A computer program to calculate the size of tympanic membrane perforations

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Chronic suppurative otitis media is characterized by the presence of a persistent perforation of the tympanic membrane. Accurate estimation of the perforation size is helpful in clinical management and research. In this study, a computer program was developed to calculate the percentage of a perforation relative to the whole tympanic membrane including the pars tensa and pars flaccida. In order to demonstrate the variability of estimations of perforation size by different surgeons, we calculated the percentage of perforation for four tympanic membranes, and compared the results with those estimated by five experienced otologists and 10 senior residents. The results show that the estimations from both otologists and residents departed from the values calculated by the computer program quite substantially. Beside, the variance of the estimation is large. However, the variances of computer calculation are quite small, which means that the results obtain from different users are quite consistent. Therefore, we concluded that this program is necessary and useful to evaluate the size of the perforation as the differences in visual estimations can be very big and the variances can be large for different individuals, even by experienced otologists.

Keywords chronic otitis media perforation size computer program

Chronic suppurative otitis media is characterized by the presence of a persistent perforation of the tympanic membrane. The size of the perforation may vary from a pinhole to a large subtotal defect confined to the pars tensa. Clinically, the perforation size is one of the most important prognostic factors for tympanoplasty. For those patients who choose hearing aids instead of surgery as a way of aural rehabilitation, the size of the perforation also affects the results of real ear measurements. A number of studies have found that the size of tympanic membrane perforation is closely related to the middle ear sound transmission. Therefore accurate estimation of the perforation size is helpful in clinical management and research for patients with chronic otitis media. In the literature, the size of the tympanic membrane perforation is usually assessed by otologists through visual inspection. Otherwise, the diameter of the perforation can also be measured using an operating microscope. However, visual inspection may be subject to individual errors. The diameter of a perforation may not represent the real size because not all perforations are spherical. In this study, we develop a computer program that can calculate the percentage of a perforation relative to the whole tympanic membrane including the pars tensa and pars flaccida. In order to demonstrate the variability of estimations by different surgeons, we calculated the percentage of perforation for four tympanic membranes, and compared the results with those estimated by five experienced otologists and 10 senior residents.

Materials and methods

Material and subjects

Image pictures of tympanic membranes from four different patients with chronic otitis media were obtained from a textbook fist (Fig. 1a–d). As shown in Fig. 1, these pictures represent different sizes of tympanic membrane perforation. Figure 1a is a small perforation. Figure 1b,c display medium-sized perforations, while Fig. 1d is a subtotal perforation.
Figure 1. Image pictures of tympanic membrane from four different patients with chronic otitis media.

These images were shown one by one, to five experienced otologists and 10 senior residents in this department. They were asked to estimate the percentage of the perforation relative to the tympanic membrane, then the images were loaded into the program and the percentage of the perforation for each tympanic membrane was calculated by five different doctors.

**COMPUTER PROGRAM**

The computer program was named CALAREA (CALculation of AREAs). The CALAREA was designed to determine the ratio of area of two selected regions. It is implemented by using MATLAB, a powerful mathematical function package. The program is translated to machine code for executing directly as a command under Microsoft Windows and can be delivered to the users with the run-time library files provided. At this version of CALAREA, only joint photographic experts group images can be read by the program. Images with different dimensions will be adjusted proportionally to fit the screen. Pictures of the tympanic membrane were loaded onto the main-screen of the program. The perforation margin was outlined first by using a mouse. The perforation region was defined by such a sequence of points. Then the boundary of the whole tympanic membrane was identified and marked likewise. A set of parametric periodic cubic spline curves was constructed to interpolate to the marked regions. The area volume of these to designated regions was automatically calculated and shown at the lower panel of the main screen. The ratio of these two areas was displayed at the right lower corner of the main screen. One example is given in Fig. 2. In this study, the program was tested by calculating tympanic membrane perforations with different sizes and shapes.

**Results**

The mean perforation sizes (in percentage) of the four tympanic membranes estimated by otologists and residents is shown in Table 1 and Fig. 3. In addition, the mean values and standard deviations calculated using the computer program by five different doctors are shown. The mean calculated by the computer program should be the closest estimate to the real percentage of tympanic membrane perforation for each picture. It is obvious that the estimations from both otologists and residents departed from the values calculated by the computer program quite substantially. Furthermore, the variance is large, especially in Fig. 1b,c, which represent medium-sized perforations. The mean percentage of perforation for all four images estimated by otologists and residents are significantly different from the estimations by the computer program (paired t-test, $P < 0.01$). To our surprise, the experienced otologists tended to overestimate the perforation size. Their estimates are more inaccurate than residents' estimates. For the computer program, the variances are quite small, which means that the results obtained from different users are quite consistent.

Table 1. The mean perforation sizes of the four tympanic membranes estimated by otologists, residents and calculated by the computer program

<table>
<thead>
<tr>
<th>Picture no.</th>
<th>Otologists, mean ± sd (%) (range)</th>
<th>Residents, mean ± sd (%) (range)</th>
<th>Computer program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fig. 1a</td>
<td>$13 \pm 5 (5-20)$</td>
<td>$10 \pm 4 (5-15)$</td>
<td>$4 \pm 0.1$</td>
</tr>
<tr>
<td>Fig. 1b</td>
<td>$32 \pm 13 (15-50)$</td>
<td>$26 \pm 7 (20-40)$</td>
<td>$18 \pm 0.2$</td>
</tr>
<tr>
<td>Fig. 1c</td>
<td>$54 \pm 14 (45-75)$</td>
<td>$43 \pm 17 (25-75)$</td>
<td>$40 \pm 0.4$</td>
</tr>
<tr>
<td>Fig. 1d</td>
<td>$86 \pm 9 (80-100)$</td>
<td>$79 \pm 12 (60-90)$</td>
<td>$69 \pm 0.7$</td>
</tr>
</tbody>
</table>
Discussion

There are two concerns pertaining to the accuracy of the program in calculating the percentage of the tympanic membrane perforation. First, the tympanic membrane is oblique. The inferior pole of the membrane lies further medially than the superior pole, at an inclination of about 40° relative to the floor of the auditory meatus. Therefore, the area on an image is different from the real area of the membrane. However, in this program, a ratio of two areas was calculated. The error caused by the oblique position of the membrane should be minimal. Secondly, the boundary of the fibrous annulus of the membrane is not always clear. So the area of the tympanic membrane may subject to individual difference in judgments. However, the small variances shown in the results obtained from five different operators of the programs exclude the possibility of large individual errors because of this consideration.

Conclusion

In summary, by using a computer program, the percentage of the tympanic membrane perforation can be estimated quite precisely. This program is necessary and useful to evaluate the size of the perforation as the differences in estimations can be very big and the variances can be large for different individuals, even by experienced otologists. Accurate estimation of the perforation size is helpful in clinical management and research for patients with chronic otitis media.

References