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Research paper

Handover from operating theatre to the intensive care unit: A quality improvement study

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ABSTRACT

Background: Transitioning a patient from the operating theatre (OT) to the intensive care unit (ICU) is a dynamic and complex process. Handover of the critically ill postoperative patient can contribute to procedural and communication errors. Standardised protocols are means for structuring and improving handover content. Both have been shown to be effective in reducing information omission and improve communication during this transition period.
Objectives: The aim of this uncontrolled before and after study was to improve handover processes and communication about the care for critically ill patients transferred from OT to ICU.
Methods: Thirty-two OT to ICU handovers (16 before and 16 after implementation) were observed. Using a structured tool, we documented who was present, participated in, and initiated handover during ICU admission. Where and when handover was performed, information provided, distractions and interruptions, and handover duration were also recorded. Unstructured field notes and diagrams provided information on staff interaction. Following implementation, semistructured interviews with 27 participants were conducted to understand participants' perceptions of intervention acceptability and to determine factors influencing intervention implementation and spread.
Findings: Following implementation, a "hands-off" approach was observed with fewer technical tasks completed during handover (43.8% before implementation vs 12.5% after implementation) without an increase in handover time. A single, multidisciplinary handover most often led by the anaesthetist was observed after implementation. Despite these improvements, the use of the physical checklist was not observed in practice, and an situation, background, assessment, recommendation (SBAR) format was not followed. Anaesthetists leading the handover did not view the handover checklist as being beneficial to their practice although some nurses were observed to use the checklist as a prompt for additional information.
Conclusions: A single, multidisciplinary handover demonstrated improvement in handover practice despite low uptake of the protocol checklist. Further information is required to inform targeted strategies

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to improve uptake and sustainability although broader interdisciplinary engagement and commitment may be helpful.

1. Background

In Australian hospitals, an estimated 7,068,000 handovers are conducted annually.[1] Disruption in information transfer and communication has been highlighted as a key contributing factor in serious adverse events (AEs) and a preventable cause of patient harm.[2] Transitions in patient care, owing to change of shift or patient transfer to another department, have been identified as areas of significant risk and vulnerability due to their lack of structure, variability, and unreliability.[1] Using root cause analysis of AE since 2004, the Joint Commission has identified communication as one of the top contributors to medical error, with handover contributing in approximately 80% of serious preventable AEs and also for 20% of all malpractice claims in the United States.[3,4]

The operating theatre (OT) to intensive care unit (ICU) handover is dynamic and complex, with the OT team responsible for transporting a patient and support equipment while simultaneously monitoring and performing any therapeutic tasks such as manual ventilation.[5] As such, it is unsurprising that handovers in this context can give rise to many procedural and communication errors. In addition, the handover process is often informal, unstructured, and non-standardised and is therefore inconsistent and highly variable.[6] Furthermore, clinical handover between the OT and ICU environments involves a particularly complex set of processes that require effective interprofessional communication and cooperation. Health professionals from different occupational and organisational groups need to work collaboratively to respond to often unpredictable workloads and high patient acuity. Ineffective team communication in these contexts is a common cause of AE and patient harm.

Standardised protocols are a means for structuring handover and improving handover content. “Situation, background, assessment, recommendation (SBAR)” is a technique that standardises communication tools and checklists, which can be a component of standardised protocols, by setting expectation for content around the topics “situation,” “background,” “assessment,” and “recommendation”.[7] Utilising standardised protocols can halve the number of information omissions.[8] Moreover, multiple researchers have demonstrated that standardised protocols improve intrafacility communication by 25%, without significantly changing the duration of handover.[9] The importance of standardised protocols for handover has been advocated internationally, notably in the World Health Organisation's action plan for patient safety: “High 5s,” which addresses major concerns about patient safety around the world.[10]

Locally, ICU clinicians had identified wide variability in handover practices with some feedback suggesting inconsistency in the provision of information during patient transition from OT to ICU might be occurring. There was widespread agreement that a collaborative project designed to improve handover processes and communication about the care for critically ill patients being transferred from OT to ICU was warranted.

