Am J Otolaryngol 40 (2019) 631–635

Contents lists available at ScienceDirect

Am J Otolaryngol

journal homepage: www.elsevier.com/locate/amjoto

Thermal injury to common operating room materials by fiber optic light sources and endoscopes

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ARTICLE INFO

Keywords:
Burn injury
Operating rooms
Patient safety
Heat sources
Endoscopes
Fiber optic technology

ABSTRACT

Purpose: To determine the thermal energy damage potential by heat sources, such as endoscopes and fiber optic light cables, in contact with materials commonly placed around an operating room (OR) table.
Materials and method: Injury by xenon and halogen light sources were tested by direct and indirect contact using fiber optic light bundle cables and scopes at light intensities between ranging from Standby to 100%. The scopes had diameters ranging from 2.7 mm to 10 mm and were set at varying angles. The materials tested were surgical drapes, cotton towels, child shirts, child pants, lap sponges, X-ray detectable sponges, and Mayo covers. The damage potential was determined qualitatively by presence of smoking or smell of burning.
Results: Permutations involving direct contact were able to cause thermal injury, while permutations involving indirect contact, endoscopes, or halogen lamp were not. The xenon light source with the fiber optic light cable created thermal injury at light intensities of 50%, 75%, and 100%. Time to injury increased as light intensity was decreased. Only the surgical drape, child shorts, and cotton towel showed evidence of burn injury.
Conclusions: This report supports the potential for thermal injury to the patient secondary to fiber optic light sources, although this potential may be limited in extent. The injury risk can be reduced by avoiding direct contact to materials overlying the patient, confirming standby mode or 25% light intensity, and maintaining the endoscope connected to the fiber optic cable at all times.

1. Introduction

Endoscopes are used extensively in otolaryngology, general surgery, orthopedic surgeon, obstetrics and gynecology, and urology. Even though cold light sources have built-in heat filtering systems, literature case reports have demonstrated the risk for thermal injury. In the orthopedic surgery literature, Lau and Dao (2008) describe a case report of an 11-year-old patient: a fiber optic light cable connected to a xenon light source, which was not placed on standby mode, was left unintentionally over a paper drape for less than 1 min before resulting in a 4 mm × 12 mm third degree burn [1]. In the otolaryngology literature, there is a growing awareness of the dangers of endoscopes. Smith and Roy found in a survey sent to members of the American Academy of Otolaryngology - Head and Neck Surgery that 7% of the reported fires involved a light cord melting through drapes [2]. The same group also reviewed the Manufacturer and User Facility Device Experience (MAUDE) database between 1998 and 2006 and found 25 incidents with fiber optic light cables [2]. This points to the reality of the dangers of cold light sources.

The source of the danger lies both at the tip of the endoscope and at the end of the fiber optic light cable. Multiple investigators have analyzed the thermal properties of endoscopes [3–5]. Smith and Roy analyzed the risk of burn injury from the tip of the fiber optic light cable and found that it can melt through a polypropylene drape. This study examined the end of the fiber optic cable in contact with two OR materials and did not examine endoscopes [2].

The risk of fire in the OR is well known but little attention is given to thermal injury to patients through contact with drapes and clothing. In our investigation we aimed to mimic a common scenario in which the fiber optic light source can be left incidentally abutting various OR materials commonly used around the operating table. We systematically tested whether fiber optic light sources, both at the end of the cable and the tip of the endoscope, that come into contact with these materials have the potential to generate thermal damage and thus risk harm to the patient.

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https://doi.org/10.1016/j.amjoto.2019.05.007
Received 28 March 2019

Table 1
Materials and methods.

