Chapter 6

Effects of Stapes Surgery on Speech Reception.

A.J.G. de Bruijn
R.A. Tange
W.A. Dreschler

Submitted
ABSTRACT

A retrospective, nonrandomized review of 363 cases undergoing primary stapes surgery for otosclerosis was undertaken to evaluate the effects of surgery on several parameters obtained by pre- and postoperative speech audiometry in quiet. Therefore, the change in speech reception thresholds (SRT), the maximum speech discrimination score (MSDS), the slope of the speech reception curve (SRC), and the occurrence of a slope decay of the SRC were analysed. Several data from speech audiometry were related to pure-tone audiometric data in order to examine whether postoperative loss in speech discrimination can be predicted from the shapes of pure-tone curves.

It appeared that stapes surgery had neither significant effect on the slope of the SRC, nor on the slope decay. Phonemic regression (slope decay > 0.5 %/dB) was not found before surgery, but occurred in 15 cases after surgery. In 96% of the cases the SRT improved and correlation analysis showed that the change in SRT correlates well with the change in AC levels for the pure-tone average at 0.5, 1, 2, and 4 kHz. A postoperative loss in MSDS ≥ 10% occurred in 8 cases, while 13 cases showed an improvement ≥ 10% in MSDS. Factors involved with an increase or a decrease in MSDS were elaborated. On the basis of the results it was concluded that loss in speech discrimination can not be predicted from the shape of the curves from preoperative pure-tone audiometry as either a Carhart effect or cochlear damage can occur. Cochlear damage resulting in sensorineural hearing loss is often associated with a reduction in speech discrimination. When the preoperative pure-tone hearing loss is severe and there is a preoperative loss in discrimination, there is a chance that speech discrimination improves in those cases having a successful closure of the air-bone gap and an obvious increase in bone conductive hearing due to the Carhart effect.

INTRODUCTION

Since the introduction of the stapedectomy technique for restoring impaired middle ear transmission function due to otosclerosis, many reports are published dealing with the benefits of this type of surgery. Most reports are establishing postoperative hearing results by making use of parameters retrieved from pure tone audiometry. However, the most important purpose of stapes surgery is to improve speech reception. In this respect, it is especially important to be informed about the effect of stapes surgery on speech discrimination. A good technical result (gap-closure ≤ 10) is only relative when at the same time a deterioration in speech discrimination occurs after surgery. A few articles have reported such reductions of speech discrimination which were found after successful closure of the air-bone gap (ABG). Nevertheless, on the whole only sporadically postoperative outcome is described in terms of speech audiometric parameters.

One of the mechanisms of a decrease in speech discrimination after successful stapes surgery is a masking effect of high frequency features of speech by the low frequency components. This phenomenon has been studied by Huizing, who related loss in speech discrimination.
to an increase in the steepness of the air-conduction (AC) threshold after stapes surgery. Such a decline of the AC curve can occur postoperatively in those patients showing a mixed type of hearing loss which is not an infrequent occurrence in otosclerosis, and, due to physiological ageing on cochlear function, it is often seen in middle aged and elderly patients. The hearing loss in these patients is usually made up of a high tone sensorineural hearing loss (SNHL) and a conductive loss that mainly concerns the lower and middle frequencies. Successful stapes surgery in these situations leads to a low and middle-frequency hearing gain. As a consequence the original horizontal or slightly declining AC threshold is transformed into a more or less steeply declining curve. The decline of the curve can be even more obvious when at the same time SNHL occurs in the higher frequencies due to cochlear damage, which is a well known risk factor of stapes surgery. Huizing\(^5\) observed a loss in speech discrimination when the postoperative pure tone audiogram showed a decline of the AC curve within defined criteria.

