No; Only 1 study in subgroup
Boet et al. (2018)	Percentage of hypothermic patients at the end of surgery	Patient outcome	Dichotomous	No; Only 1 study in subgroup
Rakoff et al. (2018)	Compliance with the surgical safety checklist	Process of care	Rate treated as continuous	Yes
Acar et al. (2019)	Completion of pre-defined critical actions	Process of care	Dichotomous	Yes
	Total evacuation time	Process of care	Time-to-event treated as continuous	Yes
Donze et al. (2019)	Difference in pre & post test scores- technical	Process of care	Ordinal treated as continuous	Yes
	Difference in pre & post test scores- non - technical	Process of care	Ordinal treated as continuous	No; Less clinically relevant
Sessler et al. (2019)	90-day mortality	Patient outcome	Time-to-event treated as dichotomous	Yes
Ambardekar et al. (2019)	Performance during the management of crises	Process of care	Ordinal treated as continuous	Yes
Shear et al. (2018)	Task checklist performance	Process of care	Ordinal treated as continuous	Yes
Linganna et al. (2020)	Difference between the post-test score and the pre-test score on a multiple-choice examination	Process of care	Rate	No; Not enough information provided

Appendix A: Forest plots of all meta-analysis

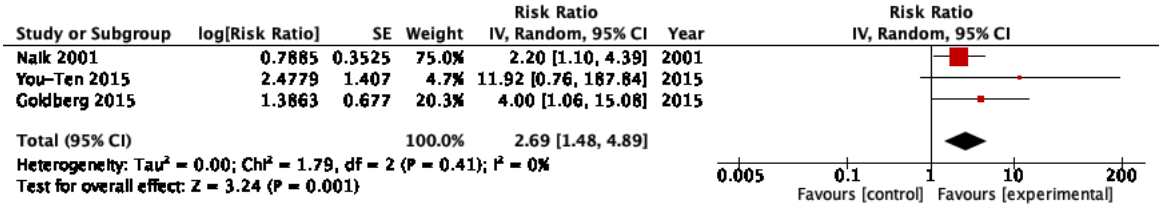


Figure 5 Forest plot displaying meta-analytic results of the dichotomous process of care outcomes for the KTI type Education.

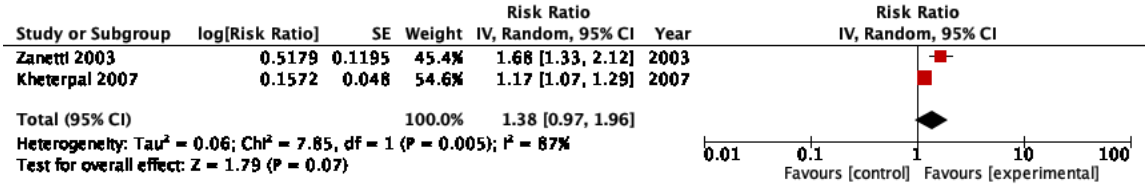


Figure 6 Forest plot displaying meta-analytic results of the dichotomous process of care outcomes for the KTI type Reminder.

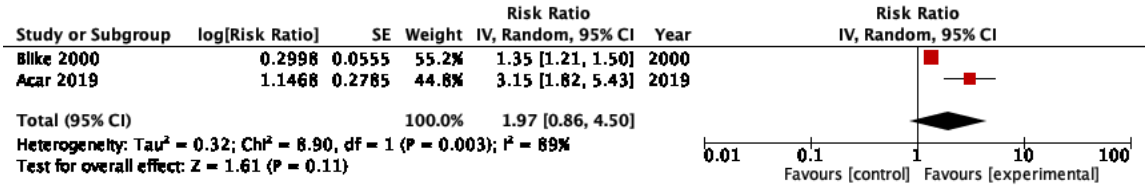


Figure 7 Forest plot displaying meta-analytic results of the dichotomous process of care outcomes for the KTI type Checklist/Bundle.

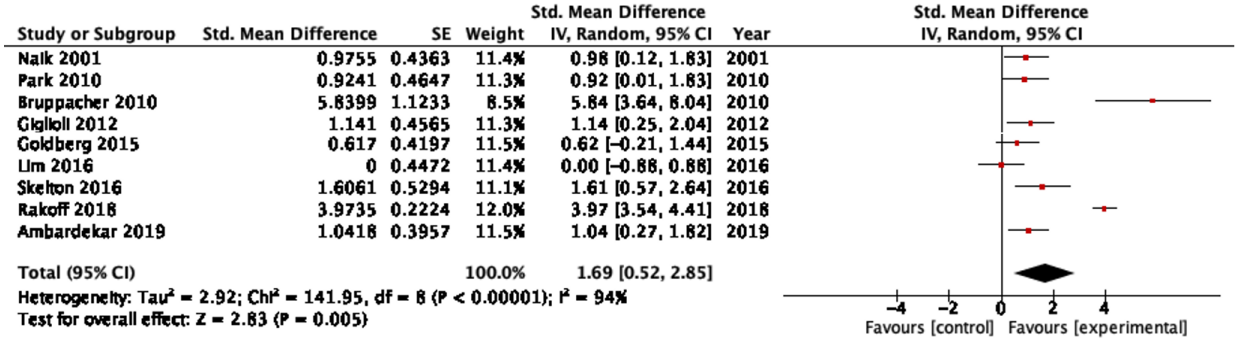


Figure 8 Forest plot displaying meta-analytic results of the continuous process of care outcomes for the KTI type Education.

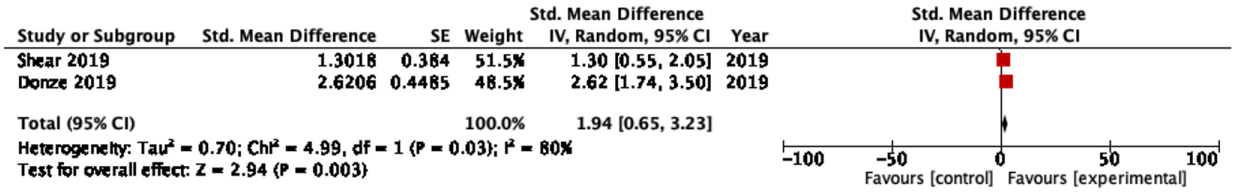


Figure 9 Forest plot displaying meta-analytic results of the continuous process of care outcomes for the KTI type Reminder.

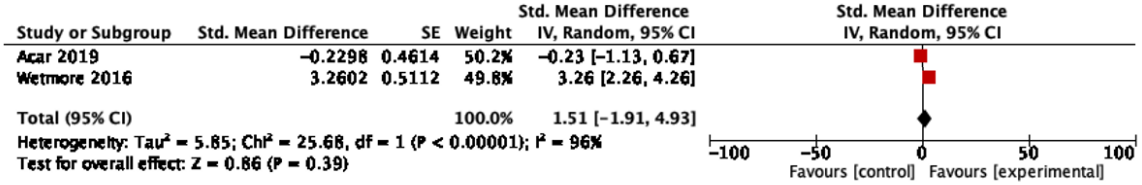


Figure 10 Forest plot displaying meta-analytic results of the continuous process of care outcomes for the KTI type Checklist/Bundle.

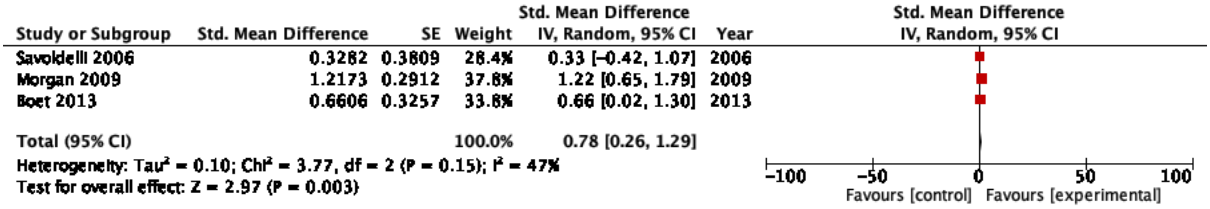


Figure 11 Forest plot displaying meta-analytic results of the continuous process of care outcomes for the KTI type Audit & Feedback.

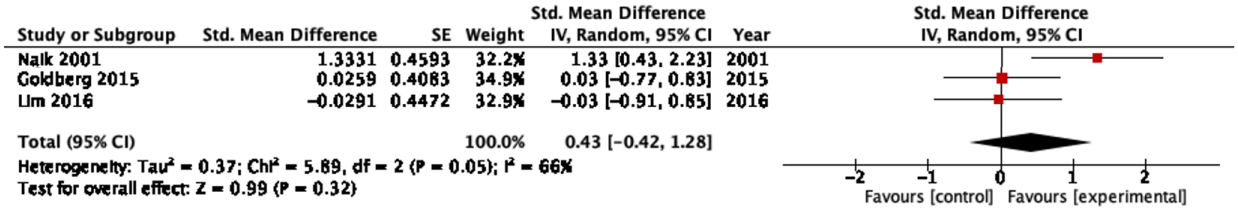


Figure 12 Forest plot displaying meta-analytic results of the time to event process measur outcomes for the KTI type Education.

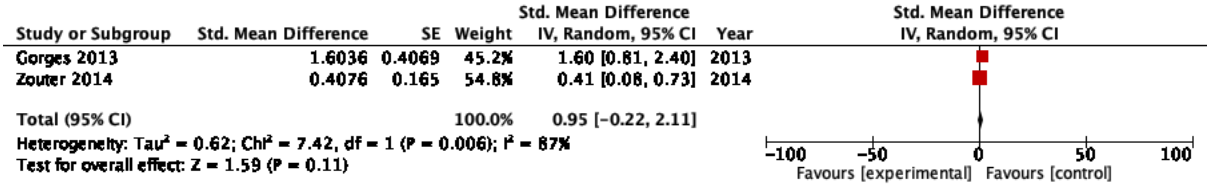


Figure 13 Forest plot displaying meta-analytic results of the Time to event process measure outcomes for the KTI type Reminder.

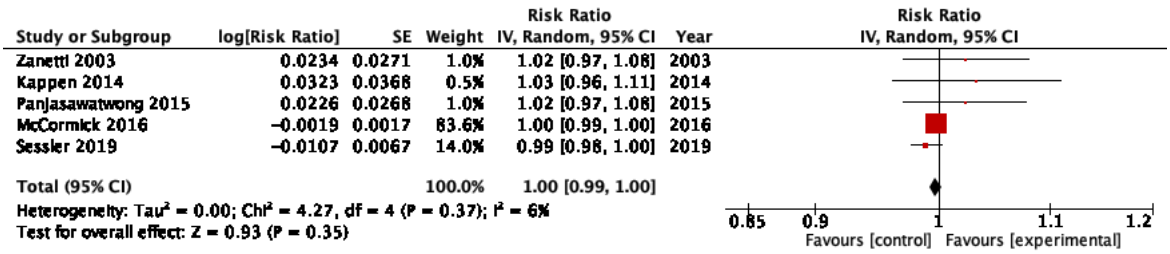


Figure 14 Forest plot displaying meta-analytic results of the dichotomous patient outcomes for the KTI type Reminder.

Appendix B: Funnel plots for all meta-analysis

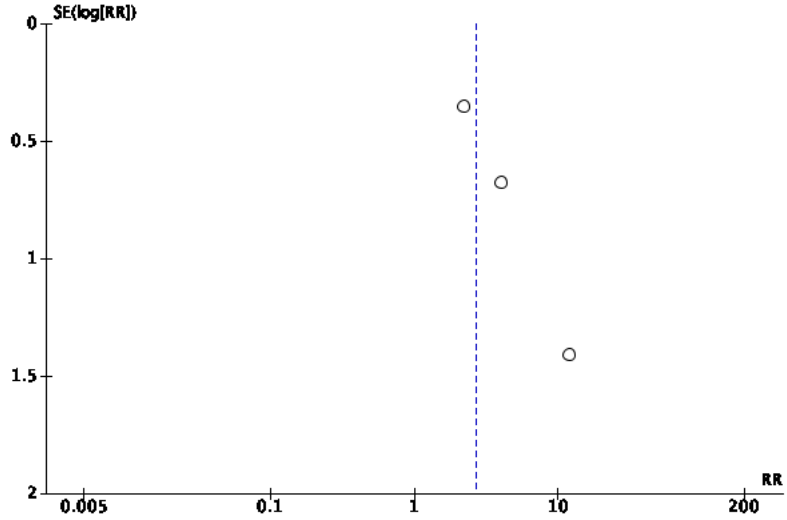


Figure 15 Funnel plot for the meta-analytic results of the dichotomous process of care outcomes for the KTI type Education.

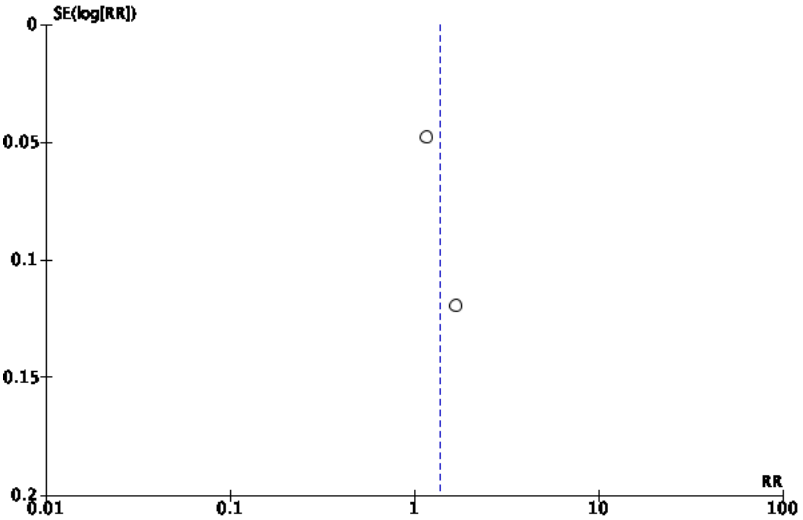


Figure 16 Funnel plot for the meta-analytic results of the dichotomous process of care outcomes for the KTI type Reminder.

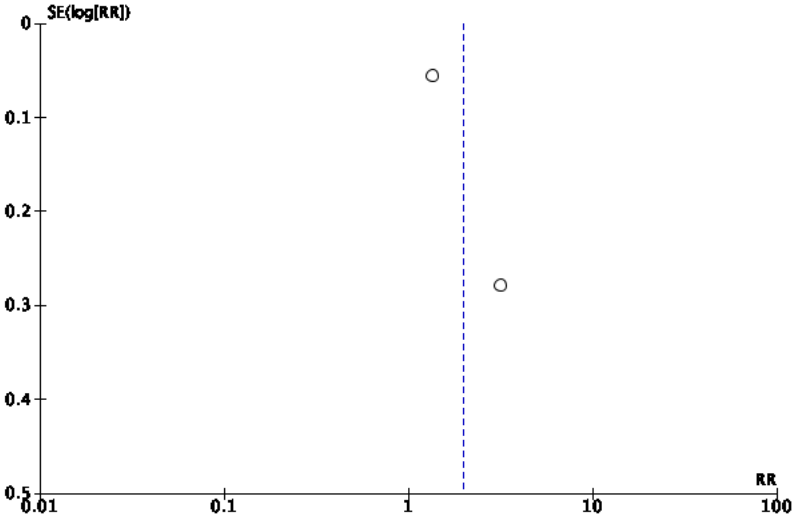


Figure 17 Funnel plot for the meta-analytic results of the dichotomous process of care outcomes for the KTI type Checklist/Bundle.

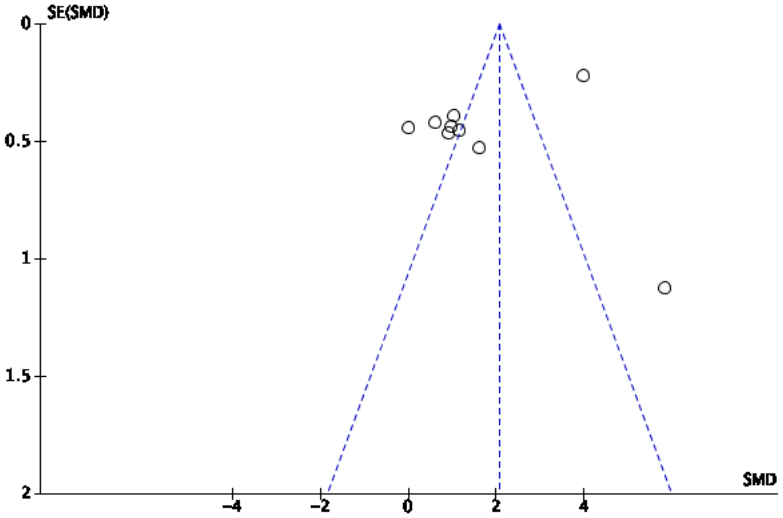


Figure 18 Funnel plot for the meta-analytic results of the continuous process of care outcomes for the KTI type Education.

