Critical Events Leading to Endotracheal Reintubation in the Postanesthesia Care Unit: A Retrospective Inquiry of Contributory Factors

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The tracheal reintubation of a surgical patient in the postanesthesia care unit (PACU) is a critical event that increases patient morbidity and mortality, cost, and staff demands. We performed a descriptive retrospective cohort study to identify the incidence of reintubation after planned extubation (RAP) in the PACU from 2010 to 2017. The incidence of RAP was 0.00083% (89/107,845) for the entire study period, an incidence range from 0.00014% to 0.00172% (1/7,407 to 26/15,139) with a steady decline from 2011 to 2017. A post hoc application of published prediction tools demonstrated that most RAP cases could be predicted preoperatively when the RAP predictive risk index (described in 2013) was applied to patients over the age of 64 years. Preoperative attention to increased risk of RAP decreases the incidence of RAP. Neuromuscular blockade (NMB) must be monitored, and reversal must be ensured. Attempting to reverse moderate to deep NMB with increased dosing of neostigmine should be avoided, and NMB reversal with sugammadex should be used in these cases and when residual weakness is observed. Hypothermia must be avoided, and a multimodal pain management regimen must be adopted.

Keywords: Critical respiratory events, postanesthesia care, quality indicator, reintubation, respiratory failure.

The postoperative reinsertion of an endotracheal tube after planned extubation (RAP) in the postanesthesia care unit (PACU) is a rare occurrence.[1-3] This unwelcomed critical respiratory event results in prolonged PACU stays, increase in the level of care, increased costs (patient and institutional), and the increases in mortality and morbidity are reasons to make this rare event extinct.[3-5] Many organizations have identified postoperative respiratory complications such as reintubation during the first 48 hours after anesthesia, postoperative respiratory failure, and unplanned extended PACU stays as anesthesia quality indicators[6]; RAP would be captured by each indicator.

Preoperative identification of surgical patients at risk of RAP has recently been explored. Several authors reported the comorbidities and surgical procedures most associated with RAP.[1-3,7-9] Brueckmann et al[2] and Lin et al[3] not only identified risk factors but also developed RAP prediction tools that stratify risk probability (Table 1).

The goals of this study were to first determine the incidence of intubation (and reintubation) in the PACU, identify the commonalities and then to determine whether these events could have been predicted by retrospectively applying previously published prediction tools.[2,3]

Materials and Methods

A descriptive, retrospective cohort of patients was identified by electronic medical chart review through the institutional incident reporting system as undergoing tracheal intubation (reintubation) in the postanesthesia care unit (PACU) between August 2010 and April 2015 initially, then extended through February 2017. Ethical approval was obtained from the local institutional review board (IRB; IRBnet identification No. 754179-4), which granted consent exempt status.

All patients admitted to the PACU requiring intubation or reintubation were included and are referred to as the reintubation group or RAP group. A randomized, matched control group was obtained by filtering PACU admissions by year of occurrence, gender, and ASA physical status. Random numbers were assigned to each subgroup from 0 to 9. The first computerized run retained approximately 10% of the list. The sample was further reduced by repeating this process until 2 patients remained per each incidence. Surgical patients bypassing admission to the PACU after anesthesia administration were excluded (eg, direct admission to the intensive care or short stay units) before randomization. Patients in the control group who remained intubated throughout their

Prediction tool (source)	Risk factors	Points	Score range	Risk stratification
SPORC (Brueckmann et al,[2] 2013)	ASA physical status > 2	3	0-11	Low = 0-3; moderate = 4-6; high = 7-11
	Emergency status[a]	3		
	High-risk service[b]	2		
	Congestive heart failure	2		
	Chronic pulmonary disease	1		
RAP predictive risk index (Lin et al,[3] 2013)	AA physical status 2, 3	9,18		Low < 21; moderate = 21-42; high > 42
	Surgical type (abdominal, neurologic, head/neck, airway)	5,7,11,16		
	COPD/asthma	15		
	Conscious disturbance	16		
	Pneumonia	20		
	SIRS	19		
	Room air Sao_2 < 95%	18		
	Temperature < 35.0°C (< 95°F)	10		
	Use of rocuronium[c]	8		
	Ascites	15		

Table 1. Reintubation After Planned Extubation (RAP) Prediction Tools

Abbreviations: COPD, chronic obstructive pulmonary disease; Sao_2; arterial oxygen saturation; SIRS, systemic inflammatory response syndrome; SPORC, score for prediction of postoperative respiratory complications.