2. Methods

This quality improvement project was informed by the Medical Research Council's process evaluation guidance[11] which provides recommendations to support developers and implementers in the evaluation of the design and implementation of their intervention.[11] Following these recommendations, we first planned the intervention, decided on the team supporting the intervention, and selected research methods.[11] The intervention was piloted with four clinicians and subsequently refined by the research team before implementation. Finally, the intervention was evaluated by assessing intervention adherence and process measures including acceptability, factors which influenced adherence, and spread.[11] Reporting of this quality improvement project was guided by the Revised Standards for Quality Improvement Reporting Excellence (SQUIRE 2.0).[12]

2.1. Context

This study was conducted in a 750-bed tertiary hospital in Queensland, Australia where over 16,000 surgeries are performed annually. The OT department services all surgical specialities except transplant surgery. The ICU had 21 funded-beds and approximately 2000 patient admissions yearly. The ratio of medical to surgical patients within the ICU was approximately 40:60. Eligible patients included in this study were patients undergoing elective or emergency surgery, who were admitted to the ICU postoperatively. Clinicians included any anaesthetist, intensivist, nurse, or surgeon who provided care to patients being transferred from OT to ICU.

2.2. Intervention development

The intervention, referred to as the handover from operating theatre to ICU (HOT ICU) protocol, comprised three components: a handover checklist to standardise communication, which was custom made and informed by an integrative review conducted by research team members[9] and developed in consultation with end-users; a single, interdisciplinary handover; and a hands-off approach to handover.

The handover checklist was developed by first identifying a list of potential items for inclusion, which was guided by the SBAR framework. The list of items was collaboratively refined with input from ICU and OT clinicians to develop a final list of items. The agreed list of items then informed a Delphi survey, which nursing and medical staff in OT and ICU completed in June/July 2015. The Delphi technique was used to assess nurses' and physicians' perceived agreement with, and importance of, each item in the survey. Survey data were analysed using descriptive statistics, including frequencies. The consensus level was set of 2/3 for agreement and importance.

Completed surveys were received from 138 clinicians; the overall response rate was 68.3%. Surveys were completed by 91/140 (65.0%) OT staff and 47/62 (75.8%) ICU staff. Agreement and importance on handover checklist items was high; only four of 27 items did not meet consensus levels: (i) 37.5% (n = 52) of staff were neutral or disagreed that patient weight should be included; (ii) 35% (n = 47) did not think inclusion of current medications was important; (iii) 44.9% (n = 62) did not think including information about patient belongings and valuables was important; and (iv) 48.1% (n = 66) viewed surgical consultant details as neutral or not important. A meeting was held with senior clinicians and researchers, and following group discussion it was decided that all items be retained in the final standardised handover checklist (Fig. 1), referred to as the HOT ICU checklist. Items that did not reach consensus were given qualifying statements, allowing clinicians to judge item relevance in the context of specific circumstances. For example, “weight” had the description added “when relevant e.g. paediatrics, body mass index <20 or >30, or recent weight loss”.

Strategies to implement the three components of the HOT ICU protocol were designed and delivered in OT by a senior anaesthetic nurse and in ICU by the ICU clinical nurse consultant. The HOT ICU protocol was implemented over 1 month in November 2015. ICU staff were introduced to the HOT ICU protocol during morning "safety scrums," where key information about clinical practice was communicated at the commencement of a shift, and laminated copies of the standardised handover checklist were placed in each ICU room (n = 21). In OT, the HOT ICU protocol was introduced during team meetings, and a physical copy of the checklist was located with other education materials.

