The shape of the osseous external auditory canal and its relationship to chronic external otitis

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ABSTRACT

Background
In literature and based on clinical observations, the shape of the osseous external auditory canal (OEAC) has often been suggested to be an etiological factor in chronic otitis externa (COE). However, to date no evidence has been presented to confirm this correlation. The aim of this study was to see whether evidence of such a correlation exists and if so, what shape of the OEAC is related to COE.

Methods
Using CT scans of two groups of patients (with and without COE), a novel and easy to use method was introduced to measure two dimensions of the OEAC: the pretympanic recess (the depth, DPTR) and anterior curvature (ACPTR). In addition, a descriptive classification of the entire OEAC was introduced.

Results
The proposed method was demonstrated to be useful as excellent inter-observer agreements were found (r=0.89). No significant differences in the descriptive classifications of the OEAC were observed between COE and the non-COE patients. The DPTR was significantly deeper in COE patients. For the ACPTR, no significant differences were observed.

Conclusions
Based on a new method of determining the DPTR, we demonstrate that the DPTR is significantly deeper in COE patients and that the shape of the OEAC is thus of importance in the pathogenesis of COE.
INTRODUCTION

Otitis externa (OE), or swimmer’s ear, is very common. In some individuals, the acute form of OE leads to chronic otitis externa (COE). This form is defined as a single episode lasting longer than four weeks or more than four episodes of OE in one year (1). It is estimated to affect 3% of the population (2,3) and has a proven negative impact on the quality of life of those inflicted (4). The shape of the osseous external auditory canal (OEAC) has often been suggested in literature to be an etiological factor in (C)OE (3,5-9). Although several classifications of the shape of the OEAC have been proposed (10,11) no attempt to correlate a certain classification to pathology has been published to date. Clinical observations suggest that certain shapes are likely to be involved in the development of a chronic inflammation as they hamper proper cleaning of the OEAC. We propose that the curvature of the OEAC, both anteriorly and inferiorly, are possible causes of this inability of (self) cleansing. Another hypothesis could be that both anterior and inferior curvatures lead to intertriginous eczema as sharper angles enable skin-to-skin contact when inflamed, thus perpetuating the inflammation and leading to chronic disease. The region of the anterior and inferior curvatures of the OEAC is called the pretympanic recess (PTR) and is located just before the tympanic membrane [Figure 1]. In literature, the nomenclature of this area varies and may bear names such as pretympanic sulcus (12-14), tympanic sulcus (15), pretympanic sinus (16-18) and inferior tympanic recess (19). Although the shape of the OEAC has been investigated before, no attempt was made to correlate the shape of the OEAC to pathology. The objective of this study was therefore twofold. First, we wanted to develop an ‘easy to use’ method in order to determine the dimensions of the PTR. Second, we wanted to investigate if and how the shape of the OEAC is related to COE.

MATERIAL AND METHODS

Participants

Retrospective analysis of high-resolution temporal bone CT images of two cohorts of adult ENT patients was performed. One cohort consisted of 42 patients (81 ears; 3 ears were excluded because of prior radicalisation) with COE with an indication for canalplasty and a second, control group consisted of 100 randomly selected patients (200 ears) who had received a cochlear implant (CI) in our centre and had no indication for canalplasty. Within our centre all COE cases are primarily treated conservatively. If conservative treatment fails all these cases are indicated for surgery regardless of the shape of the OEAC. Prior to canalplasty or CI-surgery, all patients underwent a high-resolution temporal bone CT scan as part of their pre-operative work-up. Before inclusion in this study, all patients in the CI group were checked for prior symptoms of (chronic) ear disease. If present, individuals were excluded from this study.
Figure 1. The dimensions of the pre tympanic recess (Depth and Anterior Curvature) depicted in coronal and axial plane. The DPTR is measured in the axial plane and the ACPTR is measured in the coronal plane. First slide is determined by the first contact made of the bony OEAC (*) and the last slide where the space of the PTR is totally closed (#) (arrowhead: area in front of drum). TM: tympanic membrane MJ: mandibular joint
Imaging of the osseous external auditory canal

All CT-scans were obtained using 125 mAs and 120 kV multi-detector row CT scanners (Philips Mx8000 and Philips Brilliance 64). Images were taken parallel to the orbitomeatal line. The thickness of the slides was 0.55 mm and the interval thickness was 0 mm. The window level was 600 HU and the window width was 3200 HU.

