The Journal of Laryngology & Otology (2017), **131**, 117–122.

doi:10.1017/S0022215116009828

MAIN ARTICLE

Endoscopic ear surgery: a hot topic?

S MITCHELL, C COULSON

Department of Otolaryngology, Queen Elizabeth Hospital, University Hospitals Birmingham NHS Foundation Trust, UK

Abstract

Objectives: To summarise published research investigating maximal temperatures associated with endoscopes used in otology. Possible thermal issues surrounding the use of endoscopes in middle-ear surgery are discussed, and recommendations regarding the safest ways to use endoscopes in endoscopic ear surgery are made.

Methods: A non-systematic review of the relevant literature was conducted, with descriptive analysis and presentation of the results.

Results: There are currently no reports of any temperature-related deleterious effects in patients having undergone endoscopic ear surgery. There is debate regarding heat issues in endoscopic ear surgery, with a limited body of work documenting potential negative impacts of middle-ear heat exposure from endoscopes. The diameter of endoscope, type of light source used, distance from endoscope tip and duration of exposure are highlighted potential factors for high temperatures in endoscopic ear surgery.

Conclusion: There is a trend towards endoscopes being used routinely in ear surgery. Simple practice points are recommended to minimise potential thermal risks.

Key words: Endoscopic Surgical Procedures; Otologic Surgical Procedures; Endoscopes; Middle Ear; Inner Ear; Temperature

Introduction

Since their initial introduction in the late 1950s by Harold H Hopkins and Karl Storz,[1] rigid endoscopes illuminated by fibre-optic bundles have established roles in rhinological, skull base, laryngeal and thyroid surgery. Initially, the use of endoscopes in otological surgery was limited to examination of the middle ear; however, improvements in the size of endoscopes, high-definition picture systems, improved light sources and advancements in operative techniques have led to fully endoscopic ear surgery becoming increasingly commonplace. Current indications for endoscopic ear surgery can be seen in Table I, although this list is not exhaustive.[2]

Experience with endoscopes used in other forms of minimal access surgery have highlighted some important issues related to thermal output from light sources and endoscope tips, with reports of the ignition of surgical drapes and thermal injury to tissues.[3–5]

We aimed to search the literature to: find any cases of thermal injury associated with endoscope use within otological surgery, assess factors that may play a role in temperature issues and propose methods of minimising any potential hazards.

Materials and methods

A literature search was performed of databases that included: the Allied and Complementary Medicine Database (1985 – present), the British Nursing Index (1985 – present), Embase (1985 – present), Medline (1985 – present), PsychInfo (1985 – present), the Cumulative Index to Nursing and Allied Health Literature (1985 – present) and PubMed (1985 – present). Keywords used were: ‘endoscope’, ‘thermal effects’, ‘endoscopic ear surgery’, ‘endoscope temperatures’ and ‘middle ear surgery’. Article abstracts were reviewed, and articles were subsequently selected and included based on their relevance to the review and the quality of the study. Further to this, a manual check was performed on the references included within articles.

Results

Our search highlighted several papers that had investigated the thermal effects of endoscopes commonly used in otology,[6–12] along with case reports of injuries that occurred when using endoscopes and cold light sources in general minimal access procedures such as laparoscopic surgery. No paper was identified that documented any negative effects as a result of

Accepted for publication 28 September 2016 First published online 10 January 2017

TABLE I
COMMON INDICATIONS FOR ENDOSCOPIC EAR SURGERY

Myringoplasty
Tympanoplasty
Ossiculoplasty
Evaluation of ossicular continuity
Attic retraction pocket
Cholesteatoma
Chronic suppurative otitis media
Paraganglioma
Carcinoid tumour
Osteoma
Stapedectomy
Granular myringitis

thermal issues in patients who underwent endoscopic ear surgery.

Direct comparisons between the papers are difficult as there are clear differences between the aims, methodology, measurements and equipment used in each study. However, a descriptive rather than statistical analysis of the potential variables that effect temperature exposure in endoscopic ear surgery can be made.

