REDUCING PROLONGED HYPEROXIA IN MECHANICALLY VENTILATED PATIENTS THROUGH IMPLEMENTATION OF A CONSERVATIVE OXYGEN WEANING PROTOCOL VERSUS THE CURRENT PRACTICE: A QUALITY-IMPROVEMENT PROJECT IN THREE INTENSIVE CARE UNITS AT A LEVEL II TRAUMA TERTIARY CARE HOSPITAL

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Reducing prolonged hyperoxia in mechanically ventilated patients through implementation of a conservative oxygen weaning protocol versus the current practice: A quality improvement project in three intensive care units at a Level II trauma tertiary care hospital

Abstract

Background: Hyperoxia is known to be detrimental in healthcare, yet it continues to be a problem in mechanically ventilated patients. Oxygen weaning protocols have been discussed in many studies that have evaluated various outcome measures with mixed findings. A study completed by Cuevas et al. (2020) evaluated respiratory therapists' compliance with an oxygen weaning protocol. The conclusions of this study found that the protocol was often not followed. At a level II trauma hospital tertiary care hospital in three ICUs, patients' FIO2s were not being weaned in a timely manner. Due to the previous research on the risks of hyperoxia and poor outcomes, a conservative oxygen weaning protocol was developed. The aim of this study was to assess if implementing a conservative oxygen weaning protocol would improve oxygen weaning times in mechanically ventilated patients compared to the current oxygen weaning practice.

Methods: Out weaning program evaluation was completed using the PARISH framework and Lewin's change theory to evaluate and implement evidence-based practice. This evaluation was conducted using quantitative, retrospective, consecutive sampling; a quasi-experimental methodology was used to compare the current oxygen weaning group (before intervention group) and a conservative oxygen weaning group (after intervention group) in three ICUs at a level II trauma tertiary care hospital.

Intervention: A conservative oxygen weaning protocol was developed and implemented in three ICUs at one medical center. Mechanically ventilated patients with a P/F ratio is ≥ 150 qualified for the oxygen weaning protocol. The weaning pathways are determined by the PaO2 on the ABG. After the initial FIO2 wean, the SpO2 will be used for FIO2 weaning. FIO2 weaning will be continued as long as the SpO2 level is ≥ 4% of the ordered goal SpO2 until the FIO2 is 0.3.

Results: The current oxygen weaning group had 34 patients, and the conservative oxygen weaning group had 18 patients that met the inclusion criteria. Both groups had non-normal distribution. The current oxygen group had a p-value= 1.827e-08 and the conservative oxygen group had a p-value= 6.213e-06. Mann-Whitney U test was completed, and the result was a p-value = 0.05735. Therefore, there was no statistically significant finding that the implementation of the conservative oxygen weaning protocol improved oxygen weaning times. Though there was no statistical significance, the conservative oxygen weaning groups did show improvement in weaning time.

Conclusions: The statistical findings for improvement in oxygen weaning time to 0.3 with the implementation of a conservative oxygen therapy protocol showed no statistical significance. Evaluating the conservative oxygen weaning groups' data showed improvement in weaning times. Further research is needed on the implementation of a conservative oxygen therapy protocol to evaluate the improvement of FIO2 weaning times in mechanically ventilated patients, as well as the effectiveness of consistent weaning protocols with staff compliance.

Keywords: Hyperoxia, mechanical ventilation, oxygen titration, oxygen weaning, conservative oxygen therapy, liberal oxygenation.

Introduction

Mechanically ventilated patients in three Intensive Care Units (ICUs) at a level II trauma tertiary care hospital have maintained oxygen saturation levels significantly above their goal SpO2 levels ordered by Critical Care Providers for prolonged periods. The current practice for weaning FIO2 has been to maintain SpO2 levels ≥ 92%; weaning FIO2 was determined by the individual respiratory therapists working on the unit without any formal protocol or guidelines. There were no parameters or time frame for weaning oxygen other than to wean FIO2 down to 30% as quickly as possible to maintain SpO2 levels ≥ 92%, which was provided to the respiratory therapists for the current practice. In an attempt to standardize care and improve patient outcomes we implemented an evidence-based conservative oxygen weaning protocol. So our overall aim is to have a conservative oxygen weaning protocol that improves adherence to appropriate weaning and decreases the time to an FIO2 of 30% in ventilated patients. Other outcome measures evaluated are the time of intubation to time of FIO2 to 30% and extubation or tracheostomy.

Problem Statement

Hyperoxia is a problem in intubated patients; however, medical experts have not agreed upon a specific SpO2 or PaO2 level for weaning best practice. Due to hyperoxia, not having a clear definition by the experts allows for variations in what each provider considers acceptable. It is well known that FIO2 > 60% for any prolonged period can cause lung injury and without clear weaning parameters or protocols patients' risk for prolonged hyperoxia and prolonged ventilator days. Hyperoxia increases the risk of morbidity, mortality, and ICU days, adding higher costs to patients and healthcare systems.

Hyperoxia is a significant problem in healthcare; it is known that oxygen should be treated as a medication and can be toxic. Oxygen therapy is not closely monitored and titrated, although hyperoxia is known to be detrimental to patients (Ablordeppey et al., 2018; Cuevas et al., 2020; Imanaka et al., 2015). Alhazzani et al. (2018) “in contemporary clinical practice, supplemental oxygen is frequently administered to acutely ill patients — approximately 34% of patients in ambulances, 25% of individuals in emergency rooms, and 15% of patients admitted to hospitals in the UK” (p. 1693). Although the healthcare community is aware that hyperoxia can cause iatrogenic harm, it is still accepted, and there is a lack of attention to oxygen management (Ablordeppey et al., 2018; Alhazzani et al., 2016; Cuevas et al., 2020; Imanaka et al., 2015).

Effects of hyperoxia include impaired pulmonary gas exchange due to inhibition of hypoxic pulmonary vasoconstriction, peripheral vasoconstriction, oxygen toxicity, absorptive atelectasis, tracheobronchitis, and interstitial lung fibrosis (Alhazzani et al., 2018; Antonelli et al., 2016; Jaffal et al., 2016; Martin et al., 2020). Hyperoxia causes serious harmful effects at the cellular level, which can manifest as vasoconstriction, inflammation, and formation of reactive oxygen species, which can affect the cardiovascular, central nervous, and pulmonary systems (Alhazzani et al., 2018; Antonelli et al., 2016; Martin et al., 2020). “Our [Jaffal et al.] results suggest that hyperoxemia is an independent risk factor for VAP” (Jaffal et al., 2016, p. 4). A cohort study was completed in an emergency department and found that hyperoxia increased mortality in mechanically ventilated patients. The study evaluated patients who had one episode of post-intubation hyperoxia in the ER and its effect on outcomes (Ablordeppey et al., 2018). Though this was a small study, it was the only one that looked at one episode immediately post-intubation and outcomes for mortality (Ablordeppey et al., 2018). Martin et el. (2020),

> There is an increasingly large body of evidence suggestive of an association between hyperoxia and increased mortality in critically ill adult subjects, particularly in those with recent cardiac arrest, stroke, traumatic brain injury, and sepsis. With that being said, this evidence remains incomplete given the lack of RCTs [randomized control trials]. (p. 1209)

A significant amount is known about hyperoxia and poor outcomes, but it continues in ERs and ICUs. More needs to be done to prevent hyperoxia and improve patient outcomes. The effects of hyperoxia are not only on our patients and their families but also on health insurance companies, healthcare organizations, and healthcare workers. It decreases the patients' quality of life and puts them at greater risk for Ventialtor-Associated-Pneumonia (VAP) and ICU delirium due to increased length of stay and longer time on the ventilator. The cost for an ICU stay is high, and hyperoxia can prolong ventilator and ICU days from iatrogenic causes.

Glossary of Terms

P/F ratio (perfusion ventilation ratio)

"is a common measure of inspired oxygenation and is most often employed in ventilated patients"(Theodore, 2022, PaO2/FiO2 ratio section). Different levels of the P/F ratio determine different levels of hypoxia (Theodore, 2022).

Peripheral oxygen saturation (SpO2)

SpO2 is a non-invasive way to monitor oxygen saturation. SpO2 utilizes light absorption to evaluate the amount of oxygen bound to hemoglobin to determine the SpO2 level.

Hypoxia

is when the body does not have enough oxygen to function normally. Hypoxia can occur when there is not enough oxygen supplied to the body tissue because of insufficient blood flow or insufficient oxygen in the blood (Faysal et al., 2022).

Hypoxemia is insufficient oxygen in the blood to maintain normal body function (Faysal et al., 2022).

Hyperoxemia

is when there is too much oxygen in the blood (Medical Dictionary, 2009).

Hyperoxia

is higher levels of oxygen found in tissue and organs than what should be present (The American Heritage Medical Dictionary, 2007; Medical dictionary for the health professions and nursing, 2012).

Literature review

Will implementation of a conservative oxygen weaning protocol that includes time parameters for weaning FIO2 in intubated patients improve FIO2 weaning times, improve missed opportunities to wean FIO2, and decrease the number of ventilator days and ICU days? This literature review aims to evaluate the significance of hyperoxia/ hyperoxemia on patient outcomes and compare conservative versus liberal oxygen therapy for preventing hyperoxia/hyperoxemia and adherence to oxygen weaning protocols.

Incidence of hyperoxia and hyperoxemia in mechanically ventilated patients

Hyperoxia is an issue that is known to occur in patients that are on mechanical ventilation (MV). Imanaka et al. (2015) completed a; “retrospective cohort study … retrospectively reviewed medical records of patients admitted to the ICU from January 2010 to May 2013” (p. 336). The purpose of this “retrospective cohort study, to guide future practice, we [Imanaka et al.] set out to determine how PaO2 and FIO2 change during mechanical ventilation in our ICU and to clarify which factors relate to hyperoxemia” (Imanaka et al., 2015, p. 336).

The population for this study “included subjects who were older than 15 y and had received mechanical ventilation for >48 h. Patients at risk of imminent death on ICU admission or treated by noninvasive ventilation were excluded” (Imanaka et al., 2015, p. 336). “During the study period, 1,664 patients were admitted to our [Imanaka et al.] ICU. Of the 340 subjects identified as meeting the inclusion criteria, 328 subjects were included in the final analysis” (Imanaka et al., 2015, pp. 336-337). Multiple methods were used to evaluate data points in this study, including the Mann-Whitney U test, Chi-square test, APACHE II scores, and multivariable logistic regression analysis. “Data are expressed as median with interquartile range. $P < .05$ was considered statistically significant” (Imanaka et al., 2015, p. 336).