Another factor which has an effect on postoperative speech discrimination is that in the surgical treatment of otosclerosis often the stapedius tendon is sectioned and not reconstructed. This consequently results in a loss of the attenuation of middle-ear sound transmission at higher intensities by stapedius muscle contraction. This attenuation of sound transmission is termed stapedial reflex, or acoustic reflex, and is thought to be protective to the cochlea when loud sounds are presented.\(^6\) Furthermore, the stapedial reflex plays an important role in improving the intelligibility of speech at higher sound intensities.\(^7\) An intact stapedial reflex attenuates sound energy in the low frequency portion of the speech spectrum. It therefore reduces the undesirable upward spread of masking of low frequency sounds and preserves the transmission of information for higher frequencies. In this respect, we may expect in our patients an effect after stapes surgery on speech discrimination with increasing sound intensities as the standard surgical technique in our hospital is to sacrifice the stapedius tendon without reconstruction. This negative effect of sectioning the stapedius tendon on speech discrimination is found by several authors.\(^9\)\(^10\)

The purpose of this study is to evaluate the effects of stapes surgery on several parameters obtained by speech audiometry with special reference to the following questions: (1) Which factors are involved when either a substantial deterioration or improvement in speech discrimination occurs after stapes surgery? (2) Is it possible to identify patients before surgery who are at risk for loss in speech discrimination after surgery?

**Patients and Methods**

Data were retrieved from every consecutive patient who underwent primary stapes surgery for otosclerosis during an eleven years period from January 1987 to December 1997. During this period 386 primary stapes operations were performed by the second author. Pre- and postoperative speech audiometry was available in 363 cases (94.0 %) These cases were considered for further analysis and concerned 323 patients; 40 patients had surgery at both sides. The patient group consisted of 230 women and 93 men with a mean age of 40.7 years (range 12 - 74, SD ± 11.2) at the time of their operation in our hospital. The distribution between
left and right ears was approximately even.
In the majority of patients a small fenestra stapedotomy was performed (98.9 %) and in only a few cases a stapedectomy technique was used (1.1 %). A variety of stapes replacement prostheses was implanted. The most frequently used prostheses were the Causse® Teflon piston (64 %), the gold K®-piston (26 %) and the Cawthorne® Teflon piston (9 %). Several other prostheses were used in a minority of the patients.
In our clinic the AC thresholds are routinely measured at the octave intervals from 0.125 to 8 kHz and the BC thresholds at the octave intervals from 0.25 to 4 kHz with adequate masking. For each subject complete speech audiometry was carried out at different levels, using lists of phonetically-balanced CVC-words.11 All audiograms were performed by classified personnel according to the ISO-389 (1975) standard. The mean time of audiometric testing after surgery was 2.1 months (range 0.6-12.1; SD ± 2.4). Ninety-four percent of the subjects had postoperative audiometric testing within 3 months.
All data were entered into a computer database and analysed with a spreadsheet program. In analysing our data from pure tone audiometry, the pure tone average (PTA) at 0.5, 1, 2, and 4 kHz were taken for AC and BC levels. As a measure of overclosure or SNHL due to cochlear damage the change in BC was used for the PTA at 1, 2, and 4 kHz. ABG closure data are reported using postoperative ABG computed with AC and BC from the same postoperative audiogram.
Data retrieved from speech audiometry were analysed with Matlab®. In all patients the pre- and postoperative speech reception threshold (SRT) could be derived as well as the maximum speech discrimination score (MSDS). Furthermore, the pre- and postoperative maximum slope and slope decay of the speech reception curve (SRC) were analysed, both expressed in %/dB. The maximum slope is the maximum steepness of the curve in its ascending part. The slope decay is the average steepness of the curve in its descending part after it has reached maximum speech discrimination (Fig. 1). Phonemic regression is defined as a slope decay > 0.5 %/dB.
For statistical analysis nonparametric tests were used for independent variables (Graphpad Prism®). The Wilcoxon signed rank test was performed for paired data, whereas the Mann-Whitney test was used for unpaired data. Correlation analysis was done with the Spearman test. Our criterion for statistical significance was set at p-values < 0.05 (two-tailed).
Results

Overall effects of stapes surgery upon speech reception

In the whole group of patients the average SRT before surgery was 68.8 dB (SD ± 13.1 dB) which improved to 48.8 (SD ± 12.3 dB) after surgery. Ninety-six percent of the ears showed an improvement in SRT. Figure 2 shows the change in SRT as a function of the change in AC for the PTA at 0.5, 1, 2, and 4 kHz. The change in SRT correlates well with the change in AC for this frequency combination (Spearman $r = 0.89$, $p < 0.0001$).