An overview of the studies identified and the maximal temperatures achieved from endoscopes commonly used in otology can be seen in Table II.[6–12]

Most papers reported measuring the temperature at the tip of the endoscope[6–8,10,12] or measuring temperatures directly in the light emitted from it at varying distances from the tip.[8,9,11] The measurements were taken in a laboratory environment, in cadaveric human temporal bones or in live animal models.

The size of endoscope used appears to be linked to temperatures produced. Smaller diameter endoscopes show lower temperatures at the tip when compared to larger diameter endoscopes within the literature.[8,10]

The next significant factor seemed to be the type of light source used. In almost all studies, the use of high-powered xenon light sources resulted in the highest temperatures, ranging from 32.3 °C to 91.5 °C. Light-emitting diode (LED) light sources (39.0–44.6 °C) and halogen light sources (34.0–38.0 °C) resulted in lower maximal temperatures at the endoscope tip.

The time that it took for the endoscope to reach the maximum temperature varied between papers. Measurements were taken for a large range of times (16 seconds to 30 minutes), but it was noted in most papers that the most significant rises in endoscope temperatures occurred within 60 seconds.[6,8–10]

The power settings used, as might be expected, were shown to directly affect the temperature measured at the endoscope tip. In the only paper to vary the power settings, Tomazic *et al.* showed that as power levels were increased from 33 per cent to 66 per cent and then 100 per cent, so the maximum tip temperature increased, regardless of which type of light source was used.[6]

Two papers investigated the temperature of light measured at varying distances from the endoscope tip.[8,9] Perhaps the most applicable to clinical practice is that performed by Kozin *et al.*, who used a fresh human cadaveric temporal bone, maintained at 36 °C, and measured the temperature at the round window membrane while shining a 3 mm, 0-degree endoscope, using 100 per cent power at 0, 2, 4, 6 and 8 mm distances.[9] It was found that even at 8 mm, temperatures rose up to approximately 39 °C within 124 seconds. After shutting off the light source, heat dissipated quickly to less than 25 per cent of the baseline within 22–88 seconds.

Discussion

There are well-documented positive and negative aspects of endoscopic ear surgery. Endoscopes can allow an improved view of middle-ear structures such as the facial recess, sinus tympani, anterior epitympanum and Eustachian tube orifice, because of the wide-angled lens and the light source being situated at the endoscope tip. Typically, the ear canal is used as the conduit for surgery, without the need to drill access pathways or retract soft tissues. Difficulties can be encountered operating this way because of the size limitations of the ear canal; the surgeon requires one hand to hold the endoscope and the other to perform surgery, which limits the possibility of bimanual manipulation of tissues that is possible when using traditional operating microscopes.

There is also a substantial learning curve to performing this surgery successfully, as there is a loss of binocular vision compared to operating microscopes; in addition, for endoscopic ear surgery to proceed at an efficient pace, a dry surgical field is required, but it is difficult to provide suction while continuing dissection. Practically speaking, many of these limitations cease to be a problem as the surgeon becomes accustomed to the technique.

- **The smallest endoscope that can achieve adequate clarity (e.g. 3 mm) should be used and xenon light sources should be avoided**
- **A light-emitting diode source at the lowest possible power setting should provide adequate illumination**
- **Endoscopes should not be placed in the middle ear for long periods (over 5 minutes)**
- **Regular breaks and endoscope tip irrigation should be considered**
- **The endoscope tip should not come into direct contact with tissues**
- **A distance of 8 mm should prevent the endoscope getting too close to tissues**

These limitations have led to the development of endoscope holders,[13] which can enable two-handed endoscopic ear surgery; however, these are not yet in common use. A significant temperature rise could

https://doi.org/10.1017/S0022215116009828 Published online by Cambridge University Press