[a]Emergency status = nonscheduled or after hours (nonelective).

[b]High-risk service = general surgery, neurosurgery, vascular, transplant, thoracic, and burn.

[c]Rocuronium was identified as a risk factor for RAP.[3]

stay were excluded from the sample during final data collection, resulting in the exclusion of 8 cases.

Statistical analyses were conducted using statistical software (IBM SPSS 19.0.1, IBM Corp) and a spreadsheet (Microsoft Excel 2016, Microsoft Corp). Descriptive statistics were used for all demographic data, χ^2 or Fisher exact test for categorical data, and *t* test for ratio data. Trends were evaluated using the Mann-Kendall test, and discriminant function testing.

Results

Of the 107,845 patients admitted to the PACU during the study period (August 2010 to February 2017), only 89 patients required reintubation (0.00083%). Complete demographic data (data points of interest) were not available for all patients (Table 2). Because there were no a priori imputation plans in place (a process of handling missing data points), the decision was made to report complete data only. Males constituted 58.4% of the RAP group (52/89) compared with 52.4% in the control group (89/170; *P* = .35). Abdominal procedures were most common in both groups with 32.6% of RAP cases (29/89) and 55.9% in the control group (95/170; *P* = .99). Airway/thoracic procedures were the second most prevalent in RAP with 29.2% (26/89) but least common in only 1.8% of control group (3/170; *P* = .99). Neurosurgical/head/neck procedures were similar in both groups: 10.1% of RAP cases (9/89) and 10.6% of control (18/170; *P* = .9).

ASA physical status 3 and 4 represented 83.2% (74/89) of patients with RAP compared with 83.5% (142/170; *P* = .94) of the control group. The most common comorbidity was chronic obstructive pulmonary disease (COPD) at 48.3% (43/89) compared with 35.3% (60/170; *P* = .042). Emergency surgery classification was documented in 16.9% of the RAP group (15/89) compared with 4.7% of controls (8/170; *P* = .001), and recent pneumonia was present in 9% (8/89) compared with 1.8% of the control group (3/170; *P* = .006).

Neuromuscular blockade (NMB) monitoring was undocumented in more than 61% of RAP cases (55/89) compared with 69.4% in the control group (118/170; *P* = .22). Rocuronium was administered in 89.9% of RAP cases (80/89) and 65.9% of control group cases (112/170; *P* = .01). Examination of neostigmine dosing for NMB reversal yielded a RAP mean dose of 3.5 mg (median dose = 4 mg, range = 0-8 mg) compared with 2.8 mg (median dose = 3 mg, range = 0-6 mg) in the control group (*P* = .013). Sugammadex was not used for primary reversal of NMB reversal nor administered perioperatively in any case, although sugammadex was available in early 2016. Hypothermia (temperature < 36°C [96.8°F]) on arrival to the PACU was noted in 7.9% of RAP cases (7/89) compared with 3.5% of controls (6/170; *P* = .10). There was no documentation of temperature in 5.6% of RAP cases (5/89), but the control group had temperature documented in all cases.

A post hoc utilization of the Score for Prediction of Postoperative Respiratory Complications (SPORC)[2] and the RAP predictive risk index developed by Lin et al[3] resulted in a statistical difference in total score. The mean SPORC score for the RAP group was 5.4 (SD 2.5) and 4.4 (SD 1.9) in the control group (*P* = .00018). The mean (SD) for the tool created by Lin and colleagues was also higher in the RAP group, 43.6 (15.7) vs 31.9 (12.1) in the control group (*P* < .00001). The question remained, Which tool was better at predicting RAP in our study population?

