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Surgical Fires: Decreasing Incidence Relies on Continued Prevention Efforts

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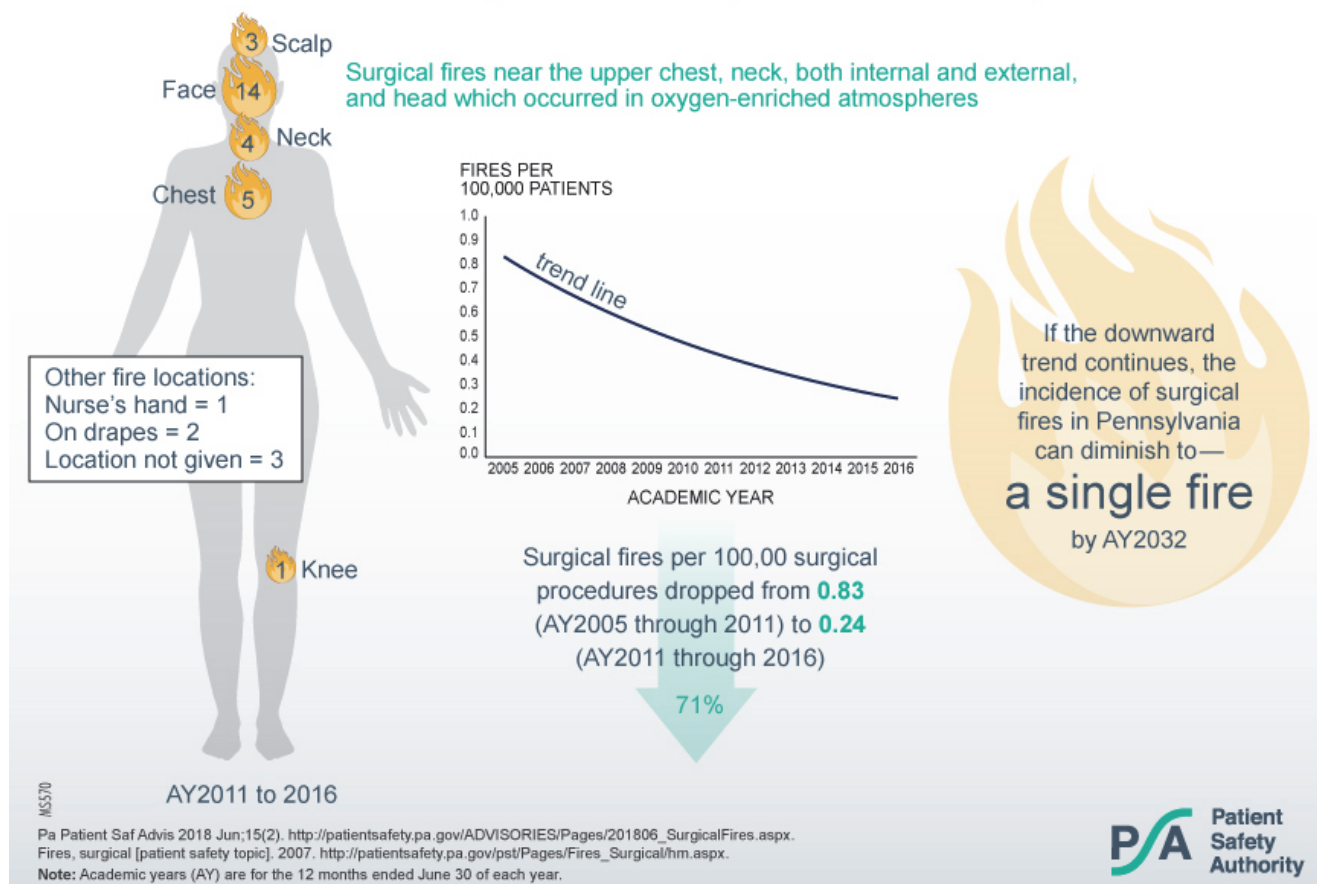
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Abstract

