Fire and Burn Hazards in Minimally Invasive Surgery

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The Joint Commission (TJC) is an independent, not-for-profit organization that drives quality improvements and oversees patient safety in healthcare. In April 2023, in its Quick Safety Issue 69, TJC highlighted a critical, underrecognized hazard in minimally invasive surgery (MIS): the risk of operating room fires and patient burns due to light-source and fiber-optic cable use. Since 2019, more than 50% of the fire/burn incidents reported to TJC occurred during surgical procedures; 15% were linked directly to the tools designed to illuminate these life-saving surgeries. "Even momentary proximity between an illuminated laparoscopic, thoracoscopic or arthroscopic light cable and a surgical drape," TJC notes, "can cause a full thickness burn to the patient's skin." As these burns don't typically produce smoking or charring, they often go unnoticed by the surgery team.

Illuminating the Risk at Hand

Minimally invasive surgery depends upon an endoscope, a camera, and a surgical monitor for indirect visualization of the surgical field. A light box and a power box connect to the camera by a fiber-optic cable and power cable, respectively. A full 80% of light transmitted via fiber-optic cables gets released as thermal energy.[1] In turn, illumination of the surgical field requires the use of a high-intensity light source and creates the potential for fires and patient burns.

Our research at the Computational Fire Dynamics (CFD) Lab at Case Western Reserve University (CWRU) offers a deeper understanding of these risks. We analyzed the temperatures reached by fiber-optic light cables in various configurations to mimic settings in the operating room.

The simulated OR setup included a Stryker L9000 300-watt LED light source (100% brightness), Stryker clear-case fiber-optic light cables, an Arthrex 4 mm 30° arthroscope, and Cardinal Health three-quarter sheets—the surgical drape—folded into four layers and placed over a ceramic fiberboard. K-Type 0.51mm Omega SCASS-020G-6 thermocouples measured temperatures every 0.5 seconds. We tested various scenarios.

In one configuration, a cable was held vertically, in direct contact with a thermocouple and an aluminosilicate refractory ceramic fiberboard (Figure 1A). The fiberboard performed as an insulating material, mimicking the low conductivity of human skin and preventing heat dissipation. The tip of the cable increased to 60°C within 0.5s and reached 90°C within 1.0s. The temperature continued to increase at a logarithmic rate (max rate of 62°C/s) until reaching 369°C, where the increase in temperature began to taper off. Notably, this measurement exceeds the maximum temperature of 268.6°C described by TJC.

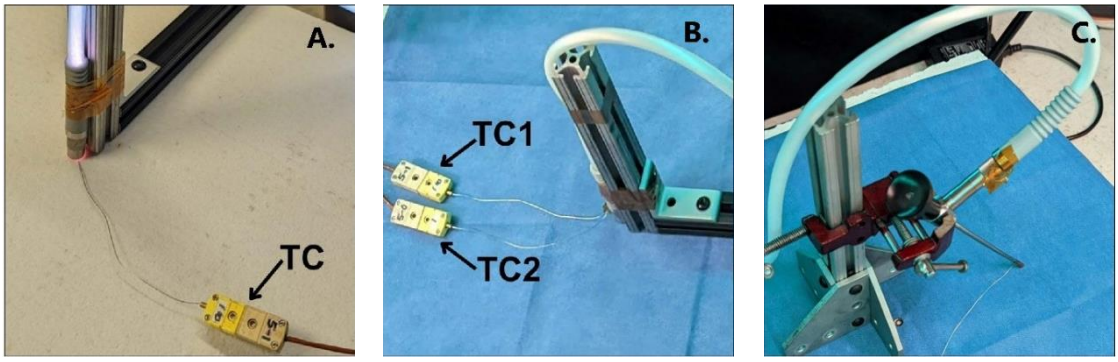

Figure 1. Fiber-Optic Cable Layouts (A, B, C)

In a second configuration, we replicated an operating room scenario where a fiber-optic cable comes into direct contact with a surgical drape. This scenario resembles general surgery, during which a surgeon is more likely, for example, to swap scope sizes in order to utilize an available port. During the swap, the fiber-optic light cable may be inadvertently placed on top of the patient drape while it's still powered on and hot. In our test, a surgical drape was placed over a non-insulating ceramic fiberboard with the tip of the fiber optic cable held in direct contact with a surgical drape (Figure 1B). Two thermocouples were attached to the outside of the cable: one 5 mm away from the tip (TC1) and the other an additional 10-12 mm away (TC2). Momentary exposure to the tip of the fiber-optic light cable caused visible damage to the surgical drape, melting all four layers and penetrating the fiberboard. The temperatures measured on the outside of the cable were much lower than those reached at the tip of the cable, with the thermocouple placed on the outside of the cable closest to the tip (TC1) measuring higher (73.2°C) than the one placed farther away (TC2, 52.7°C).

