A Novel Clinical Approach for Cochlear Duct Length Estimation

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Objectives

Prior to cochlear implantation (*CI*) surgery, the length of the cochlea (*CDL*) to be implanted should be taken into account for choosing an electrode array optimally suited for the individual patient. A popular method to estimate the *CDL* be performed by using the basal diameter "A" (see figure 1) as it was proposed by Escudé et al. in 2006:

$$CDL = 2.62\ A \ln(1 + \frac{\theta}{235})$$

These estimations are especially attractive from a clinical point of view since they can be done very quickly. However, within our studies we found that a fundamental assumption of this approach, namely the linear dependency of the diameters *A* and *B* (see Fig. 1) is incorrect (see Fig. 2).

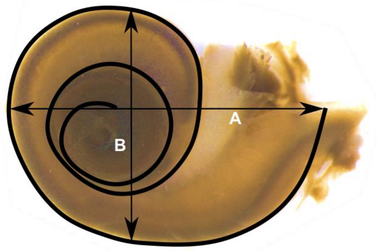

Figure 1: Image of the cochlea showing the basal diameters ,,A" and ,,B" as well as the cochlear lateral wall

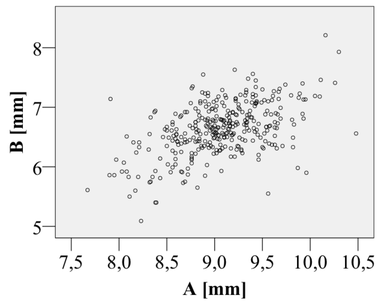

Figure 2: Distribution of ,,A" and ,,B" values measured in the clinical data of 340 patients

Methods

The variation of the *A* to *B* ratio motivated the development of a novel length estimation approach which covers the variability of the cochlear shape by taking *A* and *B* into account independently.

The approach consists of two steps:

Step 1: Approximation of the Basal Turn Length (*BTL*) as a half ellipse and a half circle where *B* was assumed by the work distributed by Pietsch et al. (2017) (see Fig. 3):

$$BTL = 1.18A + 2.6B - \sqrt{0{,}72AB}$$

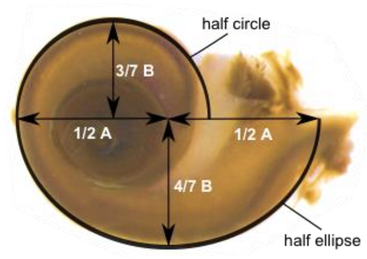

Figure 3: Image of the cochlea with the scheme of our proposed method using both basal diameter ,,A" and ,,B"

Step 2: Multiplication of the respective *BTL* with factors describing the length of the cochlea in 90 degrees segments from base to apex as percent *BTL*, e.g. $CDL(720°) = 157\%\ BTL$. These percentage values were derived by converting factors proposed by Erixon et al. (2009) which describe the relative contribution of the cochlear quadrants (Fig. 4) to the overall *CDL* (see Fig 5).

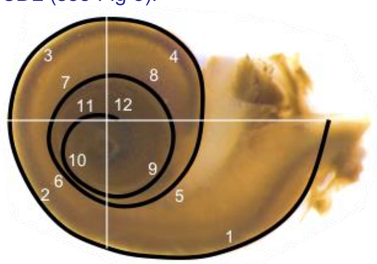

Figure 4: The cochlea divided into quadrants according to Erixon et al. (2009)

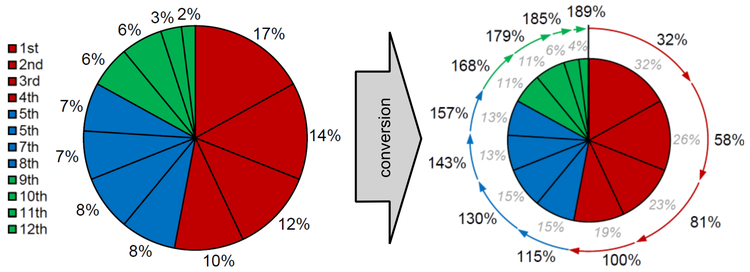

Figure 5: (left) relative contribution of the cochlear quadrants to the overall *CDL* according to Erixon et al. (2009); (right) Conversion of these percentage values into ones describing the length of the cochlea quadrants as percentage *BTL* (in grey). Adding these values yields the desired factors which describe the cochlear length up to the respective quadrants (in black)

Results

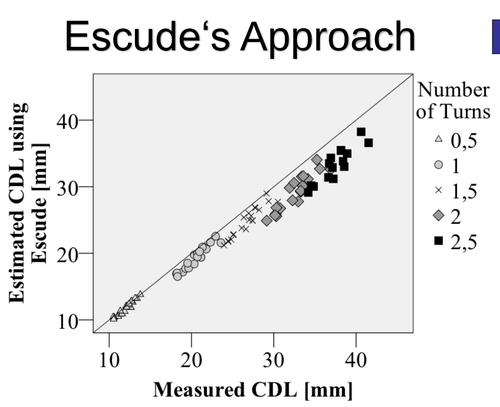

Figure 6: Comparison of measured and estimated CDL Values using the Escude's method

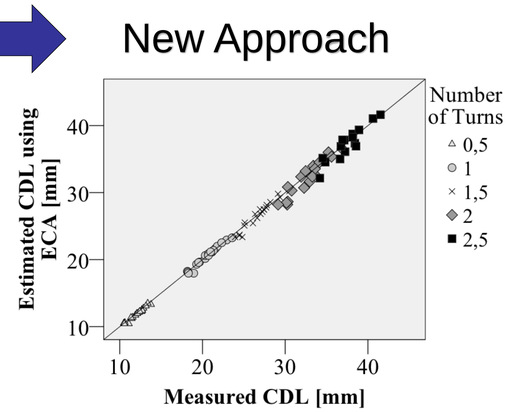

Figure 7: Comparison of measured and estimated CDL Values using our novel approach

The basal diameters *A* and *B* as well as the length of the lateral wall were measured in 20 micro-CTs (Lexow et al. 2016) to evaluate both Escude's formula and our novel approach:

•Escude's estimations agree fairly well with the lateral wall measurements but tend to underestimate the actual length of the cochlea. The underestimation increases with the number of turns (see Fig. 6).

•The novel approach shows an noticeable improvement in length estimation accuracy with deviation staying below 1 mm over the entire range of cochlear turns (see Fig, 7 and 8).

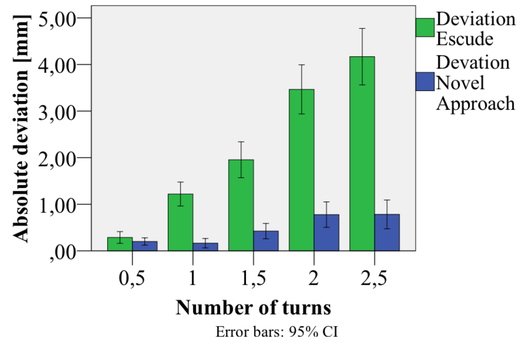

Figure 8: Estimation errors of the ECA and Escude (mean +/- standard deviation)

Discussion and Conclusion

The determination of the patient specific CDL prior to CI surgery is important for optimal implantation outcomes. If measurements cannot be performed, the derived estimation approach is a feasible alternative with improved accuracy compared to approaches previously proposed in the literature. Due to the simplicity of the proposed method it may actually be possible to include the corresponding length estimation into the clinical routine.

References

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