Risk factors and outcomes of postoperative emergency response team activation: a matched case–control study

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The choice of postoperative disposition after anaesthesia recovery can be roughly categorised into ambulatory, standard inpatient care, and intensive (progressive) care. The decision about the appropriate care level depends on patient comorbidities, postoperative care needs, and predicted physiological changes during convalescence. Patients discharged to lower levels of care are not expected to have life-threatening physiological abnormalities. However, invariably, patients deemed clinically stable may have acute deterioration, with resultant potential for major morbidity or death.[1]

Emergency response teams (ERTs) are the effector arm of a rapid response system (RRS) and have been adopted by many health organisations to provide prompt evaluation and intervention for hospitalised patients.[2] The true seriousness of acute postoperative deterioration may be difficult to define in a retrospective manner (eg, heterogeneous cause, varying acuity, no standard definition). Yet the need to activate an ERT for postoperative patients discharged to regular hospital wards represents a substantial deviation from the expected postoperative course. Thus, ERT activation can be a useful objective surrogate for a health care emergency.

In 2012, we examined our institutional experience with postoperative ERTs and made several observations about the association between patient and clinical factors and ERT outcomes.[3] Since that time, substantial practice changes have occurred, namely increased use of less invasive surgical techniques, anaesthetic management changes,[4] and adoption of components of enhanced recovery after surgery (ERAS) protocols.[5,6] We have reported troubling associations between gabapentin use, a component of the ERAS protocol,[6] and respiratory depression during anaesthesia recovery.[7] Because of these changes in clinical practice, we decided to re-examine our contemporary practice for rates, clinical factors associated with ERT activation, and outcomes of postoperative ERT activations. Because we were interested primarily in perioperative outcomes, our study was limited to ERTs activated within the first 48 postoperative hours, which is also the timeframe

ABSTRACT

Objective: To determine patient and perioperative characteristics associated with unexpected postoperative clinical deterioration as determined for the need of a postoperative emergency response team (ERT) activation.

Design: Retrospective case–control study.

Setting: Tertiary academic hospital.

Participants: Patients who underwent general anaesthesia discharged to regular wards between 1 January 2013 and 31 December 2015 and required ERT activation within 48 postoperative hours. Controls were matched based on age, sex and procedure.

Main outcome measures: Baseline patient and perioperative characteristics were abstracted to develop a multiple logistic regression model to assess for potential associations for increased risk for postoperative ERT.

Results: Among 105 345 patients, 797 had ERT calls, with a rate of 7.6 (95% CI, 7.1–8.1) calls per 1000 anaesthetics (0.76%). Multiple logistic regression analysis showed the following risk factors for postoperative ERT: cardiovascular disease (odds ratio [OR], 1.61; 95% CI, 1.18–2.18), neurological disease (OR, 1.57; 95% CI, 1.11–2.22), preoperative gabapentin (OR, 1.60; 95% CI, 1.17–2.20), longer surgical duration (OR, 1.06; 95% CI, 1.02–1.11, per 30 min), emergency procedure (OR, 1.54; 95% CI, 1.09–2.18), and intraoperative use of colloids (OR, 1.50; 95% CI, 1.17–1.92). Compared with control participants, ERT patients had a longer hospital stay, a higher rate of admissions to critical care (55.5%), increased postoperative complications, and a higher 30-day mortality rate (OR, 3.36; 95% CI, 1.73–6.54).

Conclusion: We identified several patient and procedural characteristics associated with increased likelihood of postoperative ERT activation. ERT intervention is a marker for increased rates of postoperative complications and death.

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when a substantial proportion of these events occur.[8,9] Further, since we were interested in the patients deemed appropriate for regular postoperative care, our study was limited to patients admitted to the regular wards. The aims of this study were to identify patient and procedural characteristics associated with risk of unexpected postoperative clinical deterioration (as identified by ERT activations) and evaluate whether patients who required an ERT call had worse clinical outcomes compared with control patients. Identification of factors associated with risk of unexpected postoperative clinical deterioration may facilitate better triage of surgical patients.

