Rapid Response Team Activation After Major Hip Surgery: Patient Characteristics and Outcomes

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Research article

Abstract

Background: Rapid Response Teams (RRT) are a critical care resource that reviews deteriorating patients within the hospital. Whilst contemporary literature has focused on outcomes of RRTs, little is known about the detailed perioperative course and characteristics of patients who require RRT activation after major hip surgery. We aimed to describe demographic, preoperative, surgical, anesthetic and postoperative characteristics of patients who required RRT activation after major hip surgery. We also sought to assess if these characteristics affected mortality during the index hospital admission.

Methods: We reviewed a RRT database of adult patients undergoing orthopedic surgery at a university teaching hospital. We then retrospectively reviewed the medical records to extract a priori defined patient, preoperative, surgical, anesthetic and postoperative data of major hip surgery admissions between September 2014 and December 2017. Patients who survived the index hospital stay were compared to those who died.

Results: Overall, 187 patients had a postoperative RRT activations. Mean (SD) age was 82.1 (11.6) years; 125 (67%) were female and most patients had at least one significant comorbidity: mean (SD) Charlson Comorbidity Index (CCI) of 5.6 (2.1). The majority of patients (68%) were frail, ASA class 3 or greater (91%) and underwent non-elective surgery (88%). Median (IQR) time from surgery to RRT activation was 29.4 hours (11.3:75.0), and 25 (13%) patients had unplanned admissions to ICU/HDU. Compared to patients who survived RRT activation, those who died displayed higher CCI [6.5 (1.8) vs. 5.5 (2.1); p=0.02], were more frail (80.1% vs. 56.5%; odds ratio 3.2; 95%CI: 1.2 to 8.1; p=0.03) and received less intraoperative opioids [median (IQR) intravenous morphine equi-analgesia 5.8 (0.1:8.2) mg vs. 11.7 (3.7:19.0) mg; p=0.03]. They were also more likely to receive an urgent medical review prior to RRT activation (62% vs 40%; odds ratio 2.4; 95%CI: 1.1 to 5.6; p=0.05).

Conclusions: Death after RRT activation occurred in 1 out of 7 patients undergoing major hip surgery. Common patient characteristics included advanced age (>82 years), frailty, high CCI and emergency surgery. Further studies investigating perioperative surveillance teams in the identification of the high-risk patients before surgery, and deteriorating patients after major hip surgery, are warranted.

Background

A Rapid Response Team (RRT) is an interdisciplinary team of critical care health professionals who manage deteriorating patients within the hospital (1). RRTs, also referred to as "Medical Emergency Teams" or "Emergency Response Teams" are commonplace in many modern hospitals. The composition of a RRT can include critical care physicians, anesthetists, critical care nurses and respiratory therapists (2). Major surgery poses a significant physiological challenge to patients, which in turn can predispose them to an increased risk of postoperative deterioration (3, 4). Past case-control and cross-sectional studies have implicated an array of preoperative and anesthetic factors that may be associated with postoperative patient deterioration and the need for RRT activation (5-7). However, these studies provide

insufficient information on patient characteristics, preoperative and postoperative anesthesia related variables, including perioperative hemodynamic data, use of fluid, vasoactive drugs, and opioid medications. Furthermore, no studies to date have specifically explored RRT activation in the setting of major hip surgery.

Therefore, we sought to describe the perioperative course of patients who underwent major hip surgery and required a postoperative RRT review. We describe patient characteristics, and the detailed preoperative, surgical, anesthetic and postoperative factors of patients who required RRT activation after major hip surgery in a university hospital. Specifically, we evaluate the effects of fluids, vasoactive medications and opioids on the development of RRT activation and assess if these perioperative characteristics affect mortality during the index hospital admission. In addition, we assess the incidence and severity of perioperative hypotension and whether this impacts adversely on in-hospital mortality. This in turn may facilitate the identification of patients at risk of postoperative deterioration, guide intraoperative patient management, and allow for a focused allocation of critical care and hospital resources, all of which may provide opportunities for proactive prevention strategies.

Methods

After Austin Health Human Research Ethics committee approval (LNR/17/Austin/616), we performed a retrospective cross-sectional study of patients who required RRT activation after major hip surgery over a consecutive 3-year period (Sept 2014 to Nov 2017). The need for informed written consent from participants was waived due to the observational and retrospective nature of the study. The study was conducted at Austin Health, a tertiary teaching hospital affiliated with the University of Melbourne in Melbourne, Victoria, Australia. Austin Health performs approximately 38,000 surgical procedures annually, including complex cardiothoracic surgery, hepatobiliary-pancreatic surgery, including liver transplantation, and major spinal and orthopedic surgery. The orthopedic surgical unit provides services to over 15,000 outpatients annually and performs over 2,500 operations per year, of which approximately 650 are major hip operations.

