## Section II

## Review of the Literature

The purpose of this literature review was to examine the existing published research to identify risk factors for extubation failure in surgical intensive care patients. Databases that were searched included OVID MEDLINE and CINHAL. Each was examined using the following key terms "*critical care*", "*ICU*", "*intensive care*", "*reintubation*", "*failed extubation*" and "*unplanned extubation*". The search was limited to recent publications between 2009 and 2015, human, adult, and English language. Abstract review allowed exclusion of non-relevant studies to the surgical ICU patient population. OVID MEDLINE search yielded 94 articles. Abstract review yielded eight articles included in current literature review. CINHAL search yielded 77 articles. Abstract review after deletion of duplicate articles identified in OVID MEDLINE yielded two additional articles. Additional searching methods included ancestry review of pertinent journal articles resulting in a total of 15 published studies.

A summary of these studies is provided in Table A1. A brief synopsis of salient points from selected studies follows, addressing three distinct areas: Predicting Extubation Failure, Post Anesthesia Care Unit and ICU Risk Factors for Reintubation, and American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) Related Literature.

### Predicting Extubation Failure

Five reports provided insights into prediction of extubation failure. Although the reports varied either from a STICU setting or from extubation-to-reintubation intervals up to 30 days, the report processes were instructive in terms of methodology, data, and findings but of limited applicability to the focus of this study. Therefore, a synopsis of these five studies is presented with an assessment of the applicability to the STICU setting.

Thille et al. (2014), studied 225 patients intubated more than 24 hours who underwent a planned extubation. Of the total sample, 31 patients (14%) experienced extubation failure. The study was conducted in a medical ICU to determine the effects of delirium, ICU acquired paresis, and cardiac function on extubation failure, and to predict the risk of extubation failure as identified by care providers. Three factors, mechanical ventilation greater than seven days, an ineffective cough, and severe systolic dysfunction, were reported as better predictors of extubation failure than ICU acquired weakness and delirium (Thille et al., 2014).

Miu et al. (2014) developed a prediction model for the need for reintubation that included demographic, hemodynamic, respiratory, and neurologic variables prior to extubation. The study sample (N=2007) was drawn from ICUs in a single tertiary referral medical center. Data was compared between subjects who were successfully extubated and those who required reintubation. Data analysis demonstrated that the Simplified Acute Physiology Score II, minute ventilation, breathing frequency, airway suctioning frequency and quantity, and heart rate differed significantly between successful and failed extubation groups. Lower oxygenation was a risk factor for failure within 24 hours, however the number of previously failed spontaneous breathing trials (SBTs), high minute ventilation, and lower diastolic blood pressure were found to be risk factors at any time (Miu et al., 2014).

A bedside clinical predictor rule, designed by Mokhlesi et al. (2007) was used to predict extubation failure and reintubation within 48 hours. In the sample of 122 patients, 16 required reintubation within 48 hours. Clinical variables predicting reintubation were moderate to copious endotracheal secretions ($p = 0.001$), Glasgow Coma Scale $\leq 10$ ($p = 0.004$), and hypercapnia during the spontaneous breathing trial ($p = 0.001$). Mokhlesi concluded that a created prediction rule composed of an assessment of mental status, endotracheal secretions, and pre-extubation

$P_aCO_2$, can predict the patients who will fail extubation after successfully passing a SBT (Mokhlesi et al., 2007).

Frutos-Vivar et al. (2006) conducted an international prospective study with 900 consecutive patients, who had successfully passed a SBT after mechanical ventilation of > 48 hours and were declared ready for extubation. Each of the ICUs in 37 hospitals in 8 countries used the same general methodology for weaning mechanical ventilation. Extubation failure occurred in 121 (13.4%) patients. Among patients requiring reintubation, analysis revealed they had a higher rapid shallow breathing index (RSBI), a positive fluid balance in the 24 hours prior to extubation, and pneumonia at the initiation of ventilation (Frutos--Vivar et al., 2006).

