

# Prolonged patient emergence time among clinical anesthesia resident trainees

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## Abstract

**Background and Aims:** Emergence time, or the duration between incision closure and extubation, is costly nonoperative time. Efforts to improve operating room efficiency and identify trainee progress make such time intervals of interest. We sought to calculate the incidence of prolonged emergence (i.e., >15 min) for patients under the care of clinical anesthesia (CA) residents. We also sought to identify factors from resident training, medical history, anesthetic use, and anesthesia staffing, which affect emergence.

**Material and Methods:** In this single-center, historical cohort study, perioperative information management systems provided data for surgical cases under resident care at a tertiary care center in the United States from 2006 to 2008. Using multiple logistic regression, the effects of variables on emergence was analyzed.

**Results:** Of 7687 cases under the care of 27 residents, the incidence of prolonged emergence was 13.9%. Emergence prolongation decreased by month in training for 1<sup>st</sup>-year (CA-1) residents ( $r^2 = 0.7$ ,  $P < 0.001$ ), but not for CA-2 and CA-3 residents. Mean patient emergence time differed among 27 residents ( $P < 0.01$  for 58.4% or 205/351 paired comparisons). In a model restricted to 1<sup>st</sup>-year residents, patient male gender, American Society of Anesthesiologists (ASA) physical status >II, emergency surgical case, operative duration  $\geq 2$  h, and paralytic agent use were associated with higher frequency of prolonged emergence, while sevoflurane or desflurane use was associated with lower frequency. Attending anesthesiologist handoff was not associated with longer emergence.

**Conclusion:** Incidence of prolonged emergence from general anesthesia differed significantly among trainees, by resident training duration, and for patients with ASA >II.

**Key words:** Anesthesia trainee, emergence time, resident education

## Introduction

Emergence time encompasses the time from surgical incision closure to extubation. This anesthesia-controlled time interval is largely under the control of the anesthetist. Given the transition to competency-based assessments by the Accreditation Council for Graduate Medical Education (ACGME) through the milestones project, reliable outcome metrics are necessary

to assess anesthesia trainee proficiency.<sup>[1]</sup> This transition to quality- rather than quantity-based curricula necessitates measurable surrogates of competency.<sup>[2]</sup> Patients intubated under the care of clinical anesthesia (CA) residents have longer emergence times than more experienced counterparts.<sup>[3]</sup> Emergence time and other anesthesia-controlled time intervals may be useful, readily obtainable standards for assessing resident progress. Furthermore, given the cost of operating room time (OR),<sup>[4-8]</sup> identifying factors which influence prolonged emergence time may direct improvement of OR efficiency.<sup>[9,10]</sup>

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10.4103/0970-9185.194776

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**How to cite this article:** House LM, Calloway NH, Sandberg WS, Ehrenfeld JM. Prolonged patient emergence time among clinical anesthesia resident trainees. J Anaesthesiol Clin Pharmacol 2016;32:446-52.

A resident's experience and management choices likely influence the progression of events that are readily captured in clinical information systems. In the current study, data collected from perioperative information management systems (PIMS) were analyzed to understand the effect of anesthesia resident training duration on patient emergence time. We hypothesized that resident experience would be negatively correlated to patient wake up time. Understanding these factors is essential before considering emergence time as an outcome metric for trainees.

## Material and Methods

This single-center, historical cohort study was initiated after Institutional Review Board approval and waiver of informed consent requirements were obtained prior to data collection. Adults (>18 years of age) undergoing general anesthesia at Massachusetts General Hospital, Boston, MA from February 01, 2006 to November 30, 2008 (33 months total) were included. Only surgical encounters under the care of anesthesia residents were included. Intraoperative data were maintained by an PIMS (Metavision; iMDsoft, Needham, MA, USA) as previously described.<sup>[11]</sup> We obtained demographic, intraoperative, and staffing data from PIMS and anesthesia trainee data from the anesthesiology residency office. Patient and resident information was de-identified, and residents were assigned aliased identification numbers (i.e., number 1-27).