Table 1 presents the number of ears with MSDS within certain categories before and after surgery. Before operation there were 342 ears within the category 91-100 %, while 21 ears had a score of $\leq 90 \%$. Analysis of the slopes of the preoperative AC for these 21 ears revealed that only 3 cases showed a rather steep pure-tone audiogram: two ears with an average audiometric slope $\geq 20$ dB/octave in the frequency range 0.5 - 8 kHz with a cut-off frequency of 1 kHz and one ear with an average slope decay $\geq 10$ dB/octave in the frequency range 0.5 - 8 kHz with a cut-off frequency of 0.5 kHz. The average preoperative AC threshold (PTA at 0.5, 1, 2, and 4 kHz) in the group of ears with a preoperative MSDS $\leq 90 \%$ differed highly significant from the group of ears with MSDS $> 90 \%$ (Mann Whitney test, $p < 0.0001$); in the category $\leq 90 \%$ MSDS the mean preoperative AC value was 71.3 dB (SD ± 15.5 dB) and in the category 91-100 % MSDS it was 48.2 dB (SD ± 12.0 dB). Furthermore, also the difference in average BC values was highly significant (Mann Whitney test, $p < 0.001$) between these two categories with values of 34.1 dB (SD ± 10.1) and 21.1 dB (SD ± 8.7 dB), respectively.

Fig. 1. Analysis of maximum slope and slope decay of a speech reception curve (SRC). The maximum slope represents the maximum steepness of the SRC in its ascending part and is expressed in %/dB. The slope decay is the average steepness of the SRC in its descending part after it has obtained its maximum speech discrimination score, and is also expressed in %/dB.
three ears with a preoperative MSDS ≤ 80% had AC values exceeding 90 dB (PTA at 0.5, 1, 2, and 4 kHz), suggesting far advanced otosclerosis. The average age in the category 91-100% MSDS was 39.6 years (SD ± 10.5, range 12 - 67) and differed significantly (Mann Whitney test, p < 0.01) from the average age in the category ≤ 90% SDS, which was 54.1 years (SD ± 12.8, range 32 - 70).

After surgery there were 349 ears with a MSDS in the category 91-100% and 14 ears in the category ≤ 90% (Table 1). Overall, the average MSDS before surgery was 97.9% (SD ± 4.5%) which improved to 98.6% (SD ± 4.2%) after surgery.

The effect of stapes surgery on the slope and slope decay of the SRCs was not significant. Before surgery the average slope was 6.0%/dB (SD ± 1.5%/dB) and it was 5.7%/dB (SD ± 1.6%/dB) after surgery. The average preoperative slope decay was 0.02%/dB and impaired slightly after surgery to 0.09%/dB. None of the ears showed preoperatively a regression (slope decay > 0.5%/dB), while 15 ears showed a regression of the SRC after surgery. No significant relations were found between the occurrence of postoperative phonemic regression and either postoperative change in BC or age.

**Fig. 2.** Change in speech reception threshold (SRT) as a function of the change in air-conduction (AC) for the pure-tone average (PTA) at 0.5, 1, 2, and 4 kHz. The change in SRT correlates well with the change in AC for this frequency combination (Spearman r = 0.89, p < 0.0001) as is also shown by the regression line.
Effects of Stapes Surgery on Speech Reception

Fig. 3. Preoperative (preop) and postoperative (postop) median speech reception curve for the 8 ears with a decrease ≥ 10% in maximum speech discrimination score.

