The Efficacy of a Midfacial Seal Drape in Reducing Oculofacial Surgical Field Fire Risk

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Purpose: To evaluate the efficacy of a midface seal drape in eliminating fire risk oxygen concentrations from nasal cannulated oxygen delivery compared with a standard open oculofacial surgical field.

Methods: Controlled experiment using the SimMan patient simulator and an oxygen detector. Oxygen concentrations were measured at 9 facial surgical locations with nasal cannula flow rates of 2, 4, and 6 l/min of 100% FiO_2 in both the draped and undraped conditions.

Results: The mean oxygen concentration in the oculofacial surgical field with the seal drape was 21.4% and 26.3% without (p = 0.0002; paired t test, 2-tailed). The draped condition provided safe oxygen concentration levels at all anatomical landmarks at all 3 flow rates, whereas the undraped condition was associated with suprathreshold oxygen concentration levels at 13 of 27 measurements. There was a direct correlation between oxygen flow rate and surgical field oxygen concentration in the undraped condition.

Conclusions: A midfacial seal drape reduced oxygen concentrations from nasal cannula oxygen in the oculofacial surgical field and may reduce fire risk.

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Operating room fires represent a preventable cause of morbidity and mortality. Although drastically underreported, the Food and Drug Administration and Emergency Care Research Institute (ECRI), an independent nonprofit health services research agency, estimate approximately 100 surgical fires annually, resulting in 20 cases of severe injury and 2 cases of mortality per year in the United States. Approximately 28% of those occur on the head and face. In the June 2003 report, the Joint Commission on Accreditation of Healthcare Organizations recommends that surgical centers include routine fire prevention education and precautions for staff members.[1] For fires to occur, 3 environmental conditions must be present simultaneously: an oxidizer (e.g., oxygen, nitrous oxide), ignition source (e.g., electrocautery, electrosurgery, laser), and fuel (e.g., alcohol-based prepping agents, aerosols, surgical gowns, drapes, towels, hoods, masks, hair, tissue). According to Joint Commission on Accreditation of Healthcare Organizations, electrosurgical/electrocautery equipment accounts for 68% of ignition sources in surgical fires, whereas lasers account for 13%. Oxygen is required for initiating combustion, sustaining, and accelerating fires. According to the International Electrotechnical Commission (1977) and Verband Deutscher Electrotechniker Commission 0750, a significant hazard for fire exists with a 26% or greater oxygen concentration. Reyes et al.[2] found that the minimum parameters for risk of combustion using an electrosurgical unit at a coagulation level of 30 W was an oxygen flow rate of 2 l/min and a distance of 5 cm from the oxygen source in the midline and 2 cm on either side of the midline.

Of all reported hospital fires, 74% have been identified as having an oxygen-enriched atmosphere as a significant contributing factor. Furthermore, fires in oxygen-enriched atmospheres burn hotter and more intensely than fires occurring in ambient air, thus increasing the potential harm to patients.[3] An oxygen-rich environment enables many materials to burn or sustain a fire that would normally not do so in ambient air, such as plastic facemasks and nasal cannulas, which are commonly placed only centimeters away from the surgical site in many plastic, head and neck, and ophthalmic procedures.[4] Furthermore, ignition of the flow of highly combustible oxygen itself can induce a highly dangerous blow torch effect from the nasal cannula. Minimizing supplemental oxygen use is one tactic to forestall these events; however, oxygen may be necessary in patients with poor cardiopulmonary reserve and even in healthy patients who are pharmacologically sedated. The ECRI recommends stopping supplemental oxygen at least 1 minute before and during the use of electrosurgical devices or lasers,[5] but this is often impractical in surgical settings where this equipment is used frequently and often in response to rapidly changing patient conditions, such as abrupt bleeding. Engel et al.[6] found that oxygen concentrations at and above the nose were statistically lower using a system that connects the ends of a nasal cannula to a nasopharyngeal tube. This system, although a significant improvement over standard nasal cannula devices, may be limited due to a lack of a seal. Egress of oxygen from the nares and mouth into the surgical field may pose persistent fire risks. In addition, the tubing placed deep into the nares may be uncomfortable and limits air exchange.

Oculofacial surgery is often performed with nasal cannulated oxygen very near electrocautery or laser, therefore fire is a serious concern. The best methods to prevent fire in the oculofacial surgery setting may not be clear. There are no studies to date that relate oxygen concentration and fire risk to surgical draping technique. We hypothesize that a midfacial seal drape may reduce surgical field oxygen concentration that may improve fire safety.

