



Surgical fire: principles, risk factors, and prevention

Paulo Renato de Paula^{1,2,3,4,5} • Fabiano Calixto Fortes de Arruda^{3,6,7,8} • Marcelo Prado^{3,6,9} • Carlos Gustavo Neves^{3,6,9}

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A surgical fire is potentially devastating for a patient and the best way to avoid its complications is through prevention. Although fires in the operating rooms (ORs) are rare events, they can quickly cause serious injury, disfigurement, and be fatal [1–4].

According to the Emergency Care Research Institute (ECRI), facial surgery is the second most common site of fire (tonsil is the first), and facial surgeons should be aware of potential risks of fire and explosions and how to manage injuries caused by them [5, 6].

This problem is of a similar order of magnitude as wrong-site surgery [7], and it is estimated that patients are harmed by 20% of the 550 to 700 operating room fires that are reported each year with more than 500 cases unreported or near misses [8–15], ranking as number 3 on the list of technology-related hazards in the hospital [16–18].

A US study found 17 to 20% of anesthetic malpractice claims are related to burns from surgical fires [19, 20].

Many will be minor fires causing no harm, but some may include major burns, inhalation injuries, infection, and others. It is estimated that of the surgical fires that occur, 20–30 patients are disabling or disfiguring each year in the USA and 1 or 2 are fatal [21–27]. Related adverse outcomes may include psychological trauma, prolonged hospitalization, delay or cancellation of surgery, additional hospital resource utilization, and liability [28–32].

The fire triangle (or “fire triad”) has become the standard for diagramming the three necessary components for combustion. The triangle includes a *heat or ignition source*, an *oxidizer*, and a *fuel source* [33–36] (Fig. 1).

The surgeon’s, anesthesiologist’s, and nurse’s knowledge of the fire triad is the most important part of burns prevention in every surgical procedure [3, 4, 7, 10, 13, 22, 36–41].

As a heat or ignition source, an electrosurgical unit provides the ignition required for the fire to start in 70 to 90% of all surgical fires [42–46]. The surgeon should use the lowest possible power and there should be a safe distance from the heat and oxygen source [46].

Each element of the “fire triad” is essential for a fire to occur but the concentration of the oxidizer (oxygen or nitrous oxide) can also have a great importance on the fuel component of the triad [13, 19, 37]. It is unusual for a surgical fire to occur in the absence of an oxygen enriched environment [47–50]. It can happen within closed or semi-closed breathing systems, including an open oxygen sources (e.g., masks, nasal cannula) [48–51].

Oxygen supplementation via nasal cannula or oxygen mask works like the oxidizer in this exothermic reaction, which was responsible for a high oxygen concentration in the microenvironment beneath the drape’s “tent” over the patient’s nose [52–57]. Another way to reduce this concentration is to reduce the oxygen supply from 100 to 24% and O₂ supply beneath 3 l/min as a way to establish an environmental concentration (FIO₂) below 30% or less, a concentration where there are no reports of this issue [38, 58].

✉ Paulo Renato de Paula
p-renato@uol.com.br

¹ Plastic Surgery Unit, Federal University of Goiás, Rua T-50, Numero. 540, Setor Bueno, Goiania, Goiás 74215-200, Brazil

² Internship Program in Plastic Surgery, Teaching Hospital, Medical School, Federal University of Goiás, Goiania, Goiás 74215-200, Brazil

³ Sociedade Brasileira de Cirurgia Plástica, São Paulo, Brazil

⁴ American Society of Plastic Surgeons, Arlington Heights, USA

⁵ International Society of Aesthetic Plastic Surgery, Hanover, USA

⁶ Residency Program in Plastic Surgery, Federal University of Goiás, Goiania, Goiás, Brazil

⁷ Burn Unit Care, Hospital de Urgencias Governador Otavio Lage de Siqueira (HUGOL), Goiania, Goiás, Brazil