Incidence of Surgical Fires Improves in Pennsylvania



Fires on the operating field, although preventable and declining in number, continue to be a hazard to patients and providers. The Pennsylvania Patient Safety Authority has updated its 2012 analysis of surgical fires reported through the Pennsylvania Patient Safety Reporting System. Using the same analytical criteria, analysts identified reports of fires submitted over the subsequent five years that occurred in the operating room (OR) on the sterile operating field and involved flaming combustion resulting from a combination of heat, oxygen, and fuel. Twenty-eight events that met the analysts' definition of fires on the operating field were reported from July 2011 through June 2016, equating to 5.6 fires per year in Pennsylvania. That incidence is down from the 10 fires per year found in the 2012 analysis and represents a 44.0% reduction since 2011. Since 2004, the rate of surgical fires varied from 0.83 per 100,000 OR procedures in the academic year 2005 (AY2005; July 2004 through June 2005) to 0.24 per 100,000 OR procedures in AY2016. This represents a statistically significant ($p < 0.001$) reduction in the patient risk of surgical fires of 71% since 2004. In this updated analysis, one-half of the reported events indicated some degree of harm to the patient. The operative sites of the head, neck, and upper chest constituted about two-thirds of the locations that were mentioned; oxygen-enriched atmospheres continue to be a major contributing factor to these incidents. Surgical fires with devastating consequences remain a significant risk. Facilities should consider using the Fire Risk Assessment Score and adhere to the recommendations of the American Society of Anesthesiologists Task Force on Operating Room Fires, the Anesthesia Patient Safety Foundation, and those of ECRI Institute.

Introduction

Surgical fires are rare events that should never happen, but do, despite established preventive measures and continuing educational initiatives. Devastating patient injuries including death have been reported.^{1,2} Surgical fires are dangerous not only to the patient, but to operating room (OR) team members, as well. In 2012, the Pennsylvania Patient Safety Authority published an analysis of surgical fires reported through its database³ for the primary purpose of determining whether surgical fires continued to be a problem, as identified by the Joint Commission⁴ or had responded to advisories on prevention, such as those promulgated by the American Society of Anesthesiologists,⁵ the Anesthesia Patient Safety Foundation,⁶ and ECRI Institute⁷. This updated analysis of events reported through the Authority's database sought to determine whether the incidence of surgical fires changed in the years after the 2012 publication.

Methods

For this updated analysis, a panel of patient safety analysts identified surgical fires reported to the Authority between July 1, 2011, and June 30, 2016. Using the same analytical criteria as in the prior study, 937 potential reports of interest were identified using the following key terms: fire, flam*, ignit*, extinguish*, burn*, spark*, singe*, singi*, ignit*, dous*, smok* and flash. Reports were excluded during the search if they contained the following terms: brush burn, flashing, eye burn, inflammatory debris, c/o burn, candle burn, cigar, betadine, outlet, be flashed, denies*burn, match, autoclave, cool, evapor, iodine, chemical, cig*rette, tape burn, smoker, flash ster, stapl, sparkle, and did not fire. The wildcard (*) allows variations (e.g., flam* could include flame, flames, flaming, or flamed).

A report was classified as a surgical fire if it—

- Occurred on the operating field or in the patient's airway, and
- Caused combustion of surgical or anatomic substance

The operating field is defined as the surgical operative site within the drape/towel fenestration and includes the sterile field surrounding and above the drapes.

The analysts reviewed each narrative and excluded 909 reports based on the following circumstances:

- Heat-related injuries caused by direct contact with a heat source, such as electrosurgical active electrodes (e.g., Bovie units), lasers, fiberoptic light cord, surgical lights, hot water, hot instruments
- Normal arcing from electrosurgical active electrodes between tip and tissue without secondary ignition of a substance
- Arcing or ignition of the insulation of electrosurgical active electrodes without secondary ignition of a substance
- Reports of smoke without evidence of combustion
- Heat-related melting without evidence of combustion
- Fires off the operating field (e.g., equipment fires not in direct contact with the patient)
- Fires as a cause of the patient's presenting medical condition (e.g., the patient was burned in a house fire or industrial accident, and was then admitted for treatment)

