An Evaluation of Risk Factors for Extubation Failure in Surgical Patients in Intensive Care

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Abstract

Background: Risk factors for extubation failure in postoperative surgical ICU patients extending 30 postoperative days are not evident in the literature.
Objectives: To identify risk factors related to 30 day reintubation in postoperative non trauma SICU patients.
Method: A retrospective descriptive comparative study of non-trauma surgical patients who were admitted postoperatively to the SICU with an endotracheal tube in place requiring invasive mechanical ventilation was conducted using electronic medical records covering 2.5 years. Exclusion criteria included SICU trauma and transplant patients, patients younger than 18 years of age, patients not eligible for reintubation that have elected to receive only comfort care and those who expired prior to extubation. A database of clinical factors predicting extubation failure was created using the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) framework, with study variables identified from a review of literature, national guidelines, and SICU expert consultation to evaluate the primary outcome of extubation failure. Subjects who were successfully extubated (SE) were compared to those who failed extubation (FE).
Results: Logistical regression model analysis demonstrated a statistically significant relationship between respiratory rate and extubation failure. Respiratory analysis revealed an odds ratio of 1.086, (P = 0.034, CI = 1.006 – 1.172).
Discussion: The respiratory rate during the 24 hours prior to extubation was found to be a statistically significant risk factor in preparing for SE in postoperative surgical ICU patients. Respiratory rate is a factor readily available to all clinicians. It can readily be incorporated into the extubation decision making process. Yet given the limited data set and small sample size, further investigation is warranted.

Key Words
Keywords: critical care, ICU, intensive care, reintubation, failed extubation, unplanned extubation

Post extubation respiratory failure is related to high hospital costs, increased morbidity, and increased mortality (Brown et al., 2011; Brueckmann et al., 2013). Mechanical ventilation and ventilator support are frequent interventions utilized in the Intensive Care Unit (ICU) to provide life saving measures. The decision to extubate the patient on mechanical ventilation includes assessment of the continued need for mechanical ventilation and the need for an artificial airway (Miu et al., 2014). Interprofessional teams in critical care continue to explore methods to identify factors to optimize the preparations to enhance the success of extubation. The timing of extubation requires expert clinical judgment to optimize successful liberation from mechanical ventilation. Both early and delayed extubation times have been associated with increased mortality (Brown et al., 2011; Frutos-Vivar et al., 2006). Prolonged endotracheal intubation is associated with complications including laryngeal trauma, pulmonary damage, pneumonia, and psychologic sequela (Brown et al., 2011). Premature extubation may necessitate reintubation that requires emergent and uncontrolled endotracheal tube placement (Brown et al., 2011). Extubation failure is the need for replacement of the endotracheal tube due to the inability to sustain spontaneous breathing within a specific time period. The ability to correctly identify ICU patients at high risk for failing extubation and defining the causes of failure may have potential to decrease extubation failure and enhance patient safety during reintubation (Menon et al., 2012). The core concern of this study is identification of risk factors for extubation failure to increase the likelihood of timely and successful liberation from mechanical ventilation.

Numerous studies have been published over the last two decades investigating the weaning process and successful extubation from mechanical ventilation. However gaps remain in evaluating unplanned extubations over 30 postoperative days in general and vascular surgical patients in the ICU using clinical factors.

Methods

The focus of the current work was to initiate a retrospective evaluation of risk factors for extubation failure in a surgical ICU population with the goal of improving successful liberation from mechanical ventilation. Specific clinical risk factors of extubation failure were identified from the literature, clinical experts, and experience, to establish study variables. Institutional review board study approval was received.

The institutional ACS NSQIP database was utilized to identify surgical and vascular patients, demographic, comorbidities, and specific clinical factors during the hospital operative encounter within the study time period of 30 days observation interval. Additionally, records of patients admitted to the surgical ICU postoperatively with an endotracheal tube in place were identified between July 1, 2013 and December 31, 2015.

