AN ANALYSIS OF THE STAPES MOBILIZATION SURGICAL PROCEDURE AS A TREATMENT FOR OTOSCLEROTIC DEAFNESS

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AN ANALYSIS OF THE STAPES MOBILIZATION SURGICAL PROCEDURE AS A TREATMENT FOR OTOSCLEROTIC DEAFNESS

by

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ABSTRACT

The stapes mobilization surgical procedure was originally conceived in 1876, by Kessel; abandoned in the early nineteen hundreds in favor of the fenestration operation; and revived in 1952 by Rosen. Since its revival, stapes mobilization has been practiced internationally and new surgical techniques have been developed.

The purpose of this study was to present a picture of the current status of the stapes mobilization surgical procedure.

The methodology involved bibliographical research of the following: (a) anatomy and physiology of the human ear; (b) nature of the fenestration operation; (c) history of stapes mobilization; (d) nature of otosclerosis; (e) history of stapes mobilization; (f) nature of the fenestration operation; (g) preoperative audiometric testing; (h) diagnosis of, and candidate selection for, stapes mobilization; (i) objectives of stapes mobilization; (j) preoperative care; (k) anesthesia involved; (l) surgical techniques; (m) surgical audiometry; (n) operative complications; (o) post-operative care; (p) evaluation criteria; (q) review of stapes mobilization results; (r) personal opinions of surgeons regarding stapes mobilization.

The other research source involved the personal observation by the author, of three stapes mobilization operations performed by Dr. Harold F. Schuknecht at Henry

Ford Hospital on April 27, 1957. Dr. Schuknecht is an Associate Surgeon in the Division of Otolaryngology at Henry Ford Hospital in Detroit, Michigan. The author had the opportunity to assist Dr. Schuknecht by performing the surgical audiometrical phases of the operations.

The conclusions were as follows:

A. In regard to diagnosis of stapes ankylosis and the selection of prospective candidates for stapes mobilization: (1) A thorough otologic examination and audiometric testing battery are necessary in the diagnosis of stapes ankylosis. (2) Post-operative results cannot be predicted accurately. (3) A stapes mobilization candidate classified as "ideal" cannot be guaranteed a successful post-operative result.

B. In regard to the operation: (1) The stapes mobilization surgical procedure is not a standard operation. Surgical methods that are employed depend upon the otologic surgeon performing the operation. (2) Stapes mobilization surgery is not "simple," its administration requires a skilled otologic surgeon. (3) Surgical audiometry is essential as a guide to aid the surgeon in determining the effectiveness of his mobilization techniques. (4) Pre-operative and post-operative care are minor.

C. In regard to post-operative results: (1) Stapes mobilization has restored normal hearing in some cases.

(2) Operative complications can produce post-operative hearing losses more severe than preoperative hearing losses. (3) Immediate post-operative successful results have regressed, in some cases, to their preoperative level over a period of time following the operation. (4) The time span between the operation and post-operative audiogram is significant when evaluating post-operative results. (5) The amount of time necessary, before a post-operative gain in hearing will stabilize, is unknown at this time. (6) Stapes reankylosis can result post-operatively. However, if this occurs, another stapes mobilization operation, or a fenestration operation on the same ear, can be performed. (7) Recent improvements in mobilization techniques have increased the percentage of successful results.

ACKNOWLEDGMENTS

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To his wife whose encouragement and understanding provided the sufficient motivation to complete this study and whose assistance in proofreading the material was invaluable, the author expresses his extreme gratitude.

D.C.S.

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Ideas for picture composition were gather from those pictures appearing in the various publications reviewed by the author.

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CHAPTER I

INTRODUCTION

Stapes mobilization is a recently revived surgical procedure administered as a treatment for otosclerotic deafness. Deafness of this type is the result of the formation of spongy bone substance within the bone of the inner ear capsule that impairs the stapes and inhibits its mobility. The mobility of the stapes is a necessary function for the proper transmission of sound waves from the ear drum, through the middle ear, into the inner ear.

The idea of stapes mobilization was originally conceived in 1876, by Kessel.[1] Since the early nineteen hundreds it had been disregarded by most members of the medical profession because of various unsuccessful attempts to prove its value.

In 1916, Holmgren[2] introduced a surgical method of opening the horizontal semi-circular canal to create an acoustic route, in order that sound waves could by-pass the

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[1]Victor Goodhill, "Present Status of Stapedolysis," The Laryngoscope, 66:333, April, 1956.

[2]Meyer Wiener and others (eds.), Progress in Optholmmology and Otolaryngology (New York: Grune and Stratton, 1952), p. 408.

fixed stapes. This idea was later developed by Sourdille[3] in 1926 and in 1938 Lempert[4] developed the technique further and termed it the fenestration operation. This operation was then adopted universally as a surgical treatment for otosclerotic deafness.

In 1952, Rosen[5] revived the method of stapes mobilization and with it the interest of many of those persons engaged in the field of Otology. Since its revival there has been much skepticism on the part of otologic surgeons regarding the value of stapes moblization. Goodhill reasons, "the earlier failures in the stapes approach, and recent refinements and successes in fenestration surgery, obviously created a skeptical attitude toward its revival."[6]

I. THE PROBLEM

Purpose of the Study

The purpose of this study is to present a picture of the current status of the stapes surgical procedure.

Limitations Imposed

Research is limited to bibliographical sources and personal observations by the author of three stapes mobilization operations.

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[3] Ibid.

[4] Ibid.

[5] Goodhill, op. cit., p. 333.

[6] Ibid.

Value of the Study

A study of the nature of stapes mobilization would be of considerable value to persons directly affected by otosclerotic deafness as an aid toward their understanding of its history, preoperative care, method, postoperative care, complications, successes, failures and value as a surgical treatment for otosclerotic deafness.

This study would be of primary value to the author and other students in the field of Audiology as a direct insight into one of the functions of the audiologist. A major role in the stapes mobilization surgical procedure is played by the audiologist.

II. DEFINITION OF TERMS

Otosclerosis

Black's Medical Dictionary defines otosclerosis as being, ". . . the condition in which spongy bone forms in the capsule of the labyrinth of the ear. . ."[7]

The word "otosclerosis" is a combination of the two terms, "oto" and "sclerosis." The definitions of these two terms are:

oto-, a word meaning "ear."[8]

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[7]John D. Comrie and William Thomson, Black's Medical Dictionary (London: Adam and Charles Black, 1952), p. 658.

[8]Clarence L. Barnhart (ed.), The American College Dictionary (New York: Harper and Brothers, 1953), p. 858.

> sclerosis, a hardening or induration of a tissue or part; increase of connective tissue or the like at the expense of more active tissue.[9]

A definition of otosclerosis derived from the combination of the meanings of "oto" and "sclerosis" might be, a hardening of a tissue that increases at the expense of more active tissue in the labyrinth of the inner ear.

Otosclerotic Deafness

Otosclerotic deafness occurs when the otosclerotic bone growth forms in the region of the oval window of the labyrinth (bony casing of the inner ear), grows to its margin and from here through the annular ligament of the stapes footplate.[10] At this point, the otosclerotic bone causes the stapes to become immobile and therefore produces a conductive block in the middle ear prohibiting sounds waves from entering the inner ear.

Otosclerotic deafness is primarily of an air conductive nature. Air conduction can be defined as the transmission of sound waves through the external ear canal and middle ear to the inner ear. However, it can also be of a nerve type if the otosclerotic condition impairs the auditory nerve.

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[9] Ibid., p. 1087.

[10] L. Meurman and O. Meurman, "Stapes Mobilization in Otosclerosis; Primary Results of a Review of 63 Cases," A.M.A. Archives of Otolaryngology, 62:166, August, 1955.

This study will be concerned mainly with the air conductive type, as stapes mobilization is of little value to sufferers of nerve deafness caused by otosclerosis.

Stapes Mobilization

Stapes mobilization is a surgical procedure employed for the reopening of a closed acoustic pathway in the middle ear. It is a method practiced by an otologic surgeon to alleviate the condition of otosclerotic deafness.

The procedure involves the artificial mobilization of the fixed stapes by a surgeon in an effort to break it free from an otosclerotic condition. The stapes is the innermost of three small bones in the middle ear of man.

III. METHOD OF PROCEDURE

Procedure

The method of procedure for the development of this study involved bibliographical research of the following: (a) Anatomy and physiology of the human ear; (b) nature of otosclerosis; (c) history of stapes mobilization; (d) nature of the fenestration operation; (e) preoperative audiometric testing; (f) diagnosis of, and candidate selection for, stapes mobilization; (g) objectives of stapes mobilization; (h) preoperative care; (i) anesthesia involved; (j) surgical techniques; (k) surgical audiometry; (l) operative complications; (m) postoperative care; (n) evaluation criteria; (o) review of stapes mobilization results; (p) personal opinions regarding stapes mobilization.

The other research source involved the personal observations, by the author, of three stapes mobilization operations performed by Dr. Harold F. Schuknecht at Henry Ford Hospital on April 27, 1957. Dr. Schuknecht is an Associate Surgeon in the Division of Otolaryngology at Henry Ford Hospital in Detroit, Michigan.

CHAPTER II

ANATOMY AND PHYSIOLOGY OF THE HUMAN EAR

This chapter will be concerned with the anatomy of the human ear and the functions of its component parts. Basically, the function of the ear in its entirety is to transmit sound waves from the surrounding air to the brain. In the brain these sound waves are decoded and interpreted into understandable messages. A condition causing the dysfunction of any of the parts of the ear interferes with hearing and hampers man's communication process. Otosclerosis which causes stapes ankylosis is such a condition. (Stapes ankylosis is discussed in Section I, Chapter III.)

An understanding of the anatomy and physiology of the ear is necessary in order that the effect of otosclerosis and its possible result, stapes ankylosis, can be properly understood. It will also aid the reader in adequately forming a complete picture of the stapes mobilization surgical procedure.

The human ear is composed of three divisions: the external ear, the middle ear, and the inner ear. These divisions will be discussed in reference to their parts and the functions of those parts in the process of hearing.

I. EXTERNAL EAR

The component parts of the external ear include the auricle or pinna and the external auditory meatus or auditory canal. Primarily, the function of the external ear is to gather sound waves from the surrounding air and direct them to the tympanic membrane.

The Auricle

The auricle, Figure 1, is the visible portion of the external ear. Polyak explains that the auricle is, ". . . attached to the side of the head, at about an angle of 30°."[1] Bast and Anson describe the auricle in the following manner:

> The auricula consists of a thin plate of cartilage covered by integument (skin). It is fixed in position by certain ligaments and possesses two sets of small muscles.[2]

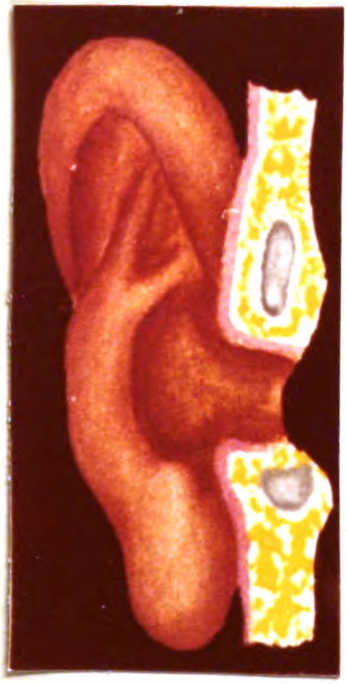

Figure 1. The Auricle

The purpose of the auricle is to collect the sound waves and direct them into the external auditory meatus. Polyak explains:

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[1]Stephen L. Polyak, The Human Ear in Anatomical Transparencies (New York: Sonotone Corporation, 1946), p. 55.

[2]Theodore H. Bast and Harry J. Anson, The Temporal Bone and the Ear (Chicago: Charles C. Thomas, 1949), pp. 12-13.

> The function of the auricle is to collect sound vibrations that reach it through the air, to concentrate, or condense these vibrations, and to convey them through the external auditory meatus to the vibratile tympanic membrane.[3]

External Auditory Meatus

The external auditory meatus, Figure 2, is a canal leading from the auricle to the tympanic membrane. Polyak describes its size as, ". . . approximately 1 inch or 25 mm. long and about 1/4 inch or 6 to 7 mm. wide."[4] The skeleton of the external auditory meatus consists of cartilage and bone. Polyak states, ". . . the external one-third meatus is cartilaginous; of the internal two-thirds it is osseous (bone)."[5]

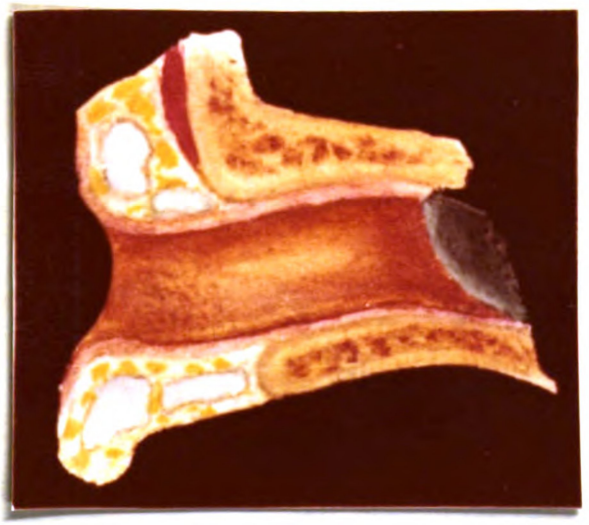

Figure 2. The external auditory meatus

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[3]Polyak, op. cit., p. 55. [4]Ibid., p. 54. [5]Ibid.

The wall of the canal is lined with a thin skin. According to Bast and Anson, this skin continues through the length of the meatus and over the lateral surface of the tympanic membrane.[6] Polyak observes that the skin located at the outer one-third of the meatus contains numerous hairs. There are also ceruminous glands and sebaceous glands that secret a wax-like substance. This author explains that this substance is, ". . . of brown color and bitter taste."[7] He further explains the function of the ear-wax and hairs. Polyak says:

> The function of this earwax and the hairs is to protect the skin of the meatus from desiccation (to dry up) and to prevent intrusion of insects and other foreign bodies.[8]

The purpose of the external auditory meatus is to direct the sound vibrations to the tympanic membrane.

II. THE MIDDLE EAR

The component parts of the middle ear that will be discussed in this section are the tympanic membrane, the tympanic cavity, the eustachian tube, the auditory ossicles and their ligaments, and the muscles of the ossicular chain.

All of the above mentioned components play important roles in the basic function of the middle ear in the hearing process. In regard to the function of the middle ear, Browd

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[6] Bast and Anson, op. cit., p. 13.

[7] Polyak, loc.cit. [8] Ibid.

explains, "It is nothing more than an amplifier. It picks up sound waves, increases their intensity and delivers them to the oval window (the oval window is discussed in Section III)."[9]

Browd further states:

> The middle ear operates on the principle that sound waves lose intensity when they pass from rare medium (air) to a denser medium (fluid), but that this loss can be overcome if they are first made to strike a larger vibrating surface than that which separates the two media. This surface is the eardrum, or tympanic membrane.[10]

Tympanic Membrane

The tympanic membrane, Figure 3, better known as the eardrum, separates the external auditory canal from middle ear. Polyak describes the tympanic membrane as a, ". . . glistening, greyish-pink curtain, placed at a slant at the deepest point of the meatus."[11]

Figure 3. The tympanic membrane

According to Bast and Anson the tympanic membrane is composed of three layers. The layer facing the external auditory meatus is skin. The medial layer consists of

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[9]Victor L. Browd, The New Way to Better Hearing (New York: Crown Publishers Inc., 1951), p. 29.

[10]Ibid.

[11]Polyak, op. cit., p. 67.

fibrous lamina (narrow thin plates of sensitive tissue). The layer facing the tympanic cavity consists of a mucous membrane.[12]

The tympanic membrane seals the external auditory canal completely. Polyak describes the placement of the eardrum in the following manner:

> The tympanic membrane is held in place by a thickened fibrous annulus, or ring, fitted into a circular grove. . . at the inner end of the bony meatus. In this way the tension of the tympanic membrane is maintained at a constant level.[13]

Browd describes the size of the eardrum in relation to the eize of the membrane covering the oval window. He also explains its value. Browd states:

> Its area is about thirty times that of the skin covering the oval window and it increases a person's hearing acuity by approximately 30 per cent.[14]

When viewing this membrane there may be seen running from above and extending to approximately the center, an opaque whitish streak. This streak indicates the handle of the malleus, which is one of the bones of the ossicular chain.

Tympanic Cavity

The tympanic cavity is principally a chamber sheltering the bones, ligaments, and muscles of the ossicular

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[12]Bast and Anson, op. cit., p. 15.

[13]Polyak, op. cit., p. 69. [14]Browd, loc. cit.

mechanism. A necessary function of this cavity is that of neutralizing sound waves. Polyak explains:

> Of no less significance is its role as a barrier . . . an acoustically dead space. . . against whose irregular walls the sound waves break up and are thus neutralized.[15]

This author also explains that it serves to:

> . . . maintain the atmospheric pressure on the inner, acoustically blind side of the tympanic membrane equal to the pressure on its outer, acoustically active side.[16]

The tympanic cavity separates the external auditory meatus from the bony labyrinth of the inner ear (the bony labyrinth is discussed in Section III). Bast and Anson describe:

> The tympanic cavity consists of an upper part, the epitympanic recess, which extends upwards beyond the level of the tympanic membrane; and the tympanum proper which is situated medial to the membrane.[17]

Within the wall separating the tympanic cavity from the bony labyrinth are two covered holes, one above the other. The upper hole is oval shaped and the lower hole is round. These two apertures allow for the passage of sound waves from the tympanic cavity to the bony labyrinth. They communicate directly with the oval and round windows of the bony labyrinth.

Bast and Anson observe that the walls of the tympanic cavity are lined with a thin mucous membrane. This membrane

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[15]Polyak, op. cit., p. 115. [16]Ibid.

[17]Bast and Anson, op. cit., p. 16.

also covers the bones of the ossicular chain and the tendons of the stapedius and tensor tympanic muscles, all of which are located within the tympanic cavity.[18]

Eustachian Tube

The eustachian tube extends from the back of the nose and throat to the tympanic cavity. Stevens explains its function in the hearing process:

> Ordinarily the eustachian tube is closed at its lower end, but it regularly opens during the act of swallowing and thereby allows equalization of any difference in pressure on the two sides of the tympanic membrane.[19]

Ossicular Chain

The principal parts of the ossicular chain are three small bones. The first bone is connected to the tympanic membrane. This bone is called the malleus or hammer. Connected to the malleus is the incus or anvil. The third bone in the chain is named the stapes or stirrup, and it joins the entire ossicular chain to the oval window of the bony inner ear labyrinth.

The malleus. Bast and Anson describe the malleus, Figure 4, as consisting of a head, neck, a manubrium (resembling a handle) and two processes (bony outgrowths). The manubrium is attached to the tympanic membrane. The

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[18] Ibid.

[19] Stanley Smith Stevens and Hallowell Davis, Hearing (New York: John Wiley and Sons, Inc., 1938), p. 249.

Figure 4.
The malleus

lateral process of the malleus rests against the eardrum, and its anterior process serves as a point of attachment for its anterior ligament. A ligament is also attached to the head of the malleus. Bast and Anson state, "On the posterior (rear) aspect there is a notch-like articular surface, for articulation with the body of the incus."[20]

The incus. Connected to the articular surface of the malleus is the incus, Figure 5. According to Bast and Anson, the incus is shaped like a premolar tooth. They state, "It is divisible into a body and two crura (limbs) of unequal length."[21] The short crus is a point of attachment for a ligament. The longer crus extends downward. On the bottom end of the long crus there is a small knob of bone. It is called the "lenticular process" and serves as an articulation surface for the head of the stapes.[22]

Figure 5.
The incus

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[20]Bast and Anson, op. cit., pp. 19-20.

[21]Ibid.

[22]Ibid.

The stapes. The stapes, Figure 6, is attached to the incus and is the last link in the ossicular chain. According to Bast and Anson, the principle parts of the stapes are the head, neck, two crura and the staples footplate. The footplate fits into the oval window of the inner ear labyrinth and completes the sound transmission chain from the tympanic membrane across the tympanic cavity to the inner ear.[23]

Figure 6.
The stapes

Ligaments of the ossicular chain. There are five ligaments that are attached to the bones of the ossicular chain. Bast and Anson explain that the ligaments are, ". . . certain bands which connect the bones to the walls of the tympanic cavity and serve to restrain their movements."[24]

Three ligaments connect the malleus to the tympanic cavity. One is attached to the head of the malleus, one extends from the neck, and one extends from its anterior process.

The short crus of the incus is a connecting point for the ligament attaching it to the tympanium wall.

The ligament that is of primary concern in otosclerotic deafness is the annular ligament. This is the ligament

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[23] Ibid. [24] Bast and Anson, op. cit., p. 21.

of the stapes that connects the margin of the stapes footplate to the oval window of the bony labyrinth. Otosclerotic bone grows through the annular ligament and fuses the footplate to the margin of the oval window.

Muscles of the ossicular chain. There are two muscles attached to the bones of the ossicular chain. These are the tensor tympani muscle and the stapedial muscle.

Stevens and Davis describe the placement of the tensor tympani and its effect upon the ossicular chain:

> The tensor tympani attaches to the handle of the malleus and draws it inward, thereby placing the tympanic membrane under tension. The effect of its action on the stapes is to force the footplace upward and inward into the oval window and its action is thus antagonistic to the action of the stapedius.[25]

These authors state that the stapedius muscle:

> . . . is attached to the head of the stapes close to its articulation with the incus. Its contraction draws the head of the stapes outward and downward in the direction opposite to the inward and upward movement of the long process of the incus caused by increase of pressure on the outside of the tympanic membrane.[26]

Browd explains his opinion of the function of these two muscles:

> By contracting automatically when sound waves of great force strike the ear, they reduce the movements of the middle ear parts by as much as 40%. This function enables us to understand conversation and

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[25]Stevens and Davis, op. cit., pp. 250-251.

[26]Ibid.

> hear in comfort in noisy surroundings, and makes the middle ear the only amplifier which boasts an automatic control.[27]

These muscles cannot be seen in the tympanic cavity, only their tendons project into this area. The muscles lie within bony canals in the cavity walls.

Value of the ossicular mechanism. Stevens and Davis list the following four primary values of these structures. They state:

> 1. They provide for preferential delivery of sound-energy to the oval window as opposed to the round window.
>
> 2. They serve to collect energy from a relatively large cross-section of air and deliver it to the much smaller area of the footplate of the stapes.
>
> 3. Theyprovide a slight mechanical reduction in amplitude of motion between the tympanic membrane and the part of the stapes which is directly in contact with the fluid of the cochlea. (This fluid is discussed in Section III.)
>
> 4. In conjunction with the intra-aural muscles, they provide a protective mechanism for the inner ear against loud low tones without undue impairment of hearing for faint tones of high frequency.[28]

Assemblage of the Middle Ear Components

Figure 7, illustrates the assemblage of the eardrum, the assemblage of the eardrum, malleus, incus, stapes, and ligaments and muscles of the ossicular chain within the tympanic cavity.

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[27]Browd, op. cit., p. 31.

[28]Stevens and Davis, op. cit., p. 259.

Figure 7. Assemblage of the middle ear components

The tube running down toward the right-hand corner of the illustration indicates the eustachian tube. The blue area seen on the right-hand side of the eustachian tube represents a section of cartilage that supports the tube.

The red muscle extending toward the tympanic cavity is the tensor tympani muscle. Its tendon can be seen as a thin white line running toward the handle of the malleus. As was previously stated, this tendon attaches to the handle.

The stapedius muscle and its tendon cannot be seen in the illustration. However, the tendon extends from the rear wall of the tympanic cavity and attaches itself to the head of the stapes.

Only three ligaments can be seen. Two extend from the malleus, one is attached to the neck and one is attached to the head. The other ligament pictured is attached to the head of the incus.

III. THE INTERNAL EAR

The internal ear is a very intricate and complicated mechanism. A detailed discussion of its complete make-up is not necessary to this study. However, an understanding of its basic components and their functions is of importance in comprehending the hearing process and the effects of otosclerotic growth on the hearing mechanism.

This section will be concerned with the bony labyrinth and its divisions, which are the vestibule, the semi-circular canals and the cochlea. Other elements that will be considered are the oval window, the round window, the membranous labyrinth, the membranous cochlea, and the organ of Corti. The fluids of the inner ear and the auditory nerve will be included within the discussions of the specific inner ear components to which they are related. All of these elements are important for the proper transference of sound waves from the stapes of the ossicular chain to the brain.

Bony Labyrinth

This portion of the inner ear is a bony capsule that encases all of the inner ear mechanism.

According to Wolfson and Fischer the bony labyrinth consists of three bone layers. The external layer (periostal capsule) is made up of compact bone tissue. The medial (enchondral capsule) consists of a very thick compact layer of bone enclosing interglobular bodies (a spherical mass).

The innermost layer (endostal capsule) is made up of a layer of membranous bone. It is within the bony layers of the labyrinth that otosclerotic growth takes place.[29]

The bony labyrinth, Figure 8, is divided into three parts; the vestibule, the semi-circular canals, and the cochlea. All of these divisions of the labyrinth contain perilymph. Stevens and Davis explain, "They contain a clear fluid, the perilymph, in which the membranous labyrinth is situated."[30] These three divisions are in direct communication with each other.

Figure 8. The bony labyrinth

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[29]Louis E. Wolfson and Joseph Fischer, The Inner Ear (New York: Grune and Stratton, 1943), p. 178.

[30]Stevens and Davis, op. cit., p. 268.

The vestibule. In Figure 8, the vestibule can be seen as the central portion of the labyrinth. Stevens and Davis observe:

> The vestibule is the central part of the osseous (bony) labyrinth, and is situated just medial (toward the medium plane which divides the body into right and left halves) to the tympanic cavity.[31]

Within the wall of the vestibule directly facing the tympanic cavity is the oval window into which the footplate of the stapes is attached.

Oval window. In Figure 8, the oval window is located in the upper surface of the vestibule. Marshall and Lazier explain that the stapes footplate:

> . . . lies in a small oval aperture, the fenestral vestibule, in the bony median wall of the tympanic cavity leading to the vestibule of the inner ear.[32]

According to Browd, the oval window, ". . . is sealed with a delicate membrane so that no fluid can escape."[33] He further states, in reference to the placement of the stapes, ". . . the stirrup, rests with its footplate firmly secured against the delicate skin covering of the oval window."[34]

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[31] Ibid.

