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Airway Fire Prevention in the Operating Room

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Abstract

Airway fires during surgical procedures are preventable events that result in devastating outcomes for patients, healthcare providers, and healthcare facilities. Minimization of the risk of fires is a subsection of Standard 6 of the American Association of Nurse Anesthetists' Standards for Nurse Anesthesia Practice. A central priority of operating room fire mitigation is the minimized use of oxidizing agents. Oxygen is one component of the fire triad responsible for increasing the likelihood of these events, which is controlled by anesthesia providers in the operating room. The primary aim of this quality improvement project was to increase anesthesia provider knowledge pertaining to airway fire risk mitigation strategies through the implementation of an evidenced-based educational intervention. The secondary aim of this quality improvement project was to demonstrate a quantitative reduction of airway fire risk through a comparison of pre-intervention and post-intervention supplemental oxygen administration levels during surgical procedures. The overall goal of this project was to highlight the value of optimized provider knowledge regarding airway fire risk mitigation techniques, especially among high-risk airway fire procedures.

Keywords

airway fires, oxygen administration, otolaryngology, ENT, patient safety, quality improvement

Disciplines

Anesthesiology | Nursing | Otolaryngology | Perioperative, Operating Room and Surgical Nursing | Surgery

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Anesthesia Prevention of Operating Room Airway Fires

Problem Description

Airway fires are defined as problematic situations in which a fire occurs in or around a patient's breathing pathway. The presence of airway fire risk remains a national problem as well as a local issue at Pennsylvania Hospital. Pennsylvania Hospital is a 780-bed private non-profit teaching hospital that serves the greater Philadelphia region as well as patients from around the world. This hospital has over 93 anesthesia providers consisting of physician anesthesiologists, certified registered nurse anesthetists (CRNA), as well as student registered nurse anesthetists (SRNA). The risk of airway fires at this hospital is attributed to its robust otolaryngology department, which performs nearly 1,352 Ear, Nose and Throat (ENT) cases per year.

The American Society of Anesthesiologists (ASA) recognizes ENT cases as high-risk procedures and defines these as situations in which an ignition source, such as an electrical surgery device, has the increased likelihood of coming within proximity of an oxygen-rich atmosphere (Caplan et al., 2013). This is a situation that will increase the risk of an airway fire. Most pertinent to the problem we intend to address, there has been one occurrence of a facial fire at Pennsylvania Hospital within the past three years which resulted in direct patient harm. This is in stark comparison to other hospitals in the nation that are comparable in size and have not experienced an airway fire in over a decade. Retrospective electronic medical record (EMR) data has shown a lack of adherence to the standard of care that includes less than thirty percent supplemental oxygen administration at various points in high-risk airway fire procedures (Jones, et al., 2019). Wide variability in airway fire risk reduction strategies during ENT cases at Pennsylvania Hospital has created a need for frameworks that improve anesthesia provider knowledge on this topic. Increased standardization of appropriate supplemental oxygen use and

administration among anesthesia providers has the potential to improve patient safety and reduce the likelihood of oxygen-related fire occurrences.

Available Knowledge

While airway fires are rare events, they result in devastating physical and emotional outcomes for patients as well as a major legal and economic burden on the healthcare system and surgical team. Recent reports indicate the incidence of fires in the operating room in the United States each year ranges from 217 to 650 events (Clarke & Bruley, 2012). The impact on a patient after an operating room airway fire may vary from painful and altering burns to face and neck or severe airway injuries resulting in permanent lung damage (Mehta et al., 2013). When an operating room fire occurs, all members of the surgical team including anesthesiologists, CRNAs, surgeons, nurses, and the hospital are impacted with at least some degree of negligence and culpability. An observational study from Connor et. al (2018) used medical legal analysis to highlight specific monetary incurrences of these situations, including a median financial payout of $120,000 for all cases. According to Mehta et al. (2013), closed claims data showed a payout in over seventy-five percent of these airway fire cases, with greater than $100,000 in payouts for each case. In particular, one case reported a $30 million settlement to a patient with severe injuries from an airway fire. These numbers support the idea that all members of the surgical team are at a heightened risk of developing consequential physical, emotional, legal, and economic backlash following airway fires in the operating room.

