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Investigating the learning curve in endoscopic compared to microscopic myringotomy and ventilation tube insertion

O Denton[1], A Daglish[2], L Smallman[3] and S Fishpool[4]

[1]Postgraduate Centre, Glasgow Royal Infirmary, NHS Greater Glasgow and Clyde, UK, [2]Postgraduate Medical Education Centre, Royal Berkshire NHS Foundation Trust, Reading, UK, [3]School of Mathematics, Cardiff University, Wales, UK and [4]Department of ENT, Cwm Taf Morgannwg University Health Board, Ynysmaerdy, Wales, UK

Main Article

Dr O Denton takes responsibility for the integrity of the content of the paper

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Author for correspondence:
Dr Oliver Denton, Postgraduate Centre, St Mungo Building, Glasgow Royal Infirmary, 84 Castle St, Glasgow G4 0SF, Scotland, UK
E-mail: dentonOG@doctors.org.uk

Abstract

Objective. Rate of learning is often cited as a deterrent in the use of endoscopic ear surgery. This study investigated the learning curves of novice surgeons performing simulated ear surgery using either an endoscope or a microscope.
Methods. A prospective multi-site clinical research study was conducted. Seventy-two medical students were randomly allocated to the endoscope or microscope group, and performed 10 myringotomy and ventilation tube insertions. Trial times were used to produce learning curves. From these, slope (learning rate) and asymptote (optimal proficiency) were ascertained.
Results. There was no significant difference between the learning curves ($p = 0.41$). The learning rate value was 68.62 for the microscope group and 78.71 for the endoscope group. The optimal proficiency (seconds) was 32.83 for the microscope group and 27.87 for the endoscope group.
Conclusion. The absence of a significant difference shows that the learning rates of each technique are statistically indistinguishable. This suggests that surgeons are not justified when citing 'steep learning curve' in arguments against the use of endoscopes in middle-ear surgery.

Introduction

Traditionally, the microscope has been the 'gold standard' for middle-ear surgery,[1–3] but improvements in technology, such as fibre-optics and high-definition video, have made the endoscope a viable alternative.[1]

The main advantage of the endoscope is a wider field of view, as well as the ability to visualise structures from different angles, to see around corners (using angled endoscopes), and to adjust magnification by simply advancing or withdrawing the probe.[3] Conversely, microscopy provides a linear view that is restricted by a narrow external ear canal (Figure 1). Experienced endoscopic surgeons report shorter operative times.[3] Furthermore, patients experience less operative morbidity,[4] faster post-operative recovery[3] and a more favourable cosmetic outcome with endoscopic approaches.[5,6]

Despite established advantages, there is resistance to the widespread adoption of endoscopic ear surgery. One of the most commonly cited disadvantages of endoscopic ear surgery is the 'one-handed' approach, which is perceived as challenging to learn.[5,7,8] Combined with the relatively recent emergence of the necessary technology, this perception has resulted in fewer teaching opportunities, and is a barrier to the widespread adoption of endoscopic ear surgery in the UK.[2]

Attempts have been made to assess the learning curve of endoscopic ear surgery, but studies are retrospective,[8] or they 'chunk' evidence to facilitate comparison with the microscope over different time intervals.[9,10] Thus, these studies fail to directly compare the endoscopic approach with an operating microscope. There are few examples of research assessing the overall rate of learning in order to estimate the point of curve plateau,[11] despite a method using non-linear regression to fit an inverse curve being described by Feldman *et al.* in 2009.[11]

This study aimed to directly compare endoscopic and microscopic middle-ear surgery by analysing novice surgeons performing myringotomy and ventilation tube insertions using a surgical simulator. The study attempted to answer the following questions: (1) how does the rate of learning differ when a novice surgeon is trained to perform a middle-ear surgical procedure using an endoscope as opposed to a microscope?; (2) is there any difference in final proficiency when performing middle-ear surgery using an endoscope or a microscope?; and (3) is the learning curve a justifiable reason for resistance to adopt an endoscopic approach for middle-ear surgery?

Materials and methods

Design and participants

This was a multi-centre, prospective study, using data collected over six sessions at the Prince Charles Hospital (Cwm Taf University Health Board), Morriston Hospital

Fig. 1. (a) Image demonstrating the position of the 'Bradford Grommet Trainer' within the external ear canal of the manikin. (b) Image showing a participant inserting a ventilation tube using an endoscopic approach. (c) Image showing the arrangement for the traditional microscopic technique.

(Swansea Bay University Health Board), Wrexham Maelor Hospital and Ysbyty Gwynedd (both Betsi Cadwaladr University Health Board). Ethical approval was granted by the Cardiff University School of Medicine Research Ethics Committee.