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METHODS

Experiments were conducted at the University of California, Irvine School of Medicine Anesthesiology Simulation Center; 100% FiO_2 was delivered to a supine mechanical full body patient simulator mannequin (SimMan) via standard nasal cannula with 2 curved prongs inserted into the external nares. The mannequin had a fixed respiration rate of 12 breaths per minute and a tidal volume of 500 cm^3/breath. After allowing 5 minutes for equilibration between each measurement, atmospheric oxygen concentrations were recorded at 9 facial landmarks (Fig. 1) using a Datex Ohemed Aisys Carestation (GE) anesthesia unit for 5 minutes continuously for oxygen flow rates of 2, 4, and 6 l/min. The oxygen sensor was oriented parallel to the floor and pointed perpendicular to the presumed direction of oxygen flow. A range and average oxygen concentration were recorded.

Subsequently, the identical measurements were repeated with a 45 cm × 30 cm 3M 1000 Steri-Drape surgical drape with an adhesive side seal across the bridge of the nose and midface covering the nasal cannula and along the malar eminence to the angle of the mandible. The drape was modified with a 3-cm slit venting aperture over the mouth (Fig. 2). The caudal edge of the slit was tented up to allow vented oxygen to egress away from the surgical field. The rest of the drape was placed as flat as possible against the mannequin.

Data from draped and undraped conditions were compared for each nasal cannula flow setting. For landmarks covered by the drape, measurements were recorded above (atmospheric side) and below (patient side) of the drape. A paired *t* test was used to compare the oxygen concentrations between the draped and undraped conditions. Twenty-six percentage of oxygen concentration was considered threshold for fire risk. The study adhered to the principles of the Declaration of Helsinki and the authors have been Health Insurance Portability and Accountability Act compliant.

RESULTS

The difference in the mean oxygen concentration between the draped and undraped conditions was statistically significant. The mean oxygen concentration in the undraped condition was 26.3% with a standard deviation of 4.148, whereas the draped condition (for all locations on the surgical field side of the drape) had a mean of 21.4% with a standard deviation of 0.804 (2-tailed $p = 0.0002$). All locations on the atmospheric side of the drape had oxygen concentrations of 21.0%. The mean oxygen concentration below the drape was 52.9% with a standard deviation of 26.062. The draped condition provided safe oxygen concentration levels at all anatomical landmarks

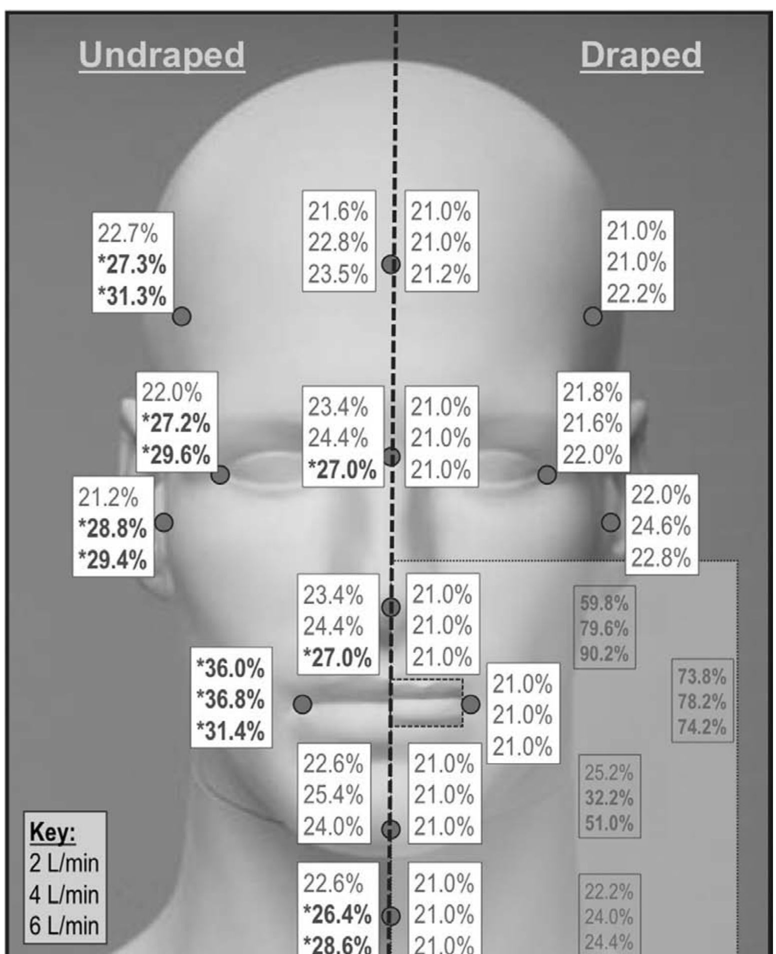

FIG. 1. Oxygen concentrations without drape (**left**) and with modified rectangular midfacial seal drape (**right**) with nasal cannula 100% FiO_2. Readings shown in the draped area represent oxygen concentrations underneath the drape. All readings were 21% on the atmospheric side of the drape. Concentrations above threshold (26%) are given in bold, and concentrations above threshold and caudal to the seal are denoted by an asterisk.

