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"What health service initiatives undertaken within operating suite recovery rooms have been shown to improve patient outcomes after adult non-cardiac surgery: a systematic review."

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TITLE PAGE

"What health service initiatives undertaken within operating suite recovery rooms have been shown to improve patient outcomes after adult non-cardiac surgery: a systematic review."

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ABSTRACT

Context: Post-operative recovery rooms have existed since 1847, and the concept of Overnight Intensive Recovery has been successful since the 1990s. However, there is sparse literature investigating the interventions undertaken in recovery, and their impact on patients after recovery room discharge.

Objective: This review aimed to investigate any health service initiatives undertaken in post-operative recovery room up to 48 hours post-operatively; and their effect on patient outcomes; including mortality, morbidity, return to theatre, unplanned intensive care unit (ICU) admission and length of hospital stay.

Data sources: NCBI PubMed, EMBASE and CINAHL.

Study selection: Studies published from 1990 onwards, investigating health service initiatives undertaken in the post-operative recovery room, and their impact on patient outcomes. One author screened titles and abstracts, with two authors completing full text reviews to determine inclusion based on pre-determined criteria. A total of 3288 unique studies were identified, with 14 selected for full text reviews, and 8 included in the review.

Data extraction: End Note 8 (Clarivate Analytics, Boston, USA) was used to manage references and exclude duplicates. One author extracted data from each study using a data extraction form adapted from the Cochrane Data Extraction Template, with all data checked by a second author.

Data synthesis: Narrative synthesis of data was the primary outcome measure, with all data of individual studies also presented in the summary results table.

Conclusions: Managing selected post-operative patients in a Recovery Room, or PACU, instead of ICU, does not appear to be associated with worse patient outcomes, however due to the high risk of bias within studies, the strength of evidence is moderate at best. Four of eight studies also examined hospital length of stay, and two found the intervention was associated with decreased length of stay and two found no association.

Key words: Post-operative care, post-anaesthetic care, recovery room, post-anaesthetic care unit (PACU)

STRENGTHS AND LIMITATIONS OF THIS STUDY

- This is the first systematic review to provide a summary of health service interventions in recovery and their impact on patient outcomes. It is a current area of interest for many hospitals/health networks, due to the frequency and cost of post-operative complications.
- The PRISMA statement was strictly adhered to, with a broad search strategy in an attempt to capture all relevant publications.
- The variation in study designs and primary outcome measures meant that we were unable to combine data for aggregate analysis or meta-analysis.
- Narrative synthesis of key results may introduce bias; however, steps were taken to minimise this, including the review of all data by a second author.

INTRODUCTION

Rationale

The concept of a post-operative recovery room, or post anaesthesia care unit (PACU), was first described in 1847[1], and the progression of surgical and anaesthetic techniques has seen marked advances in their form and function. However, there is a striking paucity of literature investigating the interventions undertaken in recovery, and their impact on patients after recovery room discharge. An editorial by C. Aps in 2004, discussed the concept of Overnight Intensive Recovery; where patients can be managed in the PACU for up to 24 hours[1], to avoid unnecessary intensive care unit (ICU) admissions and decrease cancellations due to lack of bed availability. This concept was introduced in the 1990s at St Thomas' Hospital, London[1]; and despite its apparent success, has not spawned further research surrounding such a model of care. Swart et al retrospectively examined the impact of the loss of access to a high dependency unit (HDU) for post-operative management of medium risk patients, and showed a significant increase in emergency laparotomies and unplanned critical care admissions[2]. However, the use of HDU for post-operative patients has also been associated with an increase in post-operative respiratory complications[3]. The concept of extended 6-hour recovery followed by a monitored ward bed, instead of an elective ICU admission post-operatively, has also shown to be safe, with no worsening in patient outcomes[4]. This is the first systematic review to provide a summary of all health service interventions provided in recovery, and their impact on patient outcomes after recovery room discharge. In presenting

these finding, we hope to highlight the need for further research to help improve the care of patients in the post-operative period.

Objectives

The objective of this systematic review was to investigate any health service initiatives undertaken in operating suite recovery rooms, in the post-operative period, that have been shown to improve outcomes after PACU discharge, for adult, non-cardiac surgical patients. Important outcomes included mortality, morbidity, return to theatre, unplanned ICU admission and length of hospital stay. Prospective and retrospective randomised control trials, cohort studies, case control studies and comparison studies were included for analysis.

METHODS

Protocol and registration

A review protocol was developed in line with the Preferred Reporting of Observational Studies and Meta-Analysis (PRISMA) statement by the author team prior to commencing the systematic review. This protocol is registered on the International Prospective Register of Systematic Reviews (PROSPERO) database, registration number CRD42018106093.

Eligibility criteria

Included studies investigated health service initiatives in the PACU, in the post-operative period, up to 48 hours post-operatively. Adult patient groups were the primary focus, however, studies that included a small cohort of children were not automatically excluded. Studies that explored the relationship between interventions in recovery and mortality, morbidity, hospital length of stay, unplanned ICU admission and return to theatre were included. Varying study designs were eligible for inclusion; such as randomised control trials, cohort studies, case control studies and before and after studies. Cross-sectional studies and case reports were excluded. Only studies published from 1990 onwards were included, to focus on up to date clinical practice, and minimise the inclusion of irrelevant data. Studies published in a language other than English, grey literature and studies focussing solely on ambulatory surgery were excluded.

Information sources and search strategy

Medical Subject Headings (MeSH) terms were generated from the NCBI PubMed advanced search area with the assistance of the University of Adelaide Health Sciences librarian. Logic grids were used as a tool,

to replicate the search throughout the three databases. The full electronic search strategy for the PubMed database is presented in Appendix 1. This search strategy was utilized from 23/3/18 to 8/4/18 to yield the articles screened for inclusion in the review.

Study selection

Search results from each data base were recorded, and imported into EndNote 8 (Clarivate Analytics, Boston, USA). Key word searching was also performed to identify new studies that had not yet been assigned indexing terms for the databases. Reference lists from key articles were also reviewed to identify further papers that may have been relevant to the review. Titles and abstracts were screened by one reviewer (CL), who was not blinded to journal titles or to the study authors or institutions. Articles selected for full text review were reviewed by two reviewers (CL and GL), and any discrepancies arising regarding the relevance of a study were resolved by consulting a third party. The list of references for inclusion was sent to all authors to ensure consensus.

Data collection process

The Cochrane Data Extraction Template for Included Studies from their consumers and communication page, was used as a base for our data extraction form. This form was piloted on two initial studies for usability, with no further modifications required. One reviewer extracted the initial data from each study (CL), and this data was confirmed by a second reviewer (GL) before inclusion in the review. One study only included data in pictorial form, and an attempt was made to contact the authors to obtain the raw data. Unfortunately, this was unsuccessful.

Data items

Data items extracted from each study included patient population and characteristics, intervention aims and methods, comparison groups and outcome measures. These data items are presented in the Characteristics of Included Studies Tables.

Risk of bias in individual studies

Risk of bias in individual studies was assessed by two reviewers (CL and GL) using Gate-Lite and Robins-I (previously known as A Cochrane Risk of Bias Assessment Tool: for Non-Randomized Studies of Interventions (ACROBAT-NRSI)). Narrative synthesis of data placed more weight on higher quality studies,

however, all studies and their results are presented, with caveats to highlight the individual biases that will affect interpretations of results.

Summary measures and planned methods of analysis

Narrative synthesis of data was the principle summary measure. This was due to the differing study designs and variable outcome measures in each study. Meta-analysis was not appropriate for the data in this systematic review. All data is presented individually, in relation to each study, with further narrative synthesis to summarise results. Results from studies were unable to be combined due to the variation in primary and secondary outcome measures, and differences in study design. No additional analysis or subgroup analysis was performed during this systematic review.

Risk of bias across studies

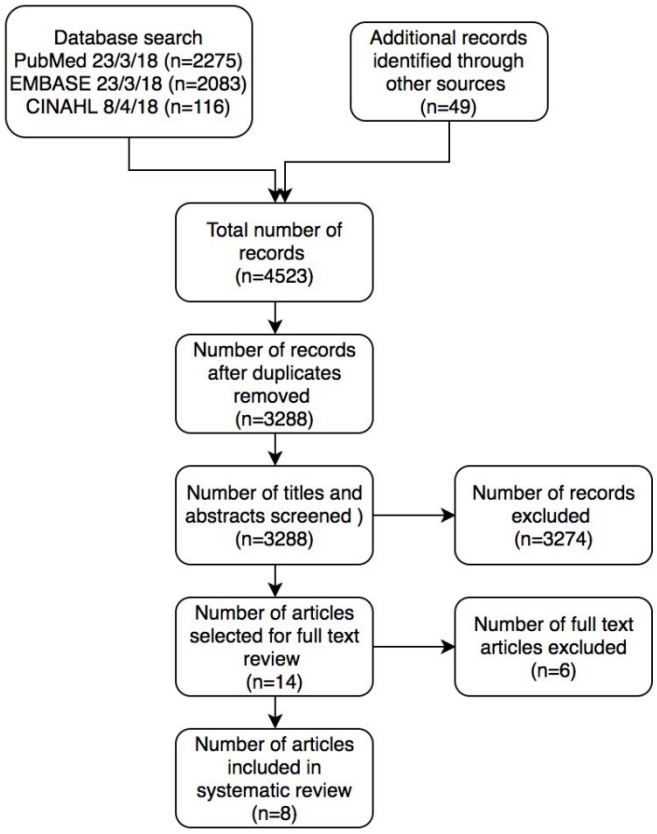
Risk of bias across studies was assessed by two reviewers (CL and GL), using the Cochrane Risk of Bias Tool, and discussing any evident publication bias or selective reporting.

RESULTS

Study selection

Database results, and numbers of studies screened are presented in the flow diagram (Figure 1). All references were imported into EndNote 8 (Clarivate Analytics, Boston, USA) for title and abstract screening. One reviewer (CL) screened all titles and abstracts, with ambiguous studies included for full text review. 14 studies were selected for full text review. Full text reviews were completed by two reviewers (CL and GL), and 8 studies were selected for inclusion in the review. A summary of included and excluded studies was sent to the third and fourth authors for consensus.

Figure 1. *Search Results*



Study characteristics

Of the eight studies included, four of the included studies were retrospective cohort studies[5-8], two were observational cohort studies[9, 10], one was a prospective non-randomised pre-post intervention study[11], and one was a prospective randomised cohort study[12]. Study characteristics for each of the included studies are outlined in the Characteristics of Included Studies Summary Table (Table 1). Four studies investigated the use of PACU as a non-ICU pathway for post-operative patients[5, 7, 9, 10]. Two investigated the implementation of physiotherapy in PACU, and the impact on patient outcomes[8, 12]. One evaluated the use of a new nursing scoring tool, and its impact on recognition of patient deterioration in PACU[11], and one evaluated the implementation of a two-track clinical pathway in PACU, and the effect on patient outcomes[6]. All studies focussed primarily on adults, but one included small cohort of children[7]. Common outcome measures included in-hospital mortality, PACU length of stay and hospital length of stay. Further details regarding patient population characteristics, study methodology and outcome measures are also outlined in the supplementary tables published online.

Table 1. *Characteristics of Included Studies Summary Table*

Source	*Aim*	*Study Design*	*Number of arms/groups*	*Population*	*Intervention*	*Comparison group*	*Outcome measures*
Callaghan, Lynch et al. 2005	To determine the safety of introducing non-ICU pathways for selected patients. And evaluate the effect on cost, ICU beds availability and cancellation rates of elective surgery.	Retrospective cohort study.	Intervention group: patients selected for overnight intensive recovery. Comparison group: patients booked for an elective ICU admission.	All patients undergoing elective open aortic surgery between 1/01/98 and 31/12/02.	Introduction of OIR (Overnight Intensive Recovery)	Elective post-operative ICU bed	In hospital mortality In hospital morbidity Post-operative length of stay ICU length of stay
Eichenberger, Haller et al. 2011	To assess the impact of a clinical pathway implemented in a post-anaesthesia care unit on post-operative outcomes.	Retrospective cohort study based on electronic patient records.	Fast track: nurse driven, ASA 1-2. Slow track: physician driven, ASA 3-5 who have undergone minor or major surgery, or developed post-op complications. Comparison group: Pre-existing PACU conditions without the clinical pathway.	All elective and non-elective inpatients, who underwent a surgical or endoscopic procedure under anaesthesia during the study period.	Introduction of a two-track clinical pathway that clearly defined & coordinated medical and nursing interventions.	Pre-existing PACU conditions without the clinical pathway.	PACU length of stay In-hospital mortality Unplanned ICU admissions after PACU stay.
Fraser and Nair 2016	To assess if elective surgical patients were stable enough to return to the general ward after a stay in Extended Recovery instead of being routinely admitted to ICU	Observational cohort study.	One arm. No control group	Elective surgical patients who would have previously been booked for level 2 care post-operatively.	Opening of an extended recovery unit.	Nil	Discharge destination after extended recovery unit admission
Kastrup, Seeling et al. 2012	To evaluate the effect of around-the-clock intensivist PACU coverage on the structure of ICU, and to demonstrate the economic effect on the hospital.	Retrospective cohort study.	Intervention group: after the introduction of 24-hour intensivist coverage. Comparison group: prior to introduction of 24-hour	All patients undergoing a surgical procedure (adults and children) between 1/01/08 – 30/04/11.	Introduction of 24-hour intensivist coverage in PACU	Pre-existing PACU with no intensivist coverage	PACU LOS ICU LOS Pre-operative days Hospital LOS Case mix index Cost

			intensivist coverage.				
Schweizer, Khatchatourian et al. 2002	To assess the impact of a new PACU on ICU utilisation, hospital length of stay and complications following major non-cardiac surgery.	Observational cohort study.	Intervention group: after opening of a new PACU. Control group: before opening of the new PACU	Adult patients undergoing abdominal aortic reconstruction or resection of lung cancer during the study periods.	Opening of a new PACU (post-anaesthesia care unit)	Pre-existing PACU	Mortality Reoperation Secondary admission to ICU Post-operative complications Hospital LOS
Street, Phillips et al. 2017	To evaluate whether use of a discharge criteria tool for nursing assessment of patients in PACU would enhance nurses' recognition and response to patients at-risk of deterioration and improve patient outcomes.	Prospective non-randomised pre-post intervention study.	Intervention group: after the implementation of the Post-Anaesthetic Care Tool (PACT) Comparison group: prior to the implementation of PACT.	All adult patients undergoing elective surgery on days of data collection.	Implementation of a Post Anaesthesia Care Tool (PACT)	Standard PACU care without PACT	Nursing management of symptoms Rates of adverse events Mortality PACU LOS Hospital LOS Health service usage and healthcare costs
Tayrose, Newman et al. 2013	To address the impact of rapid rehabilitation beginning in the recovery room on length-of-stay after primary hip and knee arthroplasty.	Retrospective cohort study.	Intervention group: rapid rehabilitation group. Comparison group: standard rehabilitation protocol	900 consecutive hip and knee arthroplasty patients	Rapid rehabilitation pilot program where the first two cases of the day were mobilised in the recovery room.	Remainder of cases received standard rehabilitation protocol starting on the morning of post-operative day one.	Overall hospital LOS Hip arthroplasty subgroup LOS Knee arthroplasty subgroup LOS
Zoremba, Dette et al. 2009	To evaluate the impact of short-term respiratory physiotherapy during the PACU stay, on postoperative lung function tests and pulse oximetry values in obese adults after minor surgery.	Prospective randomised cohort study	Intervention group: physical therapy treatment group that performed incentive spirometry in the PACU Control group: patients who did not undergo physical therapy	60 obese adult patients (BMI 30-40) ASA 2-3, scheduled for minor peripheral surgery.	Patients performed incentive spirometry in the PACU.	Not instructed to do any breathing exercises or spirometry.	Pulse oximetry and spirometry at 1, 2, 6 and 24 hours post-operatively

Risk of bias within studies

The overall risk of bias within studies was serious. Critical risk of bias was identified in two studies[8, 9], serious risk of bias in three studies[5, 10, 11], moderate risk of bias in one study[7] and low risk of bias in two studies[5, 6]. Significant patient selection and allocation bias was the most common identified cause[5, 7, 8, 10, 11]; as patients in these studies were not randomly allocated to their post-operative level of care. The most clinically unwell patients were sent to ICU automatically, and only the lower risk patients, as deemed by the treating teams, were allowed a trial of care in the PACU. The risk of bias summary table provides further analysis, and comment regarding the risk of bias within individual studies.

Table 2. *Risk of Bias Summary Table*

Source	***Bias Due to Confounding***	***Bias in Selection & Allocation of Participants***	***Bias in Measurement of Interventions***	***Bias Due to Departures from Intended Interventions***	***Bias Due to Missing Data***	***Bias in Measurement of Outcomes***	***Bias in Selection of Reported Results***	***Overall Risk of Bias Judgement***	***Comments***
Callaghan, Lynch et al. 2005	Low	Serious	Low	Moderate	Low	Moderate	Low	Serious	Significant selection bias of lower risk patients who were sent to OIR. Used predictive values for mortality (based on POSSUM variables) as a comparison measure.
Eichenberger, Haller et al. 2011	Low	Low	Low	Low	Low	Low	Low	Low	High quality study. No specific concerns from review authors.
Fraser and Nair 2016	Low	Moderate	Moderate	Moderate	Critical	Serious	Moderate	Critical	Over 25% of data missing. No clear objective stated, no explanation of methodology. Poorly defined selection criteria.

Kastrup, Seeling et al. 2012	Low	Serious	Low	Moderate	Low	Low	Low	Moderate	Significant selection bias of patients allocated to PACU, intermediate care unit or ICU by intensive care physician. This study also included a population of children (numbers not given).
Schweizer, Khatchatourian et al. 2002	Critical	Serious	Low	Low	Low	Low	Low	Serious	Introduction of preoperative risk assessment guidelines (AHA/ACC) with increased antiadrenergic administration pre-operatively confounds results. Significant selection bias, no admission criteria stated for PACU or ICU. Patient allocation was determined by treating clinician.
Street, Phillips et al. 2017	Low	Serious	Low	Moderate	Low	Serious	Critical	Serious	Power analysis included all patients (including day surgery) when investigating post-operative outcomes after PACU discharge, giving inaccurate results. Poor objective (with different objectives stated in the abstract and the article).

Tayrose, Newman et al. 2013	Low	Critical	Serious	Moderate	Low	Serious	Low	Critical	Patients who were deemed too unwell to be mobilised in recovery, were included in analysis for the standard recovery group. Operative order bias, by including the first two cases of the day. No methods reported for data collection.
Zoremba, Dette et al. 2009	Low	Low	Low	Low	Low	Low	Low	Low	Good quality study. However, does not address the longer-term outcomes of interest.

Results of individual studies

The results of each individual study are presented in the results of included study table (Table 3). Four studies [5, 7, 9, 10] investigated non-ICU pathways for care of post-operative patients, and these pathways were not associated with increased mortality rates. Four of eight studies also examined hospital length of stay [5, 7, 8, 10], and two found the intervention was associated with decreased length of stay and two found no association (Table 3). Kastrup et al demonstrated a significant decrease in length of stay for all surgical patients after their introduction of 24-hour intensivist coverage to the PACU [7]. Tayrose et al, also demonstrated a decreased length of stay for patients who received early mobilisation in PACU[8]. However, Callaghan et al and Schweizer et al did not demonstrate any statistically significant decrease in length of stay. PACU length of stay was another common outcome measure in three of the included studies[6, 7, 11]. Eichenberger et al demonstrated a decreased PACU length of stay for ASA 1-2 patients, but no difference for ASA3-5, while Kastrup et al and Street both demonstrated an increase in PACU length of stay following their interventions[7, 11]. Due to the variations in study designs, we were unable to combine the data for further aggregate analysis.

Table 3. *Results of Included Studies*

Source	***Intervention***	***Mortality***	***Other Key results***

Callaghan, Lynch et al. 2005	Introduction of OIR (Overnight Intensive Recovery)	No significant difference between groups. Overall in hospital mortality was 2%. fewer than predicted patients died (observed mortality 3 versus predicted 95% CI 8-21).	Morbidity: No significant difference between groups. Overall, fever than predicted patients experienced one or more complications (observed 101 versus predicted morbidity 103-125 95%CI) Hospital length of stay: No significant difference between groups
Eichenberger, Haller et al. 2011	Introduction of a two-track clinical pathway that clearly defined & coordinated medical and nursing interventions.	Overall in-hospital mortality decreased significantly from 68 patients (1.5%) to 39 patients (0.8%) (P<0.001). In ASA 3-5 patients, mortality was nearly halved (adjusted OR 0.40) (P< 0.001).	Unplanned ICU admission: Total number of unplanned ICU admissions after stay in PACU decreased from 113 (2.5%) to 90 (1.9%) (adjusted OR 0.70) (P=0.70) PACU length of stay: After adjustment for differenced in patients and procedures. Statistically significant decrease in PACU length of stay for ASA 1-2 patients (adjusted P< 0.001). There was no difference for ASA 3-5 patients (adjusted P= 0.768)
Fraser and Nair 2016	Opening of an extended recovery unit.	Not investigated	Discharge destination after extended recovery unit admission: Data from the first 119 patients admitted to the Extended Recovery unit were collected. 76 patients (63.9%) who would have otherwise gone to critical care were able to go back to the ward.
Kastrup, Seeling et al. 2012	Introduction of 24-hour intensivist coverage in PACU	No difference between groups	Hospital length of stay: Overall length of stay decreased significantly for all surgical patients. From 8.3 (+/- 11.8) days to 7.71 (+/- 10.99) days. PACU length of stay: More patients were treated in the PACU for a longer period of time. Mean LOS increased from 0.27 (+/- 0.2) days to 0.45 (+/- 0.41) days Cases treated in ICU: Mean number of cases treated in the ICU per month decreased significantly from 164.7 (+/- 14.37) to 133.8 (+/- 19.42) (P=<0.001) ICU treatment days: Mean number of treatment days per month did not change. Relative number of patients with longer LOS (>7 days) increased after introduction of PACU, whereas average number of patients staying <24 hours in the ICU decreased by ~50%.
Schweizer, Khatchatourian et al. 2002	Opening of a new PACU (post-anaesthesia care unit)	No difference between study periods	Morbidity: Vascular patients had decreased rates of myocardial infarction (6.4% vs 1.3% p=0.009) and decreased rates of pulmonary oedema (5.1% vs 1.7% p=0.08) Re-operation: No difference between study periods Hospital length of stay: Total hospital length of stay did not change over time
Street, Phillips et al. 2017	Implementation of a Post Anaesthesia Care Tool (PACT)	No significant difference between groups.	Patient management in PACU: More requests for medical review 19% vs 30% (P=<0.001), more patients with MET criteria modified by an anaesthetist 6.5% vs 13.8% (P<0.001), higher rates of analgesia administration37.3% vs 54.2% (P=0.001). Adverse events in PACU: More adverse events recorded in PACU in phase 2, 29.4% vs 21.2% (P<0.001). May represent a greater recognition of adverse events in PACU after implementation of PACT. Adverse events after PACU: Significant decrease in rates of clinical deterioration and significant decrease in cardiovascular events after PACU discharge. PACU length of stay: Increase in median PACU length of stay from 45min in phase 1 to 53min in phase 2 (P<0.001)
Tayrose, Newman et al. 2013	Rapid rehabilitation pilot program where the first two cases of the day were mobilised in the recovery room.	Not investigated	Overall hospital length of stay: Rapid rehabilitation had significantly decreased length of stay that patient who began therapy on post-op day 1 (P<0.001). Hip arthroplasty subgroup length of stay: Decreased length of stay for rapid rehab patients in the hip arthroplasty subgroup (P<0.001). Knee arthroplasty subgroup length of stay: Decreased LOS for rapid rehab patients in the knee arthroplasty subgroup (P=0.16).

Zoremba, Dette et al. 2009	Patients performed incentive spirometry in the PACU.	Not investigated	Pulse oximetry: Significantly improved pulse oximetry values at 1 and 2 hours in PACU, and at 6 hours post mobilisations (P<0.0001), and significant improvement in pulse oximetry values at 24 hours post-op (P<0.0001). Spirometry results: Incentive spirometry group recovered lung function faster in during the PACU stay (P<0.0001). Lung function had almost reached baseline at 6 hours in the incentive spirometry group, however the control group were up to 25% below baseline (P<0.0001). Overall difference in lung function between groups had decreased 24 hours after surgery, but significant differences still remained (P=0.0040).

Synthesis of results

The overall quality of studies was poor, with significant selection and allocation bias; however, managing post-operative patients outside of the ICU is not associated with worse patient outcomes, especially in an extended recovery setting. There was no increase in mortality rates identified in any of the four studies investigating non-ICU pathways for post-operative patients [5, 7, 9, 10]. Use of extended recovery also meant that ward discharge was usual, bypassing the ICU[5, 9]. Kastrup et al showed that the addition of intensivist coverage to PACU was associated with decreased length of hospital stay, and Tayrose et al demonstrated that early mobilisation in PACU was associated with decreased length of hospital stay, but significant pre-selection bias for early mobilisation of arthroplasty patients confounds results[8]. Other changes to the PACU environment, including the opening of a new PACU[10] and introduction of Overnight Intensive Recovery[5] did not appear to have any effect on hospital length of stay. The use of a two-track pathway for nurse-driven and physician-driven PACU management and discharge appears to be beneficial in reducing PACU length of stay, and improving outcomes after discharge from PACU, including a significant decrease in post-operative mortality[6]. However, introduction of a Post Anaesthetic Care Tool, and introduction of 24-hour intensivist coverage in PACU was associated with increased length of stay in PACU[7, 11]. There were no long-term positive effects were investigated for the use of incentive spirometry[12].

Risk of bias across studies and additional analyses

Risk of bias across studies for the key common outcome measures of mortality, hospital length of stay and PACU length of stay was high due to the study designs, with no level I or II evidence available. There was no additional analysis required for this review.

DISCUSSION

Summary of evidence

Of the eight studies included in this systematic review, only one was a prospective randomised cohort study[12], and one was a prospective non-randomised pre-post intervention study[11]. The rest were observational and retrospective cohort studies[5-10]. There was no level I or level II evidence available for inclusion in this review. Common outcome measures identified, included mortality, hospital length of stay and PACU length of stay. Despite the poor quality of evidence, we found that managing selected higher risk post-operative patients in the PACU instead of ICU was not associated with worse outcomes[5, 7, 9, 10], and may be associated with decreased unnecessary ICU admissions, with potential large cost savings. However, due to study types, and the significant selection and allocation bias of patients within these studies, the overall strength of evidence is only moderate. The addition of intensivist coverage to PACU was associated with deceased hospital length of stay in one study [7], as was the rapid mobilisation of arthroplasty patients[8]. However, the introduction of overnight intensive recovery and the opening of a new PACU had no effect on hospital length of stay[5, 10]. The introduction of a two-track clinical pathway appeared to be associated with a decreased PACU length of stay[6], however the introduction of a Post Anaesthesia Care Tool and introduction of intensivist coverage was associated with increased PACU length of stay[7, 11]. This has significant implications for future research and health resource allocation. Further studies that prospectively randomly allocate patients to a treatment arm would be of great value, however, we acknowledge that due to the risk profile and care requirements of surgical patients, this may not be possible until further safety is proven.

Limitations

The protocol development and search strategy for this review were developed in accordance with the PRISMA statement. With help from experienced health science research librarians, we attempted to ensure that all references were captured; however, it is possible that studies were missed. Due to the variation in study design and primary outcome measures, we were unable to combine data for aggregate analysis or meta-analysis. The narrative synthesis of key results may introduce bias; however, steps were taken to minimise this, including the review of all data by a second author. The most significant limitation of this systematic review, was the high risk of bias within the individual studies included in the review. Selection and allocation bias, missing data, inclusion of inappropriate patient groups such as day surgery, and lack of fidelity assessment were some of the key flaws within each study. However, the thorough risk of bias assessment and its implications on reported results allows readers to interpret the data appropriately.

Conclusions

Managing selected post-operative patients in PACU instead of ICU does not appear to be associated with worse patient outcomes, however due to study design, and the high risk of bias within studies, the strength of evidence is moderate at best. The addition of intensivist coverage to PACU and early mobilisation was associated with decreased hospital length of stay. While the use of a two-track clinical pathway decreased PACU length of stay, however there is no evidence of this improving patients' overall outcomes. This is the first systematic review to investigate the health service initiatives undertaken in recovery rooms, and their impact on patient outcomes after PACU discharge. There is a striking paucity of literature on this topic, with very few high-quality studies; and further research is required to evaluate and improve the care of post-operative patients in the recovery room setting.