Table 1. Number of ears categorised by maximum speech discrimination scores (MSDS) before and after surgery.

<table>
<thead>
<tr>
<th>Preoperative MSDS (%)</th>
<th>N</th>
<th>91-100</th>
<th>81-90</th>
<th>71-80</th>
<th>≤ 70</th>
</tr>
</thead>
<tbody>
<tr>
<td>91-100</td>
<td>342</td>
<td>332</td>
<td>6</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>81-90</td>
<td>18</td>
<td>15</td>
<td>2</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>71-80</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>≤ 70</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Factors involved when loss in discrimination occurred

Because we were interested in identifying the patients who had postoperatively a MSDS that was markedly lower compared to the preoperative percentage, we analysed the findings for the 8 patients who had a reduction ≥ 10% in MSDS after surgery. Table 2 shows the age, gender, the pre- and postoperative MSDS, and the postoperative change in MSDS, AC and BC for these 8 patients. The mean age in this group of patients was 48.9 years and differs not significantly from the rest of the population. The average loss in MSDS for this group of patients was 20.1% (SD ± 12.2%). Figure 3 shows the median pre- and postoperative SRC for this group of patients. For each of the 8 ears, there were no significant changes in the pre- and postoperative maximum slope of the SRCs and phonemic regression did not occur.

It was found that before surgery a great variety existed in the AC and BC values (PTA at 0.5, 1, 2, and 4 kHz) in this group of patients. However, statistical analysis revealed that the average preoperative AC and BC levels (PTA at 0.5, 1, 2, and 4 kHz) in this group of patients do not significantly differ from the average levels in the rest of the population. The values were 52.6 dB (SD ± 20.2 dB) and 24.1 dB (SD ± 14.0 dB), respectively.
Table 2. Patients with a postoperative reduction $\geq 10\%$ in maximum speech discrimination score (MSDS).

<table>
<thead>
<tr>
<th>Patient nr.</th>
<th>Age (years)</th>
<th>Gender</th>
<th>Preop MSDS (%)</th>
<th>Postop MSDS (%)</th>
<th>$\Delta$ MSDS (%)</th>
<th>$\Delta$ AC (dB HL)</th>
<th>$\Delta$ BC (dB HL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>57</td>
<td>Female</td>
<td>100</td>
<td>67</td>
<td>-33</td>
<td>5</td>
<td>-23</td>
</tr>
<tr>
<td>2</td>
<td>59</td>
<td>Female</td>
<td>100</td>
<td>88</td>
<td>-12</td>
<td>14</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>36</td>
<td>Male</td>
<td>100</td>
<td>53</td>
<td>-47</td>
<td>-51</td>
<td>-42</td>
</tr>
<tr>
<td>4</td>
<td>38</td>
<td>Female</td>
<td>100</td>
<td>83</td>
<td>-17</td>
<td>3</td>
<td>-27</td>
</tr>
<tr>
<td>5</td>
<td>30</td>
<td>Female</td>
<td>100</td>
<td>90</td>
<td>-10</td>
<td>-4</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>44</td>
<td>Male</td>
<td>96</td>
<td>80</td>
<td>-16</td>
<td>6</td>
<td>-15</td>
</tr>
<tr>
<td>7</td>
<td>65</td>
<td>Male</td>
<td>91</td>
<td>79</td>
<td>-12</td>
<td>31</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>62</td>
<td>Female</td>
<td>100</td>
<td>86</td>
<td>-14</td>
<td>23</td>
<td>3</td>
</tr>
</tbody>
</table>

$\Delta$ MSDS = postoperative change in maximum speech discrimination score.
$\Delta$ AC = postoperative change in air-conduction calculated for the PTA at 0.5, 1, 2, and 4 kHz.
$\Delta$ BC = postoperative change in bone-conduction calculated for the PTA at 1, 2, and 4 kHz.