Measurement of the PTR dimensions

The depth of the PTR (DPTR) was measured in the axial plane. First, the first slide in which the inferior part of the OEAC was entirely visible was identified. Next, the number of slides inferiorly of this point was counted until the PTR was not visible anymore (i.e. a complete closure of the area in front of the tympanic membrane, [Figure 1]). Then, the number of slides was multiplied by 0.55 mm (thickness of one slide), resulting in the DPTR.

The anterior curvature of the PTR (ACPTR) was measured in the coronal plane and was determined in an almost similar way to the DPTR. Using the first slide in which the anterior part of the OEAC was completely visible, the starting point of the ACPTR was determined. Next, the number of slides was counted until the most anterior point next to the drum was reached [Figure 1]. Finally, the number of slides was multiplied by 0.55 mm, resulting in the ACPTR.

Data were evaluated in two separate ways. First, both ears of our patients were evaluated as belonging either to the normal group or to the COE group. Left and right ears were evaluated separately. Secondly, only affected ears of the COE group were studied. In bilateral cases, one of two the two COE ears (e.g. left or right) was used. In these cases, the ears were randomised based on the date of birth (1-15 left ear and 16-31 right ear). A similar way of randomisation was performed in the control group.

Validation of the measurement method

In order to assess and evaluate the method of measuring the DPTR and ACPTR, measurements of the DPTR and ACPTR were performed by two independent observers. In this validation session, only CT scans of the CI (control) group were used. In this way, the interobserver agreement of this technique could be determined, thus enabling us to identify whether the suggested technique produced reliable results.

Descriptive evaluation of the shape of the OE AC

In addition to the DPTR and the ACPTR, we evaluated various shapes of the OEAC shapes using a descriptive method developed by Virapongse et al. These shapes are determined in the axial plane (20). Using forced choice, the shape of the OEAC was determined after reviewing all CT images. The various shapes of the OEAC were numbered: 1: uniform, 2: slight flaring, 3: narrowing from posterior wall, 4: uniform convex, 5 narrowing of both walls lateral to drum, 6: narrowing at drum 7: uniform angulated and 8: uniform convex angulated.
Statistical analysis

Statistical analysis was carried out using SPSS 16.0.2 (Chicago, IL, USA). Data are expressed as number (%) and mean (SD). A Pearson product-moment correlation coefficient was computed to assess the inter-observer agreement between the two independent observers regarding DPTR and the ACPTR measurements. A Bland-Altman plot was made to investigate the existence of a fixed inter-observer bias or systematic error between our measurements. A Pearson product-moment correlation coefficient was determined to assess a possible association between DPTR and ACPTR and the left and right ear of the participants. Rho values were interpreted using the arbitrary but common scale of inter class comparisons values: 0.00 = no agreement, 0.01 to 0.20 = slight agreement, 0.21 to 0.40 = fair agreement, 0.41 to 0.60 = moderate agreement, 0.61 to 0.80 = substantial agreement, 0.81 to 0.99 = excellent agreement and 1.00 = perfect agreement. Independent T-tests were performed to check for significant changes between DPTR and the ACPTR of the OEAC between males and females and control patients and COE patients. Crosstabs and a Chi-square analyses were used to identify differences in the distribution of the various Virapongse shapes classified. *P* values of less than 0.05 were considered statistically significant.