In this study, Imanaka et al. (2015) have “defined hyperoxemia as a PaO2 of 120 mm Hg or higher and assessing single arterial blood gas data at each time point … carry out analysis of variance of PaO2 and FIO2 data obtained during mechanical ventilation” (p. 336). Multiple data points were collected for this study, with some of these data points collected at three-time points.

> Arterial blood gas analysis … serum lactate levels and ventilator settings of PEEP and FIO2 data were sampled at 3 time points: within 24 hours of intubation (T1), ~48 h after initiation of mechanical ventilation (T2), and before extubation (T3). (Imanaka et al., 2015, p 336)

Findings for the time points were:

> At the 3 time points (T1-T3), PaO2 was 90 (74-109) mm Hg, 105 (89-120) mm Hg, and 103 (91-119)mm Hg and FIO2 was 0.4 (0.3-0.35), 0.3 (0.3-0.4), and 0.3 (0.3-0.35, respectively … PEEP level was 6 (6-8) cm H2O at all 3 time points. (Imanaka et al., 2015, p. 337)

Findings in Immanaka et al. (2015):

> The retrospective cohort study evaluating the incidence of hyperoxemia in mechanically ventilated subjects, despite decreasing FIO2, PaO2 significantly increased during mechanical ventilation. … hyperoxemia at 48 h after initiation of mechanical ventilation was particularly associated with age of < 40 y, APACHE II score of ≥ 30, and decompensated heart failure. (p. 339)

Hyperoxia or hyperoxemia on morbidity and mortality

Several studied methodologies have been utilized regarding hyperoxia/hyperoxemia in mechanically ventilated patients on morbidity and mortality outcomes. Some studies looked at hyperoxia on morbidity, in-hospital mortality, and mortality over time. Bouma et al. (2018) "performed a systematic review to assess the association between hyperoxemia in acutely ill patients in the ED and outcome in terms of increased morbidity and mortality" (p. 2).

> Our [Bouman et al.] literature search identified 35 manuscripts describing the association between hyperoxemia and clinically relevant outcomes in acutely ill patients. The most important outcomes are mortality, in-hospital mortality, survival, neurological outcome, and organ function. Of the 35 articles, 31 could be subdivided into four groups: cardiac arrest, stroke, traumatic brain injury (TBI), and sepsis. (Bouma et al., 2018, p. 2)

The evidence found in post-cardiac arrest studies had different outcomes. Several had hyperoxemia having no difference in mortality and neurologic outcomes. Other study findings showed an increase in in-hospital mortality and poor neurologic outcomes (Bouma et al., 2018).

Bouma et al. (2018) summarized, “the association between hyperoxemia after stroke … described in a low number of studies, … describe no effect of hyperoxemia on clinically relevant outcomes or suggest minor transient protective effects of hyperoxemia” (p. 6). Findings from Alhazzani et al.'s (2018) study did not show improvement in residual side effects from stroke patients who were administered liberal oxygen, as was seen in other studies. Alhazzani et al.'s (2018) study may have had different findings because it was completed at a single medical center and was a small sample size to generalize the results. Due to the study’s limitations, the benefit of higher oxygen administration could not be negated in this population of patients. “The occurrence of hyperoxemia after severe TBI is associated with a decreased good clinical outcome … and higher levels of mortality … hyperoxemia within 24 hours after admission to the ICU is independently associated with higher in-hospital mortality rates” (Bouma et al., 2018, p. 6).

When evaluating septic patients and hyperoxia, studies found that “In contrast to cardiac arrest, stroke, and TBI, optimizing cellular oxygen delivery may be more difficult in patients with sepsis, which is characterized by a reduced cellular oxygen extraction from circulation” (Bouma et al., 2018, p. 7). This reduced cellular oxygen extraction from circulation is called Cytopathic hypoxia.

> “Cytopathic hypoxia” is reflected in the relatively high venous oxygen level as compared to the arterial oxygen level and is likely due to mitochondrial dysfunction. Mitochondrial dysfunction is an early and important event that may progress to loss of cellular homeostasis, organ failure, and ultimately death of the patient. (Bouma et al., 2018, p. 6)

“High levels of oxygen supplementation (refected by FiO2 >60%) and also hypoxemia … are associated with higher in-hospital mortality rates among … patients with severe sepsis or septic shock admitted to the ICU” (Bouma et al., 2018, p. 7).

Liberal and conservative oxygenation strategies in critically ill patients have been an area of discussion for years due to the concern for hyperoxia. Evaluating liberal versus conservative oxygen protocols for morbidity and mortality outcomes has varied findings from study to study. In-hospital mortality was increased in liberal oxygen therapy groups compared to conservative oxygen therapy groups (Alhazzani et al., 2018; Antonelli et al., 2016). Andel et al. (2018), “This study did not find a correlation between hyperoxia and increased in-hospital mortality. Normoxic patients showed lower in-hospital and ICU mortality compared to hyperoxic patients, without being statistically significant” (p. 354). The findings in Andel et al. (2018) were like those in Bailey et al. (2016), where conservative versus liberal oxygen therapies showed no significant difference in ICU or 90-day mortality. Alhazzani et al. (2018) found that;

> A liberal oxygen strategy increased the risk of death compared with a conservative strategy in hospital, … at 30 days, … and at longest reported follow-up. No statistically significant association was identified between SpO2 and 30-day mortality, … or FiO2 and mortality at anytime point. (p. 1701)

The ICU-ROX Investigators et al. (2020) study” did not find evidence of significant between-group differences in 90-day mortality, 180-day mortality, or survival” (p. 996). The ICU-ROX Investigators et al. (2020) utilized a wide confidence interval (CI) when evaluating the outcomes of the conservative oxygen protocol implemented in this study; due to the wide CI, the effects the seen in the conservative oxygen arm could not be disregarded.

An observational cohort study in one emergency department was completed by Ablordeppey et al. (2018). The study evaluated the outcomes of patients admitted to the ICU

after being cared for in the emergency department with one episode of hyperoxia after intubation and had no other known hyperoxic events (Ablordeppey et al., 2018). Key findings in this study include;

> the liberal use of oxygen in the ED was common, with the median (IQR) FiO2 of 70% (47-100) … pre-ICU hyperoxia rate of 43.6%. Pre-ICU exposure to hyperoxia in the ED is associated with a mortality rate of 29.7%, higher than in patients in both the hypoxia (13.2%) and normoxia (19.4%) groups. (Ablordeppey et al., 2018, p. 4)

"After controlling for confounders … hyperoxia remained an independent predictor of in-hospital mortality in multivariable analysis" (Ablordeppey et al., 2018, p. 4). The overall conclusion of Ablordeppey et al. (2018) was that:

> ED exposure to hyperoxia is common and associated with increased mortality in mechanically ventilated patients achieving normoxia after admission. This suggests that hyperoxia in the immediate post-intubation period could be particularly injurious, and targeting normoxia at the initiation of mechanical ventilation may improve outcomes. (p. 8)

An observational cohort study completed in the Netherlands by Abu-Hanna et al. (2017) was conducted between July 2011 and July 2014 at three sizeable tertiary care medical and surgical ICUs.

> The aim of this study was to 1) comprehensively assess the metric-related association of arterial oxygenation with clinical outcomes in different subsets of critically ill patients, and 2) systematically evaluate the influence of choosing a certain metric on the composition of subgroups of patients with arterial hyperoxia and mortality in those subgroups. (Abu-Hanna et al., 2017, p. 188)

“Admissions were only eligible for inclusion when requisite data from more than one ABG measurement were available. Patient’s on Extracorporeal membrane oxygenation were excluded from the study” (Abu-Hanna et al., 2017, p. 188).

The Dutch National Intensive Care Evaluation Registry is where data on critically ill patients for this study was obtained (Abu-Hanna et al., 2017). Statistical analyses were completed using multiple methods, including data distribution (quintiles) or median quintiles, multivariate models, APACHE score, pairwise correlations, and cluster analysis. (Abu-Hanna et al., 2017).

The study concluded that,

> metrics of central tendency for severe arterial hyperoxia, as well as exposure time for mild and severe arterial hyperoxia, were associated with unfavorable outcomes of ICU patients, and this association was found both within and beyond the first day of admission. (Abu-Hanna et al., 2017, p. 194)

Clinical outcomes from Abu-Hanna et al.'s (2017) study found;

> Unadjusted analysis showed higher mortality rates and fewer VFDs [ventilator free days] for severe hyperoxia in comparison to both mild hyperoxia and normoxia for all metrics except for WOR [worst PaO2], where lower or equal mortality rates and more VFDs for severe hyperoxia were assessed. (p. 190)

Liang et al. (2019) completed a systematic review and meta-analysis through an extensive electronic databases search. This study evaluated all trials between 1946 to December 2016 that were trying to determine the role of hyperoxia in ICU outcomes. Inclusion

criteria for this study were, “1) the subjects enrolled in each study included patients admitted to ICUs; 2) patients were divided into hyperoxia group and normoxia group; and 3) outcomes contained but not limited to mortality” (Liang et al., 2019, p. 2). Liang et al.’s (2019) research;

> Excluded studies if the patients were 1) less than 18 years old; 2) chronic pulmonary disease; 3) acute lung injury or acute respiratory distress syndrome; and 4) in perioperative phase. Animal studies and studies published as reviews or case reports were also excluded (p. 2).

The studies reviewed by Liang et al. (2019) had varying definitions of what they considered hyperoxia. Because there is no agreed-upon PaO2 or SpO2 level for hyperoxia by the experts, each study used its own PaO2 and SpO2 definition for hyperoxia. The studies in Liang et al. (2019) utilized a range of PaO2 and SpO2 levels as follows:

> Hyperoxia defined as partial arterial pressure of oxygen (PaO2) >487 mm Hg (mmHg), 341 mmHg, 300mmHg, 200mmHg, 156.7mmHg, 150mmHg, 120mmHg, and 100mmHg … One study defined hyperoxia as an FIO2 of 1.0, and the other two studies did not give a definition of hyperoxia. (Liang et al., 2019, p. 2)

A significant difference was found in mortality in ICU patients in the Liang et al. (2018) study.