The RRT at our institution is an intensive care led service introduced 18 years ago (year 2000). The RRT is governed by the Department of Intensive Care Medicine, and the RRT team comprizes an intensive care registrar and critical care nurse. Escalation of medical resources to assist with the RRT activation are immediately available if required e.g. anesthesia support for airway management etc. At our institution, the RRT is activated whenever a patient meets predetermined criterion, which include acute changes in any of the following: conscious state; airway (noisy breathing/stridor); breathing (respiratory rate <8 or >30 breaths/min; pulse oximetry saturation <90% despite supplemental 10 litres/min oxygen therapy); circulation (heart rate <40 or >130 beats/min; systolic blood pressure <90 mmHg; urine output <50mL in 4 hours); bleeding (>100mL/hr); or if any member of staff is worried about the patient. In addition, an RRT is activated for any "code blue". A "code blue" is activated whenever a patient suffers a cardiac or respiratory arrest. Our institution's RRT reviews approximately 3000 patients annually, of which the majority are post-surgery.

For our study, inclusion criteria were adult patients (age greater 18 years) undergoing major hip surgery who had a RRT or "code blue" activation post-surgery, and within the index hospital admission. In the case of multiple RRT activations, we only analyzed the first event. We used the following International statistical Classification of Diseases (10th revision) coded procedures to select patients: total hip arthroplasty, partial hip replacement/hemi-arthroplasty (unipolar or bipolar femoral head), revision of hip replacement not otherwize specified, arthrotomy for removal of prosthesis, revision of hip replacement both acetabular and femoral components, revision of hip replacements (acetabular liner), resurfacing hip, total (acetabulum and femoral head), resurfacing hip (partial femoral head or acetabulum), and insertion or removal of any internal fixation device. We excluded superficial procedures of the hip joint including joint arthrocentesis and wound debridement.

As part of routine perioperative care for major hip surgery, patients were assessed by a multidisciplinary team consisting of surgeon, anesthetist, perioperative physician or ortho-geriatrician (if age >70 years). Routine preoperative investigations include biochemical, hematological and coagulation tests, and where necessary, all patients were optimized from a cardio-respiratory perspective prior to surgery. All patients underwent preoperative hemoglobin optimisation, based on the National Blood Authority of Australia's patient blood management initiative (8). When appropriate, standard perioperative care included strict transfusion practice in accordance with these guidelines. Further, as part of a Diabetes Discovery Initiative, all patients with a HbA1c of 8.3% (67 mmol/mol) and above were seen by the Endocrinology Unit, who generated a personalized plan for glycemic control according to our institution's guidelines. Patients with a HbA1c between 7.5% (58 mmol/mol) to 8.2% (66 mmol/mol), and those with newly diagnosed diabetes were seen by a general physician. All patients were managed according to the hospital's perioperative guidelines for patients with diabetes, with an inpatient blood glucose target of 5-10 mmol/L based on the Australian Diabetes Society guidelines (9). In addition, for patients with decision making capacity, an advance care plan is undertaken, which allows patients to communicate their future preferences relating to medical treatment, in advance, to their families, friends and health professionals. A legally defined 'person responsible' is appointed in accordance with existing legislation to make medical decisions on behalf of a patient who lacks the capacity to give their own consent to treatment.

Data were extracted from the patient's electronic medical records and form Austin Hospital's computerized laboratory results by two independent study investigators. Austin Health utilizes Cerner® electronic medical records that allows comprehensive electronic data capture and access to patient health information from the perioperative setting. We collected a priori defined data on patient characteristics, comorbidities and preoperative management. All other comorbidities were extracted from patient medical records. Patient comorbidity was further defined using the Charlson Comorbidity Index (CCI), a validated metric that predicts one-year patient mortality (10). For the calculation of the CCI, moderate/severe chronic kidney disease was defined as an estimated glomerular filtration rate of less than 60mL/min (Stage 3 or worse) and chronic liver disease was defined based on the Child-Pugh classification (11). Congestive cardiac failure was defined as any patient a history of documented heart

failure or ejection fraction of less than 40% on echocardiography. We used a modified Canadian Study of Health and Aging (CSHA) Clinical Frailty Scale to determine frailty (12).

Intraoperatively, we recorded type of procedure, anesthesia (regional or general) as well as use of fluids, vasoactive and opioid medications. Furthermore, the number of epochs of intraoperative hypotension, and the magnitude of each hypotensive event was recorded. Similar data was collected from the Post Anesthesia Care Unit (PACU). A hypotensive event was defined as any reduction in systolic, diastolic or mean arterial pressure by 30% as compared to preoperative values; severe hypotension was defined as a reduction in any of the above-mentioned blood pressures by 50%. The duration of hypotensive episodes was not assessed, and each hypotensive measure was counted as a discrete epoch. Postoperatively, we collected post-surgical discharge destination, indication for RRT activation, time to RRT activation from surgery as well as length of stay and in-hospital mortality.

Due to the exploratory and observational design of this study, our primary objectives were to describe the demographic and perioperative profile of patients who required RRT activation after major hip surgery. We also compared the perioperative characteristics of patient who survived the index hospital admission to those who did not. Specifically, we further explored differences between these two groups in the following a priori variables: i). preoperative comorbidities including frailty ii). type of anesthesia (general or regional) iii). elective or emergency surgery iv). perioperative hypotension and v). use of opioids and vasoactive drugs.