A review in ENT procedures exhibited an inspired oxygen delivery of more than thirty percent in ninety-seven percent of surgical fires in general anesthesia cases (Mehta et al., 2013). In studies conducted by Roy & Smith (2011), an oxygen concentration of thirty percent or greater can generate heat and provide a source of fuel for a fire. Even with a secure endotracheal

tube in place, use of a surgical laser can cause a penetration in an endotracheal tube and lead to airway fires in less than two seconds during instances of one-hundred percent oxygen delivery. Furthermore, there is often a lag time between reduction in oxygen content during inspiration, as well as expiration. In one study, it took up to five minutes to reduce both of these oxygen concentrations from sixty percent down to thirty percent (Jones et al., 2019). Jones et al. (2019) recommends, even in reinforced laser resistant endotracheal tubes, to use oxygen content less than thirty percent due to the risk of fire if damage or leaking occurs. Thus, it is safe to say anesthesiologists and CRNAs can significantly reduce the risk of surgical airway fires by maintaining the oxygen content as close to thirty percent as possible. Improving prevention strategies for airway fires will reduce healthcare costs and legal burden for providers while simultaneously harboring safer medical care for all surgical patients.

Rationale

The project team worked in collaboration with key members of the anesthesia and ENT departments at Pennsylvania Hospital to optimize airway fire risk mitigation strategies using the Failure Modes and Effects Analysis (FMEA) framework. Tenets of the FMEA model were accomplished, which included identifying key scenarios of the intended quality improvement process, identifying potential barriers that would contribute to failure modes, addressing elements that would prompt reevaluation due to failure effects, and development of ways to continually measure progress of the project (Institute for Healthcare Improvement, 2017). The quality improvement process was mapped, potential failure mode scenarios were identified, severity of each situation was determined, strategies on how to alleviate these challenges were ascertained, a method for evaluating results was developed, and means to evaluate the process as a whole were assessed. Upon utilization of this quality improvement model, it was concluded

that airway fire risk and its measurable associations related to supplemental oxygen administration would be best reformed through the assessment and improvement of provider knowledge. The potential positive impact of assessing and improving oxygen administration levels was deemed significant given the potential failure mode routes of this project. Discussions with team members at the institution determined that surveys and a video-based intervention would be the most efficient form of knowledge assessment and enhancement, taking into account departmental buy-in factors.

Specific Aims

The aim of this quality improvement project was to reduce the risk of airway fires, specifically during ENT procedures. Our primary objective was to demonstrate sustainable improvement of fraction of inspired oxygen concentration (FiO2) levels at various times during ENT procedures, exhibited as decreased FiO2 levels. Secondarily, we investigated change in provider knowledge pertaining to airway fires following an educational intervention. In order to accomplish this goal, retrospective chart data was compiled to determine the current use of oxygen concentration levels during surgical procedures. In addition, a survey was created with adaptations from ASA guidelines to assess baseline provider knowledge of airway fire risk (Caplan et al., 2013). See Appendix A for an example of the knowledge survey. Following initial survey dissemination, video-based presentations were administered to anesthesia providers on-site at Pennsylvania Hospital. These presentations provided information on best-practice techniques for airway fire prevention, including promoting the use of minimal necessary oxygen concentrations. Positive results of this intervention highlight the value in video-based education platforms in providing a safe operating room environment. This project may also serve as a

framework for other institutions to integrate evidence-based practices that may lead to an improved quality of care given to this patient population.

Methods

Context

Anesthesia department culture and climate has a major impact on the utilized techniques of anesthesia providers in various settings. The fact that airway fires do not occur often contributes to potentially systemic permissive approaches for safety measures for such events. If providers drift from best practices due to never witnessing a rare event, he or she may contribute to increasing the risks of an event such as an airway fire. In order to address this gap, all individuals should partake and engage in learning opportunities to foster knowledge about rare but devastating events. It is important in these situations to implement projects and strategies such as this quality improvement project. The posed strategies of this project serve to not only be effective in improving patient safety, but also elicit institutional and departmental collaboration. This project will require minimal day-to-day change from department providers, while also having a potentially profound impact on patient safety at Pennsylvania Hospital.