> Significant difference in the mortality was found between hyperoxia and normoxia groups in patients with cardiac arrest … ELS [extracorporeal life support]. However, Hyperoxia did not contribute to higher mortality in patients with TBI [traumatic brain injury], … stroke, … hemorrhage, … post-cardiac surgery, … and mechanical ventilation. (Liang et al., 2019, pp.6-7)

Overall, the findings that “hyperoxia in patients admitted to the ICU would lead to higher mortality, which had been further confirmed in patients with cardiac arrest and ELS” (Liang et al., 2019, p. 9).

Bi et al.’s (2018) study aimed to “search and analyze available literature to describe the relationship between hyperoxia exposure and mortality in critically ill patients” (p. 261). The study was completed using a systematic review and meta-analysis of the literature and followed the PRISMA guidelines (Bi et al., 2018). Inclusion and exclusion criteria were clearly stated and included articles had to be English studies completed between 2008 and 2018 (Bi et al., 2018). With the primary requirements for English studies between 2008 and 2018, Bi et al. (2018) had further inclusion and exclusion criteria.

> Eligibility criteria included clinical studies assessing the effect of arterial hyperoxia on outcome [sic] in critically ill adults (≥18 yr) admitted to critical care facilities. We [Bi et al.] excluded studies in patients who were younger than 18 years old or pregnant, in patients with chronic obstructive pulmonary disease (COPD) or acute lung injury (ALI). Data from studies with hyperbaric oxygen therapy or extracorporeal life support were not considered. Editorials, letters to the editor, review articles, case reports, and animal experimental studies were also excluded. (p. 261)

After meeting all inclusion criteria, twenty-nine articles were included in Bi et al.’s (2018) study and included several methodologies; therefore, several statistical methods were used to compare studies. Statistical methods used were odds ratios, crude odds ratios, and confidence intervals. Study findings were:

> This meta-meta analysis … investigated the crude and adjusted association between arterial hyperoxia and hospital mortality in major subgroups of critically ill patients. Meta-analysis … demonstrated that hyperoxia exposure was associated with increased hospital mortality. … On subgroup analysis, this association was also found in patients admitted to critical care units following cardiac arrest, ischemic stroke [*sic*] and intracerebral hemorrhage, but this effect was not found in other subgroups. (Bi et al., 2018, p. 262)

The overall findings of "this meta-analysis indicated that arterial hyperoxia may be associated with increased hospital mortality in critically ill patients. This association may be established in patients admitted to critical care units following cardiac arrest, ischemic stroke, and intracerebral hemorrhage" (Bi et al., 2018, p. 267).

Sepsis, Infections, Organ failure, ICU and Hospital Length of Stay

Hospital-acquired infections were not statistically different between the conservative and liberal oxygen arms (Alhazzani et al., 2018; Antonelli et al., 2016). Antonelli et al. (2016) found in their outcomes that "the occurrence of new infections was similar between groups, the conservative oxygen strategy was associated with lower risk for bloodstream infection … and more hours free from mechanical ventilation (median difference 24hours; P = .02)" (p. 1586).

Alhazzani et al.'s (2018) study was a

> systematic review and meta-analysis… for randomised [sic] control trials that compare the use of liberal and conservation oxygen therapies in acutely ill adults. Studies were included if they were randomised controlled trials comparing liberal and conservative oxygenation strategies in acutely ill adults … and reported an outcome of interest. (p. 1694)

When evaluating infections, pneumonia, and length of stay, Alhazzani et al. (2018) found;

> the risk of hospital-acquired infections were not statistically different between groups … patients who had emergency surgery had fewer hospital-acquired infections when treated with liberal oxygen therapy … than patients treated with conservative therapy. This effect was not seen in patients admitted with medical diagnoses … Both studies in emergency surgery were at high risk of bias. (p.1701)

Alhazzani et al. (2018) found “no significant between-group differences were identified in the risk of hospital-acquired pneumonia … or length of hospital stay” (p. 1701).

According to Jaffal et al. (2016),

> previous animal studies strongly suggest a relationship between hyperoxemia and VAP [ventilator-associated pneumonia]. However, in spite of the obvious potential link between hyperoxemia and VAP, to our [Jaffal et al.] knowledge no study to date has evaluated the relationship between these two conditions. (p. 2)

Jaffal et al. (2016) “conducted this retrospective observational study to determine whether hyperoxemia is a risk factor for VAP” (p. 2). This study was completed in a mixed ICU in France over eighteen months (Jaffal et al., 2016). Inclusion criteria, “all patients requiring invasive mechanical ventilation for more than 48h, during 18-month period, were eligible. The only exclusion criterion was duration of mechanical ventilation for ≤ 48 h” (Jaffal et al., 2016, p. 2).

Findings from the study showed “the median (IQR) duration from starting mechanical ventilation to diagnosis of VAP was 14 (8, 23) days” (Jaffal et al., 2016, p. 3). Many of the points evaluated in this study, such as mortality rate, length of time on a ventilator, and days in the ICU, did not show a significant difference between groups (Jaffal et al., 2016). Jaffal et al., (2016) found “hyperoxemia at ICU admission and percentage of days with hyperoxemia were independently associated with VAP, using two different Cox proportional hazards models” (p. 4).

A multicenter pilot randomized control trial (RCT) was completed by Bailey et al. (2016), where they evaluated conservative oxygen targets to liberal oxygen targets in patients that required mechanical ventilation. Outcome measures of organ dysfunction found, “there were no significant differences between the groups in regard to any of the measures of organ dysfunction (△ SOFA score, △ P/F ratio, new onset ARDS, △ creatinine, hemodynamic instability, vasopressor-free days, arrhythmia-free days, or ventilator-free days)” (Bailey et al., 2016, p. 46).

> We [ICU-ROX Investigators et al.] conducted the multicenter, bi-national ICU-ROX (Intensive Care Unit Randomized Trial Comparing Two Approaches to Oxygen Therapy) to test the hypothesis that conservative oxygen therapy would result in more ventilator-free days than the usual oxygen therapy in adults who were expected to undergo mechanical ventilation in the ICU beyond the day after recruitment. (ICU-ROX Invenstigators et al., 2020, p. 990)

ICU-ROX Investigators et al.’s (2020) primary outcome measure was the number of ventilator-free days. From the study, "key secondary outcomes were death from any cause at day 90 and day 180 after randomization, … . Cause-specific mortality was also recorded” (p. 991). Primary outcome findings,

> at 28 days, there was no significant between-group differences in the number of ventilator-free days, with a median of 21.3 days … in the conservative-oxygen group and 22.1 days … in the usual-oxygen group (absolute difference, -0.3 days; 95% CI, -2.1 to 1.6; P=0.08). (ICU-ROX Investigators et al., 2020, p. 995)

Andel et al.’s (2018) study on hyperoxia which evaluated length of stay, “observed that patients with hyperoxia had shorter HLOS [hospital length of stay] and ICU-LOS [ICU length of stay],

potentially attributed to the fact that patients of young age predominantly experienced episodes of hyperoxia. After propensity score matching, no differences were observed anymore" (p.354). The findings of higher rates of hyperoxia were also noted in Imanaka et al.'s study (2015) in patients less than 40 years.

Bailey et al. (2020) "conducted a post hoc analysis of patients who had sepsis at the time of enrollment in the ICU-ROX" (p. 18). Patients diagnosed with sepsis were evaluated in this post hoc analysis to analyze the effects of oxygen therapy on mortality at 90-days. These patients were already randomly assigned to either the conservative oxygen therapy group or the usual oxygen therapy group through the ICU-ROX trial (Bailey et al., 2020).

Although sepsis has been studied and sepsis guidelines have been implemented and re-implemented based on new findings;

> despite a growing body of sepsis-related research, there are no published studies evaluating oxygen regimens in patients with sepsis. Given this limited evidence base, we [Bailey et al.] undertook a post hoc exploratory analysis to evaluate the effect of conservative vs. usual oxygen therapy on 90-day mortality and other patient-centered outcomes in the subset of patients with sepsis at the time of recruitment to ICU-ROX. (Bailey et al., 2020, p. 18)

The post hoc analysis of septic patients in the conservative versus the usual oxygen group had to meet specific criteria to be defined as having sepsis.

> There were three ways for a patient to be defined as having sepsis: (1) having an explicit diagnosis of sepsis or septic shock recorded at baseline in the ICU-ROX database; (2) having an explicit diagnosis of infection in the ICU-ROX database; and (3) having an

> admission diagnostic subcode for infection in the Australian and New Zealand Intensive Care Society Adult Patient Database. (Bailey et al., 2020, p. 18)

Bailey et al. (2020) determined, “in this post hoc analysis of patients with sepsis who were enrolled in the ICU-ROX, conservative oxygen therapy was not associated with a statistically significant decrease in 90-day mortality compared with the usual oxygen therapy” (p. 21).

Hyperoxemia vs. Normoxemia/Normoxia in Severe Trauma

Abback et al. (2020) completed, “This was an observational study using a multicenter, prospective trauma registry in France, the Traumabase … from May 2016 through March 2019” (p.2). “The TraumaBase consecutively collects data on trauma patients from 15 trauma centers in France … the TraumaBase is approved by Institutional Review Board as well as the National Commission on Informatics and Liberties” (Abback et al., 2020, p. 2).

Abback et al. (2020),

> The primary objective of this study was to assess the association between elevated PaO2 on admission and in-hospital mortality in level I trauma centers. We [Abback et al.] hypothesized that a PaO2 ≥ 150 mmHg on admission was associated with increased in-hospital mortality. (Abback et al., 2020, p. 2)

Criteria for participants in this study were; “Trauma patients above 17 years of age with a PaO2 measured and registered in the Traumabase registry were included. Hypoxemic patients (PaO2 < 60 mmHg on arrival) and patients withdrawn from life support were excluded”(Abback et al., 2020, p. 2).

Results of the study found that;

> The median age was 39 years and the majority were males. More than half of all patients had an ISS score [Injury Severity Score] above 15, and one third presented with TBI [traumatic brain injury]. The overall in-hospital mortality was 10%. (Abback et al., 2020, p. 3).

Abback et al. (2020) utilized multiple statistical analysis techniques to compare the collected data. Abback et al. (2020)"On univariate analysis, the in-hospital mortality was higher for hyperoxemic patients (12% vs. 9%, $p<0.0001$)" (p. 3).