Variables analyzed		
Type of contact	Indirect	
	Direct	
Type of light source	Xenon	
	Halogen	
Heat source	Fiber optic light cable 4.8 mm	
	Hopkins II 2.7 mm × 18 cm	0°
		30°
	Hopkins II 4 mm × 18 cm	0°
		30°
		45°
		75°
	Hopkins II 5 mm × 18 cm	0°
		30°
	Hopkins II 10 mm × 18 cm	0°
Light intensity	Standby	
	25%	
	50%	
	75%	
	100%	
Surface material	Surgical drape	
	Blue OR cotton towel	
	Child shirt	
	Child shorts	
	Lap sponge	
	X-ray detectable sponge	
	Mayo cover	

2. Materials and methods

The experimental setup included a light source attached to a fiber optic cable alone or together with an endoscope set at different light intensities. This setup was exposed by direct and indirect contact to the surface of the material. The endpoint was the time elapsed to presence of smoke, visible charring damage, smell of burning, or otherwise to a maximum of 5 min of contact. We compared the effects of five variables: method of contact, type of light source, type of heat source, structure of endoscope, amount of light intensity, and type of OR material (Table 1). We performed permutations with each of the variables, and the trials were repeated for accuracy and reproducibility.

The xenon and halogen light sources and OR materials were provided by Georgetown University Hospital. For indirect contact, the fiber optic cable and scopes were laid on the top of the surface of the material with the cable or scope in a horizontal orientation (Fig. 1a). For direct contact, the ends of the fiber optic cables and scopes were held firmly in a vertical orientation against the materials which were laid upon a firm surface (Fig. 1b). The xenon light source was part of the video-endoscopic system: video tower-SCB xenon 300 W, model 20133120. The halogen light source was a Pilling Weck with dual 150 W halogen lamp, model 521317. The light sources were connected to the heat sources by a standard gray fiber optic cable of 4.8 mm thickness and the endoscopes were subsequently attached for their part in the experiment. We used the following Hopkins II endoscopes: 2.7 mm by 18 cm (at 0 and 30°), 4 mm by 18 cm (at 0, 30, 45, and 75°), 5 mm by 18 cm (at 0 and 30°), and 10 mm by 18 cm. (at 0°) The light intensity was also analyzed for each permutation. This was modeled after the standard scope intensities of 25% 75%, 50%, 100% and standby settings for the xenon lamp. The Pilling halogen lamp was used at the maximum intensity of 100%. We used seven different materials that are commonly used during cases in the Georgetown University Hospital operating rooms: polypropylene surgical drapes, cotton towels, child gown, child shorts, lap sponge, X-ray-detectable sponge, and Mayo stand cover. Finally, we measured the maximum temperature reached by the fiber optic light cable at the five different intensities of the xenon lamp with infrared thermometry (Model ETC8380).

3. Results

Our study found thermal injury in the scenario when the xenon lamp with at least 50% intensity was connected to the fiber optic light cable alone and placed directly against the surgical drape, cotton towel, and child shorts. We did not find any evidence of thermal injury when the experimental setup included the variables of indirect contact, halogen lamp, light intensities of 25% or standby, child shirt, lap sponge, X-ray sponge, or Mayo cover.

Direct contact between the fiber optic light and OR material has the potential to result in thermal injury. Indirect contact, represented by placing the fiber optic light on top of the OR material, did not result in thermal injury with any of the permutations of the setup. The higher the light intensity, the larger the potential for injury becomes. Only 100%, 75%, and 50% light intensity created holes on the materials and even caused burn marks on the underlying table. The 25% and standby light intensity did not result in injury to any of the materials. Connecting the scope to the fiber optic light cable functioned to prevent thermal injury, as damage was only noted when the light source was connected to the cable alone. There was no thermal injury noted to any of the materials by the endoscopes at any of the diameters or the various angles. No visible change in fabric texture was visualized either.

Thermal injury was visible within 5 min when the xenon lamp was connected to the fiber optic cable alone and placed in direct contact with the surgical drape, cotton towel, and child shorts (Table 3). The time to injury of the surgical drape increased from 1 s at 100% light intensity (Fig. 2a) to 1.43 s with 75% light intensity to 2.56 s with 50% light intensity. The cotton towel was noted to burn after 3 min at 100% light intensity (Fig. 2b). By the 5-minute mark with 75% intensity, the cotton towel only displayed mild yellowing at the site of contact. The child shorts melted within 1 s at 100% (Fig. 2c) as well as at 75% intensity and by 19 s at 50% intensity.

