AN AUDIOMETRIC COMPARISON OF THE RESULTS OF TOTAL STAPEDECTOMY AND PARTIAL STAPEDECTOMY TECHNIQUES OF STAPES SURGERY FOR OTOSELEROSIS

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# CHAPTER I

## INTRODUCTION

### Otosclerosis and History of Surgical Techniques

Otosclerosis is a disease process that affects the bony capsule of the inner ear. It turns the normally hard bone into spongy bone and produces a progressive hearing loss through fixation or ankylosis of the stapes in the oval window (29, p. 38). The Caucasian race is primarily affected, and women appear to be slightly more susceptible to the disease than men, according to a study by Altmann, Glasgold, and MacDuff (2). Goodhill (8, p. 5) reports that long-standing otosclerotic processes may result either in extensive calcification of the crura of the stapes, which become extremely rigid structures, or in the reverse, atrophy, with complete loss of bony integrity, so that they become merely elastic remnants of tissue, which yield to the very slightest pressure, and thus cannot effectively transmit acoustic energy from the ossicular chain to the footplate.

A diagnosis of otosclerosis is made when all or most of the following classic signs are observed in a patient complaining of deafness:

1. A family history of otosclerosis is obtained.

2. Deafness for air-conducted sound is present, which is progressive, either slowly or rapidly, beginning in the low frequencies, and ultimately involving the higher frequencies. This deafness may be unilateral, though it is usually bilateral.

3. Hearing by bone conduction is better than that by air conduction in all frequencies in which hearing by air conduction is impaired.

4. The patient believes he hears conversation better in noisy places.

5. Audiometric tests following eustachian-tube inflation show that such inflation does not improve hearing temporarily, though some patients feel it does.

6. An annoying tinnitus is frequently present which may be unilateral or bilateral, mild or severe, continuous or intermittent.

7. The tympanic membranes are usually atrophic and extremely translucent.

8. As a rule, the eustachian tubes are patent.

9. The Weber test shows a lateralization to the poorer ear, when there is a marked difference in air-conduction acuity, provided that the hearing by bone conduction in that ear is greater than in the less deafened ear.

10. Hearing by bone conduction may remain normal, although the hearing for air-conducted sound may have sunk to a low decibel level (22, p. 2).

It must be kept in mind that this is the classical picture, and few patients are encountered who demonstrate all of these signs. For example, Sheehy (40) studied sixty-two patients, with no measurable bone conduction, and surgically confirmed the preoperative diagnosis of far-advanced otosclerosis in forty-six cases. In another study, he (42) states that results obtained from stapes surgery on patients whose bone-conduction level is 30 decibels (dB) or more are in every way comparable to those obtained on patients whose bone-conduction level is less than 30 dB, and that there does not appear to be a maximum bone-conduction level beyond which stapes surgery is contraindicated.

The restoration of hearing to those deafened by otosclerosis is the goal of all surgery for this disorder, and its achievement has challenged otolaryngologists for years. Campbell (3) provides a very complete history of surgery for otosclerosis, and Goodhill (9) also presents surgical history, although in an abbreviated form. In 1875, Kessel, a German surgeon, tried to mobilize the stapes, and then extracted it. In the ensuing years, many European otologists performed stapes surgery. Miot, in 1890, analyzed results in 200 cases operated for mobilization of the stapes. It is noteworthy that he observed listerian antiseptic techniques in preparation of the canal, instrument sterilization, and hand preparation. In properly selected cases, he claimed to have obtained good results. At the turn of the century, Siebenmann and Moure reported all attempts at stapes surgery useless and dangerous, so the procedures were abandoned, and other techniques were investigated. This led to the beginning of the era of fenestration of the semicircular canal, climaxed by Lempert's techniques in the late 1930's. Shambaugh, in Chicago, began to specialize in these techniques and performed thousands of fenestrations. The results obtained were quite good, with the restoration of hearing to a practical level in 80 to 90 per cent of properly selected cases. However, fenestration leaves an air-bone gap of never less than 15 dB, and more often a 25 dB gap is present (8, p. 10).

In December, 1952, Rosen reported his rediscovery of the stapes mobilization, and interest in this approach greatly revived. He developed several techniques to be used in situations in which the original technique could not be used or did not work. When the excellent primary results began to dim, by virtue of reankylosis, the use of more radical procedures began. Various modifications of the stapes mobilization were instituted, but these also showed a low percentage of lasting good results.

It was inevitable that other operative methods would be investigated, designed to obtain lasting results. In 1956, Shea suggested removing the entire stapes and replacing it with a plastic prosthesis connecting the incus to tissue graft placed on the oval window. He was soon using a vein graft to cover the oval window and a polyethylene tube to replace the stapes.

The popularity of the stapedectomy and prosthesis operation has increased tremendously, and many variations have developed. Some surgeons prefer polyethylene tubing, while others use stainless steel wire. Some prefer vein graft in the oval window, while others advocate soft tissue such as fat or fascia. Some surgeons are opposed to removal of the stapes footplate and use a prosthesis directly on a mobilized footplate, while others, to avoid foreign material in the inner ear, prefer to reposition the stapes crura on a loosened footplate. Whatever the technique, it is clear that surgery has come full circle, back to the stapedectomy as originally advocated by Kessel.

## Purpose of the Study

The purpose of this study is to compare the audiometric results of two variations of the stapedectomy procedure: the partial stapedectomy as performed by Hough, and the total stapedectomy as performed by Schuknecht and House.

## Description of Partial and Total Stapedectomy

Hough (13, p. 414) performed the first partial stapedectomy in 1956, as a result of a surgical error, and its development progressed and came to be more widely applied. The diseased footplate and anterior crus of the stapes is removed, but the posterior crus is retained for sound transmission. The oval window is sealed by two pieces of absorbable gelatin sponge, one anteriorly and another posteriorly. The total footplate may be removed, if it is totally involved or technically necessary. The incudostapedial joint remains intact. According to Hough (15, p. 631), the partial stapedectomy is definitely more difficult and cannot be done in every situation. He does state, however, that the crural arch can be preserved in almost all anatomic and pathologic conditions encountered in stapedial surgery and that the posterior crus may be used, if it is only two-thirds of its normal length (14, p. 425). In fact, he reports that in 80 per cent of the ears with stapedial fixation, he has been able to do partial stapedectomy (13, p. 414).

The advantages of this technique are numerous. The oval window is always partially closed by the presence of the normal tissue of the posterior crus and/or attached footplate, which lessens the possibility of fistula formation. There may be a higher rate of initial refixation during the first few months, due to the fact that the posterior crus is a living structure, but apparently there is a lower rate of long-term regression and less cochlear loss than is seen in some of the other procedures. The principal advantage is the fact that prosthetic materials are not used, and the danger of their reaction, deterioration, or lack of function in the future is eliminated (15, p. 631; 13, p. 418).

The total stapedectomy, as performed by House and Schuknecht, involves complete removal of the stapes, replacing it with a metal prosthesis, and covering the oval window with a fat graft or Gelfoam. Schuknecht routinely uses fat graft and reports excellent results in over 90 per cent of carefully done stapedectomy procedures (36, p. 16). House reports, in a 1962 publication, that "vein, fat, and Gelfoam plugs have performed about the same in my hands" (19, p. 299), but in the same article he claims the best results are obtained with the prefabricated wire loop-Gelfoam technique (19, p. 302). In 1964, he again credits the latter technique as the one giving better results than any other method he has used (20, p. 8).

Both polyethylene and wire prostheses are well tolerated in the middle ear. House believes wire is more adaptable than polyethylene, and it binds without a tendency to spring back. It can also be readily removed if revision is necessary. He reports no necrosis developing from a wire prosthesis (19).

Hough (15), in a discussion of various surgical techniques, relates the advantages and disadvantages of the total stapedectomy. It is a technique which requires a minimum of surgical equipment and can be carried out in a systematized, routine fashion. Because of these qualities, it can be performed more readily by the infrequent operator and by those in training. However, the labyrinth is opened widely by removing the entire footplate, and a prosthesis must be used, because the stapedial superstructure has been sacrificed. As a result, there is a risk of poor union of the prosthesis at either end of the device, and there is persistently a future chance of fistula formation and incus necrosis.

In this study, the two procedures discussed above are compared audiometrically in terms of: (1) air-conduction improvement in the speech frequencies, (2) improvement in the speech reception threshold, (3) difference in discrimination ability, and (4) incidence of high-frequency hearing loss.

## Literature Review

New techniques for old problems are constantly evolving; therefore, it would seem appropriate to look at the literature chronologically in order to appreciate the evolution of these techniques and the results obtained. In 1958, Shea (39) described a technique which he termed "occasionally more time consuming and difficult than fenestration of the semicircular canal" (39, p. 950), but which seemed initially more successful and perhaps more permanent. This technique was the fenestration of the oval window and is used in the Hough, House, and Schuknecht techniques when the stapedial footplate is thickened.

In 1960, Hough (16) reported on 115 ears which had had anterior partial stapedectomies. His results showed 82.6 per cent, or ninety-five ears, reached a level of hearing within 10 dB of the preoperative bone-conduction results or better. The average preoperative air-bone gap was 33.1 dB, while the average postoperative gap was 1.5 dB. The average gain was 31.6 dB. One ear in the series was made worse. There were no serious postoperative complications and no dead ears. The time from surgery to the postoperative audiometric test was not given.