> In a propensity score model, patients were matched based upon significant determinants of mortality amongst the baseline characteristics. The model revealed an inverse relationship between hyperoxemia and in-hospital mortality: mortality was significantly decreased in hyperoxemic patients compared to normoxemic patients … and hyperoxemia thus appeared as a protective factor. (p. 3)

" In this large observational study … hyperoxemia above 150 mmHg on hospital admission to be independently associated with significantly decreased in-hospital mortality compared to normoxemia" (Abback et al., 2020, p. 4). Due to the findings, "the study calls for a randomized clinical trial to further investigate this [decreased in-hospital mortality with hyperoxemia in trauma patients] association" (Abback et al., 2020, p. 9).

Andersen et al. (2019),

> Due to limited evidence available on oxygen for trauma patients, we [Andersen et al.] chose to carry out a pilot randomised clinical trial (TRAUMOX-1) where we aimed to

> determine whether maintenance of normoxia using a restrictive oxygen strategy is feasible within the first 24 hours after trauma and secondarily to evaluate the incidence of 30-day mortality and major in-hospital pulmonary complications (combined endpoint). (p. 948)

Andersen et al. (2019) “carried out a parallel group, two-arm, pilot trial with a 1:1 allocation ratio in an acute care setting” (p.948). “The trial was conducted at a tertiary university hospital in Denmark … a level 1 trauma centre and treats approximately 1,000 trauma patients each year” (Andersen et al., 2019, p.948).

Characteristics of the patients’ in the study were as follows:

> Patients above 18 years of age with blunt or penetrating trauma, that generated a trauma team activation and were directly transferred from the scene of the accident to our [Andersen et al.] trauma centre, were included. We [Andersen et al.] excluded patients in cardiac arrest before/on admission, patients with suspicion of smoke inhalation, and patients not admitted to a hospital ward after the initial treatment in the trauma bay. (Andersen et al., 2019, p. 948)

Baseline characteristics for participants were equally distributed between groups; “a majority of patients were male (78%), and the mean age was 53 (17.9) years”(Andersen et al., 2019, p. 950). In both groups, most of the patients received oxygen before arriving at the hospital. “The most common trauma mechanism was blunt trauma (90%) due to motor vehicle/-cycle collisions (26.8%) followed by bicycle accidents and falls from height (both 17.1%)” (Andersen et al., 2019, p. 950).

The outcome, “in this single-centre randomised [*sic*] clinical pilot study we [Andersen et al.] found that maintenance of normoxia using a restrictive oxygen strategy following trauma is feasible” (Andersen et al., 2019, p. 952). Secondary outcomes showed:

> The median GOSE [Glasgow Outcome Scale Extended] score at 30 days was 5.5 (4-6) in the restrictive group and 5.0 (3.0-5.5) in the liberal group (P = 0.15). The incidence of sepsis and surgical site infections did not differ between the two groups, nor did number of days on mechanical ventilation. (Andersen et al., 2019, p. 951)

As this is a pilot study, Andersen et al. (2019) recommended more extensive studies to evaluate further the utilization of restrictive oxygen to prevent hyperoxemia in trauma patients.

Adherence to Oxygen Weaning Protocols

Protocols and guidelines improve patient care and outcomes; therefore, Cuevas et al. (2020) evaluated adherence to an oxygen weaning protocol by evaluating specific measures.

> The goals of this [Cuevas et al.] study were to determine whether the oxygen-weaning protocol at a university-affiliated hospital was followed and to measure the length of time respiratory therapists took to wean patients once the oxygen-weaning parameters were met. (Cuevas et al., 2020, p. 2)

In this study, it was noted that the oxygen weaning protocol was not always followed, which caused patients to remain on higher oxygen levels longer than they needed to be. (Cuevas et al., 2020).

> The median time to first change in FIO2 when subjects met weaning criteria was 5 h … . Almost half of the subjects (46.9%) were weaned within the first 4 h of meeting the

> criteria; for 30% of the subjects, it took 12 h to make the first change in FIO2 after meeting weaning criteria. (Cuevas et al., 2020, p. 3)

Prolonged weaning times in patients that meet the criteria for weaning FIO2 are concerning; it is known that hyperoxia can be harmful to patients and increase the potential for poor outcomes.

Use of Excessive Oxygen in Mechanically Ventilated Patients Due to Unit Practices

Brooks et al. (2020) completed “a multi-method observational study, that included (1) a cross-sectional ICU staff survey and (2) focus group discussions with critical care nurses was conducted” (p. 344). The study was completed at a ”regional hospital in Australia, a level III adult mixed medical, surgical, and cardiothoracic 24-bed ICU” (Brooks et al., 2020, p. 344).

Oxygen titration is an essential component in the medical management of patients that are on mechanical ventilation; because of this,“ when titrating supplemental oxygen, ICU clinicians need to balance the associated risk and benefits of this treatment; however, little is known about what factors influence their clinical decision-making” (Brooks et al., 2020, p. 344). Due to nursing staff being an integral component in oxygen titration of ventilated patients, Brooks et al. (2020) wanted to fill the gaps in research in this area.

> The purpose of the study was to (1) obtain opinions from medical, nursing, and physiotherapy staff working in the study site ICU regarding their understanding and management of oxygen administration in patients who are mechanically ventilated and (2) explore their clinical decision-making process when weaning oxygen therapy in this patient group. (Brooks et al., 2020, p. 344)

Brooks et al. (2020) utilized surveys and focus group discussions to collect data points, which was done through convenience sampling. Two focus group discussions were offered to the ICU staff, with a total participant size of 11 (Brooks et al., 2020). “The staff survey was

completed by 49 staff members working at the study site ICU: 42 nursing staff (85.7%), six medical staff (12.2), and one physiotherapist (2.1%)" (Brooks et al., 2020, p. 345).

Notable findings from Brooks et al. (2020):

> This study shows that ICU clinicians are aware of the importance of preventing hyperoxia in mechanically ventilated patients; however, the unit culture and routine practices enabled the liberal use of supplemental oxygen at the study site. Participants identified that inconsistent documentation of oxygenation targets, a lack of focus on minimizing supplemental oxygen use, and a tendency to base clinical decision-making on prior experience and routine rather than current evidence were barriers to achieving practice change. (Brooks et al., 2020, p. 348)

Hyperoxemia in Mild to Moderate Acute Respiratory Distress Syndrome

Bellani et al. (2020) completed "a sub-study of the LUNG SAFE study, an international, multicenter, prospective cohort study of patients receiving invasive or noninvasive ventilation, … have been published elsewhere" (p. 2). This sub-study's

> primary objective was to determine the prevalence of early and sustained hyperoxemia and excess oxygen use in patients with hyperoxemia. Secondary objectives included identifying factors associated with hyperoxemia and with excess oxygen use and examining the relationship between hyperoxemia and excess oxygen use and outcomes from ARDS. (Bellani et al., 2020, p. 2).

Data collection was obtained at the same time each day for all participants in the study. Data points of interest for Bellani et al. (2020) were ventilator settings and arterial blood gases. For this study,

> the following definitions were applied on day 1 and on day 2 of ARDS: hypoxemia (PaO2< 55 mmHg), normoxemia (PaO2 55-100 mmHg), and hyperoxemia (PaO2 > 100 mmHg). Excess oxygen use was defined as the use of FIO2 ≥ 0.6 in patients with hyperoxemia (PaO2 > 100mmHg). Patients with hyperoxemia on days 1 and 2 of ARDS were considered to have sustained hyperoxemia. (Bellani et al., 2020, p. 3)

Multiple statistical methods were utilized in this study to determine outcomes. "Propensity score matching method was used to evaluate the possible impact of sustained hyperoxemia on main outcomes (mortality, ventilation-free days, and duration of mechanical ventilation) in patients with mild-moderate ARDS" (Bellani et al., 2020, p. 4).

Further restrictions were implemented for the sub-study of the patients included in the LUNG SAFE study. "Given the study focus on early hyperoxemia and excess oxygen use, we [Bellani et al.] restricted to patients that fulfilled ARDS criteria within 48 hours of ICU admission and remained in the ICU for at least 2 days from ARDS onset. Patients transferred from other ICUs after 2 days, … developed ARDS later in their ICU stay, and patients that received early ECMO were excluded. (Bellani et al., 2020, pp. 2-3).

Bellani et al.'s conclusion was:

> Our findings demonstrate that hyperoxemia and high fractional inspired oxygen use is prevalent in patients with early ARDS in patients enrolled in the LUNG SAFE cohort. Higher FIO2 use decreased from day 1 to day 2 of ARDS, with most day 2 hyperoxemia seen in patients at lower FIO2, in whom gas exchange was improving. Reassuringly, we

> [Bellani et al.] found no relationship between hyperoxemia or excessive oxygen use and patient outcomes in this cohort. (Bellani et al., 2020, p. 11)

Conservative Oxygen Therapy in Mechanically Ventilated Patients

A Conservative oxygen therapy quasi-experimental pilot study was completed by Bellomo et al. (2014) for mechanically ventilated patients. They evaluated using a before and after group to assess the effects of implementing conservative oxygen therapy in this patient population (Bellomo et al., 2020). The study was completed at a single tertiary care hospital in Australia (Bellomo et al., 2014). The study was nine months long and was made up of three phases. The initial phase was the current oxygen weaning practice. In the second phase, education was provided on conservative oxygen therapy. The final phase was implementing and utilizing conservative oxygen therapy practices (Bellomo et al., 2014). The aim of the study, "We [Bellomo et al.] tested the hypothesis that a conservative approach to oxygen therapy (target Spo2 of 90-92%) is feasible and safe in mechanically ventilated critically ill patients and can reduce exposure to excess oxygen" (Bellomo et al., 2014p. 1415).

Data was collected using a standardized form, and statistical analysis was completed. Statistical methods used in this study were the Fisher exact tests, Student t-tests, Wilcoxon rank-sum test, mixed linear model repeated measures, and multivariable logistic regression analysis (Bellomo et al., 2014).