Statistical analysis

Continuously distributed data was tested for normality and measures of central tendency analysed. Normally distributed data was expressed as means and standard deviations (SD) and compared using a Student t-test; non-normally distributed data was expressed as medians and interquartile range (IQR) and compared using the Mann-Whitney U test. Categorical variables were described as proportions and compared using the chi-squared test or the Fisher Exact test. All p-values of less than 0.05 were treated as indicative as statistical significance and no correction for multiplicity of testing was undertaken due to the exploratory nature of the study. We reported this study using the STROBE guidelines for reporting observational studies (13). Analyses were performed using GraphPad Prism (version 7.00 for Mac, GraphPad Software, La Jolla California USA).

Results

Over the 3-year time period a total of 8094 patients underwent elective and non-elective orthopedic surgery at our institution. A total of 1825 patients underwent surgery on the hip. We excluded 39 patients who underwent minor/superficial hip procedures. A total of 1786 patients underwent major hip surgery, of which 187 (9%) had a postoperative RRT activation. Of these patients, 7 patients (3.7%) fulfilled criteria for a "code blue" activation. The consort flow diagram is presented in **Figure 1**.

Patients who had a RRT activation had a mean (SD) age and CCI of 82.1 (11.6) years and 5.6 (2.1), respectively. 125 (67%) patients were female. The majority of patients (60%) were frail, ASA class 3 or greater (91%) and underwent non-elective surgery (88%). The preoperative mean (SD) hemoglobin and albumin values were 119.5 (17.7) g/L and 31.2 (5.5) g/L, respectively. Median (IQR) preoperative creatinine was 85 (68:108) µmol/L. The median (IQR) time period from hospital admission to surgery was 24.7 (13.8:38.7) hours. The preoperative characteristics of patients undergoing major hip surgery are presented in **Table 1**.

The operative course of patients who underwent a RRT activation is summarized in **Table 2**. Most patients underwent hip arthroplasty, with 40% of these being total hip arthroplasty. One quarter had surgery out of hours (between 18h00 and 08h00, or over a weekend). Almost one in three patients had surgery performed under regional anesthesia, one third under general anesthesia, and the rest had a combined general and regional anesthesia. The median (IQR) duration of surgery was 128 minutes. Median (IQR) intraoperative intravenous morphine equi-analgesia dose was 10.0 mg, and a detailed breakdown of opioid use in outlined in **Table 2**. The mean (SD) lowest recorded temperature in theatre was 36.2 degrees Celsius.

During anesthesia, two thirds of patients received an arterial line as part of intraoperative advanced hemodynamic monitoring. Almost all patients received intraoperative vasopressor support and 58% had a documented intraoperative hypotensive event. Of those patients who were hypotensive, the median (IQR) number of hypotensive episodes was 3.5. A detailed overview is presented in **Table 3**.

Postoperatively, in the PACU, 10% of patients received vasopressor support and 45% of patients had a documented hypotensive episode; the median (IQR) number of hypotensive epochs was 2. An overview of hypotension and vasopressor use in PACU is presented in **Table 3**. Almost all patients were transferred directly to a standard surgical ward, and 7 (4%) patients directly to critical care services (ICU or HDU). The median (IQR) time to RRT activation from discharge from theatre was 29.4 hours. The majority of RRT activations occurred within the first 48 hours of surgery. The most common reason for RRT activation was hypotension (34%), followed by tachycardia (25%) and high respiratory rate (11%). Most of the RRT activations occurred after hours and 25 (13%) patients had unplanned admissions to critical care services (ICU or HDU) after RRT activation. Of those that survived, the median (IQR) length of hospital stay was 9 days. Overall, 26 (14%) patients did not survive their acute hospital admission and died a median (IQR) of 2.9 days after RRT review. A detailed overview of RRT activations and patient outcomes is presented in **Table 4**.

Patients who did not survive admission had a higher mean (SD) CCI score [6.5 (1.8) vs. 5.5 (2.1); p=0.02], were more likely to be frail (80.1% vs. 56.5%; odds ratio 3.2; 95%CI: 1.2 to 8.1; p=0.03), and received less intraoperative opioids [median (IQR) IV morphine equi-analgesia 5.8 (0.1:8.2) mg vs. 11.7 (3.7:19) mg; p=0.03]. Further, patients who did not survive admission were more like to require an urgent medical review prior to RRT activation (62% vs. 40%; odds ratio 2.4; 95%CI: 1.1 to 5.6; p=0.05), compared to those who survived. There were no significant differences observed between those who survived and those who

died in regard to type of surgery or anesthesia (regional vs. general), number of episodes of perioperative hypotension, use of vasoactive medications, inotropes or fluid therapy. Similarly, there was no observed statistical difference in the time from surgery to RRT activation, and unplanned admissions to critical care services (ICU or HDU).

Discussion

Key findings

We performed a retrospective observational study describing the perioperative characteristics of patients who required RRT activation after major hip surgery. We found that in-hospital mortality after RRT activation occurred in 1 out of 7 patients. Moreover, we found that common patient characteristics associated with such activation included advanced age (>82 years), frailty, high CCI and emergency surgery. Finally, we found that overall mortality was close to one in seven patients.

Relationship to other studies

To date, there are no studies investigating RRT activation after major hip surgery. There is also limited research focusing on the perioperative determinants of postoperative RRT activation after major surgery. Three studies have identified perioperative characteristics that have impacted on patient deterioration in the postoperative setting (5-7). Lee et al. conducted a retrospective case control study investigating early postoperative emergencies requiring an intensive care team intervention (7) with 34 RRT activations for 32 patients. RRT participants were matched with a nested cohort of 126 controls. Similar to our findings, there were significant preoperative associations with early RRT activation such as high ASA status. The authors did not report on frailty or detailed patient comorbidity, and the association with perioperative hypotension, and detailed anesthesia and surgical variable was not assessed.

