

BMJ Open Effect of a newly designed observation, response and discharge chart in the Post Anaesthesia Care Unit on patient outcomes: a quasi-experimental study in Australia

Maryann Street,^{1,2,3} Nicole M Phillips,^{1,3} Mohammadreza Mohebbi,⁴ Bridie Kent⁵

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¹School of Nursing and Midwifery, Deakin University, Geelong, Australia

²Eastern Health-Deakin University Nursing and Midwifery Research Centre, Box Hill, Australia

³Quality and Patient Safety Research Centre, Deakin University, Burwood, Australia

⁴BioStatistics Unit, Faculty of Health, Deakin University, Geelong, Australia

⁵School of Nursing and Midwifery, University of Plymouth, Plymouth, UK

Correspondence to

Dr Maryann Street;
maryann.street@deakin.edu.au

ABSTRACT

Objectives This study aimed to evaluate whether use of a discharge criteria tool for nursing assessment of patients in Post Anaesthesia Care Unit (PACU) would enhance nurses' recognition and response to patients at-risk of deterioration and improve patient outcomes.

Methods A prospective non-randomised pre–post intervention study was conducted in three hospitals in Australia. Participants were adults undergoing elective surgery before (n=723) and after (n=694) implementation of the Post-Anaesthetic Care Tool (PACT).

Results Nursing response to patients at-risk of deterioration was higher using PACT, with more medical consultations initiated by PACU nurses (19% vs 30%, P<0.001) and more patients with Medical Emergency Team activation criteria modified by an anaesthetist while in PACU (6.5% vs 13.8%, P<0.001). There were higher rates of analgesia administration (37.3% vs 54.2%, P=0.001), nursing assessment of pain and documentation of ongoing analgesia prior to discharge (55% vs 85%, P<0.001). More adverse events were recorded in PACU after introduction of the PACT (8.3% vs 16.7%, P<0.001). The rate of adverse events after discharge from PACU remained constant (16.5%), but the rate of cardiac events (5.1% vs 2.6%, P=0.021) and clinical deterioration (8.7% vs 4.3%, P=0.001) following PACU discharge significantly decreased, using the PACT. Despite the increased number of patients with adverse events in phase 2, healthcare costs did not increase significantly. Length of stay in PACU and length of hospital admission for those patients who had an adverse event in PACU were significantly reduced after implementation of the PACT.

Conclusion This study found that using a structured discharge criteria tool, the PACT, enhanced nurses' recognition and response to patients who experienced clinical deterioration, reduced length of stay for patients who experienced an adverse event in PACU and was cost-effective.

BACKGROUND

Surgery is an integral part of healthcare throughout the world, with an estimated 234 million operations performed annually.¹

Strengths and limitations of this study

- This study examined the real-time impact of nursing care, for the recognition and response to patient deterioration in the Post Anaesthesia Care Unit.
- The prospective design identified processes relating to nursing management not captured in the medical record.
- The sourcing of some data obtained from patients' medical record and organisational datasets was a limitation of the study. For most variables, including key outcome variables, the frequency of missing data was less than 1%.
- There may be factors external to the implementation of the Post-Anaesthetic Care Tool that increased or decreased surgical risk; however, this quasi-experimental study design was practical and effective health services research.

Studies in industrialised countries have shown a death rate after surgery of 0.4% to 4.0% and a rate of major complications of 3% to 17%.^{2–6} Approximately 40% of in-hospital complications are associated with surgery and 15% of surgical patients will experience at least one complication,⁷ such as bleeding, infection, cardiac and/or respiratory problems (congestive cardiac failure and pulmonary oedema); these being the most commonly occurring events.⁸ Hospital costs for surgical patients experiencing a complication are substantially higher than for patients without a complication.^{9 10}

The intensive observation of patients in PACU by nurses can result in the early detection of complications and adverse events.¹¹ These adverse events include clinical deterioration, unresolved pain, unplanned admission to intensive care, prolonged hospital stay, disability or death. Postoperative deterioration occurs frequently, with a reported

rate of 20% in PACU and 17% on the wards¹² and 20% of patients who experienced clinical deterioration in PACU required medical review.¹³ The early recognition of clinical deterioration and timely response can reduce the incidence or severity of postoperative complications, mortality and length of hospital stay.¹⁴

AIMS

The aims of this study were to evaluate whether use of the Post-Anaesthetic Care Tool (PACT) would (1) enhance the recognition and response to patients at risk of clinical deterioration, (2) result in improved patient outcomes and (3) reduce healthcare costs.

METHODS

Design

This study used a non-randomised prospective before and after intervention design. The study protocol has been published¹⁵; therefore, a brief overview is provided here. The setting for the study was the Post Anaesthesia Care Units (PACUs) at three hospitals within one Australian metropolitan healthcare organisation using primarily non-participant observation.

Development of the tool

The intervention was the PACT, developed locally to address concerns raised by clinicians and managers about the lack of standardised documentation within the perioperative services of the healthcare organisation, which was impacting on patient outcomes immediately following surgery. For example, one hospital was using a modified Aldrete scoring system¹⁶ to assess patient readiness for discharge from PACU while another used a simple checkbox. A working party was established to determine the best way to address these issues and improve outcomes for patients. An interdisciplinary subcommittee including nursing and medical health professionals, quality assurance and planning representatives and the researchers who were experienced in exploring PACU evaluation tools undertook extensive review of the current processes at each hospital. The researchers conducted two projects, a systematic review¹⁷ and an expert consensus study,¹⁸ to synthesise and evaluate the current evidence and generate key elements to form a new PACT for safe patient discharge from PACU. The findings from these two studies were considered and incorporated into the PACT when the new assessment documentation for perioperative care at this health organisation was developed between March 2011 and November 2012.