The temperature at the end of the fiber optic light cable as the light intensity increases from 25% to 50% is substantially different, increasing from 80 °C to 160 °C. The temperature reaches a maximum of 246 °C at 100% intensity (Fig. 3).

4. Discussion

A limited number of studies describe the dangers of cold light sources. In the general surgery literature, studies were performed to determine the heat generated by fiber optic lights and the damage they can cause to OR materials and biologic tissue. Yavuz et al. quantified the thermal injury secondary to laparoscopic endoscopes on porcine small bowel mucosa [6]. The group found that the temperature of the endoscope tip ranged from 60 °C to 100 °C, while the tip of the fiber optic cable measured up to 250 °C. The group exposed these sources of heat to pig bowel mucosa and quantified the presence of injury histologically. As expected, the wall of the mucosa completely carbonized on direct contact with the fiber optic cable. Surprisingly, histologic damage was also evident with temperatures as low as 60 °C, which our scopes could reach. The authors concluded that direct contact of the mucosa with the tip of endoscope should be avoided [6]. Hindle et al. looked at the thermal injury caused by the fiber optic cable end alone on both surgical drapes and porcine skin.[7] Direct contact with the fiber optic cable end caused charring of the surgical drapes by 4.4 s, and histologic injury to porcine skin occurred by 5 s [7]. Both groups raised awareness of the dangers of endoscopes with their experiments. They showed that the tip of the fiber optic cable reaches very high temperatures which can damage surgical drapes, porcine bowel mucosa, and skin, and they also showed that the scope tip reaches lower temperatures, yet still can cause histologic damage to porcine bowel mucosa. These authors did not examine whether the scope can cause damage to surgical drapes. We found in our experiment that direct contact with the cable end causes significant damage to polypropylene surgical drapes within seconds.