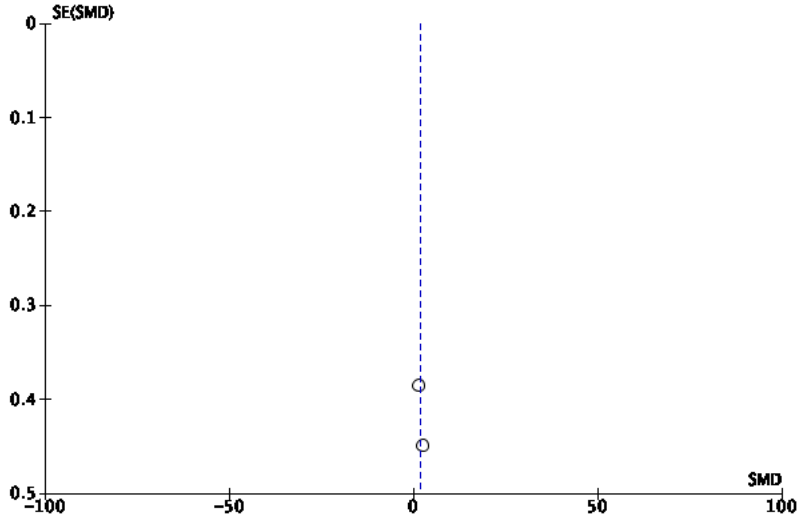


Figure 19 Funnel plot for the meta-analytic results of the continuous process of care outcomes for the KTI type Reminder.

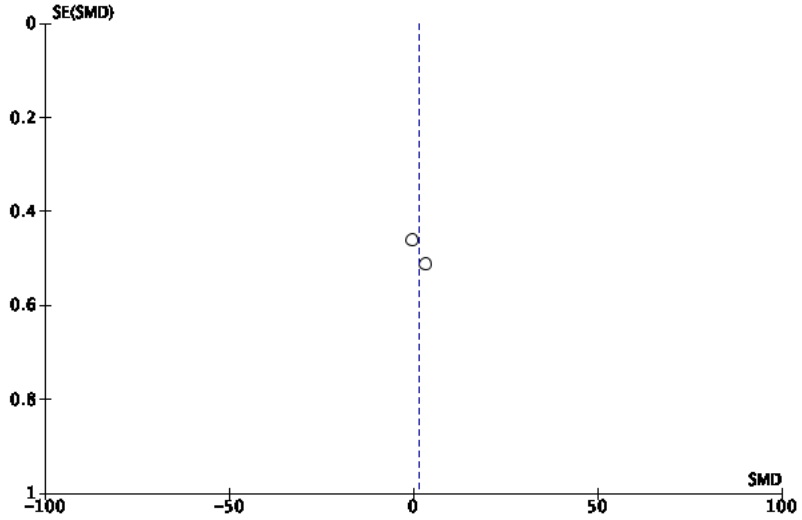


Figure 20 Funnel plot for the meta-analytic results of the continuous process of care outcomes for the KTI type Checklist/Bundle.

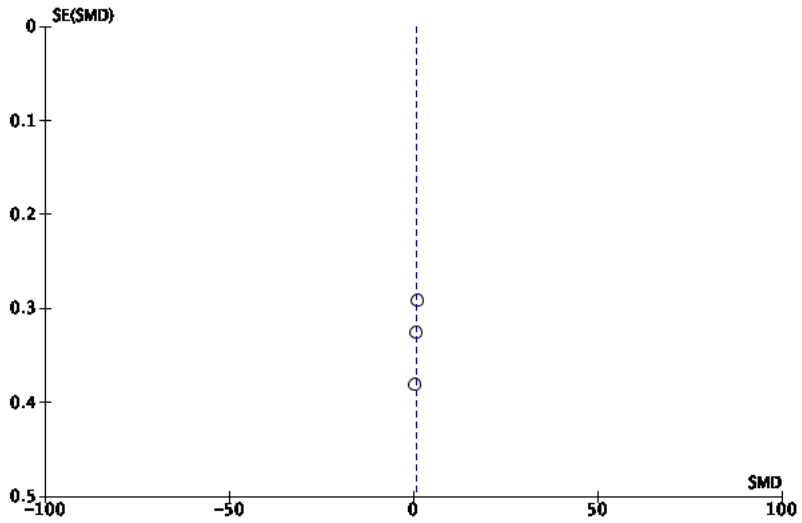


Figure 21 Funnel plot for the meta-analytic results of the continuous process of care outcomes for the KTI type Audit & Feedback.

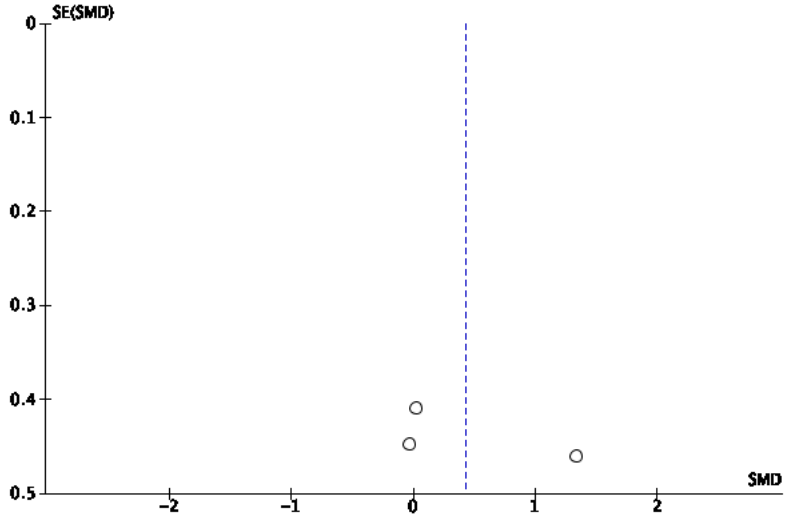


Figure 22 Funnel plot for the meta-analytic results of the time to event process measure outcomes for the KTI type Education.

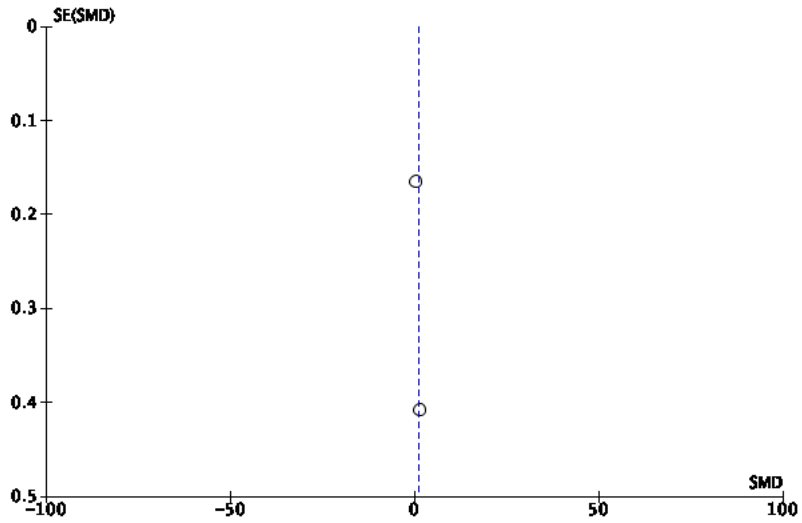


Figure 23 Funnel plot for the meta-analytic results of the Time to event process measure outcomes for the KTI type Reminder.

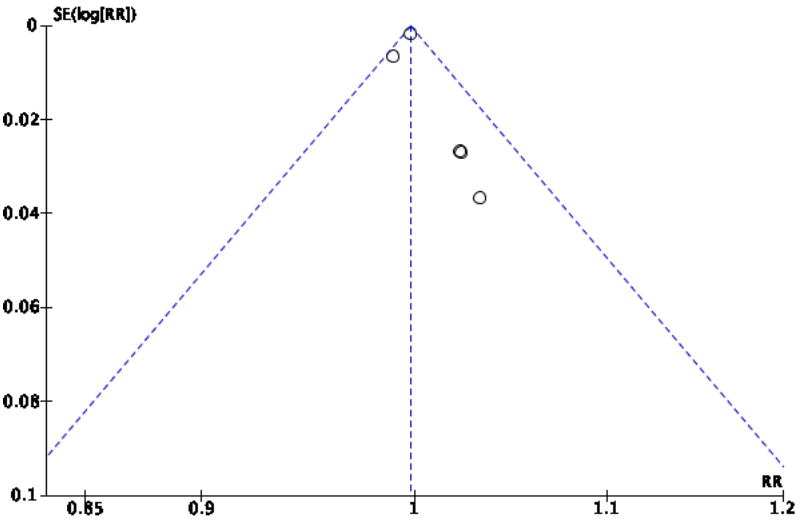


Figure 24 Funnel plot for the meta-analytic results of the dichotomous patient outcomes for the KTI type Reminder.

Appendix C: Screening form for abstract and full-text screening

1. Is the article published in English?
    a. Yes
    b. No
    c. Unclear

If yes/unclear

2. Does this article discuss a knowledge translation intervention relevant to anesthesia/perioperative medicine or surgery?
    a. Yes
    b. No
    c. Unclear

If yes/unclear next question
If no, then exclude

3. Is this article a randomized controlled trial (e.g., parallel group, crossover, cluster, factorial design RCTs)?
    a. Yes
    b. No
    c. Unclear

If yes/unclear
If no, then exclude

4. Is the intervention relevant to the intra-operative process of care?
    a. Yes
    b. No
    c. Unclear

If yes/unclear
If no, then exclude

5. Does the RCT involve a control group that received no KT intervention or another type of KT intervention?
    a. Yes
    b. No
    c. Unclear

If yes/unclear
If no, then exclude

6. Did the intervention evaluate:
    a. Self-assessment only
    b. Other

If not "Other" then exclude
If other

7. Are the outcomes assessed in the intraoperative and post-operative period as specified by the Triple Aim Initiative for improving healthcare:
    - Improving the patient experience of care
    - Improving the health of populations, and/or
    - Reducing the cost of care?
        a. Yes
        b. No
        c. Unclear

If yes/unclear include
If no, then exclude

Appendix D: Data extraction form

Study characteristics

1. First author name
2. Year of publication
3. Language of publication
4. Location (country) of study
5. Funding source type
6. Study design: parallel-group, crossover, cluster, factorial etc.
7. Sample size for participants screened, randomized & completed
    a. Screened: #
    b. Randomized: #
    c. Completed (total final sample size): #
8. Clinical setting (e.g., type of surgery &/or anesthesia)
9. Patient characteristics (e.g., number in control group, number in experimental group)
10. Provider characteristics (e.g., profession(s), level of experience (trainees vs. non-trainees))
11. Type of KT intervention (select all that apply):
    a. Clinical practice guideline
    b. Protocol
    c. Bundle/checklists
    d. Person/team/organization change
    e. Education
    f. Reminders
    g. Opinion leader(s) (or "Champion")
    h. Academic detailing
    i. Audit & Feedback
    j. Other (please describe):
    k. Other (please describe):

Outcome details

12. For primary outcome measures only:
    a. For dichotomous outcomes: events and total in intervention and control group, or OR/RR. OR=Odds Ratio, RR=Risk Ratio.
    b. For continuous outcomes: mean(SD), median(IQR/range), mean(SE), or mean(95% CI). SD=standard deviation, IQR=interquartile range, CI=confidence interval.
    c. For counts/rate, ordinal and time-to-event outcomes, effect estimates for these outcome measures as reported in study.

Appendix E: Search strategy by Databases

MEDLINE

1 Anesthesia/ or Anesthesiology/
2 **exp Surgeons/**
3 (an?esthesiologist* or anesthetist*).ti,ab,kf.
4 **Perioperative Nursing/ or ((perioperative* or peri-operative* or surgical) adj2 nurs*).**ti,ab,kf**.**
5 Monitoring, Intraoperative/
6 "Postoperative Nausea and Vomiting"/
7 perioperative period/ or intraoperative period/ or postoperative period/ or preoperative period/
8 surgical patient*.ti,ab,kf.
9 or/1-8
10 Reminder Systems/ or reminder*.ti,ab,kf.
11 electronic alert*.ti,ab,kf.
12 Feedback/ or Feedback, Psychological/ or medical audit/ or (audit adj3 feedback*).ti,ab,kf.
13 Quality Improvement/
14 Decision Support Systems, Clinical/ or decision support.ti,ab,kf.
15 Guideline Adherence/
16 (guideline* adj3 (introduc*or issu* or impact* or effect* or distribut* or adher* or compl* or utiliz* or utilis* or "use" or uptake or diffuse* or transfer* or implement* or translat* or disseminat* or adopt*)).ti,ab,kf.
17 Checklist/ or checklist*.ti,ab,kf.
18 academic detailing.ti,ab,kf.
19 ((research or knowledge or evidence) adj2 (uptake or "use" or diffus$ or disseminat$ or utiliz$ or utilis$ or transfer$ or translat$ or implement$ or adopt$)).ti,ab,kf.
20 Information Dissemination/
21 dissemination.ti,ab,kf.
22 implementation.ti,ab,kf.
23 "diffusion of innovation"/ or innovation.ti,ab,kf.
24 Organizational Innovation/
25 Translational Medical Research/ or (translational adj2 research).ti,ab,kf.
26 education, continuing/ or education, medical, continuing/
27 complex intervention*.ti,ab,kf.
28 or/10-27
29 randomized controlled trial.pt.
30 random*.ti,ab,kf.
31 control*.ti,ab,kf.
32 intervention*.ti,ab,kf.
33 evaluat*.ti,ab,kf.
34 controlled before-after studies/ or interrupted time series analysis/
35 research support, non us gov't.pt.

36 or/29-35
37 9 and 28 and 36
38 limit 37 to yr="2018 -Current"

EMBASE

1. anesthesia/ OR anesthesiology/
2. exp surgeons/
3. (an?esthesiologist* OR anesthetist*).ti,ab,kw.
4. perioperative nursing/ OR ((perioperative* OR peri-operative* OR surgical) ADJ2 nurs*).ti,ab,kw.
5. intraoperative monitoring/
6. "postoperative nausea and vomiting"/
7. perioperative period/ OR intraoperative period/ OR postoperative period/ OR preoperative period/
8. surgical patient*.ti,ab,kw.
9. 1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8
10. reminder system/ OR reminder*.ti,ab,kw.
11. electronic alert*.ti,ab,kw.
12. feedback system/ OR psychological feedback/ OR clinical audit/ OR (audit ADJ3 feedback*).ti,ab,kw.
13. total quality management/
14. clinical decision support system/ OR decision support.ti,ab,kw.
15. protocol compliance/
16. (guideline* ADJ3 (introduc*or issu* OR impact* OR effect* OR distribut* OR adher* OR compl* OR utiliz* OR utilis* OR "use" OR uptake OR diffuse* OR transfer* OR implement* OR translat* OR disseminat* OR adopt*)).ti,ab,kw.
17. checklist/ OR checklist*.ti,ab,kw.
18. academic detailing.ti,ab,kw.
19. ((research OR knowledge OR evidence) ADJ2 (uptake OR "use" OR diffus$ OR dissemi nat$ OR utiliz$ OR utilis$ OR transfer$ OR translat$ OR implement$ OR adopt$)).ti,ab,kw.
20. information dissemination/
21. dissemination.ti,ab,kw.
22. implementation.ti,ab,kw.
23. mass communication/ OR innovation.ti,ab,kw.
24. Organizational Innovation.ti,ab,kw.
25. translational research/ OR (translational ADJ2 research).ti,ab,kw.
26. continuing education/ OR medical education/
27. complex intervention*.ti,ab,kw.
28. 10 OR 11 OR 12 OR 13 OR 14 OR 15 OR 16 OR 17 OR 18 OR 19 OR 20 OR 21 OR 22 OR 23 OR 24 OR 25 OR 26 OR 27
29. randomized controlled trial.pt.
30. random*.ti,ab,kw.
31. control*.ti,ab,kw.