TABLE II

MAXIMUM ENDOSCOPE TEMPERATURES IN PUBLISHED STUDIES

Study (year)	Endoscope angle, diameter	Light source	Power details	Measurements & tests performed	Time until max temp	Max temp (°C)
Tomazic *et al.*[6] (2012)	0 degree, 4 mm	Halogen	250W, 100%	Endoscope tip temp measured in room air	200 s (steepest increase within 30 s)	38.0
		Xenon	300W, 100%			91.5
		LED	175W, 100%			40.2
Nelson & Goyal[7] (2011)	0 degree, 4 mm	Xenon	300W (old Circon unit)	Old & new endoscope tip temp measured, at room temp	30 min	32.3
			550W (old Linvatec unit)			62.5
		Storz?	175W			38.8
			300W			38.0
MacKeith *et al.*[8] (2008)	0 degree, 3 mm	Storz light source – wattage not specified	100%	Temp measured at endoscope tip & 5 mm from tip in room air	16 s (80% of max temp)	Tip temp = 67.4, temp at 5 mm = 30.0
	0 degree, 4 mm		100%	Temp measured at endoscope tip & 5 mm from tip in room air	67 s (80% of max temp)	Tip temp = 104.6, temp at 5 mm = 35.0
Kozin *et al.*[9] (2014)	0 degree, 3 mm	Xenon	300W (Storz system), 100%	Temp in cadaveric human temporal bone, maintained at 36 °C, at round window, measured at endoscope tip, & 2, 4, 6 & 8 mm from sensor	30–127 s	Tip temp = 46.9. Temps at 2, 4, 6 & 8 mm from sensor: 44.0*, 43.0*, 41.0* & 39.0*
		LED	175W (Storz system), 100%	Temp measured at endoscope tip, & 2, 4, 6 & 8 mm from sensor		Tip temp = 44.6. Temps at 2, 4, 6 & 8 mm from sensor: 42.0*, 40.5*, 40.0* & 39.0*
Aksoy *et al.*[10] (2015)	0 degree, 2.7 mm	Halogen	250W, 100%	Temp of light emitted from endoscope measured, in room temp	5 min (significant rise within 60 s)	34.0*
		Xenon	300W, 100%			67.9
	0 degree, 4 mm	Halogen	250W, 100%			37.0*
		Xenon	300W, 100%			83.8
Botrill *et al.*[11] (1996)	0 degree, 3 mm	Xenon Storz	300W, 100%	Temp increases at LSCC probe in cadaveric temporal bone were measured (room temp was 24 °C)	4.5 min	32 (8.0 rise)
				Temp increases at LSCC probe in a live canine temporal bone were measured (37 °C)		38.1 (1.1 rise)
				Temp increases were measured 2 mm from probe placed onto promontory in cadaveric temporal bone		55
Craig & Goyal[12] (2014)	0 degree, 4 mm	Xenon	175W, 100%	Endoscope tip temp with & without sheaths (± irrigation) was measured using a thermal camera in room air	10 min	32.6

*Result taken from graph; may be an approximate result. Max = maximum; temp = temperature; LED = light-emitting diode; s = seconds; min = minutes; LSCC = lateral semicircular canal occur with an endoscope fixed in position for an extended time in the middle ear, along with potential physical damage should the patient move. Other equipment for endoscopic ear surgery has been developed over time and is becoming more specialised. Most visual systems include a 0-degree or 30-degree angled rigid endoscope, with a light source attached to a high-definition camera and video system. The endoscopes currently used in otology are 2.7 mm, 3.0 mm and 4.0 mm in diameter. A larger diameter endoscope will transmit more light, which gives better illumination and clarity; however, these decrease the amount of space available in the ear canal and transmit more heat energy as a consequence, as shown in our results.

Heat exposure

Almost all of the papers identified in our search demonstrated that the endoscope temperature will rise above body temperature. The key questions of ‘at what temperature does inner-ear function become affected during endoscopic ear surgery?’ and ‘what duration of exposure is required to produce this effect?’ are more difficult to answer.