Participants were surgically naïve medical students recruited via advertisement through Cardiff University ENT and surgical societies, and the Swansea University medical placement team. Participants completed a questionnaire detailing year of study, gender and handedness, and declared any formal endoscopic or microscopic training.

Surgical groups and procedure

Participants were randomly allocated to either the endoscope group or microscope group. A senior ENT specialist demonstrated each procedure using the appropriate equipment. Participants wore surgical gowns and gloves, and were assisted by ENT operating theatre staff to perform 10 consecutive ventilation tube insertions on the simulator using either a Storz 4 mm, 0-degree rigid endoscope or a Zeiss otomicroscope.

The chosen simulator was Jesudason and Smith's (2004) Bradford Grommet Trainer,[12] which was the preferred low-fidelity ventilation tube insertion trainer in a recent review.[13] Two disposable auricular temperature probe covers are arranged in series; the membrane of the internal cylinder is pulled taut by the second probe cover, acting as the tympanic membrane. The simulator was inserted into the right ear of a manikin and draped for enhanced realism. The right ear was chosen for comparison of the otomicroscopic technique with the potentially more challenging side used for endoscopy, thus minimising bias towards endoscopic ear surgery.

Instruction, demonstration and assessment was consistent with the procedure as classically performed *in vivo*. The tympanic membrane (of the simulator) was visualised using the assigned technique. An incision was made using a myringotome in the antero-inferior quadrant and a ventilation tube was inserted using aural forceps.

Outcome measures

The primary outcome measure was trial time, which started when the participant was handed the myringotome, and ended after either a successful insertion or a fail. Failure was defined as an 'irretrievable drop' of a ventilation tube, either into the middle ear or outside of the surgical field. 'Retrievable drops' onto the surgical field were also measured. These outcome measures are considered to be a surrogate marker of proficiency.

Trial time was used to calculate the rate of learning using the slope of the resulting learning curve, and the 'asymptote', which represents the best potential operative time following infinite attempts.

Statistical analysis

A non-linear regression model was used to calculate comparable learning curves, where the time taken was assumed to be a constant 'best performance' time plus a term inversely proportional to the number of practice attempts. The full model is given in equation 1. The mean number of ventilation tube drops was calculated for each attempt within the groups. The Wilcoxon rank-sum test was used to determine significance. No failed attempts were included in the

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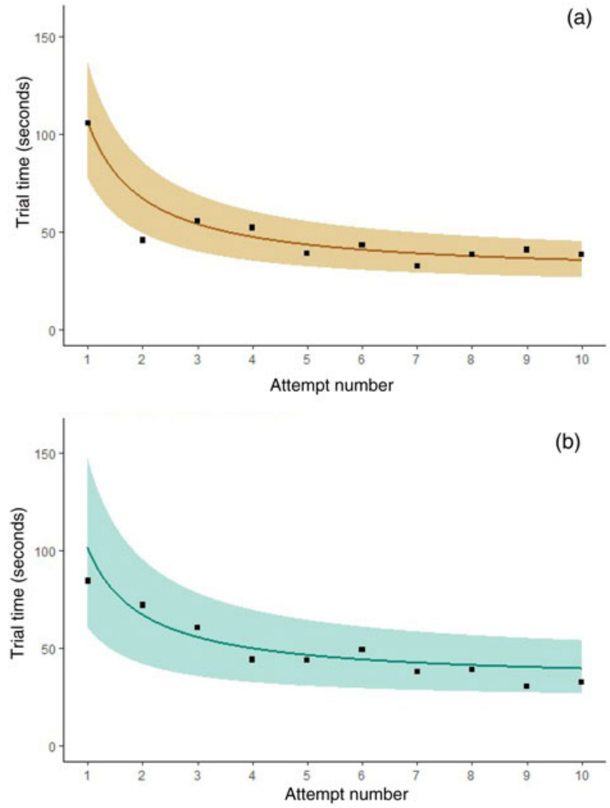

Fig. 2. Non-linear regression inverse learning curves for (a) endoscope group (learning rate value of 78.71 (95 per cent confidence interval (CI) = 56.46–101.86); asymptotic time of 27.87 seconds (95 per cent CI = 21.25–35.23)) and (b) microscope group (learning rate value of 68.62 (95 per cent CI = 37.49–103.62); asymptotic time of 32.83 seconds (95 per cent CI = 23.28–43.79)). A greater learning rate value indicates a slower rate of learning. Asymptotic time represents the best potential time after infinite attempts and, by extension, the time at which the learning curve plateaus. The coloured areas indicate approximate 95 per cent confidence intervals for the learning curve.

calculation of the mean time for each attempt. Bootstrapping was performed within each group to give an approximate 95 per cent confidence interval for the 'best performance' time and learning rate. All analyses were performed in *R* statistical software.[14]

$$time(attempt) = a + \frac{b}{attempt}$$

Results

The inverse curves fitted to the mean times for both groups are displayed in Figure 2. The R^2 value was 0.41, where 1 indicates a perfect fit where the model explains all variability of data around its mean.