Methods and materials

The Mayo Clinic Institutional Review Board approved the review of health records for study purposes (protocol No. 16-004503). Consistent with Minnesota Statute 144.295, prior authorisation was provided by all study patients for research use of their health records. This study used a retrospective case–control design to review patient characteristics and perioperative data and assess potential factors surrounding the need for ERT activation within 48 hours after procedures performed with general anaesthesia. The study took place at the Mayo Clinic (Rochester, MN, USA) — a large academic quaternary care facility that keeps a record of all ERT activations.

Emergency response team activation calls

At Mayo Clinic, an ERT can be categorised as a rapid response team (RRT) or a code (cardiac arrest) team. The code team is activated for pulseless arrest and impending respiratory arrest or threatened airway. RRTs are activated on the basis of standard criteria,[10] and indications include the following:

- decline in oxyhaemoglobin saturation;
- bradypnoea;
- tachypnoea;
- profound bradycardia or tachycardia;
- hypotension;
- concern for possible myocardial ischaemia; and
- acute neurological deficits or mental status changes (agitation, delirium).

However, an RRT call can be initiated for any other indication at the discretion of the health care team member. Any member of the health care team (eg, physicians, nurses, technicians) can activate the RRS. Depending on the circumstances, a cardiac arrest activation may occur instead of an RRT activation when, in hindsight, the RRT would likely have been sufficient. Because of this overlap, both types of activation qualified as ERT activation in our study. The RRT team consists of a critical care fellow or senior anaesthesia resident, a critical care respiratory therapist, and a critical care registered nurse. An attending physician board-certified in critical care medicine is immediately available for bedside evaluations or phone consultations as determined by the RRT lead physician. The RRT team members are the core members of the code team. If a code activation occurs, they respond along with a number of additional disciplines (eg, pharmacist, anaesthesia resident for airway management) required to provide more advanced interventions.

Study population

The Mayo Clinic Department of Anesthesiology and Perioperative Medicine maintains a log of all ERT activations that occur at the Mayo Clinic Rochester Campus. Using the ERT records, we identified all patients older than 18 years who required a postoperative ERT activation between 1 January 2013 and 31 December 2015. Patients were excluded if they did not undergo general anaesthetic (ie, had sedation only or regional anaesthesia) or were admitted directly to a higher level of care (eg, an intensive care unit [ICU]). To assess risk factors for ERT activation for each patient who required a postoperative ERT call, we randomly selected two matched control patients who did not require ERT activation within 48 postoperative hours on the basis of age, sex and exact type of procedure. Matched controls were selected from the entire surgical cohort during the study timeframe using automated interrogation of the electronic medical record.[11] Because cases and controls were matched on exact type of procedure there was little variability between groups in regards to the addition of concomitant regional anaesthesia to the general anaesthetic (cases had 115 [14.4%] and controls had 241 [15.1%] combined regional/general anaesthetic technique; $P = 0.67$). Therefore, we made the decision not to examine combined regional/general technique as a separate variable.

Data abstraction

A comprehensive chart review was undertaken of the preoperative, intraoperative and postoperative variables as previously described.[3,12-14] Preoperative patient characteristics and perioperative variables were extracted using automated interrogation of the electronic medical record with validated data extraction software, which is notable for high degree of accuracy.[11,15] Events surrounding ERT activation included the primary indication for ERT care, the interventions (eg, Utstein style[16]), immediate disposition, and death during the ERT activation were reviewed by manual review of the ERT notes. Postoperative outcomes included complications during hospitalisation and death within 30 days, and were identified using automated interrogation of the medical records[17] and each identified complication confirmed by manual review.