It is known from previous experimental studies that in mammals there are functional and physiological consequences of elevated temperature. An elevation in temperature from 18.0 °C to 39 °C alters the latency, duration and amplitude of cochlear microphonics and neural components measured at the round window in response to acoustic clicks in the hamster cochlear.[9,14] In a recent study, Aksoy *et al*. demonstrated a significant reduction in distortion product otoacoustic emissions and auditory brainstem responses in a guinea pig cochlear following exposure to temperatures produced by a 2.7 mm, 0-degree endoscope attached to a xenon 300W light source for intermittent periods of 5 minutes, with 15 second breaks, over 45 minutes’ duration.[10] The maximum temperature of light emitted from the endoscope using this setup was 67.9 °C.

Human subjects in heated climatic chambers, experiencing hyperthermia up to an average temperature of 38.4 °C, demonstrate significant inhibition of transient evoked otoacoustic emissions, suggesting that outer hair cell micromechanical activity is also sensitive to body temperature.[15] Botrill *et al*. demonstrated that exposure to an endoscope caused a significant enough rise in temperature at the lateral semicircular canal in a live canine to produce a caloric effect when compared to a standard 44 °C water caloric test.[11] Importantly, it is known that local tissue damage is induced above temperatures of 50 °C,[16] which is possible in endoscopic ear surgery given the maximal temperatures at endoscope tips reported within the literature.

Another important structure is the facial nerve. The exact thermal tolerances of the facial nerve are not known; however, previous experience with ultrasonic irradiation of the labyrinth for Ménière’s disease led to the discovery that elevations in temperature of 9 °C above body temperature resulted in facial nerve damage.[17]

Despite the potential risks of thermal damage to middle- and inner-ear structures or local tissue damage, there are no reports of these events having occurred in patients following endoscopic ear surgery.

When considering if endoscopic ear surgery is safe, it is important to compare this technique to the traditional method of performing middle-ear surgery using operating microscopes. There have recently been reports of thermal issues occurring using newer operating microscopes, with burns being observed on the external ear.[18,19] It is possible that using a fixed microscope could result in high middle-ear temperatures, although this has not yet been shown in clinical practice.

A recent pilot study aiming to quantify the thermal effects of white light illumination during microsurgery measured the temperature at the skin surface of volunteers under microscope illumination.[20] The study demonstrated temperature rises to 43 °C using low power (200 mW/cm^2) and rises towards 46 °C at very high illumination (750 mW/cm^2). This resulted in pain within 30 seconds of exposure. Conversely, a recent neurosurgical study investigating temperature rises in the brain and dura while using operating microscopes found no significant rise in temperatures under xenon microscope light of up to 120 minutes’ duration, at an intensity of 60–70 per cent, from a distance of 20–25 cm from the brain surface.[21]

It certainly seems that there are potential thermal issues associated with using operative microscopes, as published in case reports. However, the authors recognise that microscopes have been used for many years and have a long track record, with no reported issues relating to the ear canal, middle-ear tissue damage or inner-ear dysfunction.

Based on our review and on animal models, it may be sensible to set an acceptable temperature exposure for the middle ear and cochlear of between body temperature (37.0 °C) and 40.0 °C. This is well below temperatures reported at which any tissue, facial nerve, vestibular or overt cochlear impairment has been reported. To achieve this, avoidance of xenon light sources is encouraged. The light output of halogen light sources is often not strong enough for use in modern high-definition cameras,[6] making LED the recommended light source for endoscopic ear surgery. The smallest endoscope that delivers a suitable view should be used; it is the authors’ experience that an endoscope diameter of 2.7 mm does not deliver sufficient resolution to be of practical use for endoscopic ear surgery, hence a 3 mm endoscope is recommended. Using the lowest power setting while achieving adequate illumination is recommended. In addition, the proximity of the endoscope tip to tissues should be closely monitored, and should ideally be kept 8 mm or further away from middle-ear structures.