Weingarten et al. performed a retrospective case control study investigating patient characteristics and outcomes associated with RRT activation in postsurgical patients (6). 181 patients were identified and matched to 318 controls. In contrast to our findings, which showed that approximately a quarter of our cohort had a RRT activation within the first 12 hours postoperatively, Weingarten et al. reported that greater than 60% of postoperative RRT activation occurred within the first 12 hours after discharge from theatre. In addition, and in contrast to our results, preoperative opioid use, history of central neurologic disease, and intraoperative hemodynamic instability were found to be associated with postoperative decompensation requiring RRT activation. Of the 181 patients who had a RRT activation in their study, only 62 (34%) underwent orthopedic surgery. The type of orthopedic surgery was not specified.

More recently, in a tertiary children's hospital, Barry et al. performed a retrospective review of 100 RRT calls occurring within 24 h of receiving anesthesia or procedural sedation (5). These patients' medical records were reviewed to obtain patient characteristics, etiology of the RRT call, and outcomes. Only nine patients (9%) underwent orthopedic surgery, and the type of orthopedic surgery was not specified. The authors reported that high ASA status, general anesthesia administration, and the presence of acute or

chronic conditions prior to anesthetic administration predispose a patient to perioperative complications resulting in the need for an RRT review. Generalisation to patients undergoing major hip surgery are limited by lack of detailed anesthesia and surgical variables reported. Further, the pediatric context and low prevalence of orthopedic patients presented in their study limits the generalisation to our adult population.

Study implications

Our findings show that patients who require RRT activation after major hip surgery have an in-hospital mortality of 14%. These patients are elderly, frail, with multiple comorbidities and likely to be undergoing non-elective surgery. Intraoperative hypotension and use of vasoactive medications is ubiquitous, and surgery is frequently being performed after hours. Specifically, mortality after RRT activation following major hip surgery in our institution occurred in a significantly high-risk patient cohort, with a patient profile of advanced age (>82 years), frailty and a high CCI being pervasive. Further, despite these important risks, these patients have no structured critical care support. The identification of such patients may allow effective preoperative risk stratification, optimisation of medical comorbidity, and proactive planning regarding advanced care directives, and increased postoperative monitoring. Interestingly, we found that surgical factors, including type or duration of surgery, and anesthesia factors, including type of anesthesia, intraoperative hemodynamics, opioid use, and vasopressor use did not differentiate between patients who survived or died after RRT activation.

There has been a strong association reported between postoperative RRT activation and after-hours surgery (7), however in our study the majority of surgeries (77%) were undertaking during normal working hours. Further, almost all patients that required RRT activation were discharged postoperatively to a general surgical ward, and over one third of our patient cohort required an urgent medical review prior to RRT activation. These findings may be of particular interest to perioperative clinicians and health organisations as they highlight opportunities for patient risk stratification and appropriate allocation of critical care resources (HDU or ICU) in the postoperative setting. Our findings further highlight the need for enhanced postoperative ward surveillance, and more effective early warning systems detecting postoperative patient deterioration.

We report on detailed perioperative hemodynamic variables, in particular the use of invasive hemodynamic monitoring, rate of perioperative hypotension and use of fluid and vasoactive medications. Hypotension has been reported to be the most common indication for RRT activation in adult post-surgical patients (6, 7). There is mounting interest in intraoperative hypotension and its strong association with postoperative morbidity and mortality (14, 15). Over half of our patients experienced an episode of intraoperative hypotension, with 9% of patients having a severe hypotensive event. The almost ubiquitous use of invasive blood pressure monitoring possibly allowed for timely identification and treatment of perioperative hypotension, reflected in the frequent use of vasopressor medication, which was administered in nearly all patients (88%). The use of a regional technique is 69% of patients may also have impacted on the frequency of vasoactive medication use. Postoperatively, in the PACU almost

half of the patients had a documented hypotensive event and only 10% of patients required vasopressor support. Intraoperative vasopressor use has been associated with postoperative RRT requirement (6). We also identified that patients who died received a lesser intravenous morphine equi-analgesia dose, compared to those who survived. This likely reflects the more advanced age and significantly higher comorbidity profile in these patients.

Strengths and limitation

There are several strengths and limitations of this study. This is a single-centre study of patients undergoing major hip surgery, performed in a high-volume centre for orthopedic surgery, which limits the external validity of our findings to other institutions, and to other types of surgery. Importantly, given the exploratory design of this study, we only collected data on patients who had a RRT activation after major hip surgery. We did not compare these patients to those who underwent similar surgeries who did not have a RRT activation, which limits the broad application of our findings to all patients undergoing hip surgery.