Study design

A retrospective descriptive comparative study of non-trauma surgical patients who were admitted postoperatively to the SICU with an endotracheal tube in place requiring invasive mechanical ventilation was conducted. Exclusion criteria included SICU trauma and transplant patients, patients younger than 18 years of age, patients not eligible for reintubation that have elected to receive only comfort care and those who expired prior to extubation.

Sample

The electronic medical records contained in the institutional ACS NSQIP database of general surgical and surgical specialty patients admitted postoperatively to the SICU between July 1, 2013 and December 31, 2015 meeting the prior stated study criteria with an endotracheal tube in place were eligible for entry into the study.

Setting

This study was conducted at a university affiliated medical center. This institutional setting has a greater than 600 bed capacity and serves a wide catchment area in the southeastern United States. The SICU is a fifteen-bed unit in which the study population of general surgery and surgical specialty ICU patients reside postoperatively requiring critical care services. The unit interprofessional team includes: critical care intensivists, resident physicians, pharmacists, acute care nurse practitioners, nurses, respiratory therapists, physical therapists, occupational therapists, surgical nutritionalists, chaplains, and social workers.

Procedure

A database was created using the ACS NSQIP framework, with study variables identified from a review of literature, national guidelines, and SICU expert consultation to evaluate the primary outcome of extubation failure. Variables evaluated included demographic, comorbidities, perioperative characteristics and surgical ICU clinical factors.

In addition to the ACS NSQIP dataset, postoperative SICU clinical variables retrieved during the 24 hours prior to the first ICU extubation for study inclusion were: GCS lowest total score, RASS lowest score, respiratory rate highest, oxygen saturation lowest (SpO_2), temperature maximum, heart rate maximum, blood pressure lowest systolic, blood pressure lowest mean, daily weight in kilograms. The daily weight timeframe was expanded outside the original timeframe to the time the weight was

recorded closest to the 24 hours prior to extubation to obtain a more complete data set. Laboratory data reported closest to the extubation time were: pre-extubation ABG (arterial blood gas), white blood cell count, serum sodium, hematocrit, and platelets. Initial Nutrition Support Consult, and Physical Therapy Evaluation, dates were also entered in the database.

Sample electronic medical records of postoperative surgical ICU patients meeting study inclusion were identified within the ACS NSQIP database. The ACS NSQIP database in this study was the primary source for identification of a patient record during a hospital admission for a surgical procedure meeting study inclusion criteria. Clinical Data Repository (CDR) electronic patient record retrieval identified surgical ICU patients requiring mechanical ventilation and the above prior stated clinical risk factors for this study. STICU Nurse Practitioner Quality Program database identified the specific date and time of the first postoperative extubation occurring in surgical ICU. Study data from these three data bases were joined to create the data base used for analysis.

After joining the relevant data, cleaning including deleting records not meeting subject criteria, striking duplicate patient record entries, and rejecting patient record entries outside the specific surgical hospital encounter dates was performed. A hand search was undertaken to identify accuracy in 10% of the cases. Additionally an attempt was made to locate missing data entries. When documentation was found in the Electronic Health Record (EHR), it was manually entered into the study database. The database containing 140 records was submitted to a statistician for descriptive analyses. The data of 93 records met statistician criteria for analyses.

Results

The data analysis total population was 93 patients. The records were grouped by those who were successfully extubated (SE), 70 patients, and those who failed extubation (FE), 23 patients. The descriptive demographics SEs were compared to those in FEs. Of interest are the FE data points noted in the next paragraph.

In the FE sample, 73.9% were male, 87% were Caucasian/white. The majority of patients were 50-80 years old. With respect to functional status 78.3% were independent and 21.7% dependent; 13.0% had moderate exertion dyspnea and 87.0% without dyspnea. Preoperative assessment of FE patients with severe COPD were 17.4% and without severe COPD were 82.6%. For FE patients with an open wound there were 17.4% and without open wound 82.6%. Sample population preoperative baseline characteristics categories with percentages are tabulated in A1 in Appendix A comparing patients who were successfully extubated to patients who failed extubation.