Classification of emergency response team interventions

The abstracted ERT data included the probable primary cause of activation:

- cardiac causes — symptoms and signs of myocardial ischaemia, dysrhythmias, severe hypertension;
- hypotension — hypovolaemia, distributive shock including septic shock, bleeding, vasovagal reaction (syncope);
- neurological/psychiatric causes — sensorium changes (somnolence, delirium), psychiatric decompensation, seizure activity, acute motor or sensory deficit;
- pulmonary causes — oxyhaemoglobin desaturations, hypoventilation (bradypnoea, apnoea), tachypnoea;
- other causes of respiratory distress — eg, typically upper airway pathology such as bleeding, angioedema; and
- miscellaneous causes — drug or allergic reactions, fever, severe pain, sepsis without hypotension, acute postoperative bleeding without haemodynamic instability, glycaemic or electrolyte abnormalities.

Because multifactorial causes could trigger an ERT activation, the primary cause was determined after consensus among reviewers (MIH, SCK, MRS and ANC), with adjudication by the senior author (TNW). Thus, each ERT episode was counted once. For example, because collinearity between cardiac and hypotensive causes can exist, a patient with cardiac dysfunction with resultant hypotension was classified as cardiac.

Statistical analyses

Data were summarised as mean (standard deviation [SD]) or median (interquartile range [IQR]) for continuous variables and as frequency (percentage) for nominal variables. The denominator of patients admitted to the post-anaesthesia care unit was used in the estimation of incidence of ERT activation.

Analyses to identify preoperative and intraoperative characteristics associated with ERT activation were performed with multivariable conditional logistic regression that took into account the 1:2 matched set study design. Results from these analyses were summarised as odds ratio (OR) and 95% confidence interval (CI). Additional multivariable conditional logistic regression analysis was performed to assess the association between demographic and clinical characteristics and ERT activation by indication. Secondary analyses were performed to compare postoperative outcomes between ERT cases and controls. These comparisons were performed with the two-sample *t* test (or Wilcoxon rank sum test) for continuous variables and the χ^2 test (or Fisher exact test) for categorical variables. Statistical significance was considered achieved for a two-tailed $P \leq 0.05$. For analyses of ERT activation by indication, statistical significance was considered for two-tailed $P \leq 0.01$. Analyses were performed with statistical software (JMP Pro version 14.1.0 and SAS statistical software version 9.2; SAS Institute).

Results

During the study period, 105 345 patients underwent procedures that required general anaesthesia and were discharged to a regular ward. Of those patients, 797 required ERT activation within 48 hours of anaesthesia, yielding an estimated rate of 7.6 (95% CI, 7.1–8.1) activations per 1000 anaesthetics. This rate stayed stable over the 3 years of study (7.4 activations per 1000 anaesthetics in 2013, 7.9 per 1000 anaesthetics in 2014, and 7.4 per 1000 anaesthetics in 2015). Among ERT patients, 238 (29.9%) underwent orthopaedic, 131 (16.4%) general, 115 (14.4%) colorectal, 92 (11.5%) urological, 82 (10.3%) gynaecological, 56 (7.0%) head and neck, 36 (4.5%) thoracic, 17 (2.1%) breast or plastic, 17 (2.1%) vascular, and 10 (1.3%) neurological operations. Three patients (0.4%) had bone marrow harvest.

Details of emergency response team triggers and interventions

For 266 patients (34.4%), ERT activations occurred within the first 12 postoperative hours, and for 470 patients (59.0%),

Figure 1. Frequency of emergency response team activation after discharge from the post-anaesthesia care unit