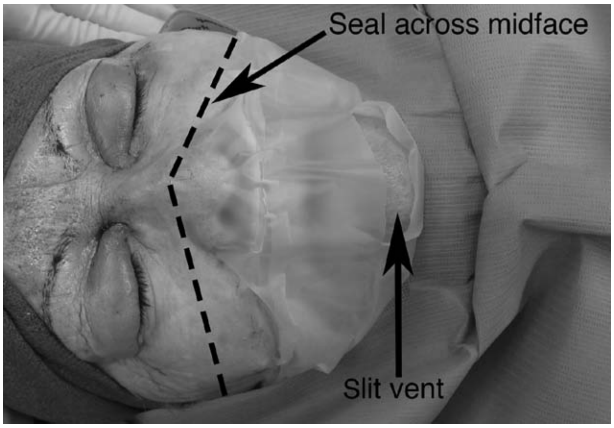

FIG. 2. Midfacial seal drape with slit vent aperture over the mouth and tented to achieve rostral oxygen egress away from the oculofacial field. The rest of the drape is flattened against the patient to minimize oxygen pooling.

at all 3 flow rates, whereas the undraped condition was associated with suprathreshold oxygen concentration levels at 13 of 27 total measurements.

In the undraped condition and at a flow rate of 2 l/min, most locations (8 of 9) exhibited subthreshold oxygen concentrations. At this low (2 l/min) flow rate, the corner of the mouth was the lone above-threshold reading and was 36% oxygen. As the flow rate increased, more facial sites exceeded the 26% oxygen concentration critical threshold. Undraped and at 4 l/min, 5 of 9 locations exhibited above-threshold oxygen levels (corner of the mouth, hyoid bone, tragus, outer canthus, and temple). At 6 l/min, the only 2 locations (tip of the chin and the center of the forehead) were below threshold.

The anatomical landmarks located along the facial midline were fairly well protected from high oxygen concentrations and only breached threshold levels at the highest cannula flow rate. Sites lateral and cranial to the nasal cannula were more affected by supplemental oxygen, even at lower flow rates.

In the draped condition, the area over the hyoid bone and all locations cranial to the drape maintained subthreshold oxygen levels for all cannula flow rates. Beneath the drape (patient side), the tip of the chin remained below threshold at 2 l/min but increased to above threshold for 4 and 6 l/min. The tip of the nose and the corner of the mouth (also covered by the drape) had above-threshold oxygen levels for all flow rates.

DISCUSSION

A modified rectangular midfacial seal drape reduced oxygen concentration and eliminated suprathreshold oxygen concentrations in the oculofacial surgical field in a simulated surgery mannequin model. The improved oxygen environment may confer improvement in operating room fire safety, but there are several important considerations.

Our data without a midfacial seal drape corroborate previous reports that nasal cannulated oxygen presents an important fire hazard during oculofacial surgery and suggests validity of our model. In general, oxygen concentrations may become dangerous (greater than 26%) at facial landmarks close to the nasal cannula or at flow rates above 4 l/min.[7] Importantly, the corner of the mouth had oxygen levels above threshold even at the lowest (2 l/min) flow rate. At higher flow rates (4 l/min and above), high-risk concentrations may be at the tragus, lateral canthus, and temple. Anatomical landmarks along the midline (forehead, bridge of nose, tip of nose, and chin) were relatively protected from suprathreshold levels of oxygen. Even with a maximal flow rate of 6 l/min, the bridge and tip of the nose only reached oxygen concentrations of 27%, just barely above threshold. Lateral and more cranial anatomical landmarks may be at greater risk due to gas flow dynamics at the central midface, in around the nose. The nares seem to capture oxygen otherwise directed toward the midline with egress predominately laterally. As oxygen is heavier than air, pooling at dependent sites closer to the ground could further explain accumulation at the lateral face that is lower than the midline in the supine position, as described by Orhan-Sungur et al.[7] In further support of this theory, we found that the hyoid bone had higher levels of oxygen than the chin for flow rates of 4 and 6 l/min. Understanding oxygen flow dynamics and accumulation due to pooling are important in preventing fires.