In three ears a good improvement in AC was achieved (patient 2, 7, and 8; Table 2). The preoperative BC curves in these ears were steep with a slope decay $\geq 15$ dB/octave in the frequency range 0.5 - 4 kHz (Fig. 4. B). Because of the good technical result with gap closure $\leq 10$ dB, the AC thresholds in these ears turned into rather steep curves (Fig. 4. A). Patient 7 and 8 had an average slope decay $\geq 10$ dB/octave in the frequency range 0.5 - 8 kHz, while patient 2 had an average slope decay $\geq 20$ dB/octave in the frequency range 1 - 8 kHz. In these three ears the possible explanation of a reduction in MSDS could be in fact a masking effect of the higher frequency elements of speech by low frequency elements, due to the increased steepness of the AC curves as mentioned in the Introduction.

In 4 ears (patient 1, 3, 4, and 6; Table 2) SNHL occurred with a decrease in BC level $> 10$ dB in the high-frequency PTA at 1, 2, and 4 kHz. The preoperative AC curves in these ears showed a flat configuration which did not change after surgery (average slope decay $< 10$ dB/octave in the frequency range 0.5 - 8 kHz). In none of these cases closure of the ABC $\leq 10$ dB was achieved and the operations performed in these cases can be considered as technical failures without repair of transmission function but with the occurrence of cochlear damage. In one ear (patient 5; Table 2) it was not succeeded to restore transmission function, while no substantial change in the postoperative BC threshold was observed. However, MSDS showed a reduction of 10 % after surgery for which we have no explanation. Test error could be a possibility.

Factors involved when gain in discrimination occurred

There were 13 ears (3.6 %) with an increase $\geq 10$ % in MSDS after surgery. For each of these patients the age, gender, pre- and postoperative MSDS, as well as the change in MSDS, AC, and BC are shown in Table 3. The average age in this group of patients was 52.2 years and was significantly higher compared to the population who showed no change in MSDS $\geq 10$ %
Effects of Stapes Surgery on Speech Reception

Effects of Stapes Surgery on Speech Reception

(Mann Whitney test, $p < 0.01$). A Carhart effect, defined as an improvement in BC $> 10$ dB for the PTA at 1, 2, and 4 kHz, was noticed in 7 ears (Table 3). Figure 5 shows the median pre- and postoperative SRC for this group of patients. The mean improvement in MSDS for this group of patients was 14.5 % (SD ± 4.0 %). For each of the 13 ears, there were no significant changes in the pre- and postoperative maximum slope of the SRCs and phonemic regression did not occur.

Before surgery the average preoperative AC and BC thresholds (PTA at 0.5, 1, 2, and 4 kHz) in this group were 73.4 dB (SD ± 18.3) and 34.9 dB (SD ± 12.4), respectively. These values are significantly worse than the average preoperative AC and BC thresholds in the rest of the population (Mann Whitney test, $p < 0.0001$ for AC; $p < 0.01$ for BC). Only one ear had an AC threshold that was above the average threshold of the total population.

In the group of 13 ears with improvement in MSDS ≥ 10 % both the AC and BC levels (PTA 0.5, 1, 2, and 4 kHz) improved significantly (Wilcoxon test, $p < 0.0001$ for AC, $p < 0.001$ for BC) after surgery with values of 36.8 dB (SD ± 7.5) and 8.3 dB (SD ± 6.2), respectively. These values are also significantly larger compared to the average gain in AC and BC for the rest of the population (Mann Whitney test, $p < 0.0001$ for AC, $p < 0.01$ for BC).

Analysis of the steepness of the pre- and postoperative BC and AC curves showed that before surgery 2 ears (patient 5 and 9; Table 3) had a steep BC curve with an average audiometric slope ≥ 15 dB/octave in the frequency range 0.5 - 4 kHz. After surgery, both ears showed an improvement in BC for the PTA at 1, 2, and 4 kHz and the BC curves turned into rather flat curves with average audiometric slopes not exceeding 10 dB/octave. In the whole group of 13 ears none of the cases had an AC curve with an average slope decay ≥ 15 dB/octave in the frequency range 0.5 - 8 kHz before and after surgery.