Interventions

The first stage of this project dealt with quantifying the problem at Pennsylvania Hospital. In conjunction with Penn Medicine's Data Analytic Center, data for FiO2 levels at various times during ENT procedures was gathered from retrospective chart reviews of Pennsylvania Hospital's electronic medical record. This was collected during one consecutive month from January 1, 2020 to January 31, 2020. Inclusion criteria for chart review consisted of elective ENT cases performed at Pennsylvania Hospital requiring electrocautery use. Examples of such cases include, but are not limited to thyroidectomy, parathyroidectomy, tracheostomy,

hemiglossectomy, and radical neck dissection. Following this chart review, a pre-intervention survey containing knowledge-based questions was adapted from a survey within an ASA practice advisory from February 2013 (Caplan et al., 2013). This anonymous, password protected, and question randomized survey was disseminated to anesthesia providers at the institution via the Qualtrics online survey platform. Surveying was conducted during a two-week period In October 2020 to determine an initial provider knowledge value. According to the data obtained from the retrospective chart review and pre-intervention surveys, it was determined that a gap existed in the knowledge of evidence-based practices associated with oxygen delivery.

A video-based intervention and presentation was then created utilizing the Vimeo online video software. This video was provided to members of the anesthesia department during staff meetings to provide insight and education regarding airway fire prevention for ENT cases. The most central component of this intervention was to emphasize the correlation of the literature suggesting minimization of supplemental oxygen administration, as well as the gold standard thirty percent oxygen threshold for airway fire risk reduction. The educational video was five minutes in length and was provided to the anesthesia staff members during normally scheduled weekly staff meetings for two consecutive weeks in the month of October 2020. Project team members were available in-person during personnel meetings to answer questions pertaining to the information in the presentation.

In order to assess the effectiveness of the intervention, two forms of evaluations were performed: one measuring provider knowledge change and another measuring provider practice change. The team disseminated a post-intervention survey containing knowledge-based questions identical to the pre-intervention survey. Similar to the first, all surveys were anonymous, password protected, and included randomized questions. The post-survey was disseminated in a

parallel fashion to the pre-survey to allow for the same pool of providers to participate in the study. This strategy ensured the outcome of the post-survey was indicative of knowledge generated directly from the project intervention. The post-intervention survey demonstrated initial improvement in knowledge of FiO2 administration and airway fire risk among anesthesia providers. In order to ascertain sustained improvement of knowledge, the research team completed a second chart review of ENT cases from October 15, 2020 to November 15, 2020. The goal of this second chart review was to assess for sustained improvement of oxygen administration relative to presentation information. The project student team leaders worked together in the extraction and recording of de-identified patient data regarding oxygen administration. All information was taken from anesthesia provider EMR documentation collected during each individual case.

Dipika Patel, Kendall Smith, and Scott Woodmansee who are Doctorate of Nursing Practice (DNP) students with a specialization in Nurse Anesthesiology at the University of Pennsylvania conducted the primary research and project development. Work for this project has been performed in conjunction with Dr. Dawn Bent; University of Pennsylvania School of Nursing faculty lead, and Colleen Wlostowski; Pennsylvania Hospital clinical site lead.

Study of the Interventions

This study used two approaches for assessing the impact of the interventions: the anesthesia provider outcome and the patient outcome. The provider outcome assessed survey scores pre-implementation compared to post-implementation survey scores. A positive change in survey scores post-implementation shows the provider improved on his or her knowledge based on the implementation of an educational presentation. The patient-centered outcomes were assessed via FiO2 levels in the chart reviews using the patient's EMR. The average weekly FiO2

levels from chart reviews were compared longitudinally between pre-implementation and post-implementation periods. Pre-implementation data was gathered from January 1, 2020 to January 31, 2020. Post-implementation data was gathered from October 16, 2020 to November 16, 2020.

Measures

The outcome measures assessed in this project are provider knowledge outcomes and patient outcomes. The provider knowledge measure was assessed based on the average score of pre-survey results compared to the average score of post-survey results. These survey scores directly correlate with the understanding of key knowledge concepts related to airway fire prevention and are simple to ascertain and analyze. The validity of the surveys pertains to the expectation that post-intervention survey scores will be higher than pre-intervention survey scores. This measure shows the survey scores assessing provider knowledge of airway fire risk as intended. The operational definition of the patient outcome measures is the average FiO2 at surgical timeout and procedure start time from the retrospective chart data, which was compared pre-intervention and post-intervention. The patient measures were defined by the actual oxygen level in the EMR. Oxygen levels range from 21% to 100% which was represented in interval/ratio level due to having actual values for this metric. Two groups were compared: pre-intervention oxygen level data and post-intervention oxygen level data.

