The Journal of Laryngology & Otology (2008), ***122***, *711–714*.

doi:10.1017/S0022215107000734

Main Article

Thermal properties of operative endoscopes used in otorhinolaryngology

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Abstract

Objectives: To measure the thermal properties of operative endoscopes used in otorhinolaryngological practice.

Methods: A series of endoscopes of varying diameters and angulations were attached to a light source and temperature measurements taken of their shaft and tip; a measurement was also taken 5 mm in front of the endoscope tip.

Results: Temperature changes took place rapidly. The amount of heat produced by the endoscopes was maximal at the tip, with larger diameter endoscopes attaining a higher temperature. Temperatures on the shaft and in front of the tip reached relatively constant temperatures independent of the type of endoscope. The maximum temperature achieved was 104.6°C for the 4 mm, 0° endoscope. Cooling occurred rapidly after the light source was switched off.

Conclusion: The heat produced by some endoscopes is sufficiently great to cause thermal injury to tissues. Awareness of the temperatures produced by these endoscopes should prompt clinicians to actively cool their endoscopes during a procedure, before any thermal injury is caused.

Key words: Otoscopy; Endoscopy; Middle Ear; Heat; Burns

Introduction

Since their introduction by Harold H Hopkins and Karl Storz in 1959,[1] rigid endoscopes, illuminated by fibre-optic bundles, have been used increasingly in otorhinolaryngology. The ability to obtain clear images of inaccessible recesses with minimal access, using angled endoscopes, has meant their use is well suited to this specialty. Otoendoscopes have established a place in rhinological surgery,[2] middle-ear examination and surgery,[3–9] and neuro-otology.[10,11]

The technology of rigid nasal endoscopy was first introduced prior to the introduction of more stringent health and safety regulations; thus, no published research was conducted to investigate the possible adverse thermal effects of their use. Rigid endoscopes are illuminated by a bundle of optical fibres which run parallel to the optical system. These fibres are in turn illuminated by a fibre-optic cable which runs from a high intensity light source. The light sources most commonly used are halogen or xenon, which produce so-called 'cold light'. Cold or luminescent light sources were first introduced circa 1939 and were initially popularised as fluorescent tubes. Their aim was to radiate 100 per cent of their energy as light. This is in contrast to the process of incandescence, whereby a standard tungsten light bulb will radiate only 10 per cent of its energy as light and the remaining 90 per cent as heat.

However, there are published, anecdotal reports of adverse thermal effects of such cold light sources, including burning of paper drapes and skin.[12,13] Proponents of the use of endoscopes in middle-ear surgery also mention that clinicians should be cautious of the thermal effects of such endoscopes, but do not quantify the risks.[14]

In the present study, we aimed to measure the thermal properties of a wide range of endoscopes used in otorhinolaryngology.

Material and methods

We used a standard Karl Storz light source and light cable, and the following endoscopes: 2.7 mm, 30°; 3 mm, 0°; 3 mm, 30°; 3 mm, 70°; 4 mm, 0°; short 6 cm, 4 mm, 0°; standard length 18 cm, 4 mm, 30°; 4 mm, 70° (Karl Storz, Endoscopy (UK) Ltd., Slough, Berks, UK). Temperature measurements were recorded with three 1.5 mm, type K thermocouples connected to a TC-08 data logger (Pico Technology, St Neots, UK). The thermocouples were calibrated prior to all recordings.

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Accepted for publication: 25 June 2007. First published online 17 October 2007.

We measured the change in temperature at three sites: firstly, on the shaft of the endoscope (1 cm proximal to the tip); secondly, at the tip of the endoscope (i.e. in contact with the end of the light bundle); and thirdly, 5 mm distal to the tip (in line with the angle of the light projected by the endoscope).

The data logger recorded a reading from each lead, every second for a total of 720 seconds, to an accuracy of 0.01°C. The room temperature was recorded for the first 30 seconds as a baseline, after which the light source was turned on (at its maximum setting). The temperature was recorded over 10 minutes, after which time the light source was turned off and the temperature recorded for a further 90 seconds to assess rates of cooling.