DISCUSSION

The aim of this study is to evaluate the effect of stapes surgery on several parameters derived from speech audiometry in quiet. Therefore, the change in SRT, the slope of the SRC, the MSDS and the presence of regression were analysed. We were especially interested in factors related with the occurrence of a deterioration or improvement in speech discrimination after surgery.

The occurrence of a substantial decrease in speech discrimination after surgery is a serious matter. Several factors can be related to a decrease in postoperative MSDS. One of the factors is that after successful stapes surgery the steepness of the AC curve increases when preoperatively there exists a rather steep BC curve. This leads to a masking effect of the low frequency on the high frequency components of speech as already mentioned in the Introduction. The amount of acoustic energy contained in the frequencies below 1 kHz is much greater than the energy contained in the frequencies above 1 kHz for a speech signal at a given decibel level. However, more of the key-information necessary for the understanding of speech is contained in the frequencies above 1 kHz.12
Fig. 4. Preoperative (Preop) and postoperative (Postop) pure tone air-conduction thresholds (A) and bone-conduction thresholds (B) for 3 ears with postoperatively a good improvement in air-conductive hearing but with a postoperative reduction ≥ 10% in speech discrimination score (SDS).
Table 3. Patients with a postoperative improvement ≥ 10 % in maximum speech discrimination score (MSDS).

<table>
<thead>
<tr>
<th>Patient nr.</th>
<th>Age (years)</th>
<th>Gender</th>
<th>Preop MSDS (%)</th>
<th>Postop MSDS (%)</th>
<th>Δ MSDS (%)</th>
<th>Δ AC (dB HL)</th>
<th>Δ BC (dB HL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>49</td>
<td>Male</td>
<td>70</td>
<td>95</td>
<td>25</td>
<td>24</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>32</td>
<td>Male</td>
<td>83</td>
<td>100</td>
<td>17</td>
<td>35</td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td>70</td>
<td>Female</td>
<td>70</td>
<td>82</td>
<td>12</td>
<td>26</td>
<td>-3</td>
</tr>
<tr>
<td>4</td>
<td>57</td>
<td>Female</td>
<td>83</td>
<td>100</td>
<td>17</td>
<td>51</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>56</td>
<td>Female</td>
<td>88</td>
<td>100</td>
<td>12</td>
<td>33</td>
<td>12</td>
</tr>
<tr>
<td>6</td>
<td>59</td>
<td>Female</td>
<td>82</td>
<td>100</td>
<td>18</td>
<td>33</td>
<td>11</td>
</tr>
<tr>
<td>7</td>
<td>50</td>
<td>Female</td>
<td>90</td>
<td>100</td>
<td>10</td>
<td>46</td>
<td>-3</td>
</tr>
<tr>
<td>8</td>
<td>35</td>
<td>Male</td>
<td>88</td>
<td>100</td>
<td>12</td>
<td>40</td>
<td>15</td>
</tr>
<tr>
<td>9</td>
<td>68</td>
<td>Female</td>
<td>82</td>
<td>94</td>
<td>12</td>
<td>35</td>
<td>15</td>
</tr>
<tr>
<td>10</td>
<td>57</td>
<td>Female</td>
<td>83</td>
<td>100</td>
<td>17</td>
<td>44</td>
<td>15</td>
</tr>
<tr>
<td>11</td>
<td>37</td>
<td>Female</td>
<td>88</td>
<td>100</td>
<td>12</td>
<td>31</td>
<td>13</td>
</tr>
<tr>
<td>12</td>
<td>69</td>
<td>Male</td>
<td>90</td>
<td>100</td>
<td>10</td>
<td>38</td>
<td>7</td>
</tr>
<tr>
<td>13</td>
<td>40</td>
<td>Male</td>
<td>79</td>
<td>94</td>
<td>15</td>
<td>43</td>
<td>2</td>
</tr>
</tbody>
</table>

Δ MSDS = postoperative change in maximum speech discrimination score.
Δ AC = postoperative change in air-conduction calculated for the PTA at 0.5, 1, 2, and 4 kHz.
Δ BC = postoperative change in bone-conduction calculated for the PTA at 1, 2, and 4 kHz.

