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Online Only Main Article

Quantitative analysis of tympanic membrane perforation: a simple and reliable method

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Abstract

Background: Accurate assessment of the features of tympanic membrane perforation, especially size, site, duration and aetiology, is important, as it enables optimum management.

Aim and objectives: To describe a simple, cheap and effective method of quantitatively analysing tympanic membrane perforations.

Materials and methods: The system described comprises a video-otoscope (capable of generating still and video images of the tympanic membrane), adapted via a universal serial bus box to a computer screen, with images analysed using the Image J geometrical analysis software package. The reproducibility of results and their correlation with conventional otoscopic methods of estimation were tested statistically with the paired *t*-test and correlational tests, using the Statistical Package for the Social Sciences version 11 software.

Results: The following equation was generated: $P/T \times 100$ per cent = percentage perforation, where P is the area (in pixels^2) of the tympanic membrane perforation and T is the total area (in pixels^2) for the entire tympanic membrane (including the perforation). Illustrations are shown. Comparison of blinded data on tympanic membrane perforation area obtained independently from assessments by two trained otologists, of comparative years of experience, using the video-otoscopy system described, showed similar findings, with strong correlations devoid of inter-observer error ($p = 0.000$, $r = 1$). Comparison with conventional otoscopic assessment also indicated significant correlation, comparing results for two trained otologists, but some inter-observer variation was present ($p = 0.000$, $r = 0.896$). Correlation between the two methods for each of the otologists was also highly significant ($p = 0.000$).

Conclusion: A computer-adapted video-otoscope, with images analysed by Image J software, represents a cheap, reliable, technology-driven, clinical method of quantitative analysis of tympanic membrane perforations and injuries.

Key words: Tympanic Membrane; Photography; Endoscopy

Introduction

Tympanic membrane perforation is a common phenomenon encountered by both general practitioners and ENT surgeons. Accurate evaluation of the tympanic membrane perforation is an important guide for informed management of this problem. The causes of tympanic membrane perforations vary from trauma, infection and tumours to iatrogenic injuries.[1,2] By far the commonest cause in the developing world is infection; this aetiology contributes to approximately 90 per cent of tympanic membrane perforations in Nigeria.[1]

The assessment of tympanic membrane perforation size, site, duration, state and aetiology is important when considering management.[3] Most acute perforations heal spontaneously. However, a tympanic membrane perforation larger than 25 per cent of the size of the entire tympanic membrane is thought to be unlikely to heal with conservative management, and probably to require surgical intervention such as myringoplasty or tympanoplasty.[4–6]

Therefore, it is imperative that accurate measurement of tympanic membrane perforation size, and detailed examination of other features, be performed in order to enable objective management. Commonly employed methods of quantitative analysis of tympanic membrane perforation include crude estimation of the percentage perforation via clinical otoscopy and micro-otoscopy with an operating microscope. However, these methods have their flaws. Some computer-based methods have been developed, such as the Cal Area system,[7] but appear expensive and cumbersome.

Therefore, we aimed to develop a simple, inexpensive and accurate method of quantitative analysis of tympanic membrane perforations.

Materials and methods

The tympanic membrane was viewed with a Welch-Allyn Compac video-otoscope system (model

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23120 (NTSC) and 23120P (PAL); Welch-Allyn, Skaneateles Falls, NY 13153-0220 USA).[8,9] Images were adapted through a universal serial bus (USB) box (Cute TV model 03020701; Cool drivers, Clear water Florida 33762, USA) and displayed and recorded on a computer (laptop or desk top). The video-otoscope was easily manoeuvrable, similar to a conventional otoscope. Both still and video images could be obtained and stored by this system.

Using the Image J (version 1.35j) geometrical analysis software package (Wayne Rasband, National Institutes of Health, Rockville, Maryland, USA),[10] the area of the perforation (P) and that of the entire tympanic membrane (T) were traced and calculated, irrespective of the size and shape of the perforation. The percentage area of perforation (P/T × 100 per cent) was then obtained.

This computerised video-otoscope system enabled the operator to view dynamic (active) images of the tympanic membrane perforation, revealing the state of the tympanic membrane (dry or wet), the edges of the tympanic membrane perforation (ragged or smooth), and the state of the middle ear (including any active points of discharge). The operator was also able to view still images, allowing accurate determination of perforation number, percentage and site (i.e. anterosuperior, posterosuperior, anteroposterior, posteroinferior, central or marginal).

We have used this method of quantitative analysis for the past three years (2005 to 2008), with great success. Figure 1 shows a typical arrangement of the computer, with Image J software, and adapted video-otoscope.