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AUTHOR STATEMENT

CL developed the review protocol, completed all title and abstract screening, full text reviews and data analysis. She completed the risk of bias assessment with GL. CL also drafted and revised the manuscript. GL developed the initial review question, and assisted writing the review protocol. He also completed the full text reviews, reviewed all data of included studies and completed the risk of bias assessment with CL. He also critically appraised the draft manuscript. DS assisted with developing the initial review question, and reviewed all included articles for consensus. He also critically appraised the draft manuscript, and assisted with revisions. GM reviewed all included articles for consensus, and critically appraised the manuscript. All authors have given final approval for publication.

Appendix 1.

PubMed Electronic Search Strategy

Postoperative period	Adults	Recovery room	Patient outcomes
“Postoperative Period”[mh] OR Anesthesia[mh] OR "surgical procedures, operative"[mh] OR "perioperative period"[mh] OR	“adult”[mh] OR adult*[tiab] OR elderly[tiab] OR “young adult*”[tiab] OR “young people”[tiab] OR “aged person”[tiab]	“recovery room”[mh] OR PACU[tiab] OR “recovery room”[tiab] OR “advanced recovery room”[tiab] OR “extended recovery room”[tiab] OR “post	"Patient outcome assessment"[mh] OR "treatment outcome"[mh] OR mortality[mh] OR "length of stay"[mh] OR "postoperative complications"[mh] OR

“Postoperative period”[tiab] OR “post anaesthes*”[tiab] OR “post anesthes*”[tiab] OR postoperative[tiab] OR “post operative”[tiab] OR "Anesthesia recovery period"[tiab] OR "Anaesthesia recovery period"[tiab] OR anesthesia[tiab] OR anaesthesia[tiab] OR "surgical procedures"[tiab] OR surger*[tiab] OR operation*[tiab] OR operative[tiab] OR "perioperative period"[tiab]	OR “aged people”[tiab] OR senior*[tiab] OR frail[tiab]	anaesthesia care unit*”[tiab] OR “post anesthesia care unit*”[tiab] OR “postanaesthesia care unit*”[tiab] OR “postanesthesia care unit*”[tiab] OR “post operative recovery unit*”[tiab]	reoperation*[mh] OR "Patient outcome assessment"[tiab] OR "patient outcome*"[tiab] or outcome*[tiab] OR "treatment outcome"[tiab] OR mortality[tiab] OR "fatal outcome*"[tiab] OR morbidity[tiab] OR "length of stay"[tiab] OR "postoperative complications"[tiab] OR "return to theatre"[tiab] OR complication*[tiab] OR "intensive care"[tiab] OR "intensive care admission"[tiab] OR "health outcome"[tiab] OR "adverse event*"[tiab]

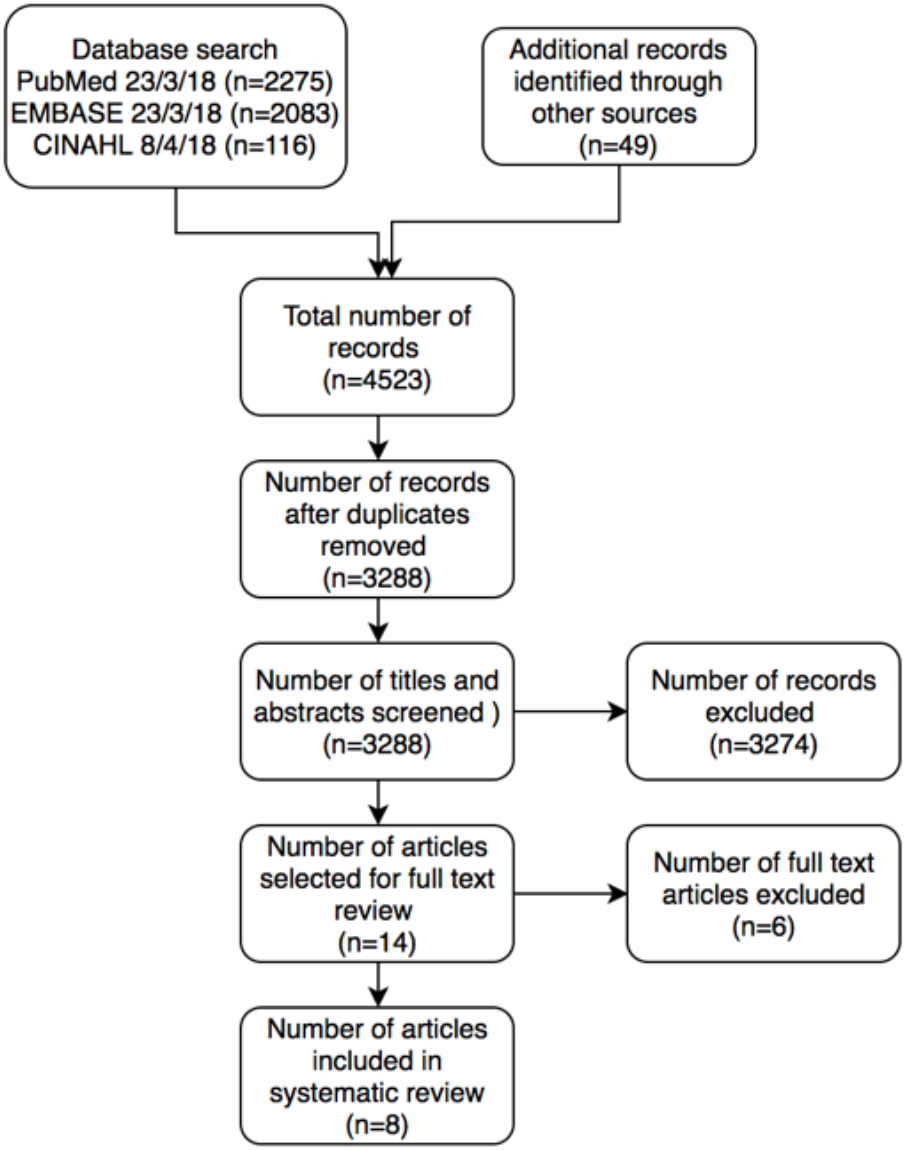

Figure 1

Characteristics of Included Studies Additional Tables

Participants additional table:

Source	*Location and Setting*	*Inclusion Criteria*	*Exclusion Criteria*	*Ages involved*	*Gender*	*Exclusion of important groups*	*Numbers involved*
Callaghan, Lynch et al. 2005	Addenbrooke's Hospital. Cambridge, United Kingdom. Cambridge vascular unit, OIR (based in PACU) and ICU, within a major teaching hospital and research centre.	All patients undergoing elective open aortic surgery between 1/01/98 and 31/12/02.	Patients with missing case notes.	Median age for all patients was 72 (66-77)	Intervention group 88% males. Comparison group 85% males.	No group appears to be excluded from the study. However, some multi-morbid patients were not offered surgery.	Intervention group n=152 Comparison group n=26
Eichenberger, Haller et al. 2011	Geneva hospital Switzerland. Post Anaesthesia Care Unit (PACU), within a tertiary teaching hospital.	All elective and non-elective inpatients, who underwent a surgical or endoscopic procedure under anaesthesia (including major surgery and high risk surgical patients required temporary NIV, haemodynamic support and continuous monitoring).	Exclusion: multi-trauma, persistent intraoperative shock, transplants, cardiac surgery and intra-operative respiratory failure.	Before period: <49yo 34.25%, 49-67yo 32.6%, >67yo 33.3% After period: <49yo 34.7%, 49-67yo 32.5%, >67yo 32.8%	Intervention group male 56.3% female 43.7% Comparison group male 55.9% female 44.1%	No groups excluded apart from those patients already specified in the exclusion criteria.	Intervention group n=3345 Comparison group n=3030
Fraser and Nair 2016	Northern General Hospital Sheffield, England. Extended recovery unit within a tertiary teaching hospital, major trauma centre.	Elective surgical patients who would have previously been booked for level 2 care post-operatively. Including patients with significant comorbidities, endovascular AAA repair, carotid endarterectomy and revision arthroplasty.	Not stated	Not stated	Not stated	No apparent exclusion of specific population groups. Not specifically addressed.	Intervention group n=119
Kastrup, Seeling et al. 2012	The Charite-University Hospital Campus Mitte Berlin, Germany. PACU within a large tertiary teaching hospital.	All patients undergoing a surgical procedure (adults and children) between 1/01/08 – 30/04/11	Ambulatory surgical patients, patients who were readmitted to hospital for the same reason as the initial admission (due to issues with accuracy of the administrative database)	Not given	Not stated	No apparent exclusion of specific population groups. Not specifically addressed.	Intervention group n=26118 Comparison group n=24972
Schweizer, Khatchatourian et al. 2002	The University Hospital of Geneva, Switzerland. PACU within a tertiary teaching hospital.	Adult patients undergoing abdominal aortic reconstruction or resection of lung cancer.	Exclusion criteria not stated	Not stated	Not stated	No apparent exclusion of specific population groups. Not specifically addressed.	Intervention group n= 485 Comparison group n= 448

Street, Phillips et al. 2017	Three hospitals within one Australian metropolitan healthcare organisation. PACUs within the three hospitals.	All adult patients undergoing elective surgery on days of data collection before and after the implementation of PACT (before period July-Oct 2012) (after period July-Sept 2014). (Half the patients were day surgery cases.)	Emergency surgery, minor procedure only requiring sedation, post-operative planned admission to ICU.	Intervention group: mean= 50.87 (SD 17.4) Comparison group: mean= 52.14 (SD 18.6)	Intervention group: male= 38.8%, female= 61.2% Comparison group: male= 41.6%, female= 58.4%	No specific groups appear to have been excluded from the study.	Intervention group n=694 Comparison group n=723
Tayrose, Newman et al. 2013	NYU hospital for Joint Diseases, New York. Recovery room and general orthopaedic ward.	900 consecutive hip and knee arthroplasty patients.	Not stated	Intervention group: mean= 63.7 Comparison group: mean= 64.3	Intervention group: male=225, female=206 Comparison group: male= 216, female=353	Unable to assess, and exclusion criteria are not stated.	Intervention group n=331 Comparison group n=569
Zoremba, Dette et al. 2009	University of Marburg, Germany. PACU within a tertiary teaching hospital.	60 obese adult patients (BMI 30-40) ASA 2-3, scheduled for minor peripheral surgery. Minimum surgery duration=40min, maximum surgery duration= 120 min.	Abdominal surgery, surgery requiring head-down tilt, history of GORD, hiatus hernia, likely difficult intubation, pregnancy, emergency operation, severe renal dysfunction, asthma requiring therapy, cardiac disease associated with dyspnoea (NYHA >2), severe psychiatric disorders or difficulties in cooperating during measurements.	Intervention group: mean 52 years Control group: mean 53 years	Not stated	Multimorbid patients with ASA >3 have been excluded (this is stated specifically in the exclusion criteria). All major surgery (including abdominal surgery) has also been intentionally excluded.	Intervention group n=30 Control group n=30

Interventions additional table:

Source	*Intervention name*	*Aims and rationale*	*Methods*	*Intervention delivery (staff and location)*	*Timing of intervention*	*Tailoring of intervention*	*Modifications made*	*Assessment of fidelity*
Callaghan, Lynch et al. 2005	Introduction of OIR (Overnight Intensive Recovery)	The majority of vascular surgical patients were routinely admitted to ICU post-operatively. However, several studies have demonstrated that extubation in theatre after AAA repair is safe[1] and that routine admission to ICU after infra-renal aortic surgery is unnecessary [2, 3].	Surgical patients assessed preoperatively by vascular surgeon and anaesthetist (ECG and full bloods). Patient referred to specialist if further pre-operative assessment is required. OIR located in theatre recovery. Maximum stay 24 hours. No facilities for mechanical ventilation or renal replacement therapy. Patients reviewed in the morning by surgical teams, and discharged to the ward if stable. If ongoing instability, patients transferred to ICU Face to face delivery of intervention No co-interventions apparent	Nurse to patient ratio 1:1 Day time medical coverage provided by PACU anaesthetist and vascular surgical teams. Overnight medical care provided by the on-call anaesthetist and general surgical teams. No specific training or upskilling period detailed. Pre-existing medical and nursing skills required	Intervention provided post-operatively for a maximum of 24 hours.	Post-operative medical care tailored to each patient. However, the OIR environment was not changed during the study.	OIR does not appear to have been modified or adapted during the study	No specific mention of steps taken to ensure fidelity in the OIR pathway. Anaesthetic techniques do appear to have been standardised, as well as post-operative analgesia.
Eichenberger, Haller et al. 2011	Introduction of a two-track clinical pathway that clearly defined & coordinated medical and nursing interventions.	Post-operative complications have a major impact on survival, especially in the older population [4, 5]. A clinical review of current practices prior to implementation of the pathway showed that poorly defined	Fast track pathway: nurse driven, ASA 1-2. At 15min intervals nursing staff evaluate patients' vitals using Aldrete score, and pain is assessed using verbal numeric rating scale. Slow track pathway: physician driven, ASA 3-	Fast-track programme: initial post-operative care prescribed by the anaesthetist and provided by the PACU nursing staff. Ongoing care is delivered by the PACU nursing staff only (unless	Fast-track programme: care provided immediately post-operatively. Discharge performed without further communication with the PACU anaesthetist if	Initial post-op treatment plan prescribed by the treating anaesthetist was tailored to the patient and their specific medical needs.	No adaptations appear to have been made to either pathway during the study period. However, this is not specifically discussed	Fast track pathway: methods of ensuring adherence to the pathway not discussed. Slow track pathway: adherence to the clinical pathway was ensured during daily rounds by the

		management and discharge criteria resulted in insecurity of the PACU physicians, nursing staff stress and delayed admission of patients from theatre. Evidence suggests that significant post-operative complications can be detected and successfully treated in well-organised PACUs, resulting in increased survival [6-9].	5 who have undergone minor or major surgery, or developed post-op complications. Formal handover to PACU anaesthetist. Standardised investigations and treatment guidelines for early post-operative complications. Intervention delivered face-to-face in PACU No co-interventions identified	there is evidence of a complication). Slow-track programme: care provided by the PACU anaesthetist with the help of nursing staff Pre-existing skills required: PACU specialist nursing staff (overnight nurse also ICU qualified). No specific training for either nursing staff or medical staff is detailed in the study.	Aldrete score is ≥ 8 and the verbal numeric rating scale is ≤ 3 Slow-track programme: care provided immediately pos-operatively. Discharge based on Aldrete score ≥8 and normal blood gas analysis. PACU physician in charge decides on discharge			medical head of the PACU, and during weekly quality control, feedback and information meetings.
Fraser and Nair 2016	Opening of an extended recovery unit	Was felt that some patients admitted to critical care post-operatively only required short term monitoring and optimisation [10]. Unnecessary admissions of patients to critical care increases bed occupancy in the unit, and was contributing to significant numbers of OT cancellations.	Extended Recovery Unit was opened in Oct 2014. Patients booked into the unit in advance. 4-6 hour stay. Standard form was completed by nursing staff for every patient: recording time and place of discharge, complications encountered and medical assistance required. (Recorded how many patients were assessed as safe to return to ward, and how many still required level 2 care) Nil co-interventions evident	Anaesthetists provided post-op medical care/ plans in the extended recovery unit. Recovery nursing staff provided care and completed the standard service evaluation form.	Patients stayed in the extended recovery unit for 4-6 hours post-op.	Not tailored	No	No mention of steps taken to ensure standardisation of treatment. Standard form provided to nursing staff, but no mention if forms were audited to ensure correct data collection.
Kastrup, Seeling et al. 2012	Introduction of intensivist coverage in PACU	Increasing demand for critical care, which can lead to capacity limitations in the ICU. This causes	PACU physician is in charge of allocation of patients to the PACU, ICU and IMCU (intermediate care unit)	Staffing of the PACU was changed so that both the nursing and physician staffing are covered by the ICU	Intervention provided immediately post-operatively.	Immediate post-operative care tailored to each patient by the treating	No apparent modification to the intervention were made	There is no mention of fidelity assessment. As intervention was a change in staffing

		delay in admissions of patients from ED, cancellation of surgery[11, 12], early discharge from ICU [11, 13-15], initiation of treatment in ED or on a standard ward and inter-hospital transfers [12, 16].	in collaboration with the surgeons. If no intensive care bed available, patients can be treated in the PACU for up to 24 hours (independent of the degree of organ failure) There are 6 beds with complete intensive care monitoring and respiratory care possibilities available. Face to face delivery of intervention No co intervention evident or discussed	team. The physician staffing was changed to a 24hr in-house critical care physician and nurse presence for the PACU. 1:3 nurse, patient ratio. 1 physician for all PACU patients.	Patients can be immediately admitted to the PACU around the clock (without any delays).	anaesthetist and surgeon.	during the study period.	model, this would have been monitored by the anaesthetist/ ICU physician in charge.
Schweizer, Khatchatourian et al. 2002	Opening of a new PACU (post-anaesthesia care unit)	Utilisation of the ICU for routine post-op care is commonplace, however ICUs account for an increasing proportion of a hospitals budget [17-19].	PACU moved to an area closer to theatres and the ICU, and was expended with additional beds to provide overnight care following major, non-cardiac surgery. Standardised rounding (morning and evening), with review of patient's clinical status, laboratory results and chest radiographs. Co-interventions: Preoperative risk assessment guidelines of the American Heart association and the American College of Cardiology (AHA/ACC) were introduced, and antiadrenergic medications (beta-blockers and alpha-2-agonists) were	New PACU staffed with anaesthesia-trained nurses (1:3 ratio), post-operative care coordinated by cardiothoracic surgical and anaesthesia teams, 24-hour medical coverage provided by one PACU resident (supervised by an attending).	New PACU provided 24-hour medical coverage. Patients were admitted immediately post-operatively. (Time limit on PACU admission not specified)	Post-operative care standardised as much as possible, but ongoing care tailored to each patient based on pre-existing medical comorbidities, intra-operative events and post-op complications	Intervention does not appear to have been altered during the study period	Variations in medical practice were minimised using standard protocols for blood test analysis, CXR orders, antibiotic prophylaxis, pain control, fluid administration, respiratory therapy, nutrition and mobilisation. All surgical procedures and approach standardised as much as possible. General anaesthesia standardised. Post-operative analgesia regimen also standardised.

			increasingly administered peri operatively					
Street, Phillips et al. 2017	Implementation of a Post Anaesthesia Care Tool (PACT)	Current post-operative death rate of 0.4-4%, and major complication rate of 3-17%. 40% of in-hospital complications are associated with surgery [20, 21]. Hospital costs for surgical patients experiencing a complication are significantly higher than for patients without complications [22-24]. Intensive observation of patients in PACU by nurses can help with the early detection of complications [25].	Implementation of the tool was supported by peri-operative nursing educators. Materials included posters summarising how to complete the PACT, and feedback sessions between the nurses using the tool and the perioperative team. PACT was included in the revised 'Post-anaesthetics care record' Working party was established to develop the tool. Extensive review of the current processes at each of the hospitals was done. Researchers conducted a systematic review and an expert consensus statement to evaluate the current evidence. PACT tool developed in line with the National Consensus Statement on the essential elements for recognising and responding to clinical deterioration. Face to face delivery of the intervention. No co-interventions apparent.	Perioperative nurse educators trained recovery nurses in the use of the tool. Feedback sessions during the training period were attended by the perioperative team including, educators, nurse unit managers and the quality unit of the organisation. Recovery nursing staff used the PACT in recovery. Medical staff responded to concerns that were triggered by the PACT	PACT used immediately post-operatively, until patient was safe for discharge to the ward (of home for day surgery patients). Patient readiness for discharge from PACU was recorded by a checklist of criteria: last 2 sets of observations were not within the MET criteria, no active vomiting, pain management ordered and all surgical concerns had been met.	Intervention does not appear to be tailored.	No modifications appear to have been made once the study period commenced.	Feedback sessions during the training period were attended by the perioperative team including, educators, nurse unit managers and the quality unit of the organisation. However, there is no mention of fidelity assessment or auditing once the tool was in use.
Tayrose, Newman et al. 2013	Rapid rehab patients started as part of a pilot	Previous studies have shown that early mobilisation after	Therapy program was the same for each group: therapist would	Physiotherapists delivered the intervention	Therapy commenced in the	Intervention was tailored to the speed of recovery	No adaptations or modifications appear to have	No assessment of fidelity reported. Unclear how the

	program where the first 2 cases of the day were mobilised in the recovery room.	total joint replacement enhances post-op recovery and promotes faster rehabilitation [26, 27]. Previous studies have also demonstrated early mobilisation leads to a decreased LOS, improve patient outcomes, and demonstrate cost savings [28-30]. However, it's unclear if early mobilisation that starts in the recovery room will lead to a reduction in LOS while maintaining patient outcomes.	start with having patients hang their legs over the side of the bed. Therapy would then progress with transferring to a chair, ambulation, and climbing stairs. The expectation for a patient was to ambulate 100 feet or greater, and climb 6 stairs, prior to discharge. Face to face delivery of intervention by physiotherapists No co-interventions described	Standard rehabilitation program implemented. Reliance of physiotherapists pre-existing skills and training.	recovery room on the day of surgery	of each patient. If a patient was unfit to mobilise on the day of surgery in PACU (as per the anaesthetist, surgeon or ICU doctor), they were not mobilised despite being one of the first 2 cases for the day.	occurred during the study.	standardisation of the rehabilitation program was ensured.
Zoremba, Dette et al. 2009	Patients performed incentive spirometry in the PACU	Even several days after surgery, obese patients exhibit a measurable amount of atelectasis, predisposing them to post-op pulmonary complications [31-35].	Physiotherapist supervised the respiratory physiotherapy treatment at all times. Exercises were started approximately 15 minutes after extubation, and the patients were encouraged to perform 15 deep breaths (incentive spirometry) every 10-15 minutes within the first 2 hours after surgery. If needed, patients were asked to cough during the pause to mobilise secretions. All therapy was performed in the sitting position if possible.	Physiotherapists supervised the respiratory physiotherapy treatment at all times Pre-existing skills required to deliver the intervention. No mention of specific training provided to the physiotherapists apart from the study protocol.	Intervention was delivered commencing 15 minutes post-operatively, continuing until 2 hours after surgery.	Intervention does not appear to have been tailored	No change to intervention during the study	Spirometry was standardised as much as possible. At each assessment time, spirometry was performed at least 3 times, and the best measurement was recorded (in line with the criteria of the European Respiratory Society). Factors that interfered with breathing (eg pain, shivering) were eliminated, or minimised to produce reliable measurements)

			No co-interventions described					

Outcomes and comparison groups additional table:

Source	*Primary outcomes*	*Method of assessing primary outcome measure*	*Timing of primary outcome assessment*	*Adverse events*	*Secondary outcomes*	*Method of assessing secondary outcome measure*	*Timing of secondary outcome measure*
Callaghan, Lynch et al. 2005	In hospital mortality In hospital morbidity Mean postoperative stay, days Mean ICU stay, days Median POSSUM operative severity score	Patients who had surgery were identified using a combination of computerized theatre records, surgeon's logbooks, and theatre booking diaries. Case notes analysed retrospectively. POSSUM variables collected prospectively (during the pre-operative assessment)	Retrospective analysis No follow-up required	OIR group: Admission to ICU within 48 hours of surgery	Operative characteristics. Common post-operative complications.	Case notes analysed retrospectively. Only complications occurring on more than four occasions during the study period are included.	Retrospective analysis of notes. No follow-up required.
Eichenberger, Haller et al. 2011	PACU length of stay	Anaesthetic Information system (computerize patient information system. PACU data entered by PACU nurses and PACU secretary)	Data entered in real time in PACU. Data reviewed retrospectively by investigators.	Nil reported	Nil reported	NA	NA
	In-hospital mortality	The hospital administrative database (administrative information used for financial purposes). Cause of death extracted from patient discharge reports, and entered into the administrative database by professional coders.	Data entered throughout the post-operative period until discharge. Data reviewed retrospectively by investigators				
	Unplanned ICU admissions after PACU stay	The hospital administrative database. Reason for unplanned ICU admission extracted from patient discharge report and entered into database by professional coders.	Data entered throughout the post-operative period. Reason for ICU admission entered after patient discharge.				
Fraser and Nair 2016	Discharge destination after extended recovery unit admission	Standard form completed by nursing staff in extended recovery, documenting time and place of discharge, complications encountered and medical assistance required.	Assessment made at time of extended recovery discharge. No follow-up done.	Nil reported	Nil reported	NA	NA

Kastrup, Seeling et al. 2012	LOS in PACU (days) LOS in ICU (all types of ICU's)(days) Pre operative days (all patients) Pre operative day (PACU-patients) Pre operative day (ICU-patients) Days on normal ward LOS hospital (days) CMI (case mix index) normal ward CM ICU CW (cost weight) per hospital stay (overall)	Data collected from the hospital administration system. All clinically relevant data are documented in a patient data management system (PDMS) and can be extracted for evaluations. Every patient admitted to the ICU in included in the system (COPRA-System® GmbH, Sasbachwalden, Germany). 24-hours after patient discharge, the record is changed to a read-only version so that no modifications can be made.	Retrospective analysis of data. Data continuously collected until patient discharge. No follow-up post-discharge.	Nil reported	General descriptive variables for the ICU, before and after the introduction of the PACU (ICU patients only).	Data extracted from patient data management system (PDMS). DRG system allows for coding of the intensive care as DRG procedure, making the severity of disease relevant for reimbursement. The "Complex intensive care treatment" is based on several scores, which are collected within the PDMS system.	Retrospective analysis of data. Data continuously collected until patient discharge. No follow-up post-discharge.
Schweizer, Khatchatourian et al. 2002	Mortality	Data prospectively collected on standardized worksheets describing the pre-operative, intraoperative and postoperative periods. One investigator also reviewed all nursing charts, medical records and hospital discharge letters.	Outcome assessments done during inpatient stay, and on review of the hospital data base. No follow-up required after hospital discharge	Nil reported	Identification of independent risk factors for mortality and major complications following thoracic surgery	Data abstracted from two institutional databases	Patient risk factors reported pre-operatively and intraoperatively (prospective data collection). Analysed at a later date
	Re-operation	Data abstracted from two institutional databases					
	Secondary admission to ICU (either from PACU or from the ward)	Data obtained from the hospital computer			Identification of independent risk factors for mortality and major complications following major vascular surgery		
	Cardiac complications • Myocardial infarct • Arrhythmias • Pulmonary oedema	Data were prospectively collected on standardized worksheets describing the pre-operative, intraoperative and postoperative periods. One investigator also reviewed all nursing charts, medical records and hospital discharge letters.					
	Respiratory complications • Atelectasis • Bronchopneumonia	As above			Evaluation of perioperative antiadrenergic treatment administration		
	Mechanical ventilation >6 hours	As above					
	Renal dysfunction	As above					

	Hospital length of stay	Data obtained from the hospital computer					
Street, Phillips et al. 2017	Nursing management of patient symptoms Rates of adverse events Mortality Length of stay in PACU Length of hospital admission Discharge destination	Data collected by research nurses from the medical record following patient discharge. Severity of each adverse event was graded using the Common Terminology Criteria for Adverse Events (V.4.03) and grouped into mild (no or minimal effect to the patient and resolved spontaneously), moderate (event with resolved after intervention, with no lasting effect for the patient) and severe (required intervention and caused harm to the patient, including death).	Data reviewed from case notes on patient discharge. No longer term follow-up required.	Nil reported	Health service usage and healthcare costs	Economic evaluation done from organization data that were routinely submitted to the regional health department for benchmarking. 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 was used to calculate the costs for all initial admissions and unplanned readmission, using the nations efficient price determination.	Data reviewed from case notes on patient discharge. No long term follow-up required.
Tayrose, Newman et al. 2013	Overall hospital length of stay Hip arthroplasty subgroup length of stay Knee arthroplasty subgroup length of stay	Retrospective review of cases, however it is not stated how this was done (case note reviews versus use of the hospital's database)	At time of discharge	Nil reported	Percentage completion of the rapid rehabilitation program	Progression of rehab was followed, however methods for assessing this were not stated.	Followed as an inpatient until the time of discharge.
Zoremba, Dette et al. 2009	Pulse oximetry at 1hr, 2hr, 6hr and 24hr post-operatively Spirometry at 1hr, 2hr, 6hr and 24hr post-operatively	Assessed face to face by an investigator. The investigators were blinded.	At 1hr, 2hr, 6hr and 24hr respectively	Nil reported	Nil reported	NA	NA

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PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	3
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	4
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	4
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	4
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	4
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	16
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	5
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	5
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	5
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	5
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	5
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	NA

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	6
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	NA
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	6
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	7
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	9-11
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	11-12
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	13
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	13
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	NA
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	13
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	14
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	14
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	15

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

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BMJ Open

"What health service initiatives undertaken within operating suite recovery rooms within 48 hours post-operatively have been shown to improve patient outcomes after adult non-cardiac surgery: a systematic review."