To calculate the rates at which fires occurred, analysts obtained the number of patients undergoing OR procedures and the number of procedures done in Pennsylvania hospital ORs and ambulatory surgical facilities from the Pennsylvania Health Care Cost Containment Council (PHC4).^{*} As with the methodology for the previous publication, "2 patients undergoing an OR procedure" could include two unique patients having one procedure each, or one patient having two procedures, typically on separate days, during this period. Reliable numbers of patients undergoing OR procedures were available from July 1, 2004, through June 30, 2016. It is possible for one patient to have more than one OR procedure at a time. Reliable numbers of OR procedures were available from July 1, 2007 (when a change in reporting processes became effective), through June 30, 2016. Using the same methodology as in the 2012 publication, the rate of fires per surgical patient and the rate of fires per OR procedure were calculated by academic year (e.g., AY2005 includes data from July 2004 through June 2005), and the results from both studies were aggregated.

For statistical analysis of the trend in surgical fires in Pennsylvania, analysts fit the data to an exponential decay model using the `nl` command in Stata (StataCorp LLC, College Station, TX). This curvilinear model is more realistic than a linear model, because the decay model makes it impossible for the rates to go below zero.

The analysts also recognized the vulnerability of any statistical regression to the data at the endpoints (AY 2005 and AY2016), because outliers at those points could produce misleading results. To address this vulnerability, the analysts performed a sensitivity analysis by doing a second nonlinear regression after removing the two years at the ends. If this latter analysis were also significant, this would give confidence that the original model was not being driven by the endpoints.

^{*} The Pennsylvania Health Care Cost Containment Council (PHC4) is an independent state agency responsible for addressing the problem of escalating health costs, ensuring the quality of health care, and increasing access to health care for all citizens regardless of ability to pay. PHC4 has provided data to this entity in an effort to further PHC4's mission of educating the public and containing health care costs in Pennsylvania.

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This analysis was not prepared by PHC4. This analysis was done by the Pennsylvania Patient Safety Authority. PHC4, its agents and staff, bear no responsibility or liability for the results of the analysis, which are solely the opinion of this entity.

