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Assessment of tympanic membrane perforation size using ImageJ software by ENT clinicians of different grades

Bhargavi Chandrasekar, Kristijonas Milinis, Natalie Lowe, Sujata De and Sunil D Sharma

ENT Department, Alder Hey Children's NHS Foundation Trust, Eaton Road, Liverpool, UK

Main Article

Sunil D Sharma takes responsibility for the integrity of the content of the paper

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Corresponding author:
Sunil D Sharma;
Email: sunilsharma@doctors.org.uk

Abstract

Objective. To compare visual estimation versus ImageJ calculation of tympanic membrane perforation size in the paediatric population between clinicians of different experience.
Methods. Five images of tympanic membrane perforations in children, captured using an otoendoscope, were selected. The gold standard was the ImageJ results by one consultant otologist. Consultants, registrars and Senior House Officers or equivalent were asked to visually estimate and calculate the perforation size using ImageJ software.
Results. The mean difference in variation from gold standard between visual estimation and ImageJ calculation was 12.16 per cent, 95 per cent CI (10.55, 13.78) $p < 0.05$, with ImageJ providing a more accurate estimation of perforation. Registrars were significantly more accurate at visual estimation than senior house officers. There was no statistically significant difference in ImageJ results between the different grades.
Conclusion. Using ImageJ software is more accurate at estimating tympanic membrane perforation size than visual assessment for all ENT clinicians regardless of experience.

Introduction

Tympanoplasties, performed for tympanic membrane perforations, aim to protect the middle ear from external pathogens. The importance of tympanic perforation size as a prognostic factor for myringoplasty success has been debated in the literature.[1] However, a recent systematic review found that small perforations had a higher rate of successful tympanic membrane closure in children.[2] Therefore, accurate estimation of perforation size pre-operatively can aid patient counselling and informed consent.

Perforation size is often estimated by the clinician pre-operatively in clinic with otoscopy or otoendoscopy. This method is subject to gross errors when compared to objective photographic size.[3] Improvements in technology have seen the development of software programs which can measure such perforations with greater accuracy, but in reality they are rarely used in clinical practice.[4,5] One such analysis software, ImageJ, has been shown to provide a cheap and reliable method of estimating tympanic perforation size.[5]

Our aim is to compare visual estimation versus ImageJ calculation of tympanic perforation size in the paediatric population among clinicians with different levels of experience.

Materials and methods

Five photographs of tympanic membranes were selected from a cohort of paediatric patients with tympanic membrane perforation who subsequently underwent a primary tympanoplasty at a tertiary paediatric otolaryngology unit. Patients were aged 11–16 years old. The aetiology of the perforation included a single episode of acute otitis media, history of recurrent acute otitis media and previous grommet surgery. All perforations were described as central perforations and were located anteriorly, inferiorly or in the anterior–inferior quadrant. Two patients had bilateral pathology; one patient had bilateral perforations managed surgically and one patient had contralateral squamous chronic otitis media. All patients underwent endoscopic myringoplasty. Graft material used included tragal cartilage and biodesign graft or biodesign alone. Patients with cholesteatoma were excluded. Photos were taken in the out-patient department, using a Henke Sass Wolf 0 degrees rigid sinus endoscope, and uploaded to the picture archiving and communication system.

The gold standards for comparison in our study were the perforation sizes generated by a paediatric consultant otologist using ImageJ 1.53.[6] This was chosen because Ibekwe *et al.*'s study found ImageJ to be devoid of inter-observer variation between consultant otologists therefore highlighting its reliability in this group and validating its use.[7] The chosen images were also assessed independently by 16 other ENT clinicians who currently work in ENT departments within the region. Clinicians were either consultants, registrars or senior house officers.