The reproducibility and reliability of data generated by this apparatus were tested by statistically analysing results independently obtained from the same patients by two ENT surgeons (of comparative experience, trained and currently practicing in the same centre), using conventional, visual, otoscopic estimation of tympanic membrane perforation, for 100 tympanic membrane perforation cases. The two ENT Surgeons were blinded to further eliminate bias. These results were analysed, and correlation with video-otoscopy Image J results assessed, using the paired *t*-test and the Pearson correlational tests (level of significance for p was set at 0.05), using the Statistical Package for the Social Sciences version 11 software (SPSS Inc, Chicago, Illinois, USA).

FIG. 1
Instruments for recording and analysis of tympanic membrane perforation.

Results

The tympanic membrane perforation areas obtained via video-otoscopy by the two independent otologists (referred to as experts one and two) were similar, with strong correlations devoid of inter-observer error ($p = 0.000$, $r = 1$); Figure 2. By comparison, the two otologists' results obtained via conventional, direct vision otoscopy were also significantly correlated, but showed some inter-observer variation ($p = 0.000$, $r = 0.896$); Figure 3. The correlation between the results obtained by each otologist, for each of the two methods, was also highly significant ($p = 0.000$). These findings are illustrated in Table I.

In addition, the system generates images with good dynamic colour image resolution (600–800 megapixels). It was easy to determine the edges of the tympanic membrane perforation and of the entire tympanic membrane, and thus to obtain an automatic calculation of the area of the perforation and of the entire tympanic membrane in pixels^2, irrespective of the perforation's size and shape. The following equation was derived: P/T × 100 per cent = percentage perforation. Figure 4 illustrates use of the video-otoscope with Image J software analysis.

Discussion

The equipment used in the above system is affordable; in our institution, only the video-otoscope head and handle required purchase. A laptop or personal computer can be used in place of the video-otoscope screen. The USB box or TV tuner box[11] is readily and cheaply available, while the Image J geometric analysis software package is freely available on the internet. This system can be assembled by individual

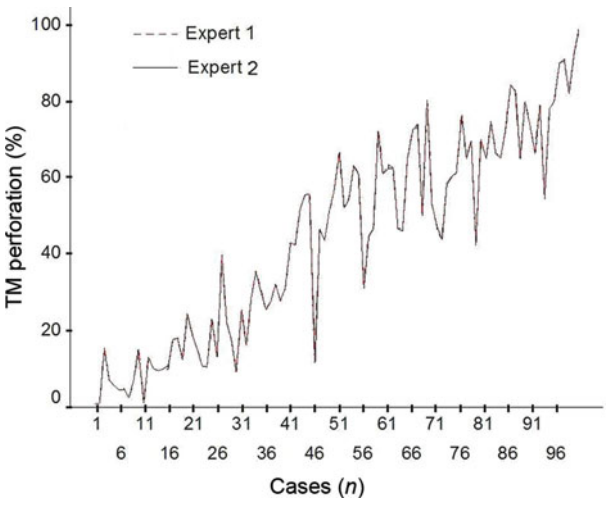

FIG. 2
Comparison of assessment of tympanic membrane perforation area via video-otoscopy, by the two otologists.

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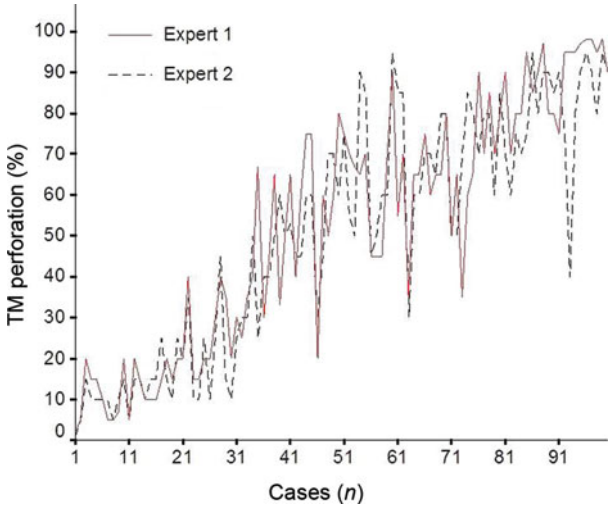

FIG. 3

Comparison of assessment of tympanic membrane perforation area via conventional otoscopy, by the two otologists.

clinicians and researchers at a moderate cost of approximately US$1500. The system is easy to operate, and the television USB connection also enables the use of free educational tools (via television and frequency modulated radio channels).

The results generated by the video-otoscopy system were reproducible and devoid of inter-observer error, as tested by two experienced otologists; see Table I and Figures 2 and 3. The video-otoscopy system was thus shown to have an advantage over conventional methods of tympanic membrane perforation area assessment. The video-otoscopy data also correlated significantly ($p = 0.000$) with blinded results obtained with conventional otoscopy by the same otologists; this correlation indicates a high probability of accurate measurement.