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Secondary Subject Heading:	Health services research, Surgery, Anaesthesia
Keywords:	Post-operative care, Post-anaesthetic care, Recovery room, Post-anaesthetic care unit (PACU), ANAESTHETICS

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TITLE PAGE

"What health service initiatives undertaken within operating suite recovery rooms within 48 hours post-operatively have been shown to improve patient outcomes after adult non-cardiac surgery: a systematic review."

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ABSTRACT

Context: Post-operative recovery rooms have existed since 1847, and the concept of Overnight Intensive Recovery has been successful since the 1990s. However, there is sparse literature investigating the interventions undertaken in recovery, and their impact on patients after recovery room discharge.

Objective: This review aimed to investigate any health service initiatives undertaken in post-operative recovery room up to 48 hours post-operatively; and their effect on patient outcomes; including mortality, morbidity, return to theatre, unplanned intensive care unit (ICU) admission and length of hospital stay.

Data sources: NCBI PubMed, EMBASE and CINAHL.

Study selection: Studies published from 1990 onwards, investigating health service initiatives undertaken in the post-operative recovery room, and their impact on patient outcomes. One author screened titles and abstracts, with two authors completing full text reviews to determine inclusion based on pre-determined criteria. A total of 3288 unique studies were identified, with 14 selected for full text reviews, and 8 included in the review.

Data extraction: EndNote 8 (Clarivate Analytics, Boston, USA) was used to manage references and exclude duplicates. One author extracted data from each study using a data extraction form adapted from the Cochrane Data Extraction Template, with all data checked by a second author.

Data synthesis: Narrative synthesis of data was the primary outcome measure, with all data of individual studies also presented in the summary results table.

Conclusions: Managing selected post-operative patients in a Recovery Room, or PACU, instead of ICU, does not appear to be associated with worse patient outcomes, however due to the high risk of bias within studies, the strength of evidence is moderate at best. Four of eight studies also examined hospital length of stay, and two found the intervention was associated with decreased length of stay and two found no association.

Key words: Post-operative care, post-anaesthetic care, recovery room, post-anaesthetic care unit (PACU)

STRENGTHS AND LIMITATIONS OF THIS STUDY

- This is the first systematic review to provide a summary of health service interventions in recovery and their impact on patient outcomes. It is a current area of interest for many hospitals/health networks, due to the frequency and cost of post-operative complications.
- The PRISMA statement was strictly adhered to, with a broad search strategy in an attempt to capture all relevant publications.
- The variation in study designs and primary outcome measures meant that we were unable to combine data for aggregate analysis or meta-analysis.
- Narrative synthesis of key results may introduce bias; however, steps were taken to minimise this, including the review of all data by a second author.

INTRODUCTION

Rationale

The concept of a post-operative recovery room, or post anaesthesia care unit (PACU), was first described in 1847 [1], and the progression of surgical and anaesthetic techniques has seen marked advances in their form and function. However, there is a striking paucity of literature investigating the interventions undertaken in recovery, and their impact on patients after recovery room discharge. An editorial by C. Aps in 2004, discussed the concept of Overnight Intensive Recovery; where patients can be managed in the PACU for up to 24 hours[2], to avoid unnecessary intensive care unit (ICU) admissions and decrease cancellations due to lack of bed availability. This concept was introduced in the 1990s at St Thomas' Hospital, London[2]; and despite its apparent success, has not spawned further research surrounding such a model of care. Swart et al retrospectively examined the impact of the loss of access to a high dependency unit (HDU) for post-operative management of medium risk patients, and showed a significant increase in emergency laparotomies and unplanned critical care admissions[3]. However, the use of HDU for post-operative patients has also been associated with an increase in post-operative respiratory complications[4]. The concept of extended 6-hour recovery followed by a monitored ward bed, instead of an elective ICU admission post-operatively, has also shown to be safe, with no worsening in patient outcomes[5]. This is the first systematic review to provide a summary of all health service interventions provided in recovery, and their impact on patient outcomes after recovery room discharge. In presenting these finding, we hope to highlight the need for further research to help improve the care of patients in the post-operative period.

Objectives

The objective of this systematic review was to investigate any health service initiatives undertaken in operating suite recovery rooms, in the post-operative period, that have been shown to improve outcomes after PACU discharge, for adult, non-cardiac surgical patients. Important outcomes included mortality, morbidity, return to theatre, unplanned ICU admission and length of hospital stay. Prospective and retrospective randomised control trials, cohort studies, case control studies and comparison studies were included for analysis.

METHODS

Protocol and registration

A review protocol was developed in line with the Preferred Reporting of Observational Studies and Meta-Analysis (PRISMA) statement by the author team prior to commencing the systematic review. This protocol is registered on the International Prospective Register of Systematic Reviews (PROSPERO) database, registration number CRD42018106093.

Patient and Public Involvement

As this is a systematic review of pre-existing literature, patients and the public were not involved in study design. However, this systematic review forms part of a broader research topic on post-operative care, and how to face the challenge of increasing post-operative complication rates. In 2012, the WHO estimated the global volume of surgery to be 312.9 million operations, an increase of 38.2 compared to 2004, resulting in a mean global surgical rate of 4469 operations per 100 000 people per year [6]. With an ageing population and increasing prevalence of comorbidities, post-operative complications are now at pandemic levels [7]. Investigating alternative health care systems and care delivery models is paramount to combatting this issue. It should be apriority of both patients and service providers, as it has the potential to provide great benefit to the broader population.

Eligibility criteria

Included studies investigated health service initiatives in the PACU, in the post-operative period, up to 48 hours post-operatively. Adult patient groups were the primary focus, however, studies that included a small cohort of children were not automatically excluded. Studies that explored the relationship between interventions in recovery and mortality, morbidity, hospital length of stay, unplanned ICU admission and return to theatre were included. Varying study designs were eligible for inclusion; such as randomised control trials, cohort studies, case control studies and before and after

studies. Cross-sectional studies and case reports were excluded. Only studies published from 1990 onwards were included, to focus on up to date clinical practice, and minimise the inclusion of irrelevant data. Studies published in a language other than English, grey literature and studies focussing solely on ambulatory surgery were excluded.

Information sources and search strategy

Medical Subject Headings (MeSH) terms were generated from the NCBI PubMed advanced search area with the assistance of the University of Adelaide Health Sciences librarian. Logic grids were used as a tool, to replicate the search throughout the three databases; NCBI PubMed, EMBASE, and Cumulative Index to Nursing and Allied Health Literature (CINAHL). The full electronic search strategy for the PubMed database is presented in Appendix 1. This search strategy was utilized across the three databases from 23/3/18 to 8/4/18 to yield the articles screened for inclusion in the review.

Study selection

Search results from each data base were recorded, and imported into EndNote 8 (Clarivate Analytics, Boston, USA). Key word searching was also performed to identify new studies that had not yet been assigned indexing terms for the databases. Reference lists from key articles were also reviewed to identify further papers that may have been relevant to the review. Titles and abstracts were screened by one reviewer (CL), who was not blinded to journal titles or to the study authors or institutions. Articles selected for full text review were reviewed by two reviewers (CL and GL), and any discrepancies arising regarding the relevance of a study were resolved by consulting a third party. The list of references for inclusion was sent to all authors to ensure consensus.

Data collection process

The Cochrane Data Extraction Template for Included Studies from their consumers and communication page, was used as a base for our data extraction form. This form was piloted on two initial studies for usability, with no further modifications required. One reviewer extracted the initial data from each study (CL), and this data was confirmed by a second reviewer (GL) before inclusion in the review. One study only included data in pictorial form, and an attempt was made to contact the authors to obtain the raw data. Unfortunately, this was unsuccessful.

Data items

Data items extracted from each study included patient population and characteristics, intervention aims and methods, comparison groups and outcome measures. These data items are presented in the Characteristics of Included Studies Tables.

Risk of bias in individual studies

Risk of bias in individual studies was assessed by two reviewers (CL and GL) using Gate-Lite and Robins-I (previously known as A Cochrane Risk of Bias Assessment Tool: for Non-Randomized Studies of Interventions (ACROBAT-NRSI)). Narrative synthesis of data placed more weight on higher quality studies, however, all studies and their results are presented, with caveats to highlight the individual biases that will affect interpretations of results.

Summary measures and planned methods of analysis

Narrative synthesis of data was the principle summary measure. This was due to the differing study designs and variable outcome measures in each study. Meta-analysis was not appropriate for the data in this systematic review. All data is presented individually, in relation to each study, with further narrative synthesis to summarise results. Results from studies were unable to be combined due to the variation in primary and secondary outcome measures, and differences in study design. No additional analysis or subgroup analysis was performed during this systematic review.

Risk of bias across studies

Risk of bias across studies was assessed by two reviewers (CL and GL), using the Cochrane Risk of Bias Tool, and discussing any evident publication bias or selective reporting.

RESULTS

Study selection

Database results, and numbers of studies screened are presented in the flow diagram (Figure 1). All references were imported into EndNote 8 for title and abstract screening. One reviewer (CL) screened all titles and abstracts, with ambiguous studies included for full text review. 14 studies were selected for full text review. Full text reviews were completed by two reviewers (CL and GL), and 8 studies were selected for inclusion in the review. A summary of included and excluded studies was sent to the third and fourth authors for consensus.

Study characteristics

Of the eight studies included, four of the included studies were retrospective cohort studies[8-11], two were observational cohort studies[12, 13], one was a prospective non-randomised pre-post intervention study[14], and one was a prospective randomised cohort study[15]. Study characteristics for each of the included studies are outlined in the Characteristics of Included Studies Summary Table (Table 1). Four studies investigated the use of PACU as a non-ICU pathway for post-operative patients[8, 10, 12, 13]. Two investigated the implementation of physiotherapy in PACU, and the impact on patient outcomes[11, 15]. One evaluated the use of a new nursing scoring tool, and its impact on recognition of patient deterioration in PACU[14], and one evaluated the implementation of a two-track clinical pathway in PACU, and the effect on patient outcomes[9]. All studies focussed primarily on adults, but one included small cohort of children[10]. Common outcome measures included in-hospital mortality, PACU length of stay and hospital length of stay. Further details regarding patient population characteristics, study methodology and outcome measures are also outlined in the supplementary tables published online (supplementary file).

Table 1. *Characteristics of Included Studies Summary Table*

Source	***Aim***	***Study Design***	***Number of arms/groups***	***Population***	***Intervention***	***Comparison group***	***Outcome measures***
Callaghan, Lynch et al. 2005 (n= 178)	To determine the safety of introducing non-ICU pathways for selected patients. And evaluate the effect on cost, ICU beds availability and cancellation rates of elective surgery.	Retrospective cohort study.	Intervention group: patients selected for overnight intensive recovery. Comparison group: patients booked for an elective ICU admission.	All patients undergoing elective open aortic surgery between 1/01/98 and 31/12/02.	(n= 152) Introduction of OIR (Overnight Intensive Recovery)	(n= 26) Elective post-operative ICU bed	In hospital mortality In hospital morbidity Post-operative length of stay ICU length of stay
Eichenberger, Haller et al. 2011 (n= 6375)	To assess the impact of a clinical pathway implemented in a post-anaesthesia care unit on post-operative outcomes.	Retrospective cohort study based on electronic patient records.	Fast track: nurse driven, ASA 1-2. Slow track: physician driven, ASA 3-5 who have undergone minor or major surgery, or developed post-op complications. Comparison group: Pre-existing PACU conditions without the clinical pathway.	All elective and non-elective inpatients, who underwent a surgical or endoscopic procedure under anaesthesia during the study period.	(n= 3345) Introduction of a two-track clinical pathway that clearly defined & coordinated medical and nursing interventions.	(n= 3030) Pre-existing PACU conditions without the clinical pathway.	PACU length of stay In-hospital mortality Unplanned ICU admissions after PACU stay.

Fraser and Nair 2016 (n= 119)	To assess if elective surgical patients were stable enough to return to the general ward after a stay in Extended Recovery instead of being routinely admitted to ICU	Observational cohort study.	One arm. No control group	Elective surgical patients who would have previously been booked for level 2 care post-operatively.	(n= 119) Opening of an extended recovery unit.	Nil	Discharge destination after extended recovery unit admission
Kastrup, Seeling et al. 2012 (n= 51090)	To evaluate the effect of around-the-clock intensivist PACU coverage on the structure of ICU, and to demonstrate the economic effect on the hospital.	Retrospective cohort study.	Intervention group: after the introduction of 24-hour intensivist coverage. Comparison group: prior to introduction of 24-hour intensivist coverage.	All patients undergoing a surgical procedure (adults and children) between 1/01/08 – 30/04/11.	(n= 26118) Introduction of 24-hour intensivist coverage in PACU	(n= 24972) Pre-existing PACU with no intensivist coverage	PACU LOS ICU LOS Pre-operative days Hospital LOS Case mix index Cost
Schweizer, Khatchatourian et al. 2002 (n= 933)	To assess the impact of a new PACU on ICU utilisation, hospital length of stay and complications following major non-cardiac surgery.	Observational cohort study.	Intervention group: after opening of a new PACU. Control group: before opening of the new PACU	Adult patients undergoing abdominal aortic reconstruction or resection of lung cancer during the study periods.	(n= 485) Opening of a new PACU (post-anaesthesia care unit)	(n= 448) Pre-existing PACU	Mortality Reoperation Secondary admission to ICU Post-operative complications Hospital LOS
Street, Phillips et al. 2017 (n= 1417)	To evaluate whether use of a discharge criteria tool for nursing assessment of patients in PACU would enhance nurses' recognition and response to patients at-risk of deterioration and improve patient outcomes.	Prospective non-randomised pre-post intervention study.	Intervention group: after the implementation of the Post-Anaesthetic Care Tool (PACT) Comparison group: prior to the implementation of PACT.	All adult patients undergoing elective surgery on days of data collection.	(n= 694) Implementation of a Post Anaesthesia Care Tool (PACT)	(n= 723) Standard PACU care without PACT	Nursing management of symptoms Rates of adverse events Mortality PACU LOS Hospital LOS Health service usage and healthcare costs
Tayrose, Newman et al. 2013 (n= 900)	To address the impact of rapid rehabilitation beginning in the recovery room on length-of-stay after primary hip and knee arthroplasty.	Retrospective cohort study.	Intervention group: rapid rehabilitation group. Comparison group: standard rehabilitation protocol	900 consecutive hip and knee arthroplasty patients	(n= 331) Rapid rehabilitation pilot program where the first two cases of the day were mobilised in the recovery room.	(n= 569) Remainder of cases received standard rehabilitation protocol starting on the morning of post-operative day one.	Overall hospital LOS Hip arthroplasty subgroup LOS Knee arthroplasty subgroup LOS

Zoremba, Dette et al. 2009 (n= 60)	To evaluate the impact of short-term respiratory physiotherapy during the PACU stay, on postoperative lung function tests and pulse oximetry values in obese adults after minor surgery.	Prospective randomised cohort study	Intervention group: physical therapy treatment group that performed incentive spirometry in the PACU Control group: patients who did not undergo physical therapy	60 obese adult patients (BMI 30-40) ASA 2-3, scheduled for minor peripheral surgery.	(n= 30) Patients performed incentive spirometry in the PACU.	(n= 30) Not instructed to do any breathing exercises or spirometry.	Pulse oximetry and spirometry at 1, 2, 6 and 24 hours post-operatively

Risk of bias within studies

The overall risk of bias within studies was serious. Critical risk of bias was identified in two studies[11, 12], serious risk of bias in three studies[8, 13, 14], moderate risk of bias in one study[10] and low risk of bias in two studies[9, 15]. Significant patient selection and allocation bias was the most common identified cause[8, 10, 11, 13, 14]; as patients in these studies were not randomly allocated to their post-operative level of care. The most clinically unwell patients were sent to ICU automatically, and only the lower risk patients, as deemed by the treating teams, were allowed a trial of care in the PACU. The relatively small numbers of participants in each study, with the exception of Kastrup et al, also introduces a significant risk of bias; as these studies were not adequately powered to assess critical outcomes such as mortality, and other serious post-operative complications. Articles that were considered as being of serious and critical risk of bias, were still included in the review, due to the sparse literature available. The risk of bias summary table (Table 2) provides further analysis, and comment regarding the risk of bias within individual studies.

Table 2. *Risk of Bias Summary Table*

Source	***Bias Due to Confounding***	***Bias in Selection & Allocation of Participants***	***Bias in Measurement of Interventions***	***Bias Due to Departures from Intended Interventions***	***Bias Due to Missing Data***	***Bias in Measurement of Outcomes***	***Bias in Selection of Reported Results***	***Overall Risk of Bias Judgement***	***Comments***
Callaghan, Lynch et al. 2005	Low	Serious	Low	Moderate	Low	Moderate	Low	Serious	Significant selection bias of lower risk patients who were sent to OIR. Used predictive values for mortality (based on POSSUM variables) as a comparison measure.

Eichenberger, Haller et al. 2011	Low	Low	Low	Low	Low	Low	Low	Low	High quality study. No specific concerns from review authors.
Fraser and Nair 2016	Low	Moderate	Moderate	Moderate	Critical	Serious	Moderate	Critical	Over 25% of data missing. No clear objective stated, no explanation of methodology. Poorly defined selection criteria.
Kastrup, Seeling et al. 2012	Low	Serious	Low	Moderate	Low	Low	Low	Moderate	Significant selection bias of patients allocated to PACU, intermediate care unit or ICU by intensive care physician. This study also included a population of children (numbers not given).
Schweizer, Khatchatourian et al. 2002	Critical	Serious	Low	Low	Low	Low	Low	Serious	Introduction of preoperative risk assessment guidelines (AHA/ACC) with increased antiadrenergic administration pre-operatively confounds results. Significant selection bias, no admission criteria stated for PACU or ICU. Patient allocation was determined by treating clinician.

Street, Phillips et al. 2017	Low	Serious	Low	Moderate	Low	Serious	Critical	Serious	Power analysis included all patients (including day surgery) when investigating post-operative outcomes after PACU discharge, giving inaccurate results. Poor objective (with different objectives stated in the abstract and the article).
Tayrose, Newman et al. 2013	Low	Critical	Serious	Moderate	Low	Serious	Low	Critical	Patients who were deemed too unwell to be mobilised in recovery, were included in analysis for the standard recovery group. Operative order bias, by including the first two cases of the day. No methods reported for data collection.
Zoremba, Dette et al. 2009	Low	Low	Low	Low	Low	Low	Low	Low	Good quality study. However, does not address the longer-term outcomes of interest.

Results of individual studies

The results of each individual study are presented in the results of included study table (Table 3). Four studies[8, 10, 12, 13] investigated non-ICU pathways for care of post-operative patients, and these pathways were not associated with increased mortality rates in three of the included studies[8, 10, 13]. However, it must be noted that due to sample size, only one study [10] was adequately powered to show a reliable difference in mortality rates, and one study[12] did not investigate mortality as an outcome measure. Four of eight studies also examined hospital length of stay [8, 10, 11, 13], and two found the intervention was associated with decreased length of stay and two found no association (Table 3). Kastrup et al demonstrated a significant decrease in length of stay for all surgical patients after their introduction of 24-hour intensivist coverage to the PACU [10]. Tayrose et al, also demonstrated a decreased length of stay for patients who received early mobilisation in PACU[11].

However, Callaghan et al and Schweizer et al did not demonstrate any statistically significant decrease in length of stay[8, 13]. PACU length of stay was another common outcome measure in three of the included studies[9, 10, 14]. Eichenberger et al demonstrated a decreased PACU length of stay for ASA 1-2 patients, but no difference for ASA3-5, while Kastrup et al and Street both demonstrated an increase in PACU length of stay following their interventions[10, 14]. Due to the variations in study designs, we were unable to combine the data for further aggregate analysis.

Table 3. *Results of Included Studies*

Source	***Intervention***	***Mortality***	***Other Key results***
Callaghan, Lynch et al. 2005	Introduction of OIR (Overnight Intensive Recovery)	No significant difference between groups. Overall in hospital mortality was 2%. fewer than predicted patients died (observed mortality 3 versus predicted 95% CI 8-21).	Morbidity: No significant difference between groups. Overall, fever than predicted patients experienced one or more complications (observed 101 versus predicted morbidity 103-125 95%CI) Hospital length of stay: No significant difference between groups
Eichenberger, Haller et al. 2011	Introduction of a two-track clinical pathway that clearly defined & coordinated medical and nursing interventions.	Overall in-hospital mortality decreased significantly from 68 patients (1.5%) to 39 patients (0.8%) (P<0.001). In ASA 3-5 patients, mortality was nearly halved (adjusted OR 0.40) (P< 0.001).	Unplanned ICU admission: Total number of unplanned ICU admissions after stay in PACU decreased from 113 (2.5%) to 90 (1.9%) (adjusted OR 0.70) (P=0.70) PACU length of stay: After adjustment for differenced in patients and procedures. Statistically significant decrease in PACU length of stay for ASA 1-2 patients (adjusted P< 0.001). There was no difference for ASA 3-5 patients (adjusted P= 0.768)
Fraser and Nair 2016	Opening of an extended recovery unit.	Not investigated	Discharge destination after extended recovery unit admission: Data from the first 119 patients admitted to the Extended Recovery unit were collected. 76 patients (63.9%) who would have otherwise gone to critical care were able to go back to the ward.
Kastrup, Seeling et al. 2012	Introduction of 24-hour intensivist coverage in PACU	No difference between groups	Hospital length of stay: Overall length of stay decreased significantly for all surgical patients. From 8.3 (+/- 11.8) days to 7.71 (+/- 10.99) days. PACU length of stay: More patients were treated in the PACU for a longer period of time. Mean LOS increased from 0.27 (+/- 0.2) days to 0.45 (+/- 0.41) days Cases treated in ICU: Mean number of cases treated in the ICU per month decreased significantly from 164.7 (+/- 14.37) to 133.8 (+/- 19.42) (P=<0.001) ICU treatment days: Mean number of treatment days per month did not change. Relative number of patients with longer LOS (>7 days) increased after introduction of PACU, whereas average number of patients staying <24 hours in the ICU decreased by ~50%.
Schweizer, Khatchatourian et al. 2002	Opening of a new PACU (post-anaesthesia care unit)	No difference between study periods	Morbidity: Vascular patients had decreased rates of myocardial infarction (6.4% vs 1.3% p=0.009) and decreased rates of pulmonary oedema (5.1% vs 1.7% p=0.08) Re-operation: No difference between study periods Hospital length of stay: Total hospital length of stay did not change over time
Street, Phillips et al. 2017	Implementation of a Post Anaesthesia Care Tool (PACT)	No significant difference between groups.	Patient management in PACU: More requests for medical review 19% vs 30% (P=<0.001), more patients with MET criteria modified by an anaesthetist 6.5% vs 13.8% (P<0.001), higher rates of analgesia administration37.3% vs 54.2% (P=0.001). Adverse events in PACU: More adverse events recorded in PACU in phase 2, 29.4% vs 21.2% (P<0.001). May represent a greater recognition of adverse events in PACU after implementation of PACT. Adverse events after PACU: Significant decrease in rates of clinical deterioration and significant decrease in cardiovascular events after PACU discharge. PACU length of stay: Increase in median PACU length of stay from 45min in phase 1 to 53min in phase 2 (P<0.001)

Tayrose, Newman et al. 2013	Rapid rehabilitation pilot program where the first two cases of the day were mobilised in the recovery room.	Not investigated	Overall hospital length of stay: Rapid rehabilitation had significantly decreased length of stay that patient who began therapy on post-op day 1 (P<0.001). Hip arthroplasty subgroup length of stay: Decreased length of stay for rapid rehab patients in the hip arthroplasty subgroup (P<0.001). Knee arthroplasty subgroup length of stay: Decreased LOS for rapid rehab patients in the knee arthroplasty subgroup (P=0.16).
Zoremba, Dette et al. 2009	Patients performed incentive spirometry in the PACU.	Not investigated	Pulse oximetry: Significantly improved pulse oximetry values at 1 and 2 hours in PACU, and at 6 hours post mobilisations (P<0.0001), and significant improvement in pulse oximetry values at 24 hours post-op (P<0.0001). Spirometry results: Incentive spirometry group recovered lung function faster in during the PACU stay (P<0.0001). Lung function had almost reached baseline at 6 hours in the incentive spirometry group, however the control group were up to 25% below baseline (P<0.0001). Overall difference in lung function between groups had decreased 24 hours after surgery, but significant differences still remained (P=0.0040).

Synthesis of results

The overall quality of studies was poor, with significant selection and allocation bias; however, managing post-operative patients outside of the ICU is not associated with worse patient outcomes, especially in an extended recovery setting. There was no increase in mortality rates identified in three of the studies investigating non-ICU pathways for post-operative patients[8, 10, 13], and the fourth did not investigate mortality as an outcome measure[12]. Use of extended recovery also meant that ward discharge was usual, bypassing the ICU[8, 12]. Kastrup et al showed that the addition of intensivist coverage to PACU was associated with decreased length of hospital stay, and Tayrose et al demonstrated that early mobilisation in PACU was associated with decreased length of hospital stay, but significant pre-selection bias for early mobilisation of arthroplasty patients confounds results[11]. Other changes to the PACU environment, including the opening of a new PACU[13] and introduction of Overnight Intensive Recovery[8] did not appear to have any effect on hospital length of stay. The use of a two-track pathway for nurse-driven and physician-driven PACU management and discharge appears to be beneficial in reducing PACU length of stay, and improving outcomes after discharge from PACU, including a significant decrease in post-operative mortality[9]. However, introduction of a Post Anaesthetic Care Tool, and introduction of 24-hour intensivist coverage in PACU was associated with increased length of stay in PACU[10, 14]. There were no long-term positive effects investigated, or identified, for the use of incentive spirometry in PACU post-operatively [15]. It must be noted that the risk of bias of the included studies confounds results. Critical risk of bias was identified in two studies[11, 12], serious risk of bias in three studies[8, 13, 14], moderate risk of bias in one study[10] and low risk of bias in two studies[9, 15]. Only one of the included studies was adequately powered[10], and reliable conclusions cannot be drawn from single studies with such small datasets.

Risk of bias across studies and additional analyses

Risk of bias across studies for the key common outcome measures of mortality, hospital length of stay and PACU length of stay was high due to the study designs, with no level I or II evidence available. There was no additional analysis required for this review.

DISCUSSION

Summary of evidence

Of the eight studies included in this systematic review, only one was a prospective randomised cohort study[15], and one was a prospective non-randomised pre-post intervention study[14]. The rest were observational and retrospective cohort studies[8-13]. There was no level I or level II evidence available for inclusion in this review. Common outcome measures identified, included mortality, hospital length of stay and PACU length of stay. Despite the poor quality of evidence, we found that managing selected higher risk post-operative patients in the PACU instead of ICU was not associated with worse outcomes[8, 10, 12, 13], and may be associated with decreased unnecessary ICU admissions, with potential large cost savings. However, due to study types, small participant numbers, and the significant selection and allocation bias of patients within these studies, the overall strength of evidence is only moderate. The addition of intensivist coverage to PACU was associated with deceased hospital length of stay in one study [10], as was the rapid mobilisation of arthroplasty patients[11]. However, the introduction of overnight intensive recovery and the opening of a new PACU had no effect on hospital length of stay[8, 13]. The introduction of a two-track clinical pathway appeared to be associated with a decreased PACU length of stay[9], however the introduction of a Post Anaesthesia Care Tool and introduction of intensivist coverage was associated with increased PACU length of stay[10, 14]. Only one of the included studies was adequately powered [10], and we are unable to draw accurate conclusions from single studies with such small participant numbers. This has significant implications for future research and health resource allocation. Further studies that prospectively randomly allocate patients to a treatment arm would be of great value, however, we acknowledge that due to the risk profile and care requirements of surgical patients, this may not be possible until further safety is proven.

Limitations

The protocol development and search strategy for this review were developed in accordance with the PRISMA statement. With help from experienced health science research librarians, we attempted to ensure that all references were captured; however, it is possible that studies were missed. Due to the variation in study design and primary outcome measures, we were unable to combine data for aggregate analysis or meta-analysis. The narrative synthesis of key results may introduce bias;

however, steps were taken to minimise this, including the review of all data by a second author. The most significant limitation of this systematic review, was the high risk of bias within the individual studies included in the review. Selection and allocation bias, missing data, inclusion of inappropriate patient groups such as day surgery, and lack of fidelity assessment were some of the key flaws within each study. However, the thorough risk of bias assessment and its implications on reported results allows readers to interpret the data appropriately.