⁸ American Society for Aesthetic Plastic Surgery, Garden Grove, USA

⁹ Health Sciences, Federal University of Goiás, Goiania, Goiás, Brazil

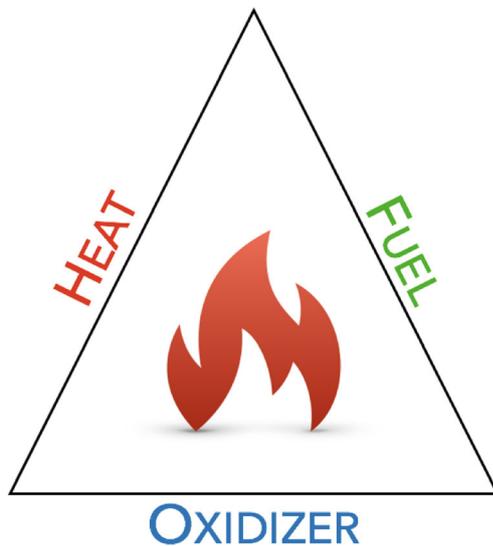


Fig. 1 The three elements representing the fire triangle

If the surgical site is close to the oxygen catheter, it is recommended to interrupt the oxygen flow and wait at least 60 s before using the electrocautery [38, 52, 58, 59].

The best choice to reduce or even prevent fire is changing the nasal cannula for a rubber nasopharyngeal tube with the cut ends of the nasal cannula passed through the tube to provide a high flow of oxygen to the nasopharynx or even an 8-French feeding tube [53, 54, 58, 59].

The fuel is the most controversial one, but a very important component. The source of fuel can be: airway supplies, surgical drapes, gauze, sponges, cotton compress, papers, plastic mask, “lint” from surgical towels, head, facial (including eyelashes) and body hair, flammable and combustible chemicals (tinctures, solvents), eye lubricant, mattresses, foam padding and clothing, plastic supplies, and wrapping materials. All of them were proposed as possible fuels in this fire, but the most common fuel to this kind of fire is an antiseptic solution such as one that is alcohol-based (e.g., povidone and chlorhexidine). They are potential fire hazards [60–68] and can initiate combustion even in a 20% concentration [67, 68].

There are many ways to control fuel source (specifically alcohol bases) and its imperative that the surgeons adopt such measures [62, 64–67] (Table 1).

Almost all surgical fires can be minimized or preventable when the operating room team understands the interactions among the sides of the classic fire triangle, bearing primary responsibility for controlling them, such as: ignition source = surgeon; oxidizing agent = anesthesiologist; fuel = circulating nurse [9, 68–71].

The lack of education among interns, residents, nurses and the negligence of some anesthesiologists and surgeons may be responsible for the failure to eliminate or at least reduce this type of accident [72–75]. Nearly two in three

Table 1 Preventing operating room fires from fuel source

1. Use nonalcoholic-based skin preparations if possible;
2. If not, avoid excessive use of alcohol-based substances in the surgical field (“pooling”);
3. If an alcohol-based antiseptic is used, this should be cleaned with a dry swab before the diathermy is used;
4. Wait at least 10 min to begin surgery, time to allow total evaporation of the product;
5. Keep the drapes open so that the residual alcohol will not vaporize in a closed space and become a hazard;
6. Caution in the use of flammable substances mainly in facial surgery, where oxygen is perilously close to the surgical field;
7. The use of an aspiration or exhaust system located under the surgical drapes can strongly minimize the risk of combustion
8. Keep all gauze sponges wet with saline; avoid “tenting” of surgical drapes that would allow accumulation of oxygen;
9. A fuel-oxidizer combination should be avoided in or near the surgical field;
10. Do not use alcohol-based solutions to prepare the scalp when the head has not been shaved.

newly qualified doctors had never heard about surgical fires [74, 76]. As such, surgical fire education should be part of all undergraduate medical, nursing and other allied health professional education [72–81].

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References

1. Akhtar N, Ansar F, Baig MS, Abbas A (2016) Airway fires during surgery: management and prevention. *J Anaesthesiol Clin Pharmacol* 32(1):109–111
2. Niskanen M, Purhonen S, Koljonen V, Ronkainen A, Hirvonen E (2007) Fatal inhalation injury caused by airway fire during tracheostomy. *Acta Anaesthesiol Scand* 51(4):509–513
3. Roy S, Smith LP (2011) What does it take to start an oropharyngeal fire? Oxygen requirements to start fires in the operating room. *Int J Pediatr Otorhinolaryngol* 275(2):227–230
4. Meneghetti SC, Morgan MM, Fritz J, Borkowski RG, Djohan R, Zins JE (2007) Operating room fires: optimizing safety. *Plast Reconstr Surg* 120(6):1701–1708