This process was repeated three times for each endoscope measured, and an average of the three readings was taken. Care was taken to allow the endoscope to cool down to room temperature between recording sessions.

Results

All endoscopes showed temperature rises, as expected, and the three readings taken for each model showed consistent results. The maximum recorded temperature was 104.6°C at the tip of the 4 mm diameter, 18 cm length, 0° endoscope. The smallest recorded temperature rise was for the 3 mm diameter, 11 cm length, 30° endoscope, the tip of which reached only 33.0°C.

For all the endoscopes assessed, the hottest part was the tip. Figures 1 and 2 show the temperature change curves recorded for the rhinological and otological endoscopes assessed.

Assessment of temperature rises at different sites showed that the endoscope shaft and the light beam (5 mm in front of the endoscope) did not get nearly as hot as the endoscope tip.

Figure 3 shows the maximum temperature reached at the endoscope tip, shaft and light beam (5 mm in front of the tip), for each of the different endoscopes.

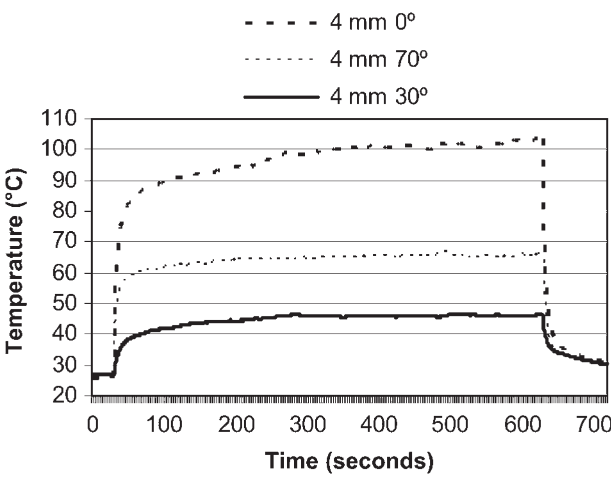

FIG. 1

Rhinology endoscope tip temperature measurements. The key shows the different endoscope models tested.

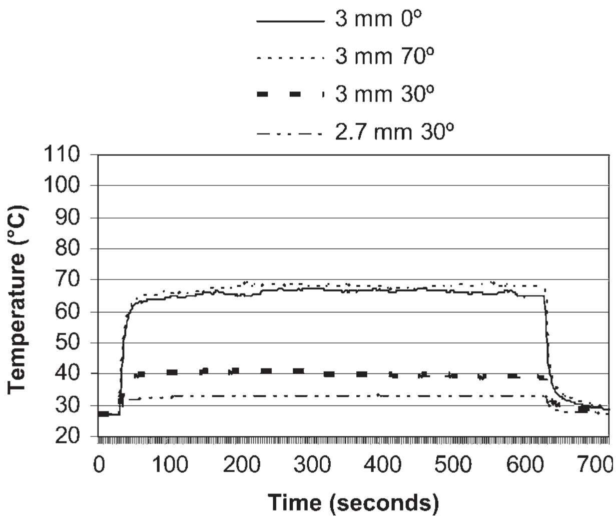

FIG. 2

Otology endoscope tip temperature measurements. The key shows the different endoscope models tested.

As expected, the larger diameter (4 mm) endoscopes produced more heat than the smaller diameter models (3 mm and 2.7 mm). The 0° endoscopes were shown to have the greatest temperature rise overall. However, interestingly, the 70° endoscopes produced significantly more heat than the 30° endoscopes of the same diameter. This was seen most clearly at the tip of the 3 mm endoscopes; the 0° model reached 67.4°C, the 70° model reached 69°C, but the 30° model reached only 40.9°C.