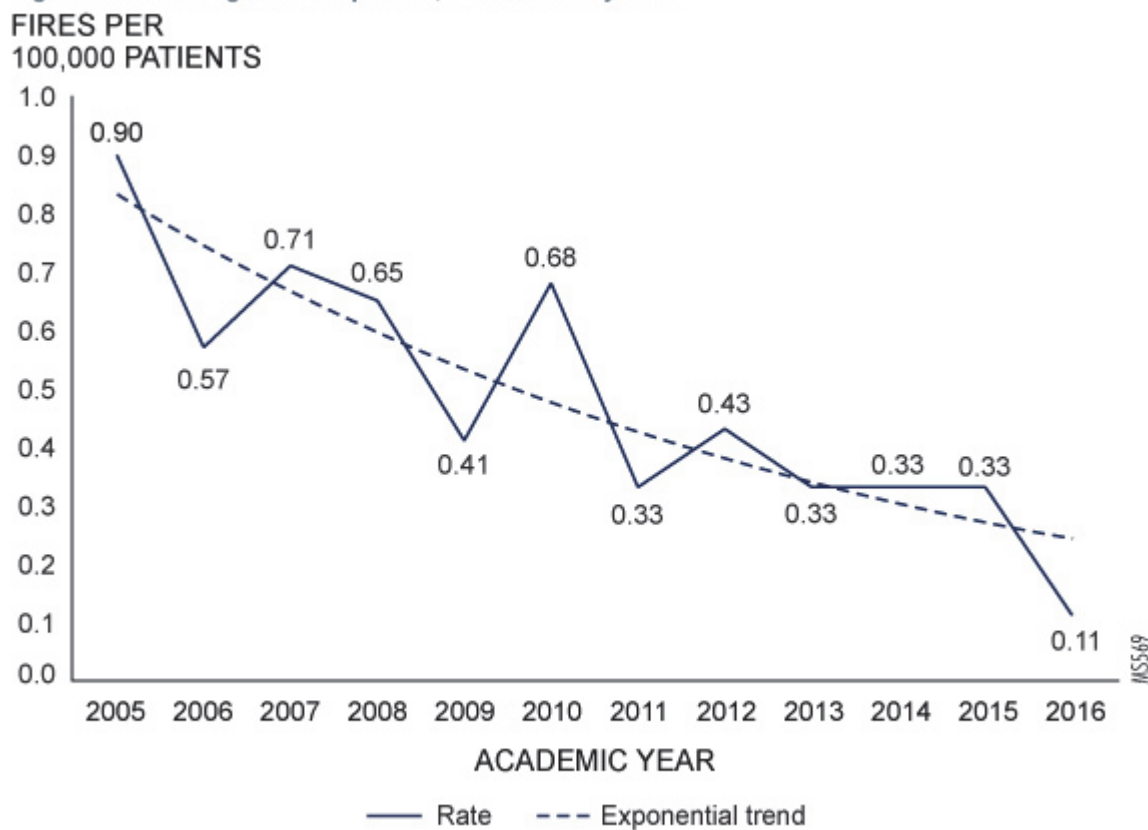
Results

The following numbers were found in the five years from July 1, 2011, through June 30, 2016:

- 28 reports met the analysts' definition of fires on the operating field
- 9,213,796 patients were reported to have undergone OR procedures
- 9,486,042 OR procedures were performed

The Figure shows the rate of surgical fires per 100,000 patients from AY2005 through AY2016. The data and the plot clearly suggest a reduction over time. This was confirmed by our statistical model of exponential decay. The reduction was statistically significant ($p < 0.001$). The model equation was $y = 0.927957 * \exp(-0.11203 * x)$ where y is the rate of fires per 100,000 patients and x is the time period, by AY.

Figure. Rate of Surgical Fires per 100,000 Patients by Year



Note: Academic years are for the 12 months ended June 30 of each year.

The plot suggests a relatively high rate in AY2005 but also a relatively low rate in AY2016, and these two endpoints could be very influential in the model. After removing these endpoints, a second analysis demonstrated that the downward trend was still statistically significant [$p = 0.021$, with a model equation of $y = 0.8017 * \exp(-0.0845 * x)$]. Thus, the statistical significance of the original analysis was not driven by the endpoints.

The model suggests a 71% decrease in the patient risk of surgical fires from AY2005 through AY2016, from a rate of 0.83 to 0.24 fires per 100,000 OR procedures; or from 1 fire per 120,500 OR procedures to 1 per 416,700 OR procedures. The analysts also note that in AY2005, there was about one surgical fire per month in Pennsylvania, and, if the downward trend continues, the rate will be only one surgical fire per year in AY2032 (as extrapolated from the exponential model based on AY2005 to AY2016).

Analysts also performed analyses using the number of OR procedures for the denominator instead of numbers of surgical patients; the results were nearly identical. The Figure and Table 1 present only the data based upon the number of surgical patients.

Table 1. Rates of Fires per 100,000 Patients Undergoing Operating Room Procedures

Academic Year*	Number of Surgical Fires†	Number of Patients‡	Rate of Surgical Fires per 100,000 Patients
2005	14	1,549,082	0.90

2006	9	1,572,611	0.57
2007	11	1,555,186	0.71
2008	11	1,683,170	0.65
2009	7	1,727,387	0.41
2010	12	1,757,928	0.68
2011	6	1,805,835	0.33
2012	8	1,874,589	0.43
2013	6	1,836,821	0.33
2014	6	1,837,449	0.33
2015	6	1,830,543	0.33
2016	2	1,834,394	0.11

* Academic year is July through June (e.g., July 2004 through June 2005).

† Surgical fires reported to the Pennsylvania Patient Safety Authority.

‡ Data obtained from the Pennsylvania Health Care Cost Containment Council.