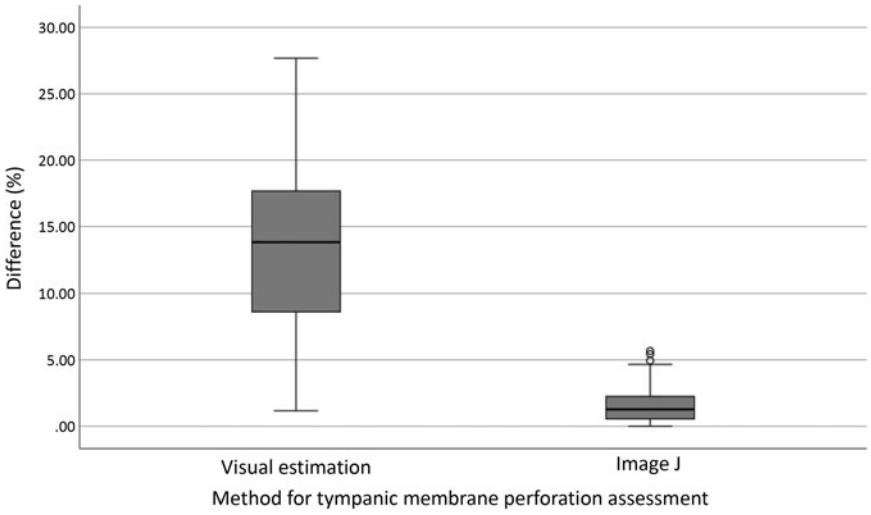

Figure 1. Variation from gold standard for visual estimation and for ImageJ calculation. The dark horizontal line in the box plots represents the means and the upper and lower boundaries shown by the vertical lines on either side of each box plot represent the confidence intervals. Please ignore the circles above the ImageJ box plot.

Clinicians first provided a visual estimation of the size of the perforation as a percentage of the total tympanic membrane including the pars tensa and flaccida. Using ImageJ, the same clinicians traced the edges of the perforation and the tympanic membrane using a mouse or mouse pad in turn. ImageJ software calculated the area for both drawings in pixels^2 (Figure 1). The percentage perforation is calculated using the equation P/T*100 where P is the area (pixels^2) of the tympanic membrane perforation and T is the area (pixels^2) of the entire tympanic membrane including the perforation.

The variations between visual estimations and gold standards and ImageJ calculations and gold standards were calculated. The differences between the two methods were compared using 2-tail student's *t*-test. The differences between different grades were analysed using analysis of variance (ANOVA). Data were analysed using IBM® SPSS® Statistics version 21.1.

Results and analysis

The average difference from gold standard for visual estimation for all clinicians was 13.79 per cent (SD ± 6.28) and 1.62 per cent (SD ± 1.33) using ImageJ. This equates to a mean difference in deviation between methods of 12.16 per cent, 95 per cent CI (10.55, 13.78) $p < 0.05$ (Figure 2). On average all clinicians' visual estimation was 2.04 times greater than the gold standard.

The differences from gold standard for each grade are demonstrated in Table 1 and Table 2. On average, registrars were the most accurate at visually estimating perforation size, followed by consultants and senior house officers (SHOs). The difference between registrars and SHOs was statistically significant ($p < 0.05$) and the differences between consultants and other grades were not. In comparison, consultants performed best using ImageJ but the differences among all grades were small and not statistically significant.

Discussion

Our study highlights that clinicians are poor at visually estimating perforation size. Hampal *et al.* first compared visual estimation against an objective drawing and found greater clinical experience did not improve accuracy of estimation, with SHOs performing best, followed by registrars and finally consultants.[3] Our findings are similar to those of Hsu *et al.* who reported that registrars were more accurate than consultants, but they did not include SHOs in their study whilst we found no statistical significance between registrars and consultants.[4] Regardless, in our study, the average difference between

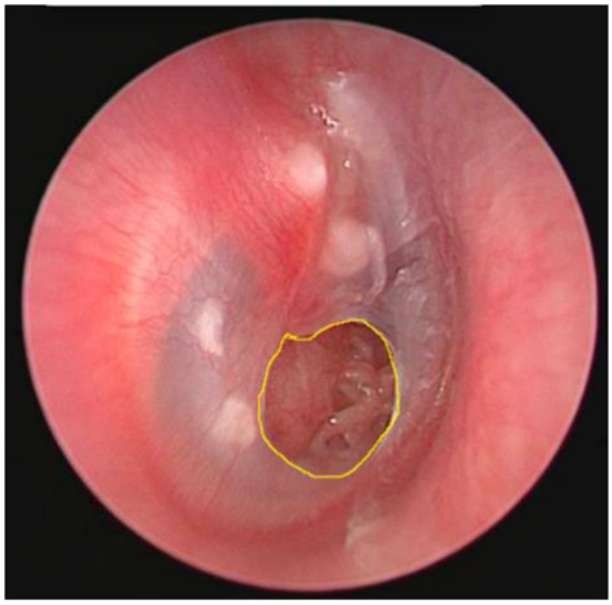

Figure 2. Assessment of perforation size area in pixels as generated on ImageJ. The yellow outline represents the assessment of the perforation edges on ImageJ.