Sample population perioperative characteristics compared SE to those in the FE group. Of interest are the FE data points noted in the following paragraph.

The FE sample surgical specialties were, as follows: 87% were general surgery, 4.3% were gynecology, and 8.7% vascular. ASA classifications were: 0 % for ASA 1, 21.7% for ASA 2, 65.2% for ASA 3, and 13% for ASA 4. Sample population perioperative characteristics are outlined in Table A2 in Appendix A.

Successful extubations occurred in 70 observations while failed extubations occurred in 23 observations. Variables built into the analysis model included: age at time of surgery, highest respiratory rate within 24 hours pre-extubation, preoperative body mass index (BMI), heart rate maximum within 24 hours pre-extubation, temperature maximum within 24 hours pre-extubation, oxygen saturation (SpO_2) lowest within 24 hours pre-extubation, pO_2 lowest within 24 hours pre-extubation, preoperative weight compared to any pre-extubation weight change, sex, and race.

Data Analysis

Logistical regression model analysis demonstrated a statistically significant relationship between respiratory rate and extubation failure. Respiratory analysis revealed an odds ratio of 1.086, (P = 0.034, CI = 1.006 – 1.172). Respiratory rate was the only variable in the analysis that reached statistical significance. The study analysis revealed the risk of extubation failure increases by 8.6% for each breath per minute. See logistic regression data Table A3 in Appendix A. A visual inspection of the logistic regression figure reveals a sharp increase in probability of failure for rates > 26 breaths per minute. See Figure A1 in Appendix A.

Limitations of the Design

Three major limitations of the study are: (1) the retrospective study design is dependent on the quality of the documentation entered in EHR, (2) the institutional systems to retrieve electronic clinical data are limited, (3) difficulties with data retrieval and resulting small sample size limited analysis options.

Retrospective electronic clinical data entries in EHR were located in multiple locations hindering the ability to electronically find the data. Missing expected EHR data entries necessitated the deletion of records.

Ability to electronically retrieve identified variables was limited. Consultation with in house EHR staff was the first method explored to obtain a comprehensive report of clinical factors impacting extubation in surgical ICU patients. Multiple EHR staff communications provided assistance in identifying specific methods of locating data within the patient record, however the request for an electronic report containing the stated desired variables necessitated a time delay of months. Consequently the search for alternative methods to obtain an electronic report of retrospective record data ensued. Respiratory Therapy services were consulted to obtain a listing of study population extubation data. Their extubation database was reviewed which pertained to unplanned extubations in SICU, but did not satisfy the required electronic report needs of extubations for this study. CDR staff were amenable to the study request for securing the data and providing an electronic report. A CDR analyst was provided with ACS NSQIP data between January 1, 2011 and December 31, 2015. The study request for clinical data retrieval from patient records was at a clinical depth necessitating education of the CDR analyst's understanding of requested clinical data and identification of the specific location where documentation occurred in the hospital record. The data systems in the CDR encountered multiple challenges, as data was not stored in locations available by hand searching EHR . Communications with the CDR analyst facilitated clarification of exact data terms. The difficulties in finding the data in the CDR led to the reduction of clinical factors included in the study. The CDR data retrieval system was hindered in identifying the first postoperative extubation time and date.

The EHR system was in the initial transition implementation phase during 2011 limiting data retrieval efforts. A hand retrieval of data collection for records during 2011 was initiated which proved labor intensive. Each hand record search necessitated a lengthy time in locating clinical variables of interest with records entered in a variety of formats prior to the EHR system. CDR data retrieval required extensive searching for specific data elements of interest within the 24 hour timeframe prior to extubation. Despite multiple attempted methods using known validated data the CDR system was unable to consistently identify the date and time of postoperative extubations in SICU patients. The required first extubation date and time in critical care was identified in the SICU NP database that was initiated in July 2013. Electronic retrieval systems within the time limits of this project limited this study from July 1, 2013 to December 31, 2015.