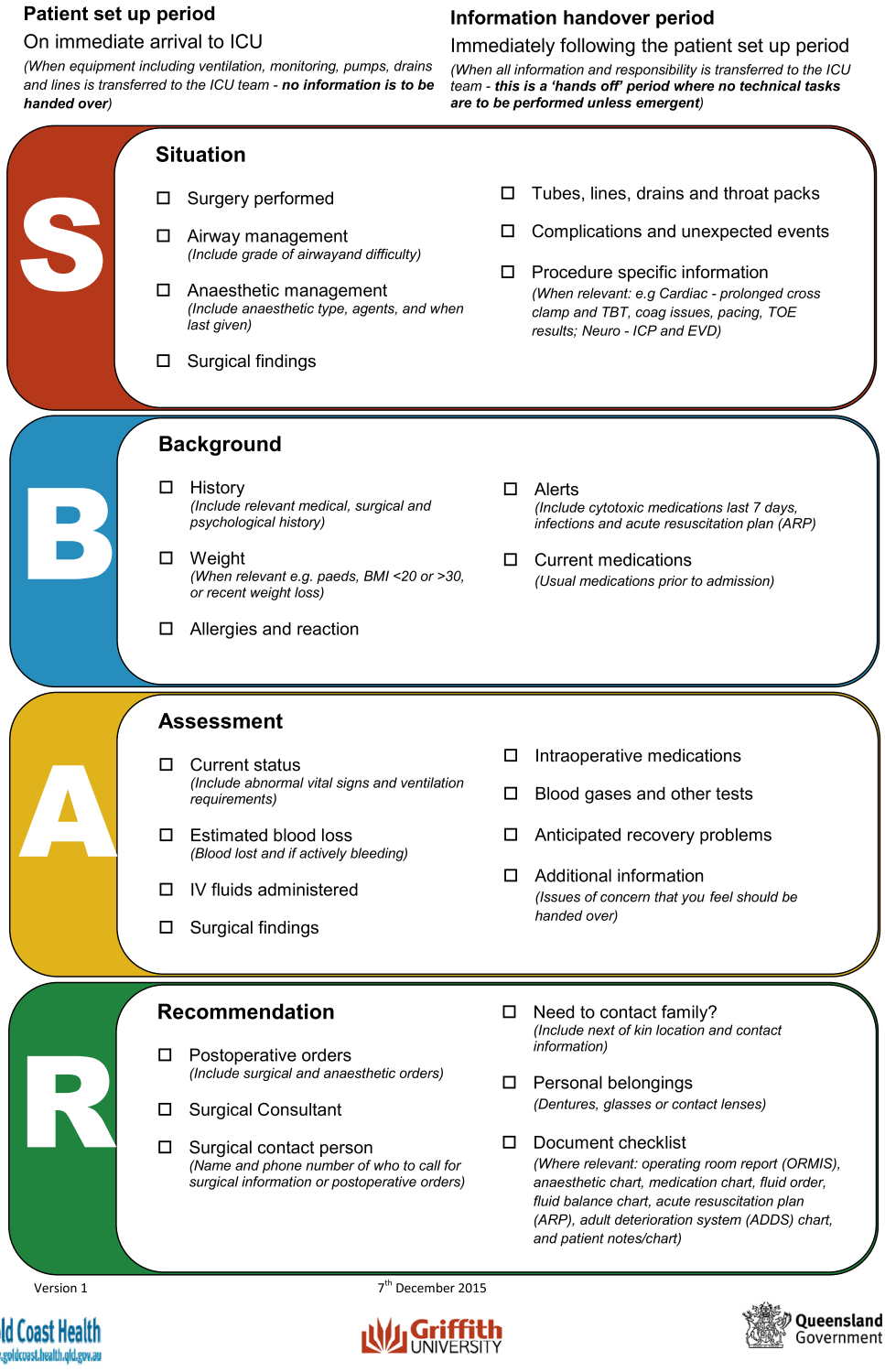

Fig. 1. OT to ICU standardised handover checklist. ICU = intensive care unit; OT = operating theatre.

