PRELIMINARY RESULTS OF CLINICAL TESTS OF A NEW NEURAL-NETWORK-BASED OTITIS MEDIA ANALYSIS SYSTEM

M. Hannula[1], T. Holma[2], E. Löfgren[2], H. Hinkula[1] and M. Sorri[2]
[1]*Medical Engineering R&D Center, Oulu University of Applied Sciences, Kotkantie 1, 90250, Oulu, Finland*
[2]*Department of Clinical Medicine/Otorhinolaryngology, University of Oulu, Oulu, Finland*

Keywords: Acute otitis media, Middle ear, Artificial neural networks.

Abstract: Evaluation of middle ear effusion is essential in diagnostics of otitis media. In this study a new otitis media diagnostic system based on acoustic reflectometry (AR) was preliminarily evaluated and tested with experimental clinical data on 114 ears of 57 children. In the study the ears of the children were measured with the new AR system and the corresponding ear status was definitively assessed in myringotomy by measuring the amount of effusion in the middle ear. The collected data included successful measurements of 71 normal ears (no effusion in the middle ear) and 43 ears with 0.02-0.37 g of middle ear effusion. In the analysis the correspondence between a neural network analysis of the AR measurement data and the corresponding amount of middle ear effusion was analysed using a leave-one-out validation procedure. The preliminary results were promising; the neural network analysis result and the amount of middle ear effusion correlated statistically significantly ($p < 0.001$), with correlation coefficient $R = 0.37$. In future studies more data will be collected to obtain higher correlation in the analysis.

1 INTRODUCTION

Otitis media is one of the most common reasons for medical contacts in children. Many studies (Linden et al., 2006; Chianese et al., 2007; Walsh et al., 1998; Block et al. 1999) have evaluated acoustic reflectometry (AR) -based (Teele and Teele, 1984) diagnostics of otitis media with good results. The idea of the new neural-network-based (Haykin, 1999) AR system (Hannula et al., 2009) was to build an Internet-integrated AR measurement and analysis system which includes neural-network-based analysis, having the capability to incrementally upgrade its performance due to an increasing amount of data in its database. In this study this system was preliminarily evaluated with a small amount of clinical data.

In this study children were examined with the new system and their ear status was determined in the Department of Otorhinolaryngology of Oulu University Hospital. The performance of the neural-network-based AR measurement analysis was assessed with a leave-one-out validation procedure (Haykin, 1999), and the correlation between the neural network result and the measured effusion status was evaluated.

2 METHODS

Fig. 1 illustrates the measurement system. In the measurement process, first the measurement tip is connected to a PC's sound card. Next the measurement software is started from a web page. Next the ears of the subject are measured. The resulting measurement data are then sent to an artificial neural network located on a web server, which predicts the corresponding ear status from the measurement data with the help of a simple index value. The result is shown to the user on the web page. In this study, after the AR measurement the status of the ears was clinically determined in myringotomy, where the amount of middle ear effusion was measured.

Hannula M., Holma T., Löfgren E., Hinkula H. and Sorri M..
PRELIMINARY RESULTS OF CLINICAL TESTS OF A NEW NEURAL-NETWORK-BASED OTITIS MEDIA ANALYSIS SYSTEM.
DOI: 10.5220/0003679703650368
In *Proceedings of the International Conference on Neural Computation Theory and Applications* (NCTA-2011), pages 365-368
ISBN: 978-989-8425-84-3

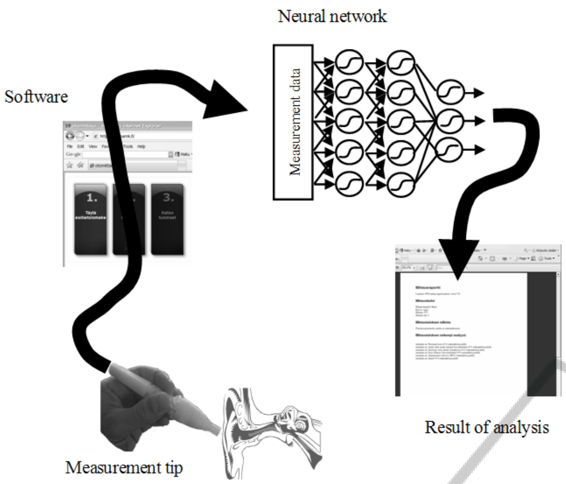

Figure 1: The measurement system.