[32] Clyde Marshall and Edgar L. Lazier, Human Anatomy (Philadelphia: W. B. Saunders Company, 1955), p. 351.

[33] Browd, loc. cit.

[34] Ibid.

The area of the oval window is of principle concern in the stapes mobilization surgical procedure. It is in this region that the stapes becomes fused and thus leaves the ossicular chain immobile.

Semi-circular canals. Extending posteriorly (to the rear) from the vestibule are the semi-circular canals.. They can be seen in the left-hand portion of Figure 8. Marshall and Lazier state, "These canals are at right angles from one another."[35] There are three canals. Their primary function involves the sheltering of the organ of balance. Stevens and Davis state:

> They are not concerned with the function of hearing. They do, nevertheless, form part of the total chamber to which changes of pressure, generated by movement of the footplate of the stapes, are delivered.[36]

In Chapter III, Section III, the semi-circular canals will be of some concern. That portion of this study will concern the fenestration operation. The area of the semi-circular canals is of utmost importance in the fenestration operation.

Bony cochlea. Opening anteriorly (to the front) of the vestibule is the bony cochlea. It can be seen in the right-hand portion of Figure 8. Stevens and Davis describe its appearance:

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[35]Marshall and Lazier, op. cit., p. 352.

[36]Stevens and Davis, op. cit., p. 269.

> In shape it resembles a snail-shell. It measures some 5 mm. from base to apex, and its breadth across the base is about 9 mm.[37]

The bony cochlea protects the most important organ of hearing, the organ of Corti. The organ of Corti is encased within the bony cochlea.

Round window. When the bony labyrinth in Figure 8, the round window can be seen below the oval window. Marshall and Lazier explain:

> Below the fenestra vestibulae (oval window) is a smaller hole, the fenestra cochlea (round window), which is closed by the secondary tympanic membrane.[38]

The function of the round window and its membrane in the hearing process is to yield to the inner ear fluid waves activated by the action of the stapes footplate against the membrane of the oval window.

Membranous Labyrinth

It was earlier stated that all three divisions of the bony labyrinth contain a fluid called perilymph. Within this perilymph the membranous labyrinth, Figure 9, is somewhat suspended.

Marshall and Lazier explain:

> Within the bony labyrinth lies a system of interconnected, delicate, membranous sacs and tubes, the membranous labyrinth, lined with epithelium

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[37] Ibid.

[38] Marshall and Lazier, op. cit., p. 351.

(tissue, one cell layer thick). . . . The membranous labyrinth is filled with a clear fluid, the endolymph.[39]

Figure 9. The membranous labyrinth

The membranous labyrinth extends throughout the vestibule, semi-circular canals and the cochlea.

Membranous cochlea. This is the portion of the membranous labyrinth extending into the bony cochlea. It can be seen in the right-hand side of Figure 9. Polyak states:

> Like the rest of the membranous labyrinth, the membranous cochlea is filled with fluid, the endolymph, and like it, is surrounded by the. . . ossious cochlea of the bony labyrinth, which contains perilymph.[40]

Polyak describes the membranous cochlea in the following manner:

> . . . a long and narrow membranous duct (tube) wound spirally around its axis, clockwise in the left ear and counterclockwise in the right ear. . .[41]

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[39] Ibid. [40] Polyak, op. cit., p. 7. [41] Ibid.

The principal organ of hearing, the organ of Corti, is enclosed within the membranous cochlea.

Organ of Corti. According to Polyak the organ of Corti extends throughout the entire length of the membranous cochlea. This author explains that in structure it is a stripe of especially modified sensory epithelium. He states that it also:

> . . .consists of specific sensory hair cells, lodged in the supporting framework. There are, besides, in contact with the hair cells, nerve fibers along which impulses are transmitted to the brain.[42]

Browd explains the organ of Corti by compairing its hair cells and nerve fibers to the keys of a piano keyboard. He explains:

> . . . it has an entire keyboard of fifteen hundred keys. Each key responds to the pressure of pure tones of a particular frequency (number of vibrations per second) and to no others; each produces a sound whose pitch differs from that of any other key on the board . . . actual size of our keyboard is one and one-quarter inches in length and one-hundredth of an inch in width.[43]

The above mentioned nerve fibers are part of the auditory nerve that carries the nerve impulses, that are transformed from the initial sound waves, to the brain.

Process of Sound Transmission Within the Inner Ear

A complete description of the workings of the inner ear mechanism is beyond the scope of this study. However,

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[42] Ibid.

[43] Browd, op. cit., p. 18.

its essential function within the hearing process will be discussed briefly.

Figure 10. The placement of the membranous labyrinth within the bony labyrinth.

Figure 10 illustrates the placement of the membranous labyrinth within the bony labyrinth. In summary, the membranous labyrinth is surrounded with perilymph and contains another fluid called endolymph. Within the cochlear portion of the membranous labyrinth is the receptor organ of hearing, the organ of Corti.

Stevens and Davis explain the structure of the bony labyrinth which makes the inner ear accessible for the transmission of sound vibrations by its fluid medium. They state:

> The bony labyrinth is a practically closed chamber with rigid walls, except for the oval and round windows. The fluid within it is incompressible, and therefore, when the footplate of the stapes vibrates, significant mass movements of the fluid within the labyrinth can occur only by virtue of the yielding of the round window membrane.[44]

[44]Stevens and Davis, op. cit., p. 276.

Therefore, the sound vibrations carried to the oval window membrane by the bones of the ossicular chain are, in this area, transferred into the fluids of the inner ear. Browd explains:

> Air waves strike against the oval window and continue on as fluid waves. These fluid waves are directed to the keyboard according to the frequency of their vibrations.[45]

Each hair cell of the keyboard, or organ of Corti is activated by the fluid waves possessing the specific frequency the cell is designated to receive. The nerve fibers are then activated by each fiber's corresponding hair cell. At this point, the frequencies carried by the fluid waves are transformed into nerve impulses. These nerve impulses are conveyed along the auditory nerve to a specific area of the brain. Within this brain area the nerve impulses are interpreted into understandable messages.

It should be mentioned that the above explanation of the inner ear function is very simply stated. By no means does it include the many specialized membranes and other intricate mechanisms that are involved in the hearing process. The author feels that a discussion involving these elements would not be pertinent to this study.

IV. ASSEMBLAGE OF THE HUMAN EAR COMPONENTS

In order that the reader may not be misled by the sizes of the foregoing illustrations of the human ear

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[45]Browd, op. cit., p. 20.

components, a total assemblage of these components in approximate actual size is represented in Figure 11.

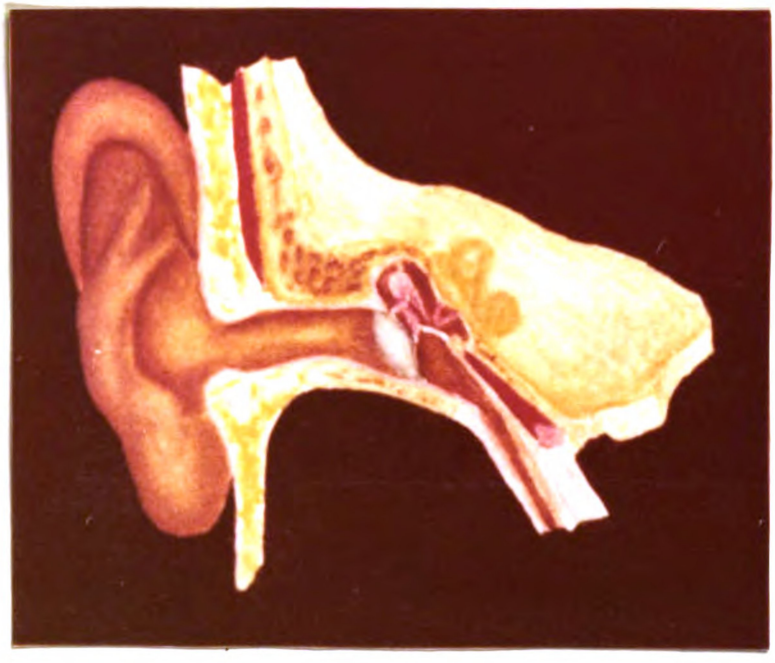

Figure 11. The assemblage of the human ear.

Figure 11 illustrates the assemblage of the auricle, external auditory meatus, tympanic membrane the ossicular mechanism within the tympanic cavity, and the approximate placement of the bony labyrinth of the inner ear.

Actually the bony labyrinth would not be seen, for it is encased within the petrous bone. However, in order that the reader can visualize its relationship with the other components, it is represented as a darkened area to the right of the tympanic cavity.

CHAPTER III

BACKGROUND

This chapter of the study will concern a discussion of the background information directly or indirectly related to the stapes mobilization surgical procedure.

The information directly related to stapes mobilization that will be considered involves the nature of otosclerosis and the history of the stapes mobilization operation. The author feels that a discussion concerning these two elements is necessary in order that the reader may obtain an understanding of the cause of otosclerotic deafness and the development of one surgical procedure (stapes mobilization) employed to alleviate this condition.

The fenestration operation is indirectly related to stapes mobilization in regard to the selection of prospective candidates and final operational goals. A patient who is suitable for the fenestration operation is also suitable for stapes mobilization. Both operations are administered in an effort to alleviate the condition of otosclerotic deafness, although their methods of approach differ.

This chapter of the study will be divided into the following three sections: nature of otosclerosis, history of stapes mobilization, and the fenestration operation.

I. NATURE OF OTOSCLEROTIC DEAFNESS

In 1897, Politzer gave a clinical picture of otosclerosis which is unchanged since that time.[1] According to Wolfson and Fischer, Politzer was the first to recognize otosclerosis as a primary disease of the labyrinthine capsule. He described the otosclerotic foci (points from which the disease develops) as proliferating (budding) bone growths occurring in certain areas of the capsule.[2]

There is a general feeling among most authors that this term is inaccurate in classifying the disease. Eggston and Wolff explain that "otosclerosis" is a misnomer because sclerosis does not begin until late in the development of the disease.[3] Wolfson and Fischer reason, "Even though we know the term is wrong. . . we use the old name applied by Politzer."[4]

This section of the chapter will be divided into the following four parts: histopathology of otosclerosis, air conductive deafness due to otosclerotic growth, etiology of otosclerosis, and incidence of otosclerosis.

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[1]Scott R. Stevenson, Recent Advances in Otolaryngology (Philadelphia: The Blakiston Company, 1949), p. 271.

[2]Wolfson and Fischer, op. cit., p. 176.

[3]Andrew Eggston and Dorothy Wolff, Histopathology of the Ear, Nose and Throat (Baltimore: Williams and Wilkens Company, 1947), p. 453.

[4]Wolfson and Fischer, loc. cit.

Histopathology of Otosclerosis

Brunner describes otosclerosis as being a primary disease of the bony capsule of the labyrinth originating within the bone of the labyrinth.[5] Wolfson and Fischer explain that otosclerosis is a disease of the labyrinthine capsule and occurs in this bone of the ear organ. They mention that it has never been observed in other bones of the skeleton.[6]

Brunner is of the opinion that otosclerosis can be classified as a tumorous disease. He calls these tumors "otosclerotic tumors."[7] Brunner states:

> The otosclerotic tumors are primary tumors of the bony capsule of labyrinth and probably originate in the area of the borderline of the enchondral and periostal layers.[8]

Eggston and Wolff believe that otosclerosis is a lesion (localized structural change) of unknown etiology (cause) resumbling a tumor. Although it resembles a tumor they do not feel that it can be classified as a tumor.[9]

The author found that the term "tumor" is not applied to this bone disease by most authors. It is referred to as being a "lesion."

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[5]Hans Brunner, "Pathology of Otosclerosis," A.M.A. Archives of Otolaryngology, 55:372, March, 1952.

[6]Wolfson and Fischer, op. cit., p. 178.

[7]Brunner, op. cit., p. 376.

[8]Ibid.

[9]Eggston and Wolff, loc. cit.

Wolff describes an otosclerotic lesion as being, "A circumscribed (limited) area of spongy pathologic bone clearly demarcated (separated) from normal bone."[10]

Jackson and Coates explain the pathology of otosclerosis in the following manner:

> The essential pathology of otosclerosis is absorption of normal bone of the labyrinth capsule and its replacement by a new type of bone formation.[11]

Fowler observed that otosclerosis starts as one or more foci in the otic capsule (labyrinth). From these small inactive areas of compact bone it can spread throughout the whole capsule sometimes involving the semi-circular canals. He also found cases in which these foci caused the closure of both the round and oval windows.[12]

Jackson and Coates state in regard to the nature of the otosclerotic foci, "The bony changes may affect the capsule in one or more foci or diffusely, and are usually symmetrical in both labyrinths."[13] Such is the nature of these foci when they are near the anterior margin of the oval window; when they are in the walls of the internal

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[10]Dorothy Wolff, "Otosclerosis: Hypothesis of its Orgin and Process," A.M.A. Archives of Otolarygology, 52:853, December, 1950.

[11]Chevalier Jackson and George Morrison Coates, The Nose, Throat and Ear and Their Diseases (Philadelphia: W. B. Saunders Company, 1930), p. 505.

[12]Edmund Prince Fowler, Medicine of the Ear (New York: Nelson and Sons, 1947), p. 251.

[13]Jackson and Coates, loc. cit.

auditory meatus; when they appear in the apex of the cochlea; and when they appear in the areas of the semi-circular canals.[14]

According to Eggston and Wolff the initial phase of otosclerotic growth is characterized as being a spongification of the bone. They explain, "The disease areas are no longer solid ossified (hardened bone) structures and contain an excessive number of marrow spaces and blood vessels."[15]

Meurman and Meurman state that the initial phase of otosclerosis begins with the development of periosteal bone within the enchondral layer of the bony wall of the inner ear. They state, "The most usual site is right in front of the oval window."[16]

Jackson and Coates describe this new bone in the following manner:

> Microscopically, the new bone manifests two distinct types of osseous growth: (1) A pink, rose-colored bone, due to an affinity for eosin, with thick osteoid beams and small marrow spaces; (2) a deep blue hematoxylinstaining spongiod bone consisting of a network of bony beams with large marrow spaces.[17]

Fowler explains that when the otosclerotic foci became active, there is a distinct tendency of progression.

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[14] Ibid. [15] Eggston and Wolff, loc. cit.

[16] Meurman and Meurman, op. cit., p. 166.

[17] Jackson and Coates, op. cit., p. 508.

There is a localized resorption of the old bone caused by the slow destruction of the minute cavities within the bone. Within the diseased areas there is a replacement of old bone tissue by weblike bone. This process continues with more resorption of bone and its replacement by more mature web-like bone tissue with fibers, into which, later on lamellar bone is disposited.[18]

Brunner states:

> At the onset of actual otosclerosis the original bone of the labyrinth capsule is resorbed by osteoclasts and the defects are filled with newly formed bone which differs in structure from the original bone.[19]

According to Jackson and Coates the bone changes can be grouped into four phases:

> 1. A primary new-bone formation. It consists of a network of blue-staining osteoid beams with small triangular or irregular-shaped bone corpuscles. Nucleated red cells, myelocytes, and fat cells, so characteristic of the red bone marrow, are not found in these spaces. This type is found in the very young or in the very rapidly progressing forms of the disease.
>
> 2. A secondary absorption of the normal capsular bone of the labyrinth. The advancing new bone by its pressure on the normal capsular bone and its blood-vessels produces a simple atrophy of the old bone without signs of cell activity.
>
> 3. A resorption of the new blue-staining bone. This resorption takes place through the joint action of a canaliculization process in which the bone cell cavities distend, communicate, and form canals in the bone. Giant-cell osteoclasts aid in the resorption.

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[18]Fowler, op. cit., p. 263.

[19]Brunner, op. cit., p. 372.

> 4. A replacement of the new blue-staining bone by a new pink-colored bone. This pink, eosin-staining bone is laid down by osteoblastic activity. It consists of a network of thick bony beams with nearly normal bone corpuscles. The marrow spaces contain connective tissue with lymphocytes, spindle-cells, and small blood-vessels. In the older areas of pink-colored bone, the bony beams become thicker and more compact, with lamellar systems developing around blood-vessels.[20]

These authors add, "These different types of new bone may represent different intensities, or rates of growth in the new forming bone, rather than cycles in its development."[21]

In describing the method of otosclerotic progression Fowler says:

> This takes place by continuous lacunar, (grooves in developing bone which is undergoing resorption), resorption of the immediate surrounding bone along a wide front or by the diffuse occurrence of finger-like processes of a peculiar bluish bone tissue in the center of which a small blood vessel is located.[22]

These fingerlike processes of bluish bone tissue are called "blue mantles." Fowler reasons that perhaps these blue mantles represent the beginning of otoslerosis and are distributed by the blood stream into the labyrinth.[23] According to Wolff, "blue mantles" may be considered as chemical indicators of the type of calcium being deposited. She states that these "blue mantles" occur in temporal bones and are a prominent feature of otosclerosis. Wolff believes that otosclerosis advances along blood channels and congestion

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[20]Jackson and Coates, loc. cit. [21]Ibid.

[22]Fowler, op. cit., p. 263. [23]Ibid.

and hemostosis (blood formation) are frequent. The blood vessels exhibit "blue mantles."[24]

In summary, Brunner discusses the following characteristics of the otosclerotic lesion, or as he terms it, the "otosclerotic tumor." It is discovered only in the human labyrinth of the ear. It develops without any apparent cause. At any time it may become active or regain activity. The resorption process may result in a moderate reconstruction of the rest of the labyrinth. Thickening of the bone is often a result of otosclerosis. There is no pain connected with otosclerosis. Otosclerotic bone grows within bone.[25]

Wolfson and Fischer state, "There is usually a sharp line of demarcation between the normal and diseased bone."[26] These authors observed that interglobular bodies are absent in the diseased area, and very large spaces of bone marrow are seen in the otosclerotic focus. They state, "There are no changes of the bone surrounding the otosclerotic focus."[27]

Brunner supports this preceding statement of Wolfson and Fischer. He observed that, "There is no degeneration of the bone surrounding a growing otosclerotic foci."[28] However, he also adds the following statement in reference

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[24]Wolff, loc. cit. [25]Brunner, op. cit., p. 378.

[26]Wolfson and Fischer, op. cit., p. 181.

[27]Ibid. [28]Brunner, op. cit., p. 373.

to the effect of otosclerosis upon the frame of the oval and round windows. "I hold the opinion that there is an atrophic degeneration of cartilage which precedes actual otosclerosis."[29]

Air Conduction Deafness Due to Otosclerotic Growth

Otosclerotic deafness of the air conductive type does not occur unless the foci affect the regions of the round or oval windows. In these instances the otosclerotic growth interferes with the transmission of sound waves to the auditory nerve.

Lindsay and Hemenway explain the effect of the otosclerotic process involving the round window:

> . . . if a small area of the round window membrane remains free the hearing will not be affected. . . occlusion of the round window could cause air conduction loss comparable with that produced by stapes ankylosis.[30]

In cases where only the round window is affected, mobilization of the stapes is of no value, and therefore will be of little concern in this study.

When the foci occur in the area of the oval window and grow through the annular ligament of the stapes footplate, partial or complete ankylosis of the footplate may result. Jackson and Coates state in reference to the otosclerotic foci growth in the oval window region:

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[29] Ibid.

[30] J. R. Lindsay and W. G. Hemenway, "Occlusion of Round Window by Otosclerosis," The Laryngoscope, 64:18, January, 1954.

> With any marked new-bone formation in this area, involvement of the annular ligament and fusion of the stapes foot-plate must result. Unless this involvement and fusion take place, otosclerosis of the middle-ear type, the common clinical form of the disease, will not be present.[31]

Covell does not feel that fusion of the stapes foot-plate is inevitable if the foci appear in this region. However, he explains that even though ankylosis of the foot-plate does not result, loss of hearing is still possible. He says:

> A lesion which does not ankylose the stapes plate to the oval window margin may, however, impair the efficiency of the ossicles as a conducting mechanism. This is caused by the distortion in the oval window niche and interference with normal function of the stapediovestibular articulation.[32]

Stapes ankylosis is of primary concern in this study because it is this condition that may be alleviated by the stapes mobilization surgical procedure. Covell explains the stapes ankylosis phenomenon in the following manner:

> Otosclerosis which results in the fixation of the stapediovestibular joint impairs the mobility of the ossicular chain by displacement of the incudiostapedial and malleoincudal joints.[33]

The stapediovestibular joint is the connective area between the vestibule of the oval window and the stapes. The incudiostapedial joint is the connective area between the incus and the stapes, and the malleoincudal joint is the

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[31]Jackson and Coates, op. cit., p. 10.

[32]W. P. Covell, "The Ossicles in Otosclerosis," Acta Oto-Laryngoscope, 28:275-276, June, 1940.

[33]Ibid.

connective area between the malleus and the incus. When the stapes is fixed, it becomes inactive, therefore causing the incus and malleus to become inactive. The ossicular chain becomes frozen and is ineffective in transmitting the sound waves to the inner ear.

Etiology of Otosclerosis

The author found that, to date, little proof has been found to transform the many hypotheses that have been presented in regard to the origin of otosclerosis into reliable theories. In their book entitled, The Nose Throat and Ear and Their Diseases, published in 1930, Jackson and Coates state, "The numerous theories advanced as to the etiology of otosclerosis prove that not one is wholly satisfactory."[34]

In their discussion concerning possible treatment for otosclerosis, Wolfson and Fischer state in their book entitled, The Inner Ear, published in 1943:

> The basis for any rational treatment of a disease lies in the proper knowledge of its etiology. The complete lack of such knowledge in otosclerosis explains the failure of all the therapeutic measures applied hitherto.[35]

Lindsay wrote in 1950, when discussing the etiology of otosclerosis:

> Attention has been directed to various diseases of glands of internal secretion, hormone inbalance,

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[34]Jackson and Coates, op. cit., p. 504.

[35]Wolfson and Fischer, op. cit., p. 187.

> vitamin deficiencies and metabolic disturbances but laboratory investigations have so far revealed no specific connection.[36]

There have been many attempts to explain the origin of this disease in relation to other diseases. Wolfson and Fischer state:

> A study of the literature concerned with the etiology of otosclerosis reveals the amazing fact that only a few diseases exist that are not brought into relation with otosclerosis in the effect to explain is genesis.[37]

Theories that have been developed from these studies involving the relationship between diseases and otosclerosis do not appear to be totally accepted by most members in the field of otology. Perhaps this is due to the lack of sufficient proof or evidence to support them.

Fowler states: "It is thought that its etiology may be hidden in some inherited factor."[38] In regard to this hypothesis Lindsy found:

> Presence of a hereditary predisposition to otosclerosis has been in as high as 50 per cent of some large series of clinical cases. . . existence of heredity factor seems definite.[39]

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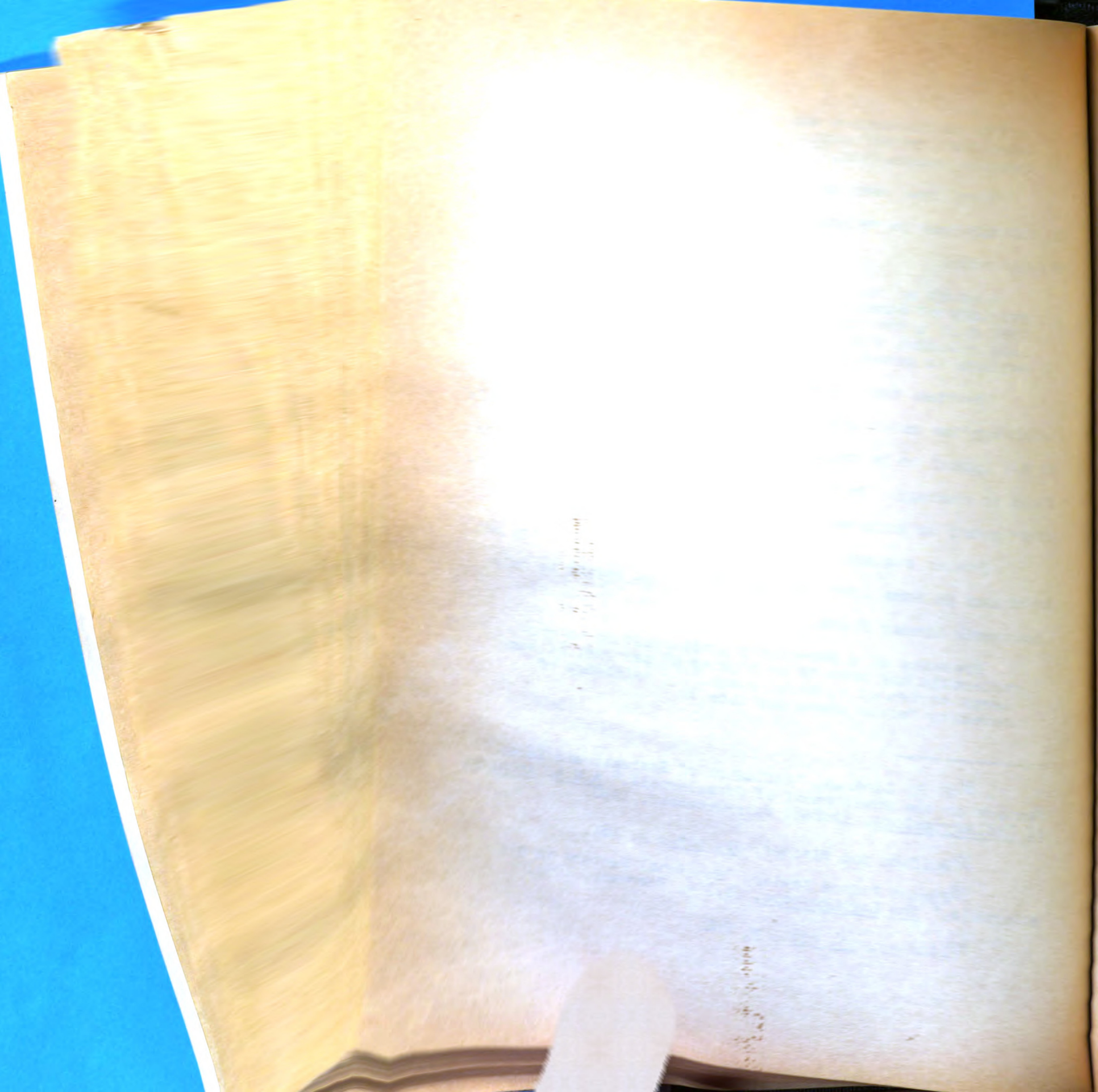
[36]J. R. Lindsay, "Influence of Systemic and Local Factors on the Development of Otosclerosis," A.M.A. Archives of Otolaryngology, 52:868, July-December, 1950.