Schuknecht (33) reported a study of 166 cases, which underwent total stapedectomies, using a tantalum or stainless steel prosthesis. The average time from surgery to the final audiogram was three months. One hundred forty-two, or 86 per cent, of the cases acquired an average of 30 dB or better in the speech frequencies. Twenty-two of the cases experienced no change, and two had losses of 6 dB or more.

In a later study, Schuknecht (35) reported on 287 total stapedectomy procedures, again with tantalum or stainless steel wire. The postoperative tests were administered an average of four months postoperatively. Those having an air-bone gap in the speech frequencies of 15 dB or less numbered 242, or 84.3 per cent. One hundred sixty-two, or 56.8 per cent, had a postoperative air-bone gap of 5 dB or less. Significant high-tone losses (defined as 20 dB or more for 4000 Hertz) were found in fifty, or 17.4 per cent, of the series. From this last group, five acquired hearing losses for 2000 Hertz (Hz) of sufficient magnitude to affect speech discrimination. In four cases, original hearing gains were lost, due to a recurrence of conductive deafness. Delayed sensorineural degeneration occurred in seven (2.4 per cent). Schuknecht states that the functional result was not dependent upon the type of tissue or type of metal used, and felt he could definitely relate the cases with losses to inner ear trauma occurring at the time of surgery or at previous stapes operations.

House (10) reported on fifty cases of total stapedectomy, using the wire-plug prosthesis, in 1961. Closure of the air-bone gap to within 10 dB of the preoperative bone-conduction level was achieved in 80-85 per cent at the four-month postoperative hearing test.

In 1962, House (19) reported closure of the air-bone gap to within 10 dB of the postoperative bone level occurring in 70-80 per cent of his cases per 100 series. Some 2 per cent of the primary stapedectomies with plug inserts developed severe discrimination changes. He does not cite the figures on these changes.

Sheehy (42), an associate of House, studied results of total stapedectomy in cases of advanced otosclerosis. Clinically, advanced otosclerosis refers to an average bone-conduction loss in the speech frequencies of 30 dB or more, with a level of 30 dB or more at 500 Hz. Sixty-five patients, who had had no previous surgery on either ear, were selected. Sixty-seven patients were selected as a control group. The criteria was the same for the latter group, except the preoperative bone-conduction level was less than 30 dB, averaged in the speech frequencies, with a bone-conduction level of 10 dB or less at 4000 Hz. Five different total stapedectomy techniques were used, but these were not differentiated in the results. A bone-conduction improvement of 5 dB or more occurred in one-fourth of both groups. One-half of each group showed a postoperative bone-conduction improvement of 5 dB or more. A bone-conduction impairment of 10 dB or more occurred in four of the advanced-otosclerosis group and in two of the control group. There were no impairments of 20 dB or more. One-third of those in the control group showed an improvement of 10 per cent or more in discrimination score. There was difficulty in evaluating changes in the discrimination score in the advanced-otosclerosis group. Three-fourths of the thirty cases at which PB words were given just short of the maximum comfortable loudness level showed postoperative discrimination score improvements. This represented an improvement in measurable or usable discrimination in each case. In half of the eighteen cases where the preoperative discrimination score was obtained at the maximum comfortable loudness level, an improvement was noted. Four patients in each group developed impairments in discrimination of 10 per cent or more. This represented 6 per cent of the control and 8 per cent of the advanced-otosclerosis group. Improvements in the discrimination score noted in the advanced-otosclerosis group ranged from 10 to 75 per cent, with a median of 30 per cent.

Schuknecht (34), reporting in 1962, stated that out of 750 stapedectomies, with wire and fat graft, only twenty (2.66 per cent) showed severe sensorineural losses. He reported excellent results in over 90 per cent of carefully done stapedectomy operations (36). Regression occurred in less than 5 per cent of the patients who had been checked repeatedly over a three-to-five-year period, but he did not give the figures for this. In some 1200 cases he noted no tissue reaction.

Guilford (10) reported on both total and partial stapedectomies. Of fifty-three carefully selected cases in which a partial stapedectomy was performed, forty-two (82.3 per cent) obtained closure of the air-bone gap to within 10 dB or better. Of 369 total stapedectomies with vein graft, 299 (86.9 per cent) closed the air-bone gap. Of fifty-eight total stapedectomies with fat graft, forty-nine (80.5 per cent) closed the air-bone gap. In considering speech discrimination losses, 2 per cent of those with vein grafts and 2.8 per cent of those with fat grafts suffered severe or disabling permanent hearing losses.

In a series of 200 consecutive stapes operations, Brown (7) reported 93.5 per cent of the patients apparently received a worthwhile hearing improvement. The hearing is reported as "good" or "very good" in 77.5 per cent, "fair" in 16 per cent, and "poor" in 6.5 per cent. These operations consisted of 5 per cent stapes reconstructions, 20 per cent partial stapedectomies, and 75 per cent total stapedectomies. The reported results were not broken down according to type of surgery.

McGee (23) reported on total stapedectomy performed with stainless steel wire and fat graft in 287 cases. These cases were operated in 1959. The air-bone gap was less than 10 dB postoperatively in 214 (74.9 per cent). Of 260 cases performed in 1960, the air-bone gap was 10 dB or less in 212 cases (80.6 per cent). Of the 287 cases done in 1959, 282 (84.3 per cent) had a postoperative air-bone gap of 15 dB or less, as compared to 231 (87.8 per cent) of the 260 cases done in 1960. High-tone losses above 2000 Hz were 50 (17.4 per cent) in 1959, and 4 (1.5 per cent) in 1960. He felt this reduction was due to careful adherence to rules designed to reduce cochlear degeneration by avoiding labyrinthine injury during surgery.

In 1962, Morrison (27) reported on stapedectomy using a polyethylene prosthesis. Forty-five patients, all with a loss of more than 40 dB and a bone-conduction level of at least 20 dB, underwent the surgery. Thirty-six patients closed the air-bone gap, two were classed as moderately improved, and seven were failures. The percentages were 80 per cent, 4.5 per cent, and 15.5 per cent, respectively.

Myers (28) discussed the results of 500 cases of stapedectomy tested one month postoperatively. Those achieving a hearing level of 30 dB or better constituted 84.6 per cent, 67.8 per cent obtained hearing within normal limits, and 74.6 per cent experienced closure of the air-bone gap. In 9.2 per cent there was no change, 6.2 per cent experienced a drop in hearing acuity, and 0.8 per cent showed a severe deafness with labyrinthosis. Of 222 patients tested six months postoperatively, 90.5 per cent obtained a level of 30 dB or better, 76.1 per cent obtained normal hearing, 85.1 per cent obtained closure of the air-bone gap, 6.3 per cent experienced no change, 3.2 per cent experienced a drop in hearing, and 1.8 per cent experienced severe deafness. Throughout the one-year post-operative period, there was a general tendency only for patients with the lesser sensorineural involvement to attain closure of the air-bone gap. On the other hand, there appeared to be a tendency for patients with a greater degree of sensorineural damage to develop more hearing loss.

Robinson (32), using a specially-designed stainless steel prosthesis as a stapes replacement in stapedectomy, reported on seventy-six patients. Closure of the air-bone gap to within 10 dB was effected in sixty-nine patients. In three, the air-bone gap remained greater than 10 dB, but the resulting hearing loss was less than 30 dB. In three cases improvement was 20-40 dB, but the resulting hearing level was greater than 30 dB. No improvement was noted in only one patient.

Cawthorne (4) reported his experiences with stapedectomy in 300 cases. He discussed only those that showed no improvement. There were fifty-two of these. Forty-one showed no change, nine had worse hearing, and two lost their hearing sensitivity following surgery.

In 1963, Gundersen (12) reported on the first one hundred stapedectomies carried out in the ENT department of Bergen University Hospital. The method employed was a steel wire-fat prosthesis _ad modum_ Schuknecht. Closure of the air-bone gap was achieved in ninety-seven cases. Two were unimproved, and one became deaf, due to an infection. Preoperatively, four patients had no measurable bone-conduction hearing. The oldest patients, eighty-two and seventy-eight, were both successfully operated. Postoperative tests were given at two weeks, three weeks, four weeks, three months, and every three months after that. The longest observation period was eighteen months in sixteen patients.

During a panel on stapes surgery in 1963, several sets of results were reported. Guilford (24, p. 557) reported on stapedectomy using vein or fat graft. The exact number of surgeries was not given, but he stated that 80-85 per cent came within 10 dB of closing the air-bone gap. Consistent, severe loss in cochlear function as measured by speech discrimination tests was experienced by 2 per cent of the patients. Schuknecht (24, p. 564) reported on 1500 operations using his wire-fat graft technique. There were twenty-five serious sensorineural losses (1.7 per cent). Portmann (24, p. 565) reported 92 per cent successes, 85 per cent with closure of the air-bone gap, and 2 per cent severe labyrinthine loss. In consecutive series, each of 100 cases, the percentage of total loss varied from 0-3 per cent. House (24, p. 570) reported a low sensorineural loss with Gelfoam and wire loop, a 0.6 per cent incidence of loss of 20 dB or more in the speech frequencies.

In a three-year report on 200 stapedectomy procedures with plastic prostheses, Mercandino and Tarasida (25) found 30 per cent achieved 100 per cent closure of the air-bone gap, 40 per cent achieved 90 per cent closure, 22 per cent achieved 60 per cent closure, 6 per cent returned to their previous levels in a week to two months, and 2 per cent presented perceptive losses of different degrees. No explanation was given regarding computation of percentage of air-bone gap closure.