There was no significant difference in learning rate ($p = 0.41$) or best potential time ($p > 0.05$) between the two groups. There was also no significant difference in the mean number of ventilation tube drops ($p > 0.05$).

Participant demographics are displayed in Table 1. Gender and handedness were roughly evenly distributed across both groups. All years of the Cardiff University School of Medicine (years 1–5, plus intercalating students) and Swansea University Medical School (post-graduate only, years 1–4) were represented. No participants reported formal training in either the endoscopic approach or microscopic technique.

Table 1. Participant demographics

Parameter	Endoscope group (*n*)	Microscope group (*n*)
Total	34	38
Males/females	16/18	17/21
Right-/left-handed	28/6	34/4

Discussion

Research question one

How does the rate of learning differ when a novice surgeon is trained to perform a middle-ear surgical procedure using an endoscope as opposed to a microscope? The lack of a significant difference suggests that the two methods have statistically indistinguishable rates of learning.

Research question two

Is there any difference in final proficiency when performing middle-ear surgery using an endoscope or a microscope? No significant difference in the best potential procedure time, or number of drops per participant, could be found between the two experimental groups. This suggests that final proficiency is similar when performing myringotomy and ventilation tube insertion using an endoscope or a microscope.

Research question three

Is the learning curve a justifiable reason for resistance in the adoption of an endoscopic approach for middle-ear surgery? The lack of a significant difference in rates of learning between the two groups does not support resistance in the adoption of endoscopic ear surgery on the basis of a learning curve alone. This is corroborated by the findings of Martellucci *et al*., who carried out a pilot study comparing the feasibility and outcomes of myringotomy and ventilation tube insertion with an endoscope versus a microscope.[7] Those authors found no significant difference in operative times or complication rates, and concluded that an endoscopic approach is a viable alternative to the operating microscope.[7] Similar findings have been reported in studies assessing the endoscopic approach in more complex middle-ear surgical procedures, with many concluding that the endoscope in fact improves optimal proficiency.[4,15]

Operative time may not be a suitable marker for rates of learning. Iannella *et al*. assessed operative times and learning curve in 20 endoscopic and 20 microscopic stapedectomies over 12 months.[8] Although average operative time was significantly longer in the endoscopic group, the length of the procedure decreased as the surgeon gained experience. When only comparing the operative times from the last 10 patients in each group, there was no significant difference in procedure times. However, Iannella *et al*. assessed the endoscopic learning curve in microscopically trained surgeons.[8] This study is unique in that it used novice surgeons, and is therefore more relevant to informing surgical curricula.

Our study findings have potential limitations. In using the Bradford Grommet Trainer, we eliminated factors that can give the microscope an advantage over the endoscope, such as anatomical variation and haemorrhage.[2,16,17] This provides an abnormally clear endoscopic view of the tympanic membrane. Maintaining adequate haemostasis without suction

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represents one of the major challenges of endoscopic ear surgery.[3,10] Conversely, the simulator also presents a simplified version of ear canal anatomy, which gives an unrealistically broad microscopic view of the middle ear. Alternative simulators could be considered for future research; for instance, an ovine ear model for fully endoscopic stapedectomy training has been validated.[18] Staff variation across multiple sites is likely to diminish the effect of collection biases. Participants experience an altered angle of approach and view of the middle ear depending on handedness.[2] Separately, video-gaming experience has been reported to improve endoscopic performance, with early studies suggesting superior hand–eye co-ordination, visualisation skills and faster reaction times.[19] These factors were not controlled.

The best potential times rely on statistical estimates of a learning curve plateau based on 10 ventilation tube insertions. Whilst not directly comparable to this study, Dogan and Bayraktar found that mastering endoscopic tympanoplasty takes approximately 60 operations for a surgeon already trained in the microscopic technique.[9] In addition, Tseng *et al.* described operative time plateauing only after 150 tympanic membrane perforation repairs.[10] Other studies that investigated the learning curves of surgical procedures, such as that by Feldman *et al.*, also used more than 10 repetitions of a task.[11] Operating theatre availability restricted the number of repetitions possible per participant in this study. Ten insertions do, however, yield sufficient data to demonstrate a learning curve and calculate an asymptote, which is a statistical prediction of a learning curve plateau.