Demographic characteristic	Reintubation group (n = 89)	Matched control group (n = 170)	*t* statistic (*df*)	*P* value[a]
Age, y				
Mean (SD)	71.1 (15.3)	58.3 (15.7)	6.26	**< .001**
Median	72	59		
Gender, No. (%)				
Male	52 (58.4)	88 (51.8)	0.87	.35[b]
Female	37 (41.6)	81 (48.2)	0.87	.35[b]
ASA physical status, No. (%)				
1	1 (1.1)	2 (1.2)	0.0014	.97
2	14 (15.7)	26 (15.3)	0.0085	.93
3	42 (47.2)	84 (49.4)	0.115	.73
4	32 (36.0)	58 (34.1)	0.087	.77
Comorbidities, No. (%)				
COPD	43 (48.3)	60 (35.3)	4.13	**.04**
Pneumonia	8 (9.0)	3 (1.8)	7.50	**.006**
Emergency status	15 (16.9)	8 (4.7)	10.65	**.001**
Hypothermia (< 36.0°C [96.8°F])	7 (7.9)	6 (3.5)	2.30	.13
NMB reversal dose, mg				
Mean (SD)	3.5 (1.9)	2.8 (1.9)	2.51	**.013**
Median	4	3		
Surgery type				
Abdominal	29 (32.6)	95 (55.9)	12.7064	**< .001**
Airway/thoracic	26 (29.2)	3 (1.8)	44.2648	**< .001**
Neurologic/head/neck	9 (10.1)	18 (10.6)	0.0142	0.91
Other	25 (28.1)	54 (31.7)	0.3721	.54

Table 2. Demographics

Abbreviations: COPD, chronic obstructive pulmonary disease; NMB, neuromuscular blockade.

[a]Boldface p values indicate statistically significant at $P < .05$.

[b]*P* value is with χ^2 test.

Discriminant function analysis identified a SPORC prediction for RAP that was correct 24.7% (22/89) although correctly predicted patients that would not undergo RAP in 95.3% (162/170) of cases. The RAP predictive risk index predicted RAP correctly in 77.5% (69/89) of RAP cases and correctly predicted the patients that would not undergo RAP in 82.4% (140/170) of cases. Identifying difference in mean age (nearly 13 years) between the RAP and control group lead to an analysis of discriminant function whereby patients above the age of 64 years received an additional 10 points in the RAP predictive risk index. This variation increased the predictive value to 83.1% in RAP cases and 84.7% in non-RAP cases.

There was a progressive reduction of RAP incidence from 2010 through 2017 (Table 3), with an obvious trend reduction in year 2014. The Mann-Kendall trend test demonstrated that 6 of the 8 years had a significant downward trend using a 2-tailed test ($P = .009$). From 2010 through 2014 there were 56,330 admissions to the PACU, of which 78 were reintubated (0.0014%). During the data collection period (2015-2017), 37,337 patients were admitted to the PACU, of which 11 were reintubated (0.0003%; $P < .00001$, Fisher exact test).

Discussion

Costs related to adverse outcomes are one method of framing fiscal impact of an event. Alvarez and colleagues[8] reported the median hospital cost of postoperative pulmonary complications to be $62,704. With use of a fiscal conversion tool, that cost is calculated to be $80,639 in 2017 (https://futureboy.us/fsp/dollar.fsp?quantity=62704&currency=dollars&fromYear=2004). Of course, this figure does not take into account changes in technology and standards of care since 2004, albeit, it allows for a rough estimate of $7.2 million in hospital costs for these 89 cases of RAP. Percentage of incidences does not always tell the entire story, as can be seen by the fiscal impact of a 0.00083% incidence.

In 2014, a perception existed that RAP was all too common at our facility, and in an attempt to move RAP into the "never event" category, we instituted preoperative screening in January 2015. When a patient was

Year	Reintubations (n)	Patients admitted to PACU (N)	Percent of reintubations
2010[a]	20	11,982	0.00167
2011	26	15,139	0.00172
2012	14	14,846	0.00094
2013	12	14,178	0.00085
2014	6	14,363	0.00042
2015	5	14,882	0.00034
2016	5	15,048	0.00033
2017[a]	1	7,407	0.00014
All years	89	107,845	0.00083

Table 3. Reintubation After Planned Extubation, Incidence and Percentages by Year
Abbreviation: PACU, postanesthesia care unit.
[a]Partial year data.
Mann-Kendall trend test (2-tailed $P = .009$).

identified as high risk (age > 70 years, advanced pulmonary disease, poor nutritional status, high-risk surgery, or history of RAP), an alert was entered on the surgical schedule to inform all providers. During this time, an emphasis on multimodal analgesia, targeted fluid management, train-of-four (TOF) monitoring and NMB reversal similar to the recommendations of Grocott[10] were practiced in the patients identified at high risk. The use of noninvasive ventilation for the first hour after extubation was instituted for patients at high risk of RAP.[11] Although this study was retrospective, the period from 2015 through 2017 constituted a postinterventional period whereby the intervention was the identification of patients at high risk of RAP. Anesthesia providers were made aware of the preoperative identification of patients with a high risk of RAP and were attuned to the departmental goal of reducing RAP. The exact anesthesia care administered to these patients was not identified because it was not within the scope of the study, although we are of the opinion that care must have been altered to achieve the decreases in incidence of RAP reported here.

