Auscultating Diagnosis Support System by Using Self-Organizing Map II

-Classification of Eustachian tube insufflation sound-

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Abstract

The Eustachian tube insufflation method is widely used for diagnosis and medical treatment. However, because the Eustachian tube insufflation method is auscultated by only the doctor who enforces it, the Eustachian tube insufflation sound is not left behind as data, and diagnosis may change depending on the doctors because the sound on which the diagnosis is based is subjective. Therefore, this research considered using feature extraction for classifying the difference in the Eustachian tube insufflation sound according to the disease condition using a self-organizing map (SOM) for the purpose of improving the objectivity and reliability of diagnosis by quantification of the Eustachian tube insufflation method. In this study, various feature vectors to be input to the SOM were prepared and examined, and the result of refinement concerning the optimal condition is reported.

Keywords: Eustachian tube, stenosis sound, health monitoring, self-organizing map.

1. Introduction

The Eustachian tube is an organ that connects the middle ear and the upper pharynx; it also undertakes functions such as maintaining air pressure, foreign substance excretion, and defense. Owing to its important role for maintenance of the constancy of the middle ear and and treatment various middle ear and Eustachian tube diseases according to the obstacle of an auditory tube

function treatment various middle ear and Eustachian tube diseases according to the obstacle of an auditory tube function, evaluation of the Eustachian tube function is important⁽¹⁾. In Eustachian tube stenosis, the Eustachian tube becomes narrow and becomes difficult to open. Patulous Eustachian tube is a disease related to the auditory tube, wherein the Eustachian tube remains open. Otitis medium with effusion is a leaching solution stored in the middle ear due to the decline of the Eustachian tube function, among others⁽²⁻⁴⁾. The point which excels the inspection methods, such as a sound method. The Eustachian tube insufflation method is a technique in which a doctor hears the sound made when air passes (Eustachian tube insufflation sounds) through the Eustachian tube. A doctor sends air from the pharyngeal opening of the Eustachian tube by means of a rubber tube at a point where medical treatment and diagnosis can be performed simultaneously⁽⁵⁾.

However, Eustachian tube insufflation sounds are not being left behind as data because auscultation is done by only the doctor who enforces, and diagnosis is left to a doctor's auditory judgment, and there is a lack of objectivity. Therefore, in this research, a number of Eustachian tube insufflation methods were examined, the Eustachian tube disease patient's Eustachian tube aeration sound was recorded for the purpose of improving the objectivity and reliability of diagnosis, and the features were investigated.

Previously, frequency analysis was performed on the Eustachian tube insufflation sounds, how to classify them according to a self-organization map (SOM) was examined,

and the possibilities for classification were shown⁽⁶⁾. Evaluating normal sound, the stenotic sound, and the crepitant whistle using data that have not been used for studying the SOM is the objective of this study. Various feature vectors to be input to the SOM were prepared and examined, and the results of refinement about the optimal condition are reported.

2. Method

2.1 Composition of recording equipment

The composition of the Eustachian tube insufflation sound extraction equipment developed in this research is shown in Fig. 1. It was supposed that measurement is performed using a PC and an analog-to-digital (A/D) converter. The counting system programmed by LabVIEW performs three-channel simultaneous measurement of air pressure, the Eustachian tube aeration sound, and environmental sound using NI9239 (National Instruments). Until listening was done, the sounds were saved as a text file while carrying out an A/D conversion using 24 b and a 50-kHz sampling frequency, displaying a waveform on the monitor of the PC, as well as the aeration sound. It was presupposed that it is possible by outputting the signal of the aeration sound which input to line-in using the sound board of the PC and headphones in real time.

A doctor puts air pressure on a subject's pharyngeal

opening of the Eustachian tube, and the Eustachian tube aeration sound comes from the subject's ear. This is changed into an electric signal with a microphone through a ear chip, and, after it has been amplified with an amplifier, it is recorded by a recorder. At this time, the Eustachian tube insufflation sound is considered as the composition output to the headphone when recording. This is to make it possible to listen in real time to the Eustachian tube insufflation sound, without barring the conventional Eustachian tube insufflation method diagnosis. They are combined, and, to also record the timing with which the doctor pressurized, simultaneous measurement of pressure is performed using a pressure sensor. Moreover, in consideration of the possibility of using signal processing for environmental sound removal, environmental sound is also recorded simultaneously. The waveform of these extracted data was displayed on the display and had a composition that can be confirmed on the spot.

2.2 Signal processing

The characteristics of abnormal Eustachian tube insufflation sounds can be observed at 5000 Hz or lower. The collected insufflation sounds were down-sampled to a sampling frequency of 10,000 Hz to reduce the number of data, and then frequency components of 5000 Hz or less were used for feature extraction. Because abnormal sound is generated locally, if the entire spectrum of the collected Eustachian tube insufflation sounds were to be obtained,

Fig. 1. Configuration of recording device

then the frequency characteristics of the abnormal sound would be diluted. For this reason, in this research, abnormal sounds were identified through auscultation, and, then, 0.1 s of data were extracted to use for feature identification. Next, frequency analysis was conducted using the maximum entropy method (MEM) ⁽⁷⁾⁽⁸⁾. Then, 0-500 to 5 kHz was equalized for the MEM spectrum by 250-225 points on a linear frequency scale, and amplitude was normalized to 0-1. The feature vectors were prepared and then classified with the SOM⁽⁹⁾.