Patient harm was reported in 15 reports (54%) and no harm to patients or staff was reported in the remaining 13 (46%) of the 28 reports.

The source of ignition was identified in 26 reports: an electrosurgical unit (e.g., "Bovie") in 22 reports (79% of 28 reports), a battery-powered cautery unit in two reports (7%), and a laser in two reports (7%). Two reports did not mention the ignition source.

The role of oxygen was mentioned in 14 reports (50%). Nitrous oxide was not mentioned as an oxidizing agent in any reports.

The materials that caught fire are listed in Table 2 along with the number of reports related to that burned material. Multiple materials were noted in some reports.

Table 2. Materials, Medications, and Ointments that Caught Fire

Item	Number of Reports
Hair, eyebrows, or beard	7
Sponge	6
Drape or towel	5
Eyelashes only	4
Flammable skin-barrier ointment	3
Alcohol-based skin prep	2
Endotracheal tube or bronchoscope	2

Adhesive	1
Bone cement	1
Electrosurgical active cable	1
Glove	1
Petroleum ether	1

Note: As reported to the Pennsylvania Patient Safety Authority, July 2011 through June 2016.

The location of the fire was noted in 25 reports, with 4 noting more than one site. Sites on the surface of the patient's body were mentioned in 14 reports, internal sites were mentioned in 6 reports, bone cement in 1 report, a fire on a nurse's hands in 1 report, and there were 2 reports of fires on the drapes where the location was unspecified (see Table 3). Of the surface and internal patient sites mentioned, 18 were located in the head or neck areas.

Table 3. Location of Surgical Fires as Reported to the Pennsylvania Patient Safety Authority

Anatomic Location		Number of Mentions	
External	Scalp (temporal region)	3	
	Face (n = 13)	Face and chin	4
		Eyelid	4
		Eyebrow	2
		Eyelashes	3
		Neck (n = 2)	Neck
	Tracheal stoma		1
	Chest	2	
Internal	Oropharynx	1	
	Trachea	2	
	Chest cavity (surgical sponges)	3	
Other	Knee incision (bone cement)	1	
	Nurse's hand	1	
	On drapes (unspecified)	2	
	Location not given	3	

Methods to extinguish fires, when mentioned, primarily involved rapidly removing the burning material, turning off delivered oxygen, and/or dowsing the burning area with sterile water or saline.

Discussion

Analysis indicates a statistically significant decrease in the rate of surgical fires per 100,000 patients from AY2005 through AY2016. The authors believe that this encouraging decline has been due to Authority efforts aligned with recent initiatives by a variety of medical professional societies and healthcare organizations.⁴⁻⁹

The principal factor contributing to surgical fires has historically been the use of open oxygen supplied at 100% concentration from an anesthesia machine or wall oxygen outlet to a disposable mask or nasal cannula on the face during surgery of the head, neck, and upper chest with monitored anesthesia care. Fires in 20 of the 28 relevant reports (80%) in this study were located in these areas, although only 7 of the reports noted open oxygen delivery (e.g., via nasal cannula or mask). Three events involved oxygen enrichment from oxygen leaking from an exposed lung during a thoracotomy.

Other studies have indicated that oxygen-enriched atmospheres contribute to about 70% of surgical fires.⁷ With 50% of the 28 reports in this analysis involving oxygen enrichment, clinical review of the need to use open oxygen is still indicated on an individual patient basis. Recommendations for such individual patient review are readily available.^{5-7,9,10}

Response to a Surgical Fire

Surgical fires are preventable, but if a fire occurs, the surgeon and other surgical team members can immediately remove burning materials from the patient and extinguish the fire with an aqueous solution or a wet sponge or towel. Burning materials that have been removed from the patient can then be extinguished by other team members, if needed, with an aqueous solution, or in extreme cases, with a carbon dioxide fire extinguisher. A summary of actions to extinguish fires burning either on the patient or in the airway is available from ECRI Institute.¹¹

Prevention of Surgical Fires

Three elements are necessary for a fire: a heat source, oxygen, and a fuel. The surgeon is usually in control of the heat source, most commonly an electrosurgical unit, and can remove it from the field. The anesthesia professional is usually in control of the supplemental oxygen source and can minimize the oxidizer component of the fire triangle. The scrub technician can help ensure meticulous application of alcohol-containing skin prepping solutions and confirm that they are dry before the application of surgical towels and drapes.