Moncur and Goodhill (26) reported the results of seventy-five cases, all original ears, who had stapedectomy using polyethylene prosthesis. Results of the six-months postoperative test revealed that the group as a whole achieved almost complete closure of the air-bone gap. Near-maximum gain was achieved by the thirty-day test period, and few differences were observable between the ninety-day and 180-day results. Analysis of results of speech testing revealed that the SRT improved in approximately the same amount as did the averages of the speech frequencies (with 1 dB). Of interest was the discrimination score which represented a mean decrease of 3.7 per cent from the preoperative score.

Both total and partial stapedectomy procedures were studied by Oppenheimer, Adamson, Shambaugh, Dorlacki and Harrison (47). The partial stapedectomy group of 795 included those patients with a polyethylene tube prosthesis to a mobilized footplate (not a classical Hough procedure). They reported 92 per cent gained 11 dB or more in the speech frequencies at the four-months test. Of 395 total stapedectomies, 88.9 per cent showed a similar gain. The partial stapedectomy group contained 7 per cent who gained 10 dB or less at the four-months test, as compared with 7.1 per cent of the total stapedectomy group with the same gain. The total stapedectomy group showed 2.5 per cent experienced complete regression, while the partial stapedectomy group showed complete regression in 4 per cent. Further loss of hearing, with cochlear involvement, claimed 3.5 per cent of the total stapedectomy group and 0.8 per cent of the partial stapedectomy group. It was felt that the higher percentage of regression noted in the nonstapedectomy group was more than balanced by a markedly higher percentage of further losses and postoperative side effects in the stapedectomy group.

Shambaugh (37), discussing stapedectomy, felt that it was the technique most dangerous to the labyrinth. His statistics, which he did not quote, indicated that the fat graft and wire and the mucosal flap and polyethylene tube methods of stapedectomy appeared the safest as far as cochlear losses are concerned. In his experience to date (October, 1963), there were no early or late cochlear losses and no regressions after partial stapedectomy.

Discussing both partial and total stapedectomies, Shea (38) examined 1500 cases done by each procedure. Of the partial stapedectomies, done in the manner of Hough, 89 per cent achieved closure of the air-bone gap, while 0.27 per cent experienced further loss of hearing. Of the total stapedectomies, done in the manner of House, 89 per cent achieved closure of the air-bone gap, while 1.3 per cent experienced further hearing loss.

Suter (47) stated that of 271 successfully operated cases of otosclerosis by stapedectomy, 9.9 per cent were regressing. He defined regression as a decrease in hearing gain of 15 dB or more. He suggested adhesions, positional anomolies or lesions, and bony closure of the oval window were responsible for the regressions.

In 1964, Hough (17) reported on 2000 consecutively done partial stapedectomies in which over 90 per cent of the group improved to within 10 dB of the average preoperative bone-conduction loss. Speech audiometry results corresponded closely to the air-conduction tests. Sixty-five per cent of the group experienced overclosure of the air-bone gap in the speech frequencies. He reported very little long-term regression after the first six postoperative months. In 1.5 per cent, there was an average regression of 11 dB or more, from the highest point of postoperative gain in the speech frequencies, during periods of up to seven years after surgery. Part of this, he states, may be accounted for on the basis of the normal adult population trend. Two patients (0.18 per cent) in the entire group suffered severe cochlear loss. The discrimination was reduced 20 per cent or more. In 1 per cent of the patients, air conduction in the speech frequencies was reduced by 10 dB or more.

Stapedectomy results with the teflon-wire prosthesis were reported by Guilford (11). Of 238 patients tested four months postoperatively, four (1.6 per cent) had additional loss of discrimination of more than 20 per cent, the final score being less than 50 per cent. Closure of the air-bone gap to within 10 dB was achieved by 77 (34.4 per cent). Complete closure was achieved by 28 (11.7 per cent). Overclosure of the gap was achieved by 105 (44.1 per cent). In a group of sixty-four patients on whom one-month and one-year postoperative results were available, the total overclosed and within 10 dB of closure was fifty-three (82.6 per cent) at one month. At one year, those overclosed and within 10 dB of closure numbered fifty-six (87.5 per cent).

Coleman (6) used a stainless steel wire pin for stapedectomy. In 100 consecutive operations with a minimum follow-up period of one year, he reported eighty-eight achieved closure of the air-bone gap to within 10 dB. Three experienced further loss. Ninety-two reduced the air-bone gap to 15 dB or less. He stated that the stapedectomy operation is either excellent or a complete failure, with few between the two extremes. He claimed the results of stapedectomy were so certain that the procedure should be the primary treatment of otosclerosis.

Abielo (1) performed 100 stapedectomies using Shea's technique. The acoustic results were classified according to (a) good, air-bone gap less than 10 dB; (b) acceptable, air-bone gap greater than 10 dB; (c) poor, dead labyrinth, better hearing but a new tinnitus, or no change in hearing. The results were: (a) seventy-three, (b) twenty-three, and (c) four.

Sixty-two patients who, without measurable bone conduction, underwent surgery with a preoperative diagnosis of far-advanced otosclerosis were discussed by Sheehy (40). Otosclerosis was confirmed by surgery in forty-six patients. The criteria of closure of the air-bone gap obviously was not feasible here. Objective improvement was noted in air-conduction threshold, in discrimination, and in ability to use a hearing aid. Subjectively, the patients' and the patients' friends' comments regarding their hearing were most important. Of the forty-six otosclerotic patients who underwent surgery, twenty-one later had surgery on the opposite ear, making a total of sixty-seven stapedectomy procedures. At four months postoperatively, the surgery was judged to have been successful in thirty-one cases (46 per cent). A one-year follow-up, available in thirty-three cases showed no regression.

Sooy, Owens, and Theurer (45) reported the results of seventy-two patients who underwent stapedectomy using polyethylene tube and vein graft. At four months postoperatively, 83.3 per cent achieved closure to within 10 dB. In the twenty-five patients who were followed for three years or longer, nine (36 per cent) showed no essential change from the earlier test, eleven (44 per cent) had dropped 3-7 dB, and five (20 per cent) were worse by 8-12 dB. Only four out of sixty-four patients tested at four months or longer showed a discrimination loss exceeding 10 dB.

One hundred consecutive cases of partial stapedectomy were reviewed by Strong and Vaughan (46). Sixty-nine achieved closure of the air-bone gap. Twenty-four others closed to within 10 dB or less. Three cases closed to within 15 dB and reached the level of 30 dB or less by air conduction. One case reduced the air-bone gap from 50 dB to 25 dB, but did not reach the 30 dB level by air conduction. Three were unimproved. There were no cases of sensorineural loss involving the speech frequencies.

Otto (31) reported in 1964, that stapedectomy was the chosen treatment for otosclerosis in Chile. He reported an average gain of 34.2 dB for air conduction and 6.4 dB for bone conduction in the speech frequencies. No other statistics were given, nor was the number of cases cited.

Weichselbaumer (48) reported on forty-six cases in which the anterior stapedial crurotomy technique (partial stapedectomy) was used. He cited average hearing improvement as 26.6 dB. There was no deterioration of hearing with time. No statement was made to specify the elapsed time between surgery and audiometry, and no idea as to rate of failure was discussed.

Cody, Simonton, Hallberg, and Hedgecock (17) reported the audiometric results of 639 stapedectomies in 1965. Of these, at the end of six months, 543 were judged to have satisfactory improvement, while twelve cases showed a severe sensorineural loss. Of 220 cases tested from six to thirty-six months postoperatively, 178 were judged successful, and two were found to have a severe sensorineural loss.

In a report on Schuknecht-type total stapedectomies, Kristensen, Terkildsen, and Thomasen (21) stated that, at two years postoperatively, 61 per cent (155) of 301 patients had thresholds better than 40 dB, with 35 per cent better than 30 dB. After one year, 19 per cent had thresholds better than 40 dB, and 47 per cent had thresholds better than 30 dB. Statistically this seemed to indicate deterioration of hearing levels, but the authors indicated that perusal of individual results showed this was not true. The explanation was sought in special circumstances with the group of patients who obtained the longest observation period. Some of these patients had previously undergone unsuccessful direct mobilization.

Sooy, Owens, and Theurer (44), in 1966, analyzed audiometric data for a series of 604 ears on which stapedectomies had been performed by a single surgeon. Air-bone gap closure for the average of the speech frequencies was achieved to within 10 dB in 92.4 per cent of the cases. Closure for individual frequencies was complete at 500 Hz, slightly better at 1000 and 2000 Hz, slightly poorer at 250 Hz, and markedly poorer at 4000 Hz. During a five-year postoperative period, hearing decreased 4.9 dB for the average of the speech frequencies.

A comparison of audiometric results of stapedectomy with polyethylene tube and stapedectomy with wire prosthesis was reported in 1966, by Sooy, Owens, and Schindler (43). Fifty-five patients having bilateral otosclerosis underwent stapedectomies in which a prosthesis of polyethylene tubing was used in one ear, and twelve or more months later a stainless steel wire prosthesis was used in the other ear. All operations were performed by the same surgeon, and procedures were the same, except for the use of the different prostheses. Similar results for the two prostheses were found at 250 Hz. The polyethylene tubing appeared slightly more effective at 2000 Hz, and the wire prosthesis appeared superior at 500, 1000, and 4000 Hz. The overall results in hearing improvement thus seemed to favor the wire prosthesis. Changes in hearing during the period from four months to one year were minimal, but tended to favor the wire prosthesis. The authors believe that the relatively greater reactivity of polyethylene and the occasional instances of incus erosion and strut separation definitely favor the use of a wire prosthesis.