The inconsistent documentation of TOF monitoring across both the RAP and control group is troubling. Numerous authors have described this phenomenon.[12,13] Although in this retrospective study, we were unable to discern the actual intraoperative use of TOF monitoring, the old adage "if it is not documented, it was not done" comes to mind.[14] The new consensus statement released by Naguib et al[15] not only recommends TOF monitoring for all patients receiving NMB but also that subjective monitoring should be "abandoned in favor of" objective (quantitative) monitoring.

Neostigmine dosing was identified previously as a possible contributor to RAP.[3] The dosing of neostigmine ranged from 0 to 6 mg in the control group and 0 to 8 mg in the RAP group. These dose ranges demonstrate a variation from the maximum dosing recommendations of 0.07 mg/kg or 5 mg "whichever is less"[16] and are inconsistent with the recommendations published by Naguib et al.[15] The upper ranges also demonstrate that there were, in fact, cases of neostigmine intoxication, which is known to cause muscle dysfunction.[16] We surmise that providers were most likely attempting to reverse moderate to deep NMB or observed residual neuromuscular weakness after an initial administration and may have administered a second dose of neostigmine, thereby exceeding dosing recommendations. An argument could be made that those patients who score at moderate to high risk of RAP should have their NMB reversed with sugammadex as opposed to neostigmine because nearly 81% of patients who experienced RAP received rocuronium. Sugammadex's mechanism of action removes rocuronium through the encapsulation of the steroid ring, thereby eliminating its ability to bind at the receptor[17] as opposed to neostigmine, which acts indirectly by increasing the amount of acetylcholine to compete at the neuromuscular junction.

Implementing the RAP predictive risk index described by Lin and coworkers[3] will identify patients at high risk of RAP, and its predictive power is increased over 5% when an additional weight of 10 points is added to the score for patients over the age of 64 years. In an editorial that accompanied the SPORC prediction tool,[2] Young and Ramachandran[18] expressed the lack of utility in the use of a prediction tool for rare events. We argue that our experience demonstrated that the preoperative identification of patients with a high risk of RAP allows for intraoperative and postoperative plans of care that reduce the incidence of RAP.

The pronounced limitation of this study is its retrospective design. At the beginning of the study period in 2010, our institution moved from a paper record to an electronic medical record (EMR), the Cerner health information system (Cerner Corp). Near the end of this retrospective review, the EMR transitioned to the Epic health information system (Epic Systems Corp). Several iterations of electronic records were in force in the Cerner electronic health information system from 2010 to 2017. These differences in record keeping prevented

the capture of data of interest across the entire study period, for instance, perioperative narcotic administration and patient weight at the time of surgery. In fact, the contracted data abstracter was unable to obtain nearly one-third of the requested data, which required the authors to abstract by hand all the data presented here.

Conclusion

The ramifications of reintubation are severe, as reported by others.[5,8] Reported rates of RAP range from 0.06% to 1.8%.[1-3,7,19] Reintubation rates are quite low by percentage. The numbers could double for the institutions in the lowest range but would remain below the median. We argue that as a quality metric, reintubation may be an inadequate indicator, whereas the documentation of NMB (standard TOF or acceleromyography) may be superior.[15,20] The absence of TOF documentation was prevalent in our study and in others.[9,12]

Preoperative attention to increased risk of RAP decreases the incidence of RAP. Care must be taken when the anesthesia provider is caring for an elderly patient with the comorbidities of COPD or pneumonia and presenting for an emergent surgery involving the abdomen, thorax, or airway. In light of current best evidence, NMB monitoring and reversal must be ensured. Attempting to reverse moderate to deep NMB with increased dosing of neostigmine should be avoided, and NMB reversal with sugammadex should be employed in these cases as well as when residual weakness is observed or when the patient scores a moderate to high risk of RAP. Hypothermia should be avoided, and a multimodal pain management regimen should be adopted.

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