Inclusion and exclusion criteria for the pilot study stated that:

> Patients were eligible if they were adult (18 years old or older) and required MV [mechanical ventilation] for more than 48 hours. Patients were ineligible if they were either considered at risk for imminent death by the treating medical team or required extracorporeal membrane oxygenation. (Bellomo et al., 2014, p. 1415)

During the study period, Belloma et al. (2014),

> we [Belloma et al.] enrolled 51 patients with 1,409 datasets on 354 MV [mechanical ventilation] days in the conventional therapy group and 54 patients with 1,760 datasets on 445 MV days in the conservative oxygen therapy group. The two groups had similar baseline characteristics. (Bellomo et al., 2014, p. 1416)

At each phase of the study, oxygen goals were pre-prescribed by the bedside clinicians (Bellomo et al., 2014). After the phase-out period, "if a patient was eligible for the trial, clinicians now prescribed an SPO2 level between 90% and 92% using the lowest possible FIO2"(Bellomo et al., 2014, p. 1415).

Outcomes evaluated by Bellomo et al. (2014) were:

> The primary outcome was change in PaO2/FIO2 ratio in the first 10 days. Secondary and tertiary outcomes included change in lactate and creatinine levels in the first 10 days; laboratory test results; new non-respiratory organ failure while the patient was in the ICU; the prevalence of arrhythmias, infection, and severe hypoxemia (defined as a PaO2 <55) in the ICU; acquired RRT in the ICU; and use of anti-delirium drugs, PRBC transfusion; ventilator, ICU and hospital free days at 28 days and survival status at 28 days. (p. 1415)

Findings, "during the conservative oxygen treatment period, patients had a significantly lower time-weight average SpO2 … (95.5% [94-97.3%] vs. 98.4% [97.3 - 99.1%]; $p < 0.001$) … compared with the conventional therapy period" (Bellomo et al., 2014, p. 1416). Bellomo et al. (2014) found, "when an SpO2 was above the target levels with and FIO2 below 0.5 (but not already 0.21), the FIO2 was more frequently decreased in the conservative therapy group" (p. 1417). Bellomo et al. (2014) concluded that

> the preliminary data suggests that implementing an oxygen therapy target of SpO2 of 90-92% in mechanically ventilated ICU patients is feasible and not associated with major

> clinical or physiological adverse events. Our findings support the safety and feasibility of further RCT of conservative versus conventional oxygen therapy. (Bellomo et al., 2014, p. 1421)

Mechanical Ventilation and the Cost of ICU Stays

ICU stays have a significant cost to patients and healthcare systems; a driving factor for the higher cost of ICU stays is patients requiring mechanical ventilation (Bluhmki et al., 2019; Heister et al., 2020). Heister et al. (2020) indicate that "In our sample, initiation of mechanical ventilation led to a 59% average cost increase" (p. 2). "Limitations of our [Heister et al.] of course is the single-center nature of the data; however, the sample was decently-sized and included all patients treated in the period examined, limiting some sources of bias" (Heister et al., 2020, p. 4).

Heister et al. (2020) evaluated other studies that looked at the cost of mechanical ventilation; they found that their results were similar to other studies, and some reported lower costs for mechanically ventilated patients (Heister et al., 2020). Heister et al. (2020) concluded that:

> Overall, the results show substantial variability of ICU costs for patients with different underlying diseased and underline mechanical ventilation as an important driver of ICU Costs. … More studies on daily costs of mechanical ventilation and intensive care are duly needed. (p. 4)

Bluhmki et al. (2019) completed a systematic review of the literature to determine the financial burden mechanical ventilation has on the daily cost of an ICU stay. The systematic review was done through a substantial database search, with literature excluded by duplication

of studies and evaluation of abstracts, to find relevant studies, and inclusion criteria Bluhmki et al. (2019) found five articles that met all of their criteria for assessment.

The daily cost of an ICU day with mechanical ventilation within the studies evaluated by Bluhmki et al. (2019) did not consider the cost of prolonged length of stay due to acuity of illness or development of VAP on the daily cost and length of stay.

> Our [Bluhlmki et al.] cost calculations were based on the simplifying assumption that the entire excess length of stay can be attributed to ventilation: thus, we may have slightly overestimated the costs. However, we refer to the results that this excess seems to be mainly triggered by ventilation. (Bluhmki et al., 2019, p. 4)

Of the studies included in Bluhmki et al.'s (2019) study found, "there was strong variability in the relative effect of mechanical ventilation across studies but overall, mechanical ventilation was associated with a 25.8% (95% CI 4.7&-51.2%) increase in the daily cost of ICU care" (p. 3).

Rationale

This program evaluation was completed using the PARISH (Promoting Action on Research Implementation) framework for evidence-based practice and Lewin's change theory, a model consisting of three phases. PARISH framework comprises three areas: evidence, context, and facilitation. The PARISH framework aims to take evidence-based research that is important or relevant to medical or nursing areas and implement it into practice. First, an investigation is completed through a literature review, evaluation of clinical and patient experience, and local data. Second, the context of the area of interest is evaluated by involving staff members with different roles who will participate in implementing research into practice. The third area of the PARISH framework is the evaluation, where the outcome of the evidence-based intervention is assessed. Once the information has been evaluated,

information should be reviewed with leadership and other healthcare workers involved in the changes to continue practice improvement. It is vital to have leaders and practitioners that encourage improvement in practice. This will allow changes and evidence-based research to be incorporated into practice (Bergstrom et al., 2020). The critical care providers noticed that patients on ventilators did not have their FIO2 levels weaned in a timely manner. There were cases of FIO2 not being weaned for several hours despite having adequate SpO2 levels. Previous research found that hyperoxia was detrimental to patients and that FIO2 levels greater than or equal to 0.6 can cause lung injury. Prior research on hyperoxia and practice findings of prolonged weaning times in mechanically ventilated patients called for the development of a new ventilator weaning protocol at this level II trauma tertiary care hospital.

Lewin's change theory also referred to as unfreeze - change - re-freeze model, is an approach to making changes in organizations, teams, and practices within groups by finding areas that need change. This is done by asking others within the group about what could be changed to improve performance, satisfaction, or outcomes, which is the area in Lewin's change model called unfreeze. In the first section of Lewin's model, the unfreeze; identification of resistance to change or barriers to change would occur. While in this phase, education or training would be provided for the change that will take place (Tracy, 2020). The second phase of Lewin's change theory is the movement phase, where the change is implemented. While in the second phase, feedback should be obtained, and any changes to improve upon should be made if possible (Tracy, 2020). The final phase in Lewin's change theory is re-freezing. In this phase, the "new way becomes ingrained into the practice as the new norm" (Tracy, 2020, p. 2).

Specific Aims

The purpose of this project was to improve oxygen weaning times in mechanically ventilated patients in the 3 ICUs at a level II trauma tertiary care hospital. A conservative oxygen weaning protocol was implemented with time and oxygen titration parameters. This provided guidance and a standard to wean intubated patients that had been previously unavailable to the respiratory therapists and nurses. The project is a multidisciplinary approach to ventilator weaning to improve care for mechanically ventilated patients in the ICUs by improving oxygen weaning times and preventing prolonged hyperoxia. The primary goal was to improve oxygen weaning times in mechanically ventilated patients from intubation to an FIO2 of 0.3.

Methods

The study program was completed using the PARISH framework and Lewin's change theory to evaluate the evidence-based practice program. This was conducted using a quantitative, retrospective, consecutive sampling, quasi-experimental methodology to compare a before intervention group (current oxygen weaning practice) and an after intervention group (Conservative oxygen weaning protocol) in a level II trauma tertiary care hospital in three ICUs (Medical, Trauma/Neuro, and Cardiovascular Thoracic). The current ventilator weaning practice (before/control group) sample frame was from May 1, 2021, to July 30, 2021. Education was then provided on the conservative oxygen weaning protocol. After education was provided, the conservative oxygen weaning protocol was implemented on February 14, 2022. Data collection for the conservative oxygen group was from February 14, 2022, to March 23, 2022.

Education was completed utilizing a voice-over PowerPoint presentation emailed to all respiratory therapists, ICU nurses, and critical care providers. A PowerPoint presentation was

provided, and other education on the conservative oxygen weaning protocol through Microsoft teams. I spoke with ICU nurses and respiratory therapists regarding any questions about the new oxygen weaning protocol and completed one-on-one education sessions as needed with the ICU nurses and respiratory therapists. Before implementing the new protocol, a weaning protocol and SpO2 titration scale were placed on every respiratory therapist's computer, the critical care providers' rolling computers, and the providers' computer stations. The SpO2 titration scale was placed on every nursing computer station outside the patient rooms. The conservative oxygen weaning protocol was implemented on February 14th. The conservative oxygen therapy (after group) sample frame was from February 14, 2022, to March 24, 2022.

The sample frames were obtained through Cerner Electronic Medical Record, limiting the search to the dates selected, orders for mechanical ventilation, and removal of any intubated patients less than 24 hours in both groups. Data collectors manually excluded patients with orders for comfort measures only (CMO) in the first group. In the after-intervention group, patients with orders for CMO were excluded through the Cerner data collection system. Further exclusion criteria for the study were patients with missing data for intubation times or time of transfer to the ICU from outside facilities.

The study's Inclusion criteria included adult patients (18 years and older), P/F ratio ≥150, and requiring mechanical ventilation longer than 24 hours. Exclusion criteria included any patient with a P/F ratio < 150 on initial arterial blood gas after intubation, diagnosis of COVID-19 Pneumonia or with severe respiratory complications likely related to COVID-19, tracheostomy at the time of admission, mechanical ventilation < 24 hours which includes post-op Cardiac Surgery patients, transfer patients from outside hospitals that are already on an FIO2 of 0.3, patients that were transitioned to comfort measures or died while on mechanical ventilation, any patient that did not have a documented ABG at three or more hours after

intubation (or arrival to the ICU) to determine P/F ratio and PaO2 level, patients that were extubated before reaching an FIO2 of 0.3, and any patient with data missing for the time of intubation (or time of arrival to the ICU from an outside hospital).

The hospital QI committee and Edinboro University of Pennsylvania's Institutional Review Board approved this quality improvement study. Informed consent was not required as the weaning practice was changed for all patients that required mechanical ventilation with a P/F ratio ≥ 150 and did not have a diagnosis of COVID Pneumonia. Before admission, patients with tracheostomies followed the weaning protocol; however, they were excluded from the current study.

Data points were collected for both current oxygen weaning practices (before/control group) and the conservative oxygen weaning protocol group (after group) through chart reviews in the Cerner EMR system. Data was collected by several data collectors; therefore, all data collectors were provided with written instructions to follow for collecting data in the Cerner EMR. All data collected was imputed into an Excel spreadsheet with predetermined data points.