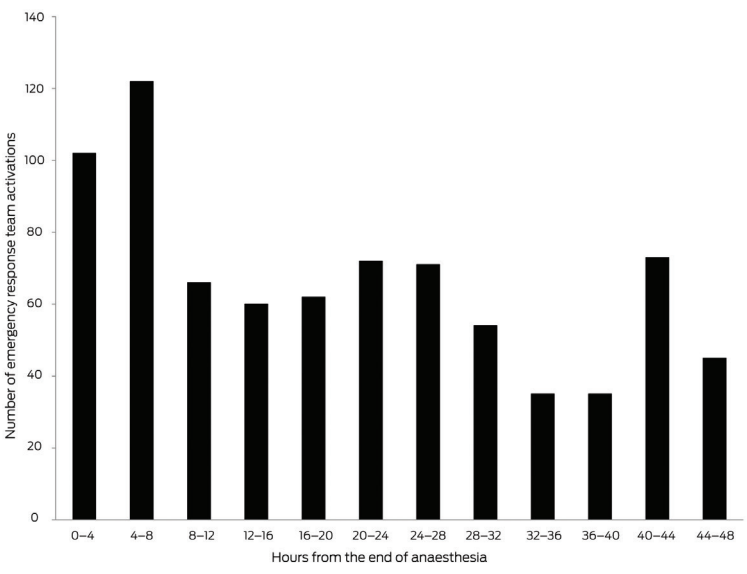

Table 1. Indications and interventions for and immediate disposition after emergency response team (ERT) activations

Characteristic	All ERT calls (*n* = 797)	ERT activation according to clinical indication *n* (%)				
		Cardiac* (*n* = 245)	Hypotension* (*n* = 216)	Neurological/ psychiatric (*n* = 83)	Pulmonary (*n* = 172)	Miscellaneous (*n* = 81)
Utstein interventions[16]						
Chest compressions	13 (1.6%)	9 (3.7%)	0 (0%)	0 (0%)	4 (2.3%)	0 (0%)
Defibrillation	6 (0.8%)	4 (1.6%)	0 (0%)	0 (0%)	2 (1.2%)	0 (0%)
Tracheal intubation	17 (2.1%)	8 (3.3%)	1 (0.5%)	0 (0%)	7 (4.1%)	1 (1.2%)
CPAP/BiPAP	35 (4.4%)	5 (2.0%)	5 (2.3%)	2 (2.4%)	23 (13.4%)	0 (0%)
Bag mask ventilation	9 (1.1%)	4 (1.6%)	0 (0%)	0 (0%)	5 (2.9%)	0 (0%)
Supplemental oxygen	482 (60.5%)	142 (58.0%)	102 (47.2%)	45 (54.2%)	149 (86.6%)	44 (54.3%)
Bolus fluids	273 (34.3%)	59 (24.1%)	172 (79.6%)	11 (13.3%)	15 (8.7%)	16 (19.8%)
Medication therapy	327 (41.0%)	105 (42.9%)	82 (38.0%)	27 (32.5%)	75 (43.6%)	38 (46.9%)
Opioid	50 (6.3%)	19 (7.8%)	3 (1.4%)	1 (1.2%)	7 (4.1%)	20 (24.7%)
Naloxone	39 (4.9%)	2 (0.8%)	3 (1.4%)	5 (6.0%)	28 (16.3%)	1 (1.2%)
Vasopressor	48 (6.0%)	12 (4.9%)	32 (14.8%)	0 (0%)	4 (2.3%)	0 (0%)
Benzodiazepine	24 (3.0%)	10 (4.1%)	2 (0.9%)	8 (9.6%)	2 (1.2%)	2 (2.5%)
Other interventions						
Blood transfusion	54 (6.8%)	7 (2.9%)	43 (19.9%)	0 (0%)	3 (1.7%)	1 (1.2%)
Immediate disposition						
Transfer to surgery	22 (2.8%)	2 (0.8%)	11 (5.1%)	0 (0%)	4 (2.3%)	5 (6.2%)
Transfer to monitored unit†	344 (43.2%)	127 (51.8%)	87 (40.3%)	31 (37.4%)	79 (45.9%)	20 (24.7%)
Treatment on ward	247 (31.0%)	60 (24.5%)	91 (42.1%)	16 (19.3%)	49 (28.5%)	31 (38.3%)
Observation on ward	179 (22.5%)	54 (22.0%)	26 (12.0%)	35 (42.2%)	39 (22.7%)	25 (30.9%)
Death during ERT activation	5 (0.6%)	2 (0.8%)	1 (0.5%)	1 (1.2%)	1 (0.6%)	0 (0%)

BiPAP = bilevel positive airway pressure; CPAP = continuous positive airway pressure. * Cardiac is differentiated from hypotension, although cardiac may have involved hypotension. Every time the primary cause was assigned to cardiac, the case was not counted in the hypotension classification even when it involved hypotension. † Indicates either intensive care unit (ICU) or progressive care (intermediate)-level bed in non-ICU settings.