The desired statistical power of the study was not achieved due to a final sample of 93 records. Data analysis options were also limited relative to the sample size necessitating a restrictive model.

Strengths of the Design

The strengths of the study design are: (1) ACS NSQIP foundational framework provided the demographic, operative, and unplanned intubation within 30 postoperative day data (2) Real time data set provided accurate extubation date and time. SICU nurse practitioners granted access to their database to obtain the extubation date and time. SICU nurse practitioners recorded the postoperative extubation time and date in near real time (daily except on weekends) in their database from EHR. The securing of a reliable extubation date allowed creation of a data set that provided the link necessary for additional clinical factor data to be obtained from the CDR. The surgical quality and research expert and project mentor linked SICU NP data records with extubation dates and times with ACS NSQIP records. The joining of the prior databases identified patient records with the needed extubation data thus allowing CDR data retrieval of study specific data elements. (3) Logistic regression was employed in order to explore the relationship between the reintubation outcomes as a function of candidate risk factors. A two-tailed alpha level of 0.05 and confidence intervals were reported.

Discussion

The respiratory rate during the 24 hours prior to extubation was found to be a statistically significant risk factor in preparing for SE in postoperative surgical ICU patients. Yet the retrospective sample size limited the power of the study and ultimately limits generalizability. The study framework created a process on which future clinical studies could be conducted utilizing electronic data retrieval systems to identify surgical patients with risk factors for extubation failure in the 24 hours prior to extubation in the ICU. The resulting data analysis could drive improvement in the extubation practice relevant to SE in surgical ICU patients.

In summary, the study data identified a salient risk factor (respiration rate) related to extubation failure in this population of postoperative non-trauma surgical ICU patients that may be incorporated into the extubation process. This revelation can be used to guide clinicians as they consider extubations.

Nursing Practice Implications

Clinical factors influencing extubation outcomes can guide nursing interventions and communications with interprofessional team members. Bedside nurses are pivotal in employing patient interventions to promote extubation success. The hard core data defining the significance of clinical factors in the 24 hours preceding extubation were underexplored in the existing literature. The results of this study contribute new information regarding the assessment of respiratory rate during the 24 hours preceding extubation as a clinical factor to consider prior to extubation. The study provides initial insight into the significance of elevated respiratory rates during the weaning process in ICU surgical patients to achieve extubation success.

The extubation process study findings can contribute to the establishment of a foundational framework on which to build a program focused on extubation outcomes to promote patient safety.

References

Alvarez, M. P., Samayoa-Mendez, A. X., Naglak, M. C., Yuschak, J. V., & Murayama, K. M. (2015). Risk factors for postoperative unplanned intubation: Analysis of a national database. *American Surgeon, 81*(8), 820-825.

American College of Surgeons, NSQIP Operations Manual, Chapter 4, ACS NSQIP Variables and definitions, 2016. Retrieve from: https://www.facs.org/quality-programs/acs-nsqip

Balas, M. C., Vasilevskis, E. E., Olsen, K. M., Schmid, K. K., Shostrom, V., Cohen, M. Z., . . . Burke, W. J. (2014). Effectiveness and safety of the awakening and breathing coordination, delirium monitoring/management, and early exercise/mobility bundle. *Critical Care Medicine, 42*(5), 1024-1036.

Barr, J., Fraser, G., Puntillo, K., Ely, E., Gelinas, C., Dasta, J., … Skrobik, Y., (2013). Clinical practice guidelines for the management of pain, agitation, and delirium in adult patients in the intensive care unit. *Critical Care Medicine,* 41(1), 263-306.

Brown, C.V., Daigle, J.B., Foulkrod, K.H., Brouillette, B., Clark, A., Czysz, C., . . . Cooper, H. (2011). Risk factors associated with early reintubation in trauma patients: A prospective observational study. *Journal of Trauma-Injury Infection & Critical Care, 71*(1), 37-41.