RESULTS

Study population

Patient characteristics are depicted in [Table 1]. The mean age of the participants was 52.7 years (range 18 – 85 years, 41% males) in the COE group and 57.6 years (range 18- 82, 48% males) in the control group. In seven patients in the COE group exostoses were observed. In one of these seven patients, bilateral COE was present. In 9 cases bilateral COE was present. Of the included CT-scans, both ears of the patient were examined. In the COE-group, 3 right ears and 1 left ear were excluded because of prior surgery (considerably changing the anatomy of the OEAC of these ears). As no CT scans were excluded in the control group, a total of 281 ears were evaluated.

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Validation of the measurements
An excellent agreement between the independent observers regarding both DPTR \((r=0.89, p<0.001)\) and the ACPTR \((r=0.89, p<0.001)\) was observed. Results are summarized in scatterplots [Figure 2ab]. Regarding the accuracy of our measurements, an exact inter-observer agreement was present in 25% of our measurements. Additional analysis, using a Bland Altman plot, demonstrated a systematic error between both observers of approximately one slide. Deducting 1 slide from one of the observers, a perfect inter-observer agreement of 42% was observed.

A clear correlation between left and right ears was observed in most of the participants regarding DPTR \((r=0.60, p<0.001)\) and ACPTR \((r=0.72, p<0.001)\). No correlation was seen between the DPTR and the ACPTR \((r=0.17, p=0.02)\).

Difference in DPTR and ACPTR between normal and COE groups
The DPTR ranged between 0.55 and 6.6 mm in the COE group. In the control group, values ranged between 0 and 6.05 mm. The DPTR in the COE group was \(3.06 \pm 1.37\) mm for the right

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**Figure 2.** Interobserver agreement of DPTR and ACPTR measurements.
and $3.25 \pm 1.36$ mm for the left ear. In the control group, it was $2.32 \pm 1.22$ mm for the right and $2.35 \pm 1.31$ mm for the left ear. There was a significant difference (AD p=0.002, AS p=0.000) in DPTR between the two groups.

The ACPTR was found not to be significantly different between both groups (AD p=0.743, AS p=0.954). In the COE-group it was $2.20 \pm 0.88$ mm for the right and $2.17 \pm 1.04$ mm for the left ear. In the control group, the ACPTR was $2.15 \pm 0.91$ mm for the right and $2.18 \pm 0.93$ mm for the left ear. In Figure 3A, the mean of the DPTR and ACPTR of both ears is depicted for both groups of patients. No significant differences between male and female participants were observed, both overall and in subgroup analysis (p values all > 0.3).

Using only affected ears in comparison to control ears as discussed above, similar results were observed [Figure 3B]. Ranges in both groups were similar. No significant changes in average and standard deviation of DPTR and ACPTR were observed using this approach. Significant differences remained present between the COE and control group regarding DPTR (p=0.002). No significant differences were observed regarding the ACPTR (p=0.93).

**Descriptive evaluation of the OEAC shape**

The distribution of the various shapes of the OEAC is shown in Figure 4. Shapes 1 and 7 were found to be most common (about 50% of all ears). Shapes 4 and 6 seem to be not or hardly present at all. No significant differences in the distribution of the various shapes of the OEAC were observed using chi-square analysis (p all > 0.2).

**DISCUSSION**

In this study we confirm, as was previously suggested by many authors (3;5-9), that the shape of the external auditory canal (OEAC) is an important contributing factor in the development of COE. It has been proposed (8) that the entire shape of the OEAC plays a role within COE. We have showed that depth of the pretympanic recess (DPTR) is of relevance. Yet, the ACPTR was not found to be relevant suggesting that the hypothesis that the entire shape is relevant is not fully supported. Still other dimensions could also be of relevance within COE but these are beyond the scope of this study. In this study we tried to identify the ideal descriptive technique of evaluating the shape of the OEAC in literature. We felt that the technique and shapes described by Virapongse were best as this method is applicable in daily practice. Using a forced choice method, two independent evaluators showed a reasonable level of consistency in the evaluation of the OEAC shapes. Unfortunately none of the shapes correlated with the development of COE.