Data points that were collected included age, gender, admission date, admitting diagnosis, if the participant qualified for the study based on inclusion and exclusion criteria, reason for intubation, date of intubation, time of intubation (or arrival to the ICU after transfer from an OSH), time of initial ABG after intubation, FIO2 level when the first ABG was obtained on after intubation, initial P/F ratio after intubation, initial O2 wean based on the post-intubation ABG, Ordered SpO2 goal, O2 saturation level every 2 hours for a total of 24 hours, FIO2 level every 2 hours for 24 hours or until 0.3 FIO2 was obtained without any further increase, time and date the FIO2 goal of 0.3 was met, date of extubation or tracheostomy, and date of discharge. Data collection on medical history included new or chronic conditions or exacerbations of chronic conditions. Diagnoses that were collected included End-Stage Renal Disease (ESRD)

or Acute Kidney Injury (AKI) requiring Continuous Renal Replacement Therapy (CRRT) or intermittent hemodialysis (I-HD), Chronic obstructive pulmonary disease (COPD) or Asthma, congestive heart failure (CHF), altered mental status (AMS), Cerebral Vascular Accident (CVA), Cardiac arrest, Sepsis or Septic Shock, and Pneumonia (PNA), Aspiration PNA or ventilator-associated PNA.

On February 14, 2022, a conservative oxygen therapy weaning protocol for mechanically ventilated patients was implemented, utilizing a multidisciplinary approach to improve oxygen weaning times. The oxygen weaning protocol was developed based on current published evidence and collaboration with the Critical Care Director. We were aware of limitations, such as staffing shortages in the respiratory therapy and the ICU nursing departments. Due to these limitations, the oxygen weaning time frame needed to be achievable; therefore, a 2-hour time limit was selected. The titration parameter of ≥ 4% of the SpO2 goal was chosen to allow the inclusion of patients with COPD or other conditions without requiring a separate protocol.

The Conservative Oxygen Weaning Protocol was implemented after education was provided to each department involved in improving FIO2 weaning times in ventilated patients. The departments that received education were the critical care, respiratory therapy, and ICU nursing departments. Each department had its areas to focus on for ventilator weaning. The conservative oxygen weaning protocol was designed for patients requiring mechanical ventilation. Once intubated, the first arterial blood gas (ABG) after intubation was used to calculate a P/F ratio. If the P/F ratio was ≥ 150 and the patient met the inclusion criteria for the conservative oxygen weaning protocol, the protocol was initiated. The Conservative Oxygen Weaning Protocol (See Figure 1) has three pathways that the participants would be placed in based on the initial PaO2 on the ABG after intubation. Once the weaning pathway was determined, the respiratory therapist had a set percentage to wean the initial FIO2. After the

initial FIO2 wean, all remaining FIO2 weans were based on the patient's SpO2 level and the weaning pathway. The time frame for weaning FIO2 was a maximum of every 2 hours if the patients' met the SpO2 weaning criteria. The goal FIO2 for all patients was an FIO2 of 0.3.

The critical care provider determined the SpO2 goal for each patient based on the patient's condition and medical diagnosis. Further weaning of the FIO2 per the protocol was based on the SpO2 level after the initial ventilator wean. The respiratory therapist should have weaned the FIO2 if the SpO2 level were ≥ 4% above the ordered SpO2 level (See Figure 2). The goal was to wean FIO2 at a maximum of every 2 hours to a goal FIO2 of 0.3.

The goal of this oxygen weaning protocol was to be a multidisciplinary approach to improve oxygen weaning times. Each department has a role in improving weaning times; the ICU nurses were to document communication with respiratory therapy or critical care in the Cerner Electronic Medical Records (EMR) if weaning criteria were met before the 2-hour time parameter. Critical care medicine providers' role was to determine the SpO2 goal of each patient, to wean FIO2, and communicate ventilator changes to the respiratory therapists. Respiratory therapy was to obtain the initial ABG after intubation and calculate the P/F ratio to determine if the patient qualified for the weaning protocol. Once determined that the patient qualified for the protocol, the respiratory therapist determined the patient's pathway in the weaning protocol. All ventilator changes were documented in the Cerner computer system by respiratory therapy. Respiratory therapy worked in collaboration with the ICU nurses and CCM to wean FIO2 at a maximum of every 2 hours if the patient met the requirements of the weaning protocol.

A program evaluation was completed to assess if there was an improvement in oxygen weaning times for mechanically ventilated patients by comparing the current oxygen weaning

practice (before/control group) to the conservative oxygen weaning practice (after group) after education and implementation of the new protocol. Data points were obtained through a retrospective chart review of the current oxygen weaning group (before/control group) and the conservative oxygen weaning group (after group). The sampling method utilized for this study was consecutive sampling, a nonprobability sampling method. Statistical analysis was completed in Python using the SciPy package. Data in both the before and after intervention groups had a non-normal distribution determined by using Shapiro Normality Test; therefore, a Mann-Whitney U test was chosen to test for statistical significance. The Mann-Whitney U test was completed to determine the statistical significance between the two groups from intubation to a goal FIO2 of 0.3.

The measures evaluated in this study were oxygen weaning times from intubation to an FIO2 of 0.3 between the current weaning group and the conservative oxygen weaning group. Additionally, oxygen weaning times between the current oxygen weaning group and the conservative oxygen weaning group of males and females were also evaluated. The main focus of this study was to improve oxygen weaning times, as prolonged-time at higher oxygen levels can be detrimental to patients' health, can cause lung injury, and prolong lengths of stay in the hospital.

This study has good internal validity; the evaluation of the current oxygen weaning group and the conservative oxygen weaning protocol group were completed through retrospective chart reviews. Data collection was conducted using Excel spreadsheets with set data points; data collectors were given written instructions on collecting the data from the EMR. The external validity of this study is not strong due to this being a single-center study with small sample sizes; due to this, the study's outcomes can not be generalized to other organizations' ICUs. The

study's reliability depends on compliance by staff members with the new protocol. Reliability and validity could be questioned due to the need for further Plan-Do-Study-Act (PDSA) cycles to improve the implemented initial protocol.

The study was completed using a quantitative, retrospective, consecutive sampling, quasi-experimental methodology to compare the current oxygen weaning group and the conservative oxygen weaning protocol group in three ICUs. Data collection forms were developed in Excel with set data points. All data collectors utilized the Excel data collection form, with instructions on where to collect data points from within Cerner EMR. The SciPy package in Python was used to complete the data analysis for this study. Time constraints of this project during the period of the conservative oxygen weaning group caused a smaller sample to be collected for the study. After implementing the conservative oxygen weaning group, the time constraints required using patients from the first day of intervention to be included in this study.

This study was approved by Edinboro University of Pennsylvania's Internal Review Board (IRB) and the Quality Improvement Review Committee at the level II trauma tertiary care hospital. Informed consent was not required as this was a practice change that applied to all admissions that required mechanical ventilation for greater than 24 hours. Patient safety was a top priority throughout the implementation of the conservative oxygen weaning protocol. If any patient on the conservative oxygen therapy protocol had a decline in their condition, they would no longer follow the protocol.

Results

The current oxygen weaning practice group (before/control group) sample size was obtained from the Cerner EMR after including the exclusion criteria of intubated patients for less

than 24 hours. The number of patients to get a sample from was 229. The 229 patients were then divided into five groups for data collection, with further exclusion criteria which included orders for comfort measures, missing data, COVID-19 Pneumonia, respiratory failure with a diagnosis of COVID-19, and a P/F ratio < 150 significantly reduced the sample size. The total sample size used for results in this study for the current oxygen weaning group (before/control group) was 34 participants. The conservative oxygen therapy group's(after group) sample size before implementing exclusion criteria and duplicate records from the Cerner EMR was 230. After including the exclusion criteria of intubated less than 24 hours and CMO orders, the number of patients who remained in the conservative oxygen therapy group was 76. The 76 patients were divided into five groups for data collection. After instituting the same exclusion criteria as with the current oxygen group (before/control group), the sample size for the conservative weaning group (after group) was 18 participants.

To evaluate for normal distribution, a Shapiro Normality Test was utilized to account for the small sample size and used an α of 0.05. Both groups did not have a normal distribution; therefore, the Mann-Whitney U Test was used to evaluate the statistical significance between the groups. The current practice group had a p-value= 1.827e-08, and the conservative oxygen weaning group had a p-value= 6.213e-06. The findings for the current weaning practice (before/control group) with a sample size of 34 had a mean ventilator weaning time of 27 hours, 38 minutes, and 2 seconds from the time of intubation to FIO2 of 0.3 (See Table 1, Figure 3, and Figure 4). The weaning time for the current weaning practice group (before/control group) in the 25th percentile was 5 hours, 38 minutes, and 15 seconds; in the 75th percentile, the weaning time was 28 hours and 36 minutes. The minimum weaning time from intubation to an FIO2 of 0.3 for the current weaning practice (before/control group) was 35 minutes, and the maximum weaning time was 211 hours (8 days and 19 hours) and 5 minutes. The standard deviation in

this current practice group was 40 hours, 51 minutes, and 53 seconds. The conservative oxygen therapy group (after group) with a sample size of 18 had a mean ventilator weaning time of 15 hours, 20 minutes, and 33 seconds from intubation to an FIO2 to 0.3 (See Table 1, Figure 3, and Figure 4). The weaning time for the conservative oxygen weaning practice group (after group) in the 25th percentile was 4 hours, 48 minutes, and 30 seconds; in the 75th percentile, the weaning time was 12 hours. The minimum weaning time from intubation to an FIO2 of 0.3 for the conservative oxygen weaning practice (after group) was 17 minutes. The maximum weaning time was 93 hours (3 days and 21 hours) and 6 minutes. The standard deviation in this conservative oxygen weaning practice group was 21 hours, 45 minutes, and 54 seconds.

