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NEWSLETTER
THE OFFICIAL JOURNAL OF THE ANESTHESIA PATIENT SAFETY FOUNDATION

CITATION: Bruley MD, Feldman J. Assessing fire risk in surgery: why limit open oxygen delivery to 30%? *APSF Newsletter.* 2025:22–23.

Assessing Fire Risk in Surgery: Why Limit Open Oxygen Delivery to 30%?

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Surgical fires continue to cause preventable morbidity and mortality despite educational efforts and well-established recommendations for eliminating the risk.[1-6] Many medical societies and regulatory bodies recommend limiting open oxygen delivery to 30%. These include the American Society of Anesthesiologists, the American College of Surgeons, the Society of American Gastrointestinal and Endoscopic Surgeons, the Association of periOperative Registered Nurses, the Joint Commission, the Emergency Care Research Institute (ECRI), the Food and Drug Administration, and the Pennsylvania Patient Safety Authority.

The root cause of the overwhelming majority of serious fires is administration of oxygen via an open delivery source, i.e., disposable facemask or nasal cannula. For this reason, the key recommendations for preventing fires are

1. Limit the delivered oxygen concentration connected to the open delivery device to 30% or less
2. Control the airway if a greater concentration of oxygen is clinically indicated.

Procedures around the head, neck, and upper chest are considered high-risk for fire and intravenous sedation is often sufficient to achieve patient comfort. Oxygen is commonly delivered during sedation via an open source to "keep the patient safe." In the case of a surgical fire, oxygen becomes the root cause of patient harm rather than improving safety. Since administering oxygen can be useful for ensuring adequate oxygenation, in procedures at high risk for fire it is important to question how much oxygen can be administered to ensure patient safety without increasing the fire risk. The following information reviews the rationale for the recommendation to limit oxygen concentrations by open delivery to 30% or less. The rationale is based upon work at ECRI (www.ecri.org) by Mark Bruley and others investigating surgical fires over several decades.[7]

In the early days of surgical fire investigation, ECRI performed laboratory testing of the flammability of surgical drapes in the presence of oxygen at concentrations of 21% (room air) and 80%.[8] Other authors have done similar testing.[9-12] While there are no data specifically testing the flammability of surgical drapes and other materials in the presence of 30% oxygen, observations from testing at higher concentrations provided useful guidance.

A video depicting surface fiber flame propagation was created by the Royal Air Force (RAF) Institute of Aviation Medicine investigating enriched oxygen fires in aircraft.

Video available: https://www.sages.org/video/fire-in-the-or-cause-and-prevention/.

The one-minute RAF video segment begins at time code 2:43. The video segment is from research and testing by the RAF Institute of Aviation Medicine. Denison D, Ernsting J, and Cresswell AW. The Fire Risks to Man of Oxygen-Rich Gas Environments. Royal Air Force (RAF) Institute of Aviation Medicine, Farnborough, England. RAF Institute of Aviation Medicine Reports 320 (April 1965) and 343 (Sept. 1965).

The 30% recommendation was derived over time from surgical fire accident investigations by ECRI in the late 1970s. During investigation testing, "surface fiber flame propagation" was observed to occur *in vitro* on cotton surgical towel fibers and human hair in the presence of oxygen concentrations of 50% and greater.[7,9] This phenomenon involves the rapid spread of fire from the inciting source. In other words, the enriched oxygen concentration creates flammable conditions that otherwise would not exist (apsf.org/ORFire30). Testing revealed that when oxygen concentration was reduced below 50%, down to about 45%, flame propagation was not as likely. **It is the oxygen-enriched atmosphere enhanced propagation that creates the two-fold risk of easier ignition of materials and subsequent very rapid spread of flames outward from the point of ignition.** When supplemental oxygen was discontinued, tests found that oxygen concentrations under drapes quickly dropped to below 30% and fire propagation was not observed.[7]

Discussions and collaborations with anesthesia professionals about the laboratory results subsequently focused around what would be an acceptable reduced delivered oxygen concentration via an open source (mask or nasal cannula). Fortunately, reliable pulse oximeters were introduced coincident with developing recommendations for preventing surgical fires in the late 1980s. The 30% recommendation was promoted as safe, knowing that pulse oximeter monitoring could be used to continuously estimate the resulting blood oxygenation and surface fiber flame propagation was unlikely to occur.

Current recommendations for preventing fires clearly describe that no more than 30% oxygen be delivered by an open source and that the airway be managed using a supraglottic airway or endotracheal tube if a greater concentration of oxygen is required to keep the patient safe.[1,3,4,6,8,9] Most patients have normal lung function, and, therefore, 30% oxygen should be sufficient to prevent hypoxemia if spontaneous ventilation is maintained and airway obstruction managed. Previous recommendations to reduce the delivered oxygen concentration prior to activating a potential ignition source (e.g., electrosurgical probe, electrocautery probe, or surgical laser) do not seem advisable if the patient is sedated to the point that a greater oxygen concentration is required to prevent hypoxemia. Therefore, controlling the airway when an oxygen concentration of greater than 30% is required becomes an important part of the fire prevention strategy.

Many anesthetizing locations only provide a source of 100% oxygen for open delivery devices. While it is possible to use the anesthesia machine to deliver a reduced oxygen concentration during sedation, incorporating an

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Oxygen Concentrations Should Be Limited to 30% or Less to Minimize Surgical Fires in High-Risk Patients

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Figure 1: Oxygen blender device for titration of oxygen concentration. Photo courtesy of Fisher Paykel Healthcare.

oxygen blender (Figure 1) into the anesthesia workspace for the open delivery devices will facilitate safe practice.

In summary, laboratory testing has shown that common materials in the surgical field become flammable and can rapidly propagate fire when oxygen is delivered by open source at concentrations of 50% or more. During procedures at high risk for fire, the oxygen concentration delivered using an open source should be limited to 30% or less.

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Mr. Bruley has no conflicts of interest. Dr. Feldman is a consultant for Medtronic and Micropore and Becton-Dickinson.

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Additional information on fire prevention including educational videos can be found at https://www.apsf.org/videos/preventing-surgical-fires/.