The AR measurement was done following the conventional measurement protocol (Linden et al., 2006; Chianese et al., 2007; Walsh et al. 1998; Block et al., 1999). The frequency band of the stimulus signal in the measurement was 0.5-5 kHz. In this study the data were analysed in the frequency band of 1-3.5 kHz, which according to the AR measurement principle (Teele and Teele, 1984), should include the most essential information on the otitis media -related status of the ear.

3 SUBJECTS AND DATA

The study was prepared following the standard clinical research protocol, and the study was approved by the Ethics Committee of the Northern Ostrobothnia Hospital District. The data set of this study originally included 133 ears of 73 children (age 0.5-5 years, median weight 12.4 kg, min 7.8 kg, max 44 kg) who were measured with the AR system and clinically examined. Due to the preliminary characteristics of the very first clinical measurements, part of the data was unusable because of a substantial amount of noise in the measured signal or missing information on the weight of the middle ear effusion. Therefore, the total number of children evaluated successfully in this study was 57, with 114 ears. The characteristics of the data are shown in Table 1.

Table 1: Characteristics of the original data.

Ear status	N (total)	N (successful)
Normal	85	71
With effusion	48	43
Total	133	114

The minimum amount of effusion in the ear in ears with effusion status was 0.02 g, and the maximum amount was 0.37 g (median 0.18 g). To simplify calculations, the amount of effusion was expressed in this study by the equation:

$$index = 1 - \frac{effusion\_weight}{0.37g} \quad (1)$$

where effusion_weight is the amount of effusion in the ear; if the ear was healthy, the value was determined to be zero. Therefore, a healthy ear (effusion_weight = 0) was indicated with an index of 1 and an ear with maximum amount of effusion occurring in the present dataset (effusion_weight = 0.37 g) was indicated with an index of 0. Fig. 2 shows the distribution of the ear statuses of the data expressed with the index values.

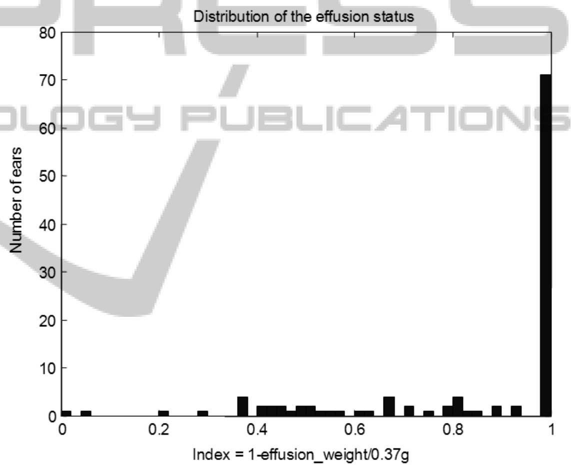

Figure 2: Distribution of ear status indexes.

4 METHODS

In the analysis a generalized-regression-based neural network (Haykin, 1999; Wasserman, 1993) was trained to estimate the index value indicating the amount of effusion in the ear on the basis of AR measurement data, Fig. 3. The performance of the neural network was evaluated with a leave-one-out validation procedure (Haykin, 1999), where the network was trained 114 times (total number of data sets). During each training period one measurement of the whole data set was excluded from the training data set and used in the validation phase.

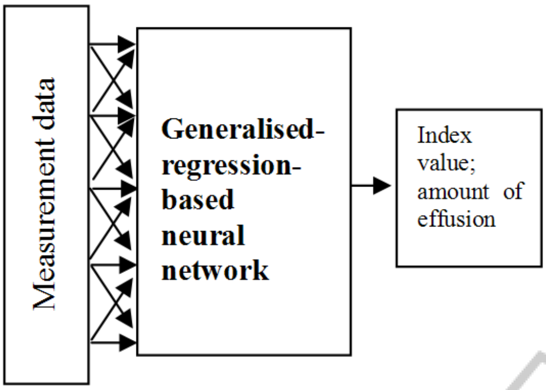

Figure 3: Neural network structure.

5 RESULTS

The neural network training and validation were done with Matlab® software (Mathworks Inc, Natick, USA). The correlation between the neural network output and the amount of effusion as index values in the ear is shown in Fig. 4.