Brueckmann, B., Villa-Uribe, J., Bateman, B.T., Grosse-Sundrup, M., Hess, D.R., Schlett, C.L., & Eikermann, M. (2013). Development and validation of a score for prediction of postoperative respiratory complications. *Anesthesiology, 118*(6), 1276-1285.

Frutos-Vivar F., Ferguson N.D., Esteban A., Epstein S.K., Arabi Y., Apezteguia C, . . . Anzueto A. (2006). Risk factors for extubation failure in patients following a successful spontaneous breathing trial. *Chest, 130*(6), 1664-1671.

Healey, C., Osler, T. M., Rogers, F. B., Healey, M. A., Glance, L. G., Kilgo, P. D., . . . Meredith, J. W. (2003). Improving the glasgow coma scale score: Motor score alone is a better

predictor. *Journal of Trauma-Injury Infection & Critical Care, 54*(4), 671-678.

Hua, M., Brady, J. E., & Li, G. (2012). A scoring system to predict unplanned intubation in patients having undergone major surgical procedures. *Anesthesia & Analgesia, 115*(1), 88-94.

Institute of Medicine. (1999). *To err is human.* Retrieved from: https://iom.nationalacademies.org/~/media/Files/Report%20Files/1999/To-Err-is-Human/To%20Err%20is%20Human%201999%20%20report%20brief.pdf

Kiekkas, P., Aretha, D., Panteli, E., Baltopoulos, G.I., & Filos, K.S. (2013). Unplanned extubation in critically ill adults: Clinical review. *Nursing in Critical Care, 18*(3), 123-134.

McCaffrey, J., Farrell, C., Whiting, P., Dan, A., Bagshaw, S., Delaney, A., (2009). Corticosteroids to prevent extubation failure: a systematic review and meta-analysis, Intensive Care Medicine, 35, 977-986.

Menon, N., Joffe, A.M., Deem, S., Yanez, N.D ., Grabinsky, Dagal, A., . . . Treggiari, M.M. (2012). Occurrence and complications of tracheal reintubation in critically ill adults. *Respiratory Care, 57*(10), 1555-1563.

Miu, T., Joffe, A.M., Yanez, N.D., Khandelwal, N., Dagal, A., Deem, S., & Treggiari, M., (2014). Predictors of reintubation in critically ill patients. *Respiratory Care, 59*(2), 178-185.

Mokhlesi, B., Tulaimat, A., Gluckman, T.J., Wang, Y., Evans, A.T., & Corbridge, T.C. (2007). Predicting extubation failure after successful completion of a spontaneous breathing trial. *Respiratory Care, 52*(12), 1710-1717.

Politano, A., Riccio, L., Lake, D., Rusin, C., Guin, L., Josef, C.,. Clark, M., … Calland, J.,

(2013). Predicting the Need for Urgent Intubation in a Surgical/Trauma Intensive Care Unit, *Surgery*, 154(5): 1110-1116.

Pronovost, P. J., Goeschel, C.A., Marsteller, J.A., Sexton J.B., Pham J.C., & Berenholtz S.M. (2009). Framework for patient safety research and improvement. *Circulation*, *119*(2), 330-337.

Ramachandran, S. K., Nafiu, O. O., Ghaferi, A., Tremper, K. K., Shanks, A., & Kheterpal, S. (2011). Independent predictors and outcomes of unanticipated early postoperative tracheal intubation after nonemergent, noncardiac surgery. *Anesthesiology*, *115*(1), 44-53.

Rujirojindakul, P., Geater, A.F., McNeil, E.B., Vasinanukorn, P., Prathep, S., Asim, W., & Naklongdee, J., (2012). Risk factors for reintubation in the post-anaesthetic care unit: A case-control study. *British Journal of Anaesthesia, 109*(4), 636-642.

Sessler, C. N., Gosnell, M. S., Grap, M. J., Brophy, G. M., O'Neal, P. V., Keane, K. A., . . . Elswick, R. K. (2002). The richmond agitation-sedation scale: Validity and reliability in adult intensive care unit patients. *American Journal of Respiratory & Critical Care Medicine, 166*(10), 1338-1344.