In 1968, Sheehy (41) reported the long-term results of the prefabricated wire loop-Gelfoam stapedectomy procedure. A four-month follow-up of 151 cases revealed that 93 per cent closed the air-bone gap to within 10 dB. Seven per cent failed to obtain optimum results, two having severe bone-conduction impairments. A one-year follow-up of 105 cases revealed 82 per cent experienced closure to within 10 dB, and 18 per cent did not obtain optimum results. Seven who had obtained a good result at four months regressed, and twelve at no time had a satisfactory result. In the two-year follow-up of sixty cases, 80 per cent closed to within 10 dB. Seven patients did not have optimum results at this time. Of these, two had good results at four months, but regressed, and five at no time had satisfactory results. At the three-year follow-up, 84 per cent of ninety-six cases had closure to within 10 dB. Fifteen patients did not have optimum results. At this time there were four who had regressed. A serious sensorineural hearing impairment developed in four cases. A severe discrimination impairment was apparent in 2.4 per cent of the cases with three-year follow-up information.

In 1968, Hough (13) reported on long-term results of the partial stapedectomy in 200 ears. No previous surgery had been performed on these ears. In none was the air conduction made worse. Improvement of 10 dB or more was obtained in almost 100 per cent of the ears, and a high percentage retained this acuity five years or more. There was a regression of approximately 5 per cent from various postoperative and natural causes, such as presbycusis. Over five years later, only one ear was worse than originally. Bone conduction for 4000 Hz at six months was made worse by 10 dB or more in 2 per cent of the ears. Also at 4000 Hz, 8.5 per cent were made better. At this frequency, five to seven years later, 4.5 per cent were worse. Eight per cent demonstrated an improvement that was evident at the six-month test.

Hough stated that the average ear in 81 per cent of the cases representing anterior focus otosclerosis gained an average of 25.5 dB. Five to seven years later there was a regression of 4 dB. The essential question, Hough believes, is how well a person hears and understands speech. Of the 200, none lost 50 per cent or more discrimination, either immediately or in the subsequent five to seven years. None had even lost 10 per cent at six months. Five to seven years later, 2 per cent demonstrated a drop in discrimination of 20 per cent, and a long-term loss of speech discrimination of 10 per cent or more was seen in 3 per cent.

Hough's long-term results from several thousand partial stapedectomy techniques showed a 0.31 per cent loss of 50 per cent discrimination or more.

## Summary

The literature reveals that the wire prosthesis appears to function more adequately than polyethylene for use as a prosthesis in stapedectomy procedures. Both total and partial stapedectomies show excellent results; however, the partial stapedectomy results (in terms of percentages) are slightly better, with slightly fewer failures and/or complications. Unfortunately, there appears to be no particular method used by the various authors in organizing information to be presented. Few authors report analyses of speech audiometry. Most results are given in terms of percentages of "success criteria" rather than employing statistical measures to interpret the findings. Little discussion is given to the procedures employed to obtain audiological data.

This study was conducted to compare statistically the audiometric results of the Hough partial stapedectomy and the House or Schuknecht total stapedectomy in fifty consecutive cases each. The cases were studied from the standpoint of change in air-conduction acuity in the speech frequencies, speech reception threshold and discrimination scores, as well as the hearing loss at the discrete frequencies of 2000 and 4000 Hz.

CHAPTER BIBLIOGRAPHY


1. Abielo, Vila P., "Correlation Between Technique and Results in 100 Cases of Stapedectomy," Acta-Oto-Rhino-Laryngologica Espanola, VI (1964), 1-5, abstracted in DSH Abstracts, VI (April, 1966), 156.

2. Altmann, Franz, Alvin Glasgold, and Jacqueline P. MacDuff, "The Incidence of Otosclerosis as Related to Race and Sex," Annals of Otology, Rhinology, and Laryngology, LXXVI (June, 1967), 377-392.

3. Campbell, Edward H., "The Development of Surgery for Otosclerosis: A Historical Review," Vol. II of Otolaryngology, edited by Walter H. Maloney (2 volumes), Hagerstown, Maryland, Hoeber Medical Division, Harper and Row, 1968.

4. Cawthorne, T., "Stapedectomy for Otosclerosis," Journal of Laryngology and Otology, LXXVI (March, 1962), 87-93, abstracted in DSH Abstracts, III (January, 1963), 47.

5. Cody, D. T., and others, "Stapedectomy for Otosclerosis: An Analysis of Results," Mayo Clinic Proceedings, XL (November, 1965), 740-744.

6. Coleman, B. H., "Stapedectomy," Acta Oto-Laryngologica, CVII (January-February, 1964), 97-112.

7. Farrior, J. Brown, "Stapedectomy," Journal of the Florida Medical Association, XLIV (October, 1962), 293-298.

8. Goodhill, Victor, Stapes Surgery for Otosclerosis, New York, Paul B. Hoeber, Inc., Medical Division of Harper and Brothers, 1961.

9. ________________, "Surgery for Otosclerosis, Direct Method (Stapedolysis and Stapedectomy)," Otolaryngology, Vol. II, edited by Walter H. Maloney (2 volumes), Hagerstown, Maryland, Hoeber Medical Division, Harper and Row, 1968.

10. Guilford, Frederick R., "Experiences in the Surgery of Otosclerosis," Otosclerosis, edited by Harold F. Schuknecht, Boston, Little, Brown and Company, 1962.

11. ________________________, "Stapedectomy Results with the Teflon-Wire Prosthesis," Laryngoscope, LXXIV (May, 1964), 656-667.

12. Gundersen, Terje, "A Hundred Stapedectomies," Acta Oto-Laryngologica, Supplement No. 188 (June, 1963), 340-345.

13. Hough, J. V. D., "Long-Term Results in Partial Stapedectomy," Archives of Otolaryngology, LXXXIX (February, 1969), 414-419.

14. ______________, "Otosclerosis-1962," Archives of Otolaryngology, LXXIX (April, 1964), 421-429.

15. ______________, "Otosclerosis," Archives of Otolaryngology, LXXXI (June, 1965), 630-639.

16. ______________, "Partial Stapedectomy," Annals of Otology, Rhinology, and Laryngology, LXIX (June, 1960), 571-596.

17. ______________, "Partial Stapedectomy," Journal of the American Medical Association, CLXXXVII (March, 1964), 697-702.

18. House, Howard, "Footplate Surgery in Otosclerosis," Journal of Laryngology and Otology, LXXVI (February, 1962), 73-86.

19. ______________, "The Prefabricated Wire Loop-Gelfoam Stapedectomy," Archives of Otolaryngology, LXXVI (October, 1962), 298-302.

20. ______________, "The Prefabricated Wire Loop-Gelfoam Stapedectomy for Otosclerosis," Armamentarium, IV (March, 1964), 8-9.

21. Kristensen, H. K., K. Terkildsen, and K. A. Thomsen, "Results of Ten Years Stapes Surgery," Acta Oto-Laryngologica, Supplement No. 224 (January, 1966), 105-108.

22. Lempert, Julius, "Surgical Treatment of Otosclerosis," Vol. II of Otolaryngology, edited by Walter H. Maloney (2 volumes), Hagerstown, Maryland, Hoeber Medical Division, Harper and Row, 1968.

23. McGee, T. Manford, "Techniques and Experiences with Stapedectomy and Metal Implant," Otosclerosis, edited by Harold F. Schuknecht, Boston, Little, Brown and Company, 1962.

24. Meltzer, Philip and others, "Panel on Techniques and Results of Stapes Surgery," Archives of Otolaryngology, LXXVIII (October, 1963), 546-573.

25. Mercandino, Eduardo C. and Juan C. Tarasido, "Artificial Stapes: A Three-Year Report," Archives of Otolaryngology, LXXVII (February, 1963), 191-197.

26. Moncur, John P. and Victor Goodhill, "Audiological Evaluation in Stapes Surgery: The Perichondrium-Polyethylene Prosthetic Assembly," Journal of Speech and Hearing Disorders, XXVIII (August, 1963), 211-220.

27. Morrison, A. W., "Treatment of Otosclerosis by Stapedectomy," British Medical Journal, No. 5295 (June, 1962), 1804-1807.

28. Myers, David, "Total Stapedectomy in the Surgical Treatment of Otosclerotic Deafness," Otosclerosis, edited by Harold F. Schuknecht, Boston, Little, Brown and Company, 1962.

29. Newby, Hayes A., Audiology, 2nd ed., New York, Appleton-Century-Crofts, 1964.

30. Oppenheimer, Peter and others, "Routine Stapedectomy or a Graduated Mobilization?," Archives of Otolaryngology, CXXVII (February, 1963), 157-165.

31. Otto, F., "Surgery for Otosclerosis," Revista de Otorrinolaringologia, XXIV (January, 1964), 53-59, abstracted in DSH Abstracts, VII (January, 1967), 61.

32. Robinson, M., "The Stainless Steel Stapedial Prosthesis, One Year's Experience," Laryngoscope, LXXII (January, 1962), 514-520.

33. Schuknecht, Harold F. and Stanley Oleksuik, "The Metal Prosthesis for Stapes Ankylosis," Archives of Otolaryngology, LXXI (February, 1960), 287-295.

34. ____________________, "Sensorineural Hearing Loss Following Stapedectomy," Acta Oto-Laryngologica, CIV (March-April, 1962), 336-348.