Emergence time was computed as the duration between surgical incision closure and extubation time, in minutes. Cases which arrived to or left from the OR intubated were excluded from the analysis, as temporal data in PIMS was unavailable for patients outside of the operative room. We report the incidence of prolonged emergence time (i.e., >15 min).<sup>[12]</sup> Since we were interested in tracking emergence times through residency training, we only included residents who had at least 10 cases within each residency year (i.e., CA-1 through CA-3), and a sufficient total case load ( $\geq 95$  cases). Thus, we were only able to study one cohort of anesthesia residents at this training institution. This cutoff was derived from a goal precision of 10% in measuring the incidence of prolonged emergence time for each comparison group (i.e., resident or month of training), assuming a standard deviation of 5% for prolonged emergence incidence. To eliminate bias, cases for residents with prior anesthesia training, with any interruption in training, or with a nonconventional training termination date were excluded.

Emergence time and incidence of prolonged emergence were compared to months in residency training. Cases where more than one resident provided care or signed into the

electronic record were excluded from the analysis for issues pertaining to accurately identifying the extubating resident. To control for differences in daytime personnel and resources, we dichotomized case start times as during (0800-1700) or after (1701-0759) standard business hours. A case with two or more attending anesthesiologists was considered to have a "handoff," or transfer from one attending to another.

## Statistical analysis

Since emergence time and surgical duration follows the right-skewed Weibull distribution,<sup>[12]</sup> we report median and interquartile range. The incidence of emergence time prolongation was reported with 95% confidence interval (CI). These two measures are reported for a month in training and for resident ID. We used least-squares linear regression to measure the effect of training time (in months) on both emergence time and incidence of prolonged emergence for 1<sup>st</sup>-year (CA-1) residents. Paired comparisons of emergence time and incidence of prolongation among resident ID was executed by nonparametric Wilcoxon method and analysis of means for proportions, respectively.

Univariate odds ratios (ORs) were computed for covariates. In this comparison, we imputed unavailable values of estimated blood loss and fluids volume administered as <2 L since these missing designations in the anesthesia report were thought to be surrogate for minimal values. We did not impute body mass index (BMI) or American Society of Anesthesiologists (ASA) values due to the lack of surrogate data for BMI and the small (0.8% of final data set) fraction of ASA data missing.

To determine independent predictors of prolonged emergence, we constructed a multivariable logistic regression model for cases under the care of CA-1 residents. Quarter in training (i.e., quarter 1 corresponds to months 1-3) was nested within the resident ID variable to measure the effect of training duration for a given resident.

In a refined multivariable model of prolonged emergence for CA-1 residents, we screened covariates for significant predictors of emergence prolongation. Interaction terms between inhaled anesthetics were included in the regression screening (e.g., nitrous oxide and isoflurane) to consider the effect of multiple inhalational use during general anesthesia. Using forward selection with inclusion criteria of  $\alpha = 0.10$ , inter-variable covariance <0.20, and omission of covariates missing >20% data, we constructed a multivariable logistic regression model for quarters 1-4. Values of  $P < 0.05$  were considered statistically significant. The analysis was performed in JMP 10 (SAS Institute, Cary, NC, USA).

## Results

The final dataset contained 7687 surgical cases under the care of 27 eligible CA trainees [Figure 1]. Patient wake-up time followed a Weibull distribution [Figure 2]. For patients under the care of all residency classes, several demographic and intraoperative covariates influenced emergence prolongation [Table 1]. Use of paralytics significantly increased odds of emergence prolongation (multivariable OR: 1.9, 95% CI: 1.7-2.2). In addition, ASA status above II and emergency cases increased emergence prolongation risk. All inhaled agents except isoflurane were associated with significantly decreased odds of prolonged emergence. The overall incidence of prolonged patient emergence was 13.9% [Table 2]. Male to female ratio was approximately 1:1 and most included cases were ASA physical status (PS) of I or II. Unadjusted emergence time decreased linearly by month in training for CA-1 residents [ $r^2 = 0.51$ ,  $P = 0.008$ , Figure 3a]. Similarly, incidence of prolonged emergence incidence decreased linearly for months 1 through 12 [ $r^2 = 0.7$ ,  $P = 0.006$ , Figure 3b].