ERT activations occurred within the first 24 hours (Figure 1). The indications for ERT activations were cardiac (*n* = 245, 30.7%), hypotension (*n* = 216, 27.1%), neurological/ psychiatric (*n* = 83, 10.4%), pulmonary (*n* = 172, 21.6%), and miscellaneous (*n* = 81, 10.2%) causes. Interventions (overall and according to ERT indication) performed and immediate outcomes are summarised in Table 1. Thirteen patients had cardiac arrest that required chest compressions, six received defibrillation, and 17 received tracheal intubation. Five patients died: two of ventricular fibrillation (one secondary to myocardial infarction and the other of an unidentified cause) and three of cardiac arrest

Table 2. Multivariate analysis of potential preoperative and perioperative risk factors for postoperative emergency response team (ERT) activation

Patient characteristic	ERT activation: Yes (*n* = 797)	ERT activation: No (*n* = 1594)	Odds ratio (95% CI)*	*P**
Age (years), mean (SD)	61.3 ± 16.6	61.3 ± 16.1	na	na
Male sex	402 (50.4%)	804 (50.4%)	na	na
Comorbidity				
Cardiovascular disease	112 (14.1%)	145 (9.1%)	**1.61 (1.18–2.18)**	**0.003**
Chronic obstructive pulmonary disease	147 (18.4%)	217 (13.6%)	1.28 (0.99–1.65)	0.06
Obstructive sleep apnoea	207 (26.0%)	376 (23.6%)	1.00 (0.81–1.25)	0.97
Neurological disease	83 (10.4%)	109 (6.8%)	**1.57 (1.11–2.22)**	**0.01**
Diabetes mellitus	164 (20.6%)	275 (17.3%)	1.14 (0.90–1.45)	0.29
Home or preoperative use				
Opioid	260 (32.6%)	442 (27.7%)	1.14 (0.92–1.41)	0.22
Benzodiazepine	130 (16.3%)	221 (13.9%)	1.15 (0.88–1.50)	0.31
Gabapentin†	184 (23.1%)	291 (18.3%)	**1.60 (1.17–2.20)**	**0.004**
Procedural				
Emergency	92 (11.5%)	149 (9.4%)	**1.54 (1.09–2.18)**	**0.02**
Surgical duration (min), mean (SD)‡	171 ± 127	153 ± 110	**1.06 (1.02–1.11)**	**0.006**
Fluid management				
Crystalloid (L), mean (SD)§	2.4 ± 1.7	2.2 ± 1.5	0.99 (0.94–1.04)	0.80
Colloid	272 (34.1%)	400 (25.1%)	**1.50 (1.17–1.92)**	**0.001**
Blood product transfusion	91 (11.4%)	127 (8.0%)	1.05 (0.74–1.47)	0.80
Antihypertensive agent	129 (16.2%)	207 (13.0%)	1.27 (0.96–1.67)	0.10
Vasopressor infusion¶	122 (15.3%)	169 (10.6%)	1.33 (0.97–1.81)	0.07
Epinephrine	3 (0.4%)	6 (0.4%)	na	na
Vasopressin	13 (1.6%)	27 (1.7%)	na	na
Norepinephrine	1 (0.1%)	3 (0.2%)	na	na
Phenylephrine	109 (13.7%)	144 (9.0%)	na	na

na = not applicable; SD = standard deviation. * Bold indicates statistical significance. † Preoperative or part of the ERAS protocol. Gabapentin is frequently administered as part of multimodal pain management. In our cohort, it was most frequently administered before colorectal (33.3%), gynaecological (29.9%), and orthopaedic operations (19.9%). ‡ For 30-minute increments of surgical time. § For 0.5 L increments. ¶ Denotes number of patients with any vasopressor infusion. Some patients had more than one type of vasopressor infusion. Intermittent boluses of ephedrine or phenylephrine were not counted.

