Threshold of hearing, vibration, and discomfort in a group of severely hard of hearing and profoundly deaf students

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III. SPEECH AND HEARING DEFECTS AND AIDS

A. THRESHOLD OF HEARING, VIBRATION, AND DISCOMFORT IN A GROUP OF SEVERELY HARD OF HEARING AND PROFOUNDLY DEAF STUDENTS

L. Ericson and A. Risberg

Abstract

When the ear is stimulated by high-intensity low-frequency sounds by means of ordinary earphones a sound pressure is reached were tactile receptors are stimulated. Different attempts have been made to establish the audiometric threshold of this tactile sensation. During pure-tone audiometry it was observed that some severely hard of hearing and profoundly deaf subjects could give three thresholds: hearing, vibration, and discomfort. Measurements were made on 52 ears. The obtained tactile threshold agrees reasonably well with the results from other studies. Comparison between the obtained hearing threshold and the obtained vibratory threshold shows that detection threshold measurements cannot be used to diagnose total hearing loss.

If, however, a detection threshold during pure-tone audiometry is obtained for any frequency above 1500 Hz or if a threshold for lower frequencies are obtained at lower intensities than the established vibratory threshold, this is very likely a sign of the existence of a residual hearing. How useful this residual hearing is for speech perception and the learning to speak must be established by means of other type of measurements.

Introduction

It is well known that subjects experience a sensation of tactile vibration when the ear is stimulated with high-intensity, low-frequency sounds. Several attempts have been made to establish the audiometric threshold for this sensation. Rösler (1957) measured the low-frequency threshold of profoundly deaf children and he also compared this threshold with the threshold obtained when the earphone was pressed against the palm of the hand. Norber (1967) repeated the measurements of Rösler and obtained very similar results. In another experiment Norber (1970) established the detection threshold on a group of severely hard of hearing and profoundly deaf subjects before and after anesthesia of the external auditory canal and the area around the auricle. For five of the subjects in the study no thresholds could be obtained for any frequency up to the maximum output of the audiometer during anesthesia. Norber draws the conclusion that the thresholds obtained before anesthesia were due to

1) Risbergska skolan, Örebro (Sweden)
tactile sensations. The mean value of these thresholds for the frequencies 250 and 500 Hz is shown in Fig. III-A-6. Boothroyd and Cawkwell (1970) measured the vibratory threshold on subjects with unilateral total deafness and obtained somewhat different results than the other investigations, Fig. III-A-6.

During routine pure-tone audiometry with students at the high school for the deaf in Örebro (Risbergska skolan) it was noted that some of the students at low frequencies could give three reliable thresholds: sensation of hearing, sensation of vibration, and sensation of discomfort. As measurements on these subjects could give a new value on the vibrotactile threshold it was decided that measurements should be made on as many of the students as possible. Similar measurements have been made on normal hearing subjects by Fletcher (1953) and by Rösler (1957) but due to interaction from the strong auditory sensation it is likely that the established vibratory threshold is less reliable.

**Measuring equipment**

As audiometer a tone generator, Brüel & Kjær type 1022 followed by an attenuator that could be varied in 1 dB steps was used. The on- and offsequence of the signal was controlled through the compressor input of the tone generator (compressor speed 1000 dB/sec) in order to avoid clicks due to rapid onset of the signal. The signal was presented to the subjects by means of earphone Telephonics TDH 39 with MX41/AR cushions. To avoid leakage at low frequencies a special headband was used that gave a pressure of 4 N as recommended by IEC 177. The maximum output of the equipment was 135 dB SPL over the frequency range used. The calibration was checked at regular intervals.

Standard audiometric techniques were used in the measurements. All subjects were well trained in the technique and gave consistent answers. In the measurement of the threshold of tactile vibration it was before the measurement ascertained that the subjects understood which type of sensation that was asked for.
Subjects

The subjects were students in a high school program for the deaf. Their ages were between 17 and 39 years with a mean age of 22.8 years. They had been auditory trained from an early age and the majority of them had been educated in classes for the partially hearing. Most of them constantly used hearing aids on both ears. They had good language and speech and it was easy to communicate with them. Measurements were made on 40 subjects. In eight cases the hearing impairment was acquired after the age of two years or later. In five cases it was suspected that the hearing impairment was hereditary and in the remaining cases the hearing loss was congenital of unknown origin.

The distribution of the mean hearing loss for the three frequencies 500, 1000, and 2000 in the best ear is shown in Fig. III-A-1.

Results

Of the 40 subjects in the study 29 could give a reliable threshold of vibration for at least one frequency in at least one ear. In seven cases it was not possible to get a threshold of vibration and in four cases the subjects said that they experienced discomfort when the signal was felt in the ear. In Fig. III-A-2 the thresholds obtained in three typical cases are shown and in Table III-A-I - III-A-III the mean and standard deviation of the thresholds obtained for the 29 subjects are shown.

The audiograms were classified in three groups according to the system described by Risberg and Mártony (1972). In 19 ears the lowfrequency part of the audiogram was mainly found in the B-area and in 27 ears the lowfrequency part was mainly found in the C-area. In eight ears the audiogram was found in the C- and D-areas but the order of the obtained hearing and vibrotactile thresholds was reversed, see Fig. III-A-2c. The mean value and standard deviation of the three thresholds obtained in these three audiogram types are shown in Figs. III-A-3 - III-A-5.
Fig. III-A-1. Distribution of the mean hearing loss for the frequencies 500, 1000, and 2000 Hz in the best ear for the subjects in the study.
Fig. III-A-2. Thresholds obtained in three different cases.