2.3. Study of the intervention

An uncontrolled before and after study design was selected to observe differences in staff performance of handover that may have been influenced by the implementation of the HOT ICU protocol.[13]

2.4. Data collection

Observations of 16 OT to ICU handovers were conducted in December 2014, before intervention development commenced. Observations were repeated in April 2016 allowing for a 6-month implementation period to embed practice. Nurses and doctors working in clinical areas of surgery, intensive care, and anaesthesia were observed. The health professionals observed were blinded to the specific information being collected but were aware of the presence of the data collectors. Observations occurred in a consecutive manner between 0800 h and 1800 h by two trained independent observers, who observed without actively participating in handover. One observer used a structured data collection tool to ascertain the interdisciplinary members present, who participated and initiated handover during ICU admission, track where and when handover was performed, identify the information content presented verbally to receiving care providers, identify the number of distractions and interruptions, and note the duration of time that elapses to complete time-sensitive components of the handover process, including arrival time to ICU, time of patient set-up, time information handover started, and time handover finished. A second observer documented unstructured field notes, drawing diagrams of the placement of the patient and clinicians, the direction, frequency, and order of communication between clinicians, and notes about anything striking occurring during the handover.

Semistructured interviews were used to understand participant's perceptions of intervention acceptability to determine factors influencing intervention implementation and spread. We interviewed a total of 27 participants 6 months after post-implementation observations occurred (October 2016), 10 ICU nurses, five anaesthetic nurses, three ICU consultants, three anaesthetists, two implementers, and four healthcare consumers, to understand their experiences of using the intervention and how it was implemented. All participants who were approached agreed to participate, two researchers from our team conducted interviews. Interviews were one-on-one, semi-structured, and informal, with examples of interview questions including “What are the barrier/facilitators to implementing the HOT ICU protocol in practice (specifically the single handover, hands-off approach and use of the handover checklist)?” and “What improvements have there been since the HOT ICU protocol was implemented?” For consumers, they were asked about their perceptions of patient safety protocols such as checklists. These consumers were recruited from the hospital consumer advisory group and were interviewed by a member of the research team.

2.5. Analysis

Observational data from before and after the intervention were analysed using descriptive statistics, including frequency, median, and interquartile range. Valid statistical comparison of pre- and post-observations measures could not be conducted because of the limited number of observations conducted. Qualitative interview data were analysed using an inductive content analysis approach to sort, code, and identify emergent concepts.[14] As part of the analytic process, ideas based on the words or phrases found in the transcripts and conversations with participants were coded. These codes were subsequently collapsed into manageable subcategories and then categories that reflected participants' views. The categories were then linked to process evaluation measures like acceptability, adherence, and spread. Flowcharts were developed to help illuminate comparisons between evolving subcategories and categories.

2.6. Ethics

This study was reviewed by the Gold Coast Hospital and Health Service Human Research Ethics Committee where it was determined to be a quality assurance project, had ethical requirement waived, and was allocated a Human Research Ethics Committee (HREC) number for publication (HREC/14/QGC/199). This study was approved by the Griffith University HREC (NRS/43/14/HREC). The study was conducted according to the National Statement[15] and the Declaration of Helsinki.[16]

3. Results

Structured and unstructured observations occurred for 32 OT to ICU handovers, for which over 85% of patients observed underwent elective surgery. Patients were admitted under a variety of surgical specialities; cardiothoracic surgical procedures were the most common with seven (42.8%) conducted before the HOT ICU protocol was implemented and six (37.5%) conducted afterwards (See Table 1). Neurosurgery was also a common procedure with three (18.8%) conducted before implementation and eight (50%) afterwards. Physicians' presence at handover was consistent across both observation periods and depended on their speciality, with members of the anaesthetic and ICU teams present most often (90.6%). An anaesthetic consultant was present 75% of the time and was supported by an anaesthetic registrar more frequently before implementation (pre n = 12 [75.0%], post n = 3 [18.8%]). ICU registrars were present 87.5% of the time during both observation periods, while ICU consultants' presence ranged from 37.5 to 56.3%. There were three instances where medical handover was given over the phone prior to patient transfer consequently no anaesthetist or intensivist was present. Surgeon consultants were present in over 30% of handovers before and after implementation; however, surgical registrars were present on fewer occasions after implementation (pre n = 7 [43.8%], post n = 2 [12.5%]). For nurses, their presence was consistent for the anaesthetic and ICU setting. Over 93% of handovers had anaesthetic nurses present, while ICU nurses were present 100% of the time. Surgical nurses attended six handovers before implementation; however, no nurses were observed after implementation.