Changes to the PACT were also required to conform to organisational policy and procedures, especially with regard to guidelines relating to the recognition and response to patient clinical deterioration. These guidelines included the use of colour-coded charts that incorporated a track and trigger system, where different colours in the charts reflect levels of physiological

abnormality or specific triggers in single or multiple parameter systems.¹⁹ Medical emergency team (MET) activation occurs when patients fulfil predefined criteria (specific abnormalities in vital signs or staff concern).²⁰ The revised documentation (PACT) conformed to the National Consensus Statement on the essential elements for recognising and responding to clinical deterioration²¹ and used a track and trigger system for assessment of a patient's conscious state, vital signs (oxygen levels, respiration rate, blood pressure and temperature), symptoms (pain, nausea and vomiting), level of activity and care plan. Patient readiness for discharge from PACU was recorded by a checklist of criteria: that the last two sets of observations were not within the MET or modified MET criteria; there was no active vomiting; pain management had been ordered; and all surgical concerns had been met.¹⁵ The PACT contained information regarding oxygen therapy, analgesia administered in PACU and related charts specific to the patient and surgical procedure (see online supplementary figure S1).

Implementation of PACT

Implementation of the PACT was supported by perioperative nursing educators, posters summarising how to complete the PACT and feedback sessions between the nurses using the tool and the perioperative team (educators, nurse unit managers and the quality unit of the organisation). The PACT was included in the revised 'Post-Anaesthetic Care Record' and was implemented at all three hospitals on the same day in March 2014. Postimplementation data collection commenced after a 3-month period from the time of implementation, as this was considered sufficient time for the tool to be embedded in nursing practice in PACU.

Participants

The study population comprised surgical patients admitted to the PACU during the study period. All adult patients (18 years or over) undergoing elective surgery on days of data collection before (phase 1; July to October 2012) and after (phase 2; July to September 2014) the implementation of PACT were eligible to be included. Patients were excluded from the study if they had undergone emergency surgery, had a minor procedure requiring only sedation rather than anaesthesia or had a postoperative planned admission to intensive care. The sample size was based on an adverse event incidence of 12% and able to detect a 7% difference before and after the PACT, or an OR of at least 2.6, using a two-sided Cochran-Mantel-Haenszel (CMH) test conducted at the 5% significance level with 80% power.

Data, collected by research nurses, were patient demographics, physiological parameters, clinical nursing care, handover to ward nurse including duration, length of stay in PACU, length of hospital admission and patient outcomes, including any adverse events or complications. Complications and serious adverse events included clinical deterioration, prolonged stay in PACU, unplanned

return to theatre, unplanned admission to intensive care unit (ICU) or readmission to hospital and were defined as any deviation from the normal postoperative course.²² Clinical deterioration was determined through assessment of respiration (difficulty in breathing, respiration rate less than 8 or greater than 30 per min; oxygen saturation less than 90% despite oxygen therapy), circulation (heart rate less than 50 or more than 130 beats/min, systolic blood pressure less than 90mm Hg) or change in conscious state.¹⁵ Severity of each adverse event was graded using the Common Terminology Criteria for Adverse Events V.4.03,²³ and grouped into mild (an event which caused no or minimal effect to the patient and resolved spontaneously), moderate (an event which resolved after intervention, with no lasting effect for the patient) and severe (an event which required intervention and caused harm to the patient, including death).

The primary outcomes were the rate of complications, adverse events and mortality, the length of stay in PACU and length of hospital admission. Patient outcomes were determined from the medical record following hospital discharge. An economic evaluation was also undertaken, from organisational data that were routinely submitted to the regional health department for benchmarking.

Statistical analyses were undertaken to describe the two groups and identify differences between phases 1 and 2, before and after implementation of the PACT. In order to account for hospitals' heterogeneity the CMH test was used to compare the proportion of adverse events and mortality between the two groups, adjusting for hospital strata as an effect modifier factor. ORs for risk of an adverse event were adjusted for age, gender, American Society of Anesthesiologist (ASA) score, type of surgery and admission type (inpatient or day/short stay) using logistic regression. Length of time in PACU, and length of hospital admission were considered as time-to-event data. Survival rates were calculated and illustrated by the Kaplan-Meier method and further analysed by the log-rank test (stratified by hospitals).

Economic evaluation

In Australia, healthcare costs for each patient admitted to hospital are calculated on a cost-weight analysis using the Australian Refined—Diagnostic-Related Groups (AR-DRGs). The AR-DRG is 'an Australian admitted patient classification system which provides a clinically meaningful way of relating the number and type of patients treated in a hospital to the resources required by the hospital'.²⁴ In this study, the AR-DRG was used to calculate the costs for all initial admissions and unplanned readmissions, using the national efficient price determination.²⁵ A weighted average cost of an unplanned admission to an ICU of \$A190/hour was taken from the National Pricing Model Technical specifications 2014–2015.²⁶ The cost of emergency department visits was assumed to be that of a non-admitted return visit, Triage 4, 5 (\$A201 per encounter) as reported by the Independent Hospital Pricing Authority.²⁶ To be included in the

cost analysis, each patient needed to have all episodes of care recorded, including the code for diagnosis-related group (DRG) and length of stay for the initial admission. A review of the data provided by the health network administration found that details of the procedure, diagnosis and consequent DRG coding were not available for all enrolled patients. Those patients with missing data were excluded from the cost analysis.

RESULTS

In total, 1417 patients were included in this study, 723 in phase 1 and 694 in phase 2. Almost half the patients were day surgery cases (48%, n=679) with the remainder being overnight (26%, n=369), or multiday admissions (26%, n=369). Surgical specialties in this study were: general (open and laparoscopic abdominal surgery), obstetric and gynaecological, orthopaedic, urology, plastics, ear, nose and throat, vascular and thoracic. There were no differences in the average age, gender distribution or patients' physical status prior to surgery for both groups (table 1). However, there were more obstetric and gynaecological and fewer general surgery procedures in phase 2 (table 1).

Nursing management of patient symptoms

Following the implementation of the PACT, it was found that nursing responses to patients with clinical deterioration were higher. There were more requests for medical review by PACU nurses (19% vs 30%, $P<0.001$) and more patients with MET activation criteria modified by an anaesthetist while in PACU (6.5% vs 13.8%, $P<0.001$) using the PACT. There were higher rates of analgesia administration (37.3% vs 54.2%, $P=0.001$) for patients in pain, and there was also a significant increase in nursing assessment and documentation that ongoing pain relief had been ordered prior to discharge from PACU (55.3% vs 84.8%, $P<0.001$).

For the 16.1% (n=228) of patients experiencing nausea and vomiting in PACU, there were more assessments and documentation relating to this after introduction of the PACT (60.0% vs 92.4%, $P<0.001$). In addition, this led to an increase in antiemetics being administered to a significantly higher proportion of patients with nausea and vomiting in phase 2, compared with phase 1 (49.2% vs 84.8%, $P=0.002$).