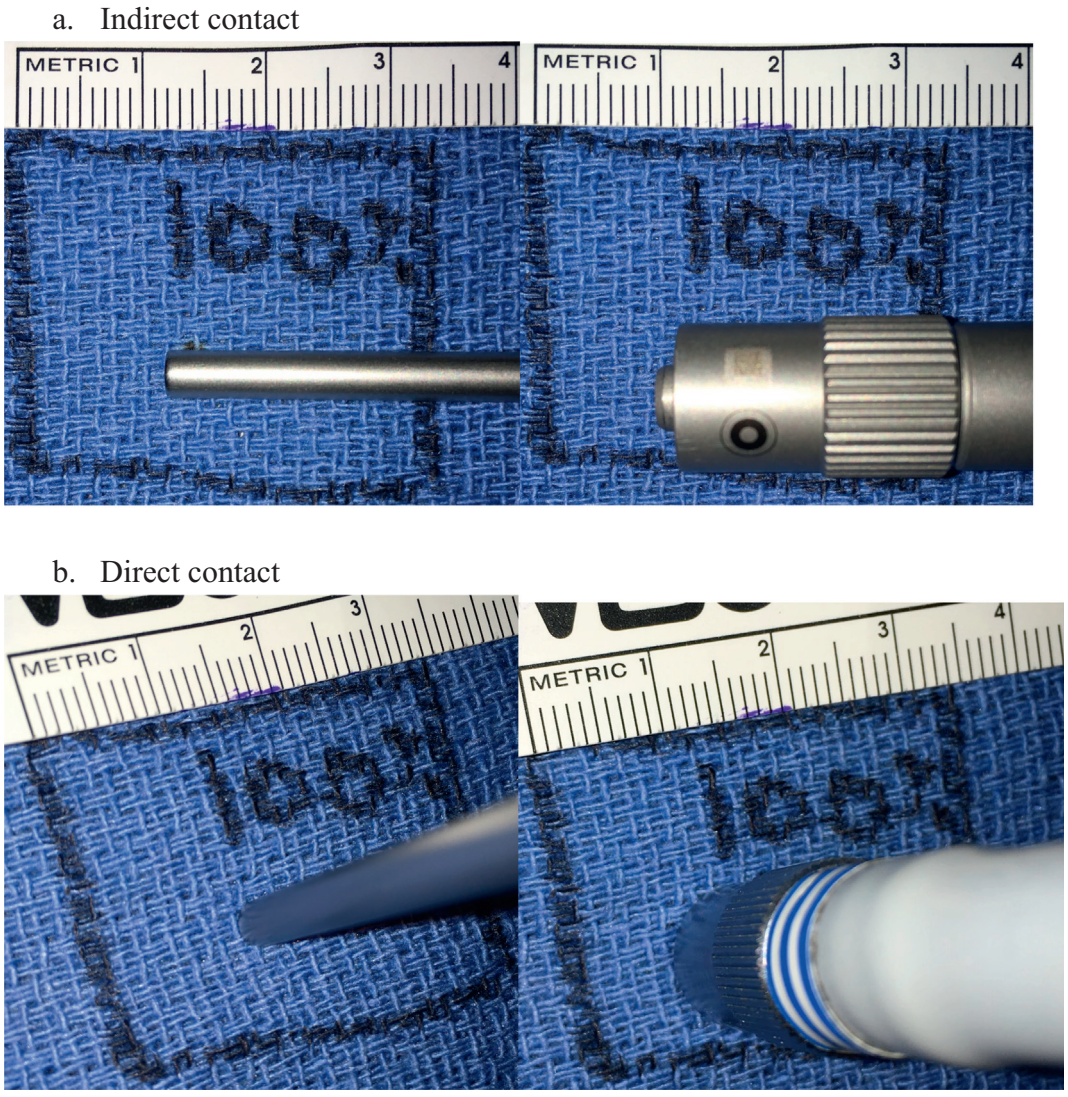

Fig. 1. Methods of contact between endoscope (left) or light source (right) with OR materials.

In the otolaryngology literature, the focus of studies has been on characterizing the thermal properties of endoscopes and less and quantifying the thermal damage [3–5]. MacKeith et al. measured the temperature of a series of endoscopes of different diameters and angulations at the tip, at 5 mm from the tip, and along the shaft. The highest temperature was found to be at the tip of the endoscope. The larger diameter scopes also produced more heat than the smaller diameter endoscopes. Although the highest temperature was always found with the 0° endoscopes, when comparing the angled scopes, the 70° scope generated more heat than the 30°. The highest temperature recorded by the group was 104.6 °C by the 4 mm 0° endoscope, the same one used in our experiment, although it is unclear what light source they used and at what intensity [3]. None of our experimental combinations with the endoscopes caused thermal damage to the OR materials.

Nelson et al. measured the temperature of both at the tip of the endoscopes and the end of the fiber optic cable. In their set up, the endoscope tip reached a maximum of 62 °C using a 4 mm 0° endoscope [4]. This same scope reached a maximum of 105 °C in the MacKeith et al. set up [3]. The difference in temperature points to the variability of the heat generated, which depends not only on the endoscope but the type of light source, light intensity, and fiber optic cable. Nelson's group

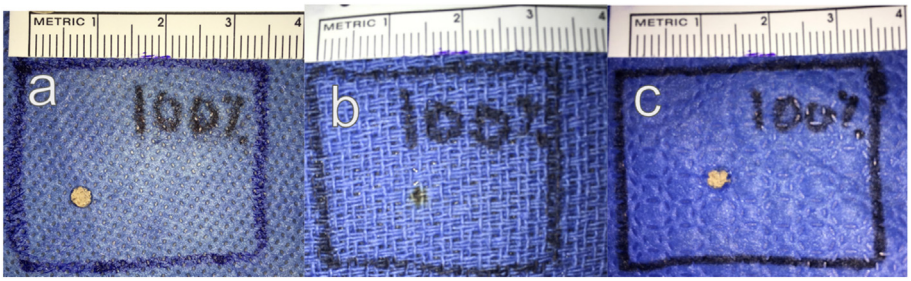

Fig. 2. Burn damage with xenon lamp connected to fiber optic light source in direct contact with OR materials at 100% light intensity.