32. intervention*.ti,ab,kw.
33. evaluat*.ti,ab,kw.
34. (controlled before-after studies OR interrupted time series analysis).ti,ab,kw.
35. research support, non us gov't.pt.
36. 29 OR 30 OR 31 OR 32 OR 33 OR 34 OR 35
37. 9 AND 28 AND 36
38. limit 37 to yr="2018 -Current"

CINAHL

1. (MH "Anesthesia") OR (MH "Anesthesiology")
2. (MH "Surgeons+")
3. ((TI an#esthesiologist* OR AB an#esthesiologist*) OR (TI anesthetist* OR AB anesthetist*))
4. (MH "Perioperative Nursing") OR (((TI perioperative* OR AB perioperative*) OR (TI peri-operative* OR AB peri-operative*) OR (TI surgical OR AB surgical)) N2 (TI nurs* OR AB nurs*))
5. (MH " Intraoperative Monitoring")
6. (TI "postoperative nausea and vomiting" OR AB "postoperative nausea and vomiting")
7. (MH "Intraoperative Period") OR (MH "Postoperative Period") OR (MH "Preoperative Period")
8. (TI "surgical patient*" OR AB "surgical patient*")
9. S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7 OR S8
10. (MH "Reminder Systems") OR (TI reminder* OR AB reminder*)
11. (TI electronic alert* OR AB electronic alert*)
12. (MH "Feedback") OR (MH "audit") OR ((TI audit OR AB audit) N3 (TI feedback* OR AB feedback*))
13. (MH "Quality Improvement")
14. (MH "Decision Support Systems, Clinical") OR (TI "decision support" OR AB "decision support")
15. (MH "Guideline Adherence")
16. ((TI guideline* OR AB guideline*) N3 ((TI "introduc*or issu*" OR AB "introduc*or issu*") OR (TI impact* OR AB impact*) OR (TI effect* OR AB effect*) OR (TI distribut* OR AB distribut*) OR (TI adher* OR AB adher*) OR (TI compl* OR AB compl*) OR (TI utiliz* OR AB utiliz*) OR (TI utilis* OR AB utilis*) OR (TI use OR AB use) OR (TI uptake OR AB uptake) OR (TI diffuse* OR AB diffuse*) OR (TI transfer* OR AB transfer*) OR (TI implement* OR AB implement*) OR (TI translat* ORAB translat*) OR (TI disseminat* OR AB disseminat*) OR (TI adopt* OR AB adopt*)))
17. (MH "Checklists") OR (TI checklist* OR AB checklist*)
18. (TI "academic detailing" OR AB "academic detailing")
19. (((TI research OR AB research) OR (TI knowledge OR AB knowledge) OR (TI evidence OR AB evidence)) N2 ((TI uptake OR AB uptake) OR (TI use OR AB use) OR(TI diffus* OR AB diffus*) OR (TI disseminat* OR AB disseminat*) OR (TI

utiliz* OR AB utiliz*) OR (TI utilis* OR AB utilis*) OR (TI transfer* OR AB transfer*) OR (TI translat* OR AB translat*) OR (TI implement* OR AB implement*) OR (TI adopt* OR AB adopt*)))

20. (TI "Information dissemination" OR AB "Information dissemination")
21. (TI dissemination OR AB dissemination)
22. (TI implementation OR AB implementation)
23. (MH "Diffusion of Innovation") OR (TI innovation OR AB innovation)
24. (TI "organizational innovation" OR AB "organizational innovation")
25. ((TI translational OR AB translational) N2 (TI research OR AB research))
26. (MH "Education, Continuing") OR (MH "Education, Medical, Continuing")
27. (TI "complex intervention*" OR AB "complex intervention*")
28. S10 OR S10 OR S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17 OR S18 OR S19 OR S20 OR S21 OR S22 OR S23 OR S24 OR S25 OR S26 OR S27
29. PT "randomized controlled trial"
30. (TI random* OR AB random*)
31. (TI control* OR AB control*)
32. (TI intervention* OR AB intervention*)
33. (TI evaluat* OR AB evaluat*)
34. (MH "Controlled Before-After Studies") OR (MH "Interrupted Time Series Analysis")
35. PT "research support, non us gov't"
36. S29 OR S30 OR S31 OR S32 OR S33 OR S34 OR S35
37. S9 AND S28 AND S36

ERIC

1. Anesthesiology/
2. exp surgery/
3. (an?esthesiologist* or anesthetist*).tw.
4. **((perioperative* or peri-operative* or surgical) adj2 nurs*)**.tw.
5. Monitoring, Intraoperative.tw.
6. "Postoperative Nausea and Vomiting".tw.
7. (perioperative period or intraoperative period or postoperative period or preoperative period).tw.
8. surgical patient*.tw.
9. or/1-8
10. (reminder systems or reminder*).tw.
11. electronic alert*.tw.
12. Medical Care Evaluation/ or ((feedback or feedback, psychological) or (audit adj3 feedback*)).tw.
13. Quality improvement.tw.
14. (Clinical decision support systems or decision support).tw.
15. Guideline adherence.tw.
16. (guideline* adj3 (introduc*or issu* or impact* or effect* or distribut* or adher* or compl* or utiliz* or utilis* or "use" or uptake or diffuse* or transfer* or implement* or translat* or disseminat* or adopt*)).tw.

17. Check Lists/ or checklist*.tw.
18. academic detailing.tw.
19. ((research or knowledge or evidence) adj2 (uptake or "use" or diffus$ or disseminat$ or utiliz$ or utilis$ or transfer$ or translat$ or implement$ or adopt$)).tw.
20. Information Dissemination/
21. dissemination.tw.
22. implementation.tw.
23. Innovation/ or diffusion of innovation.tw.
24. Organizational innovation.tw.
25. Medical Research/ or (translational adj2 research) .tw.
26. Continuing Education/ or Medical Education/
27. complex intervention*.tw.
28. or/10-27
29. randomized controlled trial.pt.
30. random*.tw.
31. control*.tw.
32. intervention*.tw.
33. evaluat*.tw.
34. (controlled before-after studies or interrupted time series analysis).tw.
35. research support, non us gov't.pt.
36. or/29-35
37. 9 and 28 and 36
38. limit 37 to yr="2018 -Current"

Cochrane Central Register of Controlled Trials

1 Anesthesia/ or Anesthesiology/
2 **exp Surgeons/**
3 (an?esthesiologist* or anesthetist*).ti,ab,kf.
4 **Perioperative Nursing/ or ((perioperative* or peri-operative* or surgical) adj2 nurs*).**ti,ab,kf**.**
5 Monitoring, Intraoperative/
6 "Postoperative Nausea and Vomiting"/
7 perioperative period/ or intraoperative period/ or postoperative period/ or preoperative period/
8 surgical patient*.ti,ab,kf.
9 or/1-8
10 Reminder Systems/ or reminder*.ti,ab,kf.
11 electronic alert*.ti,ab,kf.
12 Feedback/ or Feedback, Psychological/ or medical audit/ or (audit adj3 feedback*).ti,ab,kf.
13 Quality Improvement/

14 Decision Support Systems, Clinical/ or decision support.ti,ab,kf.
15 Guideline Adherence/
16 (guideline* adj3 (introduc*or issu* or impact* or effect* or distribut* or adher* or compl* or utiliz* or utilis* or "use" or uptake or diffuse* or transfer* or implement* or translat* or disseminat* or adopt*)).ti,ab,kf.
17 Checklist/ or checklist*.ti,ab,kf.
18 academic detailing.ti,ab,kf.
19 ((research or knowledge or evidence) adj2 (uptake or "use" or diffus$ or disseminat$ or utiliz$ or utilis$ or transfer$ or translat$ or implement$ or adopt$)).ti,ab,kf.
20 Information Dissemination/
21 dissemination.ti,ab,kf.
22 implementation.ti,ab,kf.
23 "diffusion of innovation"/ or innovation.ti,ab,kf.
24 Organizational Innovation/
25 Translational Medical Research/ or (translational adj2 research).ti,ab,kf.
26 education, continuing/ or education, medical, continuing/
27 complex intervention*.ti,ab,kf.
28 or/10-27
29 9 and 28
30 limit 29 to yr="2018 -Current"

Appendix F: PRISMA 2020 checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	5
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	7
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	8
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	10
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	9
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	54-59
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	16, 36
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	13-15
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	14, 15
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	14, 15, 32, 43-46
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	13, 14
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	14, 15,43-46
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	14-16, 43-46
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	14-16, 43-46
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	14-16, 43-46
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	14-16, 43-46

	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	14-16, 43-46
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	14-16, 43-46
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	14-16, 43-46
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	20
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	17
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	43-46
Study characteristics	17	Cite each included study and present its characteristics.	38-43
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	35-43
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	38-43
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	38-43
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	33
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	33, 47-54
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	33, 47-54
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	35- 37
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	33
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	22-25
	23b	Discuss any limitations of the evidence included in the review.	22-25
	23c	Discuss any limitations of the review processes used.	22-25
	23d	Discuss implications of the results for practice, policy, and future research.	22-25
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	1,9
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	1,9
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	9
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	2
Competing interests	26	Declare any competing interests of review authors.	1,2
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	17-21

From: Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 2021;372:n71. doi:10.1136/bmj.n71

For more information, visit: **www.prisma-statement.org**.

Chapter 3:

Title: Change strategies employed by intraoperative teamwork interventions: A systematic review

Registration:
This systematic review protocol was registered with the International Prospective Register of Systematic Reviews (PROSPERO) (CRD42021233995).

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Contributions:
HK drafted the protocol. HK, CE, SB, and JP contributed significantly to the conception and design of the study protocol, development of the criteria for eligibility, data extraction, and risk of bias assessment. LS drafted and ran the search strategies. HK, CE, RA, AD, AZ, SA, and NF contributed to data extraction. HK, SA, and NF contributed to data analysis. All authors contributed to reviewing, editing, and approving the final protocol manuscript.

Support:
Dr. Boet was supported by The Ottawa Hospital Anesthesia Alternate Funds Association and the Faculty of Medicine, University of Ottawa with a Tier 2 Clinical Research Chair. The DistillerSR licenses were funded by the Department of Anesthesiology and Pain Medicine, The Ottawa Hospital.

ABSTRACT

Interprofessional teamwork is essential for patient safety, especially in the operating room (OR). However, the association between teamwork development interventions and clinical outcomes is inconsistent. Teamwork development interventions involve members of the team changing what they do – their behaviour. Whether team members engage in interprofessional teamwork behaviours depend on several factors, some acting as barriers and others as enablers. Understanding these barriers/enablers may help to optimize the selection of strategies to include in teamwork development interventions. This systematic review aimed to synthesize the current evidence on teamwork interventions in the OR setting and identify which change strategies were used to target which teamwork behaviour barriers/enablers using the Theoretical Domains Framework (TDF). We included articles that experimentally evaluated the impact of teamwork development interventions on at least one teamwork process or clinical outcome. From the 37 included studies, we identified 57 different change strategies that collectively targeted 11 of 14 barriers/enablers in the TDF. The barrier/enabler "Behavioural regulation" was targeted by the highest proportion of change strategies (19%), followed by "Social influences" (17%). Our findings can inform the design of intraoperative teamwork interventions that will target specific barriers/enablers faced by health care teams and organizations.

INTRODUCTION

Members of a healthcare team need to collaborate with each other at a technical and non-technical level to provide optimal health care to their patients.[1–7] Teamwork is key in all healthcare settings, but is especially challenging in the operating room (OR) setting due to the involvement of multiple distinct professions each having their own specific roles and responsibilities during the care process.[5–8] Suboptimal teamwork practices in surgical care have been found to increase the odds of adverse postoperative patient outcomes.[9]

A growing body of literature has appeared with regards to teamwork development interventions in the past three decades, resulting in efforts to meaningfully synthesize this literature.[10,11] To this end, teamwork development interventions have been categorized into four overarching categories across healthcare disciplines and type of studies: 1) Training (principle-based training, method-based training, general team training), 2) Tools (structuring tools, facilitating tools, triggering tools), 3) Organizational (re)design, and 4) Programme (A collection of interventions implemented together as a programme). [10,11] This is an evidence-based list of teamwork intervention categories that can be used to streamline the process of synthesizing literature on TDIs in healthcare.[10,11]

Following best practice in implementation science, intervention design should be informed by evidence which requires investigating the barriers/enablers in order to optimize the uptake of desired changes from a teamwork development intervention (TDI) across multiple levels for example the individual, team, and organizational level.[12] Teamwork is a set of many behaviours and as such it is likely to be impacted by barriers and enablers to behaviour change. The effectiveness of an intervention aiming at changing behavior may depend partly on the extent to which they sufficiently address the known enablers/barriers to change targeted by the developed intervention.[13–15] The relationship between teamwork development interventions (TDIs), change strategies, and barriers/enablers of behaviour change is described in detail in Figure 1a. Previous empirical studies and reviews that evaluated TDIs have reported conflicting results on intervention effectiveness.[4–6,10,11,16–19] This inconsistency in findings suggests heterogeneity in the design of these interventions regarding the targeted barrier/enabler of behaviour change among the healthcare professional teams.[5] When deciding to implement a TDI, a preliminary assessment of barriers/enablers of effective teamwork can help to identify which factors are relevant to a specific context (e.g., across different hospitals).

One way to characterise the multiple types of barriers and enablers is to classify them using a comprehensive framework of known factors effecting behaviour change. The Theoretical Domains Framework (TDF) is a theoretical framework that has been developed and validated by a team of behavioral scientists and implementation researchers for the purpose of identifying determinants of behavior change which can be used to inform the design of behavioral change interventions.[15,20] It includes 14 domains derived from 84 theoretical constructs and 33 theories of behavior and behavior change: knowledge; skills; social influences; memory, attention and decision processes; behavioral regulation; professional/social role and identity; beliefs about capabilities; belief about consequences; optimism; intentions; goals; emotion; environmental context and resources; and reinforcement.[15]

This systematic review aimed to address two research questions. Firstly, what are the types of teamwork development interventions that have been evaluated empirically in the intraoperative care? Secondly, amongst these interventions, which change strategies were used to target which teamwork behaviour barriers/enablers using the Theoretical Domains Framework (TDF)?

METHODS

The systematic review was reported according to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines and registered on the International Prospective Register of Systematic Reviews (PROSPERO) (CRD42021233995).[21] The systematic review was conducted in accordance with the Cochrane Collaboration principles for systematic reviews.[22]

Eligibility criteria

We included all experimental studies evaluating the effectiveness of an intervention that aimed to improve teamwork amongst interprofessional teams working in the OR care setting. Included studies must have had a control group that did not receive any teamwork intervention or received a different intervention implemented in an actual or simulated OR setting. Alternatively, the study could have compared inter-team results (i.e., compare the teams in the study with each other) or intra-team results (i.e., compare the results collected at different time-points/stages/phases for the same team). Included studies had to report at least one teamwork process (e.g., leadership, communication, situational awareness, shared mental models, coordination, conflict management) or clinical outcome (e.g., mortality, morbidity, length of hospital stays, post-surgical complications, or clinical adverse events).

According to our predefined criteria, we limited this review to primary research articles. We excluded all reviews, editorials, commentaries, notes, letters, book chapters and opinions as they do not contain original data. We also excluded conference abstracts, case report studies, case studies, case series, and descriptive survey studies. Only articles published in peer-reviewed journals in English were included. We excluded interventions implemented as part of a medical or nursing students' curriculum as we are evaluating TDI's that can be implemented in the clinical operating room setting with practicing healthcare providers. We excluded studies that only assessed participants' perception of an intervention due to the potential of self-reporting bias.[23,24]

Information sources & search strategy

CINAHL via EBSCOHost and the Cochrane Library including EBM Reviews - Cochrane Central Register of Controlled Trials via Ovid (December 2020), Cochrane Database of Systematic Reviews via Ovid (2005 – January 28, 2021) and DARE via Ovid (1st Quarter, 2016). A search strategy was developed in Medline, and then translated into the other databases, as appropriate (see Appendix 1). All databases were searched from 1990 to February 1, 2021. Studies were restricted to human studies only, with no other publication restrictions. All references were entered into an Endnote file for processing (n = 11,179).