(one after pulmonary embolism and two of an unidentified cause). ERT activation resulted in transfer to the ICU for 344 patients (43.2%). For 179 patients (22.5%), ERT was limited to evaluation, with continued observation on the ward.

Associations with the development of an emergency response team

For assessment of the potential risk factors for ERT activation, these patients were matched 1:2 with control patients who did not require postoperative ERT (Table 2). The risk factors for ERT call included an existing cardiovascular or neurological disease, emergency procedures, longer procedures, preoperative use of gabapentin, and intraoperative use of colloids. The secondary multivariate association of clinical characteristics with ERT activation according to clinical indications was assessed (Table 3); the full model is presented in the online Appendix, Supplementary table (available at cicm.org.au/Resources/Publications/Journal).

Patient outcomes in association with emergency response team activation

Compared with control patients, ERT patients had longer hospital stay and higher rates of all major complications, especially pneumonia (14.1% *v* 4.6%; $P < .001$) (Table 4).

Table 3. Multivariate analysis of patient- and procedure-related factors as risk for postoperative emergency response team (ERT) activation according to clinical indications

Indication for ERT activation	Odds ratio (95% CI)*	P†
Cardiac indication (*n* = 245)		
Antihypertensives intraoperative	2.19 (1.34–3.59)	0.002
Surgical duration	1.09 (1.00–1.19)	0.04
Hypotension indication (*n* = 216)		
Cardiovascular disease	2.08 (1.14–3.78)	0.02
Gabapentin preoperative	2.07 (1.17–3.66)	0.01
Surgical duration	1.12 (1.02–1.22)	0.02
Neurological/psychiatric indication (*n* = 83)		
Vasopressors intraoperative	4.08 (1.17–14.27)	0.03
Central neurological disease	3.43 (1.04–11.29)	0.04
Pulmonary indication (*n* = 172)		
Gabapentin preoperative	2.81 (1.20–6.60)	0.02
Central neurological disease	2.79 (1.15–6.82)	0.02
Colloid administration	2.15 (1.26–3.67)	0.005
Vasopressors intraoperative	2.08 (1.08–4.02)	0.03
Obstructive sleep apnoea	1.82 (1.12–2.95)	0.02

* Risk factors, $P < 0.05$. † In our practice, intraoperative use of vasopressors is either for treatment of hypotension or in cases where it is used to accomplish fluid restriction. Ketamine is usually used as part of a multimodal analgesic regimen (for extensive operations expected to result in severe pain or for patients who are so-called opioid-tolerant).

Table 4. Postoperative outcomes among post-surgical patients who had emergency response team (ERT) activation and their matched controls

	ERT activation	
Postoperative outcomes*	Yes (*n* = 797)	No (*n* = 1594)
Admission to progressive care unit†	442 (55.5%)	200 (12.6%)
Reintubation within 48 hours	20 (2.5%)	5 (0.3%)
Hospital length of stay (days), median (IQR)	5 (3–9)	3 (1–5)
Hospital complication		
Stroke	18 (2.3%)	8 (0.5%)
Pneumonia	112 (14.1%)	74 (4.6%)
Pulmonary embolism	34 (4.3%)	32 (2.0%)
Myocardial infarction	42 (5.3%)	28 (1.8%)
Deep vein thrombosis	64 (8.0%)	68 (4.3%)
Death within 30 days of procedure	36 (4.5%)	16 (1.0%)

IQR = interquartile range. * All outcomes differed between groups (all $P < 0.001$, except pulmonary embolism, which was $P = 0.002$). † Includes admission to intensive care unit (ICU) or progressive care (intermediate)-level beds in the non-ICU setting after ERT call and subsequent transfers not preceded by an ERT activation.