<table>
<thead>
<tr>
<th></th>
<th>Left ear</th>
<th>Right ear</th>
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<tr>
<td>Hearing</td>
<td>X</td>
<td>O</td>
</tr>
<tr>
<td>Vibration</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Discomfort</td>
<td>V</td>
<td>A</td>
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Fig. III-A-3. Mean thresholds and standard deviations obtained for 19 ears with the main part of the hearing threshold in the B-area for low frequencies.
TABLE III-A-I. Threshold of hearing, dB ISO. Number of ears, mean value and standard deviation.

<table>
<thead>
<tr>
<th>Frequency Hz</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1000</th>
<th>1500</th>
<th>2000</th>
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<th>4000</th>
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<tr>
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<td>34</td>
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<tr>
<td>M</td>
<td>60.0</td>
<td>74.7</td>
<td>89.3</td>
<td>98.8</td>
<td>101.6</td>
<td>100.6</td>
<td>101.2</td>
<td>99.7</td>
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<tr>
<td>SD</td>
<td>16.5</td>
<td>17.0</td>
<td>12.8</td>
<td>11.0</td>
<td>11.9</td>
<td>13.3</td>
<td>17.4</td>
<td>17.7</td>
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</table>

TABLE III-A-II. Threshold of vibration, dB ISO. Number of ears, mean value and standard deviation.

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<thead>
<tr>
<th>Frequency Hz</th>
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<th>250</th>
<th>500</th>
<th>1000</th>
<th>1500</th>
<th>2000</th>
<th>3000</th>
<th>4000</th>
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<tbody>
<tr>
<td>n</td>
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<td>51</td>
<td>40</td>
<td>17</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>65.3</td>
<td>84.9</td>
<td>99.4</td>
<td>111.2</td>
<td>113</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>10.4</td>
<td>9.2</td>
<td>7.3</td>
<td>7.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

TABLE III-A-III. Threshold of discomfort, dB ISO. Number of ears, mean value and standard deviation.

<table>
<thead>
<tr>
<th>Frequency Hz</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1000</th>
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<td>n</td>
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<td>51</td>
<td>52</td>
<td>39</td>
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<td>11</td>
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<tr>
<td>M</td>
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<td>103.0</td>
<td>115.4</td>
<td>119.0</td>
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<td>116.2</td>
<td>114.7</td>
<td>113.6</td>
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<tr>
<td>SD</td>
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<td>6.9</td>
<td>7.9</td>
<td>7.8</td>
<td>8.2</td>
<td>7.3</td>
<td>7.3</td>
<td>7.5</td>
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</table>
Discussion

The threshold of tactile sensation obtained in this study and the thresholds obtained in other studies agree reasonably well with each other with the exception of the threshold obtained by Boothroyd and Cawkwell (1970), see Fig. III-A-6. It therefore seems plausible to assume that when the ear is stimulated with the earphone Telephonic TDH 39 with MX41/AR cushions a sound pressure is reached that results in the stimulation of tactile receptors when the signal is in the C-area of Fig. III-A-6. This, however, does not mean that a threshold obtained in this area always is a tactile threshold. Fig. III-A-4 shows that a hearing threshold also can be obtained in this area and that in some cases a hearing threshold can be obtained at a higher intensity than the vibratory threshold. It is therefore not possible to distinguish between a tactile or auditory sensation only based on detection threshold measurements as in pure-tone audiometry.

Measurements by among others Verrillo (1966) show that vibratory sensitivity of the skin falls off very rapidly above 500 Hz. It is therefore very difficult to stimulate vibratory receptors in the skin above 1000 Hz. This means that if a detection threshold during pure-tone audiometry can be obtained for any frequency above 1500 Hz it is very likely that this is a sign of the existence of residual hearing, which signifies that the tactile thresholds given by Barr (1955) and Norber (1967), see Fig. III-A-6, were obtained on some subjects with residual hearing. This also holds for the repetition of Norber's (1970) experiment with anesthesia made by McGargill, Egan, and Barbitt (1977). If a threshold is obtained in the B-area of Fig. III-A-6 it is also very likely that this represents residual hearing even if no response can be obtained for frequencies above 1000 Hz.

To what extent a small residual hearing can be used in speech perception and the control and learning of speech production cannot be decided from the pure-tone audiogram. The dynamic range between the detection threshold and the threshold of discomfort will be very important. Measurements show that frequency discrimination ability varies considerably for subjects with the same degree
Fig. III-A-4. Mean thresholds and standard deviations obtained for 27 ears with the main part of the hearing threshold in the C-area for low frequencies.
Fig. III-A-5. Mean thresholds and standard deviations obtained for 8 ears where the order of the hearing and vibratory threshold is reversed.
Fig. III-A-6. Threshold of vibration or threshold of detection for children "with no response to sound" published by different authors.
of hearing loss but there is a significant correlation between frequency discrimination ability and speech perception ability (Di Carlo 1962; Risberg et al 1975). This type of measurement can therefore be used to evaluate the quality of a small residual hearing. To what extent such measurements also can be used to diagnose total deafness is not clear but this measurement ought to be valuable as a part of a test battery for these diagnoses.

Acknowledgments

We sincerely thank all the students that took part in the study. Without their cooperation in the sometimes time-consuming measurements this study had not been possible.

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References