The following databases were searched by a health sciences librarian (LS) from 1990 to February 1, 2021 to identify relevant studies according to the predefined inclusion/exclusion criteria: MEDLINE and Medline in Process (Ovid), Embase Classic + Embase (Ovid), APA PsycINFO (Ovid), CINAHL (EBSCOhost), Cochrane Library (Ovid; CENTRAL database) and DARE (Ovid). A search strategy was developed in Medline, and then translated into the other databases, as appropriate (see Appendix A). We elected to restrict publication year's lower limit to 1990 as previous evidence suggests that to be the starting period of research in the field of teamwork in the healthcare setting.[10,25] Studies were restricted to human studies only, with no other publication restrictions. All references were entered into an Endnote file for processing (n = 11,179). The final list of included articles was shared with interprofessional teamwork and implementation science experts for verification.

Selection of sources of evidence

The online software DistillerSR (Evidence Partners, Ottawa, Canada) was used to coordinate screening procedures amongst all reviewers throughout the study selection phase.[26] The articles from the search results of all databases were uploaded onto DistillerSR and reviewed in pairs by two independent screeners using the pre-specified inclusion and exclusion criteria. The screening process involved two distinct stages: abstract screening and full-text screening. A pilot screening test was conducted on a sub-sample of articles for abstract screening followed by the abstract screening of the rest of the articles. Another pilot screening test was conducted before the final full-text screening of the articles deemed to be eligible for inclusion from abstract screening. The pilot screening tests were used to determine inter-rater agreement between reviewers before each screening stage and further training or clarification was provided if the rate of agreement was lower than 80%. All conflicts were resolved before moving to the next screening stage through consensus and involvement of a third reviewer if necessary. Interlibrary loan services were utilized to obtain access to subscription-based articles and the full-text availability was explored for articles at the full-text screening stage. If an article was not available in the online Interlibrary loan catalog, then a RACER request (Rapid Access to Collections by Electronic Requesting) was submitted to the librarian to obtain an electronic copy of the article from libraries and collections across Canada and internationally. If these methods were not successful by the time the review had to be submitted for publication, the studies were excluded (n=4). We did not contact corresponding authors to try to obtain articles due to limited resources and time constraints. The reasons for exclusion of any articles were documented and the study selection procedure is reported using the PRISMA flow diagram (Figure 2).

Data extraction

A data extraction form was developed *a priori*. Two independent reviewers extracted data in pairs from studies deemed eligible for inclusion from the full-text screening stage. A pilot data extraction on a sub-sample of the included studies was conducted to train and assess inter-rater reliability amongst the reviewers before extracting data from all studies. All disagreements were resolved by consensus or involvement of a third reviewer, if necessary. In the case of any ambiguous or missing data, an attempt was made to contact the primary authors.
Extracted data included details of:

- *Study characteristics*: authors, year, country, language, clinical topic, study design, sample size.
- *Team characteristics*: level of experience, professional composition of teams
- *Interventions and comparator(s):* description of teamwork intervention, control (no teamwork intervention, another type of intervention, results from another team, or results for the same team but collected at different time points).
- *Outcomes:* experimental results of the assessment of the effectiveness of the teamwork intervention

Data synthesis

We conducted content analysis of all included studies and provide a narrative, qualitative (Table 2), and descriptive quantitative summary of our results (Table 1).

We categorized teamwork interventions based on a previous study,[10,11] and grouped each teamwork intervention into four categories: Training, Tools, Organizational (re)design, and Programme. Within these four categories in our review, "Training" has two sub-categories: Principle-based training (CRM/TeamSTEPPS), and Method-based training (Simulation). The category "Tools" has two sub-categories: Structuring tools (cognitive aids/(De)briefing checklist) and Triggering tools (posters). We created cognitive aids as a new sub-category under the bigger category structuring tools. The other two categories organizational (re)design and programme do not have any sub-categories. Table 2 provides a summary of the types of interventions and their respective definitions.

We used the TDF to categorize the strategies used to target barriers and enablers of teamwork behaviour in the included teamwork interventions. The steps used to identify and code the barriers/enablers in each intervention were as follows:

1. First, a pair of screeners identified all the change strategies used in the teamwork development interventions to bring about a behavior change. We created the following definition for a change strategy: all individual training components that make up an intervention which are not necessarily temporally distinct. For example, an intervention can consist of a teamwork training didactic session, followed by a simulation scenario, and recurring coaching sessions. In this example, there are three change strategies that make up this intervention starting with a didactic session as one, simulation scenario as the second, and a recurring coaching session as a third change strategy.
2. Second, the change strategies identified in the previous step were then coded, by a pair of coders, to the most appropriate and relevant TDF domain that would likely be addressed by such a strategy. We used the TDF domain definitions and their respective constructs provided in Table 2 by Cane *et al.,* 2012 to carry out the coding process.[20] We coded a change strategy to a domain if it was targeting any of the domain's constructs identified by Cane *et al.,* 2012.[20]
3. The change strategies under each TDF domain were then grouped together if similar and assigned labels that were developed based on the extracted data in this review.

As shown in Figure 1a, we first identified the TDIs, followed by the component change strategies that make up the interventions, and finally categorized these strategies according to the

barriers/enablers to behaviour change targeted by them. Figure 1b also provides definitions of these three concepts in the context of our review. Change strategies are the individual components that make up a TDI, whereas the 14 TDF domains represent possible categories of barriers or enablers to behaviour change.

Risk of bias & quality assessment

The risk of bias at each study level was assessed independently by two reviewers. All conflicts were resolved through consensus and involvement of a third reviewer if necessary.

Version 2 of the Cochrane risk-of-bias tool for randomized trials (RoB 2) was used to assess the risk of bias in randomized trials.[27] RoB 2 assesses the following five domains of bias: randomization process, deviations from intended interventions, missing outcome data, measurement of outcome, and selection of the reported result.[27] The studies were assigned a score of having low risk of bias, having "some concerns", or high risk of bias.[27]

The Risk Of Bias In Non-randomized Studies - of Interventions (ROBINS-I) tool was used to assess risk of bias in the results of non-randomized studies comparing two or more interventions.[27] The ROBINS-I tool consists of the following domains: confounding, selection of participants into the study, classification of interventions, deviations from intended interventions, missing data, measurement of outcomes, selection of reported results, and overall bias.[27] The tool was used to assign either of the following five judgements for a study's risk of bias: low risk of bias, moderate risk of bias, serious risk of bias, critical risk of bias, or no information.[27]

RESULTS

Study selection

Our search strategy yielded 11,179 articles, and after removing duplicates, 7,572 articles proceeded to abstract screening. After assessment for eligibility, 7,535 articles were excluded at the abstract stage and 154 were excluded at the full-text stage, which resulted in 37 studies that met our inclusion criteria (Figure 2).

Study characteristics

Table 1 provides a summary of the descriptive characteristics relating to each study and Table 2 provides a more detailed qualitative synthesis of each study's characteristics including the risk of bias assessment. Included studies were published between 2008 and 2021. The vast majority of included studies were conducted from high-income countries: 19 in the United States, 6 in the United Kingdom, 5 in Canada, and one in each of the following countries (Australia, New Zealand, Sweden, Netherlands, Finland, Israel, and Colombia). Twenty-seven studies were carried out in an actual operating room and ten in a simulated operating room. Pre-/post-intervention study design was the most common type of study design (n=20), followed by retrospective/prospective cohort study (n=5), randomized controlled trial (RCT) (n=4), controlled interrupted time series (n=3), case-control study (n=3), and mixed-methods study designs (n=2). Funding source was identified to be from the industry (n=7), government (n=7),

government & industry (n=7), none (n=7), and 9 studies did not report a funding source. Only seven studies (18.9%) conducted an a priori evaluation of the needs regarding their institutional deficiencies in teamwork.

Type of teamwork interventions

We identified 39 different TDIs. One study evaluated three different TDIs and reported the results in a single article therefore, the number of interventions identified is greater than the number of included studies.[28] The most common type of teamwork intervention studied involved "Programmes" which is an intervention made up of two or more different interventions that are administered together as a programme.[10,11] The breakdown of the types of teamwork interventions found across the included studies is as follows where n is the number of studies: CRM principal-based training (n=6), TeamSTEPPS principal-based training (n=4), Simulation as method-based training (n=5), cognitive aids as structuring tools (n=2), (De)briefing checklists as structuring tools (n=8), organizational (re)design (n=2), and Programmes (n=11).

Overview of component change strategies used to influence teamwork behavior in the OR

Amongst the 39 interventions, we identified 57 change strategies (i.e., individual components that make up the TDI) that targeted 11 out of the 14 TDF domains (i.e., barriers/enablers) in the context of teamwork training in the intraoperative care setting. We did not find any strategy that targeted any of the three TDF domains "Goals", "Emotions", and "Optimism". The median and range of the number of change strategies per intervention was 7.5 and 1 - 13 respectively.

Overview of barriers and enablers targeted by change strategies

Table 3 provides details of the TDF-informed barriers/enablers targeted by the different change strategies identified in the included TDIs.

"Knowledge" (n strategies = 7)
"Education" as a determinant of teamwork behavior mostly involved educating participants about good teamwork behaviors through methods such as feedback/(de)briefing,[29–41] coaching,[42,32] lectures,[43,44,28,45–48,33,34,49,50,37–40] or workshops.[43,40]

"Skills" (n strategies =5)
Strategies targeting "Skills" focused on teaching non-technical and technical skills. A variety of methods were used to achieve this. Simulation training was predominantly used to teach non-technical teamwork skills (e.g., communication, situation awareness, leadership etc.),[47,45,51,30,33,34,52,35,36,53,41] and less commonly to teach technical procedural skills as well.[51,30,34,35,41] Simulation training was proposed to be a popular method of teaching teamwork skills as it allowed the participants to learn through practice in a controlled environment without the pressure of their mistakes resulting in adverse patient outcomes. An alternate method to teaching the "Do's" of technical procedural skills was to provide participants with the "Don'ts" in order to prevent commonly known technical procedural errors in the OR.[44,54,55,48] Lastly, TeamSTEPPS training program is a validated program that can be used to teach five overarching

teamwork skills: team structure, communication, leadership, situation monitoring, and mutual support.[29,56,46,57]

"Social/professional role & identity" (n strategies = 6)
For this determinant of teamwork behavior, we identified strategies that made use of the different ways that social and professional roles of people impact their decisions processes, credibility, and impact on other people around them. Using well known training programs such as TeamSTEPPS or Crisis Resource Management (CRM) training increases the credibility of the TDIs.[44,51,46,48,29,31,32,34,49,56,52,57,37,38,58,39,40] Similarly, using field experts as trainers,[42,43,28,45,46,32,33,49,56,52,36,59,60,57,39,40] ensuring senior staff support the TDI,[44,31,56,59,50] and letting the participants decide on the focus of the TDI promotes credibility of the training program amongst the participants and increases the chances of it being well received.[43,28,49,59,61,37] Additionally, replicating the real-life roles of an OR team during training through role play allows the participants to learn how different professional roles impact other team members.[54,47,45,51,48,34,52,57,37,39] Lastly, asking participants to report incidents of poor teamwork promotes shared accountability and the belief that teamwork is part of their professional role.[42,48,50,57]

"Beliefs about capabilities" (n strategies=2)
The two strategies we identified for the behavioral determinant "Beliefs about capabilities" include: gathering data about participants' current beliefs about their own and their colleagues' teamwork capabilities,[42,43,51,48,32,59,50] and providing feedback regarding capabilities.[42,47,45,51,46,29,31–34,49,52,35,36,60,37–39,62,41] These two change strategies push the participants to gain an understanding of their own capabilities and thus allowing them to identify areas of teamwork they are lacking in and need to improve. This is a root cause analysis approach as it tries to find where the poor teamwork behaviour is originating from.

"Beliefs about consequences" (n strategies=3)
This domain suggests that one's belief about the consequences of performing a behaviour in a particular situational context can either act as a barrier or enabler to them performing that behaviour.[15] The change strategies identified in this review involved using the consequences of performing [44,43,45,51,31,49,63,59,50,37,39,40] or failing to perform a certain teamwork behavior[42,52,35,50,37,38,58,39] as motivation to bring about a change in teamwork behaviour. In the context of teamwork interventions, this involved exploring the impact of poor teamwork on patient safety and clinical outcomes in the OR. Conversely, this can also mean looking at how effective teamwork behaviour can result in favourable consequences for patient safety and clinical outcomes.[42,43,32,59,37,39,53,41]

"Intentions" (n strategies=1)
Intentions can be a determinant of bringing about a change in behavior. This is because a participant needs to actively have the intention of wanting to change their behavior. The strategy we identified to achieve this involves having regular meetings or check-ins during or post implementation of the main intervention program to gauge and ensure continued commitment of participants towards teamwork improvement.[37–40,42,46] Therefore, this strategy focuses on ensuring that the participants' intentions to learn and maintain good teamwork practices stays consistent.

"Memory, attention, and decision processes" (n strategies=5)
The ability to retain information, focus our attention on specific factors, and our ability to make decisions in a logical manner is a determinant of behaviour change and since teamwork is a behaviour these factors also determine one's ability to perform effective teamwork behavior. As such, strategies that promote retention of best practices for teamwork amongst OR personnel, help direct their attention to relevant teamwork behaviours to be carried out and aid them in making decisions collaboratively when faced with complex problems can help them achieve better and effective teamwork in the OR. The strategies we identified for this barrier/enabler include tools such as checklists,[30,31,33,37,38,40,42,46,48,49,51,52,58,59,61–64] cognitive aids,[45,54] briefing posters,[39,40,60] and pocket cards[39] to be used as memory aids to streamline decision processes in the time sensitive OR environment.

"Environmental context & resources" (n strategies=5)
Six strategies targeted "Environmental context & resources" as a possible determinant of better teamwork behaviour and involved changing the environment or environmental resources. We identified three strategies that consider the environmental context and resource constraints and incorporate solutions into the training intervention for example, standardizing operating procedures to achieve greater efficiency in workflow and safety practices,[43,44,48] working around the physicians' busy schedules,[37,38,44,49,50,59] or train a subset of staff and deploy them as champions to train the rest of the hospital staff.[46,50,56,57,59] Additionally, we identified three strategies that introduced new resources to promote teamwork for example, coaching,[38,39,43,49,50,56] audits & feedback,[37,39,46] and regular staff meetings to increase communication amongst staff.[37,40,42,46,49]

"Social Influences" (n strategies=10)
The social influences in the OR setting can act as a barrier/enabler to effective teamwork behaviour [15]. The barrier/enabler to teamwork behaviour "Social influences" was targeted by the second highest proportion of change strategies identified in this review. Amongst the ten strategies targeting "Social influences", we identified five strategies that promoted social interactions[30,31,33–44,46–52,54–57,59,61–64] and five strategies that considered how to overcome two barriers to effective teamwork which are a hierarchal team structure and personality differences amongst team members.[39,57]

"Behavioral regulation" (n strategies=13)
Among included articles, the highest proportion of strategies were identified to target "Behavioral regulation" (n=13) as a possible barrier/enabler of better teamwork behaviour. Twelve out of the thirteen strategies targeting "Behavioral regulation", required participants to learn and perform a new behavior that facilitates effective teamwork in the OR.[46,38,58,57,37,62,49,39,50,59,63,60,40,48,54,45,31] Whereas one strategy involved informing participants how existing behaviours promote or interfere with teamwork behaviours. [29,31,37,39–41,44,46,50]

"Reinforcement" (n strategies=3)
Methods of reinforcement which can be positive or negative in nature can either act as barriers or enablers of participation in a teamwork intervention and performing effective teamwork behaviours. We found three strategies that targeted this domain. One strategy utilized certificate

of attendance as an incentive to promote participation in teamwork training.[43] Another strategy made teamwork training a mandatory requirement to be able to continue working in the OR and so a physician's ability to work in the OR became contingent on their participation in teamwork training.[50] Lastly, to reinforce effective teamwork behaviours, a strategy involved recognition of good teamwork behaviours during training as a positive reinforcer.[37,39,42]

Risk of bias assessment

The risk of bias assessment is summarized in figure 3 for non-randomized studies and figure 4 for RCTs. Amongst the 33 non-randomized studies, there was a low risk of bias in five domains (bias due to selection of participants, bias in classification of interventions, bias due to deviations from intended interventions, bias due to missing data, and bias in selection of the reported results), low to moderate risk in the domain " bias in measurement of outcomes", and moderate to critical risk in the domain "bias due to confounding" (Figure 3). Amongst the four RCTs, there was a low risk of bias in the domains "bias due to randomization process" and "bias in selection of reported results", and low or high risk for other domains (Figure 4). In summary, 2 RCTs had an overall low risk and 2 had an overall high risk of bias, and amongst the non-randomized intervention studies, 11 had a moderate risk, 19 were at critical risk, and 3 had a serious risk overall.