Patient outcomes

Patient outcomes included rates of adverse events and mortality, the length of stay in PACU, length of hospital admission and discharge destination.

Adverse events

In total, 25.2% (357/1417) of patients experienced 379 adverse events following surgery; one-third occurred in PACU (33.9%, 121/357). The most common adverse events in PACU in both phases were clinical deterioration, other cardiovascular and respiratory events which

Table 1 Patient characteristics before (phase 1) and after (phase 2) implementation of the Post Anaesthetic Care Tool

Patient characteristic	Phase 1, N=723, n (%)	Phase 2, N=694, n (%)	P value
Age years: mean (SD)	52.14 (18.6)	50.87 (17.4)	0.186
Gender			
Male	301 (41.6)	269 (38.8)	0.257
Female	422 (58.4)	425 (61.2)	
ASA score			
1	211 (32.5)	190 (32.9)	0.134
2	305 (47.0)	278 (48.1)	
3	115 (17.7)	102 (17.6)	
4	18 (2.8)	6 (1.0)	
Not recorded	74 (10.2)	118 (16.7)	
Charlson Comorbidity score			
Low (<2)	587 (81.1)	582 (83.9)	0.407
Moderate (2–4)	114 (15.7)	95 (13.7)	
High (>4)	22 (3.0)	17 (2.4)	
Admitting hospital			
Hospital A	244 (33.7)	244 (35.2)	0.648
Hospital B	294 (40.7)	287 (41.4)	
Hospital C	185 (25.6)	163 (23.5)	
Day of surgery			
Monday	165 (22.8)	104 (15.0)	0.001*
Tuesday	167 (23.1)	199 (28.7)	
Wednesday	127 (17.6)	118 (17.0)	
Thursday	144 (19.9)	129 (18.6)	
Friday	120 (16.6)	144 (20.7)	
Surgical category			
General	278 (38.5)	243 (35.0)	0.007*
Obstetric and gynaecological	139 (19.2)	177 (25.5)	
Orthopaedic	143 (19.8)	101 (14.6)	
Urology	67 (9.3)	76 (11.0)	
Plastics	60 (8.3)	50 (7.2)	
Ear, nose and throat	24 (3.3)	21 (3.0)	
Vascular	12 (1.7)	22 (3.2)	
Thoracic	0 (0)	4 (0.6)	
Admission type			
Inpatient	407 (56.3)	333 (48.3)	0.003*
Day/short stay	316 (43.7)	357 (51.7)	

*P<0.05.

ASA, American Society of Anesthesiologists.

required intervention and unresolved severe pain (pain score of at least 8 out of 10 after analgesia; [figure 1](#)).

The number of adverse events recognised and recorded significantly increased from 21.2% (153/723) in phase 1 to 29.4% (204/694) in phase 2 (P<0.001). As shown in [table 2](#), there was greater recognition of

adverse events in PACU following the implementation of the PACT, as more adverse events were recorded in PACU during phase 2 (OR 2.08, 95% CI 1.49 to 2.91, P<0.001). In particular, there was a significant increase in the detection of cardiovascular events (OR 2.51, 95% CI 1.55 to 4.06, P<0.001) and respiratory events

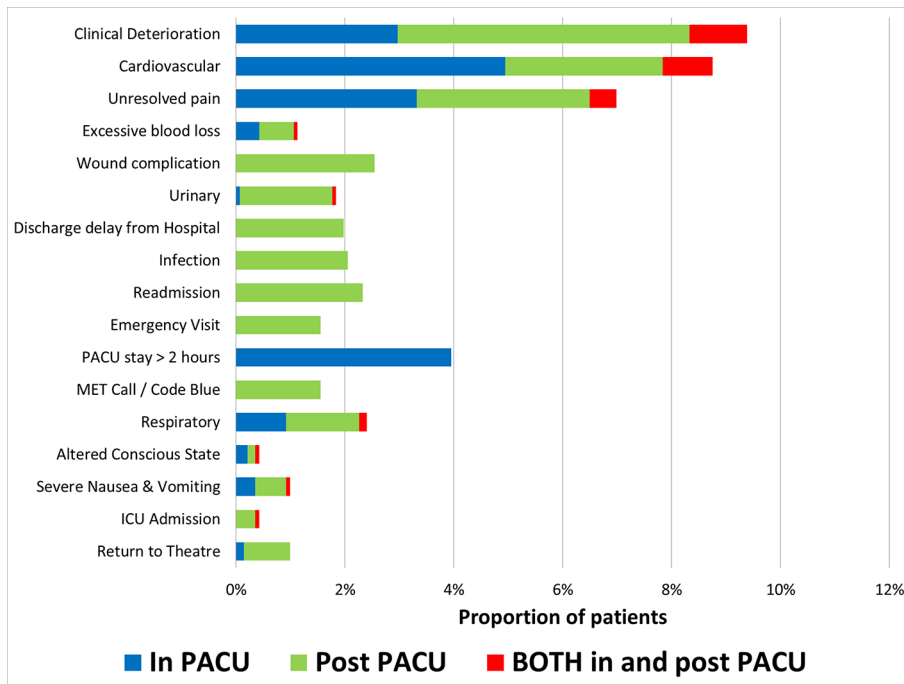


Figure 1 Frequency of patients experiencing adverse events in Post Anaesthesia Care Unit (PACU) (blue), after discharge from PACU (green) and starting in PACU and continuing after discharge from PACU (red) for both phases combined. ICU, intensive care unit; MET, medical emergency team.

(OR 4.29, 95% CI 1.19 to 15.40, $P=0.032$) and an increase in episodes of unresolved pain recorded in PACU (OR 2.57, 95% CI 1.42 to 4.66, $P=0.002$). There was no significant difference in the rate of clinical deterioration (OR 0.86, 95% CI 0.50 to 1.47, $P=0.579$).

While the rates of all events occurring in PACU increased in phase 2, the rates of these same events following PACU discharge decreased or remained the same after the implementation of the PACT (figure 2). There was a significant decrease in the rates of clinical deterioration (OR 0.47, 95% CI 0.30 to 0.74, $P=0.001$) and cardiovascular events (OR 0.49, 95% CI 0.28 to 0.88, $P=0.021$) on the ward in phase 2 (table 2).