The above studies identified bedside parameters that predicted extubation failure in ICU patients. Airway secretion quantity and suctioning frequency was a significant common thread across the studies. Mokhlesi (2007) evaluated mental status and pre-extubation $P_aCO_2$, with good predictive results, however, the study sample included both medical and surgical ICUs. Frutos-Vivar (2006) added the significance of monitoring fluid balance within 24 hours of extubation and prior pneumonia status. Study times varied in defining the time for reintubation from within 48 hours (Mokhlesi et al., 2007) to duration of hospital stay (Miu et al., 2014).

Thille performed an analysis using data obtained from caregivers including nursing, respiratory therapists, ultrasonographers, and physicians on the ICU staff. However, the study was performed in a medical ICU with extubation failure defined as requiring reintubation within 7 days, which did not address extubation failure within a time period of 30 days in surgical ICU patients.

The conclusions of Miu et al. (2014) were significant because the study included a large sample of ICU patients at a university medical center evaluating predictors of reintubation early

(within the first 24 hours) or anytime during the hospital stay. Focusing on only a surgical population could identify surgical-related factors to employ in the decision to extubate and attain successful liberation from mechanical ventilation.

Vital signs and bedside monitoring waveform data of heart rate, respiratory rate, and pulse-oxygen saturation were collected from bedside monitors to design and validate a predictive model for the risk of reintubation in a Surgical/Trauma ICU (STICU) (Politano et al. 2013). The study demonstrated changes in the stated vital and bedside monitor signs in the 24 hours prior to a reintubation in STICU patients. Study analysis reported the risk of reintubation increasing 2.5 fold in the first 24 to 48 hours following extubation. Additional clinical trials are required to determine whether bedside monitoring data is sufficient to detect changes prior to caregiver suspicion and to affect outcomes (Politano et al. 2013).

These studies provide insights into predictive strategies, yet the need persists to study the surgical and vascular population in the ICU separate from trauma patients. The vital sign and monitor data prediction model has the potential to alert nurses, physicians, and respiratory therapists of the change in clinical status requiring timely evaluation to reduce the risk of reintubation in the STICU patients.

**Post Anesthesia Care Unit and ICU Risk Factors for Reintubation**

The following studies utilized database records extracted from electronic medical records to identify risk factors for extubation failure in the surgical ICU patients.

Brueckmann et al. (2013) used electronic anesthesia records, billing data, and chart review to develop and validate a score for prediction of postoperative reintubation after initial extubation in the operating room. The sample was obtained from 33,769 surgical cases. Reintubation was required in 137 cases (0.41%). Independent predictors of reintubation were an

American Society of Anesthesiologists (ASA) score of 3 or more, emergency surgery, high-risk surgical service, history of congestive heart failure, and chronic pulmonary disease. Reintubations that occurred in the first 3 postoperative days were included in the study. The most common reasons for reintubation were pulmonary edema, atelectasis, pneumonia, impaired brain function, and aspiration (Brueckmann et al., 2013).

Risk factors for reintubation in general surgery patients in the immediate postoperative period in post anesthesia care units were identified by Rujirojindakul et al. (2012) using an anesthesia database. Chronic pulmonary disease, preoperative hypoalbuminemia, and renal insufficiency were identified risks for reintubation. Operative risk factors for reintubation included an ASA score 3 and use of certain neuromuscular blocking agents, surgery longer than 3 hours, emergency surgery, airway surgery, cardiothoracic surgery, and head and neck surgery (Rujirojindakul et al., 2012). Rujirojindakul et al. (2012) identified pertinent preoperative and surgical risk factors for reintubation.

Menon et al. (2012) investigated the risk factors, timing, complications, and occurrence of extubation failure in a cohort study of 2007 adult patients admitted to the ICU with an endotracheal tube. Data from medical, surgical and emergency surgery ICU patient records was analyzed. Reintubations occurred in older adults, more frequently in males, and in patients with higher admission severity scores. In the initial sample of 2,007 ICU patients, 376 required reintubation and of those, 230 were reintubated within 48 hours. Reintubation was associated with a five-fold increase relative odds of death (adjusted odds ratio 5.86, 95% CI 3.87-8.89, $P < .01$) and longer hospital stay. This study validated the severity of reintubation complications and poorer outcomes for reintubated patients.