Conclusions

Managing selected post-operative patients in PACU instead of ICU does not appear to be associated with worse patient outcomes, however due to study design, and the high risk of bias within studies, the strength of evidence is moderate at best. The addition of intensivist coverage to PACU and early mobilisation was associated with decreased hospital length of stay. While the use of a two-track clinical pathway decreased PACU length of stay, however there is no evidence of this improving patients' overall outcomes. This is the first systematic review to investigate the health service initiatives undertaken in recovery rooms, and their impact on patient outcomes after PACU discharge. There is a striking paucity of literature on this topic, with very few high-quality studies; and further research is required to evaluate and improve the care of post-operative patients in the recovery room setting.

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COMPETING INTERESTS

No conflicts of interest known at the time of writing the review. Affiliations; The Royal Adelaide Hospital and the University of Adelaide.

AUTHOR STATEMENT

CL developed the review protocol, completed all title and abstract screening, full text reviews and data analysis. She completed the risk of bias assessment with GL. CL also drafted and revised the manuscript. GL developed the initial review question, and assisted writing the review protocol. He also completed the full text reviews, reviewed all data of included studies and completed the risk of bias assessment with CL. He also critically appraised the draft manuscript. DS assisted with developing

the initial review question, and reviewed all included articles for consensus. He also critically appraised the draft manuscript, and assisted with revisions. GM reviewed all included articles for consensus, and critically appraised the manuscript. All authors have given final approval for publication. There were no other contributors.

DATA SHARING STATEMENT

There was no new data produced by this research. Data extracted from the original studies is available in the online supplementary tables.

FIGURE LEGEND

Figure 1: Flow diagram for selection of studies included in review

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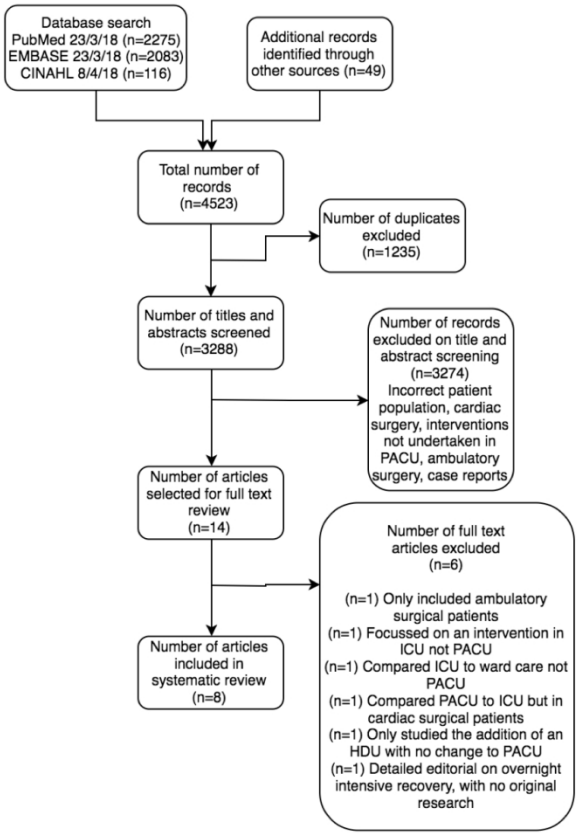

Figure 1

Appendix 1.

PubMed Electronic Search Strategy

Postoperative period	Adults	Recovery room	Patient outcomes
“Postoperative Period”[mh] OR Anesthesia[mh] OR "surgical procedures, operative"[mh] OR "perioperative period"[mh] OR “Postoperative period”[tiab] OR “post anaesthes*”[tiab] OR “post anesthes*”[tiab] OR postoperative[tiab] OR “post operative”[tiab] OR "Anesthesia recovery period"[tiab] OR "Anaesthesia recovery period"[tiab] OR anesthesia[tiab] OR anaesthesia[tiab] OR "surgical procedures"[tiab] OR surger*[tiab] OR operation*[tiab] OR operative[tiab] OR "perioperative period"[tiab]	“adult”[mh] OR adult*[tiab] OR elderly[tiab] OR “young adult*”[tiab] OR “young people”[tiab] OR “aged person”[tiab] OR “aged people”[tiab] OR senior*[tiab] OR frail[tiab]	“recovery room”[mh] OR PACU[tiab] OR “recovery room”[tiab] OR “advanced recovery room”[tiab] OR “extended recovery room”[tiab] OR “post anaesthesia care unit*”[tiab] OR “post anesthesia care unit*”[tiab] OR “postanaesthesia care unit*”[tiab] OR “postanesthesia care unit*”[tiab] OR “post operative recovery unit*”[tiab]	"Patient outcome assessment"[mh] OR "treatment outcome"[mh] OR mortality[mh] OR "length of stay"[mh] OR "postoperative complications"[mh] OR reoperation*[mh] OR "Patient outcome assessment"[tiab] OR "patient outcome*"[tiab] or outcome*[tiab] OR "treatment outcome"[tiab] OR mortality[tiab] OR "fatal outcome*"[tiab] OR morbidity[tiab] OR "length of stay"[tiab] OR "postoperative complications"[tiab] OR "return to theatre"[tiab] OR complication*[tiab] OR "intensive care"[tiab] OR "intensive care admission"[tiab] OR "health outcome"[tiab] OR "adverse event*"[tiab]

Characteristics of Included Studies Additional Tables

Participants additional table:

Source	*Location and Setting*	*Inclusion Criteria*	*Exclusion Criteria*	*Ages involved*	*Gender*	*Exclusion of important groups*	*Numbers involved*
Callaghan, Lynch et al. 2005	Addenbrooke's Hospital. Cambridge, United Kingdom. Cambridge vascular unit, OIR (based in PACU) and ICU, within a major teaching hospital and research centre.	All patients undergoing elective open aortic surgery between 1/01/98 and 31/12/02.	Patients with missing case notes.	Median age for all patients was 72 (66-77)	Intervention group 88% males. Comparison group 85% males.	No group appears to be excluded from the study. However, some multi-morbid patients were not offered surgery.	Intervention group n=152 Comparison group n=26
Eichenberger, Haller et al. 2011	Geneva hospital Switzerland. Post Anaesthesia Care Unit (PACU), within a tertiary teaching hospital.	All elective and non-elective inpatients, who underwent a surgical or endoscopic procedure under anaesthesia (including major surgery and high risk surgical patients required temporary NIV, haemodynamic support and continuous monitoring).	Exclusion: multi-trauma, persistent intraoperative shock, transplants, cardiac surgery and intra-operative respiratory failure.	Before period: <49yo 34.25%, 49-67yo 32.6%, >67yo 33.3% After period: <49yo 34.7%, 49-67yo 32.5%, >67yo 32.8%	Intervention group male 56.3% female 43.7% Comparison group male 55.9% female 44.1%	No groups excluded apart from those patients already specified in the exclusion criteria.	Intervention group n=3345 Comparison group n=3030
Fraser and Nair 2016	Northern General Hospital Sheffield, England. Extended recovery unit within a tertiary teaching hospital, major trauma centre.	Elective surgical patients who would have previously been booked for level 2 care post-operatively. Including patients with significant comorbidities, endovascular AAA repair, carotid endarterectomy and revision arthroplasty.	Not stated	Not stated	Not stated	No apparent exclusion of specific population groups. Not specifically addressed.	Intervention group n=119
Kastrup, Seeling et al. 2012	The Charite-University Hospital Campus Mitte Berlin, Germany. PACU within a large tertiary teaching hospital.	All patients undergoing a surgical procedure (adults and children) between 1/01/08 – 30/04/11	Ambulatory surgical patients, patients who were readmitted to hospital for the same reason as the initial admission (due to issues with accuracy of the administrative database)	Not given	Not stated	No apparent exclusion of specific population groups. Not specifically addressed.	Intervention group n=26118 Comparison group n=24972
Schweizer, Khatchatourian et al. 2002	The University Hospital of Geneva, Switzerland. PACU within a tertiary teaching hospital.	Adult patients undergoing abdominal aortic reconstruction or resection of lung cancer.	Exclusion criteria not stated	Not stated	Not stated	No apparent exclusion of specific population groups. Not specifically addressed.	Intervention group n= 485 Comparison group n= 448

Street, Phillips et al. 2017	Three hospitals within one Australian metropolitan healthcare organisation. PACUs within the three hospitals.	All adult patients undergoing elective surgery on days of data collection before and after the implementation of PACT (before period July-Oct 2012) (after period July-Sept 2014). (Half the patients were day surgery cases.)	Emergency surgery, minor procedure only requiring sedation, post-operative planned admission to ICU.	Intervention group: mean= 50.87 (SD 17.4) Comparison group: mean= 52.14 (SD 18.6)	Intervention group: male= 38.8%, female= 61.2% Comparison group: male= 41.6%, female= 58.4%	No specific groups appear to have been excluded from the study.	Intervention group n=694 Comparison group n=723
Tayrose, Newman et al. 2013	NYU hospital for Joint Diseases, New York. Recovery room and general orthopaedic ward.	900 consecutive hip and knee arthroplasty patients.	Not stated	Intervention group: mean= 63.7 Comparison group: mean= 64.3	Intervention group: male=225, female=206 Comparison group: male= 216, female=353	Unable to assess, and exclusion criteria are not stated.	Intervention group n=331 Comparison group n=569
Zoremba, Dette et al. 2009	University of Marburg, Germany. PACU within a tertiary teaching hospital.	60 obese adult patients (BMI 30-40) ASA 2-3, scheduled for minor peripheral surgery. Minimum surgery duration=40min, maximum surgery duration= 120 min.	Abdominal surgery, surgery requiring head-down tilt, history of GORD, hiatus hernia, likely difficult intubation, pregnancy, emergency operation, severe renal dysfunction, asthma requiring therapy, cardiac disease associated with dyspnoea (NYHA >2), severe psychiatric disorders or difficulties in cooperating during measurements.	Intervention group: mean 52 years Control group: mean 53 years	Not stated	Multimorbid patients with ASA >3 have been excluded (this is stated specifically in the exclusion criteria). All major surgery (including abdominal surgery) has also been intentionally excluded.	Intervention group n=30 Control group n=30

Interventions additional table:

Source	*Intervention name*	*Aims and rationale*	*Methods*	*Intervention delivery (staff and location)*	*Timing of intervention*	*Tailoring of intervention*	*Modifications made*	*Assessment of fidelity*
Callaghan, Lynch et al. 2005	Introduction of OIR (Overnight Intensive Recovery)	The majority of vascular surgical patients were routinely admitted to ICU post-operatively. However, several studies have demonstrated that extubation in theatre after AAA repair is safe[1] and that routine admission to ICU after infra-renal aortic surgery is unnecessary [2, 3].	Surgical patients assessed preoperatively by vascular surgeon and anaesthetist (ECG and full bloods). Patient referred to specialist if further pre-operative assessment is required. OIR located in theatre recovery. Maximum stay 24 hours. No facilities for mechanical ventilation or renal replacement therapy. Patients reviewed in the morning by surgical teams, and discharged to the ward if stable. If ongoing instability, patients transferred to ICU Face to face delivery of intervention No co-interventions apparent	Nurse to patient ratio 1:1 Day time medical coverage provided by PACU anaesthetist and vascular surgical teams. Overnight medical care provided by the on-call anaesthetist and general surgical teams. No specific training or upskilling period detailed. Pre-existing medical and nursing skills required	Intervention provided post-operatively for a maximum of 24 hours.	Post-operative medical care tailored to each patient. However, the OIR environment was not changed during the study.	OIR does not appear to have been modified or adapted during the study	No specific mention of steps taken to ensure fidelity in the OIR pathway. Anaesthetic techniques do appear to have been standardised, as well as post-operative analgesia.
Eichenberger, Haller et al. 2011	Introduction of a two-track clinical pathway that clearly defined & coordinated medical and nursing interventions.	Post-operative complications have a major impact on survival, especially in the older population [4, 5]. A clinical review of current practices prior to implementation of the pathway showed that poorly defined	Fast track pathway: nurse driven, ASA 1-2. At 15min intervals nursing staff evaluate patients' vitals using Aldrete score, and pain is assessed using verbal numeric rating scale. Slow track pathway: physician driven, ASA 3-	Fast-track programme: initial post-operative care prescribed by the anaesthetist and provided by the PACU nursing staff. Ongoing care is delivered by the PACU nursing staff only (unless	Fast-track programme: care provided immediately post-operatively. Discharge performed without further communication with the PACU anaesthetist if	Initial post-op treatment plan prescribed by the treating anaesthetist was tailored to the patient and their specific medical needs.	No adaptations appear to have been made to either pathway during the study period. However, this is not specifically discussed	Fast track pathway: methods of ensuring adherence to the pathway not discussed. Slow track pathway: adherence to the clinical pathway was ensured during daily rounds by the

		management and discharge criteria resulted in insecurity of the PACU physicians, nursing staff stress and delayed admission of patients from theatre. Evidence suggests that significant post-operative complications can be detected and successfully treated in well-organised PACUs, resulting in increased survival [6-9].	5 who have undergone minor or major surgery, or developed post-op complications. Formal handover to PACU anaesthetist. Standardised investigations and treatment guidelines for early post-operative complications. Intervention delivered face-to-face in PACU No co-interventions identified	there is evidence of a complication). Slow-track programme: care provided by the PACU anaesthetist with the help of nursing staff Pre-existing skills required: PACU specialist nursing staff (overnight nurse also ICU qualified). No specific training for either nursing staff or medical staff is detailed in the study.	Aldrete score is ≥ 8 and the verbal numeric rating scale is ≤ 3 Slow-track programme: care provided immediately pos-operatively. Discharge based on Aldrete score ≥8 and normal blood gas analysis. PACU physician in charge decides on discharge			medical head of the PACU, and during weekly quality control, feedback and information meetings.
Fraser and Nair 2016	Opening of an extended recovery unit	Was felt that some patients admitted to critical care post-operatively only required short term monitoring and optimisation [10]. Unnecessary admissions of patients to critical care increases bed occupancy in the unit, and was contributing to significant numbers of OT cancellations.	Extended Recovery Unit was opened in Oct 2014. Patients booked into the unit in advance. 4-6 hour stay. Standard form was completed by nursing staff for every patient: recording time and place of discharge, complications encountered and medical assistance required. (Recorded how many patients were assessed as safe to return to ward, and how many still required level 2 care) Nil co-interventions evident	Anaesthetists provided post-op medical care/ plans in the extended recovery unit. Recovery nursing staff provided care and completed the standard service evaluation form.	Patients stayed in the extended recovery unit for 4-6 hours post-op.	Not tailored	No	No mention of steps taken to ensure standardisation of treatment. Standard form provided to nursing staff, but no mention if forms were audited to ensure correct data collection.
Kastrup, Seeling et al. 2012	Introduction of intensivist coverage in PACU	Increasing demand for critical care, which can lead to capacity limitations in the ICU. This causes	PACU physician is in charge of allocation of patients to the PACU, ICU and IMCU (intermediate care unit)	Staffing of the PACU was changed so that both the nursing and physician staffing are covered by the ICU	Intervention provided immediately post-operatively.	Immediate post-operative care tailored to each patient by the treating	No apparent modification to the intervention were made	There is no mention of fidelity assessment. As intervention was a change in staffing

		delay in admissions of patients from ED, cancellation of surgery[11, 12], early discharge from ICU [11, 13-15], initiation of treatment in ED or on a standard ward and inter-hospital transfers [12, 16].	in collaboration with the surgeons. If no intensive care bed available, patients can be treated in the PACU for up to 24 hours (independent of the degree of organ failure) There are 6 beds with complete intensive care monitoring and respiratory care possibilities available. Face to face delivery of intervention No co intervention evident or discussed	team. The physician staffing was changed to a 24hr in-house critical care physician and nurse presence for the PACU. 1:3 nurse, patient ratio. 1 physician for all PACU patients.	Patients can be immediately admitted to the PACU around the clock (without any delays).	anaesthetist and surgeon.	during the study period.	model, this would have been monitored by the anaesthetist/ ICU physician in charge.
Schweizer, Khatchatourian et al. 2002	Opening of a new PACU (post-anaesthesia care unit)	Utilisation of the ICU for routine post-op care is commonplace, however ICUs account for an increasing proportion of a hospitals budget [17-19].	PACU moved to an area closer to theatres and the ICU, and was expended with additional beds to provide overnight care following major, non-cardiac surgery. Standardised rounding (morning and evening), with review of patient's clinical status, laboratory results and chest radiographs. Co-interventions: Preoperative risk assessment guidelines of the American Heart association and the American College of Cardiology (AHA/ACC) were introduced, and antiadrenergic medications (beta-blockers and alpha-2-agonists) were	New PACU staffed with anaesthesia-trained nurses (1:3 ratio), post-operative care coordinated by cardiothoracic surgical and anaesthesia teams, 24-hour medical coverage provided by one PACU resident (supervised by an attending).	New PACU provided 24-hour medical coverage. Patients were admitted immediately post-operatively. (Time limit on PACU admission not specified)	Post-operative care standardised as much as possible, but ongoing care tailored to each patient based on pre-existing medical comorbidities, intra-operative events and post-op complications	Intervention does not appear to have been altered during the study period	Variations in medical practice were minimised using standard protocols for blood test analysis, CXR orders, antibiotic prophylaxis, pain control, fluid administration, respiratory therapy, nutrition and mobilisation. All surgical procedures and approach standardised as much as possible. General anaesthesia standardised. Post-operative analgesia regimen also standardised.

			increasingly administered peri operatively					
Street, Phillips et al. 2017	Implementation of a Post Anaesthesia Care Tool (PACT)	Current post-operative death rate of 0.4-4%, and major complication rate of 3-17%. 40% of in-hospital complications are associated with surgery [20, 21]. Hospital costs for surgical patients experiencing a complication are significantly higher than for patients without complications [22-24]. Intensive observation of patients in PACU by nurses can help with the early detection of complications [25].	Implementation of the tool was supported by peri-operative nursing educators. Materials included posters summarising how to complete the PACT, and feedback sessions between the nurses using the tool and the perioperative team. PACT was included in the revised 'Post-anaesthetics care record' Working party was established to develop the tool. Extensive review of the current processes at each of the hospitals was done. Researchers conducted a systematic review and an expert consensus statement to evaluate the current evidence. PACT tool developed in line with the National Consensus Statement on the essential elements for recognising and responding to clinical deterioration. Face to face delivery of the intervention. No co-interventions apparent.	Perioperative nurse educators trained recovery nurses in the use of the tool. Feedback sessions during the training period were attended by the perioperative team including, educators, nurse unit managers and the quality unit of the organisation. Recovery nursing staff used the PACT in recovery. Medical staff responded to concerns that were triggered by the PACT	PACT used immediately post-operatively, until patient was safe for discharge to the ward (of home for day surgery patients). Patient readiness for discharge from PACU was recorded by a checklist of criteria: last 2 sets of observations were not within the MET criteria, no active vomiting, pain management ordered and all surgical concerns had been met.	Intervention does not appear to be tailored.	No modifications appear to have been made once the study period commenced.	Feedback sessions during the training period were attended by the perioperative team including, educators, nurse unit managers and the quality unit of the organisation. However, there is no mention of fidelity assessment or auditing once the tool was in use.
Tayrose, Newman et al. 2013	Rapid rehab patients started as part of a pilot	Previous studies have shown that early mobilisation after	Therapy program was the same for each group: therapist would	Physiotherapists delivered the intervention	Therapy commenced in the	Intervention was tailored to the speed of recovery	No adaptations or modifications appear to have	No assessment of fidelity reported. Unclear how the

	program where the first 2 cases of the day were mobilised in the recovery room.	total joint replacement enhances post-op recovery and promotes faster rehabilitation [26, 27]. Previous studies have also demonstrated early mobilisation leads to a decreased LOS, improve patient outcomes, and demonstrate cost savings [28-30]. However, it's unclear if early mobilisation that starts in the recovery room will lead to a reduction in LOS while maintaining patient outcomes.	start with having patients hang their legs over the side of the bed. Therapy would then progress with transferring to a chair, ambulation, and climbing stairs. The expectation for a patient was to ambulate 100 feet or greater, and climb 6 stairs, prior to discharge. Face to face delivery of intervention by physiotherapists No co-interventions described	Standard rehabilitation program implemented. Reliance of physiotherapists pre-existing skills and training.	recovery room on the day of surgery	of each patient. If a patient was unfit to mobilise on the day of surgery in PACU (as per the anaesthetist, surgeon or ICU doctor), they were not mobilised despite being one of the first 2 cases for the day.	occurred during the study.	standardisation of the rehabilitation program was ensured.
Zoremba, Dette et al. 2009	Patients performed incentive spirometry in the PACU	Even several days after surgery, obese patients exhibit a measurable amount of atelectasis, predisposing them to post-op pulmonary complications [31-35].	Physiotherapist supervised the respiratory physiotherapy treatment at all times. Exercises were started approximately 15 minutes after extubation, and the patients were encouraged to perform 15 deep breaths (incentive spirometry) every 10-15 minutes within the first 2 hours after surgery. If needed, patients were asked to cough during the pause to mobilise secretions. All therapy was performed in the sitting position if possible.	Physiotherapists supervised the respiratory physiotherapy treatment at all times Pre-existing skills required to deliver the intervention. No mention of specific training provided to the physiotherapists apart from the study protocol.	Intervention was delivered commencing 15 minutes post-operatively, continuing until 2 hours after surgery.	Intervention does not appear to have been tailored	No change to intervention during the study	Spirometry was standardised as much as possible. At each assessment time, spirometry was performed at least 3 times, and the best measurement was recorded (in line with the criteria of the European Respiratory Society). Factors that interfered with breathing (eg pain, shivering) were eliminated, or minimised to produce reliable measurements)

			No co-interventions described					

Outcomes and comparison groups additional table:

Source	*Primary outcomes*	*Method of assessing primary outcome measure*	*Timing of primary outcome assessment*	*Adverse events*	*Secondary outcomes*	*Method of assessing secondary outcome measure*	*Timing of secondary outcome measure*
Callaghan, Lynch et al. 2005	In hospital mortality In hospital morbidity Mean postoperative stay, days Mean ICU stay, days Median POSSUM operative severity score	Patients who had surgery were identified using a combination of computerized theatre records, surgeon's logbooks, and theatre booking diaries. Case notes analysed retrospectively. POSSUM variables collected prospectively (during the pre-operative assessment)	Retrospective analysis No follow-up required	OIR group: Admission to ICU within 48 hours of surgery	Operative characteristics. Common post-operative complications.	Case notes analysed retrospectively. Only complications occurring on more than four occasions during the study period are included.	Retrospective analysis of notes. No follow-up required.
Eichenberger, Haller et al. 2011	PACU length of stay	Anaesthetic Information system (computerize patient information system. PACU data entered by PACU nurses and PACU secretary)	Data entered in real time in PACU. Data reviewed retrospectively by investigators.	Nil reported	Nil reported	NA	NA
	In-hospital mortality	The hospital administrative database (administrative information used for financial purposes). Cause of death extracted from patient discharge reports, and entered into the administrative database by professional coders.	Data entered throughout the post-operative period until discharge. Data reviewed retrospectively by investigators				
	Unplanned ICU admissions after PACU stay	The hospital administrative database. Reason for unplanned ICU admission extracted from patient discharge report and entered into database by professional coders.	Data entered throughout the post-operative period. Reason for ICU admission entered after patient discharge.				
Fraser and Nair 2016	Discharge destination after extended recovery unit admission	Standard form completed by nursing staff in extended recovery, documenting time and place of discharge, complications encountered and medical assistance required.	Assessment made at time of extended recovery discharge. No follow-up done.	Nil reported	Nil reported	NA	NA

Kastrup, Seeling et al. 2012	LOS in PACU (days) LOS in ICU (all types of ICU's)(days) Pre operative days (all patients) Pre operative day (PACU-patients) Pre operative day (ICU-patients) Days on normal ward LOS hospital (days) CMI (case mix index) normal ward CM ICU CW (cost weight) per hospital stay (overall)	Data collected from the hospital administration system. All clinically relevant data are documented in a patient data management system (PDMS) and can be extracted for evaluations. Every patient admitted to the ICU in included in the system (COPRA-System® GmbH, Sasbachwalden, Germany). 24-hours after patient discharge, the record is changed to a read-only version so that no modifications can be made.	Retrospective analysis of data. Data continuously collected until patient discharge. No follow-up post-discharge.	Nil reported	General descriptive variables for the ICU, before and after the introduction of the PACU (ICU patients only).	Data extracted from patient data management system (PDMS). DRG system allows for coding of the intensive care as DRG procedure, making the severity of disease relevant for reimbursement. The "Complex intensive care treatment" is based on several scores, which are collected within the PDMS system.	Retrospective analysis of data. Data continuously collected until patient discharge. No follow-up post-discharge.
Schweizer, Khatchatourian et al. 2002	Mortality	Data prospectively collected on standardized worksheets describing the pre-operative, intraoperative and postoperative periods. One investigator also reviewed all nursing charts, medical records and hospital discharge letters.	Outcome assessments done during inpatient stay, and on review of the hospital data base. No follow-up required after hospital discharge	Nil reported	Identification of independent risk factors for mortality and major complications following thoracic surgery	Data abstracted from two institutional databases	Patient risk factors reported pre-operatively and intraoperatively (prospective data collection). Analysed at a later date
	Re-operation	Data abstracted from two institutional databases					
	Secondary admission to ICU (either from PACU or from the ward)	Data obtained from the hospital computer			Identification of independent risk factors for mortality and major complications following major vascular surgery		
	Cardiac complications • Myocardial infarct • Arrhythmias • Pulmonary oedema	Data were prospectively collected on standardized worksheets describing the pre-operative, intraoperative and postoperative periods. One investigator also reviewed all nursing charts, medical records and hospital discharge letters.					
	Respiratory complications • Atelectasis • Bronchopneumonia	As above			Evaluation of perioperative antiadrenergic treatment administration		
	Mechanical ventilation >6 hours	As above					
	Renal dysfunction	As above					

	Hospital length of stay	Data obtained from the hospital computer					
Street, Phillips et al. 2017	Nursing management of patient symptoms Rates of adverse events Mortality Length of stay in PACU Length of hospital admission Discharge destination	Data collected by research nurses from the medical record following patient discharge. Severity of each adverse event was graded using the Common Terminology Criteria for Adverse Events (V.4.03) and grouped into mild (no or minimal effect to the patient and resolved spontaneously), moderate (event with resolved after intervention, with no lasting effect for the patient) and severe (required intervention and caused harm to the patient, including death).	Data reviewed from case notes on patient discharge. No longer term follow-up required.	Nil reported	Health service usage and healthcare costs	Economic evaluation done from organization data that were routinely submitted to the regional health department for benchmarking. 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 was used to calculate the costs for all initial admissions and unplanned readmission, using the nations efficient price determination.	Data reviewed from case notes on patient discharge. No long term follow-up required.
Tayrose, Newman et al. 2013	Overall hospital length of stay Hip arthroplasty subgroup length of stay Knee arthroplasty subgroup length of stay	Retrospective review of cases, however it is not stated how this was done (case note reviews versus use of the hospital's database)	At time of discharge	Nil reported	Percentage completion of the rapid rehabilitation program	Progression of rehab was followed, however methods for assessing this were not stated.	Followed as an inpatient until the time of discharge.
Zoremba, Dette et al. 2009	Pulse oximetry at 1hr, 2hr, 6hr and 24hr post-operatively Spirometry at 1hr, 2hr, 6hr and 24hr post-operatively	Assessed face to face by an investigator. The investigators were blinded.	At 1hr, 2hr, 6hr and 24hr respectively	Nil reported	Nil reported	NA	NA

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PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	3
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	4
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	4
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	4
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	4
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	16
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	5
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	5
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	5
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	5
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	5
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	NA

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	6
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	NA
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	6
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	7
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	9-11
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	11-12
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	13
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	13
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	NA
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	13
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	14
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	14
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	15

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BMJ Open

"What health system initiatives undertaken within operating suite recovery rooms within 48 hours post-operatively have been shown to improve patient outcomes after adult non-cardiac surgery: a systematic review."

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Secondary Subject Heading:	Health services research, Surgery, Anaesthesia
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TITLE PAGE

"What health system initiatives undertaken within operating suite recovery rooms within 48 hours post-operatively have been shown to improve patient outcomes after adult non-cardiac surgery: a systematic review."

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ABSTRACT

Context: Post-operative recovery rooms have existed since 1847, and the concept of Overnight Intensive Recovery has been successful since the 1990s. However, there is sparse literature investigating the interventions undertaken in recovery, and their impact on patients after recovery room discharge.