35. Schuknecht, Harold F., T. Manford McGee, and Bernard H. Coleman, "Stapedectomy," Annals of Otology, Rhinology, and Laryngology, LXIX (June, 1960), 597-609.

36. ____________________, "Stapedectomy Operation for Hearing Loss from Otosclerosis," Sound, I (July-August, 1962), 16-21.

37. Shambaugh, George E., Jr., "Cochlear Pathology After Stapes Surgery," Archives of Otolaryngology, LXXVIII (October, 1963), 600-605.

38. Shea, John J., Jr., "Complications of the Stapedectomy Operation," Annals of Otology, Rhinology, and Laryngology, LXXII (December, 1963), 1109-1123.

39. ____________________, "Fenestration of the Oval Window," Annals of Otology, Rhinology, and Laryngology, LXVII (December, 1958), 932-951.

40. Sheehy, James L., "Far-Advanced Otosclerosis," Archives of Otolaryngology, LXXX (September, 1964), 244-248.

41. ____________________, "Prefabricated Wire Loop-Gelfoam Stapedectomy: Long Term Results," Revista Pan-Americana de Otorrinoloringologia y Broncoesofagologia, II (May-June, 1968), 147-157.

42. Sheehy, James L., "Stapes Surgery in Advanced Otosclerosis," Annals of Otology, Rhinology, and Laryngology, LXXI (September, 1962), 601-622.

43. Sooy, Francis A., Elmer Owens, and David N. Schindler, "A Controlled Comparison of Changes in Hearing After Stapedectomies with Polyethylene and Wire Stapes Prosthesis," Laryngoscope, LXXVI (July, 1966), 1220-1231.

44. ______________________________, and Deborah Theurer, "Air-Bone Closure and Stability of Hearing After Stapedectomy," Annals of Otology, Rhinology, and Laryngology, LXXV (September, 1966), 667-676.

45. ______________________________, "Stapedectomy in Obliterative Otosclerosis," Annals of Otology, Rhinology, and Laryngology, LXXIII (September, 1964), 679-693.

46. Strong, M. Stuart and Charles W. Vaughan, "Partial Stapedectomy and Vein Graft Replacement," Archives of Otolaryngology, LXXX (September, 1964), 249-255.

47. Suter, C., "Regression of Hearing Improvement After Stapedectomy," Practica Oto-Rhino-Laryngologica, XXV (January, 1963), 266-275, abstracted in DSH Abstracts, IV (April, 1964), 149.

48. Weichsilbaumer, W., "Anterior Stapedial Crurotomy in Otosclerosis," Zeitschrift fur Laryngologie, Rhinologie, Otologie und ihre Grenzgebiete, XLIII (January, 1964), 45-55, abstracted in DSH Abstracts, VI (April, 1966), 162.

## CHAPTER II

## PROCEDURE

The audiometric tests of fifty patients who had partial stapedectomy surgical procedures, performed in the manner of Hough, and fifty patients who had total stapedectomy surgical procedures, performed in the manner of House or Schuknecht, were compared. The preoperative, postoperative (within eight weeks after surgery), and one-year follow-up tests were analyzed statistically in terms of (1) change in air conduction acuity in the speech frequencies, (2) change in speech reception threshold (SRT), (3) change in the discrete frequencies 2000 and 4000 Hz, and (4) change in discrimination score.

### Description of Subjects

The 1961-1968 surgery files of M. C. Culbertson, Jr., M.D., F.A.C.S., an otologic surgeon in Dallas, Texas, were screened for all partial stapedectomies, done in the manner of Hough, and all total stapedectomies done in the manner of House or Schuknecht. These were then reviewed and fifty consecutive cases in each category were chosen which fit the following criteria: (1) No previous surgery had been performed on the ear. (2) A complete preoperative audiometric test was available. (3) A complete postoperative audiometric test, done within eight weeks of the surgery, was available. (4) A complete follow-up audiometric test, done one year (plus or minus two months) postoperatively, was available. (5) All audiometric tests included air- and bone-conduction results, speech reception threshold results, and discrimination scores. No case was accepted or rejected on the basis of test results, only for failure to meet all criteria.

No attempt was made to match the groups for age, sex, or preoperative test results. In an audiometric study evaluating the perichondrium-polyethylene prosthesis, Moncur and Goodhill (9) divided patients into three age groups: (1) fifty years of age and younger, (2) fifty-one to sixty years of age, and (3) sixty-one years of age and older. Their results revealed little, if any, observable difference between age groups regarding degree of closure of the air-bone gap. Although some surgeons prefer not to operate on teenagers or younger children (8, 13), research indicates that age itself is not an important factor in selecting candidates for surgery, nor is it of any prognostic value (1, 5, 6, 10). Shea (11), however, believes age influences the percentage of further cochlear loss in the very young and in the very old.

It is known that otosclerosis tends to occur slightly more frequently in the female sex (2), but the sex of the patient has no bearing on the results of the surgery. Regarding preoperative test results, Sheehy (12) concluded that the results obtained on patients with over a 30 dB loss by bone conduction were in every way comparable to those obtained on patients with better bone-conduction results.

## Testing Equipment and Facilities

All tests were given on a Maico MA-8 clinical audiometer, equipped with a Beltone narrow-band masking unit. The equipment was calibrated periodically throughout the time period covered by the tests, and all testing was done by experienced audiologists.

The patients were seated in an IAC chamber, while the examiner was seated in a sound-treated room. The patients could be observed by the examiner through a double window arrangement, but they were unable to observe the operation of the instrument controls.

The audiometer was calibrated to American Standards Association (ASA) standards until May, 1965, when it was calibrated to the newly adopted International Standards Organization (ISO) standards (4).

## Description of Tests

All patients who were accepted for this study had had complete pure tone air- and bone-conduction tests, speech discrimination tests, and speech reception threshold tests at each test period (preoperative, within eight weeks postoperatively, and one year postoperatively, plus or minus two months). The fifty patients in each group (total stapedectomy and partial stapedectomy) were numbered consecutively from one to fifty, and each group was assigned an identification number.

The raw data for each of the three tests given each patient included (1) average hearing loss in the speech frequencies by air conduction (500, 1000, and 2000 Hz), (2) hearing loss by air conduction at 2000 Hz, (3) hearing loss by air conduction at 4000 Hz, (4) speech reception threshold, and (5) discrimination score.

Air-conduction tests were administered following the Hughson-Westlake technique described by Carhart and Jerger (3). Quantitative masking procedures were used when appropriate. The Spondee words were used in obtaining the speech reception threshold (SRT), and the phonetically-balanced (PB) word lists were used in obtaining the discrimination score.

Because of the change in the calibration of the audiometer from ASA to ISO standards in May, 1965, several patients were given one test under one standard and two under the other. For this group, all results were calculated to conform to ISO standards using the changes given by Davis and Kranz (4).

The three sets of data from each of the two groups was fed into a computer to determine the mean and standard deviation for each of the five measurements included in each test. Each measurement was then correlated with each of the other measurements to obtain a coefficient of correlation for the tests within each group.

Student's *t* test for independent groups was computed between the two groups for each of the five variables for pre-test, post-test, and follow-up, respectively. The Student *t* for correlated means was computed for each of the five variables between pre-test and post-test, pre-test and follow-up, and post-test and follow-up for each of the two groups. The Student *t* test for amount of change between pre-test and post-test, pre-test and follow-up, and post-test and follow-up was computed comparing the two groups. Correlation of the five criterion measures across treatment periods were compared using the Student *t* for correlation coefficients to indicate significant intergroup differences. The correlation coefficients were transformed to Fisher's *z* scores in order to compute the *t* between correlation coefficients as shown by Hays (6, p. 532).

## CHAPTER BIBLIOGRAPHY


1. Abello, P., "The Effects of Differential Surgical Techniques on the Outcome of Stapedectomies," Acta Oto-Rhino-Laryngologica Ibero, Americana, XV (January, 1964), 178-191, abstracted in DSH Abstracts, V (July, 1965), 243.

2. Altmann, Franz, Alvin Glasgold, and Jacqueline P. MacDuff, "The Incidence of Otosclerosis as Related to Race and Sex," Annals of Otology, Rhinology, and Laryngology, LXXVI (June, 1967), 377-392.

3. Carhart, Raymond and James F. Jerger, "Preferred Method for Clinical Determination of Pure-Tone Thresholds," Journal of Speech and Hearing Disorders, XXIV (November, 1959), 330-345.

4. Davis, Hallowell and Fred Kranz, "The International Standard Reference Zero for Pure Tone and Its Relation to the Evaluation of Impairment of Hearing," Journal of Speech and Hearing Research, VII (March, 1964), 7-16.

5. Dudok, DeWit C. A. and D. M. H. Schuth, "Perception Deafness in Otosclerosis," Practica Oto-Rhino-Laryngologica, Basel, XXII (May, 1960), 448, abstracted in DSH Abstracts, I (January, 1961), 116.

6. Farrior, J. Brown, "Stapes Surgery in Geriatrics," Laryngoscope, LXXIII (August, 1963), 1084-1097.

7. Hays, William L., Statistics For Psychologists, Holt, Rinehart, and Winston, New York, 1964, p. 532.

8. House, Howard and James Sheehy, "Stapes Surgery: Selection of the Patient," Annals of Otology, Rhinology, and Laryngology, LXX (December, 1961), 1062-1069.

9. Moncur, John P. and Victor Goodhill, "Audiological Evaluation in Stapes Surgery: The Perichondrium-Polyethylene Prosthetic Assembly," Journal of Speech and Hearing Disorders, XXVIII (August, 1963), 211-220.