[37]Wolfson and Fischer, op. cit., p. 181.

[38]Edmund Prince Fowler, "Emotional Factors in Otosclerosis," The Laryngoscope, 61:254, February, 1951.

[39]Lindsay, op. cit., p. 868.



Jackson and Coates observed that the results of a study undertaken to determine whether or not there was a heredity factor involved in the etiology of otosclerosis revealed:

> Over 50 per cent gave a family history of non-suppurative deafness, and like other conditions of a heredity nature, it tends to be transmitted through the female line.[40]

Kopetsky is of the opinion that there are inherited elements that could be the cause of later otosclerotic growth. He explains:

> The congenitally deafened have carbohydrate metabolic mechanism defects transmitted to them which develop otosclerotic lesions on the otic capsule in intrauterine life, or they carry in their blood the biochemical pathologic changes of otosclerosis which develop lesions after birth, owing to the immediate etiologic role which an intercurrent irritant factor induces.[41]

This author further states:

> It follows that any intercurrent severe systemic infection or the presence of puberty, pregnancy or menopause may present the locally irritant factor which will start a cellular pathologic condition into activity and create symptomatic otosclerosis.[42]

Lindsay appears to agree with Kopetsky and reports that, "Existence of a hereditary predisposition has been indicated by clinical observations."[43] He mentions the following irritant factors:

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[40] Jackson and Coates, loc. cit.

[41] Samuel J. Kpetsky, "A Study of the Deafness Heritage in Otosclerosis," A.M.A. Archives of Otolaryngology, 52:416, July-December, 1950.

[42] Ibid., p. 403. [43] Lindsay, op. cit., p. 880.

> Certain constitutional states may furnish the environmental influence necessary to activate the disease. . . . Prolonged terminal illness due to intracranial diseases may play an important role in starting the otosclerotic process in a subject possessing a hereditary tendency. . . . Environmental influence of prolonged constitutional disturbances and pregnancy is suggested by clinical observation. . . . Chronic inflammatory changes in the ear may act as environmental factors.[44]

That pregnancy is an irritant factor in the development of otosclerotic growth is generally accepted by most authorities who believe that the initial element is inherited. However, Walsh lists the following common beliefs regarding pregnancy and otosclerosis, and states that evidence indicates that these beliefs are erroneous. Walsh reviews:

> (a) The deafness due to otosclerosis is made worse by pregnancy. (b) A woman with otosclerosis should be advised not to have children. (c) A woman with deafness caused by otosclerosis can reasonably be advised to have a therapeutic abortion.[45]

Barton appears not to completely accept the theory of pregnancy as an irritant factor in promoting otosclerotic growth. He does not advise abortion in pregnancy cases involving otosclerosis inherent in the prospective mother. He warns, "Abortion is never justified in management of otosclerosis."[46] He further explains:

> Effect of pregnancy on otosclerosis is extremely variable and unpredictable and no exact relation exists

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[44] Ibid.

[45] Theodore E. Walsh, "Effect of Pregnancy on Deafness Due to Otosclerosis," Journal of American Medical Association, 154:1407, April 24, 1954.

[46] Richard T. Barton, "The Influence of Pregnancy on Otosclerosis," New England Journal of Medicine, 233:436, October 11, 1945.

> between the two conditions. . . . Favorable effect of abortion on otosclerosis is inconstant; progression of deafness with pregnancy may or may not be arrested by abortion.[47]

To date, there does not seem to be any universal agreement among the authorities in the field of otology as to the specific etiology of otosclerosis. The author found the most accepted hypothesis to be that of there being an inherited element being activated by some irritant factor into progressive otosclerotic growth.

Incidence. Little information was found revealing the incidence of otosclerosis. The information found appears to be quite general with little evidence to support the findings.

For example, Fowler reports:

> It is markedly less prevalent in the Negro race, and less prevalent in males than in females, as far as we know.[48]

Nylen reveals the findings of a study he conducted involving the examination of 121 temporal bones:

> Otosclerosis was as common in men as in women in 121 temporal bones examined. . . women showed a greater tendency for stapes snkylosis. . . 90 per cent had foci in window regions. . . 40 per cent no stapes ankylosis . . . two thirds of the bones with stapes ankylosis had foci in other areas as well.[49]

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[47] Ibid. [48] Fowler, op. cit., p. 254.

[49] Bengt Nylen, "Histophathologic Investigations on Localization, Number, Activity and Extent of Otosclerotic Foci," Acta Oto-Laryngology, 38:88, February, 1950.

Apparently otosclerosis affects the young as well as the adults. Kopetzky, in his study of deafness heritage in otosclerosis used subjects under 10 years of age. This study involved 25 deaf-mutes, 15 severely deafened children, and 25 children with serviceable hearing, but deafened. All showed symptoms of otosclerosis.[50]

II. HISTORY OF STAPES MOBILIZATION

The surgical procedure of attacking the ankylosed area of the stapes footplate through the auditory canal began in 1876 with Kessel.

One technique practiced involved the removal of the eardrum, malleus, incus and leaving the stapes intact. The author found that most otologists in the late eighteen hundreds used this method. Meurman and Meurman review the results of Laucae's successes using this technique, reported in 1885:

> In 53 cases operated on, considered improvement in hearing was obtained in 9, some improvement in 19, no improvement in 18 and deterioration of hearing in 7.[51]

Another technique used concerned the complete removal of the eardrum, malleus, incus and stapes. Brunner explains, "Extraction of the stapes results in the formation of a new

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[50]Kopetzky, loc. cit.

[51]Meurman and Meurman, op. cit., p. 164.

membrane in the oval window."[52] Therefore, if this method is successful the membrane in the oval window receives the sound vibrations directly without the aid of the eardrum or the bones of the ossicular chain. Brunner reports in regard to one operation of this type:

> In one of Blake's cases perilymph drained through the oval window for 10 days. Gradually the overflow of fluid and dizziness decreased, but the gain in hearing, which was noticed after the extraction was lost.[53]

The above mentioned techniques produced few favorable results. However, they led to the development of the stapes mobilization surgical procedure. This section of the study will concern the history of stapes mobilization, which began with Kessel in 1876; was discontinued in the early nineteen-hundreds in favor of the fenestration operation; and was rediscovered by Rosen in 1952.

Kessel

Schneider reports that, "Mobilization of the stapes began with Kassel in 1876, who first advised it."[54] This was before the true nature of otosclerosis was known. At this time otosclerosis was considered to be a dry sclerosis of the middle-ear mucosa.[55]

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[53] Ibid., p. 19.

[54] Danial C. Schneider, "Revision of the Miot Technique in Moblization of the Ossicle System," A.M.A. Archives of Otolaryngology, 61:207, January-June, 1955.

[55] Meurman and Meurman, loc. cit.

Rosen and Bergman state in reference to Kessel's endeavor:

> Kessel, in 1876, tried improving hearing in cases of stapes ankylosis by removing the drum membrane, malleus, and incus. Later he tried mobilization and complete removal of the stapes . . . all unsuccessful.[56]

Brunner reviews Kessel's attempts at stapes mobilization in the following manner:

> The favorable results of experimental extraction of the stapes encouraged Kessel to mobilize the stapes in cases of conductive deafness by removing adhesions from the niche of the oval window and cutting the tendon of the stapedius muscle. Since final results were unfavorable it was replaced by extration of the stapes.[57]

The next man to be considered in the history of stapes mobilization is Boucheron. Rosen and Bergman state that Bourcheron reported in 1888, mobilization of the stapes in 60 cases. He first excised the posterior half of the drum and then separated the incus from the stapes.[58]

Meurman and Meurman describe Boucheron's technique as using a special hook to mobilize the stapes in the oval window, after he first separated the incus and the stapes from each other. These authors state that he did obtain some good results. However, the favorability of such results were not reported.[59]

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[56]Samuel Rosen and Moe Bergman, "Mobilization of the Stapes for Otosclerotic Deafness," A.M.A. Archives of Otolaryngology, 61:197, January-June, 1955.

[57]Brunner, op. cit., p. 18.

[58]Rosen and Bergman, op. cit., p. 197

[59]Meurman and Meurman, op. cit.

Schneider reports that Boucheron was enthusiastic about stapes mobilization. He says:

> Boucheron stated it was possible to quadruple a patient's hearing by this method. He hailed stapes mobilization as, "Our operation of the future."[60]

Miot

Schneider states that, "In 1890, otosclerosis was brought to a high state of development by Camille Miot."[61] Meltzer feels that Miot should receive the real credit for enlightening the otologists of that period about stapes mobilization. Meltzer explains:

> With the exception of modern incisions to expose the typanum he described with infinite detail the entire procedure of stapes mobilization, the indications, pitfalls and results.[62]

The author could find little information concerning Miot's technique or his personal description of the operation. However, Scheer reports:

> Miot described in fair detail his technique of applying pressure by a palate-like instrument on the incudostapedial joint.[63]

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[60] Schneider, op. cit., [61] Ibid.

[62] Symposium, "Operation for the Mobilization of the Stapes in Otosclerotic Deafness," The Laryngoscope, 66:730, July, 1956.

[63] Alan Austin Scheer, "Restoration of Hearing in Otosclerosis by Transtympanic Mobilization of the Stapes," A.M.A. Archives of Otolarynogology, 61:513, January-June, 1955.

In reference to Miot's technique Schneider explains:

> Miot had exerted force only in the direction perpendicular to the line of the ossicular movement. He used a backward and downward pull to "break" the ankylosis . . . he pulled backward in the direction of the stapedial tendon.[64]

According to Schneider, Miot experienced 74 good results in 126 cases involving stapes mobilization.[65] Meurman and Meurman report that Miot obtained satisfactory improvement in 28 cases out of 56.[66] Rosen and Bergman report that Miot obtained slight and only temporary improvement among 200 cases.[67] These authors did not state what was considered at that time to be good, satisfactory, slight or temporary results. Although confusion exists concerning the degree of Miot's stapes mobilization successes, all of the above mentioned otologists agree that he did obtain some success.

It is also mentioned by Rosen and Bergman that Miot had operated on the same ear in some cases, three times within the first three months.[68]

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[64]Schneider, op. cit., p. 209.

[65]Ibid., p. 207.

[66]Meurman and Meurman, loc. cit.

[67]Rosen and Bergman, op. cit., p. 197.

[68]Ibid.

Blake

Little information was found concerning the success of Dr. Clarence Blake's attempts at stapes mobilization. However, some of his attitudes towards stapes mobilization, and the technique of the removal of the drum, malleus and incus are reviewed. Blake reported in 1892, his feeling toward the removal of the eardrum, malleus and incus:

> The removal of the membrana tympani, malleus and incus not only offers an unnecessary degree of violence to the middle ear but is unscientific in the sense that it leaves untouched that portion of the ossicular chain, the stapes, which has been justly demoninated the key to the labyrinth.[70]

Blake explains the reported successes with this technique by saying:

> The improvement in hearing in the cases so operated upon has been due in the great majority of them to the mobilization of the stapes incident to the removal of the two larger ossicles rather than to the removal of an obstruction presented by these bones themselves . . . unless the stapes itself be mobile removal of the membrana tympani and the other ossicula must be in a measure ineffectual.[71]

This author reports the degree of success he obtained with one of his early attempts at stapes mobilization:

> In Oct., 1881, it was decided to attempt mobilization of the stapes with a result of slight improvement in hearing aerially, which lasted for three days and then gradually decreased.[72]

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[70]Clarence J. Blake, "Operation for Removal of the Stapes," Boston Medical and Surgical Journal, 127:470, 1892.

[71]Ibid.

[72]Clarence J. Blake, "Operation for Removal of the Stapes without Ether," Boston Medical and Surgical Journal, 132:35, 1895.

Whether or not Blake actually practiced stapes mobilization to any extent or remained exclusively with the old techniques was not discovered by the author.

Jack

Meltzer bestows upon Jack the credit for the introduction of stapes mobilization into the United States. He states:

> In this country it had its inception at the institution where I had my otological training; in fact, it was under the very man who in 1892 introduced stapes mobilization, namely Dr. Frederic L. Jack.[73]

Jack appears to agree with Blake concerining the omprovement in hearing after the eardrum, malleus, and incus are removed. He explains in an article he wrote in 1895:

> From our present knowledge it seems plausible to attribute the improvement in any individual case, of removal of the membrana tympani, malleus or incus, in part or whole, chiefly to liberating or mobilizing the stapes.[74]

It appears that during that period the two primary operations practiced by otologists were the removal of the stapes, and stapes mobilization. Jack reports:

> The interest in operations for the relief of deafness, vertigo and tinnitus has naturally centered during the last two years, upon mobilization or removal of the stapes.[75]

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[73]Symposium, loc. cit.

[74]Frederick L. Jack, "Remarks on Stapedectomy," Boston Medical and Surgical Journal, 132:35, 1895.

[75]Ibid.

Jack advocates the use of cocaine while performing the stapes mobilization operation. He felt that cocaine will allow the patient to give aid in determining the operation's progress. In this way the patient can respond if the hearing is improved.[76] Brunner says that Jack used a set of magnification lenses to perform the operation.[77]

No information was found in regard to the degree of Jack's successes or failures. However, Jack explains:

> My results in so-called cases of sclerosis have been extremely discouraging, for in nearly every instance the bone has been found so firmly ankylosed, usually in the neighborhood of the foot-place, that upon pressure a fracture of the cura has occurred, leaving the footplate firmly adherent.[78]

Jack states that, "Most operations for mobilizing the stapes or freeing the oval window must be looked upon as largely experimental."[79] However, he adds:

> In cases of non-suppurative diseases of the middle ear, surgical mobilization should first be tried before an attempt is made to remove the stapes.[80]

Sibenmann

Sibenmann is included here, not because of his experience with stapes mobilization, but because of a statement he made that seems to reflect the feeling among many otologists

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[76] Ibid.

[77] Brunner, op. cit., p. 19.

[78] Jack, op. cit.

[79] Ibid.

[80] Ibid.

of the early nineteen-hundreds. In 1900 Sibenmann stated, "All endeavors at mobilization of the stapes are not only useless but often harmful."[81]

Stapes Mobilization Discontinued

Attemps at stapes mobilization were generally discontinued during the early nineteen-hundreds. Meltzer answers the question as to why stapes mobilization was given up, "Why? I can only venture a guess. It failed; hearing was not lastingly improved."[82]

Rosen and Bergman state that one reason for stapes mobilization failures at this time might be because:

> In all these operations the attempt to mobilize the stapes was through a myringotomy (incision in the eardrum). It may be that in many cases myringotomy did not provide sufficient vision of the stapes to allow precise manipulation.[83]

The Advent of Fenestration

Further exploration into stapes mobilization ceased after the introduction of a new technique to alleviate hearing loss due to stapes ankylosis. This technique concerns the creation of a new window in the labyrinth after by-passing the fixed stapes. This new window is made in the area of the semi-circular canals. The fenestration

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[81] Schneider, loc. cit. [82] Symposium, op. cit., p.731.

[83] Samuel Rosen and Moe Bergman, "Restoration of Hearing in Otosclerosis by Mobilization of the Fixed Stapedial Footplate. An Analysis of Results," The Laryngoscope, 65:224, April, 1955.

operation will be discussed in the following section of this study.

The basic idea of the fenestration operation began with Holmgren. Stevenson explains:

> In 1917, Holmgren, of Stockholm, began the researches in the surgery of the labyrinth which he continued with varying success over many years influencing Sourdille, Simson Hall and others. To Maurice Sourdille, of Nantes, must be given credit of devising the first successful fenestration for otosclerosis . . . Julius Lempert of New York, in 1938 developed Sourdille's operation into a practicable procedure.[84]

It was Lempert who termed this procedure the fenestration operation.[85]

From Holmgren up to Rosen, fenestration had taken over the limelight. The operations directed through the auditory canal against the ossicular chain and the alkylosed area of the stapes footplate received little attention.

Holmgren

Schneider reports that in 1923, Holmgren experienced some success with stapes mobilization. However, it was not intentional on Holmgren's part. He was performing a routine pre-fenestration examination on one of his patients. During this examination Schneider explains, "He accidentally twisted the stapes in such a way that the oval window was

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[84]Stevenson, op. cit., p. 110.

[85]Ibid.

opened."[86] Holmgren then gave the patient an immediate hearing test. The test revealed an improvement in hearing.[87]

This author reviews Holmgren's explanation of why twisting the stapes may be advantageous in stapes mobilization:

> The stapes normally does not simply move "back and forth," it also moves, being the end-plate of an oscillating acoustic system, in a rotary fashion.[88]

Schneider adds, "Great caution must be observed, as Holmgren reported, it is possible to dislocate the stapes."[89]

The author found no further information regarding Holmgren's other experiences with stapes mobilization, if there were any.

Herberts

Meurman and Meurman quote Dr. Herberts as saying in 1947, "The time is ripe for new attempts in the area of the stapes."[90]

However, Herbert's interest was placed primarily upon stapedectomy. Meurman and Meurman describe Herbert's endeavors:

> After demonstration on cadaver material that the membrane covering the inner surface of the stapedial footplate is thicker than usual in otosclerosis, he exposed the middle ear in two patients through the

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[86] Schneider, op. cit., p. 209. [87] Ibid.

[88] Ibid. [89] Ibid.

[90] Meurman and Meurman, loc. cit.

process and removed the stapes leaving the membrane in site.[91]

These authors mention that Herbert's results were good, but it is unknown whether or not they were permanent.[92]

Rosen

Meltzer says, "To Rosen must go the credit of rediscovery of stapes mobilization."[93]

Dr. Samuel Rosen, like Holmgren, accidentally mobilized the stapes in one of his fenestration patients. In this respect, Rosen and Bergman explain:

> On April 3, 1952, Rosen was performing a procedure on a patient described as a method of palpating the stapes as a means of determining suitability for fenestration. . . . Result, a return of acute hearing. . . . The footplate was accidentally mobilized while the fixed stapes was being palpatated.[94]

Since Rosen's rediscovery, stapes mobilization has generated new interest and enthusiasm in the field of otology. Goodhill states, ". . . Rosen rewakened our interest in the direst approack to the ankylosed stapes footplate."[95] Meltzer says, "Rosen's recent technique has definitely given otologists a new enthusiasm."[96]

It has also motivated some adverse criticism because of its earlier failures. In this respect Meltzer reasons:

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[91] Ibid. [92] Ibid. [93] Symposium, loc. cit.

[94] Rosen and Bergman, op. cit., p. 224.

[95] Goodhill, op. cit., p. 333. [96] Symposium, loc. cit.

> What difference does it make what these early results were? Does it matter if three or four patients are improved by stapes mobilization in ten attempts? Are not three or four successes a real attainment? Given time and experience and understanding as to why we fail, should we not expect better results just as we improve our results with the fenestration operation? I believe so.[97]

He adds:

> The hearing improvement brought about by stapes mobilization is of such magnitude that I confidently look forward to its becoming as firmly established a procedure for the improvement of hearing in otosclerosis as the fenestration operation.[98]

It seems that Dr. J. H. Thomas Rambo views Rosen's re-awakening of stapes mobilization primarily from the standpoint of the method of attack. That is, the attack made directly upon the area of the ankylosed footplate and the oval window, through the auditory canal. Rambo explains:

> I believe that experience with the footplate approach in mobilization techniques is leading us inevitably to the recognition that hearing through even a small opening at the oval window is a much more physiological way for airborne sound to mobilize inner ear fluids; and we are, therefore, getting surprising good results when sound reaches the inner ear through this natural route, even without the ossicular chain.[99]

Rambo summarizes by saying:

> . . . today we have been reminded by several of the participants that mobilization is not a standard procedure; that there are many techniques used; and that we are all looking for a special procedure which will offer a better solution to this surgery. I imagine that approximately the same situation probably existed following Miot's experiences with mobilization which prompted Jack in Boston, after repeating them, to perform stapedectomy.[100]

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[97] Ibid. [98] Ibid. [99] Ibid., p. 781. [100] Ibid., p. 782.

> If such be the case, that we continue to follow faithfully the experiences of the otologists of over half a century ago, which we have done so far, we will again arrive full-circle to stapedectomy.[101]

Whether or not Dr. Rambo's above mentioned prediction is correct naturally remains to be seen in the future. However, many otologists in this country and other countries are practicing stapes mobilization, and to date, there appears to be a great deal of enthusiasm in regard to its possibilities.

III. FENESTRATION OPERATION

Today, there are but two surgical procedures commonly practiced by otologists for the possible alleviation of deafness due to stapes ankylosis. These procedures are the fenestration operation and stapes mobilization. The primary differences between the two operations concern the method of attack and the degree of simplicity in regard to the surgical procedures. Criteria for the selection of candidates is basically the same.

It was mentioned earlier in this study that Holmgren, Sourdille, and Lempert are the principle otologists responsible for the development of the fenestration operation. In 1916, Holmgren introduced the method, Sourdille developed it further, and Lempert perfected the operation and gave it its name. Farrior and Bagby state that today, "All

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[101] Ibid.

fenestration operations are Lempert fenestration operations."[102] However, they mention that some otologists have added their own individual techniques to various phases of the procedure.[103]

This section of the study will include a discussion of fenestration in regard to the selection of prospective candidates, the objectives of fenestration, the operation itself, the results of fenestration, the causes of fenestration failures and post-operative complications. The author feels that such a discussion is pertinent to this study in order that the reader may understand the advantages and disadvantages of stapes mobilization more effectively by comparison with those of the fenestration operation.

Pure-Tone Audiometric Testing

In discussing the criteria for the selection of fenestration candidates and for determining operation success, it will be necessary to use such terms as "decibel," "audiogram," "aid conduction," and "bone conduction." These terms are primarily related to the testing of hearing by the pure-tone audiometric method. An explanation of such terms is of value at this point.

There are various methods employed for testing an individual's degree of hearing loss due to otosclerosis.

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[102]J. Brown Farrior, Richard Bagby, and Cecil Thomas, "Fenestration Operation Analyzied for Nonfenestrating Otologist," A.M.A. Archives of Otolaryngology, 59:7,Jan.1954.

[103]Ibid.

One series of tests involves the use of tuning forks. Other types of tests employed are the speech reception threshold and speech discrimination tests. All of these tests of hearing and their relationship to the testing of otosclerotic severity will be discussed in Chapter IV of this study. However, the author feels that an explanation of pure-tone audiometric testing and its terms will be adequate for this section of the study.

Pure-tone audiometer. A pure-tone audiometer is an electrical instrument used for measuring the degree of hearing existing within an individual. Saltzman states that an audiometer is:

> . . . calibrated for a frequency range of 64 d.v. to about 10,000 d.v., or more and is capable . . . through an attenuator . . . to deliver sound in steps of 5 db. to the intensity level of 100 db. or higher. The "zero line" is the no loss line which signifies average normal hearing, while the -5 and -10 lines represent degrees of acuity of hearing that excel the average as far as the threshold level is concerned.[104]

The decibel. Hearing losses are measured in decibels. Stevenson defines a decibel in the following manner:

> . . . an arbitrary unit of sound intensity, which expresses the ratio of the acoustic energy required to stimulate a given ear at a given frequency to the acoustic energy found by a large number of investigations to constitute the threshold for the normal ear at this frequency.[105]

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[104]Maurice Saltzman, Clinical Audiology (New York: Grune and Stratton, 1949), p. 152.

[105]Stevenson, op. cit., p. 37.

The audiogram. An audiogram is a graphic record used for recording the information measured by an audiometer. Generally speaking, an audiogram consists of a series of horizontal lines crossed by a series of vertical lines. The horizontal lines designate the intensity measurements, and are labeled in the following order, -10 db, -5 db, 0 db, 5 db, 10 db, 15 db, and on up to 100 db. The vertical lines indicate the frequencies. They are generally labeled in the following manner, 64, 128, 256, 512, 1024, 2048, 4096, and 8192.

Air conduction and bone conduction. Air conduction is a term meaning the transmission of sound waves through the external ear canal, the middle ear, to the inner ear.

Bone conduction is a term meaning the transmission of sound waves through the temporal bones of the skull to the fluids of the inner ear.

For air conduction testing regular earphones are worn by the individual being tested. When testing by bone conduction an oscillating unit is worn usually on the mastoid bone behind the auricle.

Selection of Prospective Candidates for Fenestration

Not all persons suffering from a hearing loss due to otosclerosis can benefit from the fenestration operation. However, Farrior states:

> In the ideal candidate with the ideal fenestration operation the patient should always receive a maximum and permanent restoration of hearing.[106]

Basically, if the otosclerotic bone growth has done extensive damage to the cochlear nerve, fenestration will be of little value. It is the individual with impaired hearing due to stapes ankylosis, but whose cochlear nerve is unaffected by the bone growth that may best benefit from this operation.

Farrior offers the following definition of the ideal fenestration candidate:

> The ideal candidate for the fenestration operation is the otosclerotic patient with a flat ascending air conduction audiogram with a 40 to 60 decibel hearing loss for the speech frequencies and normal bone conduction.[107]

The interpretation of this audiogram reveals that there is considerable air conductive loss, and that because of the normal bone conduction, the cochlear nerve is unaffected.

It should be mentioned here that the speech frequencies are those frequencies important to the comprehending of normal speech. On an audiogram these frequencies are 512, 1024, and 2048. If the hearing loss at these frequencies is greater than 30 db, an individual will not have adequate hearing to communicate effectively in society.

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[106]J. Brown Farrior, "The Fenestration Operation in the Ideal Candidate," The Laryngoscope, 64:414, May, 1954.

[107]Ibid.

Walsh and Silverman state in regard to the requirements for prospective fenestration candidates, a patient:

> 1. who is young between adolescence and forty-five years of age . . . 2. who has a progressive loss of hearing . . . 3. whose air conduction curve on audiometry is generally flat or rising in the high tones, and, . . . 4. whose bone conductive loss is not more than 20 db from 200 to 4000, presents an ideal case.[108]

These authors add, "We would, however, disagree with rigid adherence to these criteria."[109] They feel that age is important only as far as the patient's response to trauma and his ability to heal is concerned.