There were no associations with third-party providers in this project. There were no additional costs associated with this project for any party involved.

Analysis

Analysis of project results assessed quantitative data. Due to the surveys being anonymous, data was unpaired which resulted in the use of descriptive statistics to summarize the provider knowledge outcomes related to pre-intervention and post-intervention survey

results. Measures of central tendency, such as mean and median, as well as dispersion and standard deviation characterized continuous variables. Frequency and percentage were used for categorical variables. Bar charts display average pre-intervention and post-intervention survey results. The x-axis on the bar chart represents the five questions asked on the survey. The y-axis represents the percentage of anesthesia providers who answered the question correctly for both the pre survey results and post survey results. The bar chart summarizes the difference between the two groups for each question. Separate bar charts were used to visualize whether FiO2 ever reached the desired threshold of thirty percent at any time during the surgical procedure.

Two separate run charts were used to highlight changes in average weekly percentage of oxygen administration over time. One chart represents FiO2 at surgical time-out, with another representing FiO2 at procedure start time. Mean levels of oxygen administration are plotted on the run chart representing surgical time-out utilizing a solid blue line. Mean levels of oxygen administration are plotted on the run chart representing procedure start time utilizing a solid red line. A solid yellow line indicates the median for both pre-intervention and post-intervention data, respectively. A dotted green line represents the gold standard thirty percent FiO2. Data was recorded in one-week intervals over the course of one month for both pre-implementation and post-implementation time periods. A red arrow indicates the period of implementation on both charts. Run chart signals such as non-random patterns in the data were assessed according to standard rules.

Ethical Considerations

This study did not encounter any conflicts or ethical issues regarding implementation. This project received Penn Institutional Review Board approval for a quality improvement project. Patient privacy was maintained, and no potential harm was done to patients.

Results

There was an improvement in *both* aims of this project with a visualized reduction in fraction of inspired oxygen concentration during surgical time-out and procedure start time by 3.4% and 4.9% respectively. There was a noted increase in average provider knowledge-based survey scores by 23% from the pre-intervention to post-intervention period.

A total of 32 pre-survey scores were collected to assess provider knowledge of preventing operating room airway fires, which elicited an average of 71.80% of correct response during the pre-intervention period. A total of 39 providers participated in the same survey post teaching intervention with an average of 95% of correct responses. See Appendix B for a detailed figure on provider survey scores. The breakdown of the five survey questions comparing the pre-intervention and post-intervention surveys proves as follows: the average number of providers that correctly responded to question 1 increased from 66.67% to 100%, question 2 increased from 17.95% to 90.8%, question 3 increased from 76.92% to 87.50% and question 4 increased from 97.44% to 100%. Question 5 was the only question that exhibited a decreased post-intervention score from 100% to 96.88%. This is possibly related to the clarity of the question. Additionally, due to anonymity of survey results, scores were not directly matched to specific providers between the two time periods.

Average FiO2 ranges from 21% - 100% and there was a larger drop in average FiO2 during procedure start compared to surgical time-out. The average weekly surgical time-out FiO2 level in the pre-intervention period was 49.80% compared to an average FiO2 of 46.40% in the post-intervention period. There were three weekly decreases in the average FiO2 administered to patients in weeks 1 from 51.08% to 39.26%, week 4 from 53.61% to 44.18%, and week 5 from 52.84% to 41.50%. On the contrary, the average FiO2 during surgical time-out

in week 2 increased from 48.11% to 55.14% and week 3 from 43.36% to 51.90%. This culminates to an average decrease of 3.4% FiO2 during surgical time-out in the post-intervention period. Procedure start time FiO2 levels were also reviewed for the exact same ENT cases to show a comparison of the FiO2 levels at two important times during a case. The average pre-intervention FiO2 level was 48.30% and post-intervention FiO2 level was an average of 43.40%. This results in a decrease of 4.9% in average FiO2 administered during procedure start in the post-implementation period. Similar to surgical time-out, the three weekly decreases in average amount of FiO2 administered were in week 1 from 46.08% to 38.53%, week 4 from 52.27% to 40.36%, and week 5 from 52.31% to 36.25%. See Appendix B for a detailed figure on FiO2 data.