5. ECRI Institute (2006) Surgical fire safety. *Health Devices* 35(2): 45–66
6. ECRI Institute (2009) New clinical guidance for surgical fire prevention. *Health Devices* 38(10):314–332
7. Bourdon L (2014) Determining the potential fire risk for each patient AORN, 2014 available at: [https://doi.org/10.1016/S0001-2092\(14\)00989-2](https://doi.org/10.1016/S0001-2092(14)00989-2) September 29, 2014
8. Lowry RK, Noone RB (2001) Fires and burns during plastic surgery. *Ann Plast Surg* 46(1):72–79
9. Hart SR, Yajnik A, Ashford J, Springer R, Harvey S (2011) Operating room fire safety. *Ochsner J* 11(1):37–42
10. Maamari RN, Custer PL (2017) Operating room fires in oculoplastic surgery. *Ophthal Plast Reconstr Surg* available at: <https://doi.org/10.1097/IOP.0000000000000885>, March 3, 2017
11. Sheinbein DS, Loeb (2010) Laser surgery and fire hazards in ear, nose, and throat surgeries. *Anesthesiol Clin* 28(3):485–496
12. VanCleave AM, Jones JE, McGlothlin JD, Saxen MA, Sanders BJ, Walker LA (2014) Factors involved in dental surgery fires: a review of the literature. *Anesth Prog* 61(1):21–25
13. Barker SJ, Polson JS (2001) Fire in the operating room: a case report and laboratory study. *Anesth Analg* 93(4):960–965
14. Stouffer DJ (1992) Fires during surgery: two fatal incidents in Los Angeles. *J Burn Care Rehabil* 13(1):114–117
15. Joint commission on accreditation of healthcare organizations (2003). Sentinel Event Alert Issue 29:1 Available at: www.jcaho.org/aboutus/newsletters/sentineleventalert?print/sea_29.htm June 24, 2003
16. ECRI Institute (2012) Top 10 technology hazards. *Health Device* 41(11):22–23
17. Top ten technology hazards for 2010. Available at: https://www.ecri.org/Documents/Top_10_Health_Technology_Hazards.pdf December 2, 2009
18. Rinder CS (2008) Fire safety in the operating room. *Anesthesiology* 21(6):790–795
19. Yardley LE, Donaldson LJ (2010) Review surgical fires, a clear and present danger. *Surgeon* 8(2):87–92
20. Metha SP, Bhananker SM, Posner KL, Domino KB (2013) Operating room fires: a closed claims analysis. *Anesthesiology* 118(5):1133–1139
21. American College of Surgeons. Committee on perioperative care. Fires in the operating room. Available at: <http://www.facs.org/> December 2016
22. Bisinotto FMB, Dezena RA, Martins LB, Galvão MC, Sobrinho JM, Calçado MS (2017) Queimaduras relacionadas à eletrocirurgia - Relato de dois casos. *Rev Bras Anestesiol* 67(5):527–534
23. Haddad R, Pereira A, Lima CE, Ferreira TD, D'Império F, Reis MCM, Haber G, Pires AMDP (2006) Fogo em via aérea durante traqueostomia cervical eletiva. *Pulmão* 15(1):52–54
24. Podnos YA, Williams RA (2002) Operating room fires. *Probl Gen Surg* 19(2):1–4
25. Daane SP, Toth BA (2005) Fire in the operating room: principles and prevention. *Plast Reconstr Surg* 115(5):73–75
26. Podnos YD, Williams RA (1997) Fires in the operating room. American College of Surgeons, Committee of Perioperative Care. *Bull Am Coll Surg* 82(8):3–4
27. Stewart MW, Bartley GB (2015) Fires in the operating room: prepare and prevent. *Ophthalmology* 122(3):445–447
28. Chang BW, Petty P, Manson PN (1994) Patient fire safety in the operating room. *Plast Reconstr Surg* 93(3):519–521
29. Bhananker SM, Posner KL, Cheney FW, Caplan RA, Lee LA, Domino KB (2006) Injury and liability associated with monitored anesthesia care. A closed claims analysis. *Anesthesiology* 104(2): 228–234