Ferrior classifies fenestration candidates into the following three categories:

> Good Candidate: . . . hearing for speech frequencies of 512, 1024 and 2048 below the critical level of 30 db. The bone conduction is normal for speech frequencies.
>
> Fair Candidate: . . . more severe loss of auditory acuity for the higher tone frequencies indicating loss of cochlear nerve. Bone conduction is still normal at 512, slight loss at 1024, but at this frequency bond conduction has not fallen below 20 db. level. Bone conduction for 2048 is near 30 db.
>
> Poor Candidate: Bone conduction is normal at 512. At 1024 bone conduction is below the critical level of 20 db. and bone conduction is below 30 db. at 2048.[110]

Jones discusses the various fenestration candidates in the following manner:

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[108]Theodore E. Walsh and S. Richard Silverman, "Diagnosis and Evaluation of Fenestration." The Laryngoscope, 56: 538, September, 1946.

[109]Ibid.

[110]J. Brown Farrior, "The Fenestration Operation-Indications, Technique and Result," The Laryngoscope, 59: 516-517, May, 1949.

> 1. Ideal cases, comparatively rare. . . 2. A good risk, is satisfactory and common. . . 3. A poor risk, the few who have a chance to recover some hearing. . . 4. Unsatisfactory, occasionally, operated on after a thorough explanation to the patient, followed by a period of three months for consideration.[111]

Pure-tone audiometric testing is not the only method used in selecting candidates for the fenestration operation. In fact, some otologists place little confidence in the results obtained from audiometric bone conduction results for determining the state of the cochlear nerve. Reasons for this, and other methods of testing for cochlear nerve damage will be discussed in the following chapter.

Objectives of Fenestration

Basically, the principal objective of the fenestration operation is to create, a new window within the horizontal (external) semi-circular canal to compensate for the occluded oval window.

If this procedure is successful, sound waves that are collected by the auricle, will be directed to this new window by passing through a newly created cavity within the mastoid bone. These sound waves will strike an artificial membrane that is placed over the new window, and innervate the inner ear fluids, which will in turn innervate the cochlear nerve.

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[111] Marvin F. Jones, "Critical Survey of the Lempert Endural Fenestration Operation," The Laryngoscope, 57:263-264, March, 1947.

The artificial membrane is constructed from the thin epithelium that lines the external auditory meatus, however, otologists have experimented using other tissues.

A successful fenestration operation restores some of the patient's hearing by air conduction, although air-born sounds by-pass the normal ossicular chain acoustic route.

Lempert says, ". . . the normally functioning ossicular chain channels 30 times the pressure of sound from the tympanic cavity to the perilymph and endolymph."[112] In cases of stapes ankylosis he adds, "A newly created fenestra in the external semicircular canal . . . channels approximately 30 to 100 times the sound of pressure of the . . . functionally impeded, ossicular chain."[113]

Lempert lists the following three objectives of fenestration surgery:

> Objective 1.-The primary objective of creating a new fenestra is to render the perilymph and endolymph freely mobilizable by normal air-borne sound. . . .
>
> Objective 2.-The second objective is to permit normally tolerated air-borne sound to do the mobilizing of the perilymph and endolympth.
>
> Objective 3.-The third objective is to reconstruct the middle ear surgically so that it would permit the mobilization of the cochlear fluids by air-borne sound energy through both the new vestibule fenestra and nature's cochlear fenestra (round window) under the most favorable phase relationship.[114]

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[112]Juluis Lempert, "Physiology of Hearing," A.M.A. Archives of Otolarynogology, 56:104, August, 1952.

[113]Ibid.

[114]Ibid., p. 105-108.

In analyzing the article within which Lempert states these three objectives it seems that his means to these ends are as follows. In regard to Objective 1, he found that the new window must be placed within the external semicircular canal. If placed within the cochlear promontary instead of the external semicircular canal, remobilization of the inner ear fluids will not be accomplished. In reference to Objective 2, he feels that in order that the best possible mobilization of the inner ear fluids is accomplished, the tympanomeatal membrane sealing the new window must be, ". . . flexible and readily yielding."[115] Concerning Objective 3, he found that it is important that the tympanic membrane be kept intact so that it hermetically seals the tympanic air space. He states that this is important so that the proper difference in phase or intensity relationship of the sound pressure exerted on the vestibular and cochlear windows be accomplished.[116]

Fenestration Operation Procedure

It has been stated that there are two basic differences between the fenestration operation and stapes mobilization. In fenestration the method of attach differs from stapes mobilization in that it is not directed against the ankylosed area of the footplate, but it by-passes this area. In regards to the other difference, fenestration is a more complicated procedure.

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[115] Ibid., 106.

[116] Ibid., 105-108.

According to Sullivan and Smith the operation is performed under either a local or general anesthesia.[117]

Farrior and Bagby describe the initial incision as a crescentric incision at the inner depth of the cartilaginous canal. The point of this incision is within the posterior wall of the external auditory meatus where the cartilage meets the bony portion. The flap that is created by this incision is elevated before bone surgery begins.[118] Sullivan and Smith explain that the flap is then covered by a paraffin gauze to protect it from the mechanical burr that is used for bone surgery, and possible bone chips.[119]

The next procedure concerns the creation of the new cavity. When completed, this cavity provides an acoustic route from the outer air through the bone encasing the external auditory canal, the mastoid bone and to the horizontal semi-circular canal. At one phase of this procedure the incus and the head of the malleus are exposed. These portions of the ossicular chain are removed. The final step in the creation of the cavity is explained by Sullivan and Smith:

> Using a diamond burr, the posterior canal wall over the facial nerve is lowered still further and the bone cells around the superior, horizontal and posterior semicircular canals are removed. . . . This latter procedure is carried out with magnifying glasses so that the facial nerve may be discerned.[120]

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[117]Wiener and others (eds.), op. cit., p. 409.

[118]Farrior, Bagby, and Thomas, op. cit., p. 6.

[119]Wiener and others (eds.), loc. cit.

[120]Ibid.

These authors further explain that after the semi-circular canal is exposed, the stapes is tested for its mobility.[121] According to Rosen palpation of the stapes could be useful in determining for which cases of otosclerosis that fenestration should or should not be done. This author states:

> One cannot determine with absolute certainty if the stapes is completely fixed by any method except palpation of it with a probe during the fenestration operation. . . . A completely fixed stapes is pathognomonic (indicative) of an otosclerotic condition which is ideal for treatment. . . . The fenestration operation should therefore be performed on patients with completely fixed stapes to insure the best results.[122]

Sullivan and Smith state that the next step is administered through a dissecting microscope using the diamond and finishing burrs. It involves the creation of the new window within the horizontal semi-circular canal. These authors state, "Opposite the oval window, the fenestra is made on top of this dome by grooving the endosteal bone which is removed as a lid."[123] They further explain that this exposes the membranous duct and the endosteal membrane (lining of the labyrinth).[124]

Farrior says, "The cutaneous lining of the anterior wall of the canal provides the thinness possible covering

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[121] Ibid.

[122] Samuel Rosen, "Palpation of Stapes for Fixation," A.M.A. Archives of Otolaryngology, 56:610, December, 1952.

[123] Wiener and others (eds.), op. cit. [124] Ibid.

for the fenestra."[125] This lining is a portion of the flap created by the initial incision. Sullivan and Smith explain that this covering is held in place over the fenestral rim by two or three paraffin mesh packs, which are later removed.[126]

Fenestration Results

Jones states in regard to the results of fenestration:

> Fenestration operation sometimes results in normal hearing, but the usual improvement falls in the zone between 15 db. and 25 db. loss. This is a useful hearing level, but it is not normal.[127]

Farrior, Bagby, and Thomas feel that if the patient has a good bone conduction prior to the operation he will obtain, ". . . a gratifying restoration of hearing. . . will last in more than 95% of cases."[128] He further implies that the restored hearing will be permanent provided the fenestra and flap and microscopically perfect. This author says:

> While initial result is primarily dependent upon the quality of bone conduction . . .the permanent result is primarily dependent upon the quality of the surgery.[129]

Jones believes that a satisfactory operation depends upon the following criteria:

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[125]Farrior, "The Fenestration Operation-Indications, Technique and Result," op. cit., p. 252.

[126]Wiener and others (eds.), op. cit.

[127]Jones, op. cit., p. 268.

[128]Farrior, Bagby and Thomas, op. cit., p. 1.

[129]Ibid.

> Pure-tones in the conversational range, (512, 1024, and 2,048) must all have better than a 30 db. loss in order to be classified as satisfactory.[130]

In regard to the amount of time required to determine the permanency of such results, Jones is of the opinion that one year is reasonable and two years are safe. If the restored hearing has lasted two years, Jones feels that the hearing is permanently improved. He further states that if any surgeon has attained 60% permanent improvement in his fenestration operations, he is getting excellent results.[131]

Sullivan and Smith explain why a hearing improvement of 30 db. or better is the best result that can be expected from the fenestration operation:

> . . . hearing at the 0 db. level is almost impossible since the normal mechanics of hearing are interfered with. It is a makeshift but ingenious operation. Nature supplied us with middle ear bones to concentrate the sound into a little window which we initiate in size in the horizontal canal, but it will not be possible to obtain the gain in volume until some mechanical device or other improvement is devised.[132]

Causes of Fenestration Failures

According to Jones, "Fenestration is not a 100% effective operation. We do have failures."[133] He says that the three most common causes for failure are, a bony regrowth which closes the newly created window, wrong diagnosis, and surgical accidents.[134]

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[130]Jones, op. cit., p. 270. [131]Ibid.

[132]Wiener and others (eds.), op. cit., p. 414.

[133]Jones, op. cit., p. 209. [134]Ibid.

In regard to surgical accidents Jones states:

> Motor driven instruments, vagaries of electrical equipment, mechanical defects in instruments, and just plain slips have been the cause of failures. I might also add they will probably continue to cause failures. When a rotating burr tangles with a delicate and carefully made membrane and flap, the damage is done. When the adjustment on electrical devices is accidentally altered or a "short" occurs, damage may be done. When a defective instrument breaks, the gods of chance control the outcome. When some entheusiastic observer bumps the surgeon's arm while he is using a suction near the fenestration, the only thing left to do is swear.[135]

Post-Operative Complications

Jones states, "A discharging ear has proven to be the most annoying post-operation feature with which I have had to deal."[136] Farrior and Bagby believe that, "Chronic discharge is one of the greatest nuisance factors in fenestration surgery."[137] Such post-operative discharges are generally caused by inflammation of the newly created cavity walls.[138] Farrior and Bagby state that, "The fenestration operation leaves a denuded area of 5 to 8 sq. cm. It takes time for this area to heal, but eventually it almost always does heal."[139]

Another complicating post-operative factor is that of labyrinthitis (inflammation of the labyrinth). Farrior and Bagby describe the three phases of labyrinthitis:

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[135] Ibid.

[136] Ibid., p. 267.

[137] Farrior, Bagby and Thomas, op. cit., p. 11.

[138] Ibid.

[139] Ibid.

> 1. Primary surgical labyrinthitis . . . immediate effect of surgical injury or hemmorrhage is demonstrable on the first post-operative day. 2. Secondary serious labyrinthitis . . . results of inflammatory response, reaches its peak on the fifth to tenth day. 3. Tertiary degenerative labyrinthitis . . . the end result. Loss of high tones is the mildest form, and nerve deafness the severe.[140]

If the facial nerve is severed during the creation of the cavity, facial paralysis will result.[141] However, in this respect Farrior and Bagby state, "Such an accident might occur, but par for facial paralysis should be zero."[142]

Vertigo is another possible result of the fenestration operation. Farrior and Bagby say, "Lasting vertigo is registered as a complaint by a small percentage of fenestration patients."[143]

After the operation the fenestration patient remains under the care of an otologist. Farrior, Bagby and Thomas explain:

> Postoperatively, when a patient returns to the care of his referring otologist, we ask him to consult this physician once a week for three weeks, one a month for three months, and three times a year thereafter. The purposes of these visits are cleansing the cavity and removal of any crust.[144]

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[140] Ibid., pp. 9-10. [141] Ibid. [142] Ibid., p. 10.

[143] Ibid. [144] Ibid.

CHAPTER IV

PREOPERATIVE AUDIOMETRIC TESTING

The various techniques of audiometric testing used in the preoperative diagnosis of stapes ankylosis, and the selection of prospective candidates for the stapes mobilization surgical procedure will be considered within this chapter.

As an aid in diagnosis, autiometric testing is employed to determine whether or not a conductive hearing loss is present, whether or not this loss is caused by stapes ankylosis, and whether or not the condition is complicated by a cochlear nerve impairment.

Audiometric testing is also employed in the selection of prospective stapes mobilization candidates. By revealing the severity and characteristics of a hearing loss due to stapes ankylosis, audiometric testing can aid the otologist in selecting affected individuals who may best benefit from surgery.

Myers and Ronis offer the following information regarding the preoperative value of audiometric testing:

> The diagnosis of otosclerosis can be made . . . audiometrically. The degree of stapes fixation cannot be predicted by the preoperative audiologic survey. At the present time, the successful

> candidate cannot be predicted preoperatively. The amount of hearing improvement cannot be predicted preoperatively.[1]

It appears that Bergman contradicts Myers and Ronis on their last two points regarding the value of preoperative audiometric testing. Bergman states that with adequate audiometric testing the otologist:

> . . . can evaluate the preoperative hearing function in all its aspects . . . can predict the amount and kind of hearing gain which can be obtained from successful surgery. . . and can determine the goal of the operation for each patient.[2]

The belief that the degree of stapes fixation cannot definitely be determined preoperatively is supported by most otologists reviewed by the author. Due to the limitations of present day audiometric testing methods, the severity of stapes ankylosis can only be ascertained after an entrance has been made into the tympanic cavity. Because of this, it would seem that Myers' and Ronis' opinions that a successful candidate cannot be predicted preoperatively nor can the amount of hearing improvement be predicated preoperatively, are most plausible.

However, audiometric testing can aid the otologist in choosing affected individuals who may best benefit from stapes mobilization. Goals may be set with the aid of

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[1]David Myers and Bernard J. Ronis, "Improvement of Hearing in Otosclerosis by Means of Stapes Moblization Operation," A.M.A. Archives of Otolaryngology, 64:308, December, 1956.

[2]Moe Bergman, "Audiologic Aspects of Audiosurgery," A.M.A. Archives of Otolaryngology , 63:280, March, 1956.

audiometric testing, but the accurate prediction of such goals is difficult because of the above mentioned unknown factors.

According to Bergman:

> The assessment of hearing function prior to surgery should be intensive and extensive . . . . Because of the limitations of tests currently in use it is necessary frequently to employ a variety of tests, to reduce doubts about the suitability of a patient for the operation and to develop realistic goals for the treatment.[3]

Audiometric tests used in the diagnosis of stapes mobilization are pure-tone audiometric tests (both air conduction and bone conduction), tuning fork tests and monitored speech reception tests. It seems apparent to the author, after reviewing the material concerning the subject, that only the results obtained from pure-tone and speech reception tests are used extensively in selecting prospective candidates and determining post-operative results that might be gained through successful surgery.

I. PURE-TONE AUDIOMETRIC TESTING

Pure-tone audiometric testing has been discussed previously in Section III, Chapter III, of this study. It was explained in relation to the selection of prospective candidates for the fenestration operation. However, the method of administering a pure-tone audiometric test was

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[3] Ibid.

not considered. Within this section of the study the method of administration will be explained, along with the value of pure-tone audiometry in the diagnosis of stapes ankylosis and in the selection of candidates for the stapes mobilization surgical procedure.

The Administration of Pure-Tone Audiometric Tests

The audiologist can test an individual's hearing by either air conduction or bone conduction with a pure-tone audiometer.

The administration of air conduction and bone conduction tests are basically the same. The difference lies in the type of receiver worn by the individual being tested. It was previously stated in Section III, Chapter III, that in air conduction testing the individual being tested wears a regular air conduction earphone, while in bone conduction testing an oscillating unit is worn on the mastoid bone behind the ear.

It is the purpose of pure-tone testing to obtain an individual's "threshold" for each of the following frequencies in cycles per second: 128, 256, 512, 1024, 2048, 4096, and 8196. In some audiometers these frequencies in cycles per second are represented in round numbers in the following manner, 125, 250, 500,1000, 2000, 4000, 6000, and 8000.

The term "threshold" is explained by Saltzman:

> By means of the modern audiometer, it became possible to standardize the least amount of sound

> power necessary to arouse an auditory sensation in a normal ear, and the term "threshold" has been adopted to designate this point.[4]

To obtain these thresholds of hearing for the various frequencies the audiologist explores each frequency by introducing it into the air or bone receiver at different intensities. The audiologist is able to regulate the transmission of frequencies by manipulating a "tone interrupter" located on the audiometer panel. He is able to choose the frequencies to be transmitted and their intensities, by adjusting two dials on the audiometer panel. One dial selects the frequency to be transmitted and the other dial selects the intensity of the frequency.

During the test the individual being tested is seated so that he cannot see the movements of the audiologist manipulating the "tone interrupter." Therefore, if the audiologist has an effective technique and does not follow a rhythmic pattern of tone transmission, the individual being tested is aware of the tone transmission only when hearing it.

In order that realistic thresholds may be obtained, it is necessary that the audiometer be properly calibrated and the test be performed in an acoustic environment free from disturbing noise.

The individual being tested signals when he hears the tone. When his "threshold" for a given frequency has

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[4]Saltzman, op. cit., p. 1.

been reached the audiologist records the finding on the audiogram and proceeds to another frequency. This method of recording the "thresholds" on the audiogram involves the use of symbols.

Generally, the symbols used in recording right ear thresholds are "O" (in red) for air conduction and "[ ]" (in red) for bone conduction. Those used for left ear thresholds are "X" (in blue) for air conduction and "<" (in blue) for bone conduction. These symbols are placed at the point on the audiogram where the verticle line designating the frequency crosses the horizontal line designating the intensity. Audiogram 1, page 80, illustrates the use of the above described symbols.

When all thresholds have been found the audiologist can obtain a profile of the individual's hearing acuity by connecting each threshold with a line. Connell and Trowbridge explain in general the interpretation of audiograms:

> No definite rule can be laid down for the interpretation of audiographs; however, as a working principle it can be stated that frequency losses not exceeding 30 db up to the frequency 1024, indicate damage to the conductive mechnaism, whereas losses above 1024 cycles and those exceeding 30 db below 1024 cycles indicate damage to the perceptive mechanism.[5]

Pure-Tone Audiometry as an Aid in Diagnosis

Saltzman describes the general characteristics of an audiogram revealing the presence of stapes ankylosis:

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[5]E. S. Connell and B. C. Trowbridge, "Essential Procedure in the Diagnosis of the Abnormalities of Hearing with Some Audiometric Findings," The Laryngoscope, 52:548,July,1942.

> Audiometry gives frequently a rather characteristic pattern. . . . By air conduction the low tones are invariably affected and most often the hearing loss is uniform for all frequencies, but shallow v-curves and dips at the higher side of the audiogram do occur. Bone conduction, in an uncomplicated case, is usually within normal range.[6]

Shambaugh explains the characteristics of an air conduction audiogram indicating stapes ankylosis:

> The air conduction audiogram of pure stapes ankylosis exhibits certain rather characteristic configurations. In the early stages of beginning stapes fixation, the stiffness of the ossicular chain is increased resulting in a greater loss for low than for high frequencies. This is termed the "stiffness tilt" in the audiogram of partial stapes fixation. As the ankylosis becomes complete, the stapes and labyrinthine capsule become one, and the mass of the capsule is added to the stiffness of the sound conducting system, with a hearing loss for the high frequencies, termed the "mass flattening" in the audiogram of complete stapes ankylosis. The maximum hearing loss of pure stapes ankylosis (without complicating nerve degeneration) is around 60 decibels for the speech frequencies.[7]

In regard to the characteristics of a bone conduction audiogram, Shambaugh explains:

> The bone conduction audiogram of pure stapes ankylosis might be expected to give a "zero" threshold reading, but Carhart has recently called attention to a characteristic notching of the bone conduction audiogram of otosclerosis, deepest at 2048, which largely disappears after fenestration. Carhart suggests that this notch is a mechanical effect of stapes ankylosis, and that to determine the true cochlear nerve response of a patient with otosclerosis the bone conduction audiogram should be corrected for this notch. The depth of the otosclerotic notch probably varies, but it averages a loss of 5 decibels for 512, 10 decibels for 1024, 15 decibels for 2048 and 5 decibels for 4096.[8]

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[6]Saltzman, op. cit., p. 70.

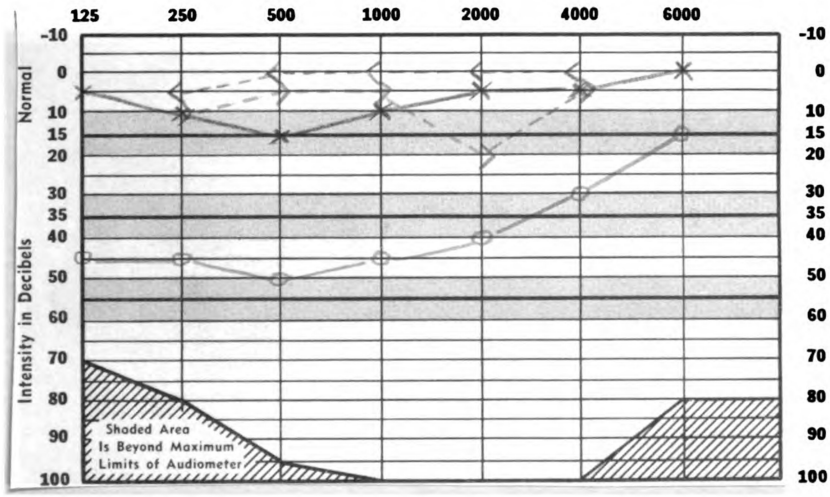
[7]Wiener and others (eds.), op. cit., pp. 399-400.

[8]Ibid., p. 400.

Audiogram 1, is an example of an audiogram indicating stapes ankylosis without cochlear degeneration in the right ear. The notch of Carhart is seen in the bone conduction curve.

Saltzman states in regard to otosclerotic involvement of both ears:

> Most often both ears are involved but not to the same degree. . . . In the case of otosclerosis, stapedial ankylosis is usually more marked in one ear than the other. Conversly, the ear with greater impairment for air-born sounds due to obstruction by ankylosis should theoretically have better bone conduction than the other.[9]



Audiogram 1. Stapes ankylosis in the right ear. The Carhart notch is indicated in the bone conduction curve. (Note: Frequencies in cycles per second are represented in round number.)

According to Saltzman the reason for their being better bone conduction in the more seriously impaired ear is

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[9]Saltzman, op. cit.

because of the fixation of the stapes footplate within the oval window. If this fixation is severe, the sound vibrations initiated through bone conduction are more effected within the bony labyrinth because their pressure is increased by the oval window closure. Only the unoccluded round window acts to reduce this pressure after the sound waves have innervated the nerve endings on the organ of Corti.[10]

Pure-Tone Audiometry as an Aid in Candidate Selection

After it has been determined that stapes ankylosis is present within an individual, the otologist must then decide whether or not the individual may benefit from the stapes mobilization surgical procedure. In this respect, Myers and Ronis state:

> The best results are obtained in the ideal cases of otosclerosis. Here, one should have the bone conduction above the 30 db level, preferably from 0-15 db, and a wide air-bone gap of 20-30 db.[11] The air-conduction curve will vary from 30-50 db.

The above mentioned criteria are also necessary for favorable post-operative results from a successful fenestration operation. However, Goodhill and Holcomb explain the differences in results that may be obtained from successful fenestration operations and successful stapes mobilization operations. These authors state:

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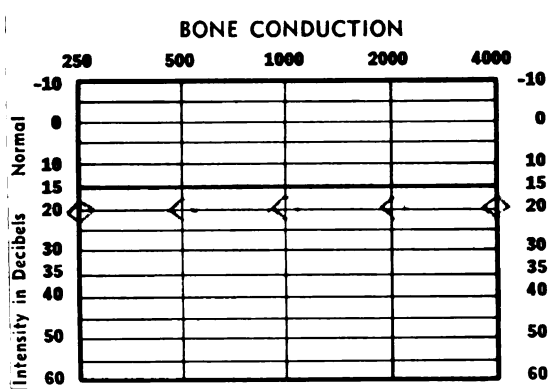
[10] Ibid., p. 71.

[11] Myers and Ronis, op. cit., p.308.

> The fenestration (detour) operation has a far more limited audiologic application in the treatment of otosclerosis than the stapedolysis (direct) approach. . . . A physiologic deficit must of necessity occur in fenestration surgery. . . . This means that post-operative air conduction will seldom be better than 15 db. below the preoperative bone-conduction response. Since an average of not worse than the 30 db. level in the speech frequencies is necessary for the restoration of practical physiological unaided hearing, it is necessary to start out with a good bone-conduction level, one not lower than 15 to 20 db. in the speech frequencies.[12]

(As previously indicated in Section III, Chapter III, the speech frequencies are 512, 1024 and 2048.)

Audiogram 2 illustrates the maximum amount of hearing loss by bone conduction that can be allowed in order that a successful fenestration operation can restore an individual's hearing to a level of practical hearing, according to the above quotation.



Audiogram 2. Degree of bone conduction loss allowed in order that the patient may receive favorable results from fenestration.

In regard to stapes mobilization, Goodhill and Halcomb explain:

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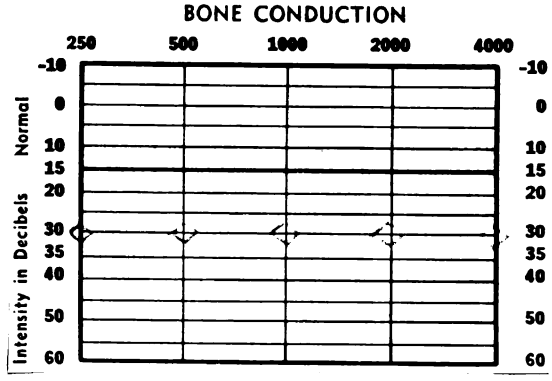
[12]Victor Goodhill and Arthur L. Holcomb, "The Surgical Audiometric Nomograph in Stapedolysis," A.M.A. Archives of Otolaryngology, 63:399, April, 1956.

> There is no minimal physiological deficit in stapedolysis (direct) surgery comparable to that in fenestration surgery . . . one can expect greater flexibility in the application of the stapedolysis (direct) approach . . . a patient with a 20 db bone-conduction level and a 70 db. air-conduction level may still achieve a post-operative 30 db air conduction level. . .[13]

Audiogram 3 illustrates the maximum amount of hearing loss by bone conduction that can be allowed in order that a successful stapes mobilization operation can restore an individual's hearing to the level of practical hearing, according to the above quotation.