The severity of the 379 adverse events in both phases was graded as mild for 31.3% (119/379), moderate for 64.4% (244/379) and severe for 4.2% (16/379). There was a significant increase in the proportion of patients with moderately severe adverse events in phase 2 (OR_{CMH}=1.67, 95% CI 1.26 to 2.21, $P<0.001$), but there was no difference in the rate of mild or severe adverse events (table 2). This increase in moderate adverse events was greater in PACU (OR_{CMH}=1.75, 95% CI 1.19 to 2.58, $P=0.001$) than for events which occurred after discharge from PACU (OR_{CMH}=1.30, 95% CI 0.93 to 1.82, $P=0.125$).

As reported in table 1, there were fewer general and orthopaedic surgical procedures in phase 2 compared with phase 1 (reduced by 3.5% and 5.2%, respectively) while there was more obstetric and gynaecological surgery (increased by 6.3%). These differences were significant. Therefore, in comparing the adverse event rates in each phase, logistic regression was conducted to adjust for type of surgery, ASA status, admission type, gender and age

(online supplementary table S1). Adjustment was made only for all adverse events in PACU, as this was the adverse event rate that was significant overall. No adjustment for subanalysis was conducted due to small sample size. As illustrated in online supplementary table S1, adjusted OR showed negligible change from the unadjusted OR.

The median length of stay for all patients in PACU was 49.0 min (95% CI 47.7 to 50.3), with a range from 6 min to 9.2 hours. Approximately 1 in 20 (4.4%, $n=63/1417$) patients remained in PACU longer than 2 hours. The most common reasons for discharge delay were patient transfer delay due to unavailability of ward nurses for PACU patient handover (6.6%) and complex recovery (5.9%). Compared with phase 1, more patients experienced a delay in discharge from PACU in phase 2 (15.5% vs 25.4%, $P<0.001$). This was primarily due to complex patient recovery (3.5% vs 8.5%, $P<0.001$), with more patients fulfilling MET activation criteria while in PACU during phase 2 (6.5% vs 13.8%, $P<0.001$).

Using Kaplan-Meier survival analysis, where discharge from PACU was the event, there was a small but significant increase in median length of stay in PACU from 45 min (95% CI 43.3 to 46.7) in phase 1 to 53 min (95% CI 51.3 to 54.7, $P<0.001$) in phase 2 (figure 3A). In contrast, for patients who experienced an adverse event in PACU, the median length of stay in PACU decreased significantly from 100 min (95% CI 83.8 to 116.2) in phase 1 to 83 min (95% CI 68.9 to 97.1, $P=0.017$) in phase 2 (figure 3B).

These differences in PACU length of stay are shown in table 3, where the results of a Cox regression are presented. Patients in phase 1 had significantly shorter median length of stay compared with those in phase 2,

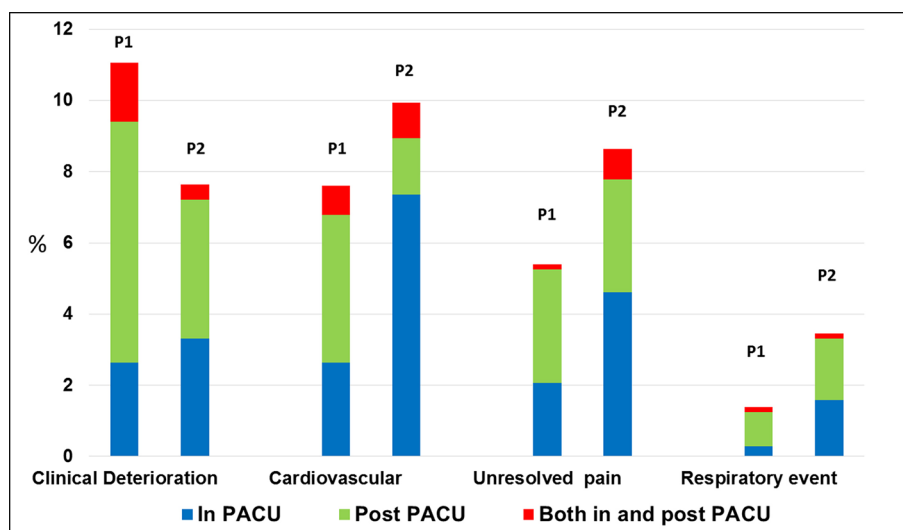
Table 2 Mantel-Haenszel common Odds Ratio estimates comparing frequency of adverse events before (phase 1) and after (phase 2) implementation of the PACT

	Phase 1, N=723, n (%)	Phase 2, N=694, n (%)	OR	95% CI	P value†*
Severity of adverse events					
Severe	10 (1.4)	6 (0.9)	0.63	0.23 to 1.74	0.368
Moderate	99 (13.7)	145 (20.9)	1.67	1.26 to 2.21	<0.001
Mild	55 (7.6)	64 (9.2)	1.23	0.84 to 1.79	0.330
Adverse events in PACU					
All events	60 (8.3)	116 (16.7)	2.22	1.58 to 3.07	<0.001*
Moderately severe events	45 (6.2)	77 (11.1)	1.88	1.28 to 2.77	0.005*
Clinical deterioration	31 (4.3)	26 (3.7)	0.86	0.50 to 1.47	0.579
Cardiovascular	25 (3.5)	58 (8.4)	2.51	1.55 to 4.06	<0.001*
Respiratory	3 (0.4)	12 (1.7)	4.29	1.19 to 15.40	0.032*
Unresolved pain	16 (3.2)	38 (5.5)	2.57	1.42 to 4.66	0.002*
Adverse event after PACU					
All events	119 (16.5)	117 (16.9)	1.03	0.78 to 1.36	0.680
Moderately severe events	69 (9.5)	84 (12.1)	1.30	0.93 to 1.82	0.125
Clinical deterioration	63 (8.7)	30 (4.3)	0.47	0.30 to 0.74	0.001*
Cardiovascular	37 (5.1)	18 (2.6)	0.49	0.28 to 0.88	0.021*
Respiratory	8 (1.1)	13 (1.9)	1.68	0.69 to 4.07	0.348
Unresolved pain	24 (3.3)	28 (4.0)	1.23	0.71 to 2.15	0.554
Day procedure patients	33 (8.1)	36 (10.8)	1.31	0.80 to 2.13	0.285
In patients	86 (27.2)	81 (22.6)	0.82	0.57 to 1.16	0.264
Total adverse events	153 (21.2)	204 (29.4)	1.55	1.21 to 1.97	<0.001*

*P<0.05.