10. Myers, David, Richard A. Winchester, and Woodrow D. Schlosser, "Otosclerosis Surgery for the Older Patient," Geriatrics, XIV (October, 1960), 681-694.

11. Shea, John J., Jr., "Complications of the Stapedectomy Operation," Annals of Otology, Rhinology, and Laryngology, LXXII (December, 1963), 1109-1123.

12. Sheehy, James L., "Stapes Surgery in Advanced Otosclerosis," Annals of Otology, Rhinology, and Laryngology, LXXI (September, 1962), 601-622.

13. Walsh, Theodore and others, "Panel on Causes of Failure in Stapes Surgery," Archives of Otolaryngology, LXXVIII (October, 1963), 613-622.

CHAPTER III

RESULTS

The results of audiometric tests of two groups of fifty patients each were compared. Group A was composed of those who had partial stapedectomies performed ad modum Hough. Group B was composed of those who had total stapedectomies ad modum House or Schuknecht. Preoperative, eight-week postoperative, and one-year follow-up audiometric tests were compared. Each comparison encompassed the following measures: (1) average of the speech frequencies, (2) loss at 2000 Hz, (3) loss at 4000 Hz, (4) speech reception threshold (SRT), and (5) discrimination score.

Table I presents the comparison of the two groups across test periods in terms of their average loss in the speech frequencies. The $t$ score shows significant improvement for both groups between pre-test and post-test and pre-test and follow-up. When post-test and follow-up are compared, Group A shows a loss of some 4 dB, and the $t$ indicates that this amount is significant. Group B also lost some of the hearing gained at post-test, but the $t$ score indicates that the change is not significant. At no time do the $t$ scores indicate a significant difference between the groups on this measure.

Table II presents the comparison of the groups over the test periods at 2000 Hz. Significant improvement for both groups is indicated by the $t$ at the pre-test-post-test comparison and at the pre-test-follow-up comparison. At the post-test-follow-up comparison, both groups lost some

TABLE I

COMPARISON OF GROUPS A (PARTIAL, N=50) AND B (TOTAL, N=50)
AT PREOPERATIVE, POSTOPERATIVE, AND FOLLOW-UP TESTS
FOR AVERAGE OF SPEECH FREQUENCIES

| Group | Preoperative Mean | Preoperative SD | Postoperative Mean | Postoperative SD | Pre-Post Change | Pre-Post t | Follow-up Mean | Follow-up SD | Pre-Follow-up Change | Pre-Follow-up t | Post-Follow-up Change | Post-Follow-up t |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 48.60** | 17.55 | 19.12 | 14.52 | 29.48 | 14.48* | 23.18 | 14.81 | 25.42 | 10.55* | -4.06 | 2.50* |
| B | 54.02 | 17.15 | 23.60 | 17.30 | 30.42 | 14.80* | 25.30 | 16.71 | 28.72 | 12.79* | -1.70 | 1.39 |
| Group Difference | 5.42 | | 4.48 | | .94 | | 2.12 | | 3.30 | | 2.36 | |
| t | 1.56 | | 1.40 | | .32 | | .67 | | 1.00 | | 1.16 | |

* Indicates significance at the .05 level.
** All numbers except t scores refer to decibels.

TABLE II

COMPARISON OF GROUPS A (PARTIAL, N=50) AND B (TOTAL, N=50)
AT PREOPERATIVE, POSTOPERATIVE, AND FOLLOW-UP TESTS
FOR 2000 Hz

| Group | Preoperative Mean | Preoperative SD | Postoperative Mean | Postoperative SD | Pre-Post Change | Pre-Post t | Follow-up Mean | Follow-up SD | Pre-Follow-up Change | Pre-Follow-up t | Post-Follow-up Change | Post-Follow-up t |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 48.08** | 22.33 | 22.70 | 18.42 | 25.38 | 9.91* | 28.50 | 18.77 | 19.58 | 6.48* | -5.80 | 3.46* |
| B | 57.30 | 19.32 | 30.30 | 21.71 | 27.00 | 11.54* | 34.40 | 24.39 | 22.90 | 8.11* | -4.10 | 2.02* |
| Group Difference | 9.22 | | 8.60 | | 1.62 | | 5.90 | | 3.32 | | 1.70 | |
| t | 2.20* | | 1.88 | | .47 | | 1.35 | | .80 | | .65 | |

* Indicates significance at the .05 level.
** All numbers except t scores refer to decibels.

hearing gained at the pre-test period, and the *t* indicates that the loss is significant.

Preoperatively, the *t* indicates a significant difference between the groups, Group B having a greater loss at this frequency. The standard deviation for the groups show Group B to be clustered somewhat more closely to the mean than Group A. At postoperative test periods, the standard deviation for Group B increases, and Group A has the smaller standard deviation. The *t* scores indicate no significant differences between the groups at either postoperative test, and there are no significant differences at either the pre-test-post-test comparison or the pre-test-follow-up comparison.

Comparison of the groups across test periods at 4000 Hz is presented in Table III. Again, significant improvement is indicated for both groups at the pre-test-post-test comparison and at the pre-test-follow-up comparison. Neither group lost a significant amount of hearing between post-test and follow-up.

The *t* score shows a significant difference between the groups at each test period, Group B having the greater loss. As stated above, both groups did improve after surgery, but the amount of improvement experienced by one group did not differ significantly from the other. Thus, while the groups retained their initial differences after surgery, and both improved, one did not improve significantly more than the other.

Summarized in Table IV is the comparison of the groups across test periods for speech reception threshold (SRT). The results in this table follow closely (within 2 dB) those in Table I for the average of the speech frequencies. Both groups achieved significant improvement, indicated by

TABLE III

COMPARISON OF GROUPS A (PARTIAL, N=50) AND B (TOTAL, N=50)
AT PREOPERATIVE, POSTOPERATIVE, AND FOLLOW-UP TESTS
FOR 4000 Hz

| Group | Preoperative Mean | Preoperative SD | Postoperative Mean | Postoperative SD | Pre-Post Change | Pre-Post t | Follow-up Mean | Follow-up SD | Pre-Follow-up Change | Pre-Follow-up t | Post-Follow-up Change | Post-Follow-up t |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 54.12** | 24.39 | 39.38 | 24.06 | 14.74 | 8.34* | 42.26 | 25.31 | 11.86 | 5.22* | -2.88 | 1.56 |
| B | 68.40 | 19.52 | 54.86 | 21.38 | 13.54 | 6.78* | 55.64 | 25.37 | 12.76 | 5.18* | - .78 | .46 |
| Group Difference | 14.28 | | 15.48 | | 1.20 | | 13.38 | | .90 | | 2.10 | |
| t | 3.23* | | 3.40* | | .50 | | 2.64* | | .27 | | .84 | |

* Indicates significance at the .05 level.
** All numbers except t scores refer to decibels.

TABLE IV

COMPARISON OF GROUPS A (PARTIAL, N=50) AND B (TOTAL, N=50)
AT PREOPERATIVE, POSTOPERATIVE, AND FOLLOW-UP TESTS
FOR SPEECH RECEPTION THRESHOLD

| Group | Preoperative Mean | Preoperative SD | Postoperative Mean | Postoperative SD | Pre-Post Change | Pre-Post t | Follow-up Mean | Follow-up SD | Pre-Follow-up Change | Pre-Follow-up t | Post-Follow-up Change | Post-Follow-up t |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 50.56** | 16.33 | 20.18 | 14.02 | 30.38 | 16.16* | 24.20 | 14.16 | 26.36 | 10.93* | -4.02 | 2.42* |
| B | 54.38 | 17.84 | 23.36 | 17.53 | 31.02 | 15.20* | 24.64 | 15.22 | 29.74 | 14.28* | -1.28 | .96 |
| Group Difference | 3.82 | | 3.18 | | .64 | | .44 | | 3.38 | | 2.74 | |
| t | 1.11 | | 1.00 | | .23 | | .15 | | 1.44 | | 1.29 | |

* Indicates significance at the .05 level.
** All numbers except t scores refer to decibels.

the $\underline{t}$ scores, at pre-test-post-test comparison and at pre-test-follow-up comparison. At post-test-follow-up comparison, Group A lost a significant amount of hearing. Group B also lost some hearing at this comparison, but the $\underline{t}$ score indicates the loss was not a significant one. There is no significant intergroup difference at any point in this comparison.

Table V summarizes the comparison of the groups across test periods for percentage of discrimination. Only Group A shows a significant improvement in discrimination ability at the pre-test-post-test comparison and at the pre-test-follow-up comparison. Group B evidenced a loss of discrimination ability. The loss was significant between the post-test and follow-up test. Group A did not change significantly between these two test periods. Intergroup comparison shows a significant difference at follow-up, with Group A having better discrimination. This is also true of the pre-test-follow-up and post-test-follow-up comparisons.

Table VI summarizes the correlation coefficients for both treatment groups for each of the five measures tested. The correlation coefficients are all relatively high. Significant $\underline{t}$ scores for correlation coefficients are found at the post-test-follow-up comparison for the average of the speech frequencies and the speech reception threshold measures. Group B has the higher correlation coefficient for both measures. A significant $\underline{t}$ score appears at the pre-test-post-test comparison, with Group A having the higher correlation coefficient.