The clinical environment where the handovers took place was similar before and after intervention. Loud (pre n = 11 [68.8%], post n = 11 [68.8%]) or constant noise (pre n = 13 [81.3%], post n = 12 [75.0%]) was present in over two-thirds of handovers. There were equipment that alarmed during handover; 23 alarms were heard during pre-implementation handover and 32 alarms post-implementation. Despite consistent noises after the HOT ICU protocol was implemented, observers noted it was easier to hear handover (pre n = 11 [68.8%], post n = 14 [87.5%]).

3.1. Adherence to “patient set-up period”

There were changes in clinicians' adherence to the “patient set-up period” and being hands off during the “information handover period”. Clinicians were viewed as more attentive after the HOT ICU protocol was introduced, improving from 68.8% to 100%. Further, there was a decrease in unnecessary conversations during handover (pre n = 13, post n = 10). Additionally, clinicians completing technical tasks during the information handover period decreased from 43.8% before implementation to 12.5% after the HOT ICU

Table 1
Surgical characteristics of patients before and after implementation of the HOT ICU protocol.

Characteristic	Before intervention n (%)	After intervention n (%)
Surgery urgency		
Emergency surgery	1 (6.3)	2 (12.5)
Elective surgery	15 (93.8)	14 (87.5)
Surgical procedure		
CABG	7 (43.8)	6 (37.5)
Internal tumour reduction for ovarian cancer	1 (6.3)	–
Laparotomy, removal of pelvic mass, TAH, BSO, bowel resection	1 (6.3)	–
Tracheostomy tube insertion	2 (12.5)	–
Endovascular aneurysm coiling	2 (12.5)	2 (12.5)
Craniotomy	1 (6.3)	2 (12.5)
Laparotomy, splenectomy	1 (6.3)	–
Supraglottic papilloma resection	1 (6.3)	–
Angiogram and clot retrieval for CVA	–	1 (6.3)
Insertion of VP shunt	–	1 (6.3)
Transsphenoidal resection of pituitary tumour	–	1 (6.3)
Open haemorrhoidectomy	–	1 (6.3)
Bilateral aortofemoral bypass	–	1 (6.3)
Endoscopic 3rd ventriculostomy for adjunct stenosis	–	1 (6.3)
Surgical speciality		
Cardiac	7 (43.8)	6 (37.5)
Gyne-oncology	2 (12.5)	
ENT	3 (18.8)	
Neurosurgical	3 (18.8)	8 (50.0)
General trauma	1 (6.3)	
Vascular		1 (6.3)
Missing data		1 (6.3)

HOT ICU = handover from operating theatre to ICU; CABG = coronary artery bypass Graft; TAH = total abdominal hysterectomy with bilateral salpingo-oophorectomy; CVA = cerebral vascular accident; VP = ventriculoperitoneal.

protocol was introduced. The median duration of time spent setting up the patient before handover commenced increased from 1.0 min (interquartile range [IQR] = 1.8) to 3.0 min (IQR = 2.0), but the median total time it took to conduct handovers (pre n = 8.5 [IQR = 5.75], post n = 8.5 [IQR = 3.5]) did not increase.

3.2. Adherence to "information handover period"

As seen in Fig. 2, pre- and post-implementation, anaesthetic medical staff most frequently initiated handover, which occurred in 68.8% of handovers before and after implementation. However, the direction of their communication changed after implementation, with around half of their first initiated comments being directed to ICU nurses; with field notes suggesting anaesthetists checked nurses' readiness for handover prior to commencing. In the second