†Mantel-Haenszel test for conditional independence.

PACT, Post-Anaesthetic Care Tool; PACU, Post Anaesthesia Care Unit.

**Figure 2** Frequency of patients experiencing adverse events before (P1) and after (P2) the implementation of Post-Anaesthetic Care Tool (PACT); events in Post Anaesthesia Care Unit (PACU) (blue), events after PACU discharge (green) and events starting in PACU and continuing after discharge (red).

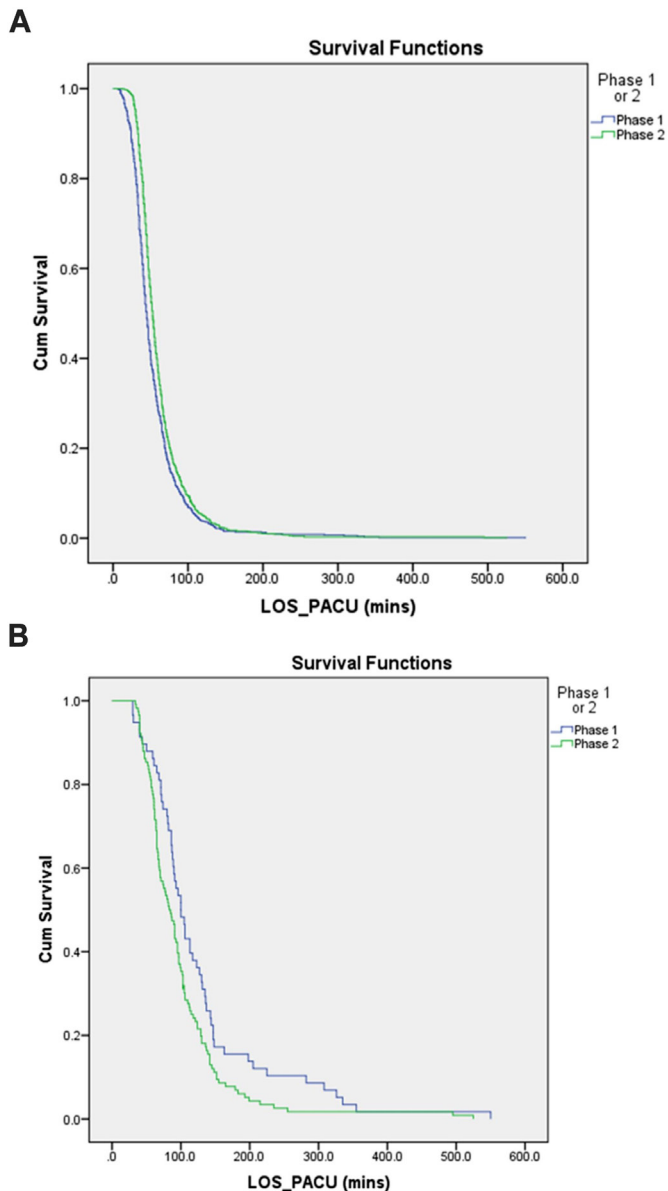


Figure 3 (A) Kaplan-Meier survival curves for length of stay in Post Anaesthesia Care Unit (PACU) for all patients before (phase 1, blue line) and after (phase 2, green line) implementation of the Post-Anaesthetic Care Tool (PACT). (B) Kaplan-Meier survival analysis of length of stay in PACU for patients who experienced an adverse event in PACU, before (phase 1, blue line) and after (phase 2, green line) implementation of the PACT.

with a HR of 1.25 translating to the rate of discharge before PACT being 25% higher than after implementation of the PACT. Having an adverse event in PACU was associated with longer median PACU length of stay of 91.0min (95% CI 84.2 to 97.8), regardless of phase. Following the implementation of the PACT, the median length of stay decreased significantly for patients who experienced an adverse event in PACU. The HR of 0.68 translates to the rate of discharge after the implementation of the PACT being 47% improved compared with before PACT (table 3).

There was no difference in discharge destination from PACU for patients in phase 1 or 2. Patients were discharged from PACU to the day procedure unit (46%, n=650/1415), the short stay unit (11%, n=158/1415) or a ward (42%, n=600/1415). A small number of patients (0.5%, n=7) had an unplanned transfer from PACU to the intensive care unit. Four patients died during the hospital admission in phase 1 while no patient died during the hospital admission in phase 2 (P=0.022).

Health service usage and healthcare costs

There was a small but significant increase in the median length of hospital admission from 0.5 days (IQR=1.7) in phase 1 to 1.0 days (IQR=1.7) in phase 2 (P=0.029). This was reflected in an increase in the proportion of patients remaining in hospital overnight from phase 1 to phase 2 (22.1% vs 30.1%, P=0.002). After the implementation of the PACT, small, non-significant changes in health service use were noted with fewer unplanned hospital readmissions in the month following discharge (3.7% vs 3.0%, P=0.732), and more emergency department visits (1.8% vs 2.5%, P=0.320).

Aggregated costs were averaged across patients with complete data for phase 1 (n=707) and phase 2 (n=669) patients, respectively (table 4). The results can therefore be interpreted as the expected average impact on costs per patient of receiving care with the PACT compared with those receiving care before implementation of PACT. The average patient acuity, determined using independent hospital pricing authority (IPHA) cost weights for 2014–2015²⁵ was found to be 1.51 in phase 1 and 1.66 in phase 2. The difference was not statistically significant, suggesting that any differences in costs and length of stay between phases 1 and 2 were not attributable to differences in the average severity of the condition of patients at the time of discharge.