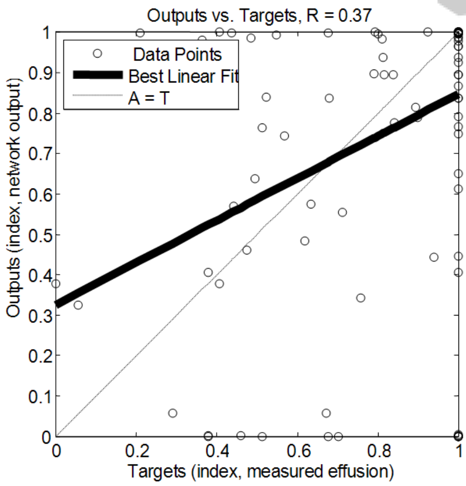

Figure 4: Results of the neural network validation (R=0.37, $p < 0.001$).

Fig. 4 shows that the neural network index and the index of the measured amount of effusion correlate statistically significantly ($R = 0.37$, $p < 0.001$).

6 DISCUSSION AND CONCLUSIONS

The validation of the neural network analysis shows that the correlation between the neural network output and the measured amount of effusion in the ear is clear, even though the correlation value is not very high due to the preliminary characteristics of the study. The result is in line with previous studies (Linden et al., 2006; Chianese et al., 2007; Walsh et al., 1998; Block et al., 1999; Teele and Teele, 1984) and illustrates that the essential characteristic features needed to estimate the amount of effusion in the ear can be found from the AR measurement data.

In future studies the amount of data will be increased in order to get higher correlations with smaller deviations in single measurements. The idea in this further development is to iteratively increase the training data of the neural network of the analysis system.

The data used in this investigation included a number of unsuccessful measurements, 29 ears in total. Technical problems which occurred during the preliminary data collection were carefully investigated and related improvements to the data collection procedure were implemented in subsequent measurements.

It should be kept in mind that in this study the output of the network was an index with a linear relationship to the amount of effusion only. Hence, for example the pressure status of the ear was not taken into account, which may account for part of the deviations between the network output and the determined ear status in the case of healthy ears with no effusion at all. In order to improve the accuracy of the measurements, further studies will more extensively take into account the features of the ear, related anthropometric characteristics and the middle ear pressure. Also, the simplified linear index-based approach used in this study may decrease the correlation value between the neural network output and the measured amount of effusion; application of an appropriate nonlinear index would be better.

To conclude, the preliminary results of this study were encouraging. The applied neural network method has the capability to estimate the amount of effusion in the ear at a statistical level, as shown with the data set presented in this study. After collection of the data set published in this study, the number of data sets was increased essentially in the next phase of the research project. In this phase an improved measurement procedure was applied, which substantially increased the repeatability and noise tolerance of the measurements. The results of those measurements will be published soon, including evaluations about sensitivity and speficity of the system in diagnostic application. Further, an especially interesting application of the presented measurement system is the possibility to use it at home as a tool to improve otitis media treatment processes in health care.

REFERENCES

Linden H., Teppo H. & Revonta M., 2006. Spectral gradient acoustic reflectometry in the diagnosis of middle-ear effusion in children. *Eur. Arch Otorhinolaryngol 264:477-481.*

Chianese J., Hoberman A., Paradise J. L., Colborn D. K., Kearney D., Rockette H. E. & Kurs-Lasky M., 2007. Spectral gradient acoustic reflectometry compared with tympanometry in diagnosing middle ear effusion in children aged 6 to 24 months. *Arch Pediatr Adolesc Med 161(9): 884-888.*

Walsh F. P., Cox L. C. & MacDonald C. B., 1998. Historic perspective of the acoustic otoscope. *J Am Acad Audiol 9: 35-40.*

Block S. L., Pichichero M. E., McLinn S., Aronovitz G., & Kimball S., 1999. Spectral Gradient Acoustic Reflectometry: Detection of Middle Ear Effusion in Suppurative Acute Otitis Media. *The Pediatric Infectious Journal 18(8): 741-744.*

Teele D.W. & Teele J., 1984. Detection of middle-ear effusion by acoustic reflectometry. *J Pediatrics 104: 832-838.*

Haykin S., 1999. *Neural networks, a comprehensive foundation.* Prentice Hall, Upper Saddle River.

Hannula M., Hinkula H., Holma T., Löfgren E. & Sorri M., 2009. Artificial Neural Network Analysis in Evaluation of Ear Canal and Tympanic Membrane Properties from Acoustic Reflectometry Data. *Proceedings of 11th World Congress on Medical Physics and Biomedical Engineering.*

Wasserman P. D., 1993. *Advanced Methods in Neural Computing*, New York: Van Nostrand Reinhold, pp. 155-161.