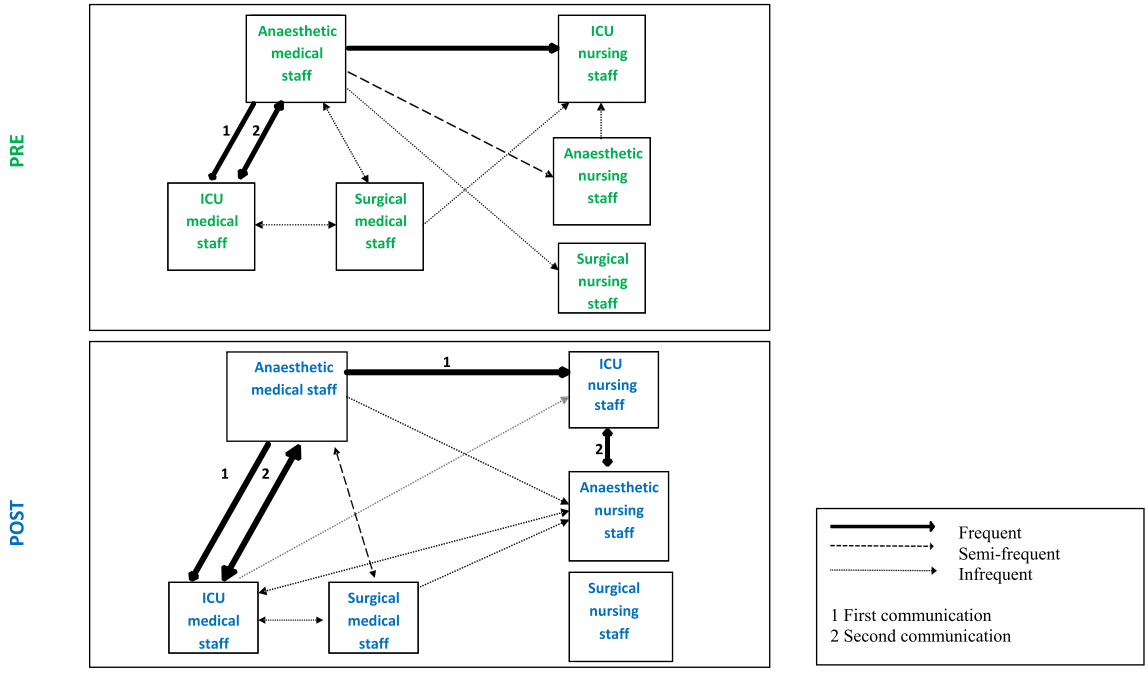

Fig. 2. Communication patterns during handover. ICU = intensive care unit.

stage, most frequent communication during handover tended to be mutual exchanges between anaesthetic and ICU medical staff. As seen in Fig. 2, after the formal handover had finished, discipline-specific communication was observed such as between the anaesthetic and ICU nurse where clarification or further information was sought. An example of this was the increase in ICU nurse and anaesthetic nurse communication in post-implementation observations (Fig. 2). There was an observed increase in more than one person talking at a time (pre n = 10, post n = 13), however, our field notes showed these were occurring after the anaesthetists initial handover, when others discussed more nuanced aspects of the case. There was also an observed increase in information clarifications or corrections (pre n = 13, post n = 16).

In the post-implementation observations, the use of the HOT ICU protocol or a SBAR structure to aid communication was not used to support the handover process. Anaesthetists who led handover used their anaesthetic notes to guide handover; this was observed in the majority (n = 30, 93.8%) of handovers. Although neither the HOT ICU protocol nor a SBAR format was followed, improvements were seen in the inclusion of content listed under the "assessment" and "recommendations" section of the HOT ICU protocol. For instance, information sharing related to current assessment of the patient increased from 20% of cases to over 80% of cases, while recommendations for medication plans improved from around 30%–87.5%. Overall, observed communication remained stable across the two observation time periods and was perceived to be smooth 68.8% of the time.

3.3. *Health care professionals' views of intervention acceptability, adherence, and spread*

Process evaluation data were collected to assess intervention acceptability, adherence, and spread. Healthcare consumers were supportive of the use of tools to promote patient safety in hospital. Nursing clinicians found the HOT ICU checklist easy to understand, succinct, and well-structured and viewed this tool as something that would likely contribute to a reduction in error during handover. However anaesthetists and intensive care consultants did not see that tool as being flexible enough to meet their needs and viewed the tool as something that would be useful for nurses although this view was not shared by anaesthetic and intensive care consultants who had input into the tool development. Anaesthetic and intensive care consultants and senior nurses also saw the HOT ICU checklist as being something that had greater utility for junior nurses and doctors.