Brueckmann et al. (2013), Rujirojindakul et al. (2012), and Menon et al. (2012) all highlight potential risk factors for reintubation specific to the immediate ICU phase of care. However, none of these studies evaluated the early bedside clinical factors related to respiratory failure in surgical ICU patients over a 30-day period.

**American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) Related Literature**

The ACS NSQIP literature provided research on predictive parameters of extubation failure. Relevant ACS NSQIP literature reports are summarized here.

Alvarez et al. (2015) performed an analysis of preoperative clinical risk factors that are predictors of postoperative unplanned intubation (PUI) in general and vascular surgery patients by comparing their institutional ACS NSQIP data to the national database data for surgical patients. The institutional rate of PUI was 1.54% contrasted against the national ACS NSQIP rate of 1.03%. Analysis of the national ACS NSQIP database revealed the following independent risk factors: male gender, older age, lower body mass index (BMI), smoking history, dyspnea, chronic obstructive pulmonary disease, congestive heart failure (CHF), weight loss over 10%, dependent functional status, inpatient status, preoperative ventilator status, general anesthesia, emergent surgery, and higher ASA class. Institutional ACS NSQIP data analysis of PUI variables revealed that emergent cases, preoperative ventilator status, smoking, chronic obstructive pulmonary disease, and older age were independent risk factors (Alvarez et al., 2015). Alvarez et al. (2015) reported narcotic related respiratory failure peaks within the first 24 hours postoperatively, and determined that 50% of PUI takes place within the first 72 hours postoperatively. The findings of Alvarez et.al. (2015) within a vascular and general surgery

sample identified risk factors for PUI related to the patient's past medical history, current health status, and surgical procedure.

Ramachandran et al. (2011) studied 222,094 non-emergent, non-cardiac surgical patients in the national ACS NSQIP database to evaluate the occurrence and independent risk factors of unanticipated early postoperative intubation. Independent predictors of unanticipated early postoperative intubation were: current smoker, current alcohol use, chronic obstructive pulmonary disease, dyspnea, diabetes requiring insulin, hypertension with medication management, current congestive heart failure, abnormal liver function, prolonged hospitalization, cancer, recent weight loss, body mass index (BMI) < 18.5 or $\geq$ 40 kg/m$^2$, medium risk surgery, high risk surgery, very high risk surgery, and sepsis. Unanticipated tracheal intubations within the first 3 postoperative days after non-emergent, non-cardiac surgery were independently associated with a nine-fold increase in death. The findings presented by Ramachandran et al. (2011) validated the need to optimize patient preparations for successful extubation.

Snyder et al. (2009) studied the occurrences, risk factors, and prognosis of unplanned intubation after general and vascular surgery in a university setting utilizing data within the institutional ACS NSQIP database. The most common underlying reason for unplanned intubation was sepsis (40%). Pertinent risk factors of unplanned intubation identified were: dependent functional status, chronic obstructive pulmonary disease, and emergency surgery (Snyder, et al. 2009).

Hua et al. (2012) utilized the ACS NSQIP database to identify risk factors for postoperative unplanned tracheal intubation and to create a scoring system to stratify patients risks for an unplanned intubation. Data were obtained from 251 participating centers for patients who had undergone major surgical procedures. The predictive variables for unplanned intubation

identified were: Age (0-4 points), ASA class (0-7 points), presence of preoperative sepsis (3 points), and total operative time (0-4 points). The Unplanned Intubation Risk Index had an accuracy of 79% for identifying patients needing reintubation.

The Alvarez (2015), Ramachandran (2011), Snyder (2009), and Hua (2012) studies employed selected ACS NSQIP variables to identify predictive risk factors for unplanned intubation in postoperative patients. These studies evaluated comorbidities and perioperative details relative to the surgical population, however immediate post operative risk factors of extubation failure were not addressed.