The final configuration tested whether such temperatures were possible at the tip of a 30° rigid arthroscope with a fiber-optic cable connected to its light post, in contact with a surgical drape atop of a non-refractory ceramic fiberboard (Figure 1C). This test confirmed that temperatures at the tip of the arthroscope were significantly lower than the fiber-optic cable, ranging from 25–40°C.

Reducing the Risk of Light-Source-Related Burns and Fires to Zero

To test the wireless camera of the ArthroFree® System, we placed temperature probes on four surface locations: the light source, C-mount camera connector, battery compartment, and the body of the handheld device. A fully charged battery was inserted into the ArthroFree camera. Temperatures were recorded in 10-minute intervals for the duration of the time required to deplete two fully charged batteries. Testing was repeated with three devices. The maximum temperature of any surface of the ArthroFree camera was 43°C, which was reached after 130 minutes.

Conclusion

In device documentation, medical device manufacturers understate the fire and burn risks posed by conventional MIS systems. Several studies of these risks and conclude that the best approach includes extensive education and training.[2,3,4,5,6,7,8,9,10,11] Hospitals and surgery centers have devised policies and procedures to address these risks. This approach, though, is less than comprehensive. In fact, it falls short of the recognized ISO standard.

In ISO 60601-1 (Medical electrical equipment—Part 1: General requirements for basic safety and essential performance),[12] the maximum temperature allowable for medical electrical equipment that comes into skin contact for more than 1 minute is 48°C. This study demonstrated multiple scenarios where temperatures are nearly certain to exceed these limits. Once the light source has been activated, the tip of the cable can rapidly exceed 350°C, and the housing itself can exceed 75°C, creating fire or burn risks in the operating room. Although such scenarios are most likely to occur due to equipment malfunction or surgeon error, this is not a risk that should be overlooked.

We have also demonstrated that, unlike the high-intensity light sources of traditional MIS systems, the wireless ArthroFree System never reaches temperatures high enough to burn human tissue or ignite surgical drapes. Its maximum surface temperature of 43°C is well below the noted ISO standard. It poses no analogous risk of burn or fire in the operating room.

References

1. Gaertner, A., Belloni, P. (2018). Analysis and Simulation of the Illumination Optics of Rigid Medical Endoscopes. Current Directions in Biomedical Engineering, 4(1), 167-172. doi:10.1515/cdbme-2018-0042.
2. Hindle, A. B. (2009). Thermal injury secondary to laparoscopic fiber-optic cables. Surgical Endoscopy, 23, 1720-1723. doi:10.1007/s00464-008-0219-z.
3. Bruley, M. E. (2004). Surgical fires: perioperative communication is essential to. BMJ Quality & Safety, 13(6), 467-417. doi:10.1136/qshc.2003.005819.

4. Chitnavis, J. (2020). Silent burn: the hidden danger and effects of bright light from fibre-optic cables in arthroscopic knee surgery. Journal of Surgical Case Reports, 4, 1-4. doi:10.1093/jscr/rjaa068.
5. Ito, T., Kubota, T., Takagi, A., Watanabe, T., Futai, K., Furukawa, T., & Kakehata, S. (2016). Safety of heat generated by endoscope light sources in simulated transcanal endoscopic ear surgery. Auris Nasus Larynx, 43(5), 501-506. doi:10.1016/j.anl.2015.12.014.
6. Kaye, A. D., Kolinsky, D., & Urman, R. (2014). Management of a fire in the operating room. Journal of Anesthesia, 28, 279-287. doi:10.1007/s00540-013-1705-6.
7. Smith, L. S. (2008). Fire/burn risk with electrosurgical devices and endoscopy fiberoptic cables. American Journal of Otolaryngology, 29(3), 171-176. doi:10.1016/j.amjoto.2007.05.006.
8. Di Pasquale, L. F. (2017). Fire Safety for the Oral and Maxillofacial Surgeon and Surgical Staff. Oral and Maxillofacial Surgery Clinics, 29(2), 179-187. doi:10.1016/j.coms.2016.12.004.
9. Sadat-Ali, M. A.-H. (1995). Fire during arthroscopy - an unusual complication. Knee Surgery, Sports Traumatology, Arthroscopy, 3(3), 178-179. doi:10.1007/BF01565479.
10. Rinder, C. S. (2008). Fire safety in the operating room. Current Opinion in Anaesthesiology, 21(6), 790-795. doi:10.1097/ACO.0b013e328318693a.
11. Jones, T. B. (2019). Operating Room Fires. Anesthesiology, 130, 492-501. doi:10.1097/ALN.0000000000002598.
12. IEC. (2005). Medical electrical equipment—Part 1: General requirements for basic safety and essential performance. IEC 60601-1:2005, Table 23.

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