30. Choudhry AJ, Haddad NN, Khasawneh MA, Cullinane DC, Zielinski MD (2017) Surgical fires and operative burns: lessons learned from a 33-year review of medical litigation. *Am J Surg* 213(3):558–564
31. Wolf GL, Sidebotham GW, Lazard JLP et al (2004) Laser ignition of surgical drape materials in air, 50% oxygen and 95% oxygen. *Anesthesiology*
32. Apfelbaum JL, Caplan RA, Barker SJ, Connis RT, Cowles C, Ehrenwerth J (2013) Practice advisory for the prevention and management of operating room fires: an updated report by the American Society of Anesthesiologists Task Force on operating room fires. *Anesthesiology* 118(2):271–290
33. Emergency Care Research Institute (ECRI) (2003) A clinician's guide to surgical fires: how they occur, how to prevent them, how to put them out. *Health Devices* 32:176
34. Poore SO, Sillah NM, Mahajan AY, Gutowski KA (2012) Patient safety in the operating room: I. Preoperative. *Plast Reconstr Surg* 130(5):1038–1047
35. Machado G, Lee FDI, Polido G, Mélega JM (2001) Explosão em face durante blefaroplastia. *Rev Bras Cir Plast* 26(3):52
36. Prasad R, Quezado Z, Andre AS, O'Grady NP (2006) Fires in the operating room and intensive care unit: awareness is the key to prevention. *Anesth Analg* 102(1):172–174
37. Ehrenwerth J, Seifert HA (2003) Fire safety in the operating room. *ASA* 31:25–33
38. Poore SO, Sillah NM, Mahajan AY, Gutowski KA (2012) Patient safety in the operating room: II. Intraoperative and postoperative. *Plast Reconstr Surg* 130(5):1048–1058
39. Rosenfield LK, Chang DS (2009) The error of omission: a simple checklist approach for improving operating room safety. *Plast Reconstr Surg* 123(1):399–402
40. Paige JT, Aaron DL, Yang T, Howell DS, Chauvin SW (2009) Improved operating room teamwork via SAFETY prep: a rural community hospital's experience. *World J Surg* 33(6):1181–1187
41. Pollock GS (2004) Eliminating surgical fires: a team approach. *AANA J* 72(4):293–298
42. Wald D, Michelow BJ, Guyuron B, Gibb AA (1998) Fire hazards and laser resurfacing. *Plast Reconstr Surg* 101(1):185–188
43. Rohrich RJ, Gyimesi IM, Clark P (1997) CO₂ laser safety considerations in facial skin resurfacing. *Plast Reconstr Surg* 100(5): 1285–1290
44. Eggleston JL, Von Maltzahn WW (2000) In: Bronzino JD (ed) *Electrosurgical devices. The biomedical engineering hand book*, 2nd edn. CRC Press LLC, Boca Raton
45. Williams DM, Littwin S, Patterson AJ, Brock-Ut JG (2006) Fiberoptic light source induced surgical fires: the contribution of forced air warming blankets. *Acta Anesthesiol Scand* 50(4):505–508
46. Trindade MRM, Grazziotin RU (1998) Eletrocirurgia: Sistemas mono e bipolar em cirurgia videolaparoscópica. *Acta Cir Bras* 13(3):194–203
47. Greco RJ, Gonzalez R, Johnson P, Scoliere M, Rekhopf PG, Heckler F (1995) Potential dangers of oxygen supplementation during facial surgery. *Plast Reconstr Surg* 95(6):978–984
48. Reyes RJ, Smith AA, Mascaro JR, Windle BH (1995) Supplemental oxygen: ensuring its safe delivery during facial surgery. *Plast Reconstr Surg* 95(5):924–928
49. Gini GM, Casagrande W (2006) Misfortune during blepharoplasty. *Plast Reconstr Surg* 117(1):325–326
50. Huddleston S, Hamadani S, Phillips ME, Fleming JC (2013) Fire risk during ophthalmic plastic surgery. *Ophthalmology* 120(6): 1309–1309.e1
51. Almeida CED, Curi EF, Brezinski R, Freitas RC (2012) Fire in the surgical center. *Rev Bras Anestesiol* 62(3):432–438
52. Wolf GL, Sidebotham GW, Lazard JLP, Charchafli JG (2004) Laser ignition of surgical drape materials in air, 50% oxygen and 95% oxygen. *Anesthesiology* 100(5):1167–1171