- Rate of learning is often cited as a deterrent in the use of endoscopic ear surgery
- Assessments of the endoscopic ear surgery learning curve have not directly compared the endoscopic approach with the microscopic technique
- Little research has assessed overall rate of learning to estimate the point of curve plateau
- This multi-centre, prospective, randomised study assessed endoscopic and microscopic learning curves in 72 students simulating myringotomy and ventilation tube insertion
- Clarification of this perceived deterrent should influence surgical training programmes, and would impact expected surgical outcomes

Whilst the learning curve must not be the only consideration when determining the benefits and drawbacks of endoscopic middle-ear surgery, the suggestion that rate of learning is comparable in novice surgeons is valuable. If there is no difference in rate of learning, fewer arguments remain in support of favouring the traditional microscopic approach for middle-ear surgery. This should influence surgical training programmes, and would impact expected surgical outcomes.

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Competing interests. None declared

References

1 Preyer S. Endoscopic ear surgery – a complement to microscopic ear surgery. *HNO* 2017;**65**:29–34
2 Kozin ED, Lee DJ. Basic principles of endoscopic ear surgery. *Oper Tech Otolaryngol Head Neck Surg* 2017;**28**:2–10
3 Akyigit A, Sakallıoglu O, Karlidag T. Endoscopic tympanoplasty. *J Otol* 2017;**12**:62–7
4 Patel J, Aiyer RG, Gajjar Y, Gupta R, Raval J, Suthar PP. Endoscopic tympanoplasty vs microscopic tympanoplasty in tubotympanic CSOM: a comparative study of 44 cases. *Int J Res Med Sci* 2017;**3**:1953–7
5 Pothier DD. Introducing endoscopic ear surgery into practice. *Otolaryngol Clin North Am* 2013;**46**:245–55
6 Tseng CC, Lai MT, Wu CC, Yuan SP, Ding YF. Comparison of the efficacy of endoscopic tympanoplasty and microscopic tympanoplasty: a systematic review and meta-analysis. *Laryngoscope* 2017;**127**:1890–6
7 Martellucci S, Pagliuca G, de Vincentiis M, De Virgilio A, Fusconi M, Gallipoli C *et al.* Myringotomy and ventilation tube insertion with endoscopic or microscopic technique in adults: a pilot study. *Otolaryngol Head Surg* 2015;**152**:927–30
8 Iannella G, Magliulo G. Endoscopic versus microscopic approach in stapes surgery: are operative times and learning curve important for making the choice? *Otol Neurotol* 2016;**37**:1350–7
9 Doğan S, Bayraktar C. Endoscopic tympanoplasty: learning curve for a surgeon already trained in microscopic tympanoplasty. *Eur Arch Otorhinolaryngol* 2017;**274**:1853–8
10 Tseng C-C, Lai M-T, Wu C-C, Yuan S-P, Ding Y-F. Learning curve for endoscopic tympanoplasty: initial experience of 221 procedures. *J Chin Med Assoc* 2017;**80**:508–14
11 Feldman LS, Cao J, Andalib A, Fraser S, Fried GM. A method to characterize the learning curve for performance of a fundamental laparoscopic simulator task: defining “learning plateau” and “learning rate”. *Surgery* 2009;**146**:381–6
12 Jesudason WV, Smith I. How we do it: the Bradford Grommet Trainer: a model for training in myringotomy and grommet insertion. *Clin Otolaryngol* 2005;**30**:371–3
13 Mahalingham S, Awad Z, Tolley NS, Khemani S. Ventilation tube insertion simulation: a literature review and validity assessment of five training models. *Clin Otolaryngol* 2016;**41**:321–6
14 R Core Team. *R: A Language and Environment for Statistical Computing*. Vienna: R Foundation for Statistical Computing, 2016
15 Huang TY, Ho KY, Wang LF, Chien CY, Wang HM. A comparative study of endoscopic and microscopic approach type 1 tympanoplasty for simple chronic otitis media. *J Int Adv Otol* 2016;**12**:28–31
16 Bakshi SS. Letter to the Editor on “Myringotomy and ventilation tube insertion with endoscopic or microscopic technique in adults: a pilot study”. *Otolaryngol Head Neck Surg* 2015;**153**:1076
17 Musbahi O, Aydin A, Al Omran Y, Skilbeck CJ, Ahmed K. Current status of simulation in otolaryngology: a systematic review. *J Surg Educ* 2017;**74**:203–15
18 Cordero A, Benitez S, Reyes P, Vaca M, Polo R, Pérez C *et al.* Ovine ear model for fully endoscopic stapedectomy training. *Eur Arch Otorhinolaryngol* 2015;**272**:2167–74
19 van Dongen KW, Verleisdonk E-J, Schijven MP, Broeders IA. Will the Playstation generation become better endoscopic surgeons? *Surg Endosc* 2011;**25**:2275–80