Females (n = 17) in the current oxygen weaning group (before/control group) have a mean age of 64 years, and a mean ventilator weaning time from intubation to an FIO2 of 0.3 was 31 hours, 12 minutes, and 8 seconds. Males (n = 27) in the current oxygen weaning group had a mean age of 60.82 years with a mean ventilator weaning time of 24 hours and 49 minutes. In the conservative oxygen therapy group (after group), the mean age for females (n = 9) was 61 years, with a mean ventilator weaning time to an FIO2 of 0.3 was 25 hours, 50 minutes, and 50 seconds. Males (n = 14) in the conservative oxygen weaning group had a mean age of 65.6 years, with a mean ventilator weaning time from intubation to FIO2 of 0.3 was 10 hours, 5 minutes, and 25 seconds (Table 2).

The Mann-Whitney U Test with one-tail and an α level of 0.05 was used on the current practice (before/control group) and the conservative oxygen weaning group (after group). The result of weaning times between groups had a p-value = 0.05735. The finding between the current oxygen weaning group (before/ control group) and the conservative oxygen weaning group (after group) were not statistically significant. Therefore, implementing a conservative

oxygen weaning protocol to improve ventilator weaning times compared to current practices did not significantly improve weaning times by statistical standards.

Unexpected findings through data collection were findings of prolonged weaning times when evaluating the two-hour intervals for FIO2 changes and SpO2 levels in the conservative oxygen weaning group when FIO2 should have been weaned. In addition, inconsistencies in documentation between nursing and respiratory therapy on FIO2 each hour. During data collection, findings of nursing documentation did not change when FIO2 changes were documented by respiratory therapy. It was also noted that a lower FIO2 level was charted earlier by nursing staff than the documentation by the respiratory therapist. In addition, through the chart review, charts were found without documented SpO2 goals, or an old order for SpO2 levels remained in place from old orders that were never removed.

Discussion

Implementing a conservative oxygen weaning protocol for mechanically ventilated patients was completed in three ICUs at a single center level II trauma tertiary care hospital to improve oxygen weaning times and prevent prolonged hyperoxia. This study's aim was to evaluate if the implementation of a conservative oxygen weaning protocol would improve oxygen weaning times from intubation to an FIO2 of 0.3. This aim was to prevent prolonged periods of higher FIO2 levels than required. The findings between the conservative oxygen weaning group (after group) and the current practice group (before/control group) for weaning FIO2 were not statistically significant. Although the findings were not statistically significant, the group data for weaning times showed improvement in the conservative oxygen weaning group (after group) compared to the current practice group (before/control group). Some articles have been published regarding opposition to the p-value and its significance in research studies.

One paper discusses opposition from statisticians on the use of P-values (Staggs, 2019). One reason for resistance is that;

> small p-values are routinely taken as an indication that a finding is important, when, in fact, the effect size may be too small to be practically meaningful; and p-values that are not small are routinely taken as evidence of no effect, when in fact an important effect can have a 'nonsignificant' p-value. (Staggs, 2019, p. 159)

This study's group data shows improvement in weaning times for the conservative oxygen weaning group compared to the current oxygen weaning group, though not statistically significant; even minor improvements are essential in preventing hyperoxia when weaning oxygen.

Implementing a conservative oxygen weaning protocol was not statistically significant, which was unexpected. This finding could be related to the hospital utilizing traveling respiratory therapists and ICU nurses who are not invested in learning the protocols at each new facility. The protocol was newly developed, and PDSA cycles were not used due to time constraints. With PDSA cycles, it is possible to see practice changes for respiratory therapists, ICU nurses, and critical care medicine providers. Due to time constraints, the data collected from the initial implementation of the new protocol did not allow time for respiratory therapists, nurses, and critical care providers to adjust to the new protocol.

The other issue noted was that FIO2 weaning was not done consistently per the new protocol, and the pattern seems to follow old practices that have not been changed. Suppose the protocol was not routinely followed, as seen in the group data; this could be why there was no statistical significance in implementing the conservative oxygen protocol. Brooks et al.(2020) found in their study that liberal oxygen use continued even though staff members knew higher

oxygen levels could adversely affect the patient. The continued use of higher oxygen levels was due to the unit culture and routine practices (Brooks et al., 2020). An article by Cuevas et al. (2020) evaluated adherence to an oxygen weaning protocol, which is relevant to the current study findings. Cuevas et al. (2020) evaluated if respiratory therapists followed a weaning protocol; once weaning goals were met, the length of time it took the respiratory therapist to wean FIO2 was assessed. Cuevas et al. (2020) found that "the oxygen weaning protocol was not routinely followed and that patients might remain at higher-than-required FIO2 after meeting the criteria for weaning for an excessive length of time" (p. 3).

Through the review of numerous studies that have been completed on hyperoxia, liberal oxygen use versus conservative oxygen therapy there has been no consensus on a specific number of what hyperoxia is. Every study used differing PaO2 levels and SpO2 goals to wean FIO2 in mechanically ventilated patients. These studies had varying questions that they were trying to answer about the effects of hyperoxia, liberal oxygen practices versus a more conservative approach for oxygen administration on sepsis, length of stay, mortality, and ICU cost. The studies reviewed had mixed findings on the significance of limiting oxygen therapy versus liberal oxygen therapy. The studies that did not have significant statistical findings between groups recommended limiting hyperoxia and that conservative oxygen therapy should continue to be studied with larger trials.

The limitations of this study were the time constraints for data collection after the conservative oxygen weaning protocol was implemented and that this was a small study at a single medical center. Due to the time constraints, a larger sample population could not be obtained for the conservative oxygen weaning group, which may have altered the study's findings. Due to time constraints, Plan-Do-Study-Act cycles (PDSA) were not completed; therefore, improvements to the conservative oxygen weaning protocol or further education were

not completed. Other limitations to the study include staffing shortages in the respiratory therapy and ICU, nursing departments, which required the need for traveling respiratory therapists and ICU nurses.

Implementing a conservative oxygen weaning protocol has been beneficial in the three ICUs, as it is known from the IOTA study that “in acutely ill adults, high-quality evidence shows that liberal oxygen therapy increases mortality without improving other patient-important outcomes” (Alhazzani et al., 2018, p. 1693). This study’s findings support the use of a more conservative approach to oxygen administration. The benefit of this study was in educating ICU nurses and respiratory therapists on the importance of preventing hyperoxia and its detrimental effects, which can be then utilized when weaning patient’s from oxygen supplementation via nasal cannula. Implementing the protocol has made FIO2 weaning a multidisciplinary approach, which improves patient care and safety. During data collection for this study, other areas for improvement were found. Areas for improvement are documentation and communication between ICU nurses and respiratory therapists when ventilator changes are made. When data collecting, missing orders were found for SpO2 goals and the need to remove old SpO2 orders that no longer apply to the patient.

The conservative oxygen weaning protocol implemented in the three ICUs will continue to be utilized as the group data showed some improvement in FIO2 weaning times. Further evaluation of the conservative oxygen weaning protocol is needed through PDSA cycles. When PDSA cycles are completed, the goal will be for further improvement in FIO2 weaning times. The hope is that after PDSA cycles and education on the conservative oxygen wean protocol, the changes to be implemented will become a change in culture throughout the three ICUs.

A conservative oxygen weaning protocol can be utilized beyond mechanically ventilated patients in the ICU. It can be used in patients that require non-invasive mechanical ventilation, high flow nasal cannula, such as Opti-flow, and nasal cannula use in the ICU and on nursing floors

throughout the hospital. Future studies based on this conservative oxygen weaning protocol should complete PDSA cycles to improve the protocol for FIO2 weaning times and other healthcare outcomes for mechanically ventilated patients. Further PDSA cycles should be completed on this protocol to continue improving on weaning times for mechanically ventilated patients. With the findings in the group data, it is encouraging that with some changes, further improvement may be seen in FIO2 weaning. Future evaluations are needed to evaluate conservative oxygen therapy and FIO2 weaning times in mechanically ventilated patients. Further research is needed to evaluate if implementing conservative oxygen weaning protocols will improve FIO2 weaning times in mechanically ventilated patients.

Other information

No funding was required for this study. The research was completed for educational and quality improvement purposes at the level II tertiary hospital where the study took place.

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Table 1

Statistics for Ventilator Weaning Time (Intubation to FIO2 0.3)		
	Control: Elapsed Time	**Treatment: Elapsed Time**
count	34	18
mean	1 days 03:38:02	0 days 15:20:33
std	1 days 16:51:53	0 days 21:45:54
min	0 days 00:35:00	0 days 00:17:00
25%	0 days 05:38:15	0 days 04:48:30
50%	0 days 13:30:00	0 days 09:21:00
75%	1 days 04:36:00	0 days 12:00:00
max	8 days 19:05:00	3 days 21:06:00

Table 2

Statistics for Ventilator Weaning Time by Gender

Test Group	Gender (M/F)	Patient # Count	Age - Mean	Age - Min	Age - Max	FIO2 level on initial ABG - Mean	FIO2 level on initial ABG - Min	FIO2 level on initial ABG - Max	elapsedTime - Mean	elapsedTime - Min	elapsedTime - Max
Control	F	17	64	36	84	85.58823529	40	100	1 days 07:12:08	0 days 02:00:00	5 days 07:00:00
Control	M	27	60.81481481	28	88	77.62592593	0.9	100	1 days 00:49:00	0 days 00:35:00	8 days 19:05:00
Treatment	F	9	61	29	79	76.66666667	40	100	1 days 01:50:50	0 days 01:19:00	3 days 21:06:00
Treatment	M	14	64.57142857	32	85	87.14285714	50	100	0 days 10:05:25	0 days 00:17:00	1 days 12:30:00