Exposure time

When considering the duration of exposure, our literature search demonstrated large variations in the time taken for endoscopes to reach the maximum reported temperatures, but significant increases occurred within 60 seconds. It is not known how long high-temperature exposure needs to last for cochlear damage to occur; however, Aksoy *et al*. demonstrated impairment of cochlear function in guinea pigs within 5 minutes.[10] This may not apply to humans as the human cochlear is much thicker than that of the guinea pig.

In a recent paper by Shah *et al*., which investigated the radiant exposure of the middle ear during endoscopic tympanoplasties with or without ossicular chain reconstruction, the maximum duration that the endoscope was continuously in the middle ear for without the use of any cooling device ranged from 114 to 454 seconds, with an average of 232.4 ± 92.9 seconds.[22] This demonstrated that the middle ear is often exposed to the endoscope for long periods during surgery, which may have an impact on middle-ear temperature, but, again, no negative outcomes were recorded.

Cooling methods

Studies have investigated possible mechanisms for cooling the middle ear during endoscopic ear surgery. Methods have included the use of suction, turning off the light source at regular intervals, and the use of plastic or metal endoscope sheaths with and without active saline irrigation.

Suction placed at the tip of the endoscope results in a drop in temperature of 10 °C within 20 seconds, and the discontinuation of light leads to a decrease in temperature to less than 25 per cent of the baseline within 22–88 seconds.[9] The use of endoscope sheaths decreased endoscope tip temperature by approximately 2 °C, with the addition of active irrigation decreasing endoscope tip temperature by approximately 5 °C.[12]

We recommend that continuous exposure of the endoscope to the middle ear, in the absence of any cooling mechanism, should be limited and, ideally, should not exceed 5 minutes. Regular breaks of longer than 88 seconds, or regular application of suction or irrigation should be considered.

Limitations of the literature

The authors note that there is a limited volume of literature on this topic. Furthermore, within the literature available, the results are difficult to fully apply to clinical practice. Most papers measured the temperature of the endoscope tip itself, or the temperature of the light in front of the endoscope, in an open laboratory setting or in a cadaveric human temporal bone model. Botrill *et al*. demonstrated that the differences in temperature recorded *in vitro* were significantly different from those obtained *in vivo*.[11] The explanation for this was that a live organism has a blood flow and perilymph circulation, which may act as a heat sink and limit the rise in temperature. In addition, the water content of living tissue is high, meaning that it has a high thermal coefficient, thereby requiring a higher energy input for a unit temperature rise. Lastly, most temporal bones used in early studies were preserved, giving them a brown colour, which would more readily absorb light and heat compared to paler middle-ear mucosa.[11]

Conclusion

To date, there have been no reported thermal injuries to the middle or inner ear as a result of endoscopic ear surgery. Potential thermal issues have been discussed within the literature in relation to endoscopes, which are used commonly in endoscopic ear surgery; however, the impact of these in actual patient care has not been demonstrated. We have suggested strategies to minimise the theoretical risks of harm. Animal models provide some indicators of the possible risks, but further studies are certainly required to fully establish the benefits of endoscopic ear surgery and to determine the incidence and extent of any risks of this relatively new technique.