53. Wolf GL, Simpson JI (1987) Flammability of endotracheal tubes in oxygen and nitrous oxide enriched atmosphere. *Anesthesiology* 67: 236–241
54. Orhan-Sungur M, Komatsu R, Sherman A, Jones L, Walsh D, Sessler DI (2009) Effect of nasal cannula oxygen administration on oxygen concentration at facial and marks. *Anaesthesia* 64: 521–526
55. Connor MA, Menke AM, Vrcek I, Shore JW (2017) Operating room fires in periocular surgery. *Int Ophthalmol* Available at: <https://doi.org/10.1007/s10792-017-0564-9> May 20, 2017
56. Aston SJ, Bornstein A (1978) An unusual complication of blepharoplasty. *Aesth Plast Surg* 2:451–453
57. Culp WC Jr, Kimbrough BA, Luna S (2013) Flammability of surgical drapes and materials in varying concentrations of oxygen. *Anesthesiology* 10(119):770–776
58. Lampotang S, Gravenstein N, Paulus DA, Gravenstein D (2005) Reducing the incidence of surgical fires: supplying nasal cannulae with sub-100% O₂ gas mixtures from anesthesia machines. *Anesth Analg* 101(5):1407–1412
59. Prado A, Andrades P, Fuentes P (2007) Fire in the operating room after reading a CME. *Plast Reconstr Surg* 19(2):770–773
60. Goldberg J (2006) Brief laboratory report: surgical drape flammability. *AANA J* 74(5):352–354
61. Patterson P (1990) UCLA fire: fire department makes recommendation for class I drapes. *OR Manager* 6(11):4–5
62. Arefiev K, Warycha M, Whiting D, Alam M (2012) Flammability of topical preparations and surgical dressings in cutaneous and laser surgery: a controlled simulation study. *J Am Acad Dermatol* 67(4): 700–705
63. Meltzer HS, Granville R, Aryan HA, Billman G, Bennett R, Levy ML (2005) Gel-based surgical preparation resulting in an operating room fire during a neurosurgical procedure. *J Neurosurg* 102(3): 347–349
64. Briscoe CE, Hill DW, Payne JP (1976) Inflammable antiseptics and theatre fires. *Br J Surg* 63(12):981–983
65. Batra S, Gupta R (2008) Alcohol based surgical prep solution and the risk of fire in the operating room: a case report. <https://doi.org/10.1186/1754-9493-2-10> April 26, 2008
66. Bonnet A, Devienne M, De Broucker V, Duquennoy-Martinot V, Guerreschi P (2015) Operating room fire: should we mistrust alcoholic antiseptics? *Ann Chir Plast Esthet* 60(4):255–261
67. Jones EL, Overbey DM, Chapman BC, Jones TS, Hilton SA, Moore JT, Tobinson TN (2017) Operating room fires and surgical skin preparation. *J Am Coll Surg* 225(1):160–165
68. American Society of Anesthesiologists Task Force on Operating Room Fires, Caplan RA, Barker SJ, Connis RT, Cowles C, Park D, Richemond AL, Ehrenwerth J, Nickinovich DG, Pritchard D, Roberson D, Wolf GL (2008) Practice advisory for the prevention and management of operating room fires. *Anesthesiology* 108(5): 786–801
69. Bruley ME (2004) Surgical fires: perioperative communication is essential to prevent this rare but devastating complication. *Qual Saf Health Care* 13(6):467–471
70. Haynes AB, Weiser TG, Berry WR, Lipsitz SR, Breizat A-HS, Dellinger EP (2009) A surgical safety checklist to reduce morbidity and mortality in a global population. *N Engl J Med* 360(5):491–499
71. Pollock H (2009) Operating room fires. *Plast Reconstr Surg* 123(1): 431 *author reply* 431–432
72. Mullen L, Byrd D (2013) Using simulation training to improve perioperative patient safety. *AORN J* 97(4):419–427
73. Erseck RA (2008) Flash fires during facial surgery. *Plast Reconstr Surg* 121(1):346–346; *author reply* 347
74. Sosis MB (2006) Anesthesiologists must do a better job of preventing operating room fires. *J Clin Anesth* 18(2):81–82
75. Sudhindra TV, Joseph A, Hacking CJ, Haray PN (2000) Are surgeons aware of the dangers of diathermy? *Ann R Coll Surg Engl* 82(1):31–32
76. Lypson ML, Stephens S, Colletti L (2005) Preventing surgical fires: who needs to be educated? *Jt Comm J Qual Patient Saf* 31(9):522–527
77. Eichhorn JH (2013) Review article: practical current issues in perioperative patient safety. *Can J Anaesth* 60(2):111–118
78. Spruce L (2016) Back to basis: preventing surgical fires. *AORN* 104(3):217–224
79. Association of periOperative Registered Nurses (2005) AORN guidance statement: fire prevention in the operating room. *AORN J* 81(5):1067–1075
80. Engel SC, Patel NK, Morrison CM, Rotemberg SC, Fritz J, Nutter B, Zins JE (2012) Operating room fires: part II. Optimizing safety. *Plast Reconstr Surg* 130(3):681–689
81. Roy S, Smith LP (2015) Prevention of airway fires: testing the safety of endotracheal tubes and surgical devices in a mechanical model. *Am J Otolaryngol* 36(1):63–66