The 30-day ERT mortality rate was 4.5% (*n* = 36), with patients with an RRT having a three-fold increased risk of death (OR, 3.36; 95% CI, 1.73–6.54). Of the deaths, cardiopulmonary arrests were most frequent (*n* = 16), followed by sepsis (*n* = 5), acute respiratory failure (*n* = 4), fulminant hepatic failure (*n* = 1), hypovolaemic shock (*n* = 1), and renal failure (*n* = 1). Eight patients died after discharge and from an unknown cause. Among control patients, 16 died within 30 postoperative days from cardiorespiratory arrest (*n* = 7), pulmonary embolism (*n* = 1), respiratory failure (*n* = 2), sepsis (*n* = 1), and after discharge with cause unknown (*n* = 5).

Discussion

In this study, we used ERT activation as a surrogate for acute deterioration of health status, with the aim of identifying patient and procedural characteristics associated with postoperative ERT activation. Our main findings were that the rate of postoperative ERT activation from 2013 to 2015 was higher than in our previous report.[3] ERT activations were more frequent in the immediate postoperative period — 34.6% in the first 12 hours — and were evenly distributed over the next 36 hours. Furthermore, we found that ERT activation was associated with a greater burden of comorbidities, longer and emergency procedures, and perioperative use of gabapentin and vasopressors. Patients with ERT activation had a more complicated hospital course with higher mortality rates.

Emergency response team activation rates and disposition following events

The incidence of ERT calls was 7.6 per 1000 anaesthetics, compared with two per 1000 anaesthetics in our previous report[3] and in reports by Lee et al[18] and by Barocas et al.[19] However, in the current study, ERT incidence was similar over the 3-year period. The immediate

disposition after ERT activation was comparable between present and earlier studies.[3] Specifically, death rates during ERT activations were 0.6% versus 1% of cases in the present study compared with the previous study; transfers to surgery were 2.8% versus 2%; transfers to ICU, 43.2% versus 39%; treatment on hospital wards, 31% versus 32%; and observation only, 22.5% versus 26%.[3] This similarity of disposition suggests a true increase in ERT in a more contemporary cohort rather than a relaxation of activation criteria. If the latter were true, the proportion of ERT activations limited to evaluation and observation should have increased. Therefore, this increased ERT rate may reflect increasing acuity of our surgical population.

Predictors of emergency response team activation

The patient and periprocedural characteristics that may be used to predict ERT activation have been reported infrequently.[3,9,18] In our previous report, we identified three markers for increased postoperative ERT: preoperative opioid therapy, intraoperative phenylephrine infusion, and comorbid central neurological disease.[3] In agreement with Lee and colleagues,[18] in the present report we confirmed that increased burden of comorbidities, specifically cardiovascular and neurological disease, represents risk for ERT call. In addition, longer operations, emergent procedures, intraoperative use of colloids (a marker for haemodynamic instability, or prolonged operations where the provider administered larger amounts of crystalloids and switched to colloids), and preoperative use of gabapentin were risk factors. The current study accounted only for preoperative and intraoperative characteristics and did not consider postoperative events or course that could have resulted in clinical deterioration. This method was selected because we were interested in identification of higher risk for ERT based on preoperative patient characteristics and intraoperative course, as these variables are a priori responsible for postoperative discharge to regular patient wards. Therefore, our study contrasts with work by other investigators which have examined changing clinical status postoperatively to predict deterioration. For example, Wengerter and colleagues[20] found that changes in the Rothman Index (calculated from vital signs, laboratory tests, cardiac rhythm, and nursing assessment) were associated with the need for ERT. Risks for ERT differed according to clinical indications and they are summarised in Table 3. For example, surgical duration was associated with ERT for "cardiac indications" and "hypotensive events on wards" and "pulmonary indication" for ERT was associated with preoperative diagnosis of obstructive sleep apnoea, central neurological disease, sedation associated with gabapentin use, and unstable intraoperative haemodynamic course as inferred form the use of vasopressor and colloids.