The average cost difference for the initial surgical admission increased from \$A5645 (n=707) in phase 1 to \$A6433 (n=669) in phase 2, an increase of \$A788 per patient (P=0.123). Cost-weight analysis using AR-DRGs for initial admissions, unplanned readmissions, intensive care admissions and visits to the emergency department were included (table 4). While the average cost for the original admissions increased, there was a decrease in the number of unplanned readmissions with a consequent decrease in the average cost per patient. The number of unplanned emergency department visits after discharge increased, but the average cost increase per patient was negligible. The researchers noted one outlier with regard to healthcare costs, in that one patient in phase 1 was readmitted for 76 days, including 295 hours in intensive care, with a total cost of \$A239 766. This was more than twice the cost of the next most costly readmission for either phase 1 or 2 of the study. The cumulative total costs per patient were therefore examined using median values. Overall, there was a cumulative total cost increase of \$A453 per patient following the intervention, which was not statistically significant (P=0.425).

Table 3 Median length of stay in PACU before (phase 1) and after (phase 2) implementation of the PACT, for all patients and for those who experienced an adverse event in PACU

	Median length of stay (min)	95% CI of median	P value	Hazard Ratio	95% CI of HR
All patients (n=1415)	49.0	47.7 to 50.3			
Phase 1*	45.0	43.3 to 46.7	P<0.001	1.25	1.13 to 1.39
Phase 2	53.0	51.3 to 54.7			
Patients with AE in PACU (n=174)	91.0	84.2 to 97.8			
Phase 1*	100.0	83.8 to 116.2	0.017	0.68	0.49 to 0.93
Phase 2	83.0	68.9 to 97.1			

Hazard Ratio given by Cox regression.

*Reference group.

AE, adverse event; PACT, Post-Anaesthetic Care Tool; PACU, Post Anaesthesia Care nit.

DISCUSSION

This study aimed to evaluate whether use of the PACT would (1) enhance the recognition and response to patients at risk of deterioration, (2) result in improved patient outcomes and (3) reduce healthcare costs. It is clear that the number of patients recognised to have an adverse event significantly increased after the introduction of the PACT (P<0.001), including cardiovascular and respiratory events and unresolved pain. Implementation of the PACT provided nurses with clear and comprehensive criteria to assess patient readiness for discharge from

PACU. Assessment tools which use a scoring system, such as the Aldrete, modified Aldrete and post-anaesthetic discharge scoring system (PADSS),^{27 28} are commonly used internationally. In contrast, the PACT is consistent with the 'track and trigger systems' specified in the national standards of the Australian Commission on Safety and Quality in Health Care (ACSQHC).²⁹ Track and trigger systems enable nurses to recognise and respond to patient deterioration by specifying thresholds in the observation chart using graphical colour shading when the patient's vital signs fall outside the 'normal'

Table 4 Economic evaluation comparing before (phase 1) with after (phase 2) implementation of the PACT.

	Phase 1, N=707		Phase 2, N=669		Observed difference of median	P value†*
	Mean (SD)	Median (95% CI)	Mean (SD)	Median (95% CI)		
Initial admission						
Length of stay (days)	1.9 (3.7)	0.5 (0.4 to 1.0)	1.9 (3.3)	1.1 (1.0 to 1.1)	0.6	<0.001*
State average length of stay	2.6 (2.8)	1.6 (1.6 to 1.7)	2.3 (2.4)	1.6 (1.5 to 1.6)	0.0	0.054
Cost difference per patient‡ (\$A)	-\$A1900 (7700)	-\$A2400 (2100 to 2600)	-\$A1400 (7600)	-\$A1900 (1800 to 2000)	\$A500	0.123
Unplanned ICU admissions						
n (%)	5 (0.7)		2 (0.3)			
ICU cost (\$A) per patient	\$A19	\$A6	\$A4	\$A4	-\$A2.0	0.130
Unplanned readmissions						
n (%)	26 (3.7)		20 (3.0)			
Cost per patient (\$A)	\$A809 (2648)	\$A199 (75 to 323)	\$A607 (1173)	\$A153 (89 to 414)	-\$A46	0.732
Emergency visits						
n (%)	13 (1.8)		17 (2.5)			
Cost per patient (\$A)	\$A4	\$A4	\$A5	\$A5	\$A1	0.320
Total cost impact per patient		-\$A2191		-\$A1738	+\$A453*	0.425

*P<0.05.

†Independent samples, Mann-Whitney U test comparing median values for phases 1 and 2.

‡Difference in costs comparing actual costs with average national cost for that diagnostic-related group. A weighted average cost of an unplanned admission to an intensive care unit of \$A190/hour and the cost of emergency department visits, was assumed to be that of a non-admitted return visit, Triage 4, 5 (\$A201 per encounter).²³

PACT, Post-Anaesthetic Care Tool.

parameters.^{19 30 31} According to ACSQHC, different track and trigger systems are used internationally, with varying parameters to identify level of abnormality. Importantly, track and trigger charts specify required responses when patient deterioration is recognised or when an observation threshold is crossed.²¹

The PACT included these thresholds in the observation section and specified that for safe patient discharge, the last two recordings of observations must not be outside the threshold. However, the tool allowed for modification of these escalation factors (MET activation criteria) if required for an individual patient by the anaesthetist.

Following the implementation of the PACT, there was an increase in nurses identifying patients with adverse events and seeking medical review. The comprehensiveness of the tool enabled nurses to identify patients whose observations fell outside the normal parameters and appropriately respond by consulting the anaesthetist prior to patient discharge from the PACU, if required. Postoperative deterioration has been shown to be a common event in PACU.¹² It is therefore not surprising that using the PACT led to the identification of and response to more adverse events in the PACU and lower rates of clinical deterioration, cardiovascular and/or respiratory events and unresolved pain in the ward setting. These findings are also consistent with a longitudinal study of 855 870 admissions by O'Connell and colleagues who found that immediately following the implementation of an observation and response chart with altered calling criteria, there was a sudden increase in the MET call rate of 82% which then gradually fell over the following 6 months, but still remained higher than prior to the introduction of the new chart.³²

There are a number of studies investigating adverse events in the acute care setting following surgery. However, to our knowledge, this is the first prospective study to explore the influence on nursing assessment and management of patients in the PACU following the introduction of a standardised, evidence-based PACU discharge tool designed to promote identification of, and response to postoperative complications. The rates of adverse events reported in the current Australian study are similar to those reported internationally. In a survey of over 2000 patients admitted to one Canadian PACU, rates of 3.5% for excessive pain, 6.0% for nausea and vomiting, 1% for a critical respiratory event and 3.5% for cardiac related events were reported.³³ Large record reviews of Medicare hospital admissions in the United States have identified postoperative complication rates of 13%–20%^{34 35} and unscheduled readmission rates of 12.8%. An Australian study of 1291 patients found 20% of patients required medical review for unexpected complications.¹³ Although lower postoperative complication rates have been cited,¹⁰ other studies often limit their analysis to serious adverse events or to specific surgical procedures. In the current study, rates of many adverse events increased significantly after the introduction of the PACT. This is a positive outcome, indicating that

the standardised discharge tool enabled nursing staff to better recognise and respond to deterioration before the patient condition became critical.