While perceptions of the benefits of using the HOT ICU checklist varied amongst healthcare professionals, the inclusion of a "hands-off" component was valued as a strategy to ensuring that the whole team was ready, listened to one handover, and for nurses this also made them feel as though they were included, respected, and part of the team. The initial focus on equipment and getting the patient settled was seen as important with handover of information about the patient not commenced until this was completed. Anaesthetists would wait for and check that the ICU nurse was ready to receive handover before commencing which made the nurses feel included in the handover.

A single handover was reported to be well-established following implementation of the HOT ICU protocol. Both nursing and medical staff commented that this was an improvement in the handover process where a single handover to ensure consistency of information exchange. However, variability in a single handover approach was also reported and considered to be dependent on the anaesthetist leading the process. Although a single handover approach was common, nurses reported that they often had follow-up conversations with nursing colleagues to communicate or clarify nursing specific issues.

The use of the physical document that was the HOT ICU checklist was not commonly used by anaesthetists although nurses did report using this when receiving handover as a strategy to elicit additional information. As clinicians became more familiar with the checklist, many indicated that they did not need to use the HOT ICU checklist as a prompt. The scale and spread of the HOT ICU checklist and protocol was limited. While many nurses reported familiarity with the HOT ICU protocol, physicians, particularly anaesthetists, were less familiar with its use. Difficulties in communicating the use of the HOT ICU checklist and protocol were reported by both OT and ICU staff, largely attributed to the high number of staff working in both areas.

4. Discussion

This study demonstrated variable improvements in the OT to ICU handover practice in one hospital. Handover was delayed until completion of patient set-up allowing for a "hands-off" handover. Further, the information handover period was enhanced, with clinicians being more attentive, handover being led by one person and being communicated to more than one receiver and minimising patient care during the handover period. Despite these improvements, the use of the physical checklist was not observed in practice and an SBAR format was not followed. Nevertheless, introduction of the tool did improve the frequency of some SBAR items.

Our findings contrast other studies, where researchers have successfully implemented standardised checklists for OT to ICU handover.[9] Previous research has demonstrated that clinicians' uptake of standardised handover checklists resulted in improved information transfer, including item frequency and handover accuracy.[9] When clinicians do not follow standardised protocols, the completeness of their handover may be compromised. In a comparison of two groups where one was given instructions about best handover content and the other was given a physical handover checklist to use during handover, only the latter group showed improved frequency of items handed over.[17] In our study, the lack of checklist adoption and infrequent use of SBAR may have contributed to items being missed because clinicians relied on memory instead of these tools.

Anaesthetists most commonly led and initiated handover before and after intervention; and their adherence with using the handover checklist was sometimes low. The social influence of this practice was evident, with nurses and implementers reluctant to change their practice without physician buy-in and compliance. Similar to our study, other physicians have found handover checklists to be unacceptable because they perceive that they do not focus on the critical information required for managing patients.[18] Further, all staff from surgical, anaesthetic and ICU teams need buy-in and high levels of motivation to improve all aspects of OT to ICU handovers,[19,20] which was not evident in our study.

Despite clinicians' poor adherence with using the checklist during handover, most nurse clinicians reported liking the tool. Consistent with previous studies, the use of a Delphi approach ensured the checklist components were decided by stakeholders and contextually developed,[9] which may be why clinicians commended the tool. Moreover, in the Australian context, when clinicians are involved in the development of standardised handover checklist and protocols, their acceptance for their use is high.[21] Like other studies, nurses liked the checklist, because it was thorough and structured,[22] and increased reliability and decreased redundancy of information.[23] However, unlike previous work,[24] active engagement in the development process and approval of the tool by clinicians did not increase use of the new handover tool. As a group, anaesthetists typically led handover, yet some members of this group were least engaged with the development of the HOT

ICU protocol, and this lack of intervention coproduction may have contributed to reduced intervention uptake during and following study completion.[25] It may also be that physicians in our study did not value the tool as much as nurses because of the differences in perceived information requirements during handover[26,27]; these different information needs were highlighted by nurses in our study seeking nursing-specific information from their colleagues following handover completion.