Table I shows the times required for the endoscope tips to reach 80 and 90 per cent of their maximum temperature, as well as to lose 80 per cent of their heat after the light source was switched off.

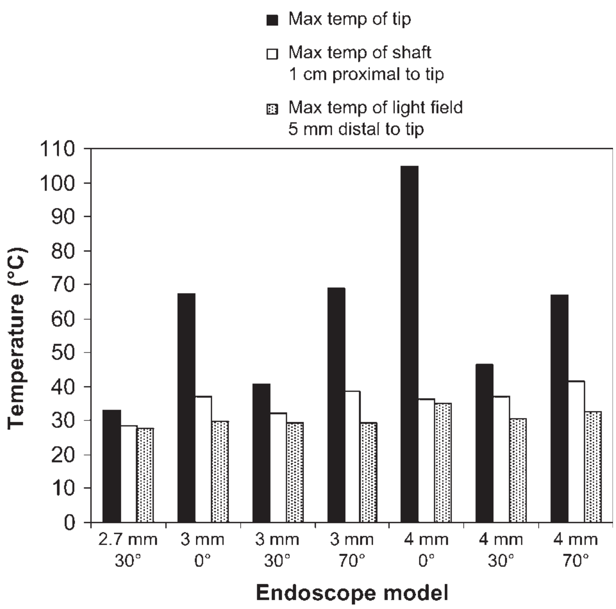

FIG. 3

Maximum (max) temperature (temp) reached at the tip, shaft and light field (5 mm in front of the tip), for various endoscope models.

https://doi.org/10.1017/S0022215107000734 Published online by Cambridge University Press

TABLE I

TIMES TAKEN FOR ENDOSCOPE TIP HEATING AND COOLING, FOR VARIOUS MODELS

Parameter	2.7 mm 30°	3 mm 0°	3 mm 30°	3 mm 70°	4 mm 0°	4 mm 30°	4 mm 70°
Max tip temp (°C)	33.0	67.4	40.9	69.0	104.6	46.6	66.7
Time duration (secs)							
Tip heating to 80% max temp	24	16	16	17	67	90	21
Tip heating to 90% max temp	74	37	28	34	217	213	97
Tip cooling to 80% heat loss	14	13	26	15	12	77	17

Endoscope models are indicated by diameter (mm) and angle. Max = maximum; temp = temperature; secs = seconds

It was also noted that different endoscope sites heated up at variable rates. For all the endoscopes, 80 per cent of the maximal temperature was reached in an average of 35 seconds at the tip, 57 seconds in the light field (measured via the thermocouple) and 128 seconds on the shaft.

Most of the endoscopes cooled rapidly; on average, 23 seconds was required for the tip to lose 80 per cent of its heat.

Discussion

There have been a small number of studies directly assessing the heat produced by cold light sources. Hensman *et al.* measured the temperature produced by fibre-optic light cables and rigid endoscopes used in laparoscopic abdominal surgery.[15] In this study, the endoscopes used were 10 mm in diameter, and reached 95°C at the tip and 239°C at the end of the fibre-optic cable. Most of this temperature rise occurred in the first 15 seconds after the light source had been turned on. Hensman *et al.* stated that the majority of the heat produced was created by radiated power in the visible light spectrum.

The only similar type of research performed in an otorhinolaryngological setting was done by Bottrill *et al.*[16] These authors demonstrated that temperature rises in the lateral semicircular canal, caused by otoendoscopes in the middle ear, were similar to those produced by a standard caloric stimulus. This supported the theory that the unpleasant phenomenon of vertigo experienced during endoscopic middle-ear examination was caused by perilymph convection currents. Bottrill and colleagues' only direct measurement around the endoscope was '2 mm beneath the tip', where they recorded a maximum temperature of 55°C with a 3 mm Hopkins rod. They noted that the larger diameter endoscopes produced more heat; there was even noted to be charring to the medial wall of the middle ear.