Objective: This review aimed to investigate any health system initiatives undertaken in post-operative recovery room up to 48 hours post-operatively; and their effect on patient outcomes; including mortality, morbidity, return to theatre, unplanned intensive care unit (ICU) admission and length of hospital stay.

Data sources: NCBI PubMed, EMBASE and CINAHL.

Study selection: Studies published from 1990 onwards, investigating health system initiatives undertaken in the post-operative recovery room, and their impact on patient outcomes. One author screened titles and abstracts, with two authors completing full text reviews to determine inclusion based on pre-determined criteria. A total of 3288 unique studies were identified, with 14 selected for full text reviews, and 8 included in the review.

Data extraction: EndNote 8 (Clarivate Analytics, Boston, USA) was used to manage references and exclude duplicates. One author extracted data from each study using a data extraction form adapted from the Cochrane Data Extraction Template, with all data checked by a second author.

Data synthesis: Narrative synthesis of data was the primary outcome measure, with all data of individual studies also presented in the summary results table.

Conclusions: Managing selected post-operative patients in a Recovery Room, or PACU, instead of ICU, does not appear to be associated with worse patient outcomes, however due to the high risk of bias within studies, the strength of evidence is moderate at best. Four of eight studies also examined hospital length of stay, and two found the intervention was associated with decreased length of stay and two found no association.

Key words: Post-operative care, post-anaesthetic care, recovery room, post-anaesthetic care unit (PACU)

STRENGTHS AND LIMITATIONS OF THIS STUDY

- This is the first systematic review to provide a summary of health system initiatives in recovery and their impact on patient outcomes. It is a current area of interest for many hospitals/health networks, due to the frequency and cost of post-operative complications.
- The PRISMA statement was strictly adhered to, with a broad search strategy in an attempt to capture all relevant publications.
- The variation in study designs and primary outcome measures meant that we were unable to combine data for aggregate analysis or meta-analysis.
- Narrative synthesis of key results may introduce bias; however, steps were taken to minimise this, including the review of all data by a second author.

INTRODUCTION

Rationale

The concept of a post-operative recovery room, or post anaesthesia care unit (PACU), was first described in 1847 [1], and the progression of surgical and anaesthetic techniques has seen marked advances in their form and function. However, there is a striking paucity of literature investigating the interventions undertaken in recovery, and their impact on patients after recovery room discharge. An editorial by C. Aps in 2004, discussed the concept of Overnight Intensive Recovery; where patients can be managed in the PACU for up to 24 hours[2], to avoid unnecessary intensive care unit (ICU) admissions and decrease cancellations due to lack of bed availability. This concept was introduced in the 1990s at St Thomas' Hospital, London[2]; and despite its apparent success, has not spawned further research surrounding such a model of care. Swart et al retrospectively examined the impact of the loss of access to a high dependency unit (HDU) for post-operative management of medium risk patients, and showed a significant increase in emergency laparotomies and unplanned critical care admissions[3]. However, the use of HDU for post-operative patients has also been associated with an increase in post-operative respiratory complications[4]. The concept of extended 6-hour recovery followed by a monitored ward bed, instead of an elective ICU admission post-operatively, has also shown to be safe, with no worsening in patient outcomes[5]. This review focusses on health services research, also known as health systems research; investigating models of care delivery, rather than single therapeutic interventions. Health systems research is a multidisciplinary field that examines access to, and the use, cost, quality, delivery, organisation, financing and outcomes of health care

services. This is used to identify new knowledge about the structure, processes, and effect of health systems for individuals and populations[6]. This is the first systematic review to provide a summary of all health system interventions provided in recovery, and their impact on patient outcomes after recovery room discharge. In presenting these finding, we hope to highlight the need for further research to help improve the care of patients in the post-operative period.

Objectives

The objective of this systematic review was to investigate any health system initiatives undertaken in operating suite recovery rooms, in the post-operative period, that have been shown to improve outcomes after PACU discharge, for adult, non-cardiac surgical patients. Important outcomes included mortality, morbidity, return to theatre, unplanned ICU admission and length of hospital stay. Prospective and retrospective randomised control trials, cohort studies, case control studies and comparison studies were included for analysis.

METHODS

Protocol and registration

A review protocol was developed in line with the Preferred Reporting of Observational Studies and Meta-Analysis (PRISMA) statement by the author team prior to commencing the systematic review. This protocol is registered on the International Prospective Register of Systematic Reviews (PROSPERO) database, registration number CRD42018106093.

Patient and Public Involvement

As this is a systematic review of pre-existing literature, patients and the public were not involved in study design. However, this systematic review forms part of a broader research topic on post-operative care, and how to face the challenge of increasing post-operative complication rates. In 2012, the WHO estimated the global volume of surgery to be 312.9 million operations, an increase of 38.2% compared to 2004, resulting in a mean global surgical rate of 4469 operations per 100 000 people per year [7]. With an ageing population and increasing prevalence of comorbidities, post-operative complications are now at pandemic levels [8]. Investigating alternative health care systems and care delivery models is paramount to combatting this issue. It should be apriority of both patients and service providers, as it has the potential to provide great benefit to the broader population.

Eligibility criteria

Included studies investigated health system initiatives in the PACU, in the post-operative period, up to 48 hours post-operatively. Adult patient groups were the primary focus, however, studies that included a small cohort of children were not automatically excluded. Studies that explored the relationship between interventions in recovery and mortality, morbidity, hospital length of stay, unplanned ICU admission and return to theatre were included. Varying study designs were eligible for inclusion; such as randomised control trials, cohort studies, case control studies and before and after studies. Cross-sectional studies and case reports were excluded. Only studies published from 1990 onwards were included, to focus on up to date clinical practice, and minimise the inclusion of irrelevant data. Studies published in a language other than English, grey literature and studies focussing solely on ambulatory surgery were excluded.

Information sources and search strategy

Medical Subject Headings (MeSH) terms were generated from the NCBI PubMed advanced search area with the assistance of the University of Adelaide Health Sciences librarian. Logic grids were used as a tool, to replicate the search throughout the three databases; NCBI PubMed, EMBASE, and Cumulative Index to Nursing and Allied Health Literature (CINAHL). The full electronic search strategy for the PubMed database is presented in Appendix 1. This search strategy was utilized across the three databases from 23/3/18 to 8/4/18 to yield the articles screened for inclusion in the review.

Study selection

Search results from each data base were recorded, and imported into EndNote 8 (Clarivate Analytics, Boston, USA). Key word searching was also performed to identify new studies that had not yet been assigned indexing terms for the databases. Reference lists from key articles were also reviewed to identify further papers that may have been relevant to the review. Titles and abstracts were screened by one reviewer (CL), who was not blinded to journal titles or to the study authors or institutions. Articles selected for full text review were reviewed by two reviewers (CL and GL), and any discrepancies arising regarding the relevance of a study were resolved by consulting a third party. The list of references for inclusion was sent to all authors to ensure consensus.

Data collection process

The Cochrane Data Extraction Template for Included Studies from their consumers and communication page, was used as a base for our data extraction form. This form was piloted on two initial studies for usability, with no further modifications required. One reviewer extracted the initial data from each study (CL), and this data was confirmed by a second reviewer (GL) before inclusion in

the review. One study only included data in pictorial form, and an attempt was made to contact the authors to obtain the raw data. Unfortunately, this was unsuccessful.

Data items

Data items extracted from each study included patient population and characteristics, intervention aims and methods, comparison groups and outcome measures. These data items are presented in the Characteristics of Included Studies Tables.

Risk of bias in individual studies

Risk of bias in individual studies was assessed by two reviewers (CL and GL) using Gate-Lite and Robins-I (previously known as A Cochrane Risk of Bias Assessment Tool: for Non-Randomized Studies of Interventions (ACROBAT-NRSI)). Narrative synthesis of data placed more weight on higher quality studies, however, all studies and their results are presented, with caveats to highlight the individual biases that will affect interpretations of results.

Summary measures and planned methods of analysis

Narrative synthesis of data was the principle summary measure. This was due to the differing study designs and variable outcome measures in each study. Meta-analysis was not appropriate for the data in this systematic review. All data is presented individually, in relation to each study, with further narrative synthesis to summarise results. Results from studies were unable to be combined due to the variation in primary and secondary outcome measures, and differences in study design. No additional analysis or subgroup analysis was performed during this systematic review.

Risk of bias across studies

Risk of bias across studies was assessed by two reviewers (CL and GL), using the Cochrane Risk of Bias Tool, and discussing any evident publication bias or selective reporting.

RESULTS

Study selection

Database results, and numbers of studies screened are presented in the flow diagram (Figure 1). All references were imported into EndNote 8 for title and abstract screening. One reviewer (CL) screened all titles and abstracts, with ambiguous studies included for full text review. 14 studies were selected for full text review. Full text reviews were completed by two reviewers (CL and GL),

and 8 studies were selected for inclusion in the review. A summary of included and excluded studies was sent to the third and fourth authors for consensus.

Study characteristics

Of the eight studies included, four of the included studies were retrospective cohort studies[9-12], two were observational cohort studies[13, 14], one was a prospective non-randomised pre-post intervention study[15], and one was a prospective randomised cohort study[16]. Study characteristics for each of the included studies are outlined in the Characteristics of Included Studies Summary Table (Table 1). Four studies investigated the use of PACU as a non-ICU pathway for post-operative patients[9, 11, 13, 14]. Two investigated the implementation of physiotherapy in PACU, and the impact on patient outcomes[12, 16]. One evaluated the use of a new nursing scoring tool, and its impact on recognition of patient deterioration in PACU[15], and one evaluated the implementation of a two-track clinical pathway in PACU, and the effect on patient outcomes[10]. All studies focussed primarily on adults, but one included small cohort of children[11]. Common outcome measures included in-hospital mortality, PACU length of stay and hospital length of stay. Further details regarding patient population characteristics, study methodology and outcome measures are also outlined in the supplementary tables published online (supplementary file).

Table 1. *Characteristics of Included Studies Summary Table*

Source	***Aim***	***Study Design***	***Number of arms/groups***	***Population***	***Intervention***	***Comparison group***	***Outcome measures***
Callaghan, Lynch et al. 2005 (n= 178)	To determine the safety of introducing non-ICU pathways for selected patients. And evaluate the effect on cost, ICU beds availability and cancellation rates of elective surgery.	Retrospective cohort study.	Intervention group: patients selected for overnight intensive recovery. Comparison group: patients booked for an elective ICU admission.	All patients undergoing elective open aortic surgery between 1/01/98 and 31/12/02.	(n= 152) Introduction of OIR (Overnight Intensive Recovery)	(n= 26) Elective post-operative ICU bed	In hospital mortality In hospital morbidity Post-operative length of stay ICU length of stay
Eichenberger, Haller et al. 2011 (n= 6375)	To assess the impact of a clinical pathway implemented in a post-anaesthesia care unit on post-operative outcomes.	Retrospective cohort study based on electronic patient records.	Fast track: nurse driven, ASA 1-2. Slow track: physician driven, ASA 3-5 who have undergone minor or major surgery, or developed post-op complications.	All elective and non-elective inpatients, who underwent a surgical or endoscopic procedure under anaesthesia during the study period.	(n= 3345) Introduction of a two-track clinical pathway that clearly defined & coordinated medical and nursing interventions.	(n= 3030) Pre-existing PACU conditions without the clinical pathway.	PACU length of stay In-hospital mortality Unplanned ICU admissions after PACU stay.

			Comparison group: Pre-existing PACU conditions without the clinical pathway.				
Fraser and Nair 2016 (n= 119)	To assess if elective surgical patients were stable enough to return to the general ward after a stay in Extended Recovery instead of being routinely admitted to ICU	Observational cohort study.	One arm. No control group	Elective surgical patients who would have previously been booked for level 2 care post-operatively.	(n= 119) Opening of an extended recovery unit.	Nil	Discharge destination after extended recovery unit admission
Kastrup, Seeling et al. 2012 (n= 51090)	To evaluate the effect of around-the-clock intensivist PACU coverage on the structure of ICU, and to demonstrate the economic effect on the hospital.	Retrospective cohort study.	Intervention group: after the introduction of 24-hour intensivist coverage. Comparison group: prior to introduction of 24-hour intensivist coverage.	All patients undergoing a surgical procedure (adults and children) between 1/01/08 – 30/04/11.	(n= 26118) Introduction of 24-hour intensivist coverage in PACU	(n= 24972) Pre-existing PACU with no intensivist coverage	PACU LOS ICU LOS Pre-operative days Hospital LOS Case mix index Cost
Schweizer, Khatchatourian et al. 2002 (n= 933)	To assess the impact of a new PACU on ICU utilisation, hospital length of stay and complications following major non-cardiac surgery.	Observational cohort study.	Intervention group: after opening of a new PACU. Control group: before opening of the new PACU	Adult patients undergoing abdominal aortic reconstruction or resection of lung cancer during the study periods.	(n= 485) Opening of a new PACU (post-anaesthesia care unit)	(n= 448) Pre-existing PACU	Mortality Reoperation Secondary admission to ICU Post-operative complications Hospital LOS
Street, Phillips et al. 2017 (n= 1417)	To evaluate whether use of a discharge criteria tool for nursing assessment of patients in PACU would enhance nurses' recognition and response to patients at-risk of deterioration and improve patient outcomes.	Prospective non-randomised pre-post intervention study.	Intervention group: after the implementation of the Post-Anaesthetic Care Tool (PACT) Comparison group: prior to the implementation of PACT.	All adult patients undergoing elective surgery on days of data collection.	(n= 694) Implementation of a Post Anaesthesia Care Tool (PACT)	(n= 723) Standard PACU care without PACT	Nursing management of symptoms Rates of adverse events Mortality PACU LOS Hospital LOS Health service usage and healthcare costs
Tayrose, Newman et al. 2013 (n= 900)	To address the impact of rapid rehabilitation beginning in the recovery room on length-of-	Retrospective cohort study.	Intervention group: rapid rehabilitation group. Comparison group: standard	900 consecutive hip and knee arthroplasty patients	(n= 331) Rapid rehabilitation pilot program where the first	(n= 569) Remainder of cases received standard rehabilitation	Overall hospital LOS Hip arthroplasty subgroup LOS Knee

	stay after primary hip and knee arthroplasty.		rehabilitation protocol		two cases of the day were mobilised in the recovery room.	protocol starting on the morning of post-operative day one.	arthroplasty subgroup LOS
Zoremba, Dette et al. 2009 (n= 60)	To evaluate the impact of short-term respiratory physiotherapy during the PACU stay, on postoperative lung function tests and pulse oximetry values in obese adults after minor surgery.	Prospective randomised cohort study	Intervention group: physical therapy treatment group that performed incentive spirometry in the PACU Control group: patients who did not undergo physical therapy	60 obese adult patients (BMI 30-40) ASA 2-3, scheduled for minor peripheral surgery.	(n= 30) Patients performed incentive spirometry in the PACU.	(n= 30) Not instructed to do any breathing exercises or spirometry.	Pulse oximetry and spirometry at 1, 2, 6 and 24 hours post-operatively

Risk of bias within studies

The overall risk of bias within studies was serious. Critical risk of bias was identified in two studies[12, 13], serious risk of bias in three studies[9, 14, 15], moderate risk of bias in one study[11] and low risk of bias in two studies[10, 16]. Significant patient selection and allocation bias was the most common identified cause[9, 11, 12, 14, 15]; as patients in these studies were not randomly allocated to their post-operative level of care. The most clinically unwell patients were sent to ICU automatically, and only the lower risk patients, as deemed by the treating teams, were allowed a trial of care in the PACU. The relatively small numbers of participants in each study, with the exception of Kastrup et al, also introduces a significant risk of bias; as these studies were not adequately powered to assess critical outcomes such as mortality, and other serious post-operative complications. Articles that were considered as being of serious and critical risk of bias, were still included in the review, due to the sparse literature available. The risk of bias summary table (Table 2) provides further analysis, and comment regarding the risk of bias within individual studies.

Table 2. *Risk of Bias Summary Table*

Source	*Bias Due to Confounding*	*Bias in Selection & Allocation of Participants*	*Bias in Measurement of Interventions*	*Bias Due to Departures from Intended Interventions*	*Bias Due to Missing Data*	*Bias in Measurement of Outcomes*	*Bias in Selection of Reported Results*	*Overall Risk of Bias Judgement*	*Comments*

Callaghan, Lynch et al. 2005	Low	Serious	Low	Moderate	Low	Moderate	Low	Serious	Significant selection bias of lower risk patients who were sent to OIR. Used predictive values for mortality (based on POSSUM variables) as a comparison measure.
Eichenberger, Haller et al. 2011	Low	Low	Low	Low	Low	Low	Low	Low	High quality study. No specific concerns from review authors.
Fraser and Nair 2016	Low	Moderate	Moderate	Moderate	Critical	Serious	Moderate	Critical	Over 25% of data missing. No clear objective stated, no explanation of methodology. Poorly defined selection criteria.
Kastrup, Seeling et al. 2012	Low	Serious	Low	Moderate	Low	Low	Low	Moderate	Significant selection bias of patients allocated to PACU, intermediate care unit or ICU by intensive care physician. This study also included a population of children (numbers not given).
Schweizer, Khatchatourian et al. 2002	Critical	Serious	Low	Low	Low	Low	Low	Serious	Introduction of preoperative risk assessment guidelines (AHA/ACC) with increased antiadrenergic administration pre-operatively confounds results. Significant selection bias, no admission criteria stated for PACU or ICU. Patient allocation was determined by treating clinician.

Street, Phillips et al. 2017	Low	Serious	Low	Moderate	Low	Serious	Critical	Serious	Power analysis included all patients (including day surgery) when investigating post-operative outcomes after PACU discharge, giving inaccurate results. Poor objective (with different objectives stated in the abstract and the article).
Bayrose, Newman et al. 2013	Low	Critical	Serious	Moderate	Low	Serious	Low	Critical	Patients who were deemed too unwell to be mobilised in recovery, were included in analysis for the standard recovery group. Operative order bias, by including the first two cases of the day. No methods reported for data collection.
Zoremba, Dette et al. 2009	Low	Low	Low	Low	Low	Low	Low	Low	Good quality study. However, does not address the longer-term outcomes of interest.

Results of individual studies

The results of each individual study are presented in the results of included study table (Table 3). Four studies[9, 11, 13, 14] investigated non-ICU pathways for care of post-operative patients, and these pathways were not associated with increased mortality rates in three of the included studies[9, 11, 14]. However, it must be noted that due to sample size, only one study [11] was adequately powered to show a reliable difference in mortality rates, and one study[13] did not investigate mortality as an outcome measure. Admission criteria for PACU care instead of ICU care post-operatively were only stated in two of the included studies[9, 11]. Callaghan et al outlined contraindications to use of Overnight Intensive Recovery; including significantly impaired renal function, technically difficult or prolonged surgery expected, poor exercise tolerance or likelihood of requiring post-operative ventilation. However, the selection of patients was ultimately at the discretion of the attending

anaesthetist and vascular surgeon. Kastrup et al only listed planned length of stay <24 hours as their admission criteria to PACU instead of ICU or the intermediate care unit. Fraser et al did not mention their admission criteria for extended recovery care[13], and Schweizer et al admitted patients to PACU instead of ICU purely at the discretion of the attending anaesthetist[14]. Four of eight studies also examined hospital length of stay [9, 11, 12, 14], and two found the intervention was associated with decreased length of stay and two found no association (Table 3). Kastrup et al demonstrated a significant decrease in length of stay for all surgical patients after their introduction of 24-hour intensivist coverage to the PACU [11]. Tayrose et al, also demonstrated a decreased length of stay for patients who received early mobilisation in PACU[12]. However, Callaghan et al and Schweizer et al did not demonstrate any statistically significant decrease in length of stay[9, 14]. PACU length of stay was another common outcome measure in three of the included studies[10, 11, 15]. Eichenberger et al demonstrated a decreased PACU length of stay for ASA 1-2 patients, but no difference for ASA3-5, while Kastrup et al and Street both demonstrated an increase in PACU length of stay following their interventions[11, 15]. Due to the variations in study designs, we were unable to combine the data for further aggregate analysis.

Table 3. *Results of Included Studies*

Source	***Intervention***	***Mortality***	***Other Key results***
Callaghan, Lynch et al. 2005	Introduction of OIR (Overnight Intensive Recovery)	No significant difference between groups. Overall in hospital mortality was 2%. fewer than predicted patients died (observed mortality 3 versus predicted 95% CI 8-21).	Morbidity: No significant difference between groups. Overall, fever than predicted patients experienced one or more complications (observed 101 versus predicted morbidity 103-125 95%CI) Hospital length of stay: No significant difference between groups
Eichenberger, Haller et al. 2011	Introduction of a two-track clinical pathway that clearly defined & coordinated medical and nursing interventions.	Overall in-hospital mortality decreased significantly from 68 patients (1.5%) to 39 patients (0.8%) (P<0.001). In ASA 3-5 patients, mortality was nearly halved (adjusted OR 0.40) (P< 0.001).	Unplanned ICU admission: Total number of unplanned ICU admissions after stay in PACU decreased from 113 (2.5%) to 90 (1.9%) (adjusted OR 0.70) (P=0.70) PACU length of stay: After adjustment for differenced in patients and procedures. Statistically significant decrease in PACU length of stay for ASA 1-2 patients (adjusted P< 0.001). There was no difference for ASA 3-5 patients (adjusted P= 0.768)
Fraser and Nair 2016	Opening of an extended recovery unit.	Not investigated	Discharge destination after extended recovery unit admission: Data from the first 119 patients admitted to the Extended Recovery unit were collected. 76 patients (63.9%) who would have otherwise gone to critical care were able to go back to the ward.
Kastrup, Seeling et al. 2012	Introduction of 24-hour intensivist coverage in PACU	No difference between groups	Hospital length of stay: Overall length of stay decreased significantly for all surgical patients. From 8.3 (+/- 11.8) days to 7.71 (+/- 10.99) days. PACU length of stay: More patients were treated in the PACU for a longer period of time. Mean LOS increased from 0.27 (+/- 0.2) days to 0.45 (+/- 0.41) days Cases treated in ICU: Mean number of cases treated in the ICU per month decreased significantly from 164.7 (+/- 14.37) to 133.8 (+/- 19.42) (P=<0.001) ICU treatment days: Mean number of treatment days per month did not change. Relative number of patients with longer LOS (>7 days) increased after introduction of PACU, whereas average number of patients staying <24 hours in the ICU decreased by ~50%.

Schweizer, Khatchatourian et al. 2002	Opening of a new PACU (post-anaesthesia care unit)	No difference between study periods	Morbidity: Vascular patients had decreased rates of myocardial infarction (6.4% vs 1.3% p=0.009) and decreased rates of pulmonary oedema (5.1% vs 1.7% p=0.08) Re-operation: No difference between study periods Hospital length of stay: Total hospital length of stay did not change over time
Street, Phillips et al. 2017	Implementation of a Post Anaesthesia Care Tool (PACT)	No significant difference between groups.	Patient management in PACU: More requests for medical review 19% vs 30% (P=<0.001), more patients with MET criteria modified by an anaesthetist 6.5% vs 13.8% (P<0.001), higher rates of analgesia administration37.3% vs 54.2% (P=0.001). Adverse events in PACU: More adverse events recorded in PACU in phase 2, 29.4% vs 21.2% (P<0.001). May represent a greater recognition of adverse events in PACU after implementation of PACT. Adverse events after PACU: Significant decrease in rates of clinical deterioration and significant decrease in cardiovascular events after PACU discharge. PACU length of stay: Increase in median PACU length of stay from 45min in phase 1 to 53min in phase 2 (P<0.001)
Tayrose, Newman et al. 2013	Rapid rehabilitation pilot program where the first two cases of the day were mobilised in the recovery room.	Not investigated	Overall hospital length of stay: Rapid rehabilitation had significantly decreased length of stay that patient who began therapy on post-op day 1 (P<0.001). Hip arthroplasty subgroup length of stay: Decreased length of stay for rapid rehab patients in the hip arthroplasty subgroup (P<0.001). Knee arthroplasty subgroup length of stay: Decreased LOS for rapid rehab patients in the knee arthroplasty subgroup (P=0.16).
Zoremba, Dette et al. 2009	Patients performed incentive spirometry in the PACU.	Not investigated	Pulse oximetry: Significantly improved pulse oximetry values at 1 and 2 hours in PACU, and at 6 hours post mobilisations (P<0.0001), and significant improvement in pulse oximetry values at 24 hours post-op (P<0.0001). Spirometry results: Incentive spirometry group recovered lung function faster in during the PACU stay (P<0.0001). Lung function had almost reached baseline at 6 hours in the incentive spirometry group, however the control group were up to 25% below baseline (P<0.0001). Overall difference in lung function between groups had decreased 24 hours after surgery, but significant differences still remained (P=0.0040).

Synthesis of results

The overall quality of studies was poor, with significant selection and allocation bias; however, managing post-operative patients outside of the ICU is not associated with worse patient outcomes, especially in an extended recovery setting. There was no increase in mortality rates identified in three of the studies investigating non-ICU pathways for post-operative patients[9, 11, 14], and the fourth did not investigate mortality as an outcome measure[13]. Use of extended recovery also meant that ward discharge was usual, bypassing the ICU[9, 13]. Kastrup et al showed that the addition of intensivist coverage to PACU was associated with decreased length of hospital stay, and Tayrose et al demonstrated that early mobilisation in PACU was associated with decreased length of hospital stay, but significant pre-selection bias for early mobilisation of arthroplasty patients confounds results[12]. Other changes to the PACU environment, including the opening of a new PACU[14] and introduction of Overnight Intensive Recovery[9] did not appear to have any effect on hospital length of stay. The use of a two-track pathway for nurse-driven and physician-driven PACU management and discharge appears to be beneficial in reducing PACU length of stay, and improving outcomes after discharge

from PACU, including a significant decrease in post-operative mortality[10]. However, introduction of a Post Anaesthetic Care Tool, and introduction of 24-hour intensivist coverage in PACU was associated with increased length of stay in PACU[11, 15]. While incentive spirometry in PACU did improve pulse oximetry values and lung function for the first 24 hours post-operatively, there were no long-term positive effects investigated, or identified[16]. It must be noted that the risk of bias of the included studies modifies results. Critical risk of bias was identified in two studies[12, 13], serious risk of bias in three studies[9, 14, 15], moderate risk of bias in one study[11] and low risk of bias in two studies[10, 16]. Only one of the included studies was adequately powered[11], and reliable conclusions cannot be drawn from single studies with such small datasets.

Risk of bias across studies and additional analyses

Risk of bias across studies for the key common outcome measures of mortality, hospital length of stay and PACU length of stay was high due to the study designs, with no level I or II evidence available. There was no additional analysis required for this review.

DISCUSSION

Summary of evidence

Of the eight studies included in this systematic review, only one was a prospective randomised cohort study[16], and one was a prospective non-randomised pre-post intervention study[15]. The rest were observational and retrospective cohort studies[9-14]. There was no level I or level II evidence available for inclusion in this review. Common outcome measures identified, included mortality, hospital length of stay and PACU length of stay. Despite the poor quality of evidence, we found that managing selected higher risk post-operative patients in the PACU instead of ICU was not associated with worse outcomes[9, 11, 13, 14], and may be associated with decreased unnecessary ICU admissions, with potential large cost savings. However, due to study types, small participant numbers, and the significant selection and allocation bias of patients within these studies, the overall strength of evidence is only moderate. The addition of intensivist coverage to PACU was associated with deceased hospital length of stay in one study [11], as was the rapid mobilisation of arthroplasty patients[12]. However, the introduction of overnight intensive recovery and the opening of a new PACU had no effect on hospital length of stay[9, 14]. The introduction of a two-track clinical pathway appeared to be associated with a decreased PACU length of stay[10], however the introduction of a Post Anaesthesia Care Tool and introduction of intensivist coverage was associated with increased PACU length of stay[11, 15]. Only one of the included studies was adequately powered [11], and we are unable to draw accurate conclusions from single studies with such small participant numbers. This has

significant implications for future research and health resource allocation. Further studies that prospectively randomly allocate patients to a treatment arm would be of great value, however, we acknowledge that due to the risk profile and care requirements of surgical patients, this may not be possible until further safety is proven.