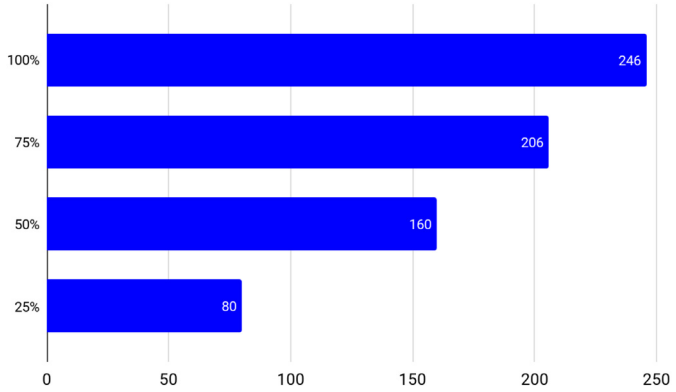

Fig. 3. Maximum temperatures (°C) recorded by the infrared thermometer at the end of the fiber optic cable at four different light intensities.

went on to demonstrate a statistically significant temperature differential with a new versus old light source. The newer xenon lamp created more heat than the older lamp–the maximum temperature at the end of the fiber optic cable was 90 °C with the old 300 W xenon light and 162 °C with the new 300 W light [4]. In our experiment we used a 300 W xenon light of unknown age. The Nelson et al. study showed that there is variability in the heat generated by fiber optic lights [4]. In our study we showed that the temperatures measured at the fiber optic light cable are in the range of Nelson's data, and we also show the visible damage which these temperatures have the ability to cause.

Tomazic et al. also measured the temperature at the tip of endoscopes. This study looked at the 4 mm 0° and 4 mm 30° endoscopes connected to three different light sources (halogen, xenon, and LED) at three different intensities 33% 66% and 100% [5]. They found the Xenon light source produced statistically significant higher temperatures than the halogen and LED lights sources [5]. Our findings are in agreement, as the xenon light source caused visible damage to the OR materials compared to the halogen light source. We did not look at LED light sources, as they are not commonly used by the Georgetown ENT department during surgery.

Smith et al. quantified the damage to our materials with fiber optic light cables attached to 300 W xenon lamps [2]. The group found that the fiber-optic light cable burned through the polypropylene surgical drape within 15 s and caused yellowing of the green cotton towel at 2 min. The temperature of the fiber optic light cable reached 190 °C. The group also found that there was no damage with indirect contact [2]. We also found that indirect contact with the fiber optic cable does not cause damage. The maximum temperature at the end of the fiber optic light cable was higher in our experiment, reaching up to 246 °C, which may explain why the surgical drape in our experiment melted almost instantaneously and the cotton towel melted at 3 min.

While our study was performed in a post-anesthesia care unit, the results can be extrapolated to what may happen in an OR with a patient on the table. The risk of flammability would likely increase in the OR, where additional oxygen is present. OR fires, such as airway fires, have been shown to be relatively common in otolaryngology [2]. This is likely related to the proximity of the head and neck operative field to supplemental oxygen sources on the face, which promote increased flammability of materials exposed to heat. In the survey to otolaryngologists by Smith and Roy, respondents claimed that 81% of OR fires occurred while additional oxygen was present around the operative field; this included situations that involved fiber optic light cables [2]. The increased flammability of common OR materials, such as the ones used in our study, has been shown in scenarios where the materials were ignited and measured to complete incineration [8]. In the study by Culp et al., flammability increased as the oxygen concentration around the OR materials increased from 21% up to 100%, as represented by decreasing times until incineration [8].

Table 2
Results summary.