DISCUSSION

This systematic review identified 37 studies that evaluated 39 unique teamwork development interventions (TDIs) in the intraoperative care context either in an actual OR or simulated OR environment. Guided by a theoretical and validated framework, our review has identified 57 key change strategies used across the 39 interventions to promote effective teamwork in the OR.

Our systematically synthesized list of change strategies in Table 3 can be used by future healthcare institutions in the intervention designing phase, to choose the strategies that target the determinants of teamwork relevant to their clinical practice and context. For example, after conducting a preliminary assessment of teamwork perceptions in a surgical department one may find that the OR personnel need more structure in the OR; they could adopt the "standardized operating procedures" strategy under the "environmental context and resources" domain. Similarly, if one finds that a barrier to effective teamwork is suboptimal technical and non-technical skills, then they can choose relevant strategies from the "skills" domain. A previous study from our group had identified key behaviour change enablers and barriers to effective interprofessional teamwork in our institution's OR.[65] However, this study did not provide any specific interventional strategies that could be used to target these enablers and barriers to effective teamwork. To this end, the results of this systematic review can be used to construct an intervention using empirically evaluated change strategies that will target institutional specific enablers/barriers to effective teamwork in the OR such as those identified in our previous work.[65] For instance, under the TDF domain, the previous study identified three barriers to effective teamwork behaviours, including hierarchies, other people's personalities, and unfamiliar teams.[65] In this study, we discovered methods for addressing the three aforementioned barriers that fall under the social influences TDF domain, such as teaching the importance of flat hierarchies, the

use of Myers-Briggs profiles to analyse individual communication styles, and implementing fixed OR teams.

We found that the median number of strategies per included teamwork intervention was 7.5, which means that multiple change strategies are often needed to address multiple barriers/enablers to teamwork in an OR. This is in line with previous studies such as those looking at teamwork in construction companies and emergency departments, which have shown teamwork is impacted by multiple enablers and barriers.[66,67] Similarly, another study found that there are many human factors that impact efficient performance of anesthetic teams with regards to successful airway management at an individual, team, and organizational level.[68] The previous study by Etherington et al.,[65] also concluded that any future teamwork interventions in the OR would need to target multiple factors at the individual, team, and organizational level. Future studies on teamwork interventions should report the behaviour change enablers/barriers targeted by them as well as details on the processes followed when building their intervention. Our review also highlights the gaps in current literature for example, future studies can identify if there are any enablers/barriers to effective teamwork for which a change strategy has not yet been designed and empirically evaluated.

There are several limitations of this review. Firstly, we did not evaluate the effectiveness of the 57 change strategies as the included empirical studies do not provide information regarding the effectiveness of each strategy but instead only provide data on the overall effectiveness of the TDIs. This limited our ability to carry out quantitative or qualitative analysis and report on the effectiveness of the extracted strategies. Secondly, we extracted descriptions of interventions from articles, and this may not provide a detailed overview as incomplete reporting may have caused us to miss some important details about the steps taken during the implementation of an intervention, study participants, and all the different training strategies used. Thirdly, we excluded studies that evaluated self-assessment data only and thus we excluded some valuable studies that had used validated self-assessment tools such as the Safety Attitudes Questionnaire (SAQ). Lastly, we excluded non-English studies and only included studies that were published in peer-reviewed journals thus introducing publication bias.

A strength of our study is that we used the TDF to characterize the barriers and enablers to teamwork behaviours, and to inform mapping the strategies used in each teamwork development intervention.[15,20] This approach of working backwards by retrospectively identifying the factors targeted by an intervention whose design was not informed by theory, has been utilized in a previous study on improving quality of care for patients at risk of osteoporosis.[69] To our knowledge, the TDF has not yet been utilized to analyze existing teamwork development interventions designed to date in the intraoperative care setting. We also used the previously developed taxonomy of types of teamwork development intervention by Buljac-Samardzic *et.al.,* (2009),[10] to guide the process of synthesizing evidence on the teamwork development interventions developed for the intraoperative setting to date. Additionally, as described above, this systematic review compliments the results from a previous qualitative study that used the TDF to guide data collection regarding the barriers/enablers of effective teamwork in the OR setting.[65]

CONCLUSION

Our review identified 57 behavioral change strategies from previously developed teamwork interventions relevant to intraoperative care, categorized according to a validated theoretical framework. Our results summarize evidence that can be used by healthcare institutions to build their own clinical and environmental context specific intraoperative teamwork interventions.

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Table 1. Summary of study characteristics of included studies (n=37).

Study descriptors	***No. of studies (%) N=37***	***References***
Country		
USA	19 (51.4)	42,51,46,29,31,32,34,63,56,35,36,50,61,57,37,38,58,53,41
UK	6 (16.2)	43,44,28,33,49,39
Canada	5 (13.5)	45,30,52,59,62
Australia, New Zeeland, Sweden, Netherlands, Finland, Israel, Colombia	1 (2.7) *each*	54,47,48,70,64,60,40
Clinical setting		
Clinical setting	27 (73.0)	42–44,54,28,46,48,29,31,32,49,63,56,70,64,36,59,50,61,60,57,37,38,58,39,62,40
Simulated setting	10 (27.0)	47,45,51,30,33,34,52,35,53,41
Study design		
Pre/postintervention or before/after study design	20 (54.1)	42,47,28,51,31,33,34,49,56,64,36,59,50,61,58,39,62,40,53,41
Controlled interrupted time series	3 (8.1)	43,44,32
Randomized controlled trial	4 (10.8)	54,29,63,52
Mixed method design	2 (5.4)	45,57
Retrospective/Prospective cohort study	5 (13.5)	46,35,48,37,38
Case control study	3 (8.1)	30,70,60
Funding		
Industry	7 (18.9)	42,47,51,36,60,39,56
Government	7 (18.9)	55,43,28,48,63,38,58
Government & industry	7 (18.9)	45,30,49,64,59,50,62
None	7 (18.9)	28,46,31,33,70,52,37
Not reported	9 (24.3)	29,32,34,56,35,61,57,53,41
Institutional specific needs assessment conducted?		
Yes	7 (18.9)	46,32,56,59,61,57,38
No	30 (81.1)	42–44,54,47,28,45,51,48,29–31,33,34,49,63,70,52,35,64,36,50,60,37,58,39,62,40,53,41

Table 2. Categories and definitions of the types of teamwork development interventions.

Intervention category	n	Definition
Training	10	A systematic approach to teaching teamwork.
Principal-based training:		
CRM-based training	6	Training program based on the Crisis Resource Management (CRM) concept adopted from the aviation industry. It includes communication skills, situational awareness, problem solving, decision making, and teamwork. [10]
TeamSTEPPS training	4	"A specific set of strategies and techniques, aimed at optimizing patient outcomes by improving communication and teamwork skills among healthcare professionals." [10]
Method-based training:		
Simulation-based training	5	"Training that recreates characteristics of the real world." [10]
Tools:	11	
Structuring tools:		"Tools that are used to partly standardize the process of team interaction." [10]
Cognitive aids	2	Use of cognitive aids to standardize teamwork processes intraoperatively.
(De)briefing checklists	8	"A tool that creates an opportunity for professionals to systematically communicate and discuss (potential) issues before or after delivering care to a patient, based on a structured format of elements/topics; checklist." [10]
Triggering tools: Poster	1	"Tools that help provide information (e.g., dashboards) to incentivize team interaction." [10]
Organizational (re)design	2	"Design or redesign of organizational structures with the aim of improving team processes and team functioning." [10]
Programme	11	"A combination of interventions (training, tools, and/or organizational (re)design) bundled in a program that aims to improve team functioning." [10]
Total	39	

Note: Table reproduced from Buljac-Samardzic *et.al.,* (2009) using the results from this review. [10]

Table 3. Summary of results at the individual study level (n=37).

Author (year)	Setting	Teamwork intervention description	Outcomes	Risk of bias
Principal-based training: CRM-based training				
Morgan (2015a)[44]	Clinical setting	CRM based teamwork training course + coaching	Improved non-technical skills but an increase in operative glitch rate	Serious
Morgan (2015b)[43]	Clinical setting	CRM based teamwork training + developing standardised operating procedures	Compliance with WHO surgical checklist improved; Improved teamwork; no effect on clinical outcomes or technical performance	Serious
Maynard (2021)[32]	Clinical setting	CRM based team leader coaching sessions	Improved performance of nontechnical skills	Critical
Neily (2010)[38]	Clinical setting	Medical Team Training program based on CRM principles	Lower surgical mortality rate	Moderate
McCulloch (2017)[28]	Clinical setting	CRM-based teamwork training evaluated against two other types of interventions	Training programs utilizing team training and systems rationalization more effective than single interventions	Moderate
McCulloch (2009)[39]	Clinical setting	CRM based classroom non-technical skills course + coaching	Improved nontechnical skills & teamwork attitudes and climate; decline in operative and non-operative errors; reduced length of stay; Operating time unchanged	Critical
Principal-based training: TeamSTEPPS training				
Rhee (2017)[46]	Clinical setting	TeamSTEPPS educational session	Team performance sustained at desired level or improved; reduced wrong site/side/person surgery and unintentional retained foreign body counts	Moderate
Bui (2018)[29]	Clinical setting	Patient safety quality improvement initiative + TeamSTEPPS training	In live observation greater improvements in non-technical skills, greater compliance with debriefs. Live	High

			observation better than video observation	
Forse (2011)[56]	Clinical setting	TeamSTEPPS program	Improved teamwork and patient outcomes initially but deteriorated overtime in OR safety culture	Critical
Weaver (2010)[57]	Clinical setting	TeamSTEPPS training program	Increase in quality & quantity of preoperative briefings; Increased use of teamwork behaviors; Improved perceptions of patient safety culture and teamwork attitudes	Critical
Method-based training: Simulation training				
Weller (2016)[47]	Simulated setting	Multidisciplinary OR simulation course (MORSim)	Improved teamwork and communication	Moderate
Sparks (2017)[51]	Simulated setting	SImulated & standardized multidisciplinary team training scenario using 3 simulators: SimMan, medium-fidelity, and a high-fidelity simulator	Medium fidelity simulation just as effective as high-fidelity simulation in improving teamwork skills	Moderate
Abdelshehid (2013)[35]	Simulated setting	Simulation-based team training	Participants had positive outlook about the intervention helping in developing communication and technical skills	Critical
Rao (2016)[53]	Simulated setting	Simulated training tasks designed to teach teamwork-related skills	Improvement in technical and non-technical skills of residents	Critical
Nicksa (2015)[41]	Simulated setting		Improvement in teamwork skills of PGY 2 residents but not PGY 1 residents. Participants found interprofessional simulations to be realistic and a valuable educational tool.	Critical
Tools: Structuring tools: Cognitive aids				
Marshall (2016)[54]	Clinical setting	How contrasting designs of cognitive aids affect team performance during simulated intra-operative anaphylaxis	Linear cognitive aid improved teamwork more than a branched aid.	Low

		crises. Each team was assigned at random to a counterbalanced order of: no cognitive aid; a linear cognitive aid; and a branched cognitive aid, and scored for team functioning.		
Di Renna (2016)[45]	Simulated setting	Use of Cognitive Aids for Role Definition (CARDs)	Positive participants perception of intervention; No difference in teamwork with or without intervention	Serious
Tools: Structuring tools: (De)briefing tools				
Everett (2017)[30]	Simulated setting	Operating theatre critical event checklists for medical management and teamwork during whole-team operating theatre crisis simulations staged in a surgical daycare facility.	No improvement in medical management or teamwork	Critical
Bui (2021)[31]	Clinical setting	Clinical Debrief Checklist + Structured feedback	Improved compliance and completeness of debriefing protocols and non-technical skills	Moderate
Calland (2011)[63]	Clinical setting	Perioperative teamwork checklist	No difference in technical skills, patient outcomes, or case times. Improved teamwork. Participants uncomfortable with the intervention	High
lepänluoma (2014)[64]	Clinical setting	Surgical safety checklist	Improved communication; reduced unplanned readmissions; reduced wound complications; improved consistency in documentation; improved safety related performance	Moderate
Lingard (2008)[59]	Clinical setting	Preoperative briefing checklist	Reduced communication failures; promoted proactive and collaborative communication	Critical
Henrickson (2009)[61]	Clinical setting	Preoperative briefing protocol/checklist	Reduced surgical flow disruptions, procedural knowledge disruptions, and miscommunication events; fewer trips to	Critical

			and less time spent in the core; decreased waste. Overall, decreased surgical flow disruptions and improved patient safety in the OR	
Paull (2010)[58]	Clinical setting	Checklist-driven preoperative briefings and postoperative debriefings	Increased antibiotic and deep venous thrombosis prophylaxis compliance rates; Improvements in patient safety	Critical
Lingard (2011)[62]	Clinical setting	Checklist-guided preoperative team briefing	Improvement in physician compliance with antibiotic administration guidelines	Critical
Tools: Triggering teamwork				
Einav (2010)[60]	Clinical setting	Preoperative briefing poster	Reduction in number of nonroutine events; significant increase in the number of surgeries with no nonroutine event observed; Team members found briefings valuable for their own work, teamwork & safety	Critical
Organizational (re)design				
McCulloch (2017)[28]	Clinical setting	Standard operating procedures (SOPs) evaluated against two other types of interventions	Training programs utilizing team training and systems rationalization more effective than single interventions	Moderate
Stepaniak (2012)[70]	Clinical setting	Fixed OR teams	Reduced procedure durations; Improved teamwork and safety climate; No adverse effects on patient outcomes	Moderate
Programme				
Kleiner (2014)[42]	Clinical setting	Surgical safety checklist + CRM based Coaching	Improvement in quality of briefing and debriefing	Critical
Savage (2017)[48]	Clinical setting	Training of staff in CRM, systematic risk assessments, and the redesign of work practices captured and reinforced through the development, implementation, and refinement of SOPs.	Adherence to new work practices sustained; Improvements in non-technical and technical skills, surgical outcomes and safety culture	Moderate

Ramjeeawon (2020)[33]	Simulated setting	Simulation training with structured debriefing	Improved technical and non-technical skills	Critical
Gettman (2009)[34]	Simulated setting	Teamwork, communication, and technical skills training in simulated OR + debriefing	Improved teamwork, communication, and technical skills	Critical
Catchpole (2010)[49]	Clinical setting	CRM based classroom series of interactive modules + checklist + coaching	Increased compliance, team performance but significant latent failures observed	Critical
Boet (2013)[52]	Simulated setting	CRM based within-Team structured debriefing + simulation	No difference between within-team briefing and instructor led debriefing; Improvements in teamwork observed in both intervention and comparison group	Low
Rochlen (2019)[36]	Clinical setting	Simulation OR Team Training (ORTT) + instructor facilitated debriefing	Improved nontechnical skills; participants had a positive perception of the intervention	Moderate
Halverson (2009)[50]	Clinical setting	Classroom curriculum, intraoperative coaching on team-related behaviors, and follow-up feedback sessions.	Improved perception of teamwork; moderate compliance with briefings in follow-up period	Critical
Wolf (2010)[37]	Clinical setting	Medical team training: interactive learning session + briefing/debriefing checklist + follow-up feedback	Decreased delays and improved case scores; Improved perceptions of teamwork and patient safety	Moderate
Amaya-Arias (2015)[40]	Clinical setting	Multi-faceted training program	Improved teamwork in operating rooms and obstetric units	Critical
McCulloch (2017)[28]	Clinical setting	System redesign approach evaluated against two other types of interventions	Training programs utilizing team training and systems rationalization more effective than single interventions	Moderate

Table 4. Breakdown of strategies used to make up each teamwork intervention within the relevant Theoretical Domains Framework (TDF) domains (n=37).