Table 1. Difference between visual estimation and gold standard

Users	Mean difference	Confidence interval
Consultants	14.35	10.73–17.98
Registrars	10.80	8.95–12.84
SHOs	16.48	13.67–19.29

SHOs = Senior House Officers

Table 2. Difference between ImageJ and gold standard

Users	Mean difference	Confidence interval
Consultants	1.48	0.89–2.06
Registrars	1.69	1.04–2.35
SHOs	1.64	1.10–2.18

SHOs = Senior House Officers

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visual estimation and the ImageJ calculation derived by a consultant otologist was large for all groups, including registrars who were still on average inaccurate by 10 per cent.

Accurate estimation of perforation size can support parent or guardian counselling regarding conversative versus surgical management of their child's tympanic membrane perforation. Perforation size has been shown to be the single most important factor in spontaneous closure and therefore a more accurate tool of assessment is needed to aid patient counselling on the likely prognosis.[8] However, other patient factors such as active infection and contralateral otitis media with effusion, and surgical factors such as surgeon experience, can influence myringoplasty outcomes and should be considered.[2]

ImageJ has been described as a reliable method for tympanic perforation estimation which is freely available to download.[5] Ibekwe *et al.* found it to be devoid of inter-observer variability between two experienced otologists. In clinical practice, patients with tympanic membrane perforations may be reviewed by clinicians of different grades and the reliability of ImageJ within these groups has not previously been studied.[5] We found that the ImageJ calculations by all grades were more accurate than visual estimation. The differences among the groups using ImageJ were small and not statistically significant, suggesting that ImageJ can be reliably used amongst clinicians of varying experience.

The accuracy of tympanic membrane perforation calculation using ImageJ depends on high-quality photos using an otoendoscope and a computer system to record and download images prior to upload onto ImageJ. One described potential limitation of an otoendoscope is the inability to focus the entire rim of the tympanic membrane in one single image.[5] A previous study using cadaveric temporal bone models widened the external auditory canal to ensure the tympanic membranes were photographed occupying only the central three-quarters of the field of view.[3] Young children are less compliant with examination and multiple attempts to capture high-quality, in-focus images may be futile. In addition, uploading and tracing the image on ImageJ is time consuming and potentially unfeasible within a patient's allocated clinic slot.

Otoendoscopy provides additional benefits for the clinical consultation. Image capture allows clinicians to compare their current findings to previous examinations particularly if they have not assessed the patient previously themselves. Furthermore, traditional examination with an otoscope or microscope excludes the patient or carer from observing the examination. Otoendoscopy, however, allows the clinician to share their findings and therefore engage the user.[9] Wong *et al.* found that adults reported greater satisfaction regarding communication and technical quality when video otoscopy was utilised in an out-patient clinic compared to standard microscopy.[9] In the paediatric population, improved parental satisfaction and patient centeredness with video-endoscopy was found with children examined in the emergency department.[10] The use of video-otoscopy or video capture at a high rate per frame with direct upload to ImageJ may negate some limiting factors to support its introduction into daily clinical practice.

Our study is limited by the small number of images of similar perforation sizes in similar positions which do not reflect the full spectrum of perforations clinicians will encounter. Whilst variation in perforation size may affect the accuracy of visual estimation, we do not expect it to affect the ImageJ calculation and therefore still consider ImageJ a reliable tool for assessment. A paediatric consultant otologist's ImageJ results were selected as the gold standard which can be subject to error. The authors justify the choice of gold standard, given the reliability of results by consultant otologists demonstrated by Ibekwe *et al.*[7] In their study, two consultant otologists reviewed 100 tympanic membranes using ImageJ software and conventional direct vision otoscopy and found the latter to be devoid of inter-user error.

- Tympanic membrane perforation size is an important prognostic factor for myringoplasty success
- Estimation of perforation size using otoscopy is subject to error
- Use of ImageJ software for analysing otoendoscopic images has been shown to be a reliable method of calculating perforation size by consultant otologists
- Using ImageJ software is reliable when used by ENT clinicians of all grades and not just consultant otologists

Conclusion

ImageJ is a reliable method for assessment of tympanic membrane perforation size and can be used by all ENT clinicians regardless of experience. However, we highlight practical limitations that should be addressed to facilitate its use in daily clinical practice.

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Competing interests. None declared.

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