We recorded much higher temperatures at the endoscope tip than those previously reported for otoendosopes by Bottrill *et al.*[16] This is probably because these authors recorded temperatures 2 mm beneath the endoscope, and not directly in contact with the tip. If Bottrill *et al.* observed burns and charring due to a maximum recorded temperature of 55°C, then our maximum recorded endoscope tip temperatures (89°C for a 4 mm, 6 cm endoscope, and 104°C for a 4 mm, 18 cm model) could certainly be presumed capable of causing significant thermal injury to tissues in direct contact.

There is little research to quantify the tissue temperature rises required to cause injury; however, some early work does give a guide. A 1959 study by Stoll and Greene recorded pain and blister thresholds on human forearm skin blackened with India ink, testing a range of skin temperatures and exposure times.[17] These authors demonstrated a time to threshold blister of 28 seconds with a tissue temperature of 50°C, but of only 2.1 seconds with a temperature of 56°C. Our study did not measure the actual tissue temperatures reached, and these would be significantly less, for reasons discussed below.

Our finding that most (80 per cent) of the temperature rise occurs on average in the first 35 seconds is comparable with Hensman and colleagues' results, obtained using laparoscopic endoscopes.

It is interesting to note that the rate of heat loss was rapid in almost all of the endoscope models studied, and most rapid in those endoscopes which reached the highest temperatures.

- **Endoscopes are being used increasingly in ENT surgery**
- **Endoscopes produce considerable heat, but exact heat levels have not previously been accurately measured**
- **The amount of heat produced by endoscopes can be sufficient to cause thermal injury**
- **Endoscopes heat up and cool off very quickly**
- **Care should be taken to cool an endoscope at appropriate intervals**
- **The endoscope tip heats most; therefore, care should be taken to keep the tip under direct vision and to avoid tissue contact, in order to avoid thermal injuries**

The main weakness in this study was that it was conducted *in vitro*; there are a number of factors which might affect thermal properties differently *in vivo*, as described by Bottrill *et al.*[16] The surrounding temperature would be 37°C, not 26°C as in this study, and therefore the temperature gradient would be less, potentially reducing the cooling rate. An intact circulation could act as a heat sink, removing warmed blood and replacing it with 37°C blood. There would be a higher moisture content or humidity, with a resultant evaporative cooling effect. The reflective properties of the tissue would also probably be important; although the endoscope tip may be radiating considerable heat, a mucosal surface which is shiny and light in colour would have substantial reflective properties, reducing heat absorption.

Even with the possible cooling mechanisms mentioned above, it is clear that endoscopes may rapidly reach temperatures capable of causing adverse effects, ranging from vertigo to possible thermal burns to middle-ear structures. Potentially, there may also be further, undocumented hazards in related fields such as transsphenoidal surgery.

This study demonstrates that although the endoscope tip may reach temperatures potentially damaging to tissues, the shaft and light field rarely reach 50 per cent of the tip temperature. Therefore, assuming that an endoscope is used continuously under direct vision, the actual tip is unlikely to be in contact with tissues for any prolonged period of time. It is the endoscope shaft and light beam which will be in prolonged contact with tissues; however, as these have significantly lower temperatures, they are unlikely to cause thermal injury.

Conclusions

Fibre-optic, rigid endoscopes are an increasingly important part of the otorhinolaryngological surgical armamentarium. The heat levels produced by rigid endoscopes are sufficient to cause thermal injury to tissues, but such temperatures are only found at the endoscope tip. The mean temperatures of the endoscope shaft and light field are considerably lower than those of the tip. Therefore, if care is taken to keep the tip under direct vision, thermal injury to tissues should be avoidable. Our results also show that endoscopes cool rapidly when removed from a light source; this information may enable further reduction in the risk of thermal injury.

Acknowledgements

The authors would like to thank Karl Storz UK for the loan of the endoscopes, and Pico Technology for the loan of the thermocouples and data logger used in this study.

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Mr S A C MacKeith takes responsibility for the integrity of the content of the paper.
Competing interests: None declared