Limitations

The protocol development and search strategy for this review were developed in accordance with the PRISMA statement. With help from experienced health science research librarians, we attempted to ensure that all references were captured; however, it is possible that studies were missed. Due to the variation in study design and primary outcome measures, we were unable to combine data for aggregate analysis or meta-analysis. The narrative synthesis of key results may introduce bias; however, steps were taken to minimise this, including the review of all data by a second author. The most significant limitation of this systematic review, was the high risk of bias within the individual studies included in the review. Selection and allocation bias, missing data, inclusion of inappropriate patient groups such as day surgery, and lack of fidelity assessment were some of the key flaws within each study. However, the thorough risk of bias assessment and its implications on reported results allows readers to interpret the data appropriately.

Conclusions

Managing selected post-operative patients in PACU instead of ICU does not appear to be associated with worse patient outcomes, however due to study design, and the high risk of bias within studies, the strength of evidence is moderate at best. The addition of intensivist coverage to PACU and early mobilisation was associated with decreased hospital length of stay. While the use of a two-track clinical pathway decreased PACU length of stay, however there is no evidence of this improving patients' overall outcomes. This is the first systematic review to investigate the health system initiatives undertaken in recovery rooms, and their impact on patient outcomes after PACU discharge. There is a striking paucity of literature on this topic, with very few high-quality studies; and further research is required to evaluate and improve the care of post-operative patients in the recovery room setting.

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COMPETING INTERESTS

No conflicts of interest known at the time of writing the review. Affiliations; The Royal Adelaide Hospital and the University of Adelaide.

AUTHOR STATEMENT

CL developed the review protocol, completed all title and abstract screening, full text reviews and data analysis. She completed the risk of bias assessment with GL. CL also drafted and revised the manuscript. GL developed the initial review question, and assisted writing the review protocol. He also completed the full text reviews, reviewed all data of included studies and completed the risk of bias assessment with CL. He also critically appraised the draft manuscript. DS assisted with developing the initial review question, and reviewed all included articles for consensus. He also critically appraised the draft manuscript, and assisted with revisions. GM reviewed all included articles for consensus, and critically appraised the manuscript. All authors have given final approval for publication. There were no other contributors.

DATA SHARING STATEMENT

There was no new data produced by this research. Data extracted from the original studies is available in the online supplementary tables.

FIGURE LEGEND

Figure 1: Flow diagram for selection of studies included in review

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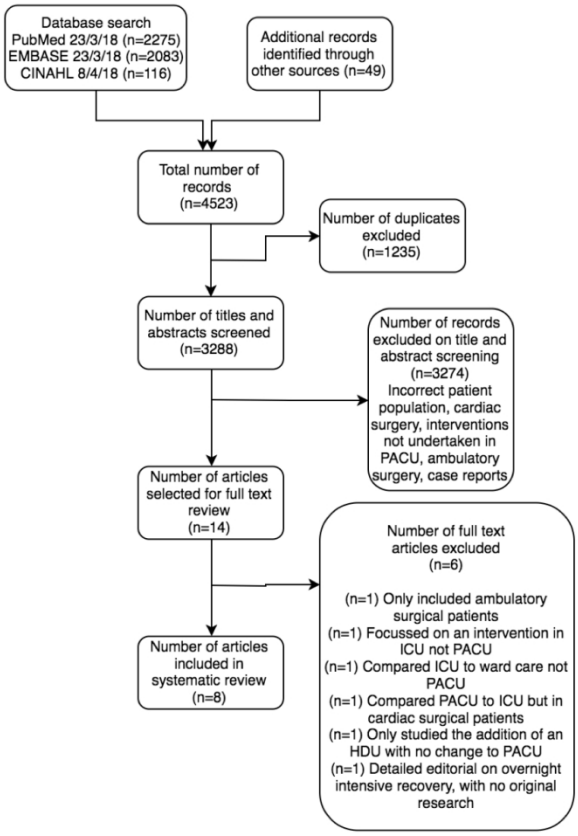

Figure 1

Appendix 1.

PubMed Electronic Search Strategy

Postoperative period	Adults	Recovery room	Patient outcomes
“Postoperative Period”[mh] OR Anesthesia[mh] OR "surgical procedures, operative"[mh] OR "perioperative period"[mh] OR “Postoperative period”[tiab] OR “post anaesthes*”[tiab] OR “post anesthes*”[tiab] OR postoperative[tiab] OR “post operative”[tiab] OR "Anesthesia recovery period"[tiab] OR "Anaesthesia recovery period"[tiab] OR anesthesia[tiab] OR anaesthesia[tiab] OR "surgical procedures"[tiab] OR surger*[tiab] OR operation*[tiab] OR operative[tiab] OR "perioperative period"[tiab]	“adult”[mh] OR adult*[tiab] OR elderly[tiab] OR “young adult*”[tiab] OR “young people”[tiab] OR “aged person”[tiab] OR “aged people”[tiab] OR senior*[tiab] OR frail[tiab]	“recovery room”[mh] OR PACU[tiab] OR “recovery room”[tiab] OR “advanced recovery room”[tiab] OR “extended recovery room”[tiab] OR “post anaesthesia care unit*”[tiab] OR “post anesthesia care unit*”[tiab] OR “postanaesthesia care unit*”[tiab] OR “postanesthesia care unit*”[tiab] OR “post operative recovery unit*”[tiab]	"Patient outcome assessment"[mh] OR "treatment outcome"[mh] OR mortality[mh] OR "length of stay"[mh] OR "postoperative complications"[mh] OR reoperation*[mh] OR "Patient outcome assessment"[tiab] OR "patient outcome*"[tiab] or outcome*[tiab] OR "treatment outcome"[tiab] OR mortality[tiab] OR "fatal outcome*"[tiab] OR morbidity[tiab] OR "length of stay"[tiab] OR "postoperative complications"[tiab] OR "return to theatre"[tiab] OR complication*[tiab] OR "intensive care"[tiab] OR "intensive care admission"[tiab] OR "health outcome"[tiab] OR "adverse event*"[tiab]

Characteristics of Included Studies Additional Tables

Participants additional table:

Source	*Location and Setting*	*Inclusion Criteria*	*Exclusion Criteria*	*Ages involved*	*Gender*	*Exclusion of important groups*	*Numbers involved*
Callaghan, Lynch et al. 2005	Addenbrooke's Hospital. Cambridge, United Kingdom. Cambridge vascular unit, OIR (based in PACU) and ICU, within a major teaching hospital and research centre.	All patients undergoing elective open aortic surgery between 1/01/98 and 31/12/02.	Patients with missing case notes.	Median age for all patients was 72 (66-77)	Intervention group 88% males. Comparison group 85% males.	No group appears to be excluded from the study. However, some multi-morbid patients were not offered surgery.	Intervention group n=152 Comparison group n=26
Eichenberger, Haller et al. 2011	Geneva hospital Switzerland. Post Anaesthesia Care Unit (PACU), within a tertiary teaching hospital.	All elective and non-elective inpatients, who underwent a surgical or endoscopic procedure under anaesthesia (including major surgery and high risk surgical patients required temporary NIV, haemodynamic support and continuous monitoring).	Exclusion: multi-trauma, persistent intraoperative shock, transplants, cardiac surgery and intra-operative respiratory failure.	Before period: <49yo 34.25%, 49-67yo 32.6%, >67yo 33.3% After period: <49yo 34.7%, 49-67yo 32.5%, >67yo 32.8%	Intervention group male 56.3% female 43.7% Comparison group male 55.9% female 44.1%	No groups excluded apart from those patients already specified in the exclusion criteria.	Intervention group n=3345 Comparison group n=3030
Fraser and Nair 2016	Northern General Hospital Sheffield, England. Extended recovery unit within a tertiary teaching hospital, major trauma centre.	Elective surgical patients who would have previously been booked for level 2 care post-operatively. Including patients with significant comorbidities, endovascular AAA repair, carotid endarterectomy and revision arthroplasty.	Not stated	Not stated	Not stated	No apparent exclusion of specific population groups. Not specifically addressed.	Intervention group n=119
Kastrup, Seeling et al. 2012	The Charite-University Hospital Campus Mitte Berlin, Germany. PACU within a large tertiary teaching hospital.	All patients undergoing a surgical procedure (adults and children) between 1/01/08 – 30/04/11	Ambulatory surgical patients, patients who were readmitted to hospital for the same reason as the initial admission (due to issues with accuracy of the administrative database)	Not given	Not stated	No apparent exclusion of specific population groups. Not specifically addressed.	Intervention group n=26118 Comparison group n=24972
Schweizer, Khatchatourian et al. 2002	The University Hospital of Geneva, Switzerland. PACU within a tertiary teaching hospital.	Adult patients undergoing abdominal aortic reconstruction or resection of lung cancer.	Exclusion criteria not stated	Not stated	Not stated	No apparent exclusion of specific population groups. Not specifically addressed.	Intervention group n= 485 Comparison group n= 448

Street, Phillips et al. 2017	Three hospitals within one Australian metropolitan healthcare organisation. PACUs within the three hospitals.	All adult patients undergoing elective surgery on days of data collection before and after the implementation of PACT (before period July-Oct 2012) (after period July-Sept 2014). (Half the patients were day surgery cases.)	Emergency surgery, minor procedure only requiring sedation, post-operative planned admission to ICU.	Intervention group: mean= 50.87 (SD 17.4) Comparison group: mean= 52.14 (SD 18.6)	Intervention group: male= 38.8%, female= 61.2% Comparison group: male= 41.6%, female= 58.4%	No specific groups appear to have been excluded from the study.	Intervention group n=694 Comparison group n=723
Tayrose, Newman et al. 2013	NYU hospital for Joint Diseases, New York. Recovery room and general orthopaedic ward.	900 consecutive hip and knee arthroplasty patients.	Not stated	Intervention group: mean= 63.7 Comparison group: mean= 64.3	Intervention group: male=225, female=206 Comparison group: male= 216, female=353	Unable to assess, and exclusion criteria are not stated.	Intervention group n=331 Comparison group n=569
Zoremba, Dette et al. 2009	University of Marburg, Germany. PACU within a tertiary teaching hospital.	60 obese adult patients (BMI 30-40) ASA 2-3, scheduled for minor peripheral surgery. Minimum surgery duration=40min, maximum surgery duration= 120 min.	Abdominal surgery, surgery requiring head-down tilt, history of GORD, hiatus hernia, likely difficult intubation, pregnancy, emergency operation, severe renal dysfunction, asthma requiring therapy, cardiac disease associated with dyspnoea (NYHA >2), severe psychiatric disorders or difficulties in cooperating during measurements.	Intervention group: mean 52 years Control group: mean 53 years	Not stated	Multimorbid patients with ASA >3 have been excluded (this is stated specifically in the exclusion criteria). All major surgery (including abdominal surgery) has also been intentionally excluded.	Intervention group n=30 Control group n=30

Interventions additional table:

Source	*Intervention name*	*Aims and rationale*	*Methods*	*Intervention delivery (staff and location)*	*Timing of intervention*	*Tailoring of intervention*	*Modifications made*	*Assessment of fidelity*
Callaghan, Lynch et al. 2005	Introduction of OIR (Overnight Intensive Recovery)	The majority of vascular surgical patients were routinely admitted to ICU post-operatively. However, several studies have demonstrated that extubation in theatre after AAA repair is safe[1] and that routine admission to ICU after infra-renal aortic surgery is unnecessary [2, 3].	Surgical patients assessed preoperatively by vascular surgeon and anaesthetist (ECG and full bloods). Patient referred to specialist if further pre-operative assessment is required. OIR located in theatre recovery. Maximum stay 24 hours. No facilities for mechanical ventilation or renal replacement therapy. Patients reviewed in the morning by surgical teams, and discharged to the ward if stable. If ongoing instability, patients transferred to ICU Face to face delivery of intervention No co-interventions apparent	Nurse to patient ratio 1:1 Day time medical coverage provided by PACU anaesthetist and vascular surgical teams. Overnight medical care provided by the on-call anaesthetist and general surgical teams. No specific training or upskilling period detailed. Pre-existing medical and nursing skills required	Intervention provided post-operatively for a maximum of 24 hours.	Post-operative medical care tailored to each patient. However, the OIR environment was not changed during the study.	OIR does not appear to have been modified or adapted during the study	No specific mention of steps taken to ensure fidelity in the OIR pathway. Anaesthetic techniques do appear to have been standardised, as well as post-operative analgesia.
Eichenberger, Haller et al. 2011	Introduction of a two-track clinical pathway that clearly defined & coordinated medical and nursing interventions.	Post-operative complications have a major impact on survival, especially in the older population [4, 5]. A clinical review of current practices prior to implementation of the pathway showed that poorly defined	Fast track pathway: nurse driven, ASA 1-2. At 15min intervals nursing staff evaluate patients' vitals using Aldrete score, and pain is assessed using verbal numeric rating scale. Slow track pathway: physician driven, ASA 3-	Fast-track programme: initial post-operative care prescribed by the anaesthetist and provided by the PACU nursing staff. Ongoing care is delivered by the PACU nursing staff only (unless	Fast-track programme: care provided immediately post-operatively. Discharge performed without further communication with the PACU anaesthetist if	Initial post-op treatment plan prescribed by the treating anaesthetist was tailored to the patient and their specific medical needs.	No adaptations appear to have been made to either pathway during the study period. However, this is not specifically discussed	Fast track pathway: methods of ensuring adherence to the pathway not discussed. Slow track pathway: adherence to the clinical pathway was ensured during daily rounds by the

		management and discharge criteria resulted in insecurity of the PACU physicians, nursing staff stress and delayed admission of patients from theatre. Evidence suggests that significant post-operative complications can be detected and successfully treated in well-organised PACUs, resulting in increased survival [6-9].	5 who have undergone minor or major surgery, or developed post-op complications. Formal handover to PACU anaesthetist. Standardised investigations and treatment guidelines for early post-operative complications. Intervention delivered face-to-face in PACU No co-interventions identified	there is evidence of a complication). Slow-track programme: care provided by the PACU anaesthetist with the help of nursing staff Pre-existing skills required: PACU specialist nursing staff (overnight nurse also ICU qualified). No specific training for either nursing staff or medical staff is detailed in the study.	Aldrete score is ≥ 8 and the verbal numeric rating scale is ≤ 3 Slow-track programme: care provided immediately pos-operatively. Discharge based on Aldrete score ≥8 and normal blood gas analysis. PACU physician in charge decides on discharge			medical head of the PACU, and during weekly quality control, feedback and information meetings.
Fraser and Nair 2016	Opening of an extended recovery unit	Was felt that some patients admitted to critical care post-operatively only required short term monitoring and optimisation [10]. Unnecessary admissions of patients to critical care increases bed occupancy in the unit, and was contributing to significant numbers of OT cancellations.	Extended Recovery Unit was opened in Oct 2014. Patients booked into the unit in advance. 4-6 hour stay. Standard form was completed by nursing staff for every patient: recording time and place of discharge, complications encountered and medical assistance required. (Recorded how many patients were assessed as safe to return to ward, and how many still required level 2 care) Nil co-interventions evident	Anaesthetists provided post-op medical care/ plans in the extended recovery unit. Recovery nursing staff provided care and completed the standard service evaluation form.	Patients stayed in the extended recovery unit for 4-6 hours post-op.	Not tailored	No	No mention of steps taken to ensure standardisation of treatment. Standard form provided to nursing staff, but no mention if forms were audited to ensure correct data collection.
Kastrup, Seeling et al. 2012	Introduction of intensivist coverage in PACU	Increasing demand for critical care, which can lead to capacity limitations in the ICU. This causes	PACU physician is in charge of allocation of patients to the PACU, ICU and IMCU (intermediate care unit)	Staffing of the PACU was changed so that both the nursing and physician staffing are covered by the ICU	Intervention provided immediately post-operatively.	Immediate post-operative care tailored to each patient by the treating	No apparent modification to the intervention were made	There is no mention of fidelity assessment. As intervention was a change in staffing

		delay in admissions of patients from ED, cancellation of surgery[11, 12], early discharge from ICU [11, 13-15], initiation of treatment in ED or on a standard ward and inter-hospital transfers [12, 16].	in collaboration with the surgeons. If no intensive care bed available, patients can be treated in the PACU for up to 24 hours (independent of the degree of organ failure) There are 6 beds with complete intensive care monitoring and respiratory care possibilities available. Face to face delivery of intervention No co intervention evident or discussed	team. The physician staffing was changed to a 24hr in-house critical care physician and nurse presence for the PACU. 1:3 nurse, patient ratio. 1 physician for all PACU patients.	Patients can be immediately admitted to the PACU around the clock (without any delays).	anaesthetist and surgeon.	during the study period.	model, this would have been monitored by the anaesthetist/ ICU physician in charge.
Schweizer, Khatchatourian et al. 2002	Opening of a new PACU (post-anaesthesia care unit)	Utilisation of the ICU for routine post-op care is commonplace, however ICUs account for an increasing proportion of a hospitals budget [17-19].	PACU moved to an area closer to theatres and the ICU, and was expended with additional beds to provide overnight care following major, non-cardiac surgery. Standardised rounding (morning and evening), with review of patient's clinical status, laboratory results and chest radiographs. Co-interventions: Preoperative risk assessment guidelines of the American Heart association and the American College of Cardiology (AHA/ACC) were introduced, and antiadrenergic medications (beta-blockers and alpha-2-agonists) were	New PACU staffed with anaesthesia-trained nurses (1:3 ratio), post-operative care coordinated by cardiothoracic surgical and anaesthesia teams, 24-hour medical coverage provided by one PACU resident (supervised by an attending).	New PACU provided 24-hour medical coverage. Patients were admitted immediately post-operatively. (Time limit on PACU admission not specified)	Post-operative care standardised as much as possible, but ongoing care tailored to each patient based on pre-existing medical comorbidities, intra-operative events and post-op complications	Intervention does not appear to have been altered during the study period	Variations in medical practice were minimised using standard protocols for blood test analysis, CXR orders, antibiotic prophylaxis, pain control, fluid administration, respiratory therapy, nutrition and mobilisation. All surgical procedures and approach standardised as much as possible. General anaesthesia standardised. Post-operative analgesia regimen also standardised.

			increasingly administered peri operatively					
Street, Phillips et al. 2017	Implementation of a Post Anaesthesia Care Tool (PACT)	Current post-operative death rate of 0.4-4%, and major complication rate of 3-17%. 40% of in-hospital complications are associated with surgery [20, 21]. Hospital costs for surgical patients experiencing a complication are significantly higher than for patients without complications [22-24]. Intensive observation of patients in PACU by nurses can help with the early detection of complications [25].	Implementation of the tool was supported by peri-operative nursing educators. Materials included posters summarising how to complete the PACT, and feedback sessions between the nurses using the tool and the perioperative team. PACT was included in the revised 'Post-anaesthetics care record' Working party was established to develop the tool. Extensive review of the current processes at each of the hospitals was done. Researchers conducted a systematic review and an expert consensus statement to evaluate the current evidence. PACT tool developed in line with the National Consensus Statement on the essential elements for recognising and responding to clinical deterioration. Face to face delivery of the intervention. No co-interventions apparent.	Perioperative nurse educators trained recovery nurses in the use of the tool. Feedback sessions during the training period were attended by the perioperative team including, educators, nurse unit managers and the quality unit of the organisation. Recovery nursing staff used the PACT in recovery. Medical staff responded to concerns that were triggered by the PACT	PACT used immediately post-operatively, until patient was safe for discharge to the ward (of home for day surgery patients). Patient readiness for discharge from PACU was recorded by a checklist of criteria: last 2 sets of observations were not within the MET criteria, no active vomiting, pain management ordered and all surgical concerns had been met.	Intervention does not appear to be tailored.	No modifications appear to have been made once the study period commenced.	Feedback sessions during the training period were attended by the perioperative team including, educators, nurse unit managers and the quality unit of the organisation. However, there is no mention of fidelity assessment or auditing once the tool was in use.
Tayrose, Newman et al. 2013	Rapid rehab patients started as part of a pilot	Previous studies have shown that early mobilisation after	Therapy program was the same for each group: therapist would	Physiotherapists delivered the intervention	Therapy commenced in the	Intervention was tailored to the speed of recovery	No adaptations or modifications appear to have	No assessment of fidelity reported. Unclear how the

	program where the first 2 cases of the day were mobilised in the recovery room.	total joint replacement enhances post-op recovery and promotes faster rehabilitation [26, 27]. Previous studies have also demonstrated early mobilisation leads to a decreased LOS, improve patient outcomes, and demonstrate cost savings [28-30]. However, it's unclear if early mobilisation that starts in the recovery room will lead to a reduction in LOS while maintaining patient outcomes.	start with having patients hang their legs over the side of the bed. Therapy would then progress with transferring to a chair, ambulation, and climbing stairs. The expectation for a patient was to ambulate 100 feet or greater, and climb 6 stairs, prior to discharge. Face to face delivery of intervention by physiotherapists No co-interventions described	Standard rehabilitation program implemented. Reliance of physiotherapists pre-existing skills and training.	recovery room on the day of surgery	of each patient. If a patient was unfit to mobilise on the day of surgery in PACU (as per the anaesthetist, surgeon or ICU doctor), they were not mobilised despite being one of the first 2 cases for the day.	occurred during the study.	standardisation of the rehabilitation program was ensured.
Zoremba, Dette et al. 2009	Patients performed incentive spirometry in the PACU	Even several days after surgery, obese patients exhibit a measurable amount of atelectasis, predisposing them to post-op pulmonary complications [31-35].	Physiotherapist supervised the respiratory physiotherapy treatment at all times. Exercises were started approximately 15 minutes after extubation, and the patients were encouraged to perform 15 deep breaths (incentive spirometry) every 10-15 minutes within the first 2 hours after surgery. If needed, patients were asked to cough during the pause to mobilise secretions. All therapy was performed in the sitting position if possible.	Physiotherapists supervised the respiratory physiotherapy treatment at all times Pre-existing skills required to deliver the intervention. No mention of specific training provided to the physiotherapists apart from the study protocol.	Intervention was delivered commencing 15 minutes post-operatively, continuing until 2 hours after surgery.	Intervention does not appear to have been tailored	No change to intervention during the study	Spirometry was standardised as much as possible. At each assessment time, spirometry was performed at least 3 times, and the best measurement was recorded (in line with the criteria of the European Respiratory Society). Factors that interfered with breathing (eg pain, shivering) were eliminated, or minimised to produce reliable measurements)

			No co-interventions described					

Outcomes and comparison groups additional table:

Source	*Primary outcomes*	*Method of assessing primary outcome measure*	*Timing of primary outcome assessment*	*Adverse events*	*Secondary outcomes*	*Method of assessing secondary outcome measure*	*Timing of secondary outcome measure*
Callaghan, Lynch et al. 2005	In hospital mortality In hospital morbidity Mean postoperative stay, days Mean ICU stay, days Median POSSUM operative severity score	Patients who had surgery were identified using a combination of computerized theatre records, surgeon's logbooks, and theatre booking diaries. Case notes analysed retrospectively. POSSUM variables collected prospectively (during the pre-operative assessment)	Retrospective analysis No follow-up required	OIR group: Admission to ICU within 48 hours of surgery	Operative characteristics. Common post-operative complications.	Case notes analysed retrospectively. Only complications occurring on more than four occasions during the study period are included.	Retrospective analysis of notes. No follow-up required.
Eichenberger, Haller et al. 2011	PACU length of stay	Anaesthetic Information system (computerize patient information system. PACU data entered by PACU nurses and PACU secretary)	Data entered in real time in PACU. Data reviewed retrospectively by investigators.	Nil reported	Nil reported	NA	NA
	In-hospital mortality	The hospital administrative database (administrative information used for financial purposes). Cause of death extracted from patient discharge reports, and entered into the administrative database by professional coders.	Data entered throughout the post-operative period until discharge. Data reviewed retrospectively by investigators				
	Unplanned ICU admissions after PACU stay	The hospital administrative database. Reason for unplanned ICU admission extracted from patient discharge report and entered into database by professional coders.	Data entered throughout the post-operative period. Reason for ICU admission entered after patient discharge.				
Fraser and Nair 2016	Discharge destination after extended recovery unit admission	Standard form completed by nursing staff in extended recovery, documenting time and place of discharge, complications encountered and medical assistance required.	Assessment made at time of extended recovery discharge. No follow-up done.	Nil reported	Nil reported	NA	NA

Kastrup, Seeling et al. 2012	LOS in PACU (days) LOS in ICU (all types of ICU's)(days) Pre operative days (all patients) Pre operative day (PACU-patients) Pre operative day (ICU-patients) Days on normal ward LOS hospital (days) CMI (case mix index) normal ward CM ICU CW (cost weight) per hospital stay (overall)	Data collected from the hospital administration system. All clinically relevant data are documented in a patient data management system (PDMS) and can be extracted for evaluations. Every patient admitted to the ICU in included in the system (COPRA-System® GmbH, Sasbachwalden, Germany). 24-hours after patient discharge, the record is changed to a read-only version so that no modifications can be made.	Retrospective analysis of data. Data continuously collected until patient discharge. No follow-up post-discharge.	Nil reported	General descriptive variables for the ICU, before and after the introduction of the PACU (ICU patients only).	Data extracted from patient data management system (PDMS). DRG system allows for coding of the intensive care as DRG procedure, making the severity of disease relevant for reimbursement. The "Complex intensive care treatment" is based on several scores, which are collected within the PDMS system.	Retrospective analysis of data. Data continuously collected until patient discharge. No follow-up post-discharge.
Schweizer, Khatchatourian et al. 2002	Mortality	Data prospectively collected on standardized worksheets describing the pre-operative, intraoperative and postoperative periods. One investigator also reviewed all nursing charts, medical records and hospital discharge letters.	Outcome assessments done during inpatient stay, and on review of the hospital data base. No follow-up required after hospital discharge	Nil reported	Identification of independent risk factors for mortality and major complications following thoracic surgery	Data abstracted from two institutional databases	Patient risk factors reported pre-operatively and intraoperatively (prospective data collection). Analysed at a later date
	Re-operation	Data abstracted from two institutional databases					
	Secondary admission to ICU (either from PACU or from the ward)	Data obtained from the hospital computer			Identification of independent risk factors for mortality and major complications following major vascular surgery		
	Cardiac complications • Myocardial infarct • Arrhythmias • Pulmonary oedema	Data were prospectively collected on standardized worksheets describing the pre-operative, intraoperative and postoperative periods. One investigator also reviewed all nursing charts, medical records and hospital discharge letters.					
	Respiratory complications • Atelectasis • Bronchopneumonia	As above			Evaluation of perioperative antiadrenergic treatment administration		
	Mechanical ventilation >6 hours	As above					
	Renal dysfunction	As above					

	Hospital length of stay	Data obtained from the hospital computer					
Street, Phillips et al. 2017	Nursing management of patient symptoms Rates of adverse events Mortality Length of stay in PACU Length of hospital admission Discharge destination	Data collected by research nurses from the medical record following patient discharge. Severity of each adverse event was graded using the Common Terminology Criteria for Adverse Events (V.4.03) and grouped into mild (no or minimal effect to the patient and resolved spontaneously), moderate (event with resolved after intervention, with no lasting effect for the patient) and severe (required intervention and caused harm to the patient, including death).	Data reviewed from case notes on patient discharge. No longer term follow-up required.	Nil reported	Health service usage and healthcare costs	Economic evaluation done from organization data that were routinely submitted to the regional health department for benchmarking. 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 was used to calculate the costs for all initial admissions and unplanned readmission, using the nations efficient price determination.	Data reviewed from case notes on patient discharge. No long term follow-up required.
Tayrose, Newman et al. 2013	Overall hospital length of stay Hip arthroplasty subgroup length of stay Knee arthroplasty subgroup length of stay	Retrospective review of cases, however it is not stated how this was done (case note reviews versus use of the hospital's database)	At time of discharge	Nil reported	Percentage completion of the rapid rehabilitation program	Progression of rehab was followed, however methods for assessing this were not stated.	Followed as an inpatient until the time of discharge.
Zoremba, Dette et al. 2009	Pulse oximetry at 1hr, 2hr, 6hr and 24hr post-operatively Spirometry at 1hr, 2hr, 6hr and 24hr post-operatively	Assessed face to face by an investigator. The investigators were blinded.	At 1hr, 2hr, 6hr and 24hr respectively	Nil reported	Nil reported	NA	NA

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PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	3
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	4
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	4
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	4
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	4
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	16
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	5
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	5
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	5
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	5
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	5
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	NA

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	6
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	NA
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	6
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	7
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	9-11
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	11-12
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	13
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	13
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	NA
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	13
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	14
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	14
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	15

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

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BMJ Open

"Organisation of delivery of care in operating suite recovery rooms within 48 hours postoperatively and patient outcomes after adult non-cardiac surgery: a systematic review."

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TITLE PAGE

"Organisation of delivery of care in operating suite recovery rooms within 48 hours postoperatively and patient outcomes after adult non-cardiac surgery: a systematic review."