The second aim of the study was to evaluate whether use of the PACT would result in improved patient outcomes. Following the implementation of the PACT, length of stay in PACU and length of hospital admission decreased significantly for those patients who had an adverse event in PACU. This suggests that early detection and response to patients in PACU resulted in improved patient outcomes, specifically reduced time in PACU and hospital. Further, there were fewer unplanned ICU admissions and unplanned hospital readmissions in phase 2. There was a non-significant increase in emergency department visits within 48 hours of discharge from 13 (1.8%) in phase 1 to 17 (2.5%) in phase 2. These severe adverse events were quite rare, so no statistically significant difference could be detected. Mild adverse events were common, but by definition these events do not require any intervention and the patient recovers from these spontaneously.

The third aim of the study was to determine through an economic analysis whether there was a reduction in healthcare costs following the intervention. The findings of the economic analysis confirm that the implementation of the PACT was cost-effective; the improved patient outcomes were not associated with any significant change in costs to the health service and only minor non-significant differences between the costs for the initial admissions, ICU stays, emergency visits and unplanned readmissions were identified. There was a non-significant increase of the average costs per patient of \$A453.

Study limitations

Emergency patients, with unscheduled surgery were not included in this prospective study due to ethical and logistical considerations, primarily relating to consent and incomplete documentation for emergency admissions.

We acknowledge that missing data are a limitation of the study. We decided not to perform statistical data manipulation using multiple imputation to fill in missing values. This has been supported by comprehensive simulation study that suggests available statistical techniques for data manipulation are naive and do not take into account the complexity of missing data mechanism.³⁶ As a result, per protocol analyses have been presented.

There was a difference between phases 1 and 2 in the characteristics of the day of surgery and surgical category. These two variables are correlated in that surgical specialty teams are scheduled to operate on certain days of the week. This was an unfortunate but not highly significant confounder in the analysis. To examine the potential for various patient, surgery and admission characteristics to confound the comparison of adverse events rates, logistic regression was conducted and the ORs adjusted for significant confounders.

This was a quasi-experimental study which had the natural limitation of all before–after studies with no parallel control group. There may be factors external

to the implementation of the PACT that increased or decreased surgical risk over the duration of the study. Determining the impact of sensitisation of the nursing staff to the PACT tool would require a full-scale cluster randomised controlled trial (RCT). Similar study designs are common in this area,^{8 32 37 38} as running a cluster RCT is not always a pragmatic option. Sensitisation is highly correlated with improvement in the early intervention implementation period and as time passes its effect will be diluted.

Conclusions

Using a structured observation, response and discharge chart in PACU enhanced nurses' recognition and response to patients who experienced clinical deterioration. Furthermore, it resulted in reduced length of stay for patients who experienced an adverse event in PACU and was cost-effective. This study provides evidence of a relatively high overall risk to patient safety following surgery, with one in four elective surgical patients experiencing an adverse event. If a patient had an adverse event in PACU, this triggered greater response by nurses in the post-implementation phase, through the use of the PACT. There was a consequent decrease in the rates of clinical deterioration and cardiac events following discharge from PACU. These findings highlight the importance of close patient monitoring in the immediate postoperative period, in PACU and continuing on the ward.

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Contributors MS designed the study, acquired the data, monitored its collection, analysed the data, and drafted and revised the paper. NMP contributed to study design and interpretation of the data. She also assisted with drafting the manuscript. MM contributed to study design, advised with regard to data analysis and reviewed the draft manuscript. BK advised on each aspect of the study, participated in interpretation of the data and critically appraised the draft manuscript.