Our study also has several strengths. To date this is the largest review of patients undergoing RRT activation after major hip surgery combined specifically with detailed patient, surgical and anesthesia factors that describe the perioperative course of patients. The collection of data on detailed preoperative co-morbid conditions, including frailty, provides a comprehensive evaluation of the baseline health characteristics of our patient population. The detailed overview and rates of hypotension, vasopressor use, and use of opioids provide an in-depth insight of this patient cohort and their perioperative journey. By reporting the rate of RRT activation and mortality in these patients, we have defined both a need for enhanced postoperative ward surveillance, and more effective early warning systems detecting postoperative patient deterioration. Our findings are hypothesis generating and may provide valuable data for power calculations for future studies on RRT activation in the major orthopedic setting. Given the exploratory nature of the study, we cannot establish a causal relationship between the perioperative variables we assessed and the impact of these on RRT activations or any other postoperative outcomes. However, we provide an in-depth insight comparing patients who survived hospital admission to those who died. This may provide data for sample size calculations for future RRT prospective studies.

Conclusion

Death after RRT activation occurred in 1 out of 7 patients who had undergone major hip surgery in a tertiary referral hospital. We have identified several important findings relevant to RRT activation after major hip surgery. Most patients were elderly (>82 years), frail, with high CCI and undergoing out of hours emergency surgery. Our findings suggest that surgical (type or duration of surgery) and anesthesia (type of anesthesia, intraoperative hemodynamics, opioid use, vasopressor use) factors did not differentiate between patients who died or survived after RRT activation. Given the high rate of RRT activation and high mortality rate after these activations, the findings, specific to major orthopedic surgery, provide good

opportunities for the implementation of strategies aimed at improving postoperative outcomes in these at-risk patients.

Abbreviations

RRT: Rapid Response Team

CCI: Charlson Comorbidity Index

CSHA: Canadian Study of Health and Aging

PACU: Post Anesthesia Care Unit

SD: Standard Deviation

IQR: Interquartile Range

ASA: American Society of Anesthesiologists

ICU: Intensive Care Unit

HDU: High Dependency Unit

IV: Intravenous

Declarations

Ethics approval and consent to participate

Ethics approval was given by the Austin Health Human Research Ethics committee (LNR/17/Austin/616) prior to initiation of the study. The need for informed written consent from participants was waived due to the observational and retrospective nature of the study.

Consent for publication

Not applicable.

Availability of data and material

The datasets generated and analysed during the study are not publicly available due to individual privacy concerns but are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Tables

Table 1. Characteristics and preoperative management of patients undergoing major hip surgery requiring rapid response team activation.

	Total (n=187)	Survived (n=161)	Did not survive (n=26)	P-value
Demographics				
Male	62 (33%)	52 (32%)	10 (38%)	0.65
Female	125 (67%)	109 (68%)	16 (62%)	
Age (years) mean, (SD), min, max	82.1 (11.6), 20, 100	81.6 (12.0), 20, 100	85.5 (8.77), 56, 99	0.18
BMI (Kg/m^2)	24.7 (6.2)	25.0 (6.2)	23.2 (6.3)	0.29
Residence				
Home	128 (68%)	113 (70%)	15 (58%)	0.09
Low level care	39 (21%)	34 (21%)	5 (19%)	
High level care	20 (11%)	14 (9%)	6 (23%)	
Frailty (modified CSHA)				
Fit, well or vulnerable	74 (40%)	70 (43%)	5 (19%)	
Frail (mild, moderate or severe	113 (60%)	91 (57%)	21 (81%)	0.03
ASA				
<3	17 (9%)	16 (10%)	1 (4%)	0.48
>=3	170 (91%)	145 (90%)	25 (96%)	
1	1 (0.5%)	1 (0.6%)	0	0.13
2	16 (9%)	15 (9%)	1 (4%)	
3	110 (59%)	98 (61%)	12 (46%)	
4	60 (32%)	47 (29%)	13 (50%)	
Presentation				
Emergency	165 (88%)	140 (87%)	25 (96%)	0.32
Elective	22 (12%)	21 (13%)	1 (4%)	
Comorbidities				
Charlson comorbidity index	5.6 (2.1)	5.5 (2.1)	6.5 (1.8)	0.02
Diabetes	31 (17%)	28 (17%)	3 (12%)	0.58
Chronic liver disease	4 (2%)	4 (3%)	0	0.64

Mod/severe liver disease	2 (1%)	2 (1%)	0	0.99
Malignancy (solid tumours/lymphoma/ leukemia)	40 (21%)	28 (17%)	12 (46%)	0.002
Metastatic malignancy	5 (3%)	4 (3%)	1 (4%)	0.99
Congestive cardiac failure	34 (18%)	29 (18%)	5 (19%)	0.99
Myocardial infarction	13 (7%)	12 (8%)	1 (4%)	0.70
Chronic obstructive pulmonary disease	41 (22%)	35 (22%)	6 (23%)	0.99
Cerebral vascular accident/ transient ischemic attack	26 (14%)	22 (14%)	4 (15%)	0.99
Dementia	36 (19%)	28 (17%)	8 (31%)	0.18
Hemiplegia	1 (0.5%)	1 (0.6%)	0	0.99
Peripheral vascular disease	9 (5%)	7 (4%)	2 (8%)	0.62
Preoperative paradigm				
Admission to surgery (hrs)	24. 7 (13.8:38.7)	24.7 (13.5:38.2)	25.7 (18.4:46.5)	0.15
Pre-admission nerve block	113 (60%)	93 (58%)	20 (77%)	0.08
Preoperative albumin (g/L)	31.2 (5.5)	31.3 (5.7)	31.1 (4.5)	0.95
Preoperative hemoglobin (g/L)	119.5 (17.7)	119.7 (16.5)	118.6 (24.0)	0.85
Preoperative creatinine (µmol/L)	85 (68, 108)	86 (67, 108)	82 (70, 116.8)	0.67

Data presented as number (proportion), mean (standard deviation) and median (interquartile range).