Snyder, C. W., Patel, R. D., Roberson, E. P., & Hawn, M. T. (2009). Unplanned intubation after surgery: Risk factors, prognosis, and medical emergency team effects. *American Surgeon*, *75*(9), 834-838.

Thille, A.W., Boissier, F., Ben Ghezala, H., Razazi, K., Mekontso-Dessap, A., & Brun-Buisson, C. (2014). Risk factors for and prediction by caregivers of extubation failure in ICU patients: A prospective study*. *Critical Care Medicine*, *43*(3), 613-620.

Appendix A

Table A1.

Preoperative Baseline Characteristics

Variable [n (%)]	Successful Extubation n=70	Failed Extubation n=23
Gender		
Male	42 (60.0)	17 (73.9)
Female	28 (40.0)	6 (26.1)
Race		
White	55 (78.6)	20 (87.0)
Black or African American	10 (14.3)	2 (8.7)
Asian	0	1 (4.3)
Unknown	5 (7.1)	0
Age (years)		
< 50	16 (22.9)	3 (13.0)
50 – 60	26 (37.1)	5 (21.7)
60 – 70	14 (20.0)	6 (26.1)
70 – 80	11 (15.7)	6 (26.1)
> 80	3 (4.3)	3 (13.0)
Diabetes		
No	55 (78.6)	18 (78.3)
Non-Insulin	7 (10.0)	2 (8.7)
Insulin	8 (11.4)	3 (13.0)
Smoker		
Yes	20 (28.6)	6 (26.1)
No	50 (71.4)	17 (73.9)
Dyspnea		
No	59 (84.4)	20 (87.0)
Moderate Exertion	11 (15.7)	3 (13.0)
At Rest	0	0
Functional Status Presurgery		
Independent	65 (92.9)	18 (78.3)
Partially Dependent	5 (7.1)	5 (21.7)
Totally Dependent	0	0
Unknown	0	0
Ventilator		
Yes	2 (2.9)	0
No	68 (97.1)	23 (100.0)
COPD (Severe)		
Yes	10 (14.3)	4 (17.4)
No	60 (85.7)	19 (82.6)
CHF		
Yes	0	0
No	70 (100.0)	23 (100.0)

Hypertension		
Yes	45 (64.3)	15 (65.2)
No	25 (35.7)	8 (34.8)
Renal		
Yes	0	0
No	70 (100.0)	23 (100.0)
Currently requiring or on dialysis		
Yes	2 (2.9)	2 (8.7)
No	68 (97.1)	21 (91.3)
Disseminated Cancer		
Yes	3 (4.3)	2 (8.7)
No	67 (95.7)	21 (91.3)
Open Wound		
Yes	6 (8.6)	4 (17.4)
No	64 (91.4)	19 (82.6)
Steroid/Immunosuppressant		
Yes	6 (8.6)	1 (4.3)
No	64 (91.4)	22 (95.7)
Weight Loss		
Yes	7 (10.0)	2 (8.7)
No	63 (90.0)	21 (91.3)
Sepsis		
None	48 (68.6)	21 (91.3)
SIRS	1 (1.4)	0
Sepsis	12 (17.1)	2 (8.7)
Septic Shock	9 (12.9)	0