References

1 Hopkins HH, Kapany NS. A flexible fiberscope, using static scanning. *Nature* 1954;**173**:39–41
2 Kozin ED, Gulati S, Kaplan AB, Lehmann AE, Remenschneider AK, Landegger LD *et al*. Systematic review of outcomes following observational and operative endoscopic middle ear surgery. *Laryngoscope* 2015;**125**:1205–14
3 Bellina JH, Haas M. Cold light sources. Are they really cold? *J Reprod Med* 1984;**29**:275–7
4 Sandhu H, Turner R, Pozo JL. No smoke without fire--simple recommendations to avoid arthroscopic burns. *Knee* 2002;**9**: 341–6
5 Yavuz Y, Skogas JG, Gulluoglu MG, Langø T, Marvik R. Are cold light sources really cold? *Surg Laparosc Endosc Percutan Tech* 2006;**16**:370–6
6 Tomazic PV, Hammer GP, Gerstenburger C, Koele W, Stammberger H. Heat development at nasal endoscopes' tips: danger of tissue damage? A laboratory study. *Laryngoscope* 2012;**122**:1670–3
7 Nelson JJ, Goyal P. Temperature variations of nasal endoscopes. *Laryngoscope* 2011;**121**:273–8
8 MacKeith SA, Frampton S, Pothier DD. Thermal properties of operative endoscopes used in otorhinolaryngology. *J Laryngol Otol* 2008;**122**:711–14
9 Kozin ED, Lehmann A, Carter M, Hight E, Cohen M, Nakajima HH *et al*. Thermal effects of endoscopy in a human temporal bone model: implications for endoscopic ear surgery. *Laryngoscope* 2014;**124**:E322–39
10 Aksoy F, Dogan R, Ozturan O, Eren SB, Veyseller B, Gedik O. Thermal effects of cold light sources used in otologic surgery. *Eur Arch Otorhinolaryngol* 2015;**272**:2679–87
11 Botrill I, Perrault D, Poe D. In vitro and in vivo determination of the thermal effects of middle ear endoscopy. *Laryngoscope* 1996;**106**:213–16
12 Craig J, Goyal P. Insulating and cooling effects of nasal endoscope sheaths and irrigation. *Int Forum Allergy Rhinol* 2014;**4**: 759–62
13 Khan M, Parab S. Concept, design and development of innovative endoscope holder system for endoscopic otolaryngological surgeries. *Indian J Otolaryngol Head Neck Surg* 2015;**67**: 113–19
14 Kahana L, Rosenblith WA, Gallambos R. Effect of temperature change on round window responses in the hamster. *Am J Physiol* 1950;**163**:213–23

15 Drescher DG. Noise-induced reduction of inner-ear microphonic response: dependence on body temperature. *Science* 1974;**185**:273–4
16 Stoll AM, Green LC. Relationship between pain and tissue damage due to thermal radiation. *J Appl Physiol* 1959;**14**: 373–82
17 Angell JA, Dalton GA, Freundlich HF, Bullen MA, Wells PN, Hughes DA *et al*. Histological, thermal and biochemical effects of ultrasound on the labyrinth and temporal bone. *Acta Otolaryngol* 1964;**57**:306–12
18 Parodi M, Thierry B, Blanchard M, Coulgigner V, Garabedian EN. Using a new otologic operating microscope: unexpected complications. *Int J Pediatr Otorhinolaryngol* 2015;**79**:755–7
19 Latuska RF, Carlson ML, Neff BA, Driscoll CL, Wanna GB, Haynes DS. Auricular burns associated with operating microscope use during otologic surgery. *Otol Neurotol* 2014;**35**: 227–33
20 Hibst R, Saal D, Russ D, Kunzi-Rapp K, Kienle A, Stock K. Thermal effects of white light illumination during microsurgery: clinical pilot study on the application safety of surgical microscopes. *J Biomed Opt* 2010;**15**:048003
21 Gayatri P, Menon GC, Suneel PR. Effect of operating microscope light on brain temperature during craniotomy. *J Neurosurg Anesthesiol* 2013;**25**:267–70
22 Shah PV, Kozin ED, Remenschneider AK, Dedmon MM, Nakajima HH, Cohen MS *et al*. Prolonged radiant exposure of the middle ear during transcanal endoscopic ear surgery. *Otolaryngol Head Neck Surg* 2015;**153**:102–4

Address for correspondence:
Mr S Mitchell,
Department of Otolaryngology,
University Hospitals Birmingham NHS Foundation Trust,
Queen Elizabeth Hospital,
Mindelsohn Way,
Edgbaston,
Birmingham B15 2WB, UK

E-mail: scottmitchell@nhs.net

Mr S Mitchell takes responsibility for the integrity of the content of the paper
Competing interests: Chris Coulson is managing director of Endoscope-i, a company involved in the production of an adapter to connect a rigid endoscope to an Apple iPhone. Neither author has received any grant monies, honoraria, financial assistance, fees, gifts or indirect financial support in the production of this work.