Table 2. Intraoperative variables of patients undergoing major hip surgery requiring rapid response team activation.

	Total (n=187)	Survived (n=161)	In hospital death (n=26)	p-value
Procedure type				
Total hip replacement	40 (21%)	37 (23%)	3 (12%)	0.63
Partial Hip Replacement	60 (31%)	51 (31%)	9 (35%)	
Intramedullary nail	55 (28%)	46 (28%)	9 (35%)	
Dynamic Hip Screw	38 (20%)	29 (18%)	5 (19%)	
Surgical approach				
Anterior	2 (1%)	2 (1%)	0	0.90
Anterolateral	9 (5%)	8 (5%)	1 (4%)	
Lateral	102 (55%)	86 (53%)	16 (62%)	
Posterolateral	1 (0.5%)	1 (0.6%)	0	
Posterior	36 (19%)	32 (20%)	4 (15%)	
Timing of procedure				
Duration of procedure (min)	128 (99:163)	125 (95:158.5)	150 (117.3:189.3)	0.07
After hours surgery (18h00-08h00)	42 (23%)	35 (22%)	6 (23%)	0.99
Anesthesia				
General only	60 (32%)	53 (33%)	7 (27%)	0.78
Regional only	55 (29%)	46 (29%)	9 (35%)	
Combined regional and general	72 (40%)	62 (39%)	10 (38%)	
Regional technique (n=127,108,19 for total, survived and did not survive respectively)				
Spinal	66 (52%)	56 (52%)	10 (52%)	0.004
Epidural	2 (2%)	0	2 (10%)	
Femoral or fascia iliaca block	66 (52%)	57 (53%)	9 (47%)	
Airway management				
Endotracheal tube	110 (59%)	97 (60%)	13 (50%)	0.71
Supraglottic device (e.g. laryngeal mask)	19 (10%)	16 (10%)	3 (12%)	
Temperature				
Intraoperative lowest temperature	36.2 (0.4)	36.2 (0.4)	36.1 (0.3)	0.80

(°C)*				
Opioids				
Patients receiving opioids	146 (78%)	129 (80%)	17 (65%)	0.12
Intravenous morphine equi-analgesia dose (mg)	10.0 (2.0:16.7)	11.7 (3.7:19.0)	5.8 (0.1:8.2)	0.03
Fentanyl				
No. of patients	132 (71%)	116 (72%)	16 (62%)	
Total dose (ug)	200 (102.5:300)	200 (125:300)	125 (100:230)	
Morphine				
No. of patients	13 (7%)	12 (8%)	1 (4%)	
Total dose (mg)	10 (5.75:10)	9 (5.125:10)	10 (10:10)	
Oxycodone				
No. of patients	6 (3%)	6 (4%)	0	
Total dose (mg)	7 (3.5:10)	7 (3.5:10)	0	
Alfentanil				
No. of patients	17 (10%)	14 (9%)	3 (12%)	
Total dose (ug)	750 (350:1000)	675 (375:1000)	1000 (250:1000)	
Other drugs				
Tramadol				
No. of patients	2 (1%)	2 (1%)	0	
Total dose (mg)	150 (100:150)	150 (100:200)	0	
Clonidine				
No. of patients	7 (4%)	7 (4%)	0	
Total dose (mg)	45 (45:60)	45 (45:60)	0	

Data presented as number (proportion), mean (standard deviation) and median (interquartile range).
*Missing values n = 30.

Table 3. Hemodynamics in patients undergoing major hip surgery requiring rapid response team activation.

	Total (n=187)	Survived (n=161)	Did not Survive (n=26)	p-value
Pre-induction blood pressure				
Systolic blood pressure (mmHg)	135 (22)	135 (22)	134 (23)	0.68
Mean arterial pressure (mmHg)	93 (15)	92 (13)	94 (15)	0.49
Diastolic blood pressure (mmHg)	72 (15)	71 (12)	75 (13)	0.12
Intraoperative hypotension				
No of patient with hypotension	108 (58%)	93 (58%)	15 (58%)	0.99
No. of Intraoperative epochs per patients	3.5 (1:9)	4 (1:10)	3 (2:4)	0.76
Epoch of systolic hypotension per patient	2 (1:4)	2 (1:5.5)	2 (1:4)	0.13
Epoch of diastolic hypotension per patient	3 (1:8)	3 (1:8)	7 (3:12.5)	0.12
Epoch of systolic and diastolic hypotension per patient	2 (1:4)	2 (1:3)	1 (1:1)	0.07
No of patient with severe hypotension	16 (9%)	13 (8%)	3 (12%)	0.99
Median no of severe hypotensive epochs per patients	1 (1:2)	1 (1:2.5)	1 (1:2)	0.67
Continuous arterial BP monitoring	127 (68%)	105 (65%)	22 (85%)	0.07
Intraoperative fluid administration				
Total fluids (ml)	1000 (1000:1900)	1000 (1000:1875)	1000 (1000:1925)	0.46
Crystalloid				0.36
No. of patients receiving	177 (95%)	151 (94%)	26 (100%	
Volume received (ml)	1000 (1000:1500)	1000 (1000:1500)	1000 (1000:1385)	0.36
4% Albumen				
No. of patients receiving	12 (6%)	12 (8%)	0 (0%)	0.22
Volume received (ml)	250 (250:500)	250 (250:500)	0	0.99
Blood transfusion				0.99
No. of patients receiving	12 (6%)	10 (6%)	2 (8%)	
No.	1 (1:2)	1 (1:1.625)	2.5 (2:3)	0.08