3. Results and Discussion

3.1 Characteristics of insufflation sounds

Fig. 2 shows a waveform of insufflation sound and air pressure. The subjects were healthy people. In the case of healthy people, insufflation sounds were observed immediately after applying air pressure, as shown in Fig. 2. Fig. 3 shows the spectrogram of the insufflation sound shown in Fig. 2. Although there are individual differences. Also, the sound was stationary in that, while air pressure was applied, its frequency component did not exhibit any notable fluctuations.

Fig. 4 shows a waveform of insufflation sound and air pressure. The subject in this case was a patient with canal stenosis; insufflation sound was not observed immediately. In Fig. 4, after 2 s of applying air pressure, an insufflation sound began to occur. In addition, it was understood that the ventilation noise does not occur when the application of the air pressure stops. Fig. 5 shows the spectrogram of the insufflation sound shown in Fig. 4. Although not shown, compared with normal sound, peaks at approximately 2 kHz had an especially high intensity.

Figs. 6 and 7 show the characteristics of the sound of otitis media with effusion. Crepitation sounds were observed. Interruptions in the insufflation sounds could be confirmed in the time series waveform. Its spectrum indicates that the intensity in the bandwidth at 3 kHz or below was high and, compared with the normal sounds and crepitation, the bandwidth below the peak at approximately 2 kHz was not attenuated.

3.2 SOM results

It was possible to collect data for learning SOM from 59 sounds. From the data, 22 normal examples were extracted, as well as 18 examples of stenosis and 19 of crepitation, obtained through auscultation.

Fig. 2. Waveform and air pressure (normal)

Fig. 3. Spectrogram of Fig.2. (normal)

Fig. 4. Waveform and air pressure (stenosis)

Fig. 5. Spectrogram of Fig.4. (stenosis)

Fig. 6. Waveform and air pressure (stenosis)

Fig. 7. Spectrogram of Fig.6. (stenosis)

SOM results shown in Fig.8 illustrate that the normal sounds (blue) are separated from other abnormal sounds except for one normal sound, but stenosis (red) and crepitation (green) do not exhibit a clear grouping, although there do appear to be some clusters. Various feature vectors to be input to the SOM were prepared and examined, and the results confirmed that the optimal conditions were reported.

Fig. 8(a) shows the results of averaging the spectrum intensity from 0 to 5000 Hz linearly at 250 points, and Fig. 8(b) shows that the results for a spectrum intensity from 500 to 5000 Hz is 225 points. As a result, the three feature sounds could not form their respective areas. However, in Fig. 8(c), where normalization was added to the condition of Fig. 8(a), an area was formed. Furthermore, the area could be formed even with the result shown in Fig. 8(d) limited to the frequency band from 500 to 5000 Hz. The length of the feature vector could be attenuated from 250 to 225 points, and the condition shown in Fig. 8(d) is more effective as a discrimination device.

Table 1 summarizes the results of performance evaluation under the conditions shown in Fig. 8(d). All crepitation sounds were identified as crepitation sounds, and the stenosis sounds were output on the stenosis sounds or the stenosis–normal boundaries. The condition in Fig. 8-(d) was effective as a discrimination device.

4. Summary

Even if the Eustachian tube performance inspection equipment marketed can confirm a blockade and opening of a Eustachian tube, because of the hardness of a Eustachian tube, examining the exudation condition of a Eustachian tube, inner ear, etc. is difficult. Diagnosis and medical treatment by the Eustachian tube insufflation method are generally performed. However, because the Eustachian tube insufflation method is auscultated by only the doctor who enforces, the Eustachian tube insufflation sound is not captured as data, and diagnosis may change with doctors also, because the diagnosis of the sound is subjective.

Therefore, this research focused on the processing of the feature extraction result for classifying the difference in the Eustachian tube insufflation sound by the condition of the disease according to the SOM for the purpose of improving the objectivity and reliability of diagnosis by quantification of the Eustachian tube insufflation method. For feature extraction, 500–5000 Hz was equalized using 225 points on the linear frequency scale, and the MEM

spectrum was normalized to 0-1. Fifteen data of normal sound, a stenotic sound, and five crepitations, each which was not used for study of the SOM, were diagnosed by the SOM. The number of the result was output to the boundary line of the settlement for every feature, and it could not be judged as three. Because there was no diagnosis in which there was an error in normalizing strangulation, among others, it is thought that the method of diagnosing the MEM spectrum that equalized 500–5000 Hz by 225 points on the linear frequency scale and was normalized by the SOM is effective.

Acknowledgment

We would like to express our gratitude to Kodai Aoyagi (FANUC Corporation) for his work. This work was supported by JSPS KAKENHI

Fig. 8. SOM results

Table 1. Test results of classification by SOM

Output					
N	N-S	S	S-C	C	C-N
4	1	0	0	0	0
0	0	3	2	0	0
0	0	0	0	5	0
N:Normal S:Stenosis C:Crepitation					

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