In comparing patient emergence time among all residents, mean emergence time differed [Figure 4] ( $P < 0.01$  for 58.4% or 205 of 351 paired comparisons via Wilcoxon method, Supplement 1).

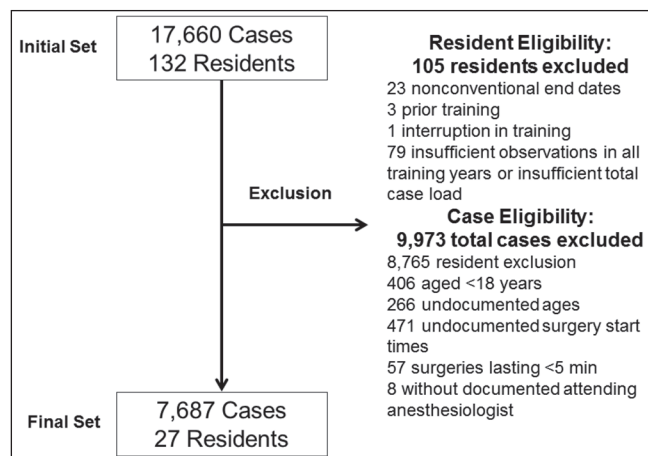
To explain the linear decrease in emergence time among CA-1 residents, we constructed a refined multivariable model of emergence prolongation [Table 3]. ASA status above II was associated with greater risk of prolonged emergence. Sevoflurane and desflurane were associated with a decrease in prolonged emergence incidence (OR:

0.8, 95% CI: 0.7-0.9,  $P < 0.01$  and OR: 0.7, 95% CI: 1.8-2.6,  $P < 0.01$ ). Again, paralytic use exerted the greatest effect for emergence time prolongation (OR: 2.1, 95% CI: 1.8-2.6). No interaction term for inhaled anesthetics (e.g., isoflurane with nitrous oxide) was a significant predictor of emergence prolongation. In contrast to prolonged emergence analysis for all resident trainees, patient age, anesthesia personnel staffing, hemodynamic, and other intraoperative factors were eliminated via forward selection.

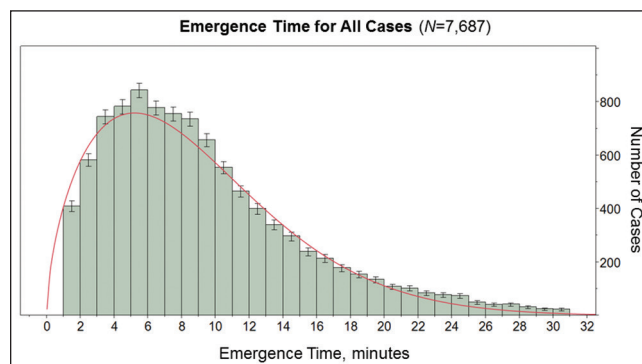
## Discussion

Emergence time is an automatically measured anesthesia-controlled time interval. Time to wake up is influenced by anesthetic agent choice, dose, and dose duration.<sup>[13]</sup> However, technical and logistic factors also influence this time interval.<sup>[14]</sup> In analyzing patient emergence time under the care of CA residents, patient demographics, as well as training duration, contributed to the time from surgical completion to extubation. The incidence of prolonged emergence decreased linearly for CA-1 trainees, but not more experienced residents.