TABLE V

COMPARISON OF GROUPS A (PARTIAL, N=50) AND B (TOTAL, N=50)
AT PREOPERATIVE, POSTOPERATIVE, AND FOLLOW-UP TESTS
FOR PERCENTAGE OF DISCRIMINATION

| Group | Preoperative | | Postoperative | | Pre-Post | | Follow-up | | Pre-Follow-up | | Post-Follow-up | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Change | t | Mean | SD | Change | t | Change | t |
| A | 86.58** | 15.35 | 89.34 | 12.36 | 2.76 | 2.71* | 90.90 | 9.63 | 4.32 | 2.97* | 1.56 | 1.40 |
| B | 86.16 | 17.05 | 86.68 | 13.89 | .52 | .23 | 82.70 | 16.20 | -3.46 | 1.54 | -3.98 | 2.39* |
| Group Difference | .42 | | 2.66 | | 2.24 | | 8.20 | | 7.78 | | 5.54 | |
| t | .12 | | 1.01 | | .90 | | 3.08* | | 2.91* | | 2.77* | |

* Indicates significance at the .05 level.
** All numbers except t scores refer to percentage.

TABLE VI

CORRELATIONS OF FIVE CRITERION MEASURES ACROSS TREATMENT
PERIODS WITH t TESTS OF DIFFERENCES
BETWEEN GROUPS A AND B

| | Treatment Periods Compared | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pre-Post | | | Pre-Follow-up | | | Post-Follow-up | | |
| Treatment groups | A | B | t | A | B | t | A | B | t |
| Variables | | | | | | | | | |
| Average of speech frequencies | .62 | .65 | .24 | .44 | .57 | 1.03 | .70 | .87 | 2.26* |
| 2000 Hz | .63 | .68 | .43 | .48 | .61 | .90 | .80 | .82 | .28 |
| 4000 Hz | .87 | .77 | 1.52 | .80 | .73 | .83 | .86 | .89 | .62 |
| SRT | .63 | .67 | .34 | .39 | .62 | 1.52 | .66 | .85 | 2.25* |
| Percentage of Discrimination | .89 | .76 | 2.07* | .76 | .56 | 1.76 | .78 | .71 | .77 |

* Indicates significance at the .05 level.

# CHAPTER IV

## SUMMARY, DISCUSSION, AND CONCLUSIONS

The results of audiometric tests of two groups, each composed of fifty patients, were compared statistically at three points in time: preoperatively, eight weeks postoperatively, and one year (plus or minus two months) postoperatively. Group A was composed of patients who had partial stapedectomies *ad modem* Hough, and Group B was composed of patients who had total stapedectomies *ad modem* House or Schuknecht. Each test included five measures: average loss in the speech frequencies (500, 1000, and 2000 Hz), loss at 2000 Hz, loss at 4000 Hz, and percentage of discrimination ability.

All subjects were patients of M. C. Culbertson, Jr., M.D., F.A.C.S., a Dallas otologic surgeon. Testing was done individually by experienced audiologists.

Data for each of the five measures for each of the three test periods was fed into a computer to determine the means and standard deviations. Each measure was then correlated with the other measures to obtain correlation coefficients. Student's *t* tests were used to determine significance of intragroup and intergroup differences.

Both groups showed significant improvement for each measure, except discrimination ability, when pre-tests and post-tests were compared, as well as when pre-tests and follow-up tests were compared. Only Group A (partial stapedectomies) improved significantly in discrimination ability at pre-test-post-test and pre-test-follow-up comparisons. Group B showed no significant change at either comparison.

Between post-test and follow-up, Group A lost a significant amount of hearing for the speech frequencies, for the discrete frequency 2000 Hz, and for speech reception threshold. No significant change was noted for hearing at the discrete frequency 4000 Hz or for discrimination ability. Group B showed no significant change between post-test and follow-up for the speech frequency average, for hearing at 4000 Hz, or for speech reception threshold. Significant changes did occur in hearing at 2000 Hz and in discrimination ability. For these measures, Group B showed a significant loss.

Intergroup comparisons showed no significant differences between the groups at any point in time for the speech frequencies and speech reception threshold measures. For 2000 Hz, Group B had a significantly greater loss preoperatively than Group A. Postoperatively, however, there was no significant intergroup difference at any time. Significant differences existed between the groups for 4000 Hz at the pre-test, post-test, and follow-up comparisons, with Group B having the greater amount of loss. The amount of change from one test period to another did not show a significant intergroup difference. Regarding discrimination ability, intergroup differences were significant at follow-up, at the pre-test-follow-up comparison, and at the post-test-follow-up comparison. At these points, Group A evidenced greater discrimination ability.

## Discussion and Conclusions

Both groups in this study showed significantly improved hearing after surgery for every measure except discrimination. Group B, composed of those who had total stapedectomies, evidenced a significant, though not severe, loss in discrimination ability one year postoperatively. This is an interesting finding in view of the fact that neither group had significant postoperative losses at 4000 Hz, while both experienced significant postoperative losses at 2000 Hz. A possible explanation is the fact that the total stapedectomy procedure often involves labyrinthine trauma which, while causing no significant loss for discrete pure tones, may cause some type of cochlear disturbance that affects discrimination. Shea (5, p. 1109) reports that, while in most ears when further cochlear loss is experienced, there is a simultaneous decline in bone conduction and discrimination, one or the other may occur separately. Moncur and Goodhill (3, p. 214) reported similar findings with total stapedectomy. Their group of seventy-five patients experienced a mean decrease of 3.7 per cent of the preoperative discrimination score at the six-month post-test. The group in this study experienced a mean loss of 3.46 per cent discrimination score between pretest and follow-up at one year.

Between the post-test at eight weeks and the one-year follow-up tests, Group A, the partial stapedectomy group, lost a small, but statistically significant, amount of hearing for the speech frequencies and speech reception threshold, about 4 dB. Group B, the total stapedectomy group, lost about 1.5 dB, which was not statistically significant. This may be accounted for by the fact that partial stapedectomy is a dynamic procedure involving the use of living tissue, and reankylosis may occur to some extent. Success or failure of total stapedectomy, on the other hand, depends on whether or not the prosthesis remains in good position. There is little "in-between."

The finding that the total stapedectomy group had significantly greater loss for 4000 Hz at all test periods, though the amount of change did not differ significantly between the groups, may be explained by the fact that otosclerosis is usually more advanced in cases requiring total stapedectomy. This can be only conjecture, since neither air-bone gap nor type and extent of otosclerotic involvement is reported in this study.

It is difficult to relate the results of this study closely to other studies, most of which report results in terms of closure of the air-bone gap and percentages, rather than the use of statistical measures. It is obvious, however, that postoperatively, both groups did improve significantly in the speech frequencies. At follow-up, the partial stapedectomy group showed a mean gain of 25 dB and the total stapedectomy group showed a mean gain of 29 dB. Oppenheimer and associates (4, p. 160) reported a gain of 11 dB or more in 92 per cent of a group of 795 partial stapedectomies and in 88.9 per cent of a group of 395 total stapedectomies at a four-month post-test. Kristensen and others (2, p. 107) reported air-conduction thresholds of better than 30 dB in the speech frequencies for 47 per cent of 139 patients tested one year postoperatively. These patients had Schuknecht-type total stapedectomies. The total stapedectomy group in this study showed a mean air-conduction threshold of 25 dB in the speech frequencies at the one-year follow-up test.

Hough (1, p. 417) reported an average threshold in the speech frequencies of 25.5 dB in 81 per cent of 200 cases at the six-month post-test. A regression of 4 dB was noted five to seven years later. These were partial stapedectomies. The partial stapedectomy group in this study showed a mean threshold of 23.2 dB in the speech frequencies at the one-year follow-up test, which represents a regression of 4.06 dB from the eight-week post-test.

In interpreting the results reported in this study, it must be remembered that the testing was done under clinical rather than research conditions and that the groups were not subdivided according to the type and extent of otosclerotic involvement found at the time of surgery.

## CHAPTER BIBLIOGRAPHY

1. Hough, J. V. D., "Long-Term Results in Partial Stapedectomy," Archives of Otolaryngology, LXXXIX (February, 1969), 414-419.

2. Kristensen, H. K., K. Terkildsen, and K. A. Thomsen, "Results of Ten Years Stapes Surgery," Acta Oto-Laryngologica, Supplement No. 224 (January, 1966), 105-108.

3. Moncur, John P. and Victor Goodhill, "Audiological Evaluation in Stapes Surgery: The Perichondrium-Polyethylene Prosthetic Assembly," Journal of Speech and Hearing Disorders, XXVIII (August, 1963), 211-220.

4. Oppenheimer, Peter and others, "Routine Stapedectomy or a Graduated Mobilization?," Archives of Otolaryngology, CXXVII (February, 1963), 157-165.

5. Shea, John J., Jr., "Complications of the Stapedectomy Operation," Annals of Otology, Rhinology, and Laryngology, LXXII (December, 1963), 1109-1123.

## BIBLIOGRAPHY

### Books


Campbell, Edward H., "The Development of Surgery for Otosclerosis: A Historical Review," Vol. II of Otolaryngology, edited by Walter H. Maloney (2 volumes), Hagerstown, Maryland, Hoeber Medical Division, Harper and Row, 1968.

Goodhill, Victor, Stapes Surgery for Otosclerosis, New York, Paul B. Hoeber, Inc., Medical Division of Harper and Brothers, 1961.

________________, "Surgery for Otosclerosis, Direct Method (Stapedolysis and Stapedectomy)," Vol. II of Otolaryngology, edited by Walter H. Maloney (2 volumes), Hagerstown, Maryland, Hoeber Medical Division, Harper and Row, 1968.