of units received

Intraoperative vasoactive medication				
Total no of patients receiving a vasoactive medication	164 (88%)	142 (88%)	22 (85%)	0.75
Metaraminol				
No. of patients receiving	149 (80%)	128 (80%)	21 (81%)	
Dose received (mg)	2.25 (1.25:4.0)	2.63 (1.5:4.19)	1.5 (1.0:3.0)	0.04
Ephedrine				
No. of patients receiving	46 (25%)	40 (25%)	6 (23%)	
Dose received (mg)	10 (6:21.5)	10 (6:22.5)	11 (5.75:21.75)	0.85
Phenylephrine				
No. of patients receiving	1 (0.5%)	1 (0.6%)	0	
Dose received (mg)	10 (10:10)	10 (10:10)	0	0.99
Noradrenaline				
No. of patients receiving	1 (0.5%)	1 (0.6%)	0	
Dose received (µg)	1405 (1405:1405)	1405 (1405:1405)	0	0.99
Adrenaline				
No. of patients receiving	1 (0.5%)	1 (0.6%)	0	
Dose received (µg)	40 (40:40)	40 (40:40)	0	0.99
Atropine				
No. of patients receiving	3 (2%)	2 (1%)	1 (4%)	
Dose received (µg)	600 (300:600)	600 (600:600)	300 (300:300)	0.36
Post Anesthesia Care Unit				
No. of patients with hypotension	73 (45%)	61 (38%)	12 (46%)	0.50
No. of epochs per patient	2 (1:4)	2 (1:4)	2.5 (1:4.5)	0.50
Epoch of systolic hypotension per patient	1 (1:1.5)	1 (1:1)	2 (2:2)	0.16
Epoch of diastolic hypotension per patient	2 (1:4)	2 (1:4)	1 (1:4)	0.14
Epoch systolic and diastolic	2 (1:4.5)	2 (1:5)	2 (1.25:3.75)	0.21

hypotension per patient				
Vasopressor use	18 (10%)	16 (10%)	2 (8%)	0.75

Data presented as number (proportion), mean (standard deviation) and median (interquartile range).

Table 4. Postoperative outcomes in patients undergoing major hip surgery requiring rapid response team activation.

	Total (n=187)	Survived (n=161)	Did not survive (n=26)	p-value
PACU Analgesia				
Patient temperature (ºC) on arrival to PACU	36.3 (0.4)	36.3 (0.4)	36.4 (0.3)	0.12
Patients with temperature <35.5 (ºC)	4 (2%)	4 (3%)	0	0.64
PACU Analgesia				
PACU analgesia	71 (38%)	62 (39%)	9 (35%)	0.67
Patients receiving opioids	56 (30%)	48 (30%)	8 (31%)	0.99
Intravenous morphine equi-analgesia (mg)	4.0 (2.7:6.7)	4 (2.7:6.7)	3 (1.3:4.8)	0.84
Fentanyl				
No. of patients	46 (25%)	38 (24%)	8 (31%)	
Total dose (µg)	50 (30:80)	50 (37.5:80)	45 (20:72.5)	
Morphine				
No. of patients	8 (4%)	8 (5%)	0	
Total dose (mg)	8 (5:10)	8 (5:10)	0	
Oxycodone				
No. of patients	3 (2%)	3 (2%)	0	
Total dose (mg)	10 (4:50)	10 (4:50)	0	
Tramadol				
No. of patients	3 (2%)	3 (2%)	0	
Total dose (mg)	200 (100:200)	200 (100:200)	0	
Discharge location				
Ward	180 (96%)	155 (96%)	25 (96%)	0.90
High dependency	4 (2%)	3 (2%)	1 (4%)	
Intensive Care	3 (2%)	3 (2%)	0	
RRT call				
Need for urgent medical review prior to RRT activation	80 (43%)	64 (40%)	16 (62%)	0.05
Time from end of surgery to RRT	29.4	29.4	29.3	0.36