Correlation between individual training duration CA-1 and patient emergence time hints at an opportunity to track residents' performance during the earliest stages of anesthesiology training. Utilization of automatically collected PIMS data has already assisted with trending resident progression in the context of the ACGME milestones.<sup>[15]</sup> These types of metrics may facilitate educators and program directors in identifying struggling residents. Since the 1<sup>st</sup>-year training effect on patient emergence time was gradual and modest, the efficacy of educational interventions targeting extubation may be analyzed. To achieve this, one must necessarily control for patient gender and ASA classification, emergency surgeries,



**Figure 1:** Flow diagram for resident and case eligibility. Cases were excluded based on resident and case eligibilities. No cases were under the care of multiple residents. Eighty thousand seven hundred and sixty-five cases were excluded due to resident ineligibility. The final dataset included 7687 surgical cases for 27 anesthesia residents over 3 years



**Figure 2:** Histogram for unadjusted patient wake-up time (WUT) from general anesthesia for all cases ( $n = 7687$ ). The distribution of wake-up time followed a Weibull distribution (curved line) with a scale ( $\alpha$ ) of  $9.8 \pm 0.1$  and shape ( $\beta$ )  $1.6 \pm 0.2$ . Errors bars represent 95% confidence interval estimates for the true number of cases per minute value for emergence time

**Table 1: Predictors of prolonged emergence time for all anesthesia residents**

Covariate	Univariate		Multivariable		
	RR	95% CI	OR	95% CI	P
<b>Demographic</b>					
Age >65 years	1.2*	1.1-1.4	1.0	1.0-1.1	0.46
Male gender	1.2*	1.0-1.3	1.1*	1.0-1.2	<0.001
BMI >30 <sup>†</sup>	1.1	0.9-1.3	N/A	N/A	N/A
ASA PS III-V <sup>†</sup>	1.6*	1.4-1.7	1.2*	1.1-1.3	<0.001
Emergent status	1.7*	1.4-2.0	1.3*	1.1-1.6	<0.001
<b>Staffing</b>					
Attending handoff	1.3*	1.1-1.5	1.1	1.0-1.2	0.08
After business hours	1.3*	1.1-1.6	1.1	0.9-1.2	0.39
<b>Intraoperative</b>					
Surgical duration ≥2 h	1.7*	1.5-1.9	1.2*	1.1-1.3	<0.001
TIVA	1.2*	1.0-1.5	1.0	0.8-1.2	0.63
Nitrous oxide	0.7*	0.6-0.8	0.9*	0.8-1.0	<0.01
Isoflurane	1.9*	1.6-2.1	1.1	1.0-1.3	0.20
Sevoflurane	0.7*	0.6-0.8	0.8*	0.7-1.0	0.01
Desflurane	0.9	0.7-1.1	0.8*	0.7-1.0	0.03
Paralytics	4.1*	3.2-5.2	1.9*	1.7-2.2	<0.001
EBL ≥2 L <sup>‡</sup>	1.6*	1.0-2.5	1.3	0.9-1.8	0.13
Fluids ≥2 L <sup>‡</sup>	1.0	0.9-1.2	1.0	0.8-1.2	0.37
Transfusion	1.0	0.8-1.2	0.9	0.8-1.0	0.24
BIS monitoring	1.2*	1.0-1.4	1.1*	1.0-1.2	0.02
<b>Resident training</b>					
Quarter in training	N/A	N/A	N/A	N/A	0.99
Resident ID (quarter in training) <sup>§</sup>	N/A	N/A	N/A	N/A	<0.001

Unadjusted, univariate RR ratios and adjusted, multivariable ORs for predictors of prolonged (>15 min) emergence time for all surgical cases (n = 7687). For the multivariable logistic model, the area under the receiver-operator characteristic curve = 0.72 and model intercept = 0.26 (95% CI: 0.20-0.42), \*P < 0.05 versus cases with emergence time ≤15 min, <sup>†</sup>Missing data were not imputed (ASA missing 55 values, BMI missing 4077 values), <sup>‡</sup>Missing data were imputed as <2 L, <sup>§</sup>Nested term, ASA PS = American Society of Anesthesiologists physical status, BIS = Bispectral index, BMI = Body mass index, EBL = Estimated blood loss, RR = Relative risk, ORs = Odds ratios, ID = Identification, TIVA = Total intravenous anesthesia (i.e., no inhalational agent used), CI = Confidence interval, N/A = Not available