**Relevant Review Studies**

This final category of reviews adds to the extubation success or failure literature findings. A systematic review and meta-analysis performed by McCaffrey et al. (2009) of 14 randomized control trials evaluated the use of corticosteroids to reduce the rate of extubation failure in ICU patients. The mean duration of mechanical ventilation prior to planned extubation ranged from 3 to 21 days. Reintubations were decreased with the administration of corticosteroids with a pooled odds ratio of 0.56 (95% CI 0.41- 0.77, $p < 0.0005$). The effects of corticosteroids were more noticeable when corticosteroids were administered at least twelve hours prior to a planned extubation. In addition, subjective manifestations of laryngeal edema, such as stridor, were also reduced in patients receiving corticosteroids. McCaffrey et al. (2009) concluded those patients with difficult intubations or those who had been intubated longer than 3 days or patients with multiple intubations may constitute a high-risk group who would benefit from corticosteroids.

A clinical review by Kiekkas et al. (2012) investigated the data relating to the risk factors and the incidence and consequences of unplanned extubations in the ICU. Thirty-four

observational studies in adult ICUs were identified by querying electronic databases. The incidence of reintubation rates after unplanned extubations varied between 28.5% and 74.7% in the selected studies. The major risk factor for unplanned extubation was agitation, particularly when linked with inadequate sedation and decreased patient monitoring (Kiekkas et al., 2012).

These two studies were of interest in terms of reducing extubation failures, but were not focused on clinical predictors leading to a reintubation within a 30-day period.

**Summary**

The day of extubation is a critical time in health management of surgical ICU populations. Planned extubation occurs frequently and generally is uneventful. However, there are postoperative ICU patients who suffer respiratory failure necessitating reintubation, with ensuing delays in health restoration and increased mortality. This subset of the ICU population as noted in the current literature review requires clinical expertise, teamwork, and refined systems processes to optimize the plans for and timing of a successful extubation.

Thille et al. (2014), Miu et al. (2014), Mokhlesi et al. (2007), Frutos-Vivar et al. (2006), and Politano et al. (2013) each provided pertinent studies leading to identification of clinical factors related to extubation failure as described in detail earlier. However, a gap in the reviewed literature persists concerning postoperative surgical patients' extubation failure within a 30 day period.

The studies by Brueckmann et al. (2013), Rujirojindakul et al. (2012), and Menon et al. (2012) highlighted potential risk factors for reintubation but were ~~s~~pecific to the immediate ICU phase of care. Thus studies are needed to evaluate the early bedside clinical factors related to respiratory failure in surgical ICU patients to decrease reintubation within a 30 day period.

Alvarez et al. (2015), Ramachandran et al. (2011), Snyder et al. (2009), and Hua et al. (2012) studied selected ACS NSQIP variables to identify risk factors for unplanned intubation in postoperative patients. These studies did not address postoperative ICU preparations, timing, and the clinical factors affecting the decision for successful extubation.

The systematic review and meta-analysis by McCaffrey et al. (2009) identified high risk patients who would benefit from appropriate scheduling of corticosteroids prior to planned extubation. This review points to a potential clinical intervention to facilitate successful extubation but did not address predictive factors.

In contrast, a clinical review by Kiekkas et al. (2012) reported agitation as a major risk factor for unplanned extubation in the ICU particularly when combined with inadequate sedation and decreased patient monitoring. However this finding varied greatly from previous reports of potential predictors. This is simply because the cause or relationship of inadequate sedation or decreased patient monitoring are of themselves often unpredictable.

**Conclusions**

The reviewed studies have advanced the knowledge of risk factors related to reintubation but do not provide guidance regarding preparations for successful extubation in the postoperative surgical ICU patient.

The current study addressed the following question: “What are the risk factors related to 30 day reintubation in postoperative, non-trauma surgical ICU patients?”