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ABSTRACT

Context: Post-operative recovery rooms have existed since 1847, however there is sparse literature investigating interventions undertaken in recovery, and their impact on patients after recovery room discharge.

Objective: This review aimed to investigate the organisation of care delivery in post-operative recovery rooms; and its effect on patient outcomes; including mortality, morbidity, unplanned intensive care unit (ICU) admission and length of hospital stay.

Data sources: NCBI PubMed, EMBASE and CINAHL.

Study selection: Studies published since 1990, investigating health system initiatives undertaken in post-operative recovery rooms. One author screened titles and abstracts, with two authors completing full text reviews to determine inclusion based on pre-determined criteria. A total of 3288 unique studies were identified, with 14 selected for full text reviews, and 8 included in the review.

Data extraction: EndNote 8 (Clarivate Analytics) was used to manage references. One author extracted data from each study using a data extraction form adapted from the Cochrane Data Extraction Template, with all data checked by a second author.

Data synthesis: Narrative synthesis of data was the primary outcome measure, with all data of individual studies also presented in the summary results table.

Results: Four studies investigated the use of PACU as a non-ICU pathway for post-operative patients. Two investigated the implementation of physiotherapy in PACU, one evaluated the use of a new nursing scoring tool for detecting patient deterioration, and one evaluated the implementation of a two-track clinical pathway in PACU.

Conclusions: Managing selected post-operative patients in a PACU, instead of ICU, does not appear to be associated with worse patient outcomes, however due to the high risk of bias within studies, the strength of evidence is only moderate. Four of eight studies also examined hospital length of stay; two found the intervention was associated with decreased length of stay and two found no association.

Key words: Post-operative care, post-anaesthetic care, recovery room, post-anaesthetic care unit (PACU)

STRENGTHS AND LIMITATIONS OF THIS STUDY

- This is the first systematic review to provide a summary of the organisation of care delivery in recovery rooms and the impact on patient outcomes. It is a current area of interest for many hospitals/health networks, due to the frequency and cost of post-operative complications.
- The PRISMA statement was strictly adhered to, with a broad search strategy in an attempt to capture all relevant publications.
- The variation in study designs and primary outcome measures meant that we were unable to combine data for aggregate analysis or meta-analysis.
- Narrative synthesis of key results may introduce bias; however, steps were taken to minimise this, including the review of all data by a second author.

INTRODUCTION

Rationale

The concept of a post-operative recovery room, or post anaesthesia care unit (PACU), was first described in 1847 [1], and the progression of surgical and anaesthetic techniques has seen marked advances in their form and function. However, there is a striking paucity of literature investigating the interventions undertaken in recovery, and their impact on patients after recovery room discharge. An editorial by C. Aps in 2004, discussed the concept of Overnight Intensive Recovery; where patients can be managed in the PACU for up to 24 hours[2], to avoid unnecessary intensive care unit (ICU) admissions and decrease cancellations due to lack of bed availability. This concept was introduced in the 1990s at St Thomas' Hospital, London[2]; and despite its apparent success, has not spawned further research surrounding such a model of care. Swart et al retrospectively examined the impact of the loss of access to a high dependency unit (HDU) for post-operative management of medium risk patients, and showed a significant increase in emergency laparotomies and unplanned critical care admissions[3]. However, the use of HDU for post-operative patients has also been associated with an increase in post-operative respiratory complications[4]. The concept of extended 6-hour recovery followed by a monitored ward bed, instead of an elective ICU admission post-operatively, has also shown to be safe, with no worsening in patient outcomes[5]. This review focusses on health services research, also known as health systems research; investigating models of care delivery, rather than single therapeutic interventions. Health systems research is a multidisciplinary field that examines access to, and the use, cost, quality, delivery, organisation, financing and outcomes of health care

services. This is used to identify new knowledge about the structure, processes, and effect of health systems for individuals and populations[6]. This is the first systematic review to provide a summary of the organisation of care delivery in recovery, and its impact on patient outcomes after recovery room discharge. In presenting these finding, we hope to highlight the need for further research to help improve the care of patients in the post-operative period.

Objectives

The objective of this systematic review was to investigate any health system initiatives undertaken in operating suite recovery rooms, in the post-operative period, that have been shown to improve outcomes after PACU discharge, for adult, non-cardiac surgical patients. Important outcomes included mortality, morbidity, return to theatre, unplanned ICU admission and length of hospital stay. Prospective and retrospective randomised control trials, cohort studies, case control studies and comparison studies were included for analysis.

METHODS

Protocol and registration

A review protocol was developed in line with the Preferred Reporting of Observational Studies and Meta-Analysis (PRISMA) statement by the author team prior to commencing the systematic review. This protocol is registered on the International Prospective Register of Systematic Reviews (PROSPERO) database, registration number CRD42018106093.

Patient and Public Involvement

As this is a systematic review of pre-existing literature, patients and the public were not involved in study design. However, this systematic review forms part of a broader research topic on post-operative care, and how to face the challenge of increasing post-operative complication rates. In 2012, the WHO estimated the global volume of surgery to be 312.9 million operations, an increase of 38.2% compared to 2004, resulting in a mean global surgical rate of 4469 operations per 100 000 people per year [7]. With an ageing population and increasing prevalence of comorbidities, post-operative complications are now at pandemic levels [8]. Investigating alternative health care systems and care delivery models is paramount to combatting this issue. It should be apriority of both patients and service providers, as it has the potential to provide great benefit to the broader population.

Eligibility criteria

Included studies investigated health system initiatives in the PACU, in the post-operative period, up to 48 hours post-operatively. Adult patient groups were the primary focus, however, studies that included a small cohort of children were not automatically excluded. Studies that explored the relationship between interventions in recovery and mortality, morbidity, hospital length of stay, unplanned ICU admission and return to theatre were included. Varying study designs were eligible for inclusion; such as randomised control trials, cohort studies, case control studies and before and after studies. Cross-sectional studies and case reports were excluded. Only studies published from 1990 onwards were included, to focus on up to date clinical practice, and minimise the inclusion of irrelevant data. Studies published in a language other than English, grey literature and studies focussing solely on ambulatory surgery were excluded.

Information sources and search strategy

Medical Subject Headings (MeSH) terms were generated from the NCBI PubMed advanced search area with the assistance of the University of Adelaide Health Sciences librarian. Logic grids were used as a tool, to replicate the search throughout the three databases; NCBI PubMed, EMBASE, and Cumulative Index to Nursing and Allied Health Literature (CINAHL). The full electronic search strategy for the PubMed database is presented in Appendix 1. This search strategy was utilized across the three databases from 23/3/18 to 8/4/18 to yield the articles screened for inclusion in the review.

Study selection

Search results from each data base were recorded, and imported into EndNote 8 (Clarivate Analytics, Boston, USA). Key word searching was also performed to identify new studies that had not yet been assigned indexing terms for the databases. Reference lists from key articles were also reviewed to identify further papers that may have been relevant to the review. Titles and abstracts were screened by one reviewer (CL), who was not blinded to journal titles or to the study authors or institutions. Articles selected for full text review were reviewed by two reviewers (CL and GL), and any discrepancies arising regarding the relevance of a study were resolved by consulting a third party. The list of references for inclusion was sent to all authors to ensure consensus.

Data collection process

The Cochrane Data Extraction Template for Included Studies from their consumers and communication page, was used as a base for our data extraction form. This form was piloted on two initial studies for usability, with no further modifications required. One reviewer extracted the initial data from each study (CL), and this data was confirmed by a second reviewer (GL) before inclusion in

the review. One study only included data in pictorial form, and an attempt was made to contact the authors to obtain the raw data. Unfortunately, this was unsuccessful.

Data items

Data items extracted from each study included patient population and characteristics, intervention aims and methods, comparison groups and outcome measures. These data items are presented in the Characteristics of Included Studies Tables.

Risk of bias in individual studies

Risk of bias in individual studies was assessed by two reviewers (CL and GL) using Gate-Lite and Robins-I (previously known as A Cochrane Risk of Bias Assessment Tool: for Non-Randomized Studies of Interventions (ACROBAT-NRSI)). Narrative synthesis of data placed more weight on higher quality studies, however, all studies and their results are presented, with caveats to highlight the individual biases that will affect interpretations of results.

Summary measures and planned methods of analysis

Narrative synthesis of data was the principle summary measure. This was due to the differing study designs and variable outcome measures in each study. Meta-analysis was not appropriate for the data in this systematic review. All data is presented individually, in relation to each study, with further narrative synthesis to summarise results. Results from studies were unable to be combined due to the variation in primary and secondary outcome measures, and differences in study design. No additional analysis or subgroup analysis was performed during this systematic review.

Risk of bias across studies

Risk of bias across studies was assessed by two reviewers (CL and GL), using the Cochrane Risk of Bias Tool, and discussing any evident publication bias or selective reporting.

RESULTS

Study selection

Database results, and numbers of studies screened are presented in the flow diagram (Figure 1). All references were imported into EndNote 8 for title and abstract screening. One reviewer (CL) screened all titles and abstracts, with ambiguous studies included for full text review. 14 studies were selected for full text review. Full text reviews were completed by two reviewers (CL and GL),

and 8 studies were selected for inclusion in the review. A summary of included and excluded studies was sent to the third and fourth authors for consensus.

Study characteristics

Of the eight studies included, four of the included studies were retrospective cohort studies[9-12], two were observational cohort studies[13, 14], one was a prospective non-randomised pre-post intervention study[15], and one was a prospective randomised cohort study[16]. Study characteristics for each of the included studies are outlined in the Characteristics of Included Studies Summary Table (Table 1). Four studies investigated the use of PACU as a non-ICU pathway for post-operative patients[9, 11, 13, 14]. Two investigated the implementation of physiotherapy in PACU, and the impact on patient outcomes[12, 16]. One evaluated the use of a new nursing scoring tool, and its impact on recognition of patient deterioration in PACU[15], and one evaluated the implementation of a two-track clinical pathway in PACU, and the effect on patient outcomes[10]. All studies focussed primarily on adults, but one included small cohort of children[11]. Common outcome measures included in-hospital mortality, PACU length of stay and hospital length of stay. Further details regarding patient population characteristics, study methodology and outcome measures are also outlined in the supplementary tables published online (supplementary file).

Table 1. *Characteristics of Included Studies Summary Table*

Source	***Aim***	***Study Design***	***Number of arms/groups***	***Population***	***Intervention***	***Comparison group***	***Outcome measures***
Callaghan, Lynch et al. 2005 (n= 178)	To determine the safety of introducing non-ICU pathways for selected patients. And evaluate the effect on cost, ICU beds availability and cancellation rates of elective surgery.	Retrospective cohort study.	Intervention group: patients selected for overnight intensive recovery. Comparison group: patients booked for an elective ICU admission.	All patients undergoing elective open aortic surgery between 1/01/98 and 31/12/02.	(n= 152) Introduction of OIR (Overnight Intensive Recovery)	(n= 26) Elective post-operative ICU bed	In hospital mortality In hospital morbidity Post-operative length of stay ICU length of stay
Eichenberger, Haller et al. 2011 (n= 6375)	To assess the impact of a clinical pathway implemented in a post-anaesthesia care unit on post-operative outcomes.	Retrospective cohort study based on electronic patient records.	Fast track: nurse driven, ASA 1-2. Slow track: physician driven, ASA 3-5 who have undergone minor or major surgery, or developed post-op complications.	All elective and non-elective inpatients, who underwent a surgical or endoscopic procedure under anaesthesia during the study period.	(n= 3345) Introduction of a two-track clinical pathway that clearly defined & coordinated medical and nursing interventions.	(n= 3030) Pre-existing PACU conditions without the clinical pathway.	PACU length of stay In-hospital mortality Unplanned ICU admissions after PACU stay.

			Comparison group: Pre-existing PACU conditions without the clinical pathway.				
Fraser and Nair 2016 (n= 119)	To assess if elective surgical patients were stable enough to return to the general ward after a stay in Extended Recovery instead of being routinely admitted to ICU	Observational cohort study.	One arm. No control group	Elective surgical patients who would have previously been booked for level 2 care post-operatively.	(n= 119) Opening of an extended recovery unit.	Nil	Discharge destination after extended recovery unit admission
Kastrup, Seeling et al. 2012 (n= 51090)	To evaluate the effect of around-the-clock intensivist PACU coverage on the structure of ICU, and to demonstrate the economic effect on the hospital.	Retrospective cohort study.	Intervention group: after the introduction of 24-hour intensivist coverage. Comparison group: prior to introduction of 24-hour intensivist coverage.	All patients undergoing a surgical procedure (adults and children) between 1/01/08 – 30/04/11.	(n= 26118) Introduction of 24-hour intensivist coverage in PACU	(n= 24972) Pre-existing PACU with no intensivist coverage	PACU LOS ICU LOS Pre-operative days Hospital LOS Case mix index Cost
Schweizer, Khatchatourian et al. 2002 (n= 933)	To assess the impact of a new PACU on ICU utilisation, hospital length of stay and complications following major non-cardiac surgery.	Observational cohort study.	Intervention group: after opening of a new PACU. Control group: before opening of the new PACU	Adult patients undergoing abdominal aortic reconstruction or resection of lung cancer during the study periods.	(n= 485) Opening of a new PACU (post-anaesthesia care unit)	(n= 448) Pre-existing PACU	Mortality Reoperation Secondary admission to ICU Post-operative complications Hospital LOS
Street, Phillips et al. 2017 (n= 1417)	To evaluate whether use of a discharge criteria tool for nursing assessment of patients in PACU would enhance nurses' recognition and response to patients at-risk of deterioration and improve patient outcomes.	Prospective non-randomised pre-post intervention study.	Intervention group: after the implementation of the Post-Anaesthetic Care Tool (PACT) Comparison group: prior to the implementation of PACT.	All adult patients undergoing elective surgery on days of data collection.	(n= 694) Implementation of a Post Anaesthesia Care Tool (PACT)	(n= 723) Standard PACU care without PACT	Nursing management of symptoms Rates of adverse events Mortality PACU LOS Hospital LOS Health service usage and healthcare costs
Tayrose, Newman et al. 2013 (n= 900)	To address the impact of rapid rehabilitation beginning in the recovery room on length-of-	Retrospective cohort study.	Intervention group: rapid rehabilitation group. Comparison group: standard	900 consecutive hip and knee arthroplasty patients	(n= 331) Rapid rehabilitation pilot program where the first	(n= 569) Remainder of cases received standard rehabilitation	Overall hospital LOS Hip arthroplasty subgroup LOS Knee

	stay after primary hip and knee arthroplasty.		rehabilitation protocol		two cases of the day were mobilised in the recovery room.	protocol starting on the morning of post-operative day one.	arthroplasty subgroup LOS
Zoremba, Dette et al. 2009 (n= 60)	To evaluate the impact of short-term respiratory physiotherapy during the PACU stay, on postoperative lung function tests and pulse oximetry values in obese adults after minor surgery.	Prospective randomised cohort study	Intervention group: physical therapy treatment group that performed incentive spirometry in the PACU Control group: patients who did not undergo physical therapy	60 obese adult patients (BMI 30-40) ASA 2-3, scheduled for minor peripheral surgery.	(n= 30) Patients performed incentive spirometry in the PACU.	(n= 30) Not instructed to do any breathing exercises or spirometry.	Pulse oximetry and spirometry at 1, 2, 6 and 24 hours post-operatively

Risk of bias within studies

The overall risk of bias within studies was serious. Critical risk of bias was identified in two studies[12, 13], serious risk of bias in three studies[9, 14, 15], moderate risk of bias in one study[11] and low risk of bias in two studies[10, 16]. Significant patient selection and allocation bias was the most common identified cause[9, 11, 12, 14, 15]; as patients in these studies were not randomly allocated to their post-operative level of care. The most clinically unwell patients were sent to ICU automatically, and only the lower risk patients, as deemed by the treating teams, were allowed a trial of care in the PACU. The relatively small numbers of participants in each study, with the exception of Kastrup et al, also introduces a significant risk of bias; as these studies were not adequately powered to assess critical outcomes such as mortality, and other serious post-operative complications. Articles that were considered as being of serious and critical risk of bias, were still included in the review, due to the sparse literature available. The risk of bias summary table (Table 2) provides further analysis, and comment regarding the risk of bias within individual studies.

Table 2. *Risk of Bias Summary Table*

Source	*Bias Due to Confounding*	*Bias in Selection & Allocation of Participants*	*Bias in Measurement of Interventions*	*Bias Due to Departures from Intended Interventions*	*Bias Due to Missing Data*	*Bias in Measurement of Outcomes*	*Bias in Selection of Reported Results*	*Overall Risk of Bias Judgement*	*Comments*

Callaghan, Lynch et al. 2005	Low	Serious	Low	Moderate	Low	Moderate	Low	Serious	Significant selection bias of lower risk patients who were sent to OIR. Used predictive values for mortality (based on POSSUM variables) as a comparison measure.
Eichenberger, Haller et al. 2011	Low	Low	Low	Low	Low	Low	Low	Low	High quality study. No specific concerns from review authors.
Fraser and Nair 2016	Low	Moderate	Moderate	Moderate	Critical	Serious	Moderate	Critical	Over 25% of data missing. No clear objective stated, no explanation of methodology. Poorly defined selection criteria.
Kastrup, Seeling et al. 2012	Low	Serious	Low	Moderate	Low	Low	Low	Moderate	Significant selection bias of patients allocated to PACU, intermediate care unit or ICU by intensive care physician. This study also included a population of children (numbers not given).
Schweizer, Khatchatourian et al. 2002	Critical	Serious	Low	Low	Low	Low	Low	Serious	Introduction of preoperative risk assessment guidelines (AHA/ACC) with increased antiadrenergic administration pre-operatively confounds results. Significant selection bias, no admission criteria stated for PACU or ICU. Patient allocation was determined by treating clinician.

Street, Phillips et al. 2017	Low	Serious	Low	Moderate	Low	Serious	Critical	Serious	Power analysis included all patients (including day surgery) when investigating post-operative outcomes after PACU discharge, giving inaccurate results. Poor objective (with different objectives stated in the abstract and the article).
Bayrose, Newman et al. 2013	Low	Critical	Serious	Moderate	Low	Serious	Low	Critical	Patients who were deemed too unwell to be mobilised in recovery, were included in analysis for the standard recovery group. Operative order bias, by including the first two cases of the day. No methods reported for data collection.
Zoremba, Dette et al. 2009	Low	Low	Low	Low	Low	Low	Low	Low	Good quality study. However, does not address the longer-term outcomes of interest.

Results of individual studies

The results of each individual study are presented in the results of included study table (Table 3). Four studies[9, 11, 13, 14] investigated non-ICU pathways for care of post-operative patients, and these pathways were not associated with increased mortality rates in three of the included studies[9, 11, 14]. However, it must be noted that due to sample size, only one study [11] was adequately powered to show a reliable difference in mortality rates, and one study[13] did not investigate mortality as an outcome measure. Admission criteria for PACU care instead of ICU care post-operatively were only stated in two of the included studies[9, 11]. Callaghan et al outlined contraindications to use of Overnight Intensive Recovery; including significantly impaired renal function, technically difficult or prolonged surgery expected, poor exercise tolerance or likelihood of requiring post-operative ventilation. However, the selection of patients was ultimately at the discretion of the attending

anaesthetist and vascular surgeon. Kastrup et al only listed planned length of stay <24 hours as their admission criteria to PACU instead of ICU or the intermediate care unit. Fraser et al did not mention their admission criteria for extended recovery care[13], and Schweizer et al admitted patients to PACU instead of ICU purely at the discretion of the attending anaesthetist[14]. Four of eight studies also examined hospital length of stay [9, 11, 12, 14], and two found the intervention was associated with decreased length of stay and two found no association (Table 3). Kastrup et al demonstrated a significant decrease in length of stay for all surgical patients after their introduction of 24-hour intensivist coverage to the PACU [11]. Tayrose et al, also demonstrated a decreased length of stay for patients who received early mobilisation in PACU[12]. However, Callaghan et al and Schweizer et al did not demonstrate any statistically significant decrease in length of stay[9, 14]. PACU length of stay was another common outcome measure in three of the included studies[10, 11, 15]. Eichenberger et al demonstrated a decreased PACU length of stay for ASA 1-2 patients, but no difference for ASA3-5, while Kastrup et al and Street both demonstrated an increase in PACU length of stay following their interventions[11, 15]. Due to the variations in study designs, we were unable to combine the data for further aggregate analysis.

Table 3. *Results of Included Studies*

Source	***Intervention***	***Mortality***	***Other Key results***
Callaghan, Lynch et al. 2005	Introduction of OIR (Overnight Intensive Recovery)	No significant difference between groups. Overall in hospital mortality was 2%. fewer than predicted patients died (observed mortality 3 versus predicted 95% CI 8-21).	Morbidity: No significant difference between groups. Overall, fever than predicted patients experienced one or more complications (observed 101 versus predicted morbidity 103-125 95%CI) Hospital length of stay: No significant difference between groups
Eichenberger, Haller et al. 2011	Introduction of a two-track clinical pathway that clearly defined & coordinated medical and nursing interventions.	Overall in-hospital mortality decreased significantly from 68 patients (1.5%) to 39 patients (0.8%) (P<0.001). In ASA 3-5 patients, mortality was nearly halved (adjusted OR 0.40) (P< 0.001).	Unplanned ICU admission: Total number of unplanned ICU admissions after stay in PACU decreased from 113 (2.5%) to 90 (1.9%) (adjusted OR 0.70) (P=0.70) PACU length of stay: After adjustment for differenced in patients and procedures. Statistically significant decrease in PACU length of stay for ASA 1-2 patients (adjusted P< 0.001). There was no difference for ASA 3-5 patients (adjusted P= 0.768)
Fraser and Nair 2016	Opening of an extended recovery unit.	Not investigated	Discharge destination after extended recovery unit admission: Data from the first 119 patients admitted to the Extended Recovery unit were collected. 76 patients (63.9%) who would have otherwise gone to critical care were able to go back to the ward.
Kastrup, Seeling et al. 2012	Introduction of 24-hour intensivist coverage in PACU	No difference between groups	Hospital length of stay: Overall length of stay decreased significantly for all surgical patients. From 8.3 (+/- 11.8) days to 7.71 (+/- 10.99) days. PACU length of stay: More patients were treated in the PACU for a longer period of time. Mean LOS increased from 0.27 (+/- 0.2) days to 0.45 (+/- 0.41) days Cases treated in ICU: Mean number of cases treated in the ICU per month decreased significantly from 164.7 (+/- 14.37) to 133.8 (+/- 19.42) (P=<0.001) ICU treatment days: Mean number of treatment days per month did not change. Relative number of patients with longer LOS (>7 days) increased after introduction of PACU, whereas average number of patients staying <24 hours in the ICU decreased by ~50%.

Schweizer, Khatchatourian et al. 2002	Opening of a new PACU (post-anaesthesia care unit)	No difference between study periods	Morbidity: Vascular patients had decreased rates of myocardial infarction (6.4% vs 1.3% p=0.009) and decreased rates of pulmonary oedema (5.1% vs 1.7% p=0.08) Re-operation: No difference between study periods Hospital length of stay: Total hospital length of stay did not change over time
Street, Phillips et al. 2017	Implementation of a Post Anaesthesia Care Tool (PACT)	No significant difference between groups.	Patient management in PACU: More requests for medical review 19% vs 30% (P=<0.001), more patients with MET criteria modified by an anaesthetist 6.5% vs 13.8% (P<0.001), higher rates of analgesia administration37.3% vs 54.2% (P=0.001). Adverse events in PACU: More adverse events recorded in PACU in phase 2, 29.4% vs 21.2% (P<0.001). May represent a greater recognition of adverse events in PACU after implementation of PACT. Adverse events after PACU: Significant decrease in rates of clinical deterioration and significant decrease in cardiovascular events after PACU discharge. PACU length of stay: Increase in median PACU length of stay from 45min in phase 1 to 53min in phase 2 (P<0.001)
Tayrose, Newman et al. 2013	Rapid rehabilitation pilot program where the first two cases of the day were mobilised in the recovery room.	Not investigated	Overall hospital length of stay: Rapid rehabilitation had significantly decreased length of stay that patient who began therapy on post-op day 1 (P<0.001). Hip arthroplasty subgroup length of stay: Decreased length of stay for rapid rehab patients in the hip arthroplasty subgroup (P<0.001). Knee arthroplasty subgroup length of stay: Decreased LOS for rapid rehab patients in the knee arthroplasty subgroup (P=0.16).
Zoremba, Dette et al. 2009	Patients performed incentive spirometry in the PACU.	Not investigated	Pulse oximetry: Significantly improved pulse oximetry values at 1 and 2 hours in PACU, and at 6 hours post mobilisations (P<0.0001), and significant improvement in pulse oximetry values at 24 hours post-op (P<0.0001). Spirometry results: Incentive spirometry group recovered lung function faster in during the PACU stay (P<0.0001). Lung function had almost reached baseline at 6 hours in the incentive spirometry group, however the control group were up to 25% below baseline (P<0.0001). Overall difference in lung function between groups had decreased 24 hours after surgery, but significant differences still remained (P=0.0040).

Synthesis of results

The overall quality of studies was poor, with significant selection and allocation bias; however, managing post-operative patients outside of the ICU is not associated with worse patient outcomes, especially in an extended recovery setting. There was no increase in mortality rates identified in three of the studies investigating non-ICU pathways for post-operative patients[9, 11, 14], and the fourth did not investigate mortality as an outcome measure[13]. Use of extended recovery also meant that ward discharge was usual, bypassing the ICU[9, 13]. Kastrup et al showed that the addition of intensivist coverage to PACU was associated with decreased length of hospital stay, and Tayrose et al demonstrated that early mobilisation in PACU was associated with decreased length of hospital stay, but significant pre-selection bias for early mobilisation of arthroplasty patients confounds results[12]. Other changes to the PACU environment, including the opening of a new PACU[14] and introduction of Overnight Intensive Recovery[9] did not appear to have any effect on hospital length of stay. The use of a two-track pathway for nurse-driven and physician-driven PACU management and discharge appears to be beneficial in reducing PACU length of stay, and improving outcomes after discharge

from PACU, including a significant decrease in post-operative mortality[10]. However, introduction of a Post Anaesthetic Care Tool, and introduction of 24-hour intensivist coverage in PACU was associated with increased length of stay in PACU[11, 15]. While incentive spirometry in PACU did improve pulse oximetry values and lung function for the first 24 hours post-operatively, there were no long-term positive effects investigated, or identified[16]. It must be noted that the risk of bias of the included studies modifies results. Critical risk of bias was identified in two studies[12, 13], serious risk of bias in three studies[9, 14, 15], moderate risk of bias in one study[11] and low risk of bias in two studies[10, 16]. Only one of the included studies was adequately powered[11], and reliable conclusions cannot be drawn from single studies with such small datasets.

Risk of bias across studies and additional analyses

Risk of bias across studies for the key common outcome measures of mortality, hospital length of stay and PACU length of stay was high due to the study designs, with no level I or II evidence available. There was no additional analysis required for this review.

DISCUSSION

Summary of evidence

Of the eight studies included in this systematic review, only one was a prospective randomised cohort study[16], and one was a prospective non-randomised pre-post intervention study[15]. The rest were observational and retrospective cohort studies[9-14]. There was no level I or level II evidence available for inclusion in this review. Common outcome measures identified, included mortality, hospital length of stay and PACU length of stay. Despite the poor quality of evidence, we found that managing selected higher risk post-operative patients in the PACU instead of ICU was not associated with worse outcomes[9, 11, 13, 14], and may be associated with decreased unnecessary ICU admissions, with potential large cost savings. However, due to study types, small participant numbers, and the significant selection and allocation bias of patients within these studies, the overall strength of evidence is only moderate. Unfortunately, only two of the included studies stated the admission criteria for PACU care instead of ICU care post-operatively[9, 11], making the use of this finding to guide care difficult, with further research into risk stratification of patients needed. The addition of intensivist coverage to PACU was associated with deceased hospital length of stay in one study [11], as was the rapid mobilisation of arthroplasty patients[12]. However, the introduction of overnight intensive recovery and the opening of a new PACU had no effect on hospital length of stay[9, 14]. The introduction of a two-track clinical pathway appeared to be associated with a decreased PACU length of stay[10], however the introduction of a Post Anaesthesia Care Tool and introduction of intensivist

coverage was associated with increased PACU length of stay[11, 15]. Only one of the included studies was adequately powered [11], and we are unable to draw accurate conclusions from single studies with such small participant numbers. This has significant implications for future research and health resource allocation. Further studies that prospectively randomly allocate patients to a treatment arm would be of great value, however, we acknowledge that due to the risk profile and care requirements of surgical patients, this may not be possible until further safety is proven.