More prudent than a coordinated team response to a surgical fire specifically would be to avoid the risk, such as by not incising the oxygen-filled trachea with an electrosurgical unit in the first place.⁷ A coordinated approach to surgical fire prevention and response, plus effective perioperative communication by the surgical team, is important to eliminate fire hazards and to minimize the time until a fire is extinguished.^{4-7,9-14}

On a broader scale for prevention, the Christiana Care Health System in Wilmington, Delaware, has developed a concise Fire Risk Assessment Score to identify operations at increased risks for surgical fires.⁹ The score assesses the presence of three elements.

Christiana Fire Risk Assessment Score (one point each):

- Surgery above the xiphoid
- Open oxygen source
- Available ignition source (e.g., electrosurgery, laser, fiberoptic light cord)

A score of 3 points indicates a high risk for a surgical fire. A score of 2 indicates a low risk with potential for conversion to high risk. A score of 1 indicates low risk. The Fire Risk Assessment Score can easily be included in either the WHO Surgical Safety Checklist preoperative briefing or the Universal Protocol time-out.

When an operation is assessed as being at high risk for a surgical fire, risk mitigation can decrease the risk. ECRI Institute has summarized mitigation strategies related to surgery of the head, face, neck, and upper chest, and for oropharyngeal procedures, bronchoscopic surgery, and tracheostomy.¹⁰

The American Society of Anesthesiologists Task Force on Operating Room Fires and the Anesthesia Patient Safety Foundation have determined that the most important practice for managing the risk of a surgical fire is to minimize the use of supplemental oxygen to the level needed for adequate arterial oxygen saturation and to minimize the free flow of supplemental oxygen through a controlled airway, such as an endotracheal tube or laryngeal mask.^{5,6}

There are defined exceptions where supplemental oxygen delivery may be required via an open source on the face, such as when a patient needs to speak during the surgery. For such cases, starting with an administered concentration of oxygen at 30% and using occlusive draping techniques can minimize the risks of dangerously high concentrations of oxygen being trapped under the drapes.^{7,10}

Electrosurgical active electrodes should be activated only when the tip is visible to the surgeon and should be holstered or removed from the sterile field when not in active use. Bipolar electrodes could also be used in conditions of high oxygen concentration at the target tissue.^{7,10}

Moistening sponges before use can minimize the risk of setting a sponge on fire. A dry sponge can be ignited easily, especially in the presence of an oxygen-enriched atmosphere, whereas a moist sponge resists ignition.^{5-7,10} Water or saline for dousing a fire should also be available on the surgical field. A 5-pound carbon dioxide fire extinguisher should be available in the OR.^{5-7,10,12}

The decreasing incidence of surgical fires in Pennsylvania hospital ORs and ambulatory surgical facilities should be considered within the context of other initiatives to prevent surgical fires, which include the following:

- 2003: Joint Commission Sentinel Event Alert on Preventing Surgical Fires⁴
- 2005 (extended through 2009): Joint Commission Patient Safety Goal for Ambulatory Surgery¹⁵
- 2006: Christiana Care Health System "Surgical Fire Risk Assessment"⁹
- 2006 and 2014: Association of periOperative Registered Nurses (AORN) "Fire Safety Tool Kit"¹⁶
- 2009: ECRI Institute's comprehensive "New Clinical Guide to Surgical Fire Prevention"⁷
- 2010: Anesthesia Patient Safety Foundation fire safety video⁶
- 2012 to 2013: American Society of Anesthesiologists "Practice Advisory for the Prevention and Management of Operating Room Fires"⁵
- 2011 to 2015: U.S. Food and Drug Administration "Preventing Surgical Fires Initiative"⁸

Limitations of this study include potential variability in the completeness of reporting, despite the requirements of Pennsylvania's Medical Care and Reduction of Error (MCARE) Act of 2002. The identification and interpretation of reports are based on the content of free-text narratives, which include nonstandardized content. As with the 2012 analysis, surgical fires without harm may have been reported as infrastructure failures.