At no point in the data collection period was an average FiO2 of 30% reached in either surgical time-out or procedure start time periods. A total of 95 ENT cases were screened in the pre-intervention period. Of these 95 cases, 47% of the cases reached the desired threshold of 30% FiO2 at *any* point of the case, whereas 53% of the cases did *not* reach the desired threshold of 30% at any point. Of the total 112 post-intervention ENT cases screened, 50% of the cases had the FiO2 reach a desired threshold of 30% at any point in the case, while 50% of the cases did not reach 30% at any point. This ultimately resulted in a 3% increase in the number of cases that reached a safe level of FiO2 in the post-implementation period compared to pre-implementation period.

Discussion

Summary

The initial goals for this project were to visualize a reduction in fraction of inspired oxygen concentration at different points in high-risk surgical cases, as well as elicit an increase in provider knowledge of airway fire risk reduction. Data highlighted in run charts exhibited a

decrease in average FiO2 at surgical time-out and procedure start time. The gold-standard safe level of FiO2 is thirty percent as indicated by current literature; data showed a continued tendency toward these FiO2 levels within the post-interventional data collection period. Descriptive statistics highlighted an increase in provider survey scores related to airway fire risk in the post-interventional period. Ultimately, this project took aim at increasing overall patient safety through decreased supplemental and unnecessary oxygen use, and this was achieved.

Interpretation

When compared to pre-interventional data, post-interventional FiO2 levels were decreased and continuing to trend toward gold-standard safe levels at both surgical time-out and procedure start times. Post-interventional data also personified a higher number of cases that actually reached the required thirty percent FiO2 at *any* point. Of note, there was a more precipitous drop in average FiO2 at procedure start time compared to surgical time-out. This correlation may be linked to one of the main interventional teaching points, which highlights the time requirement for FiO2 to drop to safe levels. Additionally, FiO2 did not average the gold-standard thirty percent at any point throughout the analysis, however the lowest point of average FiO2 occurred immediately post-implementation and ended with a downward tendency at the conclusion of data collection.

There were no costs incurred upon any party for this project, however funds allocated toward continuing education on the subject may help keep the trend moving toward safer levels of FiO2 and improved patient safety.

Limitations

Limitations for this project include the inherent potential for bias related to increased FiO2 use. For a plethora of reasons, individual patients may be unable to tolerate decreased FiO2

levels; various comorbidities may create a situation in which increased oxygen administration would outweigh the risk of airway fire and ultimately result in increased FiO2 during data collection. Further studies may be necessary to investigate patient comorbidities and how they correlate to FiO2 levels.

Internal validity issues may be associated with variability in specific providers for each case. It was noted during data collection that specific providers played a role in varying FiO2 levels during multiple ENT cases throughout one day. Individual provider habits related to FiO2 had potential to swing averages of the data. Anonymity of the survey results masked the ability to correlate survey scores to each provider's tendencies within the operating room setting. In order to minimalize limitations associated with these variabilities, strict inclusion criteria for case-type were maintained for data collection.

With data collection occurring in one-month periods, time constraints were placed on data collection and potential trends for FiO2 levels. Longer time periods for survey dissemination and chart reviews would have allowed for extrapolation and more concise data points.

Conclusions

In conclusion, increasing provider knowledge on the risk of airway fire is an efficient and cost-effective avenue for increasing patient safety with minimal to no downside. Educational information used in this project is stored online and be easily accessed and disseminated for future projects or continuing education on the subject. While early results are promising, there is still work to be done at Pennsylvania Hospital as current FiO2 levels remain above recommended values for patient safety.

Ongoing internal implementations can be made to improve compliance with evidence-based practice, such as tracking and sharing FiO2 levels for ENT cases on a monthly basis. This data may be disseminated to anesthesia providers with positive reinforcement affirmed for those that are compliant. On the other hand, allocated continuing education resources specifically for those that are not at certain thresholds within his or her own practice may prove beneficial.