Variable	Was thermal damage visualized?	
	Yes	No
Contact	Direct	Indirect
Light source	Xenon	Halogen
Heat source	Fiber optic light cable alone	All endoscopes
Light intensity	50%	Standby
	75%	25%
	100%	
OR material	Surgical drape	Child shirt
	Blue OR cotton towel	Lap sponge
	Child shorts	X-ray detectable sponge
		Mayo cover

Our study adds to the current literature evidence for potential thermal injury secondary to both fiber optic light cables and endoscopes (Table 2). We found a significant difference between direct and indirect contact, in agreement with Smith et al. Direct contact is defined as the OR material against the tip of this source of heat (perpendicular orientation), while indirect contact is defined as the material against the shaft of the source of heat (parallel orientation). This is an agreement with MacKeith et al., who found that the highest temperature is at the tip and not along the shaft of the endoscope [3]. Additionally, we found that the xenon light source is more dangerous than the halogen light source, in agreement with the data presented by Tomazic et al. [5] The halogen light source did not cause any visible damage to the OR materials. Light intensity was also a significant variable. As Tomazic et al. showed, the heat generated increased in their setup as the light intensity increased from 33% to 66% to 100%. This is relevant because damage to the OR materials was only possible when the light intensity was at least 50%. Attaching the endoscope to the cold light source was protective in our experiment, as none of the OR material were damaged in that setup. However, in otolaryngology the tip of the endoscope is at risk of touching not only the OR materials but also the patient's skin and nasal mucosa. This tip can be as hot as 105 °C, which are colleagues in the general surgery literature showed is above the threshold for damage to both mucosa and skin of porcine tissue. We did not find a significant difference between the three different diameters of endoscopes or with different angulations, even though previous studies have shown a difference in heat generated [3,5]. The threshold of injury to live tissue is lower than to OR materials, and the differences between diameters and angulations of the scopes could become relevant in such situations. This is especially significant for actual practice in the OR, where patients will be exposed to higher oxygen environments including supplemental oxygen, which is widely known to increase flammability as demonstrated in published literature [8]. Finally, we found that the potential for damage depends on the OR material. The sponges and Mayo cover were safe from damage. Interestingly, not all polypropylene was the same, as the surgical drape and child shorts were susceptible to damage within a few seconds of exposure, but the child shirt was not. Therefore, this brings into question the importance of other compounds mixed into the makeup of different OR materials.

In practice:

1. Consider using a halogen lamp over a xenon lamp as the cold light source.
2. Always attach the endoscope to the fiber optic light cable before turning on the light source and place the light source in standby mode when not in use.
3. Minimize the light intensity to provide optimal visualization and thus decrease potential for thermal injury.
4. Avoid direct contact with OR materials by placing the endoscopes on the Mayo stand when not in use.
5. While the endoscope tip did not cause visible damage to OR

Table 3
Time to thermal injury with 300 W xenon lamp connected to fiber optic light cable in direct contact against OR materials.

	Xenon lamp light intensity				
	Standby	25%	50%	75%	100%
Surgical drape	n/a[a]	n/a	2.56 s	1.43 s	< 1 s
Blue towel	n/a	n/a	n/a	n/a	180 s
Child shirt	n/a	n/a	n/a	n/a	n/a
Child shorts	n/a	n/a	19 s	< 1 s	< 1 s
Lap sponge	n/a	n/a	n/a	n/a	n/a
X-ray sponge	n/a	n/a	n/a	n/a	n/a
Mayo cover	n/a	n/a	n/a	n/a	n/a

[a] n/a: not applicable due to no appreciable burn damage.

materials, it could cause visible damage to skin or mucosa if accidentally exposed.
6. Provide endoscope safety training to all OR personnel, including house staff and medical students.
7. Be vigilant of the potential for thermal injury from endoscopes and fiber optic light cables!

5. Conclusion

In our study we showed that the end of the fiber optic cable can quickly melt through drapes and risk coming into contact with the skin of the patient. We showed that the tip of the endoscope does not burn through the drapes and therefore appears to be protective from the cable. However, the temperature which endoscopes can reach may be higher than the threshold for tissue injury. Therefore, further studies are necessary to quantify the possibility of thermal injury both to the skin and to the mucosa. Through this paper we aim to raise awareness of the dangers of fiber optic light sources, the need for safety education for all of OR staff, and the necessity for further research into fiber optic light safety in the field of otolaryngology.

Financial disclosures

The authors have no financial disclosures or sponsors.

Declaration of Competing Interest

None.

Acknowledgments

Georgetown Storz Representatives provided the stores endoscopes for use in the study.

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