TDF domain (i.e., Determinants of Behavioral Change): **Behavioral Change Strategies**	**N studies (% out of 37 studies)**	**Summary of strategies under each TDF domain (i.e., determinants of behavioral change)**
Knowledge:		
• Provide instructions & information via standardized tools: o Structured feedback or debriefing or briefing sessions [29–41]	13 (35.1)	Educate participants about good teamwork behaviors through methods such as feedback, debrief/brief, coaching, lectures, or workshops.
• Provide education through: o Coaching [42,32] o Didactic sessions: course/lecture-based team training [43,44,28,45–48,33,34,49,50,37–40] o Workshops/modules [43,40]	2 (5.4) 15 (40.5) 2 (5.40)	
Skills		
• Simulation based training to learn non-technical skills [47,45,51,30,33,34,52,35,36,53,41]	11 (29.7)	Use simulation training to allow participants to learn non-technical skills through practice in a controlled environment without the risk of any mistakes resulting in adverse outcomes.
• Technical skills training e.g., o Training on how to prevent technical procedural errors in the OR [44,54,55,48] o Simulation training to teach and practice technical/procedural skills in addition to teamwork [51,30,34,35,41]	4 (10.8) 5 (13.5)	Teach technical procedural skills through simulation training or by providing specific training on how to prevent technical procedural errors in the OR.
• TeamSTEPPS skills training: team structure, communication, leadership, situation monitoring, and mutual support [29,56,46,57]	4 (10.8)	TeamSTEPPS skills training program is a validated training program that focuses on five overarching skills: team structure, communication, leadership, situation monitoring, and mutual support.

Social/professional role & identity		
• Using qualified individuals considered to be experts in the field as trainers [42,43,28,45,46,32,33,49,56,52,36,59,60,57,39,40]	16 (43.2)	Using qualified individuals who are experts in the field and have a rapport with the participants to teach participants effective teamwork behaviors.
• Use well-established and validated principles to design training program e.g., aviation style CRM training, TeamSTEPPS training [44,51,46,48,29,31,32,34,49,56,52,57,37,38,58,39,40]	17 (45.9)	Designing training programs using well-established and validated training programs such as aviation style CRM principles-based team training and TeamSTEPPS training. These programs were used because they are well known in the field of team training and thus the healthcare professionals would be more likely to participate in training exercises.
• Target senior staff for participation [44,31,56,59,50]	5 (13.5)	Actively target senior staff to participant in team training programs so that junior staff follows their example and participates as well.
• Role play technique in a simulated OR, or a didactic session [54,47,45,51,48,34,52,57,37,39]	10 (27.0)	As part of the intervention, assign participants roles that reflect the actual role composition in a usual OR and this is termed "role play" which could take place in a simulated OR, or in traditional didactic sessions.
• Participants decide on the focus of the intervention [43,28,49,59,61,37]	6 (16.2)	Participants were asked to identify areas that needed improved teamwork practices as an interventional strategy. Therefore, the participants were allowed the freedom to decide themselves what the focus of the teamwork intervention should be.
• Cross monitoring [42,48,50,57]	4 (10.8)	Encourage individuals to report incidents of poor team behavior and/or conflict thereby promoting shared accountability and the belief that teamwork is part of their professional role.
Beliefs about capabilities		
• Gathering data about participants' current beliefs about their + colleagues' teamwork capabilities. [42,43,51,48,32,59,50]	7 (18.9)	Gather data about the participants' current beliefs about the teamwork and safety culture and attitude in their teams and organization and then address any gaps in skills via training. This strategy can also use an external

		observer to observe the teamwork and safety culture in an organization.
• Feedback regarding capabilities [42,47,45,51,46,29,31–34,49,52,35,36,60,37–39,62,41]	20 (54.1)	Have discussions or staff meetings with participants to allow them to reflect on their capabilities for example, has there been an improvement post training, what areas they need to improve, what went well and what did not.
Beliefs about consequences		
• Impact on patient safety & outcomes [44,43,45,51,31,49,63,59,50,37,39,40]	12 (32.4)	Discuss importance of teamwork and/or teamwork training for example, informing participants about the consequences of inadequate teamwork practices in the context of the negative impact on patient safety and outcomes.
• Briefing/debriefing on consequences of teamwork deficiencies [42,52,35,50,37,38,58,39]	8 (21.6)	In briefing/debriefing sessions discuss consequences of teamwork deficiencies demonstrated by participants during training.
• Improvements that can lead to favorable consequences [42,43,32,59,37,39,53,41]	8 (21.6)	Discuss areas of improvement in the context of the consequences i.e., will training in this area result in better teamwork and/or patient safety & outcomes
Intentions		
• Regular meetings or check-ins [37–40,42,46]	6 (16.2)	Having regular meetings or check-ins during or post implementation of the main intervention program to gauge and ensure continued commitment of participants towards teamwork improvement. Therefore, this strategy focuses on ensuring that the participants' intentions to learn and maintain good teamwork practices stays consistent.
Memory, attention, & decision processes		
• Tools that act as reminders: o Standardized checklists (intra-operative, pre-operative, post-operative, briefing, debriefings, feedback, time-outs) [30,31,33,37,38,40,42,46,48,49,51,52,58,59,61–64] o Cognitive aids [45,54]	18 (48.6) 2 (5.4)	Tools such as checklists, cognitive aids, briefing posters, and pocket cards are used as memory aids and to streamline decision processes in the time sensitive OR environment. With regards to the use of a standardized checklist, this could be implemented during, before, or after a surgical

○ Briefing poster in a highly visible spot outlining important information [39,40,60] ○ Pocket cards [39] ○ Checklist mounted on the anesthesia monitor [63]	3 (8.1) 1 (2.7) 1 (2.7)	procedure as a briefing or debriefing tool. Checklists can also be used to standardize feedback sessions and time-outs.
Environmental context & resources		
• Standardized operating procedures (SOPs) [43,44,48]	3 (8.1)	System redesign to achieve greater efficiency in workflow & safety practices.
• Work around the physicians' busy schedules [37,38,44,49,50,59]	6 (16.2)	Work around participants' busy schedules and organizational constraints to facilitate participation in training sessions.
• Champion trainers or coaches [46,50,56,57,59]	5 (13.5)	Train a subset of staff and deploy them as champions or coaches to train the rest of the hospital staff. This allows training to be carried out in a more efficient and less resource intensive manner.
• Provide long-term resources post main training session to support good teamwork skills in the OR: ○ Coaching [38,39,43,49,50,56] ○ Audits & feedback sessions [37,39,46] ○ Hold staff meetings to increase communication with them and discuss institution specific barriers and facilitators to teamwork [37,40,42,46,49]	 6 (16.2) 3 (8.1) 5 (13.5)	Introduce new resources to promote teamwork: coaching, audits & feedback, and regular staff meetings to increase communication amongst staff regarding institution specific barriers and facilitators to teamwork.
Social influences		
• Gain interest of senior staff [31,37,43,46,56,59]	6 (16.2)	Gaining interest of senior staff may in turn allow junior staff to participate with support from their supervisors.
• Share feedback about each other's teamwork performance [35,37,39,42]	4 (10.8)	Hold frequent discussions/staff meetings with staff and discuss peers' teamwork performance.
• Translate previously validated training program to the local context & language [40,48,64]	3 (8.1)	Translation of previously developed and validated interventions to the local context and language.

• Fixed OR teams [71]	1 (2.7)	Using fixed OR teams where the same team members work together for a pre-specified duration to facilitate better teamwork and team familiarity.
• Promote group interactions during and after training [30,33–39,41–43,48–51,55,57,59,61–63]	21 (56.7)	Actively encouraging group interactions through interactive training lectures.
• Role play [36,37,39,47,48,50,52,54,57]	9 (24.3)	Make-up of team members and/or roles during training reflect the role composition in real life i.e., multidisciplinary environment.
• Teach: o Value of flat hierarchy [39] o Clear impersonal communication [39,57] o Personal communication styles e.g., using Myers Briggs profiles [39] o Graded authority challenge [39]	 1 (2.7) 2 (5.4) 1 (2.7) 1 (2.7)	These four strategies consider the hierarchal team structure and personality differences.
Behavioral regulation		
• Monitor participants post training and advise about behaviors that facilitate or interfere with teamwork [29,31,37,39–41,44,46,50]	9 (24.3)	Monitor participants post training to advise about specific behaviors that facilitate or might be interfering with one's ability to practice effective teamwork.
• Teach behaviors that promote teamwork: o Call-and-repeat method [46,50,57,63] o Direct & closed-loop communication [37,38] o Use tools that clarify individual roles & tasks [45,54,60] o Standardized framework or standardized terminology for conveying information e.g., SBAR, CUS, DESC [48,50,57] o Introduce new team members [57,63] o Red flag statement clarifying that everyone is accountable for the safety of the patient and so should speak up if concerned [39,48,57] o Time-out/pause [38,40,46,48,49,57]	 4 (10.8) 2 (5.4) 3 (8.1) 3 (8.1) 2 (5.4) 3 (8.1) 6 (16.2) 2 (5.4) 2 (5.4)	These twelve strategies require participants to learn and perform a certain behavior that facilitates teamwork in the OR.

○ Check-back method [46,57]	2 (5.4)	
○ Huddles [46,57]	11 (29.7)	
○ Two-challenge rule [46,57]	11 (29.7)	
○ Pre-case briefing [37,38,40,46,49,50,57–59,62,63]		
○ Post-case debriefing [31,37,38,40,46,48–50,57,58,63]		
Reinforcement		
• Certificate of attendance [43]	1 (2.7)	These three strategies can be used as methods of reinforcement to increase participation in training or to continue practicing good teamwork behaviors.
• Make team training mandatory requirement for working in the OR [50]	1 (2.7)	
• Recognize good teamwork behaviors during training [37,39,42]	3 (8.1)	

Figure 1a. Description of the flow of steps taken during the data extraction and data analysis stage to extract the behavioral change strategies and analyze them thematically.

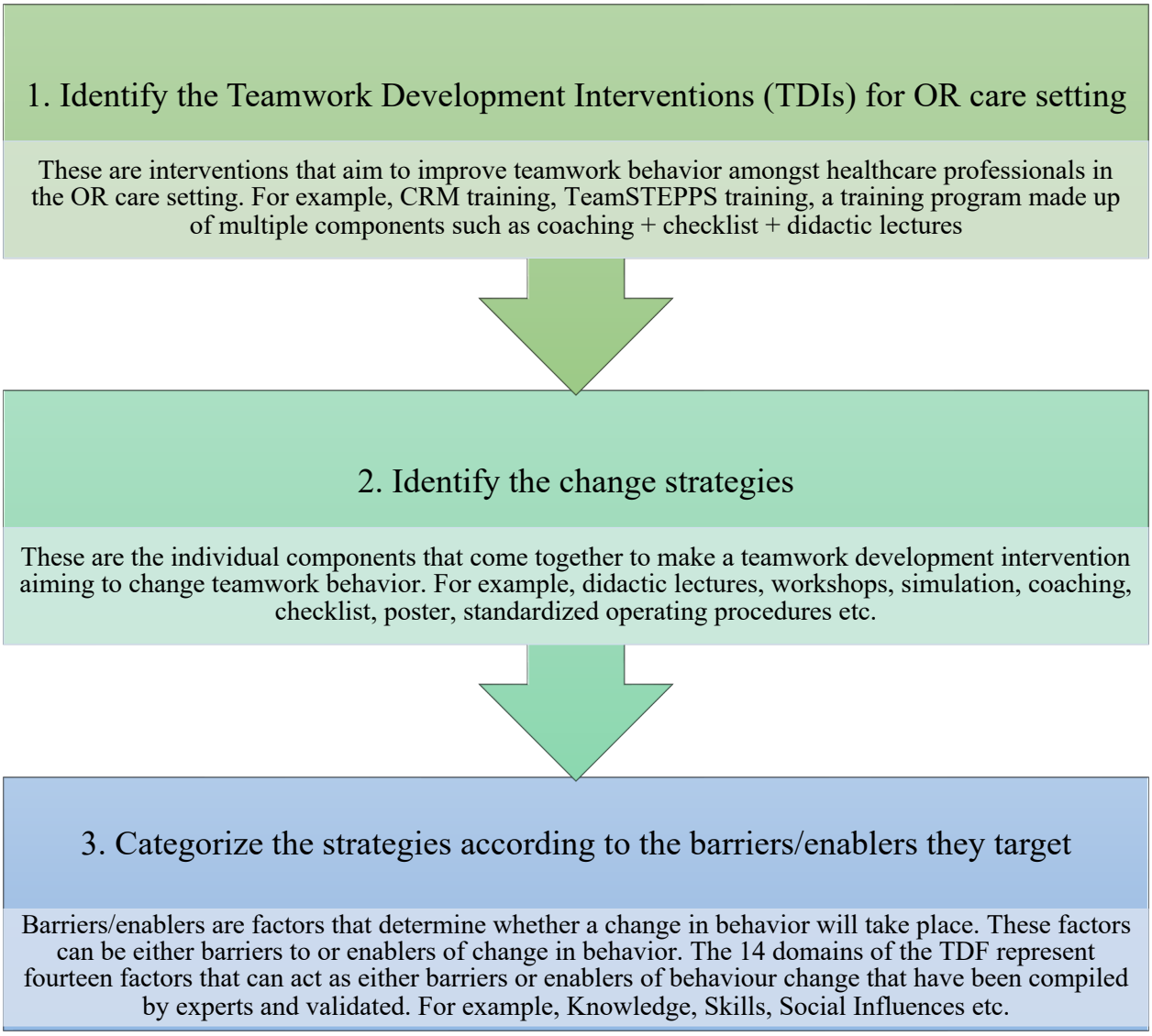


Figure 1b. The relationship between TDIs, behavioral change strategies, and determinants of behavioral change.

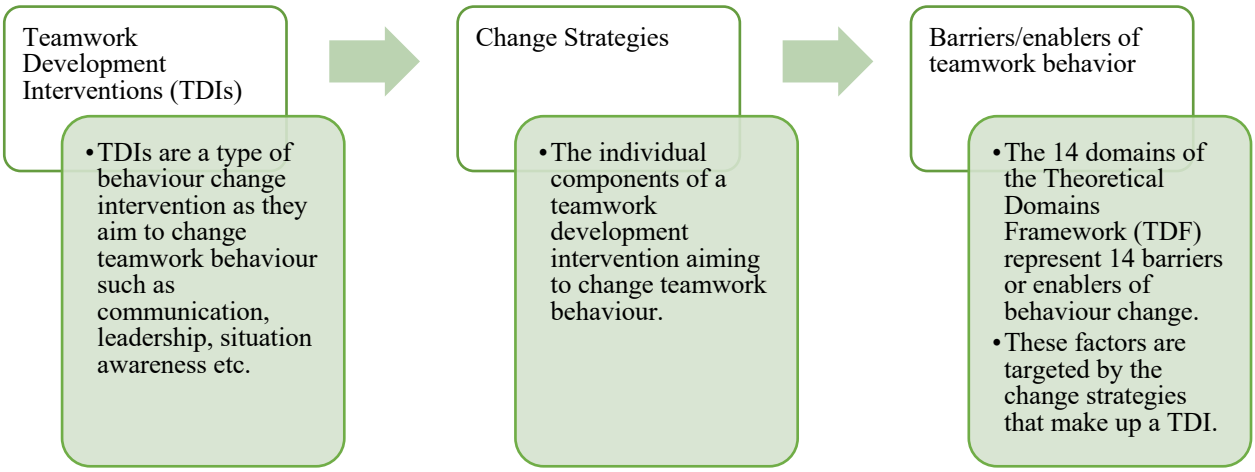


Figure 2. PRISMA flow diagram summarizing study selection procedure.