Table A2.
Perioperative Characteristics

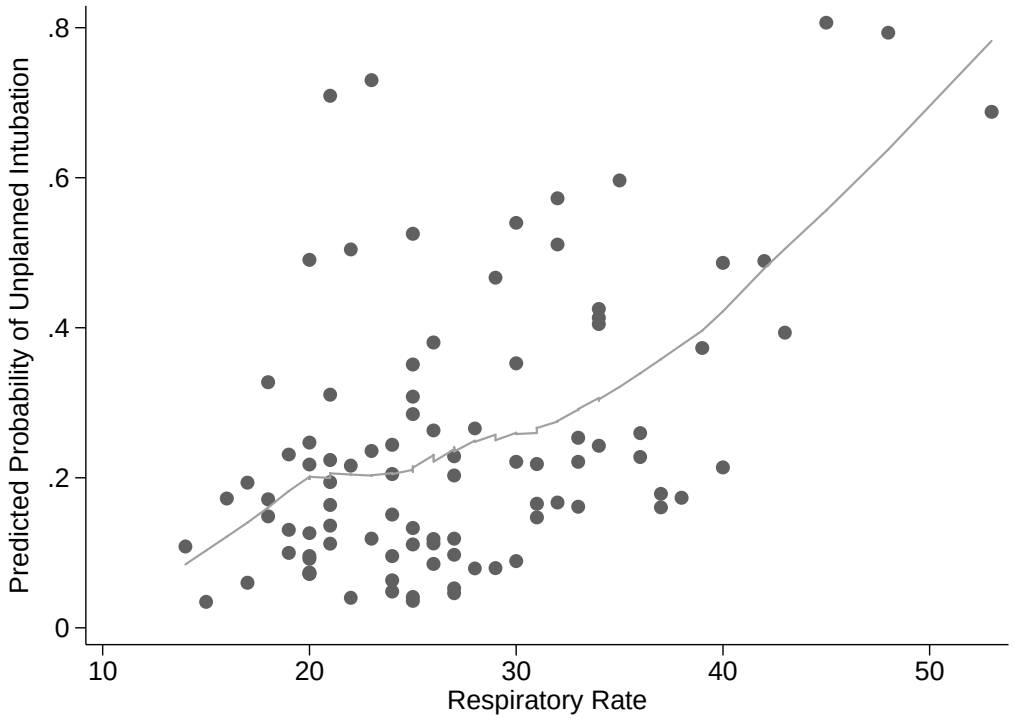
Variable	Successful Extubation n=70	Failed Extubation n=23
	n (%)	n (%)
Surgical Specialty		
General Surgery	44 (62.9)	20 (87.0)
Gynecology	5 (7.1)	1 (4.3)
Vascular	21 (30.0)	2 (8.7)
Emergency Case		
Yes	26 (37.1)	4 (17.4)
No	44 (62.9)	19 (82.6)
ASA Classification		
ASA 1 – No Disturb	1 (1.4)	0
ASA 2- Mild Disturb	7 (10.0)	5 (21.7)
ASA 3 – Severe Disturb	42 (60.0)	15 (65.2)
ASA 4- Life Threat	20 (28.6)	3 (13.0)
Wound Classification		
Clean	22 (31.4)	8 (34.8)
Clean/Contaminated	27 (38.6)	9 (39.1)
Contaminated	10 (14.3)	1 (4.3)
Dirty/Infected	11 (15.7)	5 (21.7)
Duration of Surgical Procedure		
< 250	37 (52.9)	16 (69.6)
250 - 500	23 (32.9)	7 (30.4)
> 500	8 (11.4)	0
	(2 cases = 0)	

Table A3.

Logistic Regression Data

Variable	Odds Ratio	P	95% Confidence Interval	
Age	1.024997	0.312	0.9771386	1.075199
Male	1.54902	0.494	0.4422504	5.425573
White	1.136878	0.864	0.2611488	4.949256
Respiratory rate	1.086164	0.034	1.006463	1.172178
BMI	0.9390619	0.118	0.867793	1.016184
Pulse	0.9753341	0.166	0.9414807	1.010405
Temperature	1.203357	0.323	0.6573566	2.202867
spO_2	0.9896798	0.323	0.9695205	1.010258
pO_2	0.9970285	0.706	0.9817168	1.012579
Weight change	1.000058	0.964	0.9975023	1.002621

Figure A1. Relationships Between Respiratory Rate and Extubation Failure



Logistic regression analysis graph showing predicted probability of unplanned intubation as a function of respiratory rate.