Guilford, Frederick R., "Experiences in the Surgery of Otosclerosis," Otosclerosis, edited by Harold F. Schuknecht, Boston, Little, Brown and Company, 1962.

Hays, William L., Statistics for Psychologists, New York, Holt, Rinehart, and Winston, 1964.

Lempert, Julius, "Surgical Treatment of Otosclerosis," Vol. II of Otolaryngology, edited by Walter H. Maloney (2 volumes), Hagerstown, Maryland, Hoeber Medical Division, Harper and Row, 1968.

McGee, T. Manford, "Techniques and Experiences with Stapedectomy and Metal Implant," Otosclerosis, edited by Harold F. Schuknecht, Boston, Little, Brown and Company, 1962.

Myers, David, "Total Stapedectomy in the Surgical Treatment of Otosclerotic Deafness," Otosclerosis, edited by Harold F. Schuknecht, Boston, Little, Brown and Company, 1962.

Newby, Hayes A., Audiology, 2nd ed., New York, Appleton-Century-Crofts, 1964.


### Articles


Abello, P., "The Effects of Differential Surgical Techniques on the Outcome of Stapedectomies," Acta Oto-Rhino-Laryngologica Ibero, Americana, XV (January, 1964), 178-191, abstracted in DSH Abstracts, V (July, 1965), 243.

Abielo, Vila P., "Correlation Between Technique and Results in 100 Cases of Stapedectomy," Acta Oto-Rhino-Laryngologica Espanola, VI (1964), 1-5, abstracted in DSH Abstracts, VI (April, 1966), 156.

Altmann, Franz, Alvin Glasgold, and Jacqueline P. MacDuff, "The Incidence of Otosclerosis as Related to Race and Sex," Annals of Otology, Rhinology, and Laryngology, LXXVI (June, 1967), 377-392.

Carhart, Raymond and James F. Jerger, "Preferred Method for Clinical Determination of Pure-Tone Thresholds," Journal of Speech and Hearing Disorders, XXIV (November, 1959), 330-345.

Cawthorne, T., "Stapedectomy for Otosclerosis," Journal of Laryngology and Otology, LXXVI (March, 1962), 87-93, abstracted in DSH Abstracts, III (January, 1963), 47.

Cody, D. R. and others, "Stapedectomy for Otosclerosis: An Analysis of Results," Mayo Clinic Proceedings, XL (November, 1965), 740-744.

Coleman, B. H. "Stapedectomy," Acta Oto-Laryngologica, CVII (January-February, 1964), 97-112.

Davis, Hallowell and Fred Kranz, "The International Standard Reference Zero for Pure Tone and Its Relation to the Evaluation of Impairment of Hearing," Journal of Speech and Hearing Research, VII (March, 1964), 7-16.

Dudock, DeWit C. A. and D. M. H. Schuth, "Perception Deafness in Otosclerosis," Practica Oto-Rhino-Laryngologica, Basel, XXII (May, 1960), 448, abstracted in DSH Abstracts, I (January, 1961), 116.

Farrior, J. Brown, "Stapedectomy," Journal of the Florida Medical Association, XLIX (October, 1962), 293-298.

________________, "Stapes Surgery in Geriatrics," Laryngoscope, LXXIII (August, 1963), 1084-1097.

Guilford, Frederick R., "Stapedectomy Results with the Teflon-Wire Prosthesis," Laryngoscope, LXXIV (May, 1964), 656-667.

Gundersen, Terje, "A Hundred Stapedectomies," Acta Oto-Laryngologica, Supplement No. 188 (June, 1963), 340-345.

Hough, J. V. D., "Long-Term Results in Partial Stapedectomy," Archives of Otolaryngology, LXXXIX (February, 1969), 414-419.

________________, "Otosclerosis-1962," Archives of Otolaryngology, LXXIX (April, 1964), 421-429.

________________, "Otosclerosis," Archives of Otolaryngology, LXXXI (June, 1965), 630-639.

Hough, J. V. D., "Partial Stapedectomy," Annals of Otology, Rhinology, and Laryngology, LXIX (June, 1960), 571-596.

______________, "Partial Stapedectomy," Journal of the American Medical Association, CLXXXVII (March, 1964), 697-702.

House, Howard, "Footplate Surgery in Otosclerosis," Journal of Laryngology and Otology, LXXVI (February, 1962), 73-86.

____________, "The Prefabricated Wire Loop-Gelfoam Stapedectomy," Archives of Otolaryngology, LXXVI (October, 1962), 298-302.

____________, "The Prefabricated Wire Loop-Gelfoam Stapedectomy for Otosclerosis," Armamentarium, IV (March, 1964), 8-9.

____________ and James Sheehy, "Stapes Surgery: Selection of the Patient," Annals of Otology, Rhinology, and Laryngology, LXX (December, 1961), 1062-1069.

Kristensen, H. K., K. Terkildsen, and K. A. Thomsen, "Results of Ten Years Stapes Surgery," Acta Oto-Laryngologica, Supplement No. 224 (January, 1966), 105-108.

Meltzer, Philip and others, "Panel on Techniques and Results of Stapes Surgery," Archives of Otolaryngology, LXXVIII (October, 1963), 546-573.

Mercandino, Eduardo C. and Juan C. Tarasido, "Artificial Stapes: A Three-Year Report," Archives of Otolaryngology, LXXVII (February, 1963), 191-197.

Moncur, John P. and Victor Goodhill, "Audiological Evaluation in Stapes Surgery: The Perichondrium-Polyethylene Prosthetic Assembly," Journal of Speech and Hearing Disorders, XXVIII (August, 1963), 211-220.

Morrison, A. W., "Treatment of Otosclerosis by Stapedectomy," British Medical Journal, No. 5295 (June, 1962), 1804-1807.

Myers, David, Richard A. Winchester, and Woodrow D. Schlosser, "Otosclerosis Surgery for the Older Patient," Geriatrics, XIV (October, 1960), 681-694.

Oppenheimer, Peter and others, "Routine Stapedectomy or a Graduated Mobilization?," Archives of Otolaryngology, CXXVII (February, 1963), 157-165.

Otto, F., "Surgery for Otosclerosis," Revista de Otorrinolaringologia, XXIV (January, 1964), 53-59, abstracted in DSH Abstracts, VII (January, 1967), 61.

Robinson, M., "The Stainless Steel Stapedial Prosthesis, One Year's Experience," Laryngoscope, LXXII (January, 1962), 514-520.

Schuknecht, Harold F. and Stanley Oleksuik, "The Metal Prosthesis for Stapes Ankylosis," Archives of Otolaryngology, LXXI (February, 1960), 287-295.

____________________, "Sensorineural Hearing Loss Following Stapedectomy," Acta Oto-Laryngologica, CIV (March-April, 1962), 336-348.

____________________, T. Manford McGee, and Bernard H. Coleman, "Stapedectomy," Annals of Otology, Rhinology, and Laryngology, LXIX (June, 1960), 597-609.

____________________, "Stapedectomy Operation for Hearing Loss from Otosclerosis," Sound, I (July-August, 1962), 16-21.

Shambaugh, George E., Jr., "Cochlear Pathology After Stapes Surgery," Archives of Otolaryngology, LXXVIII (October, 1963), 600-605.

Shea, John J., Jr., "Complications of the Stapedectomy Operation," Annals of Otology, Rhinology, and Laryngology, LXXII (December, 1963), 1109-1123.

__________________, "Fenestration of the Oval Window," Annals of Otology, Rhinology, and Laryngology, LXVII (December, 1958), 932-951.

Sheehy, James L., "Far-Advanced Otosclerosis," Archives of Otolaryngology, LXXX (September, 1964), 244-248.

________________, "Prefabricated Wire Loop-Gelfoam Stapedectomy: Long Term Results," Revista Pan-Americana de Otorrinoloringologia y Broncoesofagologia, II (May-June, 1968), 147-157.

________________, "Stapes Surgery in Advanced Otosclerosis," Annals of Otology, Rhinology, and Laryngology, LXXI (September, 1962), 601-622.

Sooy, Francis A., Elmer Owens, and David N. Schindler, "A Controlled Comparison of Changes in Hearing After Stapedectomies with Polyethylene and Wire Stapes Prosthesis," Laryngoscope, LXXVI (July, 1966), 1220-1231.

____________________________, and Deborah Theurer, "Air-Bone Closure and Stability of Hearing After Stapedectomy," Annals of Otology, Rhinology, and Laryngology, LXXV (September, 1966), 667-676.

____________________________________________________, "Stapedectomy in Obliterative Otosclerosis," Annals of Otology, Rhinology, and Laryngology, LXXIII (September, 1964), 679-693.

Strong, M. Stuart and Charles W. Vaughan, "Partial Stapedectomy and Vein Graft Replacement," Archives of Otolaryngology, LXXX (September, 1964), 249-255.

Suter, C., "Regression of Hearing Improvement After Stapedectomy," Practica Oto-Rhino-Laryngologica, XXV (January, 1963), 266-275, abstracted in DSH Abstracts, IV (April, 1964), 149.

Walsh, Theodore and others, "Panel on Causes of Failure in Stapes Surgery," Archives of Otolaryngology, LXXVIII (October, 1963), 613-622.

Weichsilbaumer, W., "Anterior Stapedial Crurotomy in Otosclerosis," Zeitschrift fur Laryngologie, Rhinologie, Otologie and ihre Grenzgegiete, XLIII (January, 1964), 45-55, abstracted in DSH Abstracts, VI (April, 1966), 162.