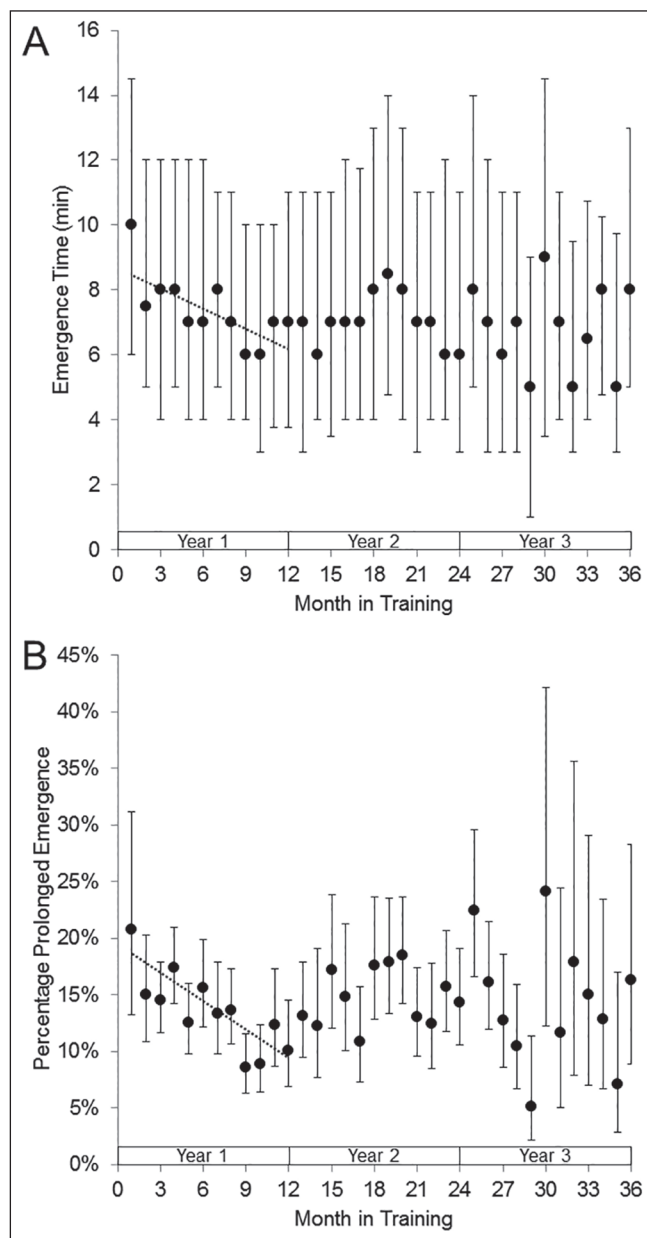
operative time, and anesthetic choices to reasonably isolate the effect of the intervention for a given resident.

However, to be a valid performance metric for trainee progress, emergence time must further be investigated in the five-source framework.<sup>[16]</sup> Thus far, validity-type evidence includes only relations to other variables: prolonged emergence from anesthesia is higher among 1<sup>st</sup> year trainees than more experienced trainees. The retrospective nature of this investigation precludes assessment of the other four sources (content, response process, internal structure, and consequences evidence), but future endeavors should address these in the consideration of patient emergence time as a performance metric.