In our study, clinicians' perceptions were that they were already competent in using SBAR in practice; therefore, the handover checklist was not overly useful. Other researchers have demonstrated that when new practice interventions are perceived as similar to routine practice, clinicians question the value of changing practice and may resist change.[28,29] It was also proposed that the handover tool was more relevant for novice nurses and physicians, a finding supported by previous work by Johnston et al.[28] Researchers suggest senior nurses perceive tools as restricting their nursing practice but aiding in educating junior staff.[28] Often senior clinicians are viewed as able to give succinct, purposeful, and prioritised handovers,[26,30] while junior clinicians adhere to rules and guidelines when delivering information related to all aspects of the patient case[30] and may not identify what information is missed or what question should be asked.[26]

We noticed improvements in the patient set-up period and clinicians being hands off during the information handover period. Like our findings, implementing a pre-handover phase increases the time spent in this phase, further others have found it may result in quicker ICU cardiorespiratory monitor transition and improvements in patient outcomes.[31] Similar to prior work, having two distinct phases in handover improved clinicians' attentiveness during the information handover period.[32] Researchers have shown that having distinct phases decreases parallel conversations between clinicians occurring at the same time and allows the nurse to focus on and hear the report.[33] Effective handover with various disciplines working as team requires communication across power gradients,[34] and establishing a patient set-up period may have enhanced nurse–physician communication in our study. The patient set-up period and “hands off” during the information handover period was valued by ICU nurses and is reportedly sustained in practice. Other nurses have stated their value for having distinct steps in the handover process,[26] as nurses perceive that their role is to immediately focus on the critical needs of the patient when they arrive to ICU, and they have issues multitasking with equipment while trying to listen to handover.[26] Other researchers have found 100% compliance with these distinct phases in handover 1 year after implementation, suggesting nurses in our study are likely to continue to sustain this practice.[31]

5. Strengths and weaknesses

This study has a number of limitations. For evaluation, the duration of time that elapsed between initial observations and implementation of the intervention was 1 year. Thus, other contextual changes could have occurred in that time, making pre-intervention data less comparable. However, the similarities in findings before and after intervention demonstrate this may not have been an issue. The data may have also been influenced by the Hawthorne Effect. It is possible that in the second round of observations clinicians were more aware of what was being assessed, and therefore this may have influenced their behaviour during data collection.

Although the study has limitations, it also has a number of strengths. A strength of this study was the use of co-production of the intervention. Implementation was led by the respective clinical teams, and during the implementation, phase variances in intervention implementation and spread was observed and likely influenced observed adherence with the HOT ICU protocol. A strategic and defined implementation process may have improved intervention uptake; however, the approach used in this study reflects the real-world of clinical practice where senior members in the respective clinical areas selected and used approaches they considered effective and appropriate for their clinical context. There was buy-in from physicians in the development stage; however, during the implementation phase, this decreased. Future researchers would benefit from identifying strategies to engage physicians throughout the research process.

6. Conclusions

This study supports the need for clinician engagement in all phases of intervention development and implementation in changes in clinical practice. Developing a standardised protocol for OT to ICU handover that involved all clinicians in development ensured the tool was acceptable for some end-users. Despite involving clinicians in development, implementation of the handover checklist had mixed results. The importance of implementing two distinct phases of OT to ICU handover is supported in this study and empowers the nurse during handover. In our study, the implementation of a single, multidisciplinary handover was seen as beneficial and also highlighted the need for greater engagement with physicians during development and implementation to ensure the intervention is acceptable for all clinicians. Overall, low uptake of the protocol requires further exploration in the setting to inform development of targeted strategies to improve uptake and sustainability.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.aucc.2018.03.009.

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