activation (hrs)	(11.3:75.0)	(10.8:68.5)	(15.8:107.5)	
<12hrs	42 (25%)	39 (24%)	3 (12%)	0.21
<24hrs	81 (43%)	71 (44%)	10 (43%)	0.44
<48hrs	122 (65%)	106 (66%)	16 (62%)	0.99
Out of hours RRT (18h00-08h00)	101 (54%)	90 (56%)	11 (42%)	0.21
RRT indication				
Hypotension	63 (34%)	59 (37%)	4 (15%)	
Hypertension	0	0	0	
Bradycardia	0	0	0	
Tachycardia	47 (25%)	42 (26%)	5 (19%)	
Low respiratory rate	3 (2%)	3 (2%)	0	
High respiratory rate	21 (11%)	16 (10%)	5 (19%)	
Breathing difficulties	3 (2%)	1 (0.6%)	3 (12%)	
Worried (clinical concern)	12 (6%)	13 (8%)	1 (4%)	
Low oxygen saturations	15 (8%)	13 (8%)	2 (8%)	
Change in conscious state	10 (5%)	9 (6%)	4 (15%)	
Severe or uncontrolled pain	2 (1%)	1 (0.6%)	1 (4%)	
Low urine output	3 (2%)	2 (1%)	1 (4%)	
Post op hemorrhage	2 (1%)	2 (1%)	0	
Remaining hospital stay				
Unplanned admission to HDU or ICU	25 (13%)	22 (14%)	3 (12%)	0.99
Days from surgery to discharge (days)	9 (6:14)	9 (6:14)	-	
Time to death after RRT (days)	-	-	2.9 (0.2:8.9)	

Data presented as number (proportion), mean (standard deviation) and median (interquartile range). (PACU: Post Anesthesia Care Unit)

Figures
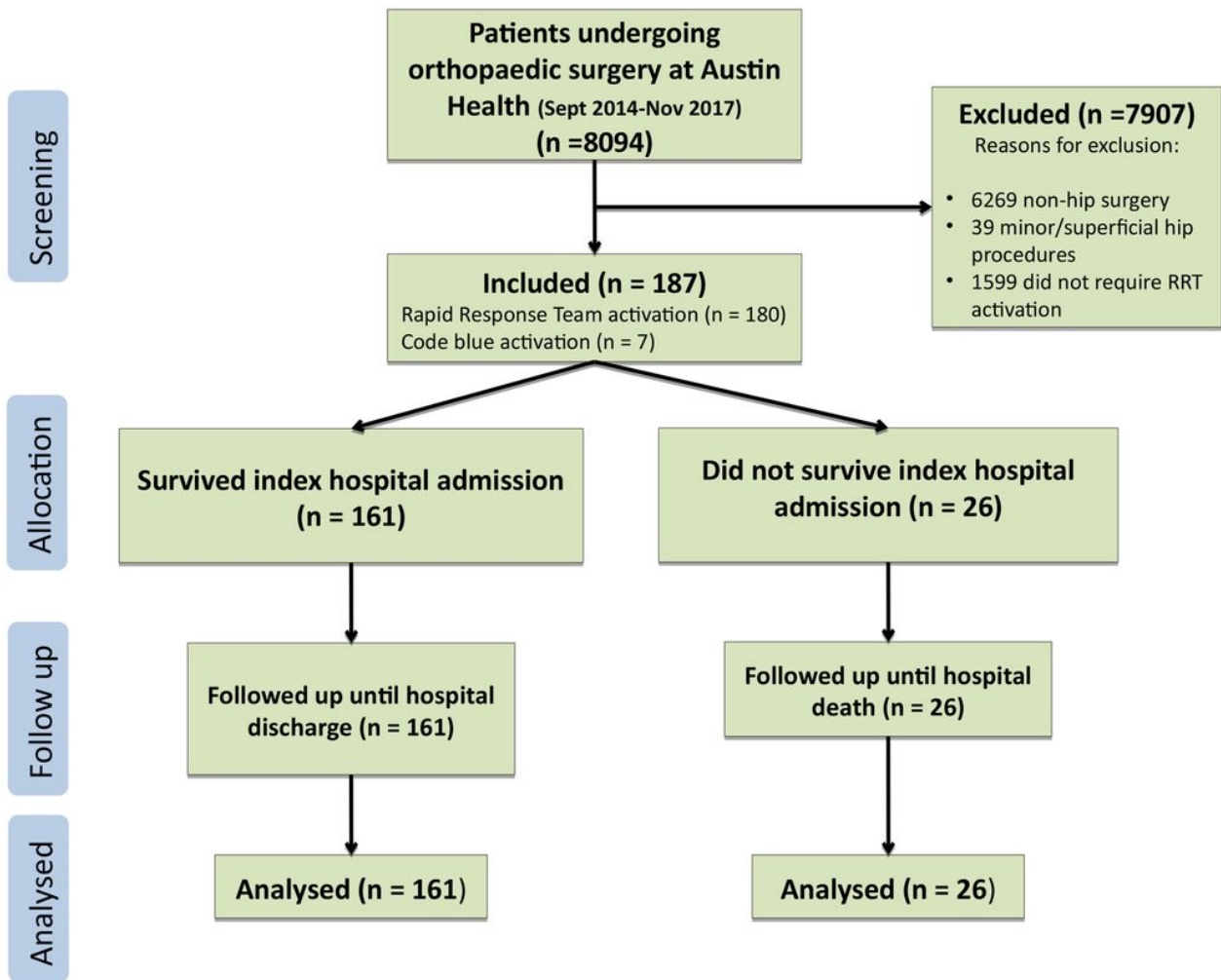
Figure 1

Consort flow diagram of patients undergoing orthopedic surgery at Austin Health and their enrolment.