Attending anesthesiologist handoff was not associated with more instances of prolonged emergence. Attending physicians may direct residents in decreasing delivery, stopping, or switching inhalational agents for timely recovery, but the transition of care and oversight had no measurable impact in the present study. Other staffing factors (daytime

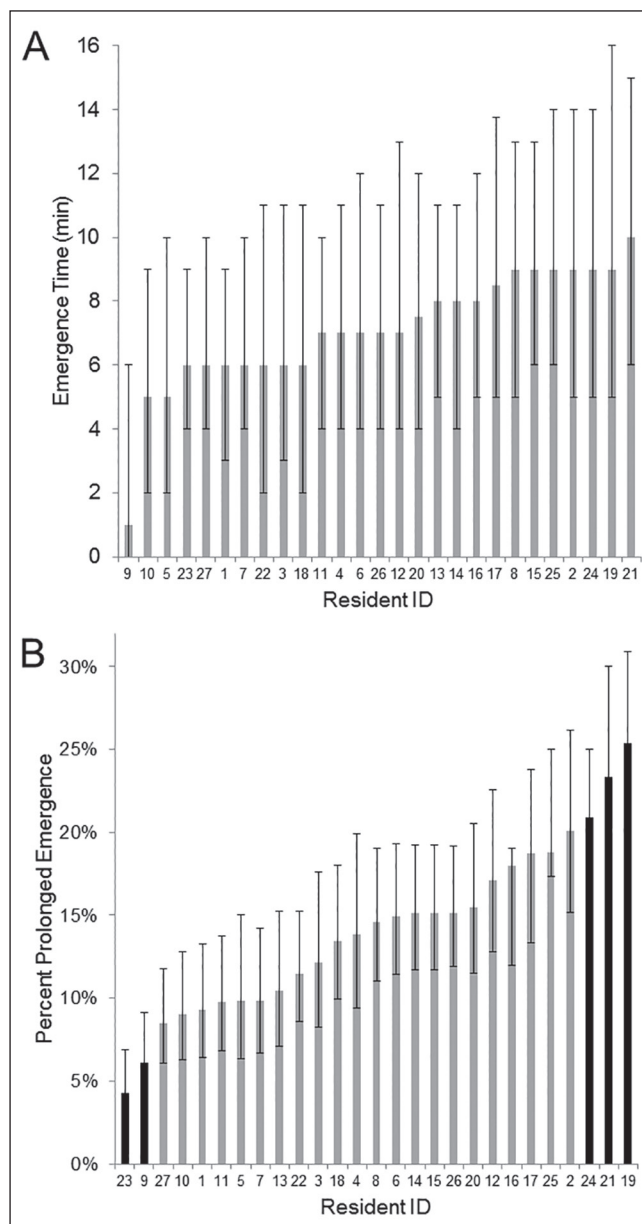
case vs. nighttime case) similarly were not associated with emergence prolongation. Since the authors desired to isolate the effect of one resident's training within a given surgical encounter, we excluded cases under the care of multiple residents. This likely eliminated patients who had longer procedure times and thus had longer exposure to anesthetic agents. Of included cases with surgical durations >2 h, longer emergence times were observed. Exclusion of cases leaving the OR intubated likely resulted in some degree of underreporting of emergence time.

The current study has several strengths. The sample size was large (n = 7687 for all data; n = 3719 for 1<sup>st</sup>-year resident only data). Measurements of longer emergence time and frequency of prolonged emergence approximated previous work.<sup>[12,13]</sup> We showed that ASA PS<sup>[17]</sup> and emergent status prolong emergence time, variables previous studies do not control for.<sup>[3,18]</sup> Consistent with recent meta-analyses, we found that desflurane or sevoflurane use was associated with lower rates of prolonged patient emergence time versus isoflurane.<sup>[12,13,19,20]</sup>



**Figure 3:** Emergence time for month in residency. Median (interquartile range) emergence time (a) and incidence (95% confidence interval) of prolonged emergence (b) by month in anesthesia residency training for 27 residents. Dashed lines represent least squares linear regression fit. Fit model for emergence time (months 1-12): Pearson  $r^2 = 0.51$ ,  $P < 0.01$ , Y-intercept = 8.8 min, slope =  $-0.21$  min/month. Fit model for prolonged emergence incidence (months 1-12): Pearson  $r^2 = 0.65$ ,  $P < 0.01$ , Y-intercept = 18.7%, slope =  $-0.8\%$ /month