Figure 1

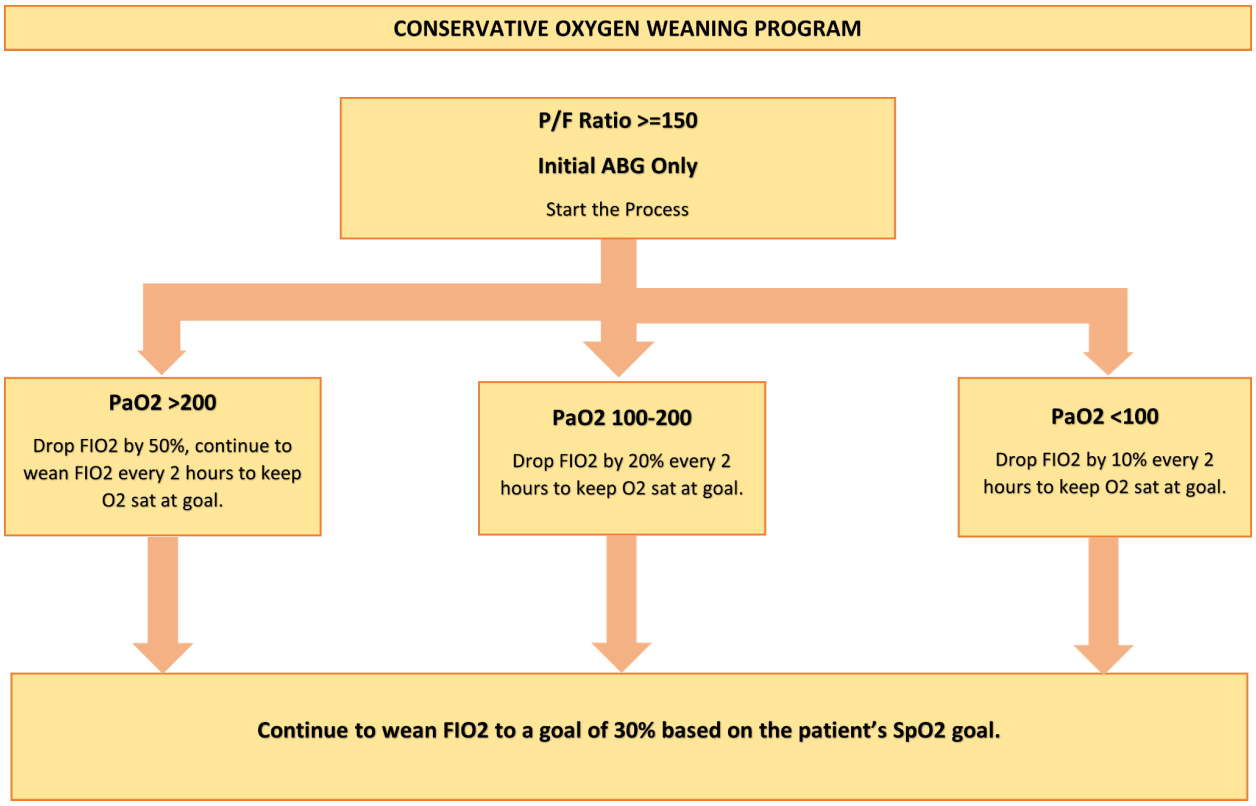

CONSERVATIVE OXYGEN WEANING PROGRAM
P/F Ratio >=150
Initial ABG Only
Start the Process
PaO2 >200
Drop FIO2 by 50%, continue to wean FIO2 every 2 hours to keep O2 sat at goal.
PaO2 100-200
Drop FIO2 by 20% every 2 hours to keep O2 sat at goal.
PaO2 <100
Drop FIO2 by 10% every 2 hours to keep O2 sat at goal.
Continue to wean FIO2 to a goal of 30% based on the patient's SpO2 goal.

Figure 2

SpO2 Titration Scale:

Goal SpO2 Level	If >= SpO2 level wean FIO2
92%	96%
91%	95%
90%	94%
89%	93%
88%	92%
87%	91%

Figure 3

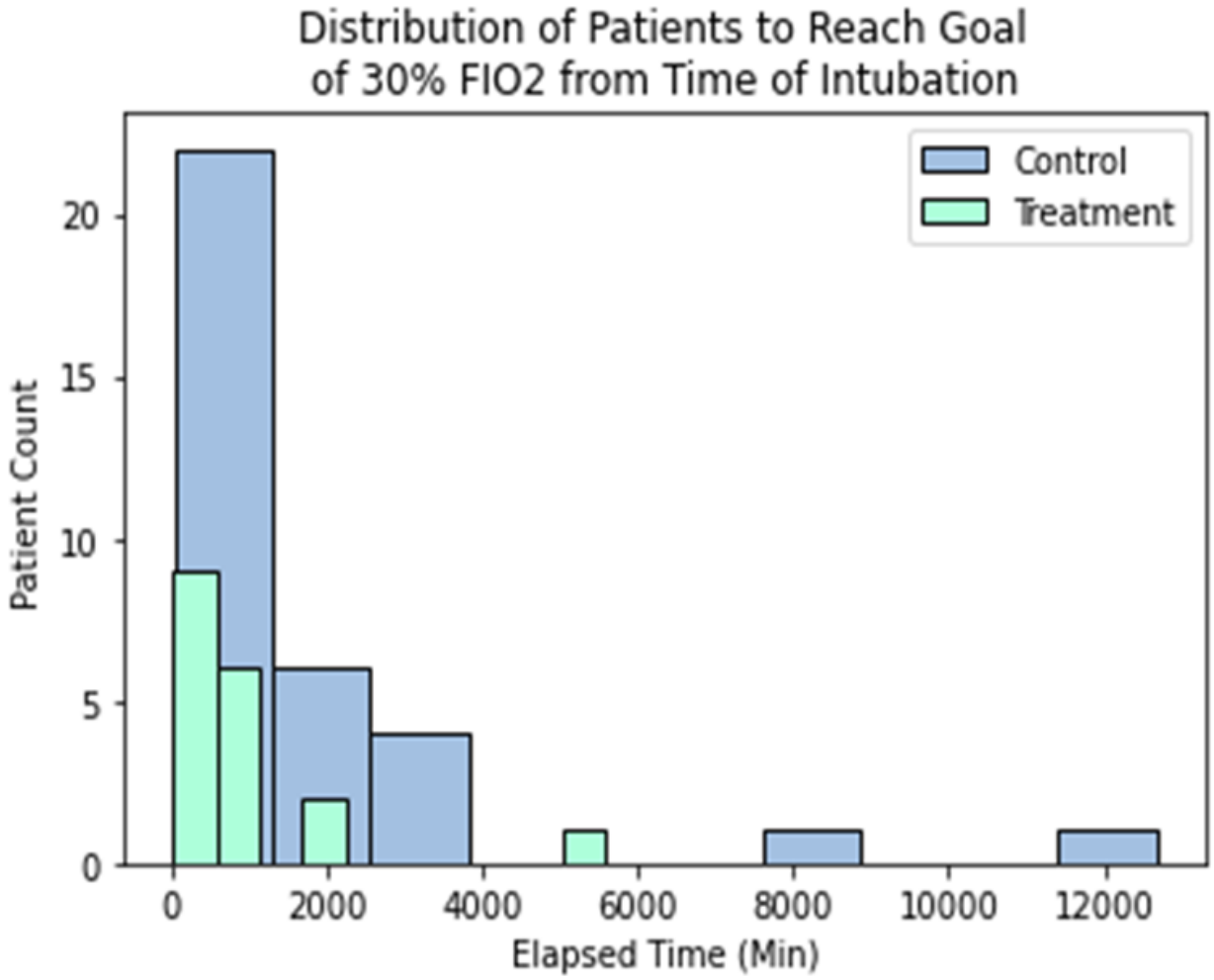
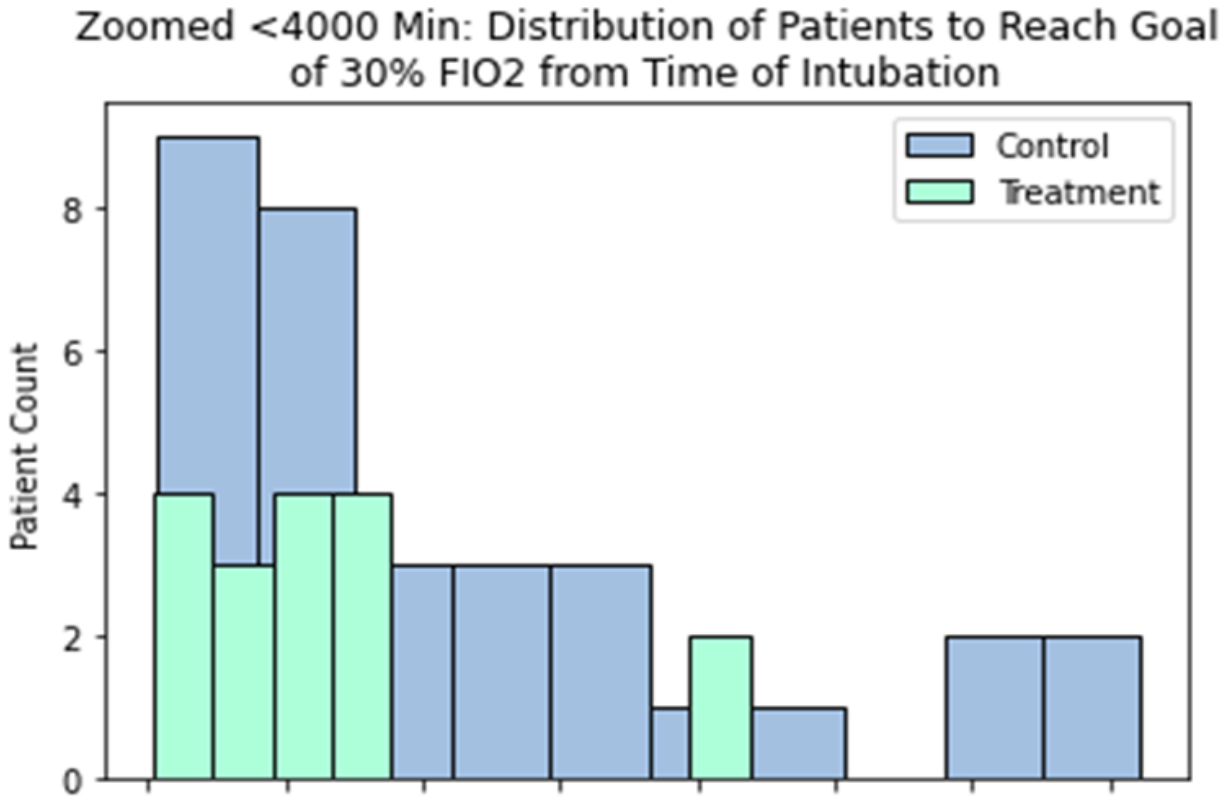

Distribution of Patients to Reach Goal
of 30% FIO2 from Time of Intubation
Control
Treatment
Patient Count
0
5
10
15
20
0
2000
4000
6000
8000
10000
12000
Elapsed Time (Min)

Figure 4


Zoomed <4000 Min: Distribution of Patients to Reach Goal of 30% FIO2 from Time of Intubation
Control
Treatment
Patient Count
0
2
4
6
8