Gabapentin in our practice is used mostly as a part of the ERAS protocol. We previously demonstrated associations between preoperative gabapentin administration and increased rate of respiratory depression during anaesthesia recovery,[7,21] and between postoperative naloxone administration on hospital wards and chronic use of gabapentin.[12] In considering risk for ERT activation related to gabapentin use, we found that its use was associated with two clinical indications for ERT call: hypotension and respiratory depression. The present finding of an association between preoperative gabapentin administration and increased ERT activation risk, combined with earlier reports,[7,12,21,22] suggests that gabapentinoid use may warrant increased levels of postoperative vigilance.

Emergency response team management and outcomes

The most frequent indications for ERT were cardiac causes and hypotension, which accounted for 58% of activations, at a rate similar to our previous study[3] and that reported by Sarani and colleagues.[23] In similarity with our previous study,[3] considerable variability in interventions was observed, ranging from full resuscitation (1.6% of ERT) to evaluation followed by observation on the ward (22.5% of ERT). The most common interventions were oxygen therapy and administration of intravenous fluid, and the frequency of intervention mirrored the ERT indication (Table 1). Immediate death and transfer after ERT were similar to our previous study, as was the 30-day mortality rate (4.5% *v* 4%).[3] A systematic review of 29 studies of the outcomes of 157 383 ERT (for surgical and medical patients) found a 30-day mortality rate of 29% but with a wide range of reported rate (8–39%).[24] We speculate that the lower 30-day mortality rate in our study is because our cohort was surgical and all our patients initially met the criteria for admission to standard wards postoperatively. Thus, we describe a lower risk population than those represented in the review by Tirkkonen and colleagues.[24] In addition, "surgical causes for RRT" are acutely induced and likely the result from the procedure, and, therefore, may be more prone to reversal with intervention. As expected, in our study, the ERT patients had worse postoperative outcomes than the controls.

Limitations

This study has all inherent limitations related to its retrospective design. Many of the details of the clinical presentation were deduced from documentation of the ERT team, recorded in medical records during the time of acute patient decompensation, and thus reflecting a degree of

subjectivity based on clinical judgements made during a time of crisis. Our use of ERT activation as a surrogate for acute clinical deterioration is somewhat arbitrary, but nevertheless, it represents an acceptable marker of substantial deviation from the expected postoperative course. Our designation of ERT indication was determined by review of retrospective data based on clinical notes and interventions. In some cases, multiple indications for ERT activation were present, and in these cases, the primary (ie, most life-threatening) indication was selected. This concern was most germane in distinguishing cardiac from hypotension causes. We are comfortable in our final adjudication that the ERT indications deemed for hypotension were truly limited to this cause. Our ERT disposition after activation, as well as the postoperative outcomes, represents outcomes of the large quaternary medical centre and, therefore, they may not be generalisable to other health institutions. Further, as indications for ERT activation may differ between institutions, our incidence rates may not be applicable to other practices. Because cases and controls were matched on exact surgical procedure, there was insufficient variability between anaesthetic techniques (general anaesthesia *v* combined regional/general anaesthesia) to meaningfully explore this variable. Lastly, data acquisition from our cohort reflects our practice from 2013 to 2015, and risk assessment and outcomes from ERT calls would be expected to change over time to mirror changes in clinical practice.

Conclusion

We identified several patient and procedure risk factors for postoperative ERT activation. More than 50% of ERT calls were considered severe enough to warrant transfer to the critical care environment for higher level monitoring and/or treatment. Because postoperative ERT activation is a marker of substantially increased morbidity and mortality, these patients deserve vigilant observation for the development of in-hospital complications.

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Competing interests

Toby Weingarten currently serves as a consultant to Medtronic in the role as chairman of the Clinical Endpoint Committee for the Prodigy Trial; has received research support from Respiratory Motion (study equipment) and unrestricted investigator-initiated grants from Merck (active) and Baxter (completed).

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