The results of this study must be interpreted in light of its limitations. As a historical cohort study, concerns for record accuracy exist. Limitations with the PIMS data extraction precluded tabulation of event rates besides prolonged emergence. Future endeavors should assess the occurrence of laryngospasm, aspiration, airway obstruction, hypoxemia, emergence agitation or delirium, and especially the need for reintubation for patients under the care of residents. Of note, laryngospasm incidence does not change with the type of inhaled anesthetic administered.<sup>[20]</sup> The authors cannot



**Figure 4:** Emergence time and incidence of prolonged emergence per resident. Median (interquartile range) emergence time and incidence of prolonged emergence (95% confidence interval) for 27 clinical anesthesia residents during 3 years of residency training. Resident identification was ordered from lowest to greatest values for emergence time and incidence of emergence prolongation. For emergence time, 205 pair differences for 351 total pair comparisons were observed by nonparametric Wilcoxon method ( $P < 0.01$ ). Residents with significantly different prolongation incidences are represented by solid black columns (analysis of means for proportions;  $P < 0.01$ )

exclude the possibility that unconsidered covariates, such as the history of anesthetic complications, documented difficult intubation, obstructive sleep apnea, and others may have exerted an effect on emergence time.

Due to data access limitations, authors were unable to follow residents for more than 3 years. In addition, parameters involving surgical staff (e.g., type of surgery, surgical service, and the presence of a surgical resident physician) and

**Table 2: Demographic, staffing, and intraoperative data of surgical cases for all resident years**

Covariate	n, mean, or median	%, SD, or IQR
All patients	7687	100
Demographic		
Age, years (mean, SD)	53.7	17.2
Gender		
Male	3675	47.8
Female	4012	52.2
BMI, mg/kg <sup>2</sup> (mean, SD) <sup>a</sup>	28.1	6.8
ASA physical status <sup>b</sup>		
I	1137	14.9
II	4491	58.8
III	1920	25.2
IV	83	1.1
V	1	0.0
Emergency case	364	4.7
Staffing		
Attending handoff	950	12.4
After business hours	631	8.2
Intraoperative		
Emergence time, min (median, IQR)	7	4-12
Prolonged emergence	1069	13.9
Surgical duration, min (median, IQR)	88	47-152
TIVA	475	6.2
Agents		
Nitrous oxide	6598	85.8
Isoflurane	763	9.9
Sevoflurane	5761	74.9
Desflurane	571	7.4
Paralytic	6033	78.5
Hemodynamics		
EBL, mL (mean, SD) <sup>c</sup>	310	711
Fluids, mL (mean, SD) <sup>d</sup>	1585	1371
Transfusion	621	8.1
BIS monitoring	1493	19.4

Variable values for <sup>a</sup>4077, <sup>b</sup>55, <sup>c</sup>4695, and <sup>d</sup>1734 cases were unavailable, Data for all surgical cases (n = 7687). Emergence time >15 min was considered prolonged, ASA PS = American Society of Anesthesiologists physical status, BIS = Bispectral index, BMI = Body mass index, EBL = Estimated blood loss, TIVA = Total intravenous anesthesia, IQR = Interquartile range, SD = Standard deviation

surgical complications were not considered at the time of data collection. However, procedure variability does not vary greatly for 1<sup>st</sup>-year residents, especially when controlling for the quarter in training. Additional factors not addressed included prone versus supine positioning,<sup>[14]</sup> BMI, and anesthetic dosing. Finally, we did not consider the type of internship prior to residency (i.e., transitional vs. categorical), or other previous medical experiences (emergency medical responder training, etc.).