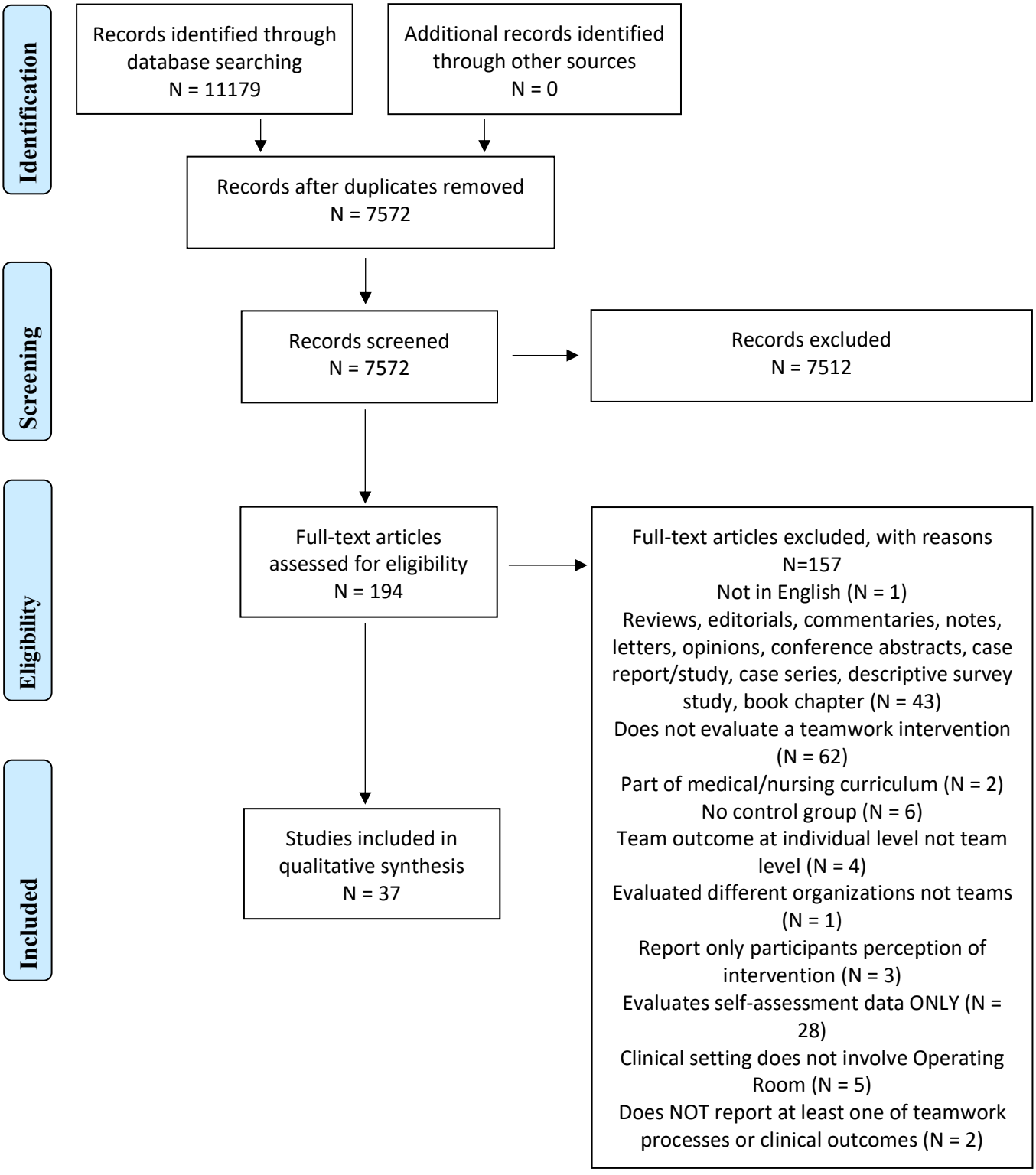


Figure 3. Risk of bias summary of included non-randomized intervention studies assessed using the Cochrane risk of bias in non-randomized studies of interventions (ROBINS-I) tool.

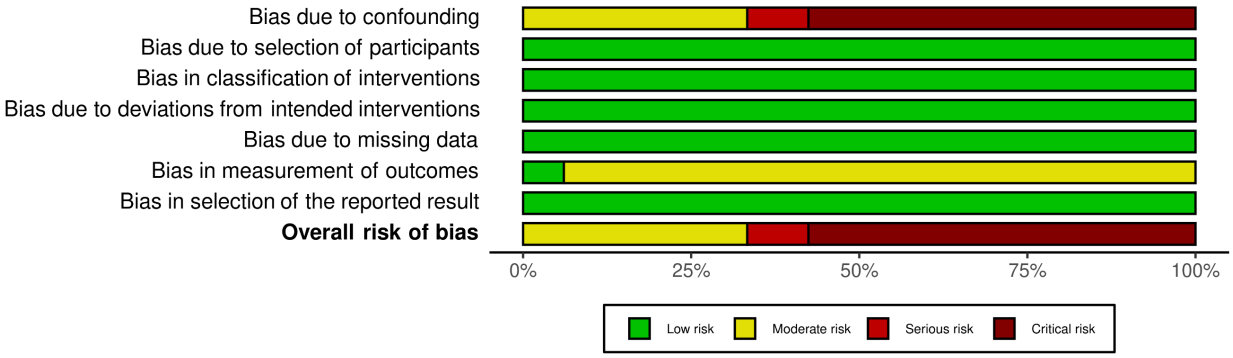
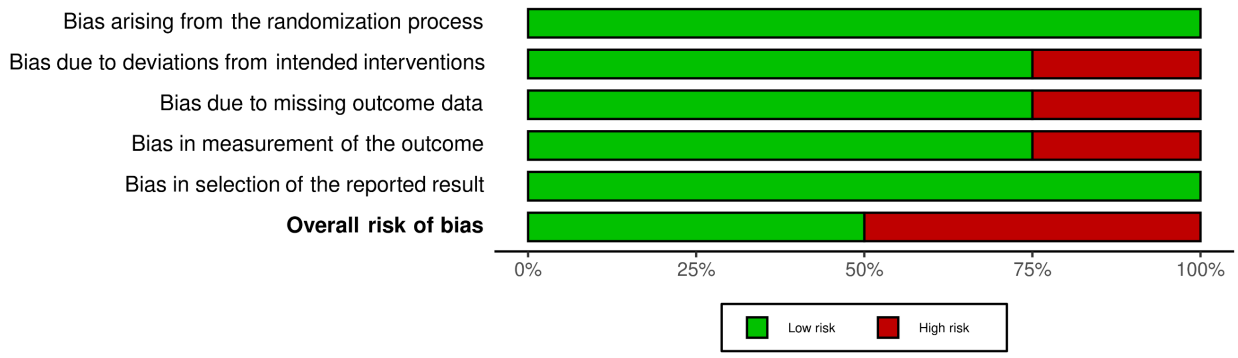


Figure 4. Risk of bias summary of randomized controlled trials (RCTs) assessed using the Cochrane risk of bias in RCTs (ROB 2) tool.



Appendix A: Search strategy

Medline

1. Patient Care Team/
2. exp anesthetists/ or nurses/ or physicians/ or anesthesiologists/ or hospitalists/ or exp surgeons/
3. (doctor* or physician* or nurse* or clinician* or hospitalist* or surgeon* or anesthetist* or anesthesiologist*).ti,ab,kf.
4. or/1-3
5. exp Interprofessional Relations/
6. (interprofessional* or inter-professional* or interdisciplin* or inter-disciplin*).ti,ab,kf.
7. team*.ti,ab,kf.
8. or/5-7
9. Operating Rooms/
10. (operating adj2 (room or rooms or theat*)).ti,ab,kf.
11. Intraoperative Care/
12. exp Intraoperative Period/
13. exp Monitoring, Intraoperative/
14. (intraoperat* or intra-operat*).ti,ab,kf.
15. or/9-14
16. 4 and 8 and 15
17. limit 16 to yr="1990 -Current"
18. 17 not (Animals/ not (Animals/ and Humans/))

Embase

1. patient care/
2. physician/ or anesthesiologist/ or emergency physician/ or hospital physician/ or exp surgeon/
3. nurse/
4. (doctor* or physician* or nurse* or clinician* or hospitalist* or surgeon* or anesthetist* or anesthesiologist*).ti,ab,kw.
5. or/1-4
6. collaborative care team/
7. teamwork/
8. (interprofessional* or inter-professional* or interdisciplin* or inter-disciplin*).ti,ab,kw.
9. team*.ti,ab,kw.
10. or/6-9
11. operating room/
12. (operating adj2 (room or rooms or theat*)).ti,ab,kw.
13. exp intraoperative period/
14. intraoperative monitoring/
15. (intraoperat* or intra-operat*).ti,ab,kw.
16. or/11-15
17. 5 and 10 and 16
18. limit 17 to yr="1990 -Current"
19. limit 18 to human

CENTRAL
1. Patient Care Team/
2. exp Nurse Anesthetists/ or nurses/ or physicians/ or anesthesiologists/ or hospitalists/ or exp Barber Surgeons/
3. (doctor* or physician* or nurse* or clinician* or hospitalist* or surgeon* or anesthetist* or anesthesiologist*).ti,ab.
4. or/1-3
5. exp Interprofessional Relations/
6. (interprofessional* or inter-professional* or interdisciplin* or inter-disciplin*).ti,ab.
7. team*.ti,ab.
8. or/5-7
9. Operating Rooms/
10. (operating adj2 (room or rooms or theat*)).ti,ab.
11. Intraoperative Care/
12. exp Intraoperative Period/
13. exp Monitoring, Intraoperative/
14. (intraoperat* or intra-operat*).ti,ab.
15. or/9-14
16. 4 and 8 and 15
17. limit 16 to yr="1990 -Current"
18. 17 not (Animals/ not (Animals/ and Humans/))

Cochrane Database of Systematic Reviews
1. (doctor* or physician* or nurse* or clinician* or hospitalist* or surgeon* or anesthetist* or anesthesiologist*).ti,ab.
2. (interprofessional* or inter-professional* or interdisciplin* or inter-disciplin*).ti,ab.
3. team*.ti,ab.
4. 2 or 3
5. (operating adj2 (room or rooms or theat*)).ti,ab.
6. (intraoperat* or intra-operat*).ti,ab.
7. 5 or 6
8. 1 and 4 and 7

DARE
1. (doctor* or physician* or nurse* or clinician* or hospitalist* or surgeon* or anesthetist* or anesthesiologist*).mp.
2. (interprofessional* or inter-professional* or interdisciplin* or inter-disciplin*).mp.
3. team*.mp.
4. 2 or 3
5. (operating adj2 (room or rooms or theat*)).mp.
6. (intraoperat* or intra-operat*).mp.
7. 5 or 6
8. 1 and 4 and 7

APA PsycINFO
1. exp nurses/ or exp physicians/

2. (doctor* or physician* or nurse* or clinician* or hospitalist* or surgeon* or anesthetist* or anesthesiologist*).ti,ab.
3. 1 or 2
4. interdisciplinary treatment approach/
5. exp teams/
6. teamwork/
7. (interprofessional* or inter-professional* or interdisciplin* or inter-disciplin*).ti,ab.
8. team*.ti,ab.
9. or/4-8
10. exp surgery/
11. (operating adj2 (room or rooms or theat*)).ti,ab.
12. (intraoperat* or intra-operat*).ti,ab.
13. or/10-12
14. 3 and 9 and 13
15. limit 14 to yr="1990 -Current"

CINAHL

Search Terms	Search Options
S16	S4 AND S9 AND S15
S15	S10 OR S11 OR S12 OR S13 OR S14
S14	(intraoperat* or intra-operat*)
S13	(operating N2 (room or rooms or theat*))
S12	(MH "Intraoperative Period")
S11	(MH "Intraoperative Care+")
S10	(MH "Operating Rooms")
S9	S5 OR S6 OR S7 OR S8
S8	team*
S7	(interprofessional* or inter-professional* or interdisciplin* or inter-disciplin*)
S6	(MH "Teamwork")
S5	(MH "Interprofessional Relations+")
S4	S1 OR S2 OR S3
S3	(doctor* or physician* or nurse* or clinician* or hospitalist* or surgeon* or anesthetist* or anesthesiologist*)
S2	(MH "Physicians") OR (MH "Anesthesiologists") OR (MH "Hospitalists") OR (MH "Surgeons") OR (MH "Nurses")
S1	(MH "Rapid Response Team")

Appendix B: Screening form for abstract and full-text screening

Language:

1. Is the article published in English?
   - Yes (neutral)
   - No (exclude)

Study design:

2. Is the article:
   - an original study (RCT/non-RCT/ Observational study) published in a peer-reviewed journal - (neutral)
   - a review (systematic/scoping/literature) - (exclude)
   - a case report/editorial/commentary/note/letter/opinion/book chapter - (exclude)
   - unclear - (neutral)

Population & Intervention:

3. Does the study evaluate an intervention primarily aiming to improve teamwork?
   - Yes - (exclude)
   - No - (neutral)
   - unclear - (neutral)

4. Does the study involve **health care** professional **teams** in a **surgical operating room care setting?**
   - Yes - (neutral)
   - No - (exclude)
   - unclear - (neutral)

5. Is the intervention implemented as part of a medical students' curriculum?
   - Yes - (exclude)
   - No - (neutral)
   - unclear - (neutral)

Comparator:

6. Is there a control group (no intervention/different intervention/inter-team results/intra-team results)?
   1. inter-team results: compare the different teams in the study with each other
   2. intra-team results: compare the results collected at different time-points/stages/phases for the same team

   - Yes - (neutral)

- No - (exclude)
- unclear - (neutral)

Outcome:

7. Did the study experimentally evaluate effectiveness of intervention at:
   - Team level - (neutral)
   - Individual level only - (exclude)
   - amongst different organizations - (exclude)
   - unclear - (neutral)

8. Did the study evaluate & report
   - ONLY the participants perception of intervention - (exclude)
   - self-assessment data ONLY - (exclude)
   - Other - (include)

Appendix C: Data extraction form

1- If this reference should be excluded, please explain why:

Reasons to exclude:

- Study does not experimentally evaluate effectiveness of a teamwork improvement intervention
- Clinical setting does not involve Operating Room (OR)
- Reviews, editorials, commentaries, notes, letters, opinions, conference abstracts, case report/study, case series, descriptive survey study, book chapter
- The intervention is implemented as part of a medical or nursing student's curriculum
- Assessed the intervention at Kirkpatrick level 1 only i.e., participants perception of the intervention
- Evaluates self-assessment data ONLY
- Does NOT report at least one of teamwork processes or clinical outcomes

2- First author's last name
3- Year of publication (format: YYYY)
4- Location (Country/countries) of study
5- Clinical setting
6- Study design: RCT (parallel-group, cluster, factorial crossover etc.), case-control study, prospective/retrospective cohort study
7- Sample size
8- Patient characteristics (e.g., age, female/male % or n, ASA-score)
9- Team characteristics
    a. Professional composition of team (if multi-professional then a list of included professions)
    b. Sex/gender composition
    c. Level of experience
    d. Team size (average size if team size not uniform)
    e. Usual team or experimental team (i.e., was the team the usual/standard or was it formed specifically for the purpose of the study)
10- Interventions and comparators:
    a. Description of teamwork intervention (e.g., name of intervention, duration, which teamwork domain is targeted by the intervention, when the intervention is performed, where the intervention is performed, etc.)
    b. Description of control (no teamwork intervention, another type of intervention, results from another team, or results for the same team but collected at different time points)
11- Which of the following categories does the teamwork intervention described in the paper, fall under:

- o CRM-based training
- o TeamSTEPPS
- o Simulation-based training
- o General team training
- o SBAR tool
- o (De)briefing checklist

- Rounds
- Facilitating tools (i.e., Tools to facilitate team processes such as communication among team members.)
- Triggering tools (i.e., Tools that may trigger or encourage teams to interact.)
- Organizational (re)design
- Programme (i.e., Multiple interventions to be implemented as part of a single training programme.)

Outcomes:

12- Name of Outcome(s) (as described in article)

13- Definition of Outcome(s) (as stated in article)

14- Type of outcome(s):

i. Change in processes of care e.g., change in clinical practice, change in the process of how care is provided to patients, organizational change etc.

ii. Patient related clinical outcome e.g., clinical outcomes such as morbidity, improvement/deterioration in patient condition post procedure etc.

15- Results (as stated in study):

a. Experimental results of the assessment of the effectiveness of the teamwork intervention

Results

16- Summary as reported in study

Appendix D: PRISMA 2020 checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	3
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	4
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	4
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	4,5
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	4,5,32-34
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	5,41,42
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	5,6,43,44
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	6,43,44
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	6,43,44
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	7
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	6,7
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	6,7
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	6,7
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	6,7
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s),	6,7

		method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	NA
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	NA
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	NA
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	NA
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	7,35
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	35
Study characteristics	17	Cite each included study and present its characteristics.	20-32
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	22-26
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	22-26
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	NA
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	NA
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	NA
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	NA
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	NA
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	NA
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	11-13
	23b	Discuss any limitations of the evidence included in the review.	11-13
	23c	Discuss any limitations of the review processes used.	11-13
	23d	Discuss implications of the results for practice, policy, and future research.	11-13
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	1
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	1
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	NA
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	1
Competing interests	26	Declare any competing interests of review authors.	1

Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	41-44

From: Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 2021;372:n71. doi:10.1136/bmj.n71

For more information, visit: **www.prisma-statement.org**.