Audiogram 3. Degree of bone conduction loss allowed in order that the patient may receive favorable results from stapes mobilization.

The physiologic deficit mentioned within the previous quotations concerns the absence of the normal air conductive route by way of the ossicular chain, after the fenestration operation.

From the above information it appears that the pre-operative qualifications for post-operative adequate hearing

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[13] Ibid.

are more flexible for stapes mobilization candidates than for fenestration candidates. This is true especially as-far as preoperative bone conduction results are concerned. Providing there are no pathologic or surgical complications to interfere with the stapes mobilization surgical procedure, post-operative air conduction can equal preoperative bone conduction.

Pathologic complications that could interfere with stapes mobilization surgical success are severe ankylosis that does not allow complete stapes mobilization and otosclerotic occulsion of the round window.

Surgical complicationswill be discussed in Section VIII, Chapter V.

Because it is not possible to predict the presence or occurrance of pathologic and surgical complications, accurate predictions as to the selection of ideal candidates and the amount of hearing that can be gained post-operatively cannot be made preoperatively.

Problem of Bone Conduction Testing

Suitability for the stapes mobilization surgical procedure is greatly dependent upon the state of the cochlear nerve. The only present day methods of determining the state of the cochlear nerve, involve the employment of the various tests for bone conduction.

However, many otologists feel that bone conduction tests are not totally reliable. Walsh and Silverman state:

> Bone conduction tests are unreliable, we pay little attention to them except from the point of view of general screening of patients.[14]

These authors further explain that such tests of bone conduction are primarily designed to determine cochlear function, but that a loss of hearing by bone conduction does not necessarily indicate cochlear damage.[15] In this respect Walsh and Silverman explain:

> Variables in the thickness of the cortex, the pneumatization and thickness of the tracebulae (partitions between mastoid air cells) in the mastoid tegether with variations in thickness of the sub-cutaneous tissues must influence the conduction of sound to the cochlea from a source placed on the bone behind the ear.[16]

Saltzman agrees with Walsh and Silverman. He feels that the degree and ease with which sound transmission through bone conduction will take place depends upon the characteristics of the respective tissues of the individual. He explains that the structure of the tracebulae within the mastoid bone is important for the proper transmission of sound waves to the labyrinth by bone conduction.[17]

Saltzman refers to a study in which the mastoid bones were examined, post mortem, of individuals with known impaired bone conduction, but whose hearing by air conduction was normal. The results revealed that all the trabeculae in the

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[14]Walsh and Silverman, op. cit., p. 544.

[15]Ibid.

[16]Ibid., p. 540.

[17]Saltzman, op. cit., p. 24.

subadicus region were fractured. This author reports, "It appears that fractures of the trabeculae are common occurrences."[18]

Although the reliability of bone conduction tests is questionable, they are used extensively in testing for cochlear damage. The author found no evidence of other present day methods used by otologists to determine the state of the cochlear nerve.

II. TUNING FORK TESTS

As an additional aid in the diagnosis of stapes ankylosis, tuning fork tests are employed by many otologists. Hirsh says, "Many clinicians still prefer the classical bone conduction tests with tuning forks."[19] Farrior, Bagby, and Thomas state:

> In testing of bone conduction the tuning forks are, in the average quiet office, the most reliable method of testing the otosclerotic patient.[20]

The author could find no explanation presented by Brown and Farrior to support the above quotation.

Hirsh believes, in reference to tuning fork tests:

> The otologist who has had experience with these tests, administered with a particular set of tuning forks, makes extremely accurate diagnostic judgments . . . designed to tell the clinician whether his

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[18] Ibid.

[19] Ira J. Hirsh, The Measurement of Hearing (New York: McGraw-Hill Book Company, Inc., 1952), p. 249.

[20] Farrior, Bagby, and Thomas, op. cit., p. 2.

> patient has a hearing loss of the conductive type or of the more central perceptive, or nerve type.[21]

Hirsh adds:

> In the hands of a precise, experienced clinician it appears that the tuning fork is a more useful diagnostic instrument than is the more precise pure-tone audiometer in the hands of an inexperienced, careless tester.[22]

Tuning forks are made of iron or an aluminium alloy, and are designed to transmit the same frequencies as the pure-tone audiometer. One fork transmits one frequency. The fork in structure, has a hilt or handle, and two tines. Tuning fork tests are among the earliest methods used in bone conduction testing. Davis explains:

> The principles of high-tone deafness and of bone conduction were established by means of tuning forks, and the method is still often used for rapid approximate work.[23]

Generally, tuning fork tests are administered in the following manner. The fork is struck, which causes the tines to vibrate at the frequency the fork was designed to transmit. Davis states, "As the vibrations die down, the sound becomes fainter, and some idea of the patient's sensitivity can be obtained by noting how long he continues to hear the tone."[24] However, all tuning fork tests results are not determined by how long the patient hears the tone. The Weber test is designed to determine where the tone is heard.

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[21]Hirsh, op. cit., p. 282. [22]Ibid., p. 283.

[23]Hallowell Davis (ed.), Hearing and Deafness (New York: Rinehart Books, Inc., 1953), p. 128.

[24]Ibid.

Davis feels that a serious limitation of tuning fork testing concerns the uncertainty as to the intensity of the sound produced. He further states, "This is true even when the blow used to start the fork is standardized as far as possible."[25]

Tuning fork tests that are used by many otologists as diagnostic aids in determining whether or not stapes ankylosis is present are the Rinne test, the Weber test, the Schwabach test and the Gelle test.

Rinne Test

According to Watson and Tolan the Rinne test has been used since 1885.[26] Its results are obtained by comparing air conduction to bone conduction. Heller, Anderman, and Singer explain that this comparison concerns the duration of time the tuning fork is heard by air conduction and the duration of time it is heard by bone conduction.[27]

Watson and Tolan describe the administration of the Rinne test:

> The hilt of the vibrating tuning fork . . . is pressed against the mastoid bone behind the ear. When the subject indicates that it is no longer audible by bone conduction, it is instantly removed and the vibrating tines of the fork are held directly in front of the open ear canal.[28]

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[25]Ibid.

[26]Leland A. Watson and Thomas Tolan, Hearing Tests and Hearing Instruments (Baltimore: The Williams and Wilkins Company, 1949), p. 93.

[27]Morris F. Heller, Bernard M. Anderman and Ellis E. Singer (New York: Springer Publishing Co., 1955), p. 94.

[28]Watson and Tolan, loc. cit.

Interpretation of Rinne test results. According to Watson and Tolan, a "positive Rinne," is indicated when the tuning fork is heard by air conduction after it is no longer heard by bone conduction. A "positive Rinne" is said to reveal a perceptive hearing loss.[29]

If the fork is no longer heard by air after it has ceased to be audible by bone, but is heard by bone conduction after it is no longer heard by air conduction, Watson and Tolin, say that the test is a "negative Rinne." Such results would reveal a hearing loss attributed to defective air conduction.[30]

Saltzman states that, "Hearing by air conduction and bone conduction may be alike and the response is called Rinne neutral."[31]

As an aid in the diagnosis of stapes ankylosis, Saltzman explains:

> Fork 512 d.v. is generally used for this test, but in otosclerosis also forks 1024 and 2048 are employed. If the Rinne is negative with all these forks, added confirmation of the diagnosis is obtained.[32]

Weber Test

The Weber tuning fork test has been in use since 1834, according to Watson and Tolan.[33] Hirsh explains that the

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[29] Ibid. [30] Ibid. [31] Saltzman, op. cit., p. 151.

[32] Ibid. [33] Watson and Tolan, op. cit., p. 95.

Weber test, ". . . concerns the apparent localization of a sound that is heard when the stem of a vibrating tuning fork is placed somewhere along the mid-line of the skull."[34] Heller states that the Weber test is, ". . . employed to ascertain the lateralization of sound by bone conduction."[35] Localization and lateralization are terms used in the field of audiology that concern the ear that is stimulated by a transmitted sound.

The element of time is not involved in determining tests results, as it is in the Rinne test. The localization of the transmitted sound is of primary concern.

Watson and Tolan state that usually the 512 cycle fork is used in the Weber test. To administer the test, the vibrating fork is placed in the center of the skull on the frontal bone.[36]

Interpretation of Weber test results. Hirsh offers the following judgments regarding Weber test results:

> . . . a person who has normal hearing in both ears usually localizes the sound either in the center of the head or "nowhere." . . . a patient with a unilateral (one ear) conductive loss will usually report the sound is heard on the side of the affected ear . . . a person with a unilateral perceptive type loss will report that the sound appears on the side of the healthy ear.[37]

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[34]Hirsh, loc. cit.

[35]Heller, Anderman and Ellis, loc. cit.

[36]Watson and Tolan, op. cit.

[37]Hirsh, loc.cit.

Hirsh further explains:

> There are many variations of these judgments, depending on combinations of these different types of hearing loss and various amounts in the two ears.[38]

The author could find no information presented by Hirsh, or other authors, regarding the above mentioned judgment variations.

Saltzman states that:

> For a reason not yet definitely determined, a vibrating tuning fork, the handle of which is placed on the vertex of the skull, will lateralize to the side of the ear having conductive deafness.[39]

Because stapes ankylosis produces a conductive hearing loss, it can be assumed in the diagnosis of otosclerosis in cases of unilateral losses, the ear that received the tone produced by the tuning fork during the administration of the Weber test is the affected one. The author found no information regarding Weber test results directly related to bilaterial (both ears) hearing losses, due to stapes ankylosis.

However, the author assumes from the gathered information concerning the characteristics of bone conduction results in cases of stapes ankylosis, that in cases of bilateral deafness due to stapes ankylosis the tone may lateralize in the ear having the most severe ankylosis, providing both cochlear nerves are unimpaired. In cases

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[38] Ibid. [39] Saltzman, op. cit., p. 148.

involving nerve impairment in both ears accompanied by stapes ankylosis, the tone may lateralize in the ear with the least amount of nerve impairment, providing neither stapes is completely inhibited due to ankylosis.

Schwabach Test

Heller, Anderman and Ellis explain that the Schwabach test, ". . . compares the duration of bone conduction of the patient with the duration of the bone conduction of normal hearing."[40] Hirsh states:

> The schwabach test is essentially a crude test of absolute threshold by bone conduction. . . . Time, rather than intensity, is used as a dependent variable.[41]

The length of time is measured in seconds by a stopwatch. According to Hirsh the person administering the Schwabach test tries to strike the tuning fork in such a way that the initial amplitude is always the same. This author explains, ". . . since the decay of the fork may be assumed to exhibit the same characteristics on successive trials the clinician may use time as a measure."[42] The duration that is measured is the time taken for the fork to decay from its initial amplitude to whatever amplitude corresponds to the patient's threshold.

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[40]Heller, Anderman, and Ellis, loc. cit.

[41]Hirsh, op. cit., p. 283.

[42]Ibid.

Interpretation of Schwabach test results. Watson and Tolan describe the interpretation of Schwabach test results in the following manner:

> The bone conduction is said to be increased, normal, or decreased depending upon whether or not he hears the tuning fork by bone conduction longer, the same or for a shorter time than the normal hearing person.[43]

Hirsh says, ". . . Schwabach tests performed on otosclerotics in sound treated rooms seem to indicate that in some cases at least, bone conduction is better than normal."[44] Therefore, in uncomplicated cases of otosclerosis, stapes ankylosis may be present in the ear perceiving the tuning fork longer than normal during the administration of the Schwabach test.

Gelle Test

Heller, Anderman and Ellis state that the Gelle test, ". . . was conceived in an effort to determine the mobility of the stapes."[45]

According to Bunch the Gelle test, ". . . is based on the fact that the acuity of hearing in a normal ear varies with the increase and decrease of pressure in the external auditory canal."[46] Air pressure is introduced into the external ear canal during the administration of the Gelle

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[43]Watson and Tolan, loc. cit. [44]Hirsh, op. cit.,p.149.

[45]Heller, Anderman and Ellis, loc. cit.

[46]C. C. Bunch, Clinical Audiometry (St. Louis: The C. V. Mosby Company, 1943), p. 25.

test. Bunch describes the administration of the Gelle test:

> An olive tip . . . and a valveless Politzer bag are attached to the opposite ends of a rubber diagnostic tube. Insert the olive tip in the external auditory meatus and compress the Politzer bag to see that no air escapes. Press the handle of the vibrating fork against the patient's head. As soon as he hears the sound of the fork, increase the air pressure in the external canal by gently compressing the Politzer bag.[47]

Interpretation of Gelle test results. Bunch states that if the listener hears the tone more faintly when the pressure is applied to the air in the canal, stapes ankylosis is not present. Stapes ankylosis may be present if there is no change in the intensity of the sound.[48]

III. SPEECH AUDIOMETRY

In regard to the selection of prospective candidates for the fenestration operation, Rosen says:

> Pure-tone and speech audiometry tests have increased knowledge and predictability as to the results to be expected following fenestration for otosclerosis.[49]

Because the criteria for candidate selection for fenestration is similar to that for stapes mobilization, the author assumes that Rosen's above statement might apply to stapes mobilization.

Speech audiometry differs from pure-tone audiometry in that the threshold does not concern just the listener's

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[47] Ibid. [48] Ibid.

[49] Rosen, "Palpation of Stapes for Fixation," op. cit., p. 610.

ability to hear sounds, but his ability to identify words, either in isolation or in context with other words. Saltzman explains in regard to speech audiometry:

> . . . The information to be derived from the procedure concerns the patient's ability to understand speech as it is delivered by his fellowman under the ordinary circumstances of life.[50]

Davis reports:

> In a speech audiometer we use as our source of power an electrical current that varies according to the pattern of the human voice. The current is generated either by speaking into a microphone or by electrical pick-up from a phonograph record.[51]

Speech audiometry tests that are used in the diagnosis of stapes ankylosis, and the selection of prospective stapes mobilization candidates are the speech reception threshold test and the speech discrimination test. Heller, Anderman and Ellis state, "Discrimination testing generally follows the determination of the speech reception threshold for spondaic words."[52]

Speech Reception Threshold Test

Carter says in reference to speech reception threshold testing, "Speech reception does not reveal the pattern of hearing loss. It gives a composite threshold."[53] The determination of this threshold is similar to the determination

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[50]Saltzman, op. cit., p. 144.

[51]David (ed), op. cit., p. 137.

[52]Heller, Anderman and Ellis, op. cit., p. 120.

[53]Howard Carter, "Review of Methods Used for Estimating Percentage of Loss of Hearing," The Laryngoscope, 52:880, Nov., 1942.

of a pure-tone threshold. Heller, Anderman, and Ellis explain:

> The pure tone audiometer uses average normal hearing as the reference level. The ratio, in decibels, between the measured threshold and the normal or zero line, is taken to be the hearing loss at a given frequency. A similar concept obtains with regard to speech reception threshold. If selected material is heard by the normal ear at zero decibels, and by a defective ear at 40 decibels, then the defective ear has a 40 decibel loss of hearing for speech.[54]

According to Heller, Anderman and Ellis the material used in obtaining an individual's speech reception threshold should concern words that are alike in their difficulty of audibility. These authors further state:

> In selecting words . . . it was considered important that they be familiar in the language, in order to minimize the importance of the factors of intelligence and knowledge of vocabulary.[55]

Watson and Tolan are of the opinion that:

> Spondee words as in Harvard test No. 9 are the most useful material for speech reception threshold tests, whether recorded at constant level or attenuated.[56]

Egan describes Spondaic words:

> . . . class of words having the highest homogeneity . . . dissyllables spoken with equal stress on both syllables. . . . Examples are railroad, iceburg, horse-shoe.[57]

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[54]Heller, Anderman and Ellis, op. cit., pp. 119-120.

[55]Ibid., p. 120.

[56]Watson and Tolan, op. cit., p. 147.

[57]James P. Egan, "Articulation Testing Methods," The Laryngoscope, 58:965, September, 1948.

Spondaic words are delivered from a previously recorded phonograph record, or by live voice. Hirsh explains:

> The procedure for measuring the Hearing Loss for Speech may employ as a source of speech, either the live voice of the tester or speech that has been recorded on a phonograph disc or magnetic tape. If live voice is used, precautions must be taken to provide the speaker with a visual indication of the intensity of his voice so that he may, with practice, monitor his voice and so keep his intensity constant. The control of the intensity of speech arriving at the listener's ear should be accomplished with attenuators in the equipment, not by varying the intensity of the speaker's voice.[58]

Other material is used, besides Spondiac word lists, to measure an individual's speech reception threshold. However, the author feels that a discussion of these other materials is beyond the scope of this study.

The administration of speech reception threshold test. Watson and Tolan explain that in live voice delivery the examiner administers, ". . . speech reception threshold tests either through microphone speech circuit of an audiometer or through special free field reproducing equipment. . ."[59]

In free field testing the individual being tested does not wear earphones. In a microphone speech circuit testing situation, earphones are worn. When earphones are worn the examiner can test either by air or bone conduction.

If unilateral testing is desired the individual is instructed to turn the ear not being tested away from the

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[58]Hirsh, op. cit., p. 90.

[59]Watson and Tolan, op. cit., p. 449.

loudspeaker and to occlude it with his forefinger, in the free field situation. In unilateral testing where earphones are worn, the examiner can inhibit the transmission of sound into the ear not being tested by the use of masking. Masking involves the transmission of noise into the ear not being tested. Masking can also be used with free field testing.

The method of test procedure involves the transmission of the Spondee word to the individual being tested and his repeating the word as he hears it. Generally, a carrier phrase such as, "Say the word," precedes the Spondee word.

The intensity of the Spondee transmission usually begins at about 40 db depending upon previous knowledge of the examinee's hearing acuity. The intensity is decreased as the test progresses. Heller, Anderman and Ellis describe one method of determining the intensity with which to begin the test. They state in regard to previous information learned from the individual's pure-tone audiogram, ". . . average the two speech frequencies showing the smallest losses. The spondiac words are then presented at a level about 15 decibels above this estimate."[60]

These authors further state, "Threshold is taken to be the lowest level at which fifty per cent of the words are correctly repeated by the patient."[61]

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[60]Heller, Anderman and Ellis, op. cit., p. 127.

[61]Ibid.

Interpretation of speech reception results. Speech reception results are helpful in determining whether or not the cochlear nerve is affected. Davis states:

> If words are delivered to the ear, either through a receiver or in a free field, at 50 db above normal threshold they begin to be heard by bone conduction.[62]

Therefore, from Davis' above observation it might be assumed that a speech reception loss 50 db above normal threshold, may indicate injury to the cochlear nerve. In this respect he further states:

> 50 db loss represents probably the greatest loss for speech that can be caused by pure conductive deafness. . . . If tests show a loss for speech greater than 50 db it is usually safe to conclude that there is a loss of sensitivity of the sense organ (nerve deafness) as well as conductive deafness.[63]

As a diagnostic aid a speech reception threshold test might prove of value in determining whether or not a conductive loss due to stapes ankylosis is further complicated by a perceptive loss.

Speech Discrimination Test

It was previously stated that the speech discrimination test generally follows the speech reception threshold test. Heller, Anderman and Ellis state:

> Once threshold has been determined, valuable diagnostic information can then be obtained by speech tests at levels above threshold. Measurements at

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[62]Hallowell Davis, "The Articulation Area and the Social Adequacy Index for Hearing," The Laryngoscope, 58:766, August, 1948.

[63]Ibid., pp. 766-767.

> these supra-liminal levels are designed to explore how a defective ear operates when its hearing loss for speech is overriden by presenting material at a sufficiently intense level.[64]

Hirst states that speech discrimination tests are important to the clinical situation for this measure providing additional information that cannot be predicted from threshold measurements. This author explains:

> It is well to say that a person has a 30 db hearing loss for spondees, but we do not know from this information alone how much speech would be intelligible if the intensity were made sufficiently great. . . . Ideally the ciling that could be reached by increasing the intensity of speech is 100 per cent, but some persons can never get more than 40 or 50 per cent no matter how intense the speech.[65]

In speech discrimination testing it is generally considered that the use of PB words produces the most reliable and valid results. Heller, Anderman and Ellis describe PB word lists in the following manner:

> They consist of familiar words of one syllable arranged in groupings of fifty words to a list. The intention is that each list be of comparable difficulty and of equal phonetic structure. . . the lists contain the elements of sounds spoken in the frequency of their occurrence in the language.[66]

According to these authors, the PB words should be delivered at least 40 decibels above the speech reception threshold to obtain the maximum PB score. If there is no

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[64]Heller, Anderman and Ellis, op. cit., p. 121.

[65]Hirsh, op. cit., p. 147.

[66]Heller, Anderman and Ellis, op. cit., p. 122.

tolerance problem (inability to tolerate certain intensities) the test may be administered at a greater intensity.[67]

Speech discrimination test "score" and "loss." According to Heller, Anderman and Ellis, the determination of speech discrimination "score" involves the number of words heard correctly by the examinee. The speech discrimination "loss" is the percentage of PB words not correctly heard. For example, "If ten words are missed then the discrimination loss is 20%."[68]

Interpretation of speech discrimination results. Saltzman states that in speech discrimination testing, "With proper amplification, the word hearing of an otosclerotic is frequently 100 per cent correct. . ."[69] However, such word intelligibility is only attainable if a nerve impairment does not accompany stapes ankylosis. In regard to sensory impairment Saltzman adds, ". . . in nerve deafness this score is hardly attained by amplification."[70]

Therefore, from Saltzman's observations it can be assumed in the diagnosis of otosclerotic severity, that a high speech discrimination loss using PB words might indicate

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[67] Ibid., p. 128.

[68] Ibid., p. 74.

[69] Saltzman, op. cit., p. 70.

[70] Ibid.

cochlear damage. For the most favorable results that can be obtained from stapes mobilization, a prospective candidate should have a speech discrimination score close to 100 per cent correct.

IV. VALUE OF AUDIOMETRIC TESTING

The above discussed audiometric testing battery is a valuable aid in diagnosing stapes ankylosis and selecting prospective candidates for the stapes mobilization surgical procedure. However, such a battery is only an aid to the otologist and decisions as to diagnosis and candidate selection should not be based upon the results of the audiometric testing battery alone.

It is important that audiometric testing be accompanied by a thorough otologic examination in order that other middle ear complications that might produce similar audiometric results, as those produced by stapes ankylosis, may be ruled out.

CHAPTER V

STAPES MOBILIZATION

The stapes mobilization surgical procedure, if successful, provides a normal conductive route for air-borne sounds to the fluids of the inner ear. Rosen and Bergman state:

> Recognizing the obvious advantages of utilizing nature's own pathway of sound conduction via the intact and freely moving ossicular chain, one of us (S.R.) developed the employed a technique . . . for the deliberate mobilization of the fixed footplate of the stapes.[1]

As it was previously mentioned in this study, Rosen revived stapes mobilization in 1952 after it had been abandoned as a cure for otosclerotic deafness due to stapes ankylosis in the early nineteen-hundreds. Since its revival stapes mobilization has been employed by otologists throughout the world and many have added their own techniques to the surgical procedure.

The author feels that in order that the purpose of this study can be adequately fulfilled, each major phase of the stapes mobilization procedure should be considered. Diagnosis and selection of prospective candidates, operation

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[1]Rosen and Bergman, "Mobilization of the Stapes for Otosclerotic Deafness," op. cit., p. 177.

goals, surgical techniques, pre-operative and post-operative treatment, surgical audiometry, operation complications and success and failure determinants will be discussed within this chapter.

All of the information that will be included within this chapter has been gathered from published materials, with the exception of that concerning the experiences of Dr. Harold Schuknecht. The author had the opportunity and privilege to observe three of Dr. Schuknecht's stapes mobilization operations at Henry Ford Hospital in Detroit, Michigan.

I. DIAGNOSIS AND CANDIDATE SELECTION

Audiometric test results aid the otologist in diagnosing stapes ankylosis. However, such results are limited in that they only reveal whether a conductive or perceptive hearing loss is present, whether a mixed hearing loss is present and the severity of a hearing loss.

The cause of a hearing impairment cannot definitely be determined through audiometric testing. Therefore, in the diagnosis of stapes ankylosis other factors must be considered.

Other Factors to be Considered in Diagnosis

According to Shambaugh:

> Otosclerosis does not produce any absolutely diagnostic symptom or sign. The history, however, is of considerable help in suggesting that a conductive

> type of hearing loss is of otosclerotic origin, and by excluding the other five causes of conduction deafness the definite diagnosis of primary otosclerotic stapes ankylosis is reached.[2]

Shambaugh further adds, "The only constant and the most characteristic symptom of otosclerosis is the slowly progressive hearing impairment."[3] Saltzman agrees with Shambaugh on this point and says, "Of utmost significance is a history of progressiveness of the deafness in the absence of an otologic condition to account for it."[4]

In discussing the rate of the hearing impairment's progress, Shambaugh explains:

> The rate of progress of the hearing loss is typically slow and gradual, but with definite differences between individuals and at different times in the same individual. The progress may be continuous or it may halt and the hearing remain stabilized for a period of years before it begins to worsen again.[5]

Walsh lists the following four points to be considered in addition to audiometric test results, upon which to base a diagnosis of stapes ankylosis:

> (1) a progressive loss of hearing, particularly in a young person; (2) a history of deafness in the family; (3) no previous infections of the ear that might account for the hearing loss; and (4) normal ear drums.[6]

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[2]Wiener and others (eds.), op. cit., p. 396.

[3]Ibid. [4]Saltzman, op. cit., pp. 72-73.

[5]Wiener and others (eds.), op. cit., p. 397.

[6]Davis (ed.), Hearing and Deafness, op. cit., p. 107.