Fig. 5. Preoperative (preop) and postoperative (postop) median speech reception curve for the 13 ears with an improvement ≥ 10 % in maximum speech discrimination score.
This masking effect resulting in loss in speech discrimination has been studied by Huizing.\(^5\) He related the maximum speech discrimination obtained by speech audiometry in quiet to the shape of the postoperative AC pure-tone thresholds of patients who had successful gap closure after stapes surgery for otosclerosis.

A loss in speech discrimination was observed when the postoperative pure-tone audiogram showed either an AC curve with a cut-off frequency of about 1 kHz and a slope that exceeded 20 dB per octave, or an AC curve with a cut-off frequency of about 0.5 kHz and a slope that amounted to 10 dB per octave or more. The loss in discrimination was more severe if the cut-off frequencies were more in the range of 0.5 kHz and the slope showed a sharp decline. In the same study, comparable results were found in young persons with normal hearing and otologically normal ears in whom speech discrimination was established with high-frequency filtered speech as a function of various combinations of cut-off frequencies and slopes. The results of this study pretend to give a general indication as to when a postoperative speech discrimination loss is to be expected if stapes surgery increases the slope of the audiogram.

In another study, carried out by Owens et al.\(^3\), the speech discriminations obtained by speech audiometry in quiet were also related to the postoperative AC configurations in patients with otosclerosis who had gap closures \(\leq 10\) dB after stapes surgery. In this study it was found that loss in discrimination occurred when the postoperative AC curve showed a decline of \(> 15\) dB/octave. On the basis of the preoperative pure-tone audiogram several declines in BC were defined which were typically associated with reductions in speech discrimination after surgery. Owens et al.\(^3\) could identify a group of patients who were at risk for loss in speech discrimination. These were patients 60 years of age or older, with a preoperative BC loss of 25 dB or more, and BC curves showing several defined declines in the frequency range 0.5 - 2 kHz. Although it was not mentioned in this study, the principle of the reduction in speech discrimination in these patients were probably the same as described by Huizing.\(^5\)

In our population a masking effect was probably the reason for a reduction in speech discrimination in three patients (Patients 2, 7, and 8; Table 2). Two of these patients were indeed over 60 years of age and all three ears showed preoperatively rather steep BC curves with slope decays \(\geq 15\) dB/octave (Fig. 3.B). The preoperative AC thresholds had flat configurations (Fig. 3.A) and each patient had a successful gap closure \(\leq 10\) dB. Consequently, the AC thresholds turned into rather steep curves with an average decline \(\geq 15\) dB/octave in the frequency range 0.5 - 8 kHz and it was found that all three patients had a loss in MSDS \(\geq 10\%\).