Recommendations in this article for prevention of surgical fires are not intended as standards, guidelines, or absolute requirements. Adoption, modification, or rejection of the recommendations may be considered based on clinical assessment of individual patient needs; and recommendations are not presented with the intent of replacing local institutional policies.

The sensitivity of surgical, anesthesia, and OR nursing staff members to surgical fire hazards has waned since the use of flammable anesthetic agents ceased in the late 1970s.¹⁴ However, it is encouraging that during the past 10 to 15 years, there has been a resurgence in awareness of this continuing risk, as well as increased understanding of the need for a team approach to surgical fire prevention.

Conclusion

Although on the decline, surgical fires remain a significant patient safety hazard. As can be observed from the Pennsylvania event reports, most fires are associated with the use of electrosurgical active electrodes around the head and neck in the presence of supplemental oxygen flow. OR personnel should consider the use of a Fire Risk Assessment Score process^{9,13} and adhere to the recommendations of the Anesthesia Patient Safety Foundation⁶ and the American Society of Anesthesiologists Task Force on Operating Room Fires^{4,7} in their ongoing efforts to prevent surgical fires.

A summary list of resources for surgical fire prevention and education is provided after the notes.

Acknowledgments

We appreciate the thoughtful editing support from Julia Barndt and Eloise DeHaan.

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Supplemental Material

Resources for Surgical Fire Prevention and Education

Anesthesia Patient Safety Foundation (APSF). Free educational video and *Supplemental Information* (released April 2010). The 18-minute video is available online (as well as a free DVD) at www.apsf.org/resources_video.php (http://www.apsf.org/resources_video.php)

APSF Prevention Algorithm 2012. Surgical fire injuries continue to occur: prevention may require more cautious use of oxygen. *APSF Newsletter Winter 2012*; 26(3):42-3. http://issuu.com/enews/docs/winter_2012/1 (http://issuu.com/enews/docs/winter_2012/1)

Association of periOperative Registered Nurses (AORN) Fire Safety Toolkit. Tools to promote fire prevention, plan effective response strategies, and develop department-specific evidence-based policies and protocols: <https://test.aorn.org/guidelines/clinical-resources/tool-kits/fire-safety-tool-kit> (<https://test.aorn.org/guidelines/clinical-resources/tool-kits/fire-safety-tool-kit>)

Christiana Hospital. Surgical fire risk assessment tools: www.christianacare.org/FireRiskAssessment (<http://www.christianacare.org/FireRiskAssessment>)

ECRI Institute. Free surgical fire prevention educational posters having the most current recommendations, a large bibliography, and recommendations on appropriate fire extinguishers for the OR and other references. www.ecri.org/surgical_fires (http://www.ecri.org/surgical_fires).

Pennsylvania Patient Safety Authority. A collection of articles and resources about incidence in Pennsylvania and prevention strategies: http://patientsafety.pa.gov/pst/Pages/Fires_Surgical/hm.aspx ([/pst/Pages/Fires_Surgical/hm.aspx](http://patientsafety.pa.gov/pst/Pages/Fires_Surgical/hm.aspx)).

SurgicalFire.org. An online resource for information on surgical fires from the family of an affected patient. www.surgicalfire.org (<http://www.surgicalfire.org/>)

U.S. Food and Drug Administration (FDA). *Preventing Surgical Fires Initiative.* Begun in Oct 2011, the initiative brought together numerous stakeholders in surgical fire prevention and education. Since 2015, the FDA initiative leadership has been taken over by The Joint Commission and The Council on Surgical and Perioperative Safety. www.cspsteam.org/7-fire-safety/ (<http://www.cspsteam.org/7-fire-safety/>)



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