A pure-tone air conduction audiogram revealing the pattern previously described in Section I, Chapter IV, by Saltzman as being indicative of stapes ankylosis, may be the result of other middle ear complications. Shambaugh describes five other causes of conductive deafness, and explains how these causes can be ruled out in stapes ankylosis diagnosis:

> 1. Occlusion of the external auditory meatus (cerumen, osteoma, atresia, etc.) is easily ruled out by otoscopy.
>
> 2. Perforation of the tympanic membrane is ruled out by otoscopy, with the Siegel-Bruning speculum and inflation of the eustachian tube, if in doubt.
>
> 3. Suppurative otitis media (infection of the middle ear) acute or chronic, is easily diagnosed by otoscopy.
>
> 4. Occlusion of the eustachian tube with secretory otitis media gives a greater loss for high tones than for low tones in the audiogram. The yellowish color of the serum filling the middle ear may be seen through a transparent tympanic membrane, often with a fluid level or bubbles, especially after inflation, and by inflation there is a measureable hearing improvement. Evacuation of the fluid by paracentesis and inflation results in a restoration of the hearing to normal.
>
> 5. Chronic adhesive otitis media is the end result of a previous severe suppurative otitis media, and the hearing loss very definitely dates from the discharging ear. Nearly always there are marked alterations in the tympanic membrane as part of the adhesive process, and the hearing loss, once established soon after the suppurative process, is not progressive.[7]

According to Shambaugh, although hearing tests of stapes ankylosis are generally characteristic, and are very

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[7]Wiener and others (eds.), op. cit., p. 405.

valuable aids in diagnosis, ". . . the definite clinical diagnosis cannot be made until the other five causes for conduction deafness have been ruled out by otoscopy and examination of the eustachian tubes. . ."[8]

Another element that is believed to be characteristic of otosclerotic deafness due to stapes ankylosis is "paracusis willisi." Walsh explains:

> The patient with otosclerosis . . . seems to hear better in a noisy place, for example, on a streetcar, in an automobile, or in a factory.[9]

Saltzman described "paracusis willisi," as, ". . . the ability to hear better in the presence of loud surrounding noise than in a quiet room."[10] Walsh is of the opinion that "paracusis willisi," is due to the fact, ". . . that people with normal hearing naturally raise their voices to overcome the surrounding noise."[11]

"Tinnitus" is another factor that may be present in otosclerosis. This phenomenon is characterized by the presence of head noises. Saltzman states that in otosclerosis, "It is usually of the nature of a low rumbling noise but it may be high-pitched."[12] Shambaugh explains:

> The tinnitus of otosclerosis is an irregular symptom, often severe, but it may be absent, or it

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[8] Ibid. [9] Davis (ed.), loc. cit.

[10] Saltzman, op. cit., p. 37.

[11] David (ed.), loc. cit.

[12] Saltzman, op. cit., p. 73.

> may disappear spontaneously, with no consistent relation to the hearing impairment, except that the most severe cases of tinnitus tend to be in patients with severe cochlear nerve degeneration complicating the conductive loss. We do not know the exact mechanism of tinnitus in otosclerosis. . .[13]

In regard to the voice characteristics of a person affected by stapes ankylosis Shamburgh states:

> First, there is a tendency for the patient to speak too softly, especially in noise, partly because his own voice sounds louder than normal to him, and partly because he is not aware of the noise. Later, the voice tends to acquire a "hollow" quality, and finally, if marked cochlear nerve degeneration complicates the picture of pure stapes ankylosis, the voice tends to acquire some of the toneless quality of profound nerve deafness.[14]

Therefore, in addition to audiometric test results, all of the above mentioned factors must be considered in the diagnosis of stapes ankylosis.

Diagnosis of Uncomplicated Cases of Stapes Ankylosis

An uncomplicated case of stapes ankylosis would be one that is free from cochlear nerve impairment. Providing that an examination by the otologist rules out the five other middle ear complications, and the patient shows a history of a slowly progressive hearing impairment, the following audiometric test results strongly suggest the presence of uncomplicated stapes ankylosis:

1. A pure-tone audiometric test by <u>air conduction</u> is suggestive of the presence of uncomplicated stapes ankylosis

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[13]Wiener and others (eds.), <u>op. cit.</u>, p. 397.

[14]<u>Ibid.</u>, p. 398.

if the results reveal that the low tones are affected and show a uniform hearing loss for all frequencies, or shallow v-curves and dips at higher frequencies. According to Shambaugh, "The maximum hearing loss of pure stapes ankylosis (without complicating nerve degeneration) is around 60 decibels for the speech frequencies (512, 1024 and 2048)."[15]

2. A pure-tone audiometric test by bone conduction is suggestive of the presence of uncomplicated stapes ankylosis if the results show that hearing for all frequencies, with the exception of 2048, is within the normal range of hearing. A loss at the 2048 frequency level, which is characteristic in otosclerosis according to Carhart, was explained in Section I, Chapter IV.

3. A Rinne tuning fork test is suggestive of stapes ankylosis free from nerve impairment if it produces "negative" results. "Negative" results are produced when the fork vibrations are no longer heard by air conduction after they have ceased to be audible by bone, but are heard by bone conduction after they are no longer heard by air.

4. A Weber tuning fork test is suggestive of uncomplicated stapes ankylosis if in unilateral deafness the tone lateralizes to the affected ear. In bilateral deafness the tone may lateralize to the worse ear.

5. A Schwabach tuning fork test is suggestive of this condition if the tone is perceived by bone conduction longer than it is heard by a normal hearing person.

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[15] Ibid., p. 400.

6. A Gelle tuning fork test is suggestive of stapes ankylosis free from nerve impairment if there is no change in the intensity of the sound after air pressure has been introduced into the external ear canal.

7. A speech reception threshold test is suggestive of this condition if the results show a threshold from 50 db to 60 db.

8. A speech discrimination threshold test is suggestive of stapes ankylosis free from nerve impairment if the results reveal a low "loss" and a consequent high "score" close to 100 per cent correct.

Diagnosis of Complicated Cases of Stapes Ankylosis

It is difficult to determine through the use of tuning forks whether or not a nerve impairment accompanies stapes ankylosis. Therefore, only the results that indicate complicated cases of stapes ankylosis obtained from pure-tone and speech audiometry will be reviewed as follows:

1. A pure-tone audiometric test by air conduction is suggestive of a complicated case of stapes ankylosis if there is an extensive loss for all frequencies, or losses in the high frequencies.

2. A pure-tone audiometric test by bone conduction is suggestive of this condition if it shows a threshold greater than 20 db for some, or all frequencies.

3. A speech reception threshold test is suggestive of stapes ankylosis accompanied by a nerve impairment if it

shows a hearing loss greater than 60 db.

4. A speech discrimination test is suggestive of an accompanying nerve impairment if the results reveal a high "loss" and a consequent low "score."

Diagnostic Summary

In summarizing the diagnosis of stapes ankylosis, Shambaugh states:

> The history of a slowly progressive hearing impairment beginning insidiously in early adult life, with the tuning fork and audiometric tests of a conductive hearing loss, strongly suggests the diagnosis of otosclerotic stapes fixation. When the other five causes for a conductive loss have been ruled out, the definite clinical diagnosis of otosclerosis may be made.[16]

In addition, a soft speaking voice, the presence of "paracusis willisi," and "tinnitus" all may be symptoms indicating a hearing loss due to stapes ankylosis.

Selection of Prospective Candidates

According to House any patient who is suitable for the fenestration operation is also suitable for the stapes mobilization surgical procedure. This author adds further:

> Many patients are suitable for mobilization who would not be eligible for fenestration surgery. Examples include the aged . . . and patients with rather far advanced cochlear deterioration.[17]

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[16] Wiener and others (eds.), op. cit., p. 407.

[17] Howard P. House, "Personal Experiences with Stapes Mobilization," A.M.A. Archives of Otolaryngology, 65:243, March, 1957.

From the gathered information presented in Section I, Chapter IV, the author assumes that if an individual with a hearing loss due to stapes ankylosis, has not more than a 30 db threshold by bone conduction, he is a favorable candidate for stapes mobilization. The ideal candidate is an individual whose pure-tone bone conduction results reveal, not more than a 20 db threshold. This would indicate normal hearing by bone conduction.

Stapes mobilization is also beneficial to individuals with severe hearing losses. Although, it cannot restore normal or near normal hearing in such cases, it can improve hearing so that aural rehabilitation will be more effective. However, it is necessary that there be a sufficient air-bone gap in order that a patient may benefit from this operation. In this respect House explains:

> Any patient with an average difference of 20 db or more between the bone conduction and air conduction in any three frequencies may be considered suitable for mobilization, regardless of the bone conduction level.[18]

In regard to the severity of preoperative air-bone difference Schuknecht is of the opinion that a maximum of 30 db difference indicates an ideal candidate for stapes mobilization. A 40 db difference indicates a moderate case of stapes ankylosis and a 40 db to 60 db difference indicates severe ankylosis.[19]

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[18] Ibid.

[19] Statement by Dr. Harold F. Schuknecht, Associate Surgeon, Division of Otolaryngology, Henry Ford Hospital, Detroit, Michigan, Personal communication, July 18, 1957.

II. OBJECTIVES OF STAPES MOBILIZATION

The primary objective of the stapes mobilization surgical procedure is to restore as much of an affected individual's hearing as is physiologically and surgically possible. The degree of hearing improvement that can be obtained through surgery is dependent upon the characteristics of the prospective candidates hearing involvement and the success of the surgical procedure itself. Bergman states:

> Surgery, such as stapes mobilization, can provide a patient with normal hearing or with hearing which can be utilized more effectively in a program of hearing rehabilitation.[20]

In considering the various objectives of stapes mobilization within this section of the study, such objectives will be divided into the following three groups; that which concerns uncomplicated cases of stapes ankylosis; those which concern complicated cases of stapes ankylosis; and that which concerns the physiological aspects of the operation.

Objective in Uncomplicated Cases

In operations involving patients with hearing losses due to stapes ankylosis free from nerve impairment there

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[20] Bergman, op. cit., p. 285.

is but one objective. Rosen and Bergman explain that this goal is, "To attain normal hearing."[21] These authors further add:

> Mobilization of the fixed stapes is capable of achieving this goal where there is as yet no cochlear (perceptive) involvement.[22]

Providing there are no complicating factors within the surgical procedure and the round window is unoccluded, normal hearing can be attained in cases of bilateral or unilateral hearing impairment free from nerve damage.

Objectives in Complicated Cases

Rosen and Berman list the following goals to be obtained through stapes mobilization in complicated cases of stapes ankylosis:

> To restore hearing to an 11 db to 20 db level in patients with some evidence of perceptive loss in whom normal hearing is not possible. . . . To restore useful binaural hearing. . . . To permit successful use of hearing aid in extreme deafness.[23]

In regard to the first objective these authors explain that a person, ". . . with a hearing loss between 11 db and 20 db rarely experiences any hearing difficulties." Therefore, in cases where the pre-operative pure-tone audiometric test reveals a 20 db threshold for bone conduction, and a greater loss for air conduction, it is still possible to

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[21] Samuel Rosen and Moe Bergman, "Functional Goals in Mobilization of the Stapes," A.M.A. Archives of Otolaryngology, 63:11, January, 1956.

[22] Ibid., p. 19.

[23] Ibid., p. 12.

restore useful, unaided hearing through successful stapes mobilization surgery.

The restoration of useful binaural hearing in cases of unilateral or bilateral deafness is advantageous. Bergman states that binaural hearing has the following advantages over monaural hearing:

> (1) localization, the ability to determine the directional source and distance of a sound; (2) selectivity, the ability to listen to a conversant's speech with little or no interference from competing noises in the area (this is implied when a patient with one normal and one defective ear reports a distressing deterioration in his ability to understand speech in a noisy enviornment); (3) discrimination, the ability to hear speech sounds and to discriminate them more clearly, both in quiet and over a background of noise; (4) sound identification, the ability to identify common sounds and noises better.[24]

Therefore, the author assumes that Rosen and Bergman advocate an attempt to restore or improve hearing in all affected ears in order that binaural hearing can be achieved, if physiologically and surgically possible.

In regard to the third objective of stapes mobilization, "To permit successful use of hearing aid in extreme deafness," Rosen and Bergman state:

> The gain or amplification of the strongest commercial hearing aid is insufficient to provide comfortable hearing for ordinary conversation in a patient with a hearing loss in the better ear greater than 85 db. Any significant improvement in hearing in such profound deafness increases greatly the benefits to be derived from the use of a hearing aid.[25]

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[24] Bergman, op. cit., p. 282.

[25] Rosen and Bergman, "Functional Goals in Mobilization of the Stapes," op. cit., p. 16.

In cases of complicated stapes ankylosis it is possible, through stapes mobilization, to eliminate the portion of deafness due to the immobility of the stapes and leave pure nerve deafness. Depending upon the severity of this pure nerve deafness, an individual may receive more benefit from a hearing aid than he would have received had the operation not taken place. Such benefits may be considered in light of the ability to understand normal conversation, or the ability to operate more effectively in a program of auditory rehabilitation.

Physiological Objective of Stapes Mobilization.

Goodhill explains that the physiological objective in stapes mobilization is, ". . . lysis (breaking down) of obstruction in the stapediovestibular junction so that remobilization of the footplate to air-borne sound may occur." [26]

Goodhill adds further:

> The ultimate physiological objective in stapedolysis depends upon two factors: a. satisfactory lysis of the footplate obstruction, and b. maintenance of the functioning middle ear mechanism.[27]

The degree to which the stapes can be mobilized is greatly dependent upon the extent of otosclerotic bone growth at the margin of the footplate. The more severe the

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[26] Goodhill, "Present Status of Stapedolysis," op. cit., p. 334.

[27] Ibid., p. 336.

extent of ankylosis, the more problems the surgeon will encounter in his attempts at mobilization.

During mobilization it is possible for the surgeon to accidently disarticulate the head of the stapes from the lenticular process of the incus. Surgeons have also reported incidents in which either of the two crura of the stapes have been fractured during mobilization. If any one of these two accidents occur a dysfunction of the middle ear apperatus will take place. It appears to be unknown if the occurrence of these two accidents is common.

Stapes Mobilization Possibilities.

Generally speaking, the amount of hearing that can be gained following a stapes mobilization operation is limited by the state of the cochlear nerve. Goodhill explains:

> Upon achievement of maximum lysis surgically it is possible to expect an almost complete eradication of the conductive block and an elimination of the air-bone gap, so that hearing post-operatively approaches the preoperative bone conduction level. In some cases this level will even be surpassed due to improved perilymph mobility.[28]

The possibilities of the stapes mobilization operation for the restoration of hearing in cases of stapes ankylosis appear to be very favorable. However, the possibilities should be evaluated in light of the characteristics of the

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[28] Ibid., p. 334.

hearing disorder involved; the extent of otosclerotic bone growth; and the effectiveness of the mobilization techniques employed by the surgeon performing the operation.

III. PREOPERATIVE CARE

The author found little information concerning the amount of time the patient is required to spend in the hospital preoperatively when involved in the stapes mobilization surgical procedure. However, in this respect, Shambaugh tells a stapes mobilization candidate:

> The advantages of stapes mobilization. . . are first of all, its simplicity as far as he is concerned, with only three days away from work as compared to three weeks with fenestration in the average case.[29]

Myers and Ronis explain, "Our patients are hospitalized for 24 hours. The patients are admitted on the morning of the operation."[30]

Schuknecht requires that his patients enter the hospital the day before the scheduled operation is to take place. During the time spent in the hospital preoperatively, the patient is given proper rest, diet and is prepared for surgery.[31]

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[29] Symposium, op. cit., p. 745.

[30] Myers and Ronis, op. cit., p. 309.

[31] Statement by Dr. Harold F. Schuknecht, Associate Surgeon, Division of Otolaryngology, Henry Ford Hospital, Detroit, Michigan, personal interview, April 27, 1957.

Factors concerned in preparation for surgery will be considered within this section of the study. Such factors involve preoperative medication and the preoperative physical preparation of the patient.

Preoperative Medication

As previously mentioned, many otologists have developed their own individual techniques for the administration of the various phases of the stapes mobilization surgical procedure.

In regard to the preoperative medication phase of stapes mobilization, the author learned that medication is administered prior to and after hospital entry. However, some otologists only administer medication after hospital entry.

Preoperative medication prior to hospital entry. The primary purpose for the administration of medication prior to hospital entry is to prevent post-operative middle ear infection. Myerson explains, "In order to prevent middle ear infection after operation strict asepsis (free from living germs of disease) is important."[32]

So that proper precautions can be taken to prevent the possible occurrence of post-operative middle ear infection, Myerson feels that attention should be paid to the nose,

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[32]Mervin C. Myerson, "Mobilization of the Stapes for Otosclerosis," A.M.A. Archives of Otolaryngology, 64:85, July-December, 1956.

nasopharynx and external auditory canal before entry into the hospital.[33] Myerson states, "The operation should not be performed in the presence of sinus suppuration or active nasal or nasopharynx infection."[34]

As preventive measures against such infections, Myerson explains:

> . . . the nasal passages are irrigated daily, for three days, before operation with warm saline solution. This is followed by the intranasal administration of tetracycline hydrochloride in nebulized form.[35]

Myerson further adds:

> The patient is instructed to introduce 3 minims (0.2 cc.) of a 0.125% phenolized oil into each nasal chamber three times a day for one week before surgery.[36]

In regard to preventive measures against possible infections occurring in the area of the external ear canal, Myerson explains:

> . . . he is instructed to introduce a dropperful of aqueous solution of benzalkonium, 1:1000, into the external ear canal three times a day for three days before the operation.[37]

From the information reviewed by the author, it seems apparent that such preoperative medication precautions are not commonly practiced by all otologists.

Preoperative medication employed after hospital entry. The objective of this phase of preoperative medication is

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[33] Ibid. [34] Ibid. [35] Ibid.

[36] Ibid. [37] Ibid.

to produce a calming effect in the patient before entry into the operating room. Goodhill says:

> The preoperative medication for stapedolysis surgery should not be heavy. It should be sufficient to produce a calm entry into the operating room, but not deep enough to obtund accurate responses for aduiometric threshold studies.[38]

In order that the above requirements be met, Goodhill explains:

> Three grains of sodium pentobarbital are sufficient for this procedure; this medication is given in divided doses about two hours and one hour before surgery.[39]

Rosen and Bergman state in regard to this phase of preoperative medication, "The patient is given pentobarbital (Nembutal) 1-1/2 grains (90 mg) an hour before the operation."[40] According to Scheer's technique, "Premedication consists of pentobarbital (Nembutal) (1-1/2 grains (0.10 gm.)) and meperidine (Demerol) hydrochloride (50 mg.)."[41]

Although these authors vary in their techniques of application in this step of preoperative medication, they all feel that such medication should produce a calming effect upon the patient, but should allow the patient to remain conscious so that he may adequately respond to audiometric testing. (Surgical pure-tone audiometric testing is discussed in Section VI of this chapter.)

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[38]Victor Goodhill, "Trans-incudal Stapedolysis for Stapes Mobilization in Otosclerotic Deafness," The Laryngoscope, 65:696, August, 1955.

[39]Ibid. [40]Rosen and Bergman, op.cit.,p.198.

[41]Scheer, op. cit., p. 513.

Preoperative Physical Preparation of the Patient

After the patient has been taken into the operating room, he is placed on the operating table. In this respect Scheer says:

> The patient is placed on his back on the operating table, with the face toward the opposite shoulder, thus bringing the selected ear into position.[42]

Hair preparation is kept at a minimum Goodhill states:

> The hair is not shaved but is usually kept out of the surgical field by the use of a modified bathing cap or adhesive tape.[43]

Scheer appears to agree with Goodhill regarding the lack of necessity for shaving the hair and applies Vasoline with a tongue depressor in order that the hair can be kept away from the auricle.[44]

As previously stated the author had the opportunity to witness three of Dr. Schuknecht's operations. The author observed that Schuknecht neither shaved the hair, used adhesive tape or applied Vasoline to keep the hair away from the surgical field. Schuknecht placed a square piece of material, with a hole in the center, over the surgical area. The ear protruded through the hold. He then placed regular green surgical draping over the material, allowing only the ear to be exposed.

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[42] Ibid.

[43] Goodhill, "Trans-Incudal Stapedolysis for Stapes Mobilization on Otosclerotic Deafness," op. cit., p. 696.

[44] Scheer, op. cit., p. 513.

The cleansing of the ear canal involves the following procedures, according to Goodhill:

> Cerumen, dead epithelium and crusts are carefully removed from the external auditory canal by the surgeon; the canal is filled with a 1-1000 aqueous zephiran solution. . . . The purpose of this aqueous zephiran preparation is two fold: a. It is designed for antiseptic preparation; b. It serves to create edema (swelling) of the tympanic membrane.[45]

The elevation of the tympanic membrane is an important stage in the stapes mobilization surgical procedure. Goodhill is of the opinion that by introducing aqueous zephiran into the ear canal and therefore creating swelling of the tympanic membrane, the elevation of the tympanic membrane is made easier with little danger of perforation.[46]

The author observed that Schknecht cleansed the surgical field by first washing the auricle and surrounding skin with antiseptic soap. He then rinsed the auditory canal three times with an antiseptic solution. The solution was left to soak in the canal for a short period of time during the last two rinses. Schuknecht feels that by letting the solution soak, it sterilizes the area effectively, prepares the walls of the auditory canal for incision and allows for easier tympanic elevation.[47]

As a final cleansing procedure, Schuknecht used a suction to remove any excess fluid, particles of dead

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[45]Goodhill, "Trans-Incudal Stapedolysis for Stapes Mobilization of the Stapes," op. cit., p. 696.

[46]Ibid. [47]Schuknecht, op. cit., April 27,1957.

epithelium and cerumen from the auditory canal. He found it necessary to clip the hairs in the auditory canal of one of the patients before surgery could take place.

IV. ANESTHESIA

A local anesthetic is administered in the stapes mobilization surgical procedure. As in other phases of this procedure, there is no standard method for the administration of anesthesia. Many surgeons have developed their own individual techniques. Although these techinques are similar in goals, they are dissimilar in solution components and methods of injection.

Solution Components

The following information will concern a review of the anesthetic solutions used by some otologists in the stapes mobilization operation.

According to Rosen and Bergman an adequate solution consists of:

> One to 2 cc. of a mixture of 3 parts of 2% lidocaine (Xylocaine) hydrochloride to 1 part of epinephrine chloride, 1:1000, is injected in equal amounts. . .[48]

Goodhill states that the cutaneous lining of the bony canal wall is adequately anesthetized by:

> . . . a mixture of 2 per cent xylocaine, three parts and 1:1000 adrenalin, one part. . . . A total of less

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[48]Rosen and Bergman, "Mobilization of the Stapes for Otosclerotic Deafness," op. cit., p. 198.

> than 1cc. of this mixture is needed for adequate local anesthesia. . .[49]

Myerson's technique involves:

> . . . injection of an average of 2 cc. of procaine, 1% solution, each ounce (30 cc.) of which contains 12 minims (0.75 cc.) of epinephrine hydrochloride has been found satisfactory.[50]

Scheer explains:

> A mixture of 2% lidocaine (Xylocaine) hydrochloride (3 cc.), hyaluronidase and epinephrine hydrochloride (1 cc. of 1:1000 solution) is used for local anesthesia.[51]

Myers and Ronis describe the solution they administer as being composed of:

> . . . 2% lidocaine (Xylocaine) (3cc. to which is added 1 cc. of epinephrine, 1:1000). Usually about 1 cc. of the solution is needed.[52]

Although all solutions described above differ from each other in composition, they are all intended to anesthetize the entire cutaneous bony canal lining and the tympanic membrane, so that surgery can be performed with as little pain as possible to the patient.

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[49]Goodhill, "Trans-Incudal Stapedolysis for Stapes Mobilization in Otosclerotic Deafness," op. cit., p. 697.

[50]Myerson, "Mobilization of the Stapes for Otosclerosis," op. cit., p. 86.

[51]Scheer, op. cit., p. 513.

[52]Myers and Ronis, loc. cit.

Methods of Injection

All methods of injection reviewed by the author are introduced into the walls of the external auditory canal. Such injections vary in number and exact points of attack, depending upon the technique of the surgeon administering the injections.

The method of injection employed by Rosen involves subcutaneous injections into the posterior, superior, anterior, and inferior walls of, ". . . the external canal at the junction of the cartilaginous and bony canal."[53] Therefore, Rosen administers four injections for anesthetic purposes in the stapes mobilization surgical procedure.

Goodhill's method is similar to Rosen's. Goodhill states that the solution is:

> . .. injected with a 3-inch 22 gauge short beveled needle at the four points of the circumference of the external canal, at the junction of the bony and cartilaginous canal walls.[54]

Myerson's technique varies from those mentioned above in that he feels that one injection is sufficient for most purposes. He states:

> The injection is made posterosuperiorly into the retroauricular fold at the junction of the cartilaginous and osseous canals. A single injection will suffice. .[55]

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[53]Rosen and Bergman, "Mobilization of the Stapes for Otosclerotic Deafness," op. cit., p. 198.

[54]Goodhill, "Trans-Incudal Stapedolysis for Stapes Mobilization in Otosclerotic Deafness," op. cit., p. 697.

[55]Myerson, "Mobilization of the Stapes for Otosclerosis," op. cit., p. 86.

However, this author adds that in cases where the operating surgeon does not wish to wait for the solution to infiltrate widely ". . . additional injection at a point corresponding to the mid-line of the roof and floor of the canal may be added. . . ."[56]

Scheer employs the use of a 24-gauge needle, which he carries down to the bone. He explains, ". . . the anesthetic is injected posteriorly and superiorly. It is desposited superficially in the inferior location."[57]

Myers and Ronis use a 25-gauge needle in their technique. In conditioning the skin surface of the auditory canal for the injections, they employ an ear speculum. An ear speculum is a small metal funnel through which the operation is performed by most surgeons. Myers and Ronis explain their technique in the following manner:

> The ear speculum is pressed against the membranous canal. This forms a ledge into which the needle is inserted. A small wheal is raised, and the point of the needle is directed against the osseous canal. The entire canal is circularized in this manner with no attempt to inject the osseous canal at this time. The skin lining of the canal is very thin and insertion of the needle directly would tear the skin of the canal.[58]

After the membranous canal is circularized with the anesthetic two times, these authors add:

> By this time the skin is thickened and a fine beveled needle (25-gauge on a tuberculin-syringe) is easily inserted into the skin lining of the osseous canal.[59]

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[56] Ibid. [57] Scheer, op. cit., p. 513.

[58] Myers and Ronis, op. cit., p. 310. [59] Ibid.

In administering their technique of anesthetic injection, Myers and Ronis state that the injection is made slowly in small amounts and therefore:

> . . . the operator can watch the solution spread into the skin of the osseous canal and over the drum membrane. Some of the solution probably gets into the middle ear and anesthetizes the mucosal surface.[60]

After the anesthetic has been administered the surgeon prepares to proceed with surgery.

V. SURGICAL TECHNIQUES

That the stapes mobilization surgical procedure should be performed by the skilled otologic surgeon is generally agreed upon by all authors reviewed in this section of the study. Before the operating surgeon can supply the stapes mobilization surgical techniques effectively, many otologists feel that he should have a considerable amount of practice.