Limitations

The protocol development and search strategy for this review were developed in accordance with the PRISMA statement. With help from experienced health science research librarians, we attempted to ensure that all references were captured; however, it is possible that studies were missed. Due to the variation in study design and primary outcome measures, we were unable to combine data for aggregate analysis or meta-analysis. The narrative synthesis of key results may introduce bias; however, steps were taken to minimise this, including the review of all data by a second author. The most significant limitation of this systematic review, was the high risk of bias within the individual studies included in the review. Selection and allocation bias, missing data, inclusion of inappropriate patient groups such as day surgery, and lack of fidelity assessment were some of the key flaws within each study. However, the thorough risk of bias assessment and its implications on reported results allows readers to interpret the data appropriately.

Conclusions

Managing selected post-operative patients in PACU instead of ICU does not appear to be associated with worse patient outcomes, however due to study design, and the high risk of bias within studies, the strength of evidence is moderate at best. The addition of intensivist coverage to PACU and early mobilisation was associated with decreased hospital length of stay. While the use of a two-track clinical pathway decreased PACU length of stay, however there is no evidence of this improving patients' overall outcomes. This is the first systematic review to investigate the health system initiatives undertaken in recovery rooms, and their impact on patient outcomes after PACU discharge. There is a striking paucity of literature on this topic, with very few high-quality studies; and further research is required to evaluate and improve the care of post-operative patients in the recovery room setting.

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COMPETING INTERESTS

No conflicts of interest known at the time of writing the review. Affiliations; The Royal Adelaide Hospital and the University of Adelaide.

AUTHOR STATEMENT

CL developed the review protocol, completed all title and abstract screening, full text reviews and data analysis. She completed the risk of bias assessment with GL. CL also drafted and revised the manuscript. GL developed the initial review question, and assisted writing the review protocol. He also completed the full text reviews, reviewed all data of included studies and completed the risk of bias assessment with CL. He also critically appraised the draft manuscript. DS assisted with developing the initial review question, and reviewed all included articles for consensus. He also critically appraised the draft manuscript, and assisted with revisions. GM reviewed all included articles for consensus, and critically appraised the manuscript. All authors have given final approval for publication. There were no other contributors.

DATA SHARING STATEMENT

There was no new data produced by this research. Data extracted from the original studies is available in the online supplementary tables.

FIGURE LEGEND

Figure 1: Flow diagram for selection of studies included in review

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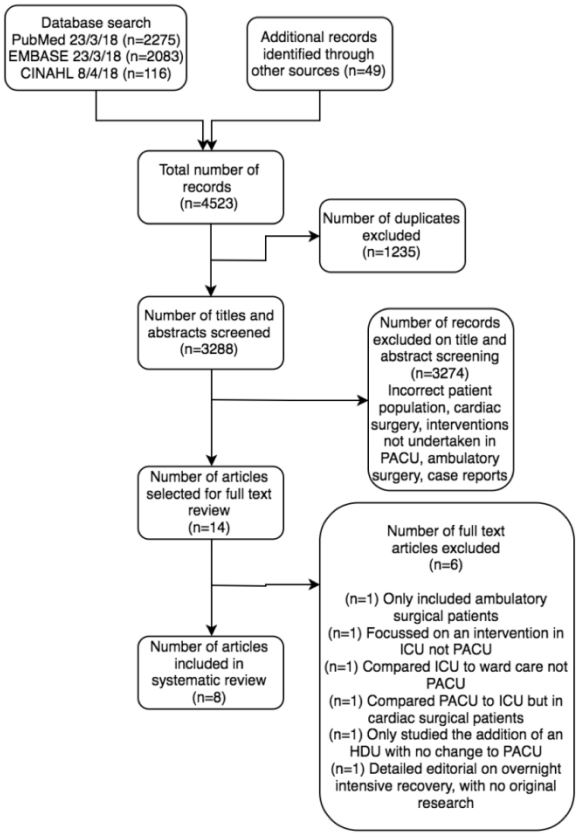

Figure 1

Appendix 1.

PubMed Electronic Search Strategy

Postoperative period	Adults	Recovery room	Patient outcomes
“Postoperative Period”[mh] OR Anesthesia[mh] OR "surgical procedures, operative"[mh] OR "perioperative period"[mh] OR “Postoperative period”[tiab] OR “post anaesthes*”[tiab] OR “post anesthes*”[tiab] OR postoperative[tiab] OR “post operative”[tiab] OR "Anesthesia recovery period"[tiab] OR "Anaesthesia recovery period"[tiab] OR anesthesia[tiab] OR anaesthesia[tiab] OR "surgical procedures"[tiab] OR surger*[tiab] OR operation*[tiab] OR operative[tiab] OR "perioperative period"[tiab]	“adult”[mh] OR adult*[tiab] OR elderly[tiab] OR “young adult*”[tiab] OR “young people”[tiab] OR “aged person”[tiab] OR “aged people”[tiab] OR senior*[tiab] OR frail[tiab]	“recovery room”[mh] OR PACU[tiab] OR “recovery room”[tiab] OR “advanced recovery room”[tiab] OR “extended recovery room”[tiab] OR “post anaesthesia care unit*”[tiab] OR “post anesthesia care unit*”[tiab] OR “postanaesthesia care unit*”[tiab] OR “postanesthesia care unit*”[tiab] OR “post operative recovery unit*”[tiab]	"Patient outcome assessment"[mh] OR "treatment outcome"[mh] OR mortality[mh] OR "length of stay"[mh] OR "postoperative complications"[mh] OR reoperation*[mh] OR "Patient outcome assessment"[tiab] OR "patient outcome*"[tiab] or outcome*[tiab] OR "treatment outcome"[tiab] OR mortality[tiab] OR "fatal outcome*"[tiab] OR morbidity[tiab] OR "length of stay"[tiab] OR "postoperative complications"[tiab] OR "return to theatre"[tiab] OR complication*[tiab] OR "intensive care"[tiab] OR "intensive care admission"[tiab] OR "health outcome"[tiab] OR "adverse event*"[tiab]

Characteristics of Included Studies Additional Tables

Participants additional table:

Source	*Location and Setting*	*Inclusion Criteria*	*Exclusion Criteria*	*Ages involved*	*Gender*	*Exclusion of important groups*	*Numbers involved*
Callaghan, Lynch et al. 2005	Addenbrooke's Hospital. Cambridge, United Kingdom. Cambridge vascular unit, OIR (based in PACU) and ICU, within a major teaching hospital and research centre.	All patients undergoing elective open aortic surgery between 1/01/98 and 31/12/02.	Patients with missing case notes.	Median age for all patients was 72 (66-77)	Intervention group 88% males. Comparison group 85% males.	No group appears to be excluded from the study. However, some multi-morbid patients were not offered surgery.	Intervention group n=152 Comparison group n=26
Eichenberger, Haller et al. 2011	Geneva hospital Switzerland. Post Anaesthesia Care Unit (PACU), within a tertiary teaching hospital.	All elective and non-elective inpatients, who underwent a surgical or endoscopic procedure under anaesthesia (including major surgery and high risk surgical patients required temporary NIV, haemodynamic support and continuous monitoring).	Exclusion: multi-trauma, persistent intraoperative shock, transplants, cardiac surgery and intra-operative respiratory failure.	Before period: <49yo 34.25%, 49-67yo 32.6%, >67yo 33.3% After period: <49yo 34.7%, 49-67yo 32.5%, >67yo 32.8%	Intervention group male 56.3% female 43.7% Comparison group male 55.9% female 44.1%	No groups excluded apart from those patients already specified in the exclusion criteria.	Intervention group n=3345 Comparison group n=3030
Fraser and Nair 2016	Northern General Hospital Sheffield, England. Extended recovery unit within a tertiary teaching hospital, major trauma centre.	Elective surgical patients who would have previously been booked for level 2 care post-operatively. Including patients with significant comorbidities, endovascular AAA repair, carotid endarterectomy and revision arthroplasty.	Not stated	Not stated	Not stated	No apparent exclusion of specific population groups. Not specifically addressed.	Intervention group n=119
Kastrup, Seeling et al. 2012	The Charite-University Hospital Campus Mitte Berlin, Germany. PACU within a large tertiary teaching hospital.	All patients undergoing a surgical procedure (adults and children) between 1/01/08 – 30/04/11	Ambulatory surgical patients, patients who were readmitted to hospital for the same reason as the initial admission (due to issues with accuracy of the administrative database)	Not given	Not stated	No apparent exclusion of specific population groups. Not specifically addressed.	Intervention group n=26118 Comparison group n=24972
Schweizer, Khatchatourian et al. 2002	The University Hospital of Geneva, Switzerland. PACU within a tertiary teaching hospital.	Adult patients undergoing abdominal aortic reconstruction or resection of lung cancer.	Exclusion criteria not stated	Not stated	Not stated	No apparent exclusion of specific population groups. Not specifically addressed.	Intervention group n= 485 Comparison group n= 448

Street, Phillips et al. 2017	Three hospitals within one Australian metropolitan healthcare organisation. PACUs within the three hospitals.	All adult patients undergoing elective surgery on days of data collection before and after the implementation of PACT (before period July-Oct 2012) (after period July-Sept 2014). (Half the patients were day surgery cases.)	Emergency surgery, minor procedure only requiring sedation, post-operative planned admission to ICU.	Intervention group: mean= 50.87 (SD 17.4) Comparison group: mean= 52.14 (SD 18.6)	Intervention group: male= 38.8%, female= 61.2% Comparison group: male= 41.6%, female= 58.4%	No specific groups appear to have been excluded from the study.	Intervention group n=694 Comparison group n=723
Tayrose, Newman et al. 2013	NYU hospital for Joint Diseases, New York. Recovery room and general orthopaedic ward.	900 consecutive hip and knee arthroplasty patients.	Not stated	Intervention group: mean= 63.7 Comparison group: mean= 64.3	Intervention group: male=225, female=206 Comparison group: male= 216, female=353	Unable to assess, and exclusion criteria are not stated.	Intervention group n=331 Comparison group n=569
Zoremba, Dette et al. 2009	University of Marburg, Germany. PACU within a tertiary teaching hospital.	60 obese adult patients (BMI 30-40) ASA 2-3, scheduled for minor peripheral surgery. Minimum surgery duration=40min, maximum surgery duration= 120 min.	Abdominal surgery, surgery requiring head-down tilt, history of GORD, hiatus hernia, likely difficult intubation, pregnancy, emergency operation, severe renal dysfunction, asthma requiring therapy, cardiac disease associated with dyspnoea (NYHA >2), severe psychiatric disorders or difficulties in cooperating during measurements.	Intervention group: mean 52 years Control group: mean 53 years	Not stated	Multimorbid patients with ASA >3 have been excluded (this is stated specifically in the exclusion criteria). All major surgery (including abdominal surgery) has also been intentionally excluded.	Intervention group n=30 Control group n=30

Interventions additional table:

Source	*Intervention name*	*Aims and rationale*	*Methods*	*Intervention delivery (staff and location)*	*Timing of intervention*	*Tailoring of intervention*	*Modifications made*	*Assessment of fidelity*
Callaghan, Lynch et al. 2005	Introduction of OIR (Overnight Intensive Recovery)	The majority of vascular surgical patients were routinely admitted to ICU post-operatively. However, several studies have demonstrated that extubation in theatre after AAA repair is safe[1] and that routine admission to ICU after infra-renal aortic surgery is unnecessary [2, 3].	Surgical patients assessed preoperatively by vascular surgeon and anaesthetist (ECG and full bloods). Patient referred to specialist if further pre-operative assessment is required. OIR located in theatre recovery. Maximum stay 24 hours. No facilities for mechanical ventilation or renal replacement therapy. Patients reviewed in the morning by surgical teams, and discharged to the ward if stable. If ongoing instability, patients transferred to ICU Face to face delivery of intervention No co-interventions apparent	Nurse to patient ratio 1:1 Day time medical coverage provided by PACU anaesthetist and vascular surgical teams. Overnight medical care provided by the on-call anaesthetist and general surgical teams. No specific training or upskilling period detailed. Pre-existing medical and nursing skills required	Intervention provided post-operatively for a maximum of 24 hours.	Post-operative medical care tailored to each patient. However, the OIR environment was not changed during the study.	OIR does not appear to have been modified or adapted during the study	No specific mention of steps taken to ensure fidelity in the OIR pathway. Anaesthetic techniques do appear to have been standardised, as well as post-operative analgesia.
Eichenberger, Haller et al. 2011	Introduction of a two-track clinical pathway that clearly defined & coordinated medical and nursing interventions.	Post-operative complications have a major impact on survival, especially in the older population [4, 5]. A clinical review of current practices prior to implementation of the pathway showed that poorly defined	Fast track pathway: nurse driven, ASA 1-2. At 15min intervals nursing staff evaluate patients' vitals using Aldrete score, and pain is assessed using verbal numeric rating scale. Slow track pathway: physician driven, ASA 3-	Fast-track programme: initial post-operative care prescribed by the anaesthetist and provided by the PACU nursing staff. Ongoing care is delivered by the PACU nursing staff only (unless	Fast-track programme: care provided immediately post-operatively. Discharge performed without further communication with the PACU anaesthetist if	Initial post-op treatment plan prescribed by the treating anaesthetist was tailored to the patient and their specific medical needs.	No adaptations appear to have been made to either pathway during the study period. However, this is not specifically discussed	Fast track pathway: methods of ensuring adherence to the pathway not discussed. Slow track pathway: adherence to the clinical pathway was ensured during daily rounds by the

		management and discharge criteria resulted in insecurity of the PACU physicians, nursing staff stress and delayed admission of patients from theatre. Evidence suggests that significant post-operative complications can be detected and successfully treated in well-organised PACUs, resulting in increased survival [6-9].	5 who have undergone minor or major surgery, or developed post-op complications. Formal handover to PACU anaesthetist. Standardised investigations and treatment guidelines for early post-operative complications. Intervention delivered face-to-face in PACU No co-interventions identified	there is evidence of a complication). Slow-track programme: care provided by the PACU anaesthetist with the help of nursing staff Pre-existing skills required: PACU specialist nursing staff (overnight nurse also ICU qualified). No specific training for either nursing staff or medical staff is detailed in the study.	Aldrete score is ≥ 8 and the verbal numeric rating scale is ≤ 3 Slow-track programme: care provided immediately pos-operatively. Discharge based on Aldrete score ≥8 and normal blood gas analysis. PACU physician in charge decides on discharge			medical head of the PACU, and during weekly quality control, feedback and information meetings.
Fraser and Nair 2016	Opening of an extended recovery unit	Was felt that some patients admitted to critical care post-operatively only required short term monitoring and optimisation [10]. Unnecessary admissions of patients to critical care increases bed occupancy in the unit, and was contributing to significant numbers of OT cancellations.	Extended Recovery Unit was opened in Oct 2014. Patients booked into the unit in advance. 4-6 hour stay. Standard form was completed by nursing staff for every patient: recording time and place of discharge, complications encountered and medical assistance required. (Recorded how many patients were assessed as safe to return to ward, and how many still required level 2 care) Nil co-interventions evident	Anaesthetists provided post-op medical care/ plans in the extended recovery unit. Recovery nursing staff provided care and completed the standard service evaluation form.	Patients stayed in the extended recovery unit for 4-6 hours post-op.	Not tailored	No	No mention of steps taken to ensure standardisation of treatment. Standard form provided to nursing staff, but no mention if forms were audited to ensure correct data collection.
Kastrup, Seeling et al. 2012	Introduction of intensivist coverage in PACU	Increasing demand for critical care, which can lead to capacity limitations in the ICU. This causes	PACU physician is in charge of allocation of patients to the PACU, ICU and IMCU (intermediate care unit)	Staffing of the PACU was changed so that both the nursing and physician staffing are covered by the ICU	Intervention provided immediately post-operatively.	Immediate post-operative care tailored to each patient by the treating	No apparent modification to the intervention were made	There is no mention of fidelity assessment. As intervention was a change in staffing

		delay in admissions of patients from ED, cancellation of surgery[11, 12], early discharge from ICU [11, 13-15], initiation of treatment in ED or on a standard ward and inter-hospital transfers [12, 16].	in collaboration with the surgeons. If no intensive care bed available, patients can be treated in the PACU for up to 24 hours (independent of the degree of organ failure) There are 6 beds with complete intensive care monitoring and respiratory care possibilities available. Face to face delivery of intervention No co intervention evident or discussed	team. The physician staffing was changed to a 24hr in-house critical care physician and nurse presence for the PACU. 1:3 nurse, patient ratio. 1 physician for all PACU patients.	Patients can be immediately admitted to the PACU around the clock (without any delays).	anaesthetist and surgeon.	during the study period.	model, this would have been monitored by the anaesthetist/ ICU physician in charge.
Schweizer, Khatchatourian et al. 2002	Opening of a new PACU (post-anaesthesia care unit)	Utilisation of the ICU for routine post-op care is commonplace, however ICUs account for an increasing proportion of a hospitals budget [17-19].	PACU moved to an area closer to theatres and the ICU, and was expended with additional beds to provide overnight care following major, non-cardiac surgery. Standardised rounding (morning and evening), with review of patient's clinical status, laboratory results and chest radiographs. Co-interventions: Preoperative risk assessment guidelines of the American Heart association and the American College of Cardiology (AHA/ACC) were introduced, and antiadrenergic medications (beta-blockers and alpha-2-agonists) were	New PACU staffed with anaesthesia-trained nurses (1:3 ratio), post-operative care coordinated by cardiothoracic surgical and anaesthesia teams, 24-hour medical coverage provided by one PACU resident (supervised by an attending).	New PACU provided 24-hour medical coverage. Patients were admitted immediately post-operatively. (Time limit on PACU admission not specified)	Post-operative care standardised as much as possible, but ongoing care tailored to each patient based on pre-existing medical comorbidities, intra-operative events and post-op complications	Intervention does not appear to have been altered during the study period	Variations in medical practice were minimised using standard protocols for blood test analysis, CXR orders, antibiotic prophylaxis, pain control, fluid administration, respiratory therapy, nutrition and mobilisation. All surgical procedures and approach standardised as much as possible. General anaesthesia standardised. Post-operative analgesia regimen also standardised.

			increasingly administered peri operatively					
Street, Phillips et al. 2017	Implementation of a Post Anaesthesia Care Tool (PACT)	Current post-operative death rate of 0.4-4%, and major complication rate of 3-17%. 40% of in-hospital complications are associated with surgery [20, 21]. Hospital costs for surgical patients experiencing a complication are significantly higher than for patients without complications [22-24]. Intensive observation of patients in PACU by nurses can help with the early detection of complications [25].	Implementation of the tool was supported by peri-operative nursing educators. Materials included posters summarising how to complete the PACT, and feedback sessions between the nurses using the tool and the perioperative team. PACT was included in the revised 'Post-anaesthetics care record' Working party was established to develop the tool. Extensive review of the current processes at each of the hospitals was done. Researchers conducted a systematic review and an expert consensus statement to evaluate the current evidence. PACT tool developed in line with the National Consensus Statement on the essential elements for recognising and responding to clinical deterioration. Face to face delivery of the intervention. No co-interventions apparent.	Perioperative nurse educators trained recovery nurses in the use of the tool. Feedback sessions during the training period were attended by the perioperative team including, educators, nurse unit managers and the quality unit of the organisation. Recovery nursing staff used the PACT in recovery. Medical staff responded to concerns that were triggered by the PACT	PACT used immediately post-operatively, until patient was safe for discharge to the ward (of home for day surgery patients). Patient readiness for discharge from PACU was recorded by a checklist of criteria: last 2 sets of observations were not within the MET criteria, no active vomiting, pain management ordered and all surgical concerns had been met.	Intervention does not appear to be tailored.	No modifications appear to have been made once the study period commenced.	Feedback sessions during the training period were attended by the perioperative team including, educators, nurse unit managers and the quality unit of the organisation. However, there is no mention of fidelity assessment or auditing once the tool was in use.
Tayrose, Newman et al. 2013	Rapid rehab patients started as part of a pilot	Previous studies have shown that early mobilisation after	Therapy program was the same for each group: therapist would	Physiotherapists delivered the intervention	Therapy commenced in the	Intervention was tailored to the speed of recovery	No adaptations or modifications appear to have	No assessment of fidelity reported. Unclear how the

	program where the first 2 cases of the day were mobilised in the recovery room.	total joint replacement enhances post-op recovery and promotes faster rehabilitation [26, 27]. Previous studies have also demonstrated early mobilisation leads to a decreased LOS, improve patient outcomes, and demonstrate cost savings [28-30]. However, it's unclear if early mobilisation that starts in the recovery room will lead to a reduction in LOS while maintaining patient outcomes.	start with having patients hang their legs over the side of the bed. Therapy would then progress with transferring to a chair, ambulation, and climbing stairs. The expectation for a patient was to ambulate 100 feet or greater, and climb 6 stairs, prior to discharge. Face to face delivery of intervention by physiotherapists No co-interventions described	Standard rehabilitation program implemented. Reliance of physiotherapists pre-existing skills and training.	recovery room on the day of surgery	of each patient. If a patient was unfit to mobilise on the day of surgery in PACU (as per the anaesthetist, surgeon or ICU doctor), they were not mobilised despite being one of the first 2 cases for the day.	occurred during the study.	standardisation of the rehabilitation program was ensured.
Zoremba, Dette et al. 2009	Patients performed incentive spirometry in the PACU	Even several days after surgery, obese patients exhibit a measurable amount of atelectasis, predisposing them to post-op pulmonary complications [31-35].	Physiotherapist supervised the respiratory physiotherapy treatment at all times. Exercises were started approximately 15 minutes after extubation, and the patients were encouraged to perform 15 deep breaths (incentive spirometry) every 10-15 minutes within the first 2 hours after surgery. If needed, patients were asked to cough during the pause to mobilise secretions. All therapy was performed in the sitting position if possible.	Physiotherapists supervised the respiratory physiotherapy treatment at all times Pre-existing skills required to deliver the intervention. No mention of specific training provided to the physiotherapists apart from the study protocol.	Intervention was delivered commencing 15 minutes post-operatively, continuing until 2 hours after surgery.	Intervention does not appear to have been tailored	No change to intervention during the study	Spirometry was standardised as much as possible. At each assessment time, spirometry was performed at least 3 times, and the best measurement was recorded (in line with the criteria of the European Respiratory Society). Factors that interfered with breathing (eg pain, shivering) were eliminated, or minimised to produce reliable measurements)

			No co-interventions described					

Outcomes and comparison groups additional table:

Source	*Primary outcomes*	*Method of assessing primary outcome measure*	*Timing of primary outcome assessment*	*Adverse events*	*Secondary outcomes*	*Method of assessing secondary outcome measure*	*Timing of secondary outcome measure*
Callaghan, Lynch et al. 2005	In hospital mortality In hospital morbidity Mean postoperative stay, days Mean ICU stay, days Median POSSUM operative severity score	Patients who had surgery were identified using a combination of computerized theatre records, surgeon's logbooks, and theatre booking diaries. Case notes analysed retrospectively. POSSUM variables collected prospectively (during the pre-operative assessment)	Retrospective analysis No follow-up required	OIR group: Admission to ICU within 48 hours of surgery	Operative characteristics. Common post-operative complications.	Case notes analysed retrospectively. Only complications occurring on more than four occasions during the study period are included.	Retrospective analysis of notes. No follow-up required.
Eichenberger, Haller et al. 2011	PACU length of stay	Anaesthetic Information system (computerize patient information system. PACU data entered by PACU nurses and PACU secretary)	Data entered in real time in PACU. Data reviewed retrospectively by investigators.	Nil reported	Nil reported	NA	NA
	In-hospital mortality	The hospital administrative database (administrative information used for financial purposes). Cause of death extracted from patient discharge reports, and entered into the administrative database by professional coders.	Data entered throughout the post-operative period until discharge. Data reviewed retrospectively by investigators				
	Unplanned ICU admissions after PACU stay	The hospital administrative database. Reason for unplanned ICU admission extracted from patient discharge report and entered into database by professional coders.	Data entered throughout the post-operative period. Reason for ICU admission entered after patient discharge.				
Fraser and Nair 2016	Discharge destination after extended recovery unit admission	Standard form completed by nursing staff in extended recovery, documenting time and place of discharge, complications encountered and medical assistance required.	Assessment made at time of extended recovery discharge. No follow-up done.	Nil reported	Nil reported	NA	NA

Kastrup, Seeling et al. 2012	LOS in PACU (days) LOS in ICU (all types of ICU's)(days) Pre operative days (all patients) Pre operative day (PACU-patients) Pre operative day (ICU-patients) Days on normal ward LOS hospital (days) CMI (case mix index) normal ward CM ICU CW (cost weight) per hospital stay (overall)	Data collected from the hospital administration system. All clinically relevant data are documented in a patient data management system (PDMS) and can be extracted for evaluations. Every patient admitted to the ICU in included in the system (COPRA-System® GmbH, Sasbachwalden, Germany). 24-hours after patient discharge, the record is changed to a read-only version so that no modifications can be made.	Retrospective analysis of data. Data continuously collected until patient discharge. No follow-up post-discharge.	Nil reported	General descriptive variables for the ICU, before and after the introduction of the PACU (ICU patients only).	Data extracted from patient data management system (PDMS). DRG system allows for coding of the intensive care as DRG procedure, making the severity of disease relevant for reimbursement. The "Complex intensive care treatment" is based on several scores, which are collected within the PDMS system.	Retrospective analysis of data. Data continuously collected until patient discharge. No follow-up post-discharge.
Schweizer, Khatchatourian et al. 2002	Mortality	Data prospectively collected on standardized worksheets describing the pre-operative, intraoperative and postoperative periods. One investigator also reviewed all nursing charts, medical records and hospital discharge letters.	Outcome assessments done during inpatient stay, and on review of the hospital data base. No follow-up required after hospital discharge	Nil reported	Identification of independent risk factors for mortality and major complications following thoracic surgery	Data abstracted from two institutional databases	Patient risk factors reported pre-operatively and intraoperatively (prospective data collection). Analysed at a later date
	Re-operation	Data abstracted from two institutional databases					
	Secondary admission to ICU (either from PACU or from the ward)	Data obtained from the hospital computer			Identification of independent risk factors for mortality and major complications following major vascular surgery		
	Cardiac complications • Myocardial infarct • Arrhythmias • Pulmonary oedema	Data were prospectively collected on standardized worksheets describing the pre-operative, intraoperative and postoperative periods. One investigator also reviewed all nursing charts, medical records and hospital discharge letters.					
	Respiratory complications • Atelectasis • Bronchopneumonia	As above			Evaluation of perioperative antiadrenergic treatment administration		
	Mechanical ventilation >6 hours	As above					
	Renal dysfunction	As above					

	Hospital length of stay	Data obtained from the hospital computer					
Street, Phillips et al. 2017	Nursing management of patient symptoms Rates of adverse events Mortality Length of stay in PACU Length of hospital admission Discharge destination	Data collected by research nurses from the medical record following patient discharge. Severity of each adverse event was graded using the Common Terminology Criteria for Adverse Events (V.4.03) and grouped into mild (no or minimal effect to the patient and resolved spontaneously), moderate (event with resolved after intervention, with no lasting effect for the patient) and severe (required intervention and caused harm to the patient, including death).	Data reviewed from case notes on patient discharge. No longer term follow-up required.	Nil reported	Health service usage and healthcare costs	Economic evaluation done from organization data that were routinely submitted to the regional health department for benchmarking. 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 was used to calculate the costs for all initial admissions and unplanned readmission, using the nations efficient price determination.	Data reviewed from case notes on patient discharge. No long term follow-up required.
Tayrose, Newman et al. 2013	Overall hospital length of stay Hip arthroplasty subgroup length of stay Knee arthroplasty subgroup length of stay	Retrospective review of cases, however it is not stated how this was done (case note reviews versus use of the hospital's database)	At time of discharge	Nil reported	Percentage completion of the rapid rehabilitation program	Progression of rehab was followed, however methods for assessing this were not stated.	Followed as an inpatient until the time of discharge.
Zoremba, Dette et al. 2009	Pulse oximetry at 1hr, 2hr, 6hr and 24hr post-operatively Spirometry at 1hr, 2hr, 6hr and 24hr post-operatively	Assessed face to face by an investigator. The investigators were blinded.	At 1hr, 2hr, 6hr and 24hr respectively	Nil reported	Nil reported	NA	NA

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PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	3
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	4
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	4
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	4
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	4
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	16
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	5
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	5
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	5
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	5
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	5
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	NA

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	6
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	NA
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	6
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	7
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	9-11
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	11-12
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	13
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	13
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	NA
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	13
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	14
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	14
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	15

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