Chapter 4: General Discussion and Conclusions

The goal of this dissertation was to explore evidence to inform addressing inadequacies in technical and non-technical skills in the OR to improve surgical patient safety and outcomes. Preventable surgical errors still occur, despite a growing collection of evidence-based literature in the field of perioperative medicine. Teamwork problems and practise inconsistencies are among the most common root causes of preventable patient harm in the OR [1–5]. Therefore, enhancing teamwork skills and reducing the knowledge-practice gap and practice variation of healthcare personnel in the operating room (OR) can lower the frequency of avoidable surgical errors [1,2,5–10].

Due to their crucial role in patient safety and the wide range of medical practices they engage in, anesthesiologists are regarded as a vital target for improvement. However, medical practice varies amongst different anesthesiologists and the knowledge-practice gap in anesthesia is documented.[11–16] To fill this research gap, the first review focuses on knowledge translation interventions (KTIs) for anesthesiologists in the OR and carries out a meta-analysis to examine their relative effectiveness related to processes of care outcomes and clinical outcomes. In addition to teaching technical skills which is addressed by the review on KTIs, the second review focuses on interventions that can be used to improve the non-technical skills of OR personnel. The second review synthesized the current literature on teamwork development interventions (TDIs) and analyzed the composition and targets of these interventions using the validated theoretical domains framework (TDF). We have focused on teamwork as it is composed of a combination of non-technical skills.

The conclusions from the two systematic studies are discussed in this chapter to enhance surgical patient safety and outcomes through continuous improvement of the technical and non-technical abilities of OR healthcare professionals (HCPs).

Overall Summary of Findings from Study 1 (Chapter 2)

In Chapter 2, I presented a quantitative systematic review with a meta-analytic component that aimed to synthesize the current evidence on KTIs in anesthesiology during the intraoperative period. Through this review, we found 35 RCTs that tested the effectiveness of KTIs on the clinical practice of anesthesiologists during the intraoperative period. Twenty-six studies were included in the meta-analysis and evaluated thirty-four different KTIs. The meta-analysis was conducted for Education, Reminder, Checklist/Bundle, and Audit & Feedback KTIs.

We found that “Education” (11 studies) and “Reminders” (11 studies) were the two most common type of KTI designed for anesthesia in the intraoperative setting. The results from this review demonstrate that implementation of KTIs that incorporate “Education” (Dichotomous = RR [95% CI]:2.69 [1.48 to 4.89], Continuous = SMD [95% CI]: 1.69 [0.52 to 2.65]), “Reminders” (Continuous = SMD [95% CI]: 1.94 [0.65 to 3.23]) , or “Audit & feedback” (Continuous = SMD [95% CI]: 0.78 [0.26 to 1.29]) as KT strategies, is associated with improvements in processes of care amongst anesthesiologists in the intraoperative period. There is limited data with regards to the impact of these KT strategies on patient outcomes, with the

exception of "Reminders" as a KT strategy which was not associated with improvements in patient outcomes (Continuous = SMD [95% CI]: 0.95 [-0.22 to 2.11]). Heterogeneity in our meta-analysis varied from none to considerable in both dichotomous and continuous outcomes and therefore, we should be cautious when interpreting the extent of the overall effectiveness of a KTI strategy however this is a good starting point when choosing between different KTI strategies. A statistically significant improvement was not found for checklist/bundle KTIs when analysing both dichotomous and continuous outcomes.

Based on the current body of literature and our meta-analysis, Educational KTIs were the most studied and effective KT strategy in improving processes of care amongst anesthesiologists in the intraoperative care setting. The educational interventions in the included trials utilized simulated OR and actual ORs as well as didactic sessions. There is a need to conduct more trials to compare the differences and effectiveness of these different educational KTI strategies since this is a broad category encompassing many kinds of educational KTIs.

Overall Summary of Findings from Study 2 (Chapter 3)

In Chapter 3, I have presented a qualitative systematic review of the current literature on teamwork development interventions (TDIs) in the OR setting and have also thematically analyzed the design of these TDIs using the theoretical domains framework (TDF) [17]. Thirty-seven studies met out inclusion criteria that described thirty-nine TDIs.

The first objective of this review was to systematically synthesize the types of TDIs that have been empirically evaluated to date. We found thirty-nine TDIs across the thirty-seven studies that met our inclusions criteria. We categorized these TDIs into the following types, where n is the number of studies, using a previously developed comprehensive list of TDI types [18,19]: CRM principal-based training (n=6), TeamSTEPPS principal-based training (n=4), Simulation as method-based training (n=5), cognitive aids as structuring tools (n=2), (De)briefing checklists as structuring tools (n=8), organizational (re)design (n=2), and Programme (n=11).

The second objective of this review was to thematically analyze the design of the included TDIs using the TDF. The 14 domains of the TDF represent 14 barriers/enablers to bringing about a desired behaviour change and therefore, we used this framework as TDIs aim to bring about a change in teamwork behaviour. We identified which of the fourteen barriers/enablers of behaviour change were targeted by what kind of change strategies used in each intervention. The TDF has been used previously to identify the factors targeted by an intervention in the context of patients at risk of osteoporosis, and to our knowledge a similar analysis has not yet been carried out on TDIs. [20]

Amongst the 39 interventions, we identified 57 change strategies (i.e., individual components that make up the TDI) that targeted 11 out of the 14 barriers/enablers to behaviour change in the context of teamwork training in the intraoperative care setting. The median and range of the number of change strategies per intervention was 7.5 and 1 – 13 respectively. The barriers/enablers of behaviour change for which a change strategy was identified are as follows, where n is the number of strategies: knowledge (n=7), skills (n=5), social/professional role &

identity (n=6), beliefs about capabilities (n=2), beliefs about consequences (n=3), intentions (n=1), Memory attention and decision processes (n=5), environmental context & resources (n=5), social influences (n=10), behavioural regulation (n=13), reinforcement (n=3).

In summary, this review on TDIs provides clinicians and healthcare organizations a systematically synthesized overview of TDIs that have been empirically evaluated thus far and provides a list of specific change strategies and the respective barriers/enablers to behaviour change targeted by these change strategies.

Interpretation of findings between reviews

The term knowledge translation (KT) in the field of healthcare refers to the process of uptake of evidence-based empirical knowledge and then applying it in the clinical context [21–24]. KTIs outline the steps required to translate experimental knowledge to the patient's bedside by making the healthcare professionals aware of the existence of relevant knowledge in a timely and efficient manner [21–24]. The KT endeavor aims to tackle the knowledge-practice gap and is deeply connected to the evidence-based-practice approach that has become a challenge in the field of medicine due to the rapid empirical advancements that are constantly being produced and published [21,23–28]. To construct a bridge between empirical research developments and evidence-based-practice, KTIs have been formulated and implemented in healthcare settings. They can be targeted towards individual healthcare professionals or even healthcare as an organization to bring about organizational change that promotes efficient use of all the available resources [21–24]. These interventions are unique pathways of disseminating knowledge among healthcare professionals to facilitating adoption of the most up to date clinical practices, with the ultimate goal of optimizing patient outcomes [23].

Our review in chapter 2 delves into the literature on KTIs in the field of anesthesiology and intraoperative care as KTIs can provide continuous learning opportunities to OR HCPs if implemented correctly and improve practice and in turn patient safety and outcomes. In our review in chapter 3, we decided to focus on the sub-type of KTIs called TDIs. In the past two decades a drastic increase in teamwork interventions has been observed [29,30]. Due to the increased interest and the importance of teaching non-technical skills in addition to technical skills in the OR setting, it is worth delving deeper and conducting an in-depth analysis of the TDI literature in addition to the broader KTI literature [31–33]. A previous study conducted in 2006, proposed that TDIs support KTIs such that while KTIs ignore barriers related to inter-professional collaboration, TDIs address this issue and so supplement KTIs.[34] However, we propose that TDIs are not distinct from KTIs but are rather a sub-category under the broader KTI category. This is because the Canadian Institutes of Health Research (CIHR) has defined the term knowledge translation to include processes of applying knowledge that aim to "provide more effective health services" and TDIs aim to do that as well.[35] When implementing TDIs, the desired outcome to be achieved is improved patient safety and outcomes which is also the desired outcome for KTIs. As such, in our review on KTIs in chapter 2, we included studies that described a TDI. The literature on KTIs and TDIs has not been combined and TDIs are often analyzed separately. However, it might be beneficial to combine the two literatures and draw from the broader KTI evidence when designing and implementing TDIs.

Anesthesiologists and the intraoperative setting primarily use educational KTIs, followed by reminders. TDIs specifically in the intraoperative setting usually involve the use of reminder-based and training/educational KT strategies for improving teamwork behaviour. Our review on the broader KTI literature in anesthesiology and intraoperative setting shows that educational and reminder-based KT strategies are both effective at improving processes of care outcomes. These results on the efficacy of these two KT strategies can be extrapolated to the TDI literature as TDIs are a sub-category of KTIs. Therefore, future research on and practical implementation of TDIs can focus on these two types of KT strategies as KTI literature already shows they are both effective. Lastly, workshops, a type of educational KTI, are the most common method of TDI administration and have a significant impact on teamwork, as shown in a 2017 study not limited to healthcare.[36] These findings align with our review on KTIs in the intraoperative setting, which also highlights the effectiveness and frequent use of educational KT strategies. This further suggests that our findings regarding the effectiveness of educational KT strategies have the potential to be generalized to the design composition of TDIs based on the concept that TDIs are also a type of KTI.

Implications for future research and practice

The significance of non-technical abilities was stressed in a narrative review that was published in 2015, presenting a strong argument for training OR HCPs in both technical and non-technical skills moving forward [37]. The review emphasises that, as shown by the continued occurrence of avoidable surgical patient harm caused by deficiencies in both non-technical skills (such as communication deficiencies) and technical skills (such as procedural knowledge) [1–5], technical skills alone are insufficient to provide competent and safe patient care in the OR setting [37]. The capacity of OR HCPs to perform technical operations can also be hindered by poor teamwork, highlighting the connection between technical and non-technical skills [38]. Addressing gaps in both technical and non-technical skills is thus of central interest for improving the medical practice of OR HCPs and enhancing surgical patient safety and outcomes [39–41]. Therefore, OR HCPs should regularly participate in KTIs that target technical skills and non-technical skills (i.e., TDIs) to achieve a holistic improvement in their medical practice. The findings of the two reviews in this dissertation can inform healthcare organizations on the interventions they can consider implementing for their OR HCPs to support their development of evidence-based technical and non-technical skills.

In both reviews, we noticed that the design of the KTIs are not frequently based on a preliminary analysis of potential factors that could hinder their effectiveness. These factors can include barriers and enablers to the successful implementation of the intervention, which can vary across ORs. Additionally, these factors can also include barriers and enablers of behavior change that impact the OR HCPs ability to adopt desired changes in their behavior, and these should be the target of an intervention [42–44]. There is also a lack of formal exploration of context-specific deficiencies in technical or non-technical skills of OR HCPs before designing an intervention. These factors directly impact an intervention's effectiveness because we cannot bring about a targeted change in OR HCPs skills if we don't know the specific skill deficiencies that need to be targeted and the implementation barriers that need to be overcome by the intervention [45].

Implementation science best practices recommend that this should be the first step in order to design an effective intervention that targets all necessary skill deficiencies and is well-received by its participants by overcoming implementation barriers [45,46].

It can be challenging for OR HCPs to keep up with the high volume of surgical research being published each year. Keeping up to date with current evidence-based findings is crucial to make informed surgical decisions and ensure patient safety [47–49]. One way to achieve this is through lifelong learning opportunities, which can be facilitated by effective intraoperative KTIs. However, there is a lack of use of evidence-based behavior change theories in the design of KTIs, which can limit their effectiveness and generalizability. Our research found that educational KTIs were the most common and effective type of KTI, but we cannot recommend the use of a specific KTI due to limited generalizability and lack of details for reproducing the intervention effects. Additionally, the category of educational KTIs is broad and includes simulated OR, actual OR, and didactic sessions. To make an informed conclusion, more trials are needed to compare the different types of educational KTIs. It's also worth noting that since educational KTIs were the most studied, we cannot disregard other types of KTIs as the results of our meta-analysis may not have been statistically significant due to the limited number of studies and small sample sizes.

In recent years, the KTI subtype TDIs have become a popular topic in literature. However, there is ambiguity surrounding their effectiveness. Despite the consensus on the importance of teamwork in healthcare and the benefits of TDIs, conclusive evidence on their success remains elusive.[50,51] A systematic review previously found that non-technical skills training for OR HCPs had no significant impact on patient outcomes, indicating a lack of evidence on the effectiveness of existing TDIs.[51] We found similar inconclusive and deficient evidence with regards to the impact of the broader KTIs targeting anesthesiologists and intraoperative care, on patient outcomes in our review in chapter 2. Appropriate outcome measures need to be identified to effectively evaluate KTI effectiveness. Future KTI studies should incorporate patient outcomes as measures of success. Furthermore, standardizing outcome measures will enable future reviews to directly compare the effectiveness of different KTIs through meta-analysis.

The effectiveness of KTIs can be difficult to generalize across different OR settings due to variations in contextual factors among the identified interventions. Our reviews have found that a lack of utilization of theory in KTI design and an analysis of what factors contribute to their success makes it difficult to determine which existing KTI would be the best choice for a particular OR. The KTI sub-category of TDIs faces the same challenge such that the current literature reviews on TDIs can be used to determine which intervention to choose based on the healthcare setting it is to be implemented in. However, there is a gap in evidence when trying to target certain barriers to teamwork that are likely to vary amongst different healthcare organizations and departments [29,30,52]. To address this gap in evidence-based and theory-informed interventions, we have broken down existing TDIs into multiple change strategies using the TDF and behavior change theory. This granular information allows for customization of future interventions by selecting the most relevant aspects from existing TDIs, taking into account context-specific factors. However, incorporating behavior change theories beyond the results of

our review and using methods outlined in implementation science literature is still needed in future intervention designs [42,45].

Strengths and Limitations

There are several limitations of this dissertation. Firstly, we excluded non-English publications from both of our reviews and therefore, we may have missed some studies that would have provided additional evidence on KTIs and TDIs in intraoperative care. Secondly, since we used the published manuscripts to extract data for our reviews, some important details about the implementation of the interventions, study participants or clinical setting may have been missed due to the limited ability of authors to report everything in published articles. Thirdly, future reviews on KTIs should include other study designs in addition to RCTs that could provide additional evidence on the effectiveness and other types of KTIs not included in our review in Chapter 2. Lastly, in the TDI review in Chapter 3, we could not evaluate the effectiveness of the fifty-seven change strategies identified due to relevant data availability limitations and not having enough studies per category to conduct a meaningful meta-analysis.

A strength of our study is that in Chapter 3 we used the theoretical domains framework (TDF) to characterise the barriers and enablers to teamwork behaviours, and to inform mapping the strategies used in each teamwork development intervention (13,20). This methodology of applying behaviour change theory to existing interventions has been utilized before and allowed us to take a first step towards incorporation of behaviour change theory and implementation science best practices in the TDI literature [42]. The review in Chapter 3 incorporates evidence-based theories to look at the TDI literature from a new lens and compliments existing behaviour change theory informed literature on TDIs [53]. In Chapter 2, we utilized both qualitative and quantitative methods of summarizing current literature on KTIs, and this gave us a deeper and more thorough understanding of the included studies. In both reviews, we were able to qualitatively synthesize the literature on KTIs and TDIs while also adding another layer of analysis through quantitative analysis and theory informed thematic analysis respectively. Therefore, we were also able to demonstrate how different methodologies can be used to synthesize evidence in systematic reviews on intervention studies.

Conclusion

Adequate technical skills are crucial for optimal performance of OR HCPs. However, deficiencies in non-technical skills can negatively impact their technical performance. To improve performance, patient safety, and outcomes of surgical patients, healthcare professionals should participate in continuous professional development activities. Our reviews of these interventions revealed that incorporating "Education," "Reminders," or "Audit & Feedback" into KTI strategies is associated with improvements in processes of care among anesthesiologists during surgery. Additionally, the KTI subtype, TDIs are composed of various components that can be used as change strategies to address context-specific barriers and facilitators to effective teamwork. To be effective, KTI design should be informed by behavior change theories and implementation science best practices. While research on KTIs has grown rapidly, more studies are needed to evaluate their overall impact on patient outcomes. Future research should also

focus on identifying barriers and facilitators to KTI implementation in the OR setting and assessing the effectiveness of single versus bundle KTIs.

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