Rosen and Bergman explain:

> This operation appears deceptively simple, yet learning to perform it skillfully is not, because all maneuvers are restricted by the limits of the bony external canal. One must learn to do the operation skillfully through external auditory canals which are wide, narrow, or tortuous.[61]

In this respect, Goodhill states:

> This is not simple surgery. Experience seems to indicate that this procedure in its present early

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[60] Ibid.

[61] Rosen and Bergman, "Restoration of Hearing in Otosclerosis by Mobilization of the Fixed Stapedial Footplate. An Analysis of Results," op. cit., p. 232.

> form should be limited to the otologic surgeon who is skilled in fenestration surgery. . .[62]

According to Goodhill, one reason for his above statement is that such a surgeon has had the specific anatomical training and has the surgical dexterity necessary for stapes mobilization.[63]

In order that the surgeon can properly prepare himself, Rosen and Bergman state:

> For the mobilization operation even the skillful surgeon should perform the operation on at least 50 fresh cadavers before the first patient is operated upon.[64]

However, Myers and Ronis explain:

> While a degree of proficiency can be obtained with cadaver practice, the feel of mobilizing the stapes can only be accomplished on the living patient with otosclerosis.[65]

So that the surgeon has adequate visualization of the surgical field when administering his surgical techniques, magnification is employed, usually through an ear speculum. Meurman and Meurman state:

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[62]Goodhill, "Trans-Incudal Stapedolysis for Stapes Mobilization in Otosclerotic Deafness," op. cit., p. 695.

[63]Ibid.

[64]Rosen and Bergman, "Restoration of Hearing in Otosclerosis by Mobilization of the Fixed Stapedial Footplate. An Analysis of Results," op. cit., p. 231.

[65]Myers and Ronis, op. cit., p. 307.

> The magnification requires special attention. The operation can be performed with a binocular loupe, magnifying 2-1/2 to 3 times. . . [66]

However, when using this binocular loupe these authors said:

> It is a disadvantage that, when working through an ear speculum, binocular vision is much hampered. . . . However, when the latest model of the Ziess binocular microscope is used, binocular vision is unimpeded.[67]

The author found that various types of magnification equipment are used by different surgeons, however, most surgeons reviewed by the author used the latest model of the Ziess binocular microscope. This piece of equipment has a built-in light, and allows the surgeon to work without the use of a head-light.

As previously described, the ear speculum is a small metal funnel that is inserted into the external auditory canal. According to Derlacki, Shambaugh and Harrison, "The entire surgical procedure is performed through an ear speculum. . ."[68] From the gathered information it seems apparent that most surgeons use the ear speculum. However, some surgeons did not state specifically in their publications whether this instrument was used or not.

The author observed that Schucknecht employed the use of both the ear speculum and Ziess binocular microscope in

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[66] Meurman and Meurman, op. cit., p. 166. [67] Ibid.

[68] Eugene L. Derlacki, George E. Shambaugh, Jr., and Wiley H. Harrison, "The Evolution of a Stapes Mobilization Technique," The Laryngoscope, 62:431, May, 1957.

his stapes mobilization operations.[69] The surgical techniques of the various surgeons, reviewed by the author, will be discribed within this section of the study. Such techniques vary from each other in administration, but all are performed in an attempt to mobilize the stapes footplate.

The following discussion will be divided according to the five major phases of stapes mobilization surgery: the incision, entrance into the tampanic cavity, exposure of the middle ear structures, mobilization of the stapes footplate, and closure of the tympanic cavity.

The Incision

There are two types of incisions administered in the stapes mobilization surgical procedure, according to the material reviewed by the author. Also, it was discovered that one surgeon performs this procedure without an incision.

One type of incision begins at 9 o'clock (posteriorly) and ends at 3 o'clock(anteriorly) in the wall of the auditory canal. The other type of incision begins at 12 o'clock (superiorly) and ends at 6 o'clock (inferiorly) in the skin of the canal wall.

In classifying these incisions, the author is considering only the incision made in the right ear.

9 o'clock to 3 o'clock incision. The information reviewed by the author revealed that Rosen and only a few other surgeons administer the 9 o'clock to 3 o'clock incision.

[69]Schuknecht, op. cit., April 27, 1957.

Rosen describes his method of incision in the following manner:

> An incision is made through the skin over the bony canal wall, beginning at about 9 o'clock and continuing downward and around to 3 o'clock on the right ear and vice versa on the left, about 6 to 7 mm. external to the drum.[70]

Meurman and Meurman state in regard to the incision:

> It is important to make the incision in the canal wall, as Rosen advises, sufficiently lateral to the drum, more than 5 mm. from the margin.[71]

Figure 12, page 135, illustrates this type of incision administered in the right ear.

12 o'clock to 6 o'clock incision. The author found that some surgeons reviewed in this area, do not strictly adhere to the method of a 12 o'clock to 6 o'clock incision. However, all types of incisions that will follow are unique from the above described 9 o'clock to 3 o'clock incision in that they begin at 12 o'clock in the superior margin and end in the inferior margin of the auditory canal wall. These incisions involve the posterior wall surface.

Myers and Ronis explain:

> The incision is started in the posterior-superior canal wall about 4-6 mm. from the drum edge . . . at 12 o'clock, with the use of the short process of the malleus to denote 12 o'clock . . . proceeds around . . . to 5 'clock in doing the right ear, and to 7 o'clock in the left ear.[72]

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[70]Rosen and Bergman, "Mobilization of the Stapes for Otosclerotic Deafness," op. cit., p. 198.

[71]Meurman and Meurman, op. cit., p. 167.

[72]Myers and Ronis, op. cit., p. 310.

According to these authors the incision is made in small steps, ". . . making each cut through the skin and into the osseous canal."[73]

Derlacki, Shambaugh and Harrison describe their method of making the incision:

> The skin of the posterior osseous meatal wall is incised from approximately 12 o'clock to 6 o'clock, beginning close to the annulus and swinging lateralward a good 5 mm. from the annulus in most of its U-shaped course.[74]

Scheer explains:

> An incision is made in the skin of the bony canal wall 6 to 7 mm. external to the tympanic membrane, extending from 12 o'clock to 6 o'clock on the posterior wall. . . . Since the skin of the external canal is thickest in its superior portion, the incision must be started at 12 o'clock, rather than below, since this will prevent tearing.[75]

Myerson creates the 12 o'clock to 6 o'clock incision in the following manner:

> The incision is made with two knives; one cuts forward and backward along the midline of the roof and floor of the ear canal, while the other joins these incisions by cutting from side to side. The juncture of these incisions is rounded, not angular.[76]

Goodhill describes his incision:

> The incision in the posterior half of the canal skin is omega shaped, starting superiorly at about the junction between the pars tensa and pars flaccida and ending at the inferior aspect of the annulus. The apex of the omega is at the lateral extremity of the posterior bony canal wall.[77]

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[73] Ibid. [74] Derlacki, op. cit., p. 431.

[75] Scheer, op. cit., pp. 513-514.

[76] Myerson, "Mobilization of the Stapes for Otosclerosis," op. cit., p. 86.

[77] Goodhill, op. cit., p. 697.

Figure 13, page 136, illustrates this type of incision created in the right ear.

No incision. Dr. Mervin C. Myerson of Beverly Hills, California, has developed a stapes mobilization technique by which, an incision is not necessary.[78] This method of stapes mobilization will be described within the discussion of the "mobilization of the stapes footplate," later on in this section of the study.

Purpose of the incision. Although the above described incisions differ from each other in regard to the area involved, they are all attempted with the purpose of preparing the skin flap for its elevation with the tympanic membrane in such a manner that they do not suffer undue injury.

It should not be assumed that these incision techniques are the only ones employed by operating surgeons in stapes mobilization. The type of incision created depends upon the surgeon performing the operation. It is quite possible that other techniques have been developed or are being developed at this moment. However, the author found information concerning only the methods discussed above.

Entrance into the Tympanic Cavity

This phase of the stapes mobilization operation concerns the separation of the skin flap from the bony canal

[78]Mervin C. Myerson, "Mobilization of the Stapes Without Incision," A.M.A. Archives of Otolaryngology, 64:373, July—December, 1956.

wall, the elevation of the tympanic membrane from its circular groove,and the folding of these combined components so that the tympanic cavity is exposed. This procedure can be difficult, depending upon the characteristics of the particular ear canal involved. Rosen explains:

> . . . in many specimens the posterior bony canal wall is concave, and the anterior canal wall is convex. Separating the skin from the bony wall without tearing it or injuring the drum in such cases is difficult.[79]

The techniques of performing this phase of stapes mobilization surgery, reviewed by the author, will be considered in the following discussion. The methods will be arranged under two classifications, the superior method, and the anterior method.

The superior method. The superior method follows the 9 o'clock to 3 o'clock incision, and concerns the dissection and folding of the skin flap and tympanic membrane superiorly.

Figure 12. The right ear canal after incision, the dissection of the skin flap and tympanic membrane, and folding according to the superior method.

According to the method employed by Rosen, Figure 12, the skin flat is separated from the bone, beginning from the incision to the base of the eardrum. At this point, ". . . the drum is finally

[79]Rosen and Bergman, "Restoration of Hearing in Otosclerosis by Mobilization of the Fixed Stapedial Footplate. An Analysis of Results," op. cit., p. 232.

lifted out of its sulcus and reflected upon itself like an apron."[80]

The anterior method. The anterior method is employed after the 12 o'clock to 6 o'clock incision and involves the dissection and folding of the skin flap and tympanic membrane anteriorly.

Myers and Ronis offer the following words of advice to any surgeon employing their method of performing this phase of the operation:

> Before any attempt is made to dissect the flap, be sure the knife can run all around the entire incision and bite into the bony ear canal. Any shreads of the skin the knife does not separate can be cut with a small iris scissors or with Bullucci's scissors.[81]

Figure 13. The right ear canal after incision, the dissection of the skin flap and tympanic membrane, and folding according to the anterior method.

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[80] Rosen and Bergman, "Mobilization of the Stapes for Otosclerosic Deafness," op. cit., p. 198.

[81] Myers and Ronis, loc. cit.

Myers and Ronis proceed with their dissection around the entire incision, ". . .5 o'clock in doing the right ear, and to 7 o'clock in the left ear.[82] These authors add:

> When the region of the sulcus is reached, one can feel the dissecting instrument dip into the sulcus and lift the fibrous annulus out of its bed. The dissection then proceeds until the end of the osseous canal, where the middle ear is entered. . . and the eardrum easily folds on itself.[83]

The technique employed by Derlacki, Shambaugh, and Harrison is described as follows:

> The incision and initial elevation are carried. . . down to the sulcus tympanicus where the fibrous annular ligament of the ympanic membrane lies in the bony groove. . . . The annular ligament is then elevated from the sulcus with the angled elevater . . . gently pushing this instrument directly inward at repeated points along the sulcus . . . and the tympanic membrane is folded forward upon itself. . .[84]

Sheer's method is quite similar to the above described procedures. He explains:

> With elevators of various sizes, the skin is lifted from the bony canal down to the annulus of the tympanic membrane. The fibrous annulus is then lifted out of its sulcus, and the tympanic membrane is folded anteriorly like an apron, thus exposing the middle ear.[85]

To facilitate the separation of the skin flap from the canal wall, Myerson, moistens the area between the flap and bony wall with, ". . . 2 minims (0.12cc.) of saline or

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[82] Ibid.

[83] Ibid.

[84] Derlacki, Shambaugh and Harrison, loc. cit.

[85] Scheer, op. cit., p. 513.

epinephrine hydrochloride solution."[86] He applies this solution by saturating small flat, elongated pieces of cotton with it, and places these pieces of cotton in the desired areas.[87]

The application of the solution is carried out periodically during the elevation procedure. Myerson describes his method of elevation:

> The flatter elevator is better for beginning the elevation. It is usually started posteriorly. Gentle pressure is made between the flap and the bony wall, using the dissector or suction tube . . . this prevents tearing of the flap. Elevation is continued until the point of attachment of the drum is reached. At this point the more curved of the elevators is insinuated into the sulcus to which the fibrocartilaginous rim of the tympanic membrane is attached. The membrane is cautiously lifted; . . . and the posterior half of the membrane reflected anteriorly so that the corresponding portion of the tympanic cavity is exposed.[88]

Goodhill states, "The elevation of the dermal-periosteal flap can be accomplished rapidly but should be done with magnification. . . ."[89] He adds:

> The elevation is carried medially until the margin of the annular sulcus is reached. When the margin of the tympanic sulcus is reached, a round angulated elevator is used to enucleate the annulus fibrous from the sulcus. Following the enucleation, penetration of the tympanic air space is accomplished.[90]

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[86] Myerson, "Mobilization of the Stapes for Otosclerosis," op. cit., p. 86.

[87] Ibid.

[88] Ibid., p. 87.

[89] Goodhill, "Trans-Incudal Stapedolysis for Stapes Mobilization in Otosclerotic Deafness," op. cit., p. 697.

[90] Ibid.

Control of bleeding. There is a certain degree of bleeding that results during the dissection of the skin flap from the bony canal wall. Scheer says, "As a rule, the only time bleeding is encountered is before the tympanic membrane is reflected forward."[91]

> To insure a dry field, small dental cotton balls occasionally saturated with epinephrine are used as wipes. Narrow-gauge spinal needles (which are beveled flat) are used as suction tips, should they become necessary.[92]

Derlacki, Shambaugh and Harrison, control the bleeding by:

> . . . placing tiny cotton balls moistened in the xylocaine-adrenalin solution between the elevated skin and the bone, and applying suction. Any remaining bleeding points are controlled by electro-cautery applied to the fine suction tip.[93]

Myers and Ronis do nothing to control the bleeding, until they have reached the middle ear. They explain:

> If the surgeon moves along, by the time the middle ear is reached, most of the bleeding stops. When the dissection is completed, the blood is aspirated and the area mopped with small cotton pellets soaked in the epinephrine solution (1:1000).[94]

The entrance into the tympanic cavity is one of the critical points in the stapes mobilization surgical procedure, according to Schuknecht. If this procedure is not administered with proper precaution, it is possible that the eardrum

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[91] Scheer, op. cit., p. 514. [92] Ibid.

[93] Derlacki, Shamburgh and Harrison, loc. cit.

[94] Myers and Ronis, loc. cit.

may be permanently perforated. Schuknecht stated that of the one hundred and fifty stapes mobilization operations he has performed, not one resulted in a permanently perforated eardrum.[95]

Exposure of the Middle Ear Structures

After an entrance has been made into the tympanic cavity it is important that the surgeon have an unimpeded view of the middle ear structures, principally, the incudo-stapedial joint, the stapes tendon, and the component parts of the stapes. Derlacki, Shambaugh, and Harrison explain, ". . . we have found that direct visualization of as much of the footplate as possible gives the best control of the mobilization procedure. . ."[96]

Two elements that may obstruct the surgeons view are, the bony rim of the auditory canal, and the chorda tympani nerve.

The bony canal rim. According to Scheer, the size and shape of the patient's auditory ear canal will determine how much of the ". . . incus and stapedius tendon will be immediately visible on lifting the drum"[97]

Sheer further adds:

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[95]Schuknecht, op. cit., April 27, 1957.

[96]Derlacki, Shambaugh, and Harrison, op. cit., p. 433.

[97]Scheer, op. cit., p. 514.

> The greater the forward angulation of the canal, the less visible will be the long arm of the incus and stapedius tendon. Occasionally it will not be possible to see even the lower end of the long arm of the incus. . .[98]

If proper visualization is impeded by the structure of the auditory canal, after the tympanic cavity has been exposed, a portion of the posterio-superior bony rim of the canal is removed. In this respect, Scheer states, "The majority of cases require that some bone be removed to get proper exposure."[99]

In cases involving an ideal canal for stapes mobilization, the incudostapedial junction is seen first after the tympanic cavity is exposed. Rosen and Bergman state, "In over 85% of the cases the incudostapedial junction is seen at once."[100] Goodhill reports that his experience with stapes mobilization revealed that after the tympanic cavity has been exposed:

> . . . in at least 50 per cent of cases a direct view of the entire incudo-stapedial joint will be obtained, along with the chorda tympani nerve, stapedial tendon, part of the posterior stapedial crus and part of the anterior crus.[101]

Although Rosen and Bergman state that the incudostapedial junction is seen at once in over 85 per cent of Rosen's cases, these authors add:

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[98]Ibid. [99]Ibid.

[100]Rosen and Bergman, "Mobilization of the Stapes for Otosclerotic Deafness," op. cit., p. 198.

[101]Goodhill, "Trans-Incudal Stapedolysis for Stapes Mobilization in Otosclerotic Deafness," op. cit., p. 698.

> about 2 to 3 mm. of the very edge of the posterior bony canal, just external to the incus, is removed in order to get a much wider exposure, especially of the stapedial tendon, which is inserted into the neck of the stapes.[102]

As previously inferred, Rosen's initial incision and elevation procedure exposes the inferior half of the auditory canal opening to the tympanic cavity. The 12 o'clock to 6 o'clock incision and elevation procedure exposes the whole posterior half of the canal opening. Therefore the author assumes that Rosen's point of attack, in regard to the removal of the bony canal rim, is directed in an area that is inferior to the posterio-superior area involved in the following procedures.

Derlacki, Shambaugh and Harrison explain:

> . . . we remove in most cases 2 or 3 mm. of posterior-superior rim above the exit of the chorda tympani nerve to expose all of the stapedial tendon.[103]

Myerson states:

> Removal of bone should be confined to the region above the point of exit of the chorda tympani nerve from the facial nerve in order to avoid injuring the facial nerve.[104]

Goodhill says:

> If . . . clear visualization is not easily obtained, it is necessary to obtain adequate exposure by removal of sufficient posterior-superior bony annular quadrant to make this possible.[105]

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[102]Rosen and Bergman, "Mobilization of the Stapes for Otosclerotic Deafness," op. cit., p. 198.

[103]Derlacki, Shambaugh, and Harrison, loc. cit.

[104]Myerson, "Mobilization of the Stapes for Otosclerosis," op. cit., p. 88.

[105]Goodhill, "Trans-Incudal Stapedolysis for Stapes Mobilization in Otosclerotic Deafness," op. cit., p. 700.

The author found that the instrument used to remove the bone from the canal rim depends upon the particular surgeon performing the procedure. Schuknecht employed the use of a long slender instrument with a barbed head on one end, called a curette.[106] It was also revealed that other surgeons use this instrument.

In order that the ossicular chain is not injured during the removal of the bone from the canal rim, Scheer explains, "If the curetting is done within out, there is little danger to the underlying ossicles."[107]

It is necessary that the surgeon keep the operating field free from bone chips and blood that may accumulate during surgery. In this phase of the operation, the collecting of bone chips in the surgical field is a particular problem. To remove these bone chips, Myerson states, ". . . suction with fine tubes is applied when necessary to keep the operative field clean."[108]

Chorda tympani nerve. The anatomical placement of the chorda tympani nerve has created problems in some cases, as far as the proper visulation of the middle ear structures

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[106]Schuknecht, loc. cit.

[107]Scheer, op. cit., p. 515.

[108]Myerson, "Mobilization of the Stapes for Otosclerosis," op. cit., p. 88.

is concerned. In this respect, Scheer states, "The chorda tympani nerve may be in such a position as to block complete visualization of the incudostapedial joint. . ."[109]

Myers and Ronis explain:

> The chorda tympani nerve is often encountered but seldom has to be disturbed since it rests in the bony ledge of the canal, at times it must be displaced from the line of vision.[110]

There are two methods which are used for the displacement of the chorda tympani nerve, if it presents itself as an obstruction to proper visualization. One method involves merely pushing it out of the line of vision. The other method concerns the severing of the nerve.

Derlacki, Shambaugh, and Harrison state:

> Depending upon its position, the chorda tympani nerve may be kept in its superior position, displaced downward, or if necessary, removed.[111]

Goodhill says, in reference to the displacing of the chorda tympani nerve:

> . . . the chorda tympani nerve . . . can usually be pushed aside with little difficulty. It is rarely, if ever, necessary to cut this nerve.[112]

According to Scheer, every precaution should be made to perserve the chorda tympani nerve, ". . . since severing it will produce changes in taste. . ."[113]

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[109]Scheer, op. cit., p. 515.

[110]Myers and Ronis, loc. cit.

[111]Derlacki, Shambaugh, and Harrison, loc. cit.

[112]Goodhill, "Trans-Incudal Stapedolysis for Stapes Mobilization in Otosclerotic Deafness," op. cit., p. 700.

[113]Scheer, op. cit., p. 515.

Providing the situation warrants the severing of the chorda tympani nerve, Scheer explains:

> If the nerve is cut against the canal wall with a curette, there is no pain. Should it be picked up, stretched, and then avulsed, there is a sharp pain that shoots down to the neck and the mandible.[114]

When Scheer was forced to cut the chorda tympani nerves of his patients in the stapes mobilization operation, he found that such patients experienced a, ". . . bitter, metallic taste that remained in their mouths, and that food, though in itself tasteless on that side, aggravated the bitterness."[115] Eight months after the operation, Scheer reports that these patients, ". . . are still slightly conscious of some change in taste, but they do not have the constant bitterness in their mouths."[116]

When the middle ear structures have been adequately exposed, the surgeon then proceeds to attempt to mobilize the stapes footplate.

Mobilization of the Stapes Footplate

Myerson refers to a book written by Helmholtz entitled, The Mechanism of the Ossicles of the Ear and Membrana Tympani, translated by A. H. Buck and N. Smith, New York, William Wood and Company, published in 1873. Myerson reports that when the stapes is functioning normally, according to

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[114] Ibid. [115] Ibid. [116] Ibid.

Helmholtz the ". . . excursions of the stapes at its footplate are from 1/18 and 1/14 mm."[117] Therefore, according to Myerson:

> This emphasized the very small field involved in mobilization of the stapes. It is obvious that a great deal of force is not necessary to mobilize this structure.[118]

However, when considering the force necessary to mobilize the stapes footplate, it is important that the degree of ankylosis in the footplate region be taken into account. In this respect Scheer states, "The amount of force that is needed to mobilize a stapes depends on the degree of fixation."[119]

The mobilization techniques employed by the surgeon, also depend upon the extent of stapes fixation. Goodhill explains:

> The actual technical maneuvers necessary for adequate lysis depend primarily upon the pathologic status of the footplate region.[120]

Stapes fixation can be complete, involving the entire margin of the footplate, or partial, involving only a portion

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[117] Myerson, "Mobilization of the Stapes for Otosclerosis," op. cit., p. 85.

[118] Ibid.

[119] Scheer, loc. cit.

[120] Goodhill, "Present Status of Stapedolysis," op. cit., p. 341.

of the footplate margin. Meurman and Meurman report that their experience with cases of stapes ankylosis seems to indicate, ". . . that fixation of the stapes to the oval window may be of highly varying character."[121] Goodhill explains, "The footplate may have varying areas in degree of otosclerotic fixation; this lysis may occur more readily in one region than in another. . ."[122] Goodhill further adds from his observations, "In most instances, it will be found that the major stiffness or fixation is at the anterior limb of the footplate."[123]

Another factor that must be considered by the surgeon, before making his choice of mobilization technique to be employed, is the structure of the stapes. According to Anson and Bast, the incus and malleus are relatively constant in form and structure, whereas the normal adult stapes shows extraordinary variability in the size, shape and strength of the crura and footplate.[124]

Scheer says, "The thickness of the crura varies. Each stapes is structurally different, aside from its basic design."[125]

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[121]Meurman and Meurman, op. cit., p. 166.

[122]Goodhill, "Present Status of Stapedolysis," op. cit., p. 346.

[123]Ibid., p. 341.

[124]Barry J. Anson and Theodore H. Bast, "Development and Adult Anatomy of the Auditory Ossicles in Relation to the Operation for the Mobilization of the Stapes in Otosclerotic Deafness," The Laryngoscope, 66:785-795, July, 1956.

[125]Scheer, loc. cit.

Not only will the degree of fixation and nature of the stapes determine what maneuvers should be employed in mobilization, but according to Scheer, "These anatomic variations together with the varying degree of fixation will determine whether the stapes can be mobilized."[126]

The following discussion will be divided in the following six areas: application of pressure, initial test of mobility, the indirect method of mobilization, the "no incision" method of mobilization, the direct method of mobilization, and the determination of mobilization.

Application of pressure. It is important that the surgeon should remain relaxed and patient during the application of pressure while mobilizing the stapes footplate. Derlacki, Shambaugh and Harrison explain:

> . . . when the surgeon finds himself becoming tense he should leave the operating table and walk about to relax for a few moments.[127]

The proper application of pressure during mobilization is necessary in order that the bones of the ossicular chain do not suffer undue injury. Meurman and Meurman state:

> Mobilization of the stapes must be carried out with utmost caution, preferably with repeated even pressure, and not by jerky movements.[128]

Scheer says, "Slow firm pulsating pressure must be applied to a fixed stapes if it is to be mobilized."[129]

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[126]Scheer, loc. cit.

[127]Derlacki, Shambaugh, and Harrison, op.cit., p. 439.

[128]Meurman and Meurman, op. cit., p. 171.

[129]Scheer, op. cit., p. 516.

According to Derlacki, Shambaugh and Harrison, it is:

> . . . very important that the pressure be applied intermittently in a pulsating manner. . . . The force should be increased only very slowly and gradually . . . an impatient rapid increase in force will crush the crura beyond repaid.[130]

Therefore, in applying pressure while mobilizing the stapes footplate, the surgeon should administer such pressure in a slow, firm, pulsating and patient manner, as opposed to a rapid, jerky and impatient manner.

Initial test of mobility. From the gathered information it seems apparent that most surgeons find it necessary to test the mobility of the stapes before employing particular mobilization techniques.

The initial test of mobility reveals to the surgeon the degree of fixation, the state of the incudostapedial joint, and the structural nature of the stapes.

Scheer describes his technique in the initial test for mobility:

> . . . a small curved instrument is placed on the anterior aspect of the neck of the stapes, exerting slight backward pressure in the line with the stapedius tendon.[131]

Rosen and Bergman explain:

> . . . a finely pointed probe is placed against the bony process of the incus close to its articulation with the stapes and moved gently downward for a fraction of a millimeter.[132]

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[130]Derlacki, Shambaugh, and Harrison, loc. cit.

[131]Scheer, op. cit., p. 513.

[132]Rosen and Bergman, "Mobilization of the Stapes for Otosclerotic Deafness," op. cit., p. 198.