The question rises whether the loss in speech discrimination could be predicted from preoperative pure-tone audiograms. In the above mentioned three patients we could retrospectively presume that a loss in speech discrimination could occur when a good technical result was obtained without substantial change of the BC level. However, the slope of the postoperative AC threshold is not always to be predicted from the preoperative BC thresholds, even when technical success is achieved with ABG closure \(\leq 10\) dB. The reason is that after surgery there is a chance that either a SNHL due to cochlear damage or a Carhart effect occurs. A SNHL will mainly impair hearing in the higher frequencies and consequently
the steepness of the AC curve will increase in most cases. The Carhart effect results in an improvement of the BC and is most pronounced at 2 kHz in the majority of cases but can improve the BC levels in the whole frequency range 0.5 - 4 kHz. Most of the patients in our study who improved in speech discrimination ≥ 10% showed a Carhart effect with a markedly improvement in BC for the PTA at 1, 2, and 4 kHz (Table 3). We could identify two patients (patient 5 and 11; Table 3) who had preoperatively rather steep BC curves with a decay ≥ 15 dB/octave. When the BC levels in these patients would not have changed after surgery, this could lead to steep AC curves after surgery and consequently a masking effect could occur with a possible reduction in MSDS. However, the BC levels in these two patients showed a Carhart effect and BC curves turned into rather flat curves (average slope decay < 10 dB/octave in the frequency range 0.5 - 4 kHz). Speech discrimination improved in both patients and we presume this is possibly related to the good technical result with overclosure of the ABG and a markedly improvement in air-conductive hearing. The improvement in speech discrimination in these two ears demonstrates that either improvement or deterioration of speech discrimination can not always be predicted from the shapes of the preoperative pure-tone thresholds. This is also supported by the finding that in the whole population of 386 ears we could identify 7 ears having BC curves with an average slope decay ≥ 15 dB/octave in the frequency range 0.5 - 2 kHz. Six of them had gap closure ≤ 10 dB and showed postoperatively an increase in the steepness of the AC curve (average decline ≥ 10 dB in the frequency range 0.5 – 8 kHz). Only three ears (patient 2, 7, and 8; Table 2) showed a reduction in discrimination. The other 3 patients had a MSDS of 100% which did not change after surgery. Furthermore, in four cases (patient 1, 3, 4, and 6; Table 2) a reduction in speech discrimination was found which was related to technical failure with cochlear damage.

Another factor which plays a role in the reduction of speech discrimination is the absence of the stapedial reflex when sectioning the stapedius tendon without reconstruction. An intact stapedial reflex attenuates sound energy in the low frequency portion of the speech spectrum. It therefore reduces the undesirable upward spread of masking of low frequency sounds and preserve the transmission of information with higher frequencies. The absence of the stapedial reflex results in phonemic regression, also called “roll-over”, and is best examined with speech audiometry in noise. However, the consequences of an absent stapedial reflex have also been demonstrated clearly in patients with Bell’s palsy and a paralysed stapedius muscle using speech audiometry in quiet. The effects of an absent stapedial reflex on speech discrimination have led to a change of the stapes surgery technique with reconstruction of the stapes tendon by several authors.

In this study we defined “phonemic regression” as a slope decay > 0.5 %/dB of the SRC after MSDS has been obtained with increasing sound intensity. With this definition we found only 15 ears (3.9%) with regression after surgery, while none of the ears showed regression before the operation. This low occurrence of postoperative regression is most likely due to the test circumstances in quiet. Probably we would find a higher incidence of postoperative regression when speech audiometry is done in noise.
CONCLUSIONS

In general, the overall results of primary surgery were good in the ears included in this study. An ABG closure ≤ 10 dB was obtained in 76 %, while in 93 % it was closed to ≤ 20 dB. On average the conductive hearing improved with 21.6 dB (SD ± 11.7 dB), and, as expected, the change in AC threshold (PTA 0.5, 1, 2, 4 kHz) correlates well with the change in the SRT (Fig. 2) which was also found in a previous study.17 Stapes surgery has little effect on the slope of the SRC; no significant postoperative changes were found, neither in the general population nor in the group of ears with a either a deterioration or improvement in MSDS ≥ 10 %.

From the results in this study it appears that we could not identify a group of patients who is at risk for loss in speech discrimination because it is not possible to predict the shape of the postoperative pure-tone discrimination as either a Carhart effect or cochlear damage can occur. Severe SNHL (deterioration in bone conductive hearing > 10 dB) is often associated with discrimination loss. On the other hand, when before surgery a loss in discrimination exists with AC and BC levels showing markedly impaired hearing, there is a chance that speech discrimination improves in those cases having a successful closure of the ABG and with an obvious increase in bone conductive hearing due to the Carhart effect.

REFERENCES