Other methods of assessment of tympanic membrane perforations can characterise the location and shape of the perforation but cannot accurately estimate its size.[12] Otologists commonly estimate these features by visual inspection via a clinical otoscope or microotoscope (operating microscope). The former method is limited by inter-observer error, while the latter (which measures the diameter of the perforation) might not give a true representation of perforation

TABLE I

CALCULATION OF TYMPANIC MEMBRANE PERFORATION AREA: COMPARISON OF TWO METHODS AND TWO OPERATORS*

Comparative analysis	Tests (n)	r	p
Expert 1 *vs* 2, conventional otoscopy	100	0.896	0.000
Expert 1 *vs* 2, video-otoscopy	100	1.000	0.000
Conventional *vs* video-otoscopy, expert 1	100	0.927	0.000
Conventional *vs* video-otoscopy, expert 2	100	0.930	0.000

*Results for percentage areas of TM perforations for video-otoscopy and conventional otoscopy were compared by paired samples correlation.

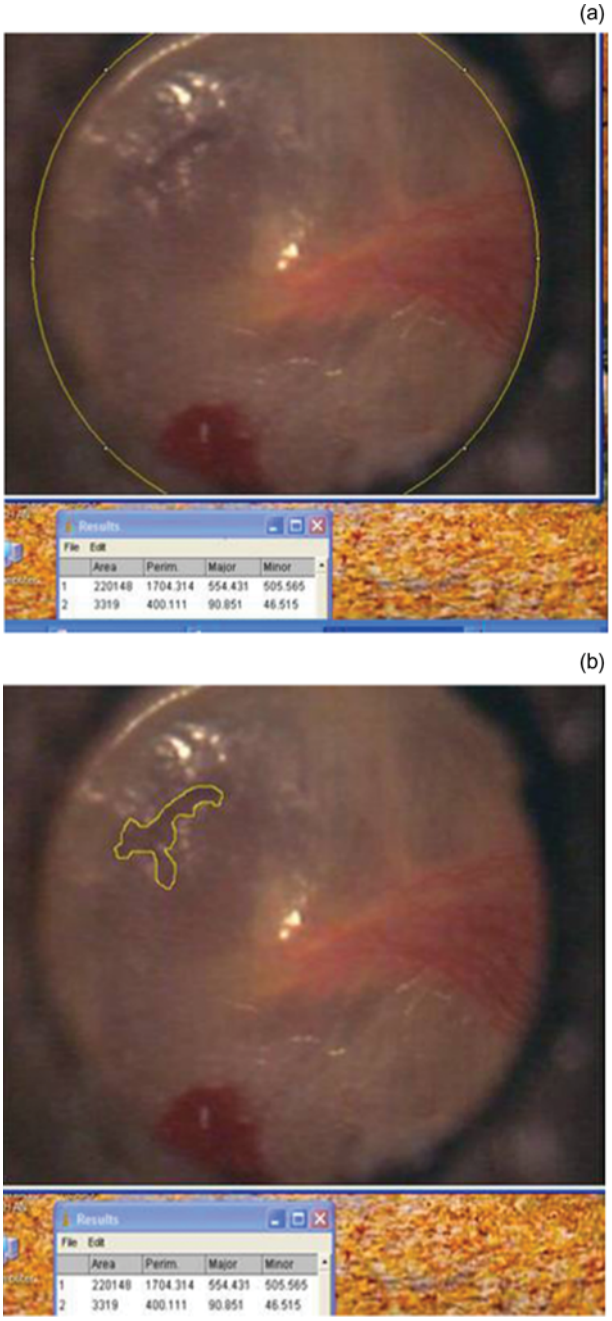

FIG. 4

Analysis of tympanic membrane perforation area by Image J software. (a) Assessment of the entire tympanic membrane area, and (b) assessment of the ragged perforation, with automatically generated perforation area shown below the image.

size, considering the many perforation shapes possible.[13] The Cal Area software package, a tympanic membrane perforation assessment system developed in Japan,[7] also appears reliable, but is expensive and mostly used in industry.

The only potential limitation of the video-otoscopy Image J system (considering the complex anatomy of the tympanic membrane)[14] is the inability to focus on the entire rim of the tympanic membrane within a single view. A small segment of the tympanic membrane rim (either the epitympanic or hypotympanic

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segment) may be out of focus in a single image. However, the effect of this shortcoming is eliminated by the ability of the Image J software to reconstruct the 'missing' segment.

In our current and earlier work,[1,15] we have been able to establish the computer adapted video-otoscope Image J system as an accurate and superior tool for the measurement of tympanic membrane perforation area, compared with conventional methods of measurement.

Conclusion

The computer adapted video-otoscope Image J system is a cheap, reliable, technology-driven, clinical method of quantitative analysis of tympanic membrane perforations and injuries. We hereby recommend its use, especially in the developing world.

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Dr T S Ibekwe takes responsibility for the integrity of the content of the paper.
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