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REFERENCES

- Weiser TG, Regenbogen SE, Thompson KD, *et al.* An estimation of the global volume of surgery: a modelling strategy based on available data. *Lancet* 2008;372:139–44.
- Brennan TA, Leape LL, Laird NM, *et al.* Incidence of adverse events and negligence in hospitalized patients: results of the Harvard Medical Practice Study I. 1991. *Qual Saf Health Care* 2004;13:145–51.
- Gawande AA, Thomas EJ, Zinner MJ, *et al.* The incidence and nature of surgical adverse events in Colorado and Utah in 1992. *Surgery* 1999;126:66–75.
- Kable AK, Gibberd RW, Spigelman AD. Adverse events in surgical patients in Australia. *Int J Qual Health Care* 2002;14:269–76.
- Bosma E, Veen EJ, Roukema JA. Incidence, nature and impact of error in surgery. *Br J Surg* 2011;98:1654–9.
- Pearse RM, Moreno RP, Bauer P, *et al.* Mortality after surgery in Europe: a 7 day cohort study. *Lancet* 2012;380:1059–65.
- de Vries EN, Ramrattan MA, Smorenburg SM, *et al.* The incidence and nature of in-hospital adverse events: a systematic review. *Qual Saf Health Care* 2008;17:216–23.
- de Vries EN, Prins HA, Crolla RM, *et al.* Effect of a comprehensive surgical safety system on patient outcomes. *N Engl J Med* 2010;363:1928–37.
- Birkmeyer JD, Gust C, Dimick JB, *et al.* Hospital quality and the cost of inpatient surgery in the United States. *Ann Surg* 2012;255:1–5.
- Khan NA, Quan H, Bugar JM, *et al.* Association of postoperative complications with hospital costs and length of stay in a tertiary care center. *J Gen Intern Med* 2006;21:177–80.
- Prowse MA, Lyne PA. Clinical effectiveness in the post-anaesthesia care unit: how nursing knowledge contributes to achieving intended patient outcomes. *J Adv Nurs* 2000;31:1115–24.
- Petersen Tym MK, Ludbrook GL, Flabouris A, *et al.* Developing models to predict early postoperative patient deterioration and adverse events. *ANZ J Surg* 2017;87:457–61.
- Seglenieks R, Painter TW, Ludbrook GL. Predicting patients at risk of early postoperative adverse events. *Anaesth Intensive Care* 2014;42:649.
- Bellomo R, Goldsmith D, Uchino S, *et al.* Prospective controlled trial of effect of medical emergency team on postoperative morbidity and mortality rates. *Crit Care Med* 2004;32:916–21.
- Street M, Phillips NM, Kent B, *et al.* Minimising post-operative risk using a Post-Anaesthetic Care Tool (PACT): protocol for a prospective observational study and cost-effectiveness analysis. *BMJ Open* 2015;5:e007200.
- Aldrete JA. Modifications to the postanesthesia score for use in ambulatory surgery. *J Perianesth Nurs* 1998;13:148–55.
- Phillips NM, Street M, Kent B, *et al.* Post-anaesthetic discharge scoring criteria: key findings from a systematic review. *Int J Evid Based Healthc* 2013;11:275–84.
- Phillips NM, Street M, Kent B, *et al.* Determining criteria to assess patient readiness for discharge from postanaesthetic care: an international Delphi study. *J Clin Nurs* 2014;23(23-24):3345–55.
- Australian Commission on Safety and Quality in Healthcare. Recognising and responding to clinical deterioration: Use of observation charts to identify clinical deterioration Secondary Recognising and responding to clinical deterioration: Use of observation charts to identify clinical deterioration, 2009. <http://www.safetyandquality.gov.au/wp-content/uploads/2012/02/UsingObservationCharts-20091.pdf> (accessed 30 June 2017).
- Chen J, Hillman K, Bellomo R, *et al.* The impact of introducing medical emergency team system on the documentations of vital signs. *Resuscitation* 2009;80:35–43.
- Australian Commission on Safety and Quality in Healthcare. A guide to support implementation of the national consensus statement: Essential elements for recognising and responding to clinical deterioration. Secondary a guide to support implementation of the national consensus statement: Essential elements for recognising and responding to clinical deterioration, 2011. <http://www.safetyandquality.gov.au/wp-content/uploads/2012/02/Nat-Consensus-Statement-PDF-Complete-Guide.pdf> (accessed 30 June 2017).
- Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. *Ann Surg* 2004;240:205–13.

23. U.S. Department of Health and Human Services NIOH, National Cancer Institute. Common Terminology Criteria for Adverse Events (CTCAE) Version 4.03. Secondary Common Terminology Criteria for Adverse Events (CTCAE) Version 4.03, 2010. http://evs.nci.nih.gov/ftp1/CTCAE/CTCAE_4.03_2010-06-14_QuickReference_5x7.pdf (accessed 30 June 2017).
24. Australian Institute of Health and Welfare. Australian refined diagnosis-related groups (AR-DRG) data cubes. Secondary Australian refined diagnosis-related groups (AR-DRG) data cubes, 2015. <http://www.aihw.gov.au/hospitals-data/ar-drg-data-cubes/>
25. The Independent Hospital Pricing Authority (IHPA). National efficient price determination 2014-15. Secondary National efficient price determination 2014-15, 2015. <https://www.ihpa.gov.au/publications/national-efficient-price-determination-2013-14>
26. Independent Hospital Pricing Authority (IHPA). National Efficient Price Determination 2014-15 Appendix F — Price Weights for Acute admitted patients – AR-DRG V7.0. Secondary National Efficient Price Determination 2014-15 Appendix F — Price Weights for Acute admitted patients – AR-DRG V7.0. 2014. <http://www.ihpa.gov.au/internet/ihpa/publishing.nsf/Content/nep-determination-2014-15-html-appendix-appendix-f> (accessed 30 June 2017).
27. Ead H. From Aldrete to PADSS: Reviewing discharge criteria after ambulatory surgery. *J Perianesth Nurs* 2006;21:259–67.
28. Phillips NM, Street M, Kent B, et al. Post-anaesthetic discharge scoring criteria: a comprehensive systematic review. *JBI Libr Syst Rev* 2010;8:1–13.
29. Australian Commission on Safety and Quality in Healthcare. Recognising and responding to clinical deterioration in acute health care. Secondary Recognising and responding to clinical deterioration in acute health care, 2012. <http://www.safetyandquality.gov.au/wp-content/uploads/2012/04/Quick-start-guide-to-Standard-9.pdf> (accessed 30 June 2017).
30. Mora JC, Schneider A, Robbins R, et al. Epidemiology of early rapid response team activation after emergency department admission. *Australas Emerg Nurs J* 2016;19:54–61.
31. Bucknall TK, Jones D, Bellomo R, et al. Responding to medical emergencies: system characteristics under examination (RESCUE). A prospective multi-site point prevalence study. *Resuscitation* 2013;84:179–83.
32. O'Connell A, Flabouris A, Kim SW, et al. A newly designed observation and response chart's effect upon adverse inpatient outcomes and rapid response team activity. *Intern Med J* 2016;46:909–16.
33. Cohen MM, O'Brien-Pallas LL, Copplestone C, et al. Nursing workload associated with adverse events in the postanesthesia care unit. *Anesthesiology* 1999;91:1882–82.
34. Dahlke AR, Merkow RP, Chung JW, et al. Comparison of postoperative complication risk prediction approaches based on factors known preoperatively to surgeons versus patients. *Surgery* 2014;156:39–45.
35. Lawson EH, Hall BL, Louie R, et al. Association between occurrence of a postoperative complication and readmission: implications for quality improvement and cost savings. *Ann Surg* 2013;258:10–18.
36. Horton NJ, Kleinman KP. Much ado about nothing: a comparison of missing data methods and software to fit incomplete data regression models. *Am Stat* 2007;61:79–90.
37. Brown I, Jellish WS, Kleinman B, et al. Use of postanesthesia discharge criteria to reduce discharge delays for inpatients in the postanesthesia care unit. *J Clin Anesth* 2008;20:175–9.
38. Dwyer S. Doctoral Dissertation. An audit of the time spent by patients in the post anesthetic care unit before and after the introduction of a discharge criteria scoring system at Tygerberg Academic Hospital. Stellenbosch: Stellenbosch University. 2014.