Our hypothesis, that the PTR is the most important area of the OEAC in relationship to the presence of absence of COE, required a novel method of determining the dimensions of this area. Our clinical impression was that both depth (DPTR) and anterior curvature (ACPTR) were of importance. The fact that the ACPTR is not significantly different between COE patients and controls was unexpected, as this curvature is likely to impede proper cleaning of the OEAC by ENT surgeons. Apparently though, it does not impede the cleaning of the OEAC itself. The only
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Figure 3. A. Both averages of DPTR and ACPTR compared between normal and COE group. Left (AS) and right (AD) ears. 95% Confidence interval is depicted. (*: significant difference, p<0.05; NS: no significant difference). B. Both DPTR and ACPTR compared between normal and COE group. Only affected ears and randomised normal ears. 95% Confidence interval is depicted. (*: significant difference, p<0.05; NS: no significant difference)
relevant measurement in our study was the DPTR. Although our data show overlapping ranges of DPTR between both groups, our 95% confidence interval, however, does not, suggesting that a DPTR of less than 2.6 mm is ‘protective’ against the development of COE.

We suggest an ‘easy to use’ method which allows independent observers to determine the dimensions of the PTR with excellent agreement, although a systematic error was found to be present. This error was only one slide and may be the result of a different interpretation of when to start counting slides.

Because ears of one subject are paired observations and thus correlated, we first compared all left and all right ears between both groups. This enabled us to include all affected ears. This method is only valid if one assumes that the DPTR acts as a maintenance or perpetuating factor within a multifactorial disease. One could then state that the non-affected side within the COE group is more prone to COE but lacks the initiating infection. As our data does not give certainty that in the control group and non-affected side of the COE group never a transient episode of OE was observed, one could debate if such an assumption is valid. We therefore decided to analyse only the affected ears and compare the affected ears to those in the control group. We could not include all affected ears as bilateral cases would force us to use paired observations in non-paired analyses. This was also the case with the control group. To solve this problem we randomised sides of the bilateral cases and ears in the control group using the date of birth. This

Figure 4. Distribution of the various descriptive shapes in the normal and COE group. (Y-axis: percentage X-axis: Shape type).
allowed us to do a non-paired analysis between affected and non-affected ears. A significant difference in DPTR remained present. Using the non-affected side as a control group did not show significant differences in DPTR and ACPTR. This was expected as left and right ears are correlated. Yet, if our abovementioned assumption is valid using the non-affected side as a control is not necessary as these ears could be regarded as being more prone to COE as well.

One could argue that we should have excluded patients with exostoses as they may belong to a group of patients suffering from a different disease entity. In our subgroup analyses, we showed that the presence or absence of exostoses did not influence outcome.

It would be interesting to evaluate how the PTR develops during childhood as children rarely develop COE (21). As our study is limited by its retrospective nature one would suggest a prospective study is warranted to strengthen the conclusions made in this manuscript. More dimensions could be included and perhaps volume and humidity could be assessed as well. In addition, future investigations should focus on the clinical implications of our findings. For example, one may hypothesize that patients with COE and a deep PTR are likely to have a better clinical outcome after adjusting the shape of the OEAC by means of a canalplasty than those patients that do not have a deep PTR and that in those individuals, preferably, the DPTR is reduced to less than 2.6 mm.

CONCLUSION

To our knowledge we are the first to provide evidence that the shape of the OEAC is associated with COE. We demonstrate that the DPTR is significantly associated with the presence of COE. We supply an 'easy to use' method of determining the DPTR using CT scans with an excellent inter-observer agreement. Treatment of COE should take into account these findings. We suggest that a reduction in the DPTR may result in better clinical outcomes in patients with COE.
REFERENCES