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Appendix A

Provider Knowledge Survey

1. According to the most recent literature, what is the gold standard of FiO2% administration at the start of surgery during ENT cases?
   A. 40%
   B. 50%
   C. 30%
   D. 21%

2. What is the required time needed to reduce oxygen concentration from 60% to a safe level before use of an ignition source near the airway?
   A. 2 minutes
   B. 3 minutes
   C. 4 minutes
   D. 5 minutes

3. Anesthesia providers should participate with the entire operating room team in assessing the risk of an operating room fire during which perioperative checkpoint?
   A. Preoperatively
   B. During preoxygenation
   C. During surgical time-out
   D. Immediately following airway/oxygen placement

4. Oxygen levels should be kept as low as clinically feasible while the ignition source is in use and within proximity of the oxygen source.
   A. True
   B. False

5. The reduction of FiO2% does not need to be guided by monitoring patient oxygenation.
   A. True
   B. False

Appendix B

Figure B1

Provider Survey Results

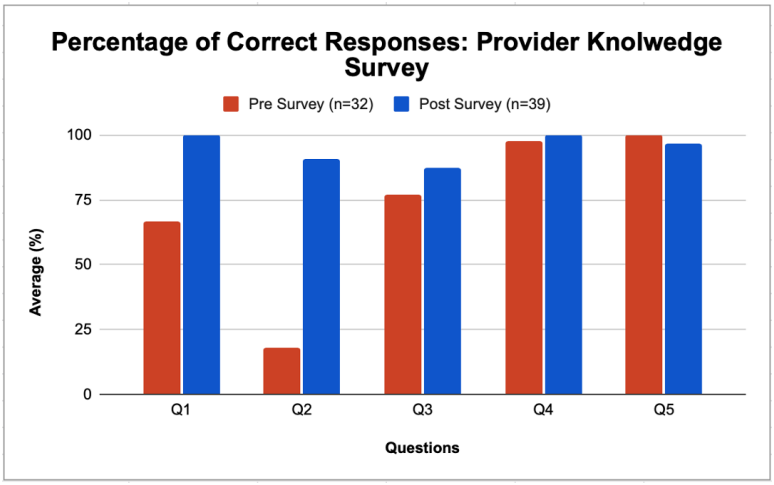
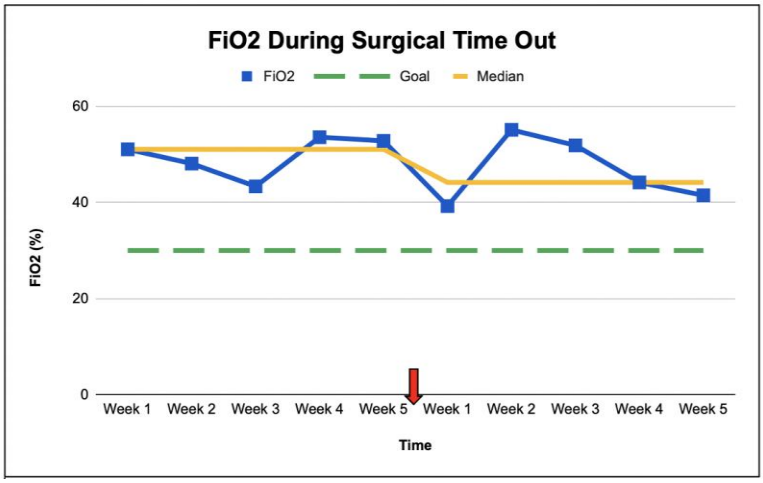


Figure B2

FiO2 Data at Various Procedure Times



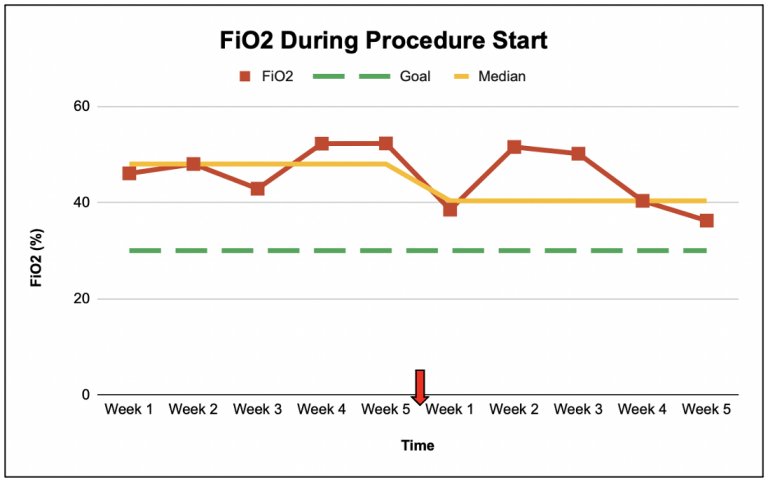


Figure B3

FiO2 Reaching 30% at Any Point