Repeating the experiments with our midface seal drape eliminated all the aforementioned suprathreshold oxygen concentrations in the simulated surgical field. Translating these findings to clinical practice in live humans undergoing oculofacial surgery depends on the validity of the mannequin model.

Indeed, the chief limitation of the study may be some differences between our simulations and live human oculofacial surgery. The airtight seal of the 3M 1000 Steri-Drape may be more robust on the rubber polymer mannequin compared with skin. Skin prep solutions, skin secretions, and head movement may all further compromise the tight seal. In addition to head and neck movement, breathing patterns may differ from our static mannequin model.

Formal experiments in human subjects would be beneficial, but the use of this drape technique in human patients in more than 35 years of combined operating room practice by the senior authors (JPT and WN) provides several insights. No fires have occurred in thousands of surgical cases, and excellent adherence to skin occurs when the drape is carefully seated across a clean and dry midface. Skin oils, sebum, and prep solution jeopardize the seal and must be removed. In our experience, meticulous drape placement and attention to drape adherence across the entire midface after thorough cleaning and skin preparation and allowing the skin to fully dry achieves a leak-free system in live human subjects.

Claustrophobia or a sense of difficulty breathing under the drape may be a problem in some patients. In the senior authors' experience, this is rare and usually related to a slit vent that is too small or not placed over the airway to allow free air exchange or a sense of it. These observations could be validated by more formal assessment.

In addition to improving comfort, the slit vent is important to limit oxygen pooling under the drape. Our experiments, not surprisingly, demonstrate significantly increased oxygen levels at landmarks near the cannula underneath the drape (tip of nose and corner of mouth). Additional areas, such as the lower neck and thorax, may harbor pooled oxygen, but these were not evaluated.

Pooling of oxygen underneath the drape may represent an additional fire hazard if ignited.[8] Yet, oxygen pooling under the seal drape or elsewhere at the neck or chest may be less relevant according to the premise that spark from the surgical field is the usual ignition source. The authors believe the drape forms an adequate barrier to these usual ignition sources (spark from electrocautery and laser), but further investigation may be warranted. Nevertheless, reducing the potential space under the drape, maintaining a barrier between igniting sources, and ensuring no other ignition sources are under the drape are all important.

Ultimately, our sealed drape technique may offer a layer of fire safety in a system that is also comfortable, simple, and allows free nasal air exchange—advantages over the extended modified nasal prong system that Engel et al.[6] describe. The drape may also be more practical than coordinating the use of electrocautery or laser with turning off supplemental oxygen that a patient may need and that may not even adequately equilibrate with the air. Yet, draping and nasal cannula configurations are not the only considerations in preventing an operating room fire. Fire safety includes using of as many fire-retardant materials as possible, minimizing pooling of skin preparatory solutions, allowing complete drying of these solutions, understanding the parameters that predispose to combustion, and above all, vigilance.

In conclusion, in an undraped condition, the areas of the head and neck at greatest risk for fire in an oculofacial surgical procedure with nasal cannulated oxygen may be the corner of the mouth, tragus, temple, lateral canthus, and hyoid. The risk seems to increase with higher oxygen flow rates. A vented, rectangular midfacial seal drape may reduce these fire risk oxygen levels in the oculofacial surgical field. This draping technique may minimize the risk of intraoperative fire during oculofacial procedures.

REFERENCES

1. JCAHO's new sentinel event alert 'raises bar' for preventing OR fires. *OR Manager*. 2003;19:1, 7.
2. Reyes RJ, Smith AA, Mascaro JR, et al. Supplemental oxygen: ensuring its safe delivery during facial surgery. *Plast Reconstr Surg* 1995;95:924–8.
3. Daane SP, Toth BA. Fire in the operating room: principles and prevention. *Plast Reconstr Surg* 2005;115:73e–5e.
4. Yardley IE, Donaldson LJ. Surgical fires, a clear and present danger. *Surgeon* 2010;8:87–92.
5. A clinician's guide to surgical fires. How they occur, how to prevent them, how to put them out. *Health Devices* 2003;32:5–24.
6. Engel SJ, Patel NK, Morrison CM, et al. Operating room fires: part II. Optimizing safety. *Plast Reconstr Surg* 2012;130:681–9.
7. Orhan-Sungur M, Komatsu R, Sherman A, et al. Effect of nasal cannula oxygen administration on oxygen concentration at facial and adjacent landmarks. *Anaesthesia* 2009;64:521–6.
8. Rinder CS. Fire safety in the operating room. *Curr Opin Anaesthesiol* 2008;21:790–5.