The study of emergence time suffers from a lack of universal methodology. We utilized electronic medical record data,

**Table 3: Predictors of prolonged emergence time for first-year residents, refined model**

Covariate	Multivariable		
	OR	95% CI	P
Demographic			
Male gender	1.1	1.0-1.2	0.04
ASA physical status III-V*	1.2	1.1-1.4	<0.01
Emergent status	1.3	1.0-1.6	0.05
Intraoperative			
Surgical duration ≥2 h	1.2	1.1-1.3	<0.01
Agents			
Sevoflurane	0.8	0.7-0.9	<0.01
Desflurane	0.7	0.6-0.9	<0.01
Paralytics	2.2	1.8-2.6	<0.001
Resident data			
Resident ID (quarter in training) <sup>†</sup>	N/A	N/A	<0.001

Refined model with adjusted, multivariable ORs for predictors of prolonged (>15 min) emergence time for cases under care of a first-year resident (n = 3719), Forward selection eliminated variables with  $\alpha > 0.10$ , covariance >0.20, and variables with >20% data missing. Area under the receiver-operator characteristic curve = 0.8 and model intercept = 0.10 (95% CI: 0.8-0.14). \*Missing data were not imputed, <sup>†</sup>Nested variable. ORs are compared to cases without emergence prolongation. ASA PS = American Society of Anesthesiologists physical status, ID = Identification, N/A = Not available, CI = Confidence interval

which included time to endotracheal extubation. Other efforts have employed time to open eyes, time to state the date of birth, and time to recover prior functional capacity after 1 day of surgery<sup>[20]</sup> to assess emergence time. Moreover, the interval between the end of surgery and patient wake up is reported varyingly: Some studies start timing at the end of anesthetic delivery,<sup>[21]</sup> some at surgical closure and others do not specify.<sup>[22]</sup> Future studies should quantify the degree to which supervising anesthetists intervened in anesthetic management at the end of surgery, such as stopping volatile anesthetic delivery and the specific criteria used for extubation. Finally, airway type (e.g., endotracheal vs. laryngeal mask airway) and the removal thereof contribute to difficulty in raw comparison of emergence time.

Retrospective modeling of data presents many challenges regarding generalizability and validity. As a single-center study, the conclusions of this study should be confirmed by multicenter efforts. With regard to “overfitting,” defined loosely as finding statistical significance when none truly exists within a retrospective model, common culprits include:

1. Small sample size,
2. Too many variables, and
3. Relatively rare events.<sup>[23]</sup>

While the number of residents studied in the dataset is small (27), the sample of included cases is quite large (7687). The rate of prolonged emergence was relatively common (13.9% of cases), and the number of variables after model refinement

was eight of 22 eligible covariates. Thus, none of the three risks for overfitting apply to the current dataset. Of multivariate model types, forward selection was favored by the authors for its limited computational demands in addition to its rapid convergence toward an asymptotic predictive value beyond a sample size of 200.<sup>[24]</sup> The elimination of resident-cases allowed for assessment of training on patient emergence; however, this decreased the resident sample size such that it precluded assignment of the cohort into a training and validation model. Concerns with excluding a large number of observations (9973 exclusions of 17,660 cases) remain and the conclusions of the current study should be interpreted with appropriate caution. External validation at other training institutions may confirm or refute the findings of the current study.

## Conclusion

In summary, the incidence of prolonged emergence from general anesthesia decreased linearly over time during the CA-1 residency year residency. Furthermore, the frequency of prolonged emergence differed among individual residents. Finally, in addition to operative time and anesthetic choice, nonobvious patient factors such as ASA PS III or greater and male gender are associated with prolonged emergence time. Thus, this frequency may be a useful index of 1<sup>st</sup>-year anesthesia resident progress pending further validity-type evidence.

## Financial support and sponsorship

Institutional Funds from the department of Anesthesiology, Vanderbilt University, Nashville, TN, USA.

## Conflicts of interest

There are no conflicts of interest.

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