Derlacki, Shambaugh, and Harrison state:

> Following careful inspection, the incus, incudo-stapedial joint and stapes head are gently palpated with the microscopic 10° hook.[133]

According to Goodhill's method:

> The needle probe is engaged within the periosteum of the lenticular incudal process and is used to palpate for incudo-stapedial stability and degree of footplate fixation.[134]

It is apparent that these methods of testing the mobility of the stapes differ to some extent from one another. Those that are described above do not include all methods that are employed, but are included to aid the reader in understanding the general area of manipulation in the initial mobility test.

In some instances, the initial test for mobility has resulted in the mobilization of the stapes footplate. In this respect, Meurman and Meurman state, "In some cases even slight touching of the neck of the stapes rendered it mobile . . ."[135] Myers and Ronis explain:

> In some patients palpation of the incudostapedial joint as an exploratory procedure has resulted in stapes mobilization, with sudden and dramatic hearing improvement.[136]

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[133]Derlacki, Shambaugh, and Harrison, op. cit.,p.436.

[134]Goodhill, "Present Status of Stapedolysis," op. cit., p. 341.

[135]Meurman and Meurman, op. cit., p. 169.

[136]Myers and Ronis, loc. cit.

In regard to the possible mobilization of the stapes during the initial mobility test, Derlacki, Shambaugh and Harrison explain:

> In cases of early partial otosclerotic fixation slight pressure in an antero-posterior, vertical or oblique direction may evoke slight mobility of the stapes . . . but as a rule the stapes is found to be rigid.[137]

Some surgeons may discontinue the stapes mobilization procedure if visual inspection, and the initial test for mobility, reveal that the severity of stapes ankylosis does not warrant further attempts at mobilization. Derlacki, Shambaugh and Harrison state:

> . . . inspection may reveal a footplate completely replaced by thick, chalky otosclerotic bone interlaced with blood vessels of variable thickness, a situation which we have found immune to successful mobilization.[138]

According to the policy of these authors, if the patient with the above described otosclerotic condition is an ideal candidate for fenestration, ". . . the operation is terminated by replacing the tympanic membrane and flap."[139]

However, Derlacki, Shambaugh and Harrison add:

> In a case unsuitable for fenestration an attempt may be made to fracture the otosclerotic footplate with the House air-driven hammer, but we are not yet convinced of the wisdom of this course.[140]

The House air-driven hammer will be discussed later, in this section of the study.

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[137] Derlacki, Shambaugh and Harrison, loc. cit.

[138] Ibid. [139] Ibid. [140] Ibid.

During the initial test for mobility, a freely movable stapes is noted in the following manner, according to Rosen and Bergman:

> . . . the gentlest pressure . . . against the long process of the incus causes free and unimpeded movement of the incus, incudostapedial joint, the head, neck, crura of the stapes, and the stapedial tendon.[141]

When the stapes is partially fixed, the structures will move slightly, requiring greater pressure, measured by the degree of movement of the stapes tendon.[142]

In cases of complete fixation, Rosen and Bergman explain:

> . . . when the stapes is completely fixed, very firm pressure of the probe against the long process of the incus causes the incus alone to move but there is no movement whatever of the head, crura, footplate, or tendon of the stapes.[143]

When measuring the degree of stapes mobility, Rosen and Bergman state:

> The tendon of the stapedius muscle is the structure to watch at all times, since its movement is the reflection of the footplate movement . . . the tendon invariable moves in proportion to the movement of the stapes.[144]

A previously stated, knowledge of the state of the incudostapedial joint can be gained during the initial test of mobility. It is important that the operating surgeon know whether or not it is possible to use this area as a point of attack during mobilization, without dislocating the incus from the stapes.

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[141]Rosen and Bergman, "Mobilization of the Stapes for Otosclerotic Deafness," op. cit.,p. 198.

[142]Ibid. [143]Ibid. [144]Ibid.

Goodhill describes the structure of the incudostapedial joint in the following manner:

> The incudo-stapedial joint is an enarthrosis, a ball and socket joint with poly-axial motion and no ligamentous limitation. Fenestration surgeons are familiar with east of disarticulation of the lenticular process of the incus from the head of the stapes. . .[145]

An incudostapedial joint that appears loose during the initial mobility test, may suffer dislocation during mobilization if the force is applied in that area. However, if the mobility test does reveal a very loose incudostapedial joint, Goodhill explains, ". . . it is intentionally immobilized by cementing before force is applied."[146]

According to Goodhill, cementing is accomplished with, ". . . pentocryl, a fast setting resinous plastic applied in a semi-solid state to the incudo-stapedial joint."[147] In regard to the success of this procedure, Goodhill reports in a more recent publication, "Attempts to cement such joints with a fast setting plastic cement 'pentocryl' were only sporadically successful."[148]

The mobility test accompanied by a visual inspection, helps the surgeon to adequately survey this structure before employing further mobilization techniques.

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[145]Goodhill, "Trans-Incudal Stapedolysis for Stapes Mobilization in Otosclerotic Deafness," op. cit., p. 703.

[146]Ibid., p. 704. [147]Ibid.

[148]Goodhill, "Present Status of Stapedolysis," op. cit., p. 344.

Goodhill states in this respect:

> It is not unusual to find pathologic atrophic fractures of the crura before any surgical attack has been directed to this area.[149]

This author further adds:

> In advanced otosclerosis with osteogenetic destruction of the stapedial footplate it is possible to find that the crura have been pathologically thinned, and actually replaced by fibrous strands in the region of the footplate, which is now no longer an anatomical footplate but a distortion bony area filling the fenestra ovalis which in itself may demonstrate deformation of its margins.[150]

It is necessary that the state of the stapes crura be known to the surgeon, in order that he may prevent accidental fractures of either of the crura by applying the mobilization force in unappropriate areas. Meurman and Meurman explain:

> It is clear that there must of necessity be many cases in which the resistance of the bony connection is greater than that of the weak crura of the stapes, and attempts at mobilization by fracture of one or both crura.[151]

As previously inferred, the results of the initial mobility test assit the surgeon in deciding what technique, or techniques, he will employ in his attempts at mobilizing the stapes footplate.

The indirect methods of mobilization. The indirect method involves the application of force in areas other than the stapes footplate. Therefore, the mobilization force

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[149]Goodhill, "Trans-Incudal Stapedolysis for Stapes Mobilization in Otosclerotic Deafness," op. cit., p. 703.

[150]Ibid.

[151]Meurman and Meurman, op. cit., p. 166.

is transmitted indirectly to the ankylosed footplate by way of the other middle ear structures. Rosen explains:

> The original technique of stapes mobilization may be referred to as the "indirect method," since the force which is applied to the neck of the stapes is transmitted to and moves the footplate.[152]

The indirect methods of stapes mobilization are most applicable in cases in which the incudostapedial joint is stable and the crura of the stapes are rigid. However, such methods can be applied if the incudostapedial joint is loose, providing the crura are rigid.

It should not be assumed, from Rosen's above statement, that all indirect methods involve the application of force to the neck of the stapes. The author found that indirect techniques also concern the application of force to the incudostapedial junction and the head of the stapes.

Providing the stapes crura are rigid, Scheer states, it is, "unbelievable the amount of force which can be applied to its neck before the crura will snap."[153] Rosen and Bergman explain, "The amount of pressure which can be exerted on the neck of the stapes without fracturing the crura is considerable."[154] Rosen says that the neck of the

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[152]Samuel Rosen, "Fenestra Ovales for Otosclerotic Deafness," A.M.A. Archives of Otolaryngology, 64:227, July-December, 1956.

[153]Scheer, op. cit., p. 515.

[154]Rosen and Bergman, "Mobilization of the Stapes for Otosclerotic Deafness," op. cit., p. 199.

stapes, ". . . is the thickest and strongest part of the stapes."[155]

In regard to the above mentioned observations concerning the strength of the stapes when pressure is applied to its neck, Scheer explains:

> This is true only if the mobilizer is in the correct position on the neck, for if it is on the crus there will be an immediate audible snap (which sounds like the clicking of two fingernails together).[156]

Rosen uses, ". . . a specially curved, narrow mobilizer. . ,"[157] when applying the mobilization pressure to the neck of the stapes. Rosen's technique is described in the following manner:

> . . . the mobilizer is first inserted over the incudostapedial joint and is carried mesially and inferiorly until one can feel the anterior crus of the stapes close to the footplate. The instrument is pulled slowly unward and outward, hugging the

Figure 14. Indirect method of mobilization, with pressure applied to the stapes neck.

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[154]Rosen and Bergman, "Mobilization of the Stapes for Otosclerotic Deafness," op. cit., p. 199.

[155]Rosen and Bergman, "Restoration of Hearing in Otosclerosis by Mobilization of the Fixed Stapedial Footplate. An Analysis of Results," op. cit., p. 231.

[156]Scheer, loc. cit.

[157]Rosen and Bergman, "Mobilization of the Stapes for Otosclerotic Deafness," op. cit., pp. 198-199.

> anterior crus until one suddenly feels a dent or depression, which is the neck of the stapes . . . pressure downward in the line of the stapedial tendon is made until the stapes is mobilized, sometimes with an audible crack.[158]

Myers and Ronis apply the mobilizer to the neck of the stapes, but their technique differs from Rosen's technique in the following manner:

> We place the instrument on the stapes neck, just below the incudostapedial articulation, rather than bring the mobilizer up along the crura of the stapes. The pull is made in the direction of the stapes tendon. This is a steady lifting motion and a pulling force posteriorly in the direction of the stapes tendon. . . one should pull as hard as necessary to get mobilization.[159]

Scheer also applies the mobilizing force to the neck of the stapes. He states that when the stapes is found to be too firmly fixed by the otosclerotic growth to be mobilized, ". . . with the mobilizer placed on the anterior aspect of its neck, . . . the use of the wabbling technique, is advised."[160] Scheer describes this technique:

> . . . if slight pressure is applied to the inferior aspect of the neck of the stapes, in the direction toward the vertex of the head, the stapes will wabble with a very restricted movement. This small amount of lateral pressure should be a pulsating type and is alternated with a greater force applied to the anterior aspect of the neck of the stapes.[161]

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[158] Ibid.

[159] Myers and Ronis, loc. cit.

[160] Alan Austin Scheer, "Observations of Five Hundred Cases of Transtympanic Mobilization of the Stapes," A.M.A. Archives of Otolaryngology, 65:245-254, March, 1957.

[161] Ibid., p. 249.

Myerson applies the mobilizing pressure to the incudostapedial joint, using a specially designed forked instrument, and a rod inserted into a dental handpiece. Myerson explains the purpose of this technique:

> . . . to create vibrations along the shaft of the forked instrument which are transmitted through the incudostapedial articulation and the crura, to the fixed footplate.[162]

The rod that is inserted into the dental handpiece has a, "'. . .flattened portion . . . in the form of an isoscles triangle, 1-1/2 in. from base to apex with the base at the distal end."[163] The rod is inserted into the dental handpiece, which causes it to revolve when operating. The revolving rod is placed in contact with the forked instrument, after the forked instrument has been placed over the incudostapedial joint. Figure 15 illustrates this method of mobilization.

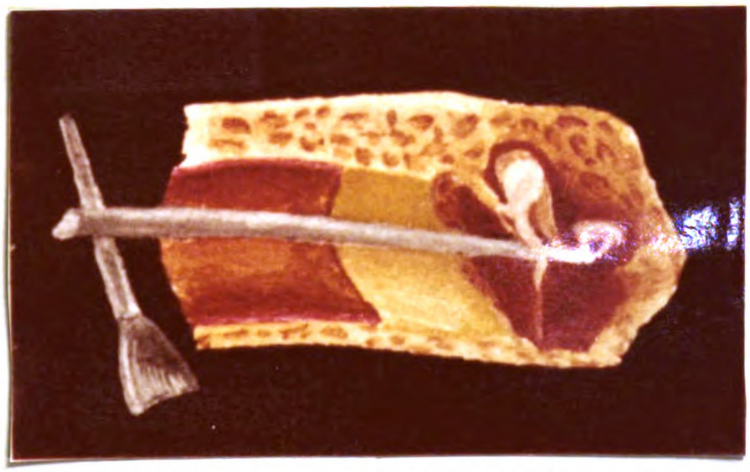

Figure 15. Indirect method of mobilization with pressure applied to the incudostapedical joint. The Myerson technique.

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[162]Myerson, "Mobilization of the Stapes for Otosclerosis," op. cit., p. 86.

[163]Ibid.

Myerson states:

> The vibrations are delicate or coarse, and generate force and amplitude according to the part of the revolving rod in contact with it.[164]

Force and amplitude also depend upon the number of revolutions per minute that the dental handpiece causes the rod to rotate. In this respect, Myerson explains:

> One should rely upon the three speeds supplied by the foot switch. . . . At low speed approximately 1500 rpm are delivered; with medium speed approximately 5000, and with high speed approximately 9000 rpm are produced. . . . The low and medium speeds should be tried first. If they do not prove successful, the high speed should be used.[165]

Myerson reports from clinical experience, ". . . 9000 rpm will mobilize any stapes that can be dislodged, short of causing irreparable damage."[166]

Myerson did not state whether or not the above described procedure is effective in cases involving atropic or weakened crura.

Goodhill's application of mobilization force is directed through the incudostapedial joint,with the mobilizer placed on the incus, if this joint does not appear dangerously loose during the initial mobility test. Goodhill explains:

> If force application seems feasible by this technique (pressure in the areas of the incudostapedial joint) interrupted delicate digital vibrato pressures are transmitted through the incudostapedial joint to the footplate region in a direction determined largely by resistance encountered.[167]

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[164] Ibid., p. 89. [165] Ibid. [166] Ibid.

[167] Goodhill, "Present Status of Stapedolysis," op. cit., p. 341.

However, this author further adds:

> . . . the direction of force is usually in a posterior direction. . . toward the posterior limb of the footplate to produce a surgical fracture either through the otosclerotic bone . . . or through the footplate itself.[168]

The above described direction of force is applied if the otosclerotic bone growth appears in the anterior area of the footplate. However, ". . . the direction of force will be in a superior direction . . . if greatest resistance is encountered in that direction on palpation."[169]

Figure 16. Indirect method of mobilization with pressure applied to the incus and directed through the incudostapedial joint.

In reference to the possible dislocation of the incudostapedial joint, Goodhill explains:

> Incudostapedial dislocation will occur more frequently when force is in an inferior direction, pulling the stapedial capitulum away from the anchored incus. There appears to be greater tolerance for slight rotation of the stapes superiorly than inferiorly. . . a combined maneuver in a posterio-superior direction will be effective in a majority of cases.[170]

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[168] *Ibid.* [169] *Ibid.*, p. 42. [170] *Ibid.*

When Derlacki, Shambaugh and Harrison first began performing the stapes mobilization surgical procedure, they employed the previously described Rosen method (applying pressure to the neck of the stapes). However, they explain:

> After a discouraging first six months, during which we attempted to follow Rosens' originally described technique we have gradually evolved a technique in which we have greater confidence and with which we are obtaining an appreciably higher percentage of initial successes.[171]

This technique is based on a particular mechanical and architectural principle. These authors explain this principle in relation to the structure of the stapes:

> The stapedial crura come together at the neck in either a pointed or a rounded arch, and, as in any arch, the structure has its greatest strength against a force applied through the apex directly downward against the base, or in the case of the stapes, directly inward toward the footplate and vestibule.[172]

According to the technique developed by Derlacki, Shambaugh, and Harrison, the mobilizing force is applied either to the incus, as in Figure 16 or to the head, as in Figure 17. The results of the initial mobility test help determine which of these areas will be directly involved. They explain:

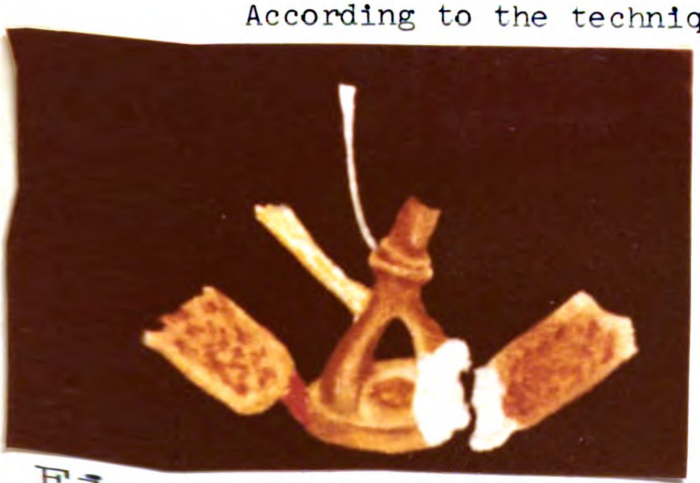

Figure 17. Indirect method of mobilization, with pressure applied to the head of the stapes.

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[171] Derlacki, Shambaugh and Harrison, op. cit., p. 421.

[172] Ibid., p. 438.

> If the incudostapedial joint is very loose, or if the lenticular process of the incus fractures, the inward force is applied directly to the head of the stapes after incising the joint capsule posteriorly with a tiny angulated knife.[173]

The joint capsule is incised in order that the head of the stapes is more accessible to the mobilizer's point.

Derlacki, Shambaugh, and Harrison state that when the inward pressure fails to gain any mobility, or the mobility gained in insufficient:

> . . . the application of the force inward may be alternated with antero-posterior, vertical, or oblique force exerted through the pointed mobilizer inserted into the incus or head of the stapes.[174]

House says, ". . . I began mobilizing the stapes footplace according to the Rosen technique. . ,"[175] However, House reports from his clinical experience of using the Rosen technique:

> Under ideal visual exposure, posterior pressure on the stapes neck, in my experience, resulted in crural fracture in some 50% of the cases.[176]

House revised his mobilization technique, after he made the following observation:

> I soon observed that the convex curve of a dulled needle placed gently on the edge of the capitulum (head of stapes) could be used for stapes mobilization. . . . It was likewise noted that slight pressure applied superiorly and interiorly resulted in motion of the superior and inferior margins of the footplate. Slight oblique pressure seemed to increase this footplate movement.[177]

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[173] Ibid., p. 439. [174] Ibid., p. 440.

[175] House, op. cit., p. 235. [176] Ibid. [177] Ibid.

House currently applies the mobilization pressure, ". . . on the distal portion of the long process of the incus or the posterior edge of the capitulum of the stapes . . ."[178] The incus is not used for mobilizing movements if:

> . . . the incudostapedial joint is too freely movable . . . the incus is eccentrically placed on the capitulum of the stapes . . . the incus is split or dislocated at the time pressure is applied . . . the incus is not at right angles to the underlying crura of the stapes.[179]

When pressure is applied to the head of the stapes, it is possible that the head may split. For such cases, House designed, ". . . a small capitulum cup . . . to fit over the entire stapes head through which manipulating motions could be carried out."[180]

Goodhill, also, directs the mobilization pressure against the head of the stapes, if the initial mobility test shows that the incudostapedial joint is loose and subject to dislocation.[181]

Before applying the point of the mobilizer to the head of the stapes, Goodhill explains:

> . . . the lenticular process is moved away from its insertion upon the capitulum, and only sufficient capitulum area is exposed to permit application of the needle probe directly into the capitular bone.[182]

When this procedure is accomplished, Goodhill applies pressure in a posterior direction, toward the posterior

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[178] Ibid., p. 240.

[179] Ibid.

[180] Ibid., p. 241.

[181] Ibid.

[182] Goodhill, "Present Status of Stapedolysis," op. cit., p. 237.

limb of the footplate.[183] Goodhill explains, in reference to cases involving extreme fixation:

> When preliminary palpation reveals a degree of fixation too great for lysis by simple digital force, the next step is the use of the microvibrator.[184]

Goodhill describes the microvibrator in the following manner:

> . . . consists of a dental handpiece with an angulated "amalpak" automatic hammer attachment, to which is added an offset right angle probe to transmit hammer-like percussion forces.[185]

The author could not discover whether or not the microvibrator, described by Goodhill, and the House air-driver hammer, previously mentioned in this section, are one and the same instruments. However, it seem apparent to the author that the principle involved is the same. House explains, in this respect:

> . . . I developed a modified dental pneumatic hammer in collaboration with Mr. Glenn Turner of Los Angeles. The principle involved was to create a controlled pulsating pressure that can be varied as desired . . .[186]

Goodhill uses the microvibrator in the same manner that he applies digital force with the manual probe. He explains:

> This microvibrator has a needle point and is also inserted into the lenticular process of the incus. Force is transmitted, as before, in a postero-superior direction, in short bursts. Frequently a rigidly fixed

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[183] Ibid. [184] Ibid., p. 342. [185] Ibid.

[186] House, op. cit., p. 237.

> footplate which would not respond to digital force will respond quickly to one or two short microvibrator bursts, following which it may be possible to obtain further footplate lysis by further digital manipulation.[187]

The information reviewed by the author, revealed that Goodhill is the only otologic surgeon using the air-driven hammer when employing indirect methods of mobilization. House uses the air-driver hammer when directing mobilization force in the area of the stapes footplate.

The "no incision" method of mobilization. The indirect technique of mobilization, that will be considered in the following discussion, is administered without an incision. The author found that only Myerson employs this technique.

This technique developed from an idea conceived in 1884 by Lucae. Myerson explains:

> In 1884, Lucae described a percussion technic for otosclerosis. He employed a steel rod at the distal ends of which was a concial depression. This he fitted over the short process of the malleus. The rod has a spring attached which enabled the operator to deliver short, sharp blows to the ossicular chain.[188]

According to Myerson, Lucae obtained some success with this technique, but discontinued the procedure because of the severe pain it caused.[189]

Myerson uses the same instruments in this technique as he employs in his previously described indirect method of

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[187]Goodhill, "Present Status of Stapedolysis," op. cit., p. 343.

[188]Myerson, "Mobilization of the Stapes Without Incision," p. 373.

[189]Ibid.

Figure 18. Indirect method of mobilization, with pressure applied to the short process of the malleus, according to the Myerson technique.

mobilization. He also administers a local anesthetic into the ear canal, and performs the operation through an ear speculum, as he does in his other indirect method of mobilization.[190]

This procedure is administered in the following manner:

> The short process of the malleus is identified. A forked instrument especially designed for the purpose is then placed over the short process. . . . When the fork is properly placed, an assistant brings into contact with its shaft, a flattening revolving rod in a dental handpiece.[191]

The applied pressure should be enough to keep the forked instrument in position upon the short process of the malleus. However, Myerson explains, "Too much pressure will dislocate the malleus and defeat the purpose of the procedure."[192]

There is some trauma to the eardrum, as a result of the severe impact of the vibrations. Myerson says, "As a result of reaction to this trauma, there are extravasation of blood into the spaces of the membrane and slight swelling."[193] However, Myerson states:

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[190] Ibid. [191] Ibid., pp. 374-375. [192] Ibid., p. 376.
[193] Ibid.

> It might be mentioned that the reaction of the tissues of the membrane is far less than that which one encounters when reflecting the tympanic membrane forward or upward for exposure of the middle-ear cavity.[194]

Myerson had performed this operation on three patients at the time his article, reviewed by the author, was published. Myerson reports the results in these three cases:

> In each of the three, there was some degree of improvement. In the first case an average level of 45 db. by pure-tone audiometer was brought up to a level of 15 db. In the other two cases the bone-conduction level would not permit such a striking result, however there was improvement in each.[195]

The direct methods of mobilization. The direct methods of mobilization concern the application of pressure directly to the footplate region. According to Rosen, the direct methods involve, ". . . applying the mobilizing force directly to the footplate itself, the site of the pathologic fixation."[196]

Goodhill explains that direct methods of mobilization should be employed:

> . .. if crura are atrophic and elastic or in the event that one or both crura have been surgically fractured, it is not advisable to persist in application of force either to the incus or to the capitulum. In such a situation, direct footplate lysis attempts are indicated.[197]

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[194] Ibid.

[195] Ibid., p. 373.

[196] Rosen, "Fenestra Ovales for Otosclerotic Deafness," op. cit., p. 228.

[197] Goodhill, "Present Status of Stapedolysis," op. cit., p. 345.

House reports from his experience:

> When excessive pressure seemed necessary and fracture of the crura appeared imminent, or if fracture of the crura did occur, obviously a direct approach to the footplate was essential. . .[198]

Rosen employs the direct approach, ". . . when the bony otosclerotic mass causes extreme fixation of the footplate so that pressure applied to the neck of the stapes is ineffective in mobilization."[199]

Rosen's technique (see Figure 19) is administered as follows:

> . . . the sharp-pointed explorer is used to exert the necessary pressure against the peripheral margin of the fixed footplate to pry it loose and render it mobile.[200]

Pressure is exerted:

> . . . at various sites, the point of the explorer is gently wedged in between the bony margin of the oval window and the peripheral margin of the stapedial footplate for a distance no greater than the thickness of the footplate, so as not to enter the vestibule.[201]

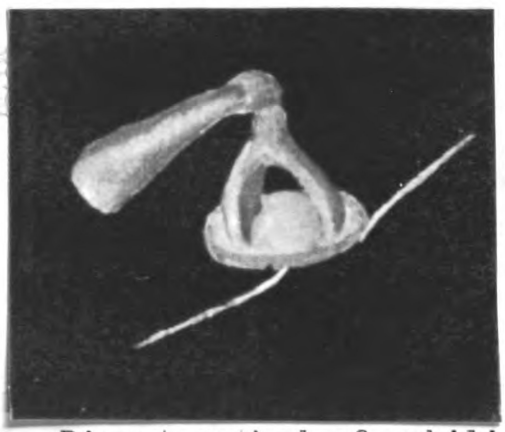

Figure 19. Direct method of mobilization, with explorer used anteriorly and inferiorly.

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[198]House, op. cit., p. 236.

[199]Rosen and Bergman, "Fenestra Ovalis for Otosclerotic Deafness," op. cit., p. 228.

[200]Ibid.

[201]Ibid.

Goodhill uses either the manually manipulated probe, or the microvibrator when administering the direct method of mobilization. According to Goodhill:

> The simpliest transmission of force to the footplate is obtained through a fine dull probe, which can be placed in the intercrural space following the curve of the anterior surface of the posterior crus. The tip of the probe will inevitably meet resistance in the footplate region and at that point gentle to and fro vibratory motion may be exerted, frequently yielding prompt lysis.[202]

This author adds, that in cases within which the probe is ineffective in obtaining lysis, the microvibrator can be used in the same manner. Goodhill states, ". . . it may be necessary to shift the locus of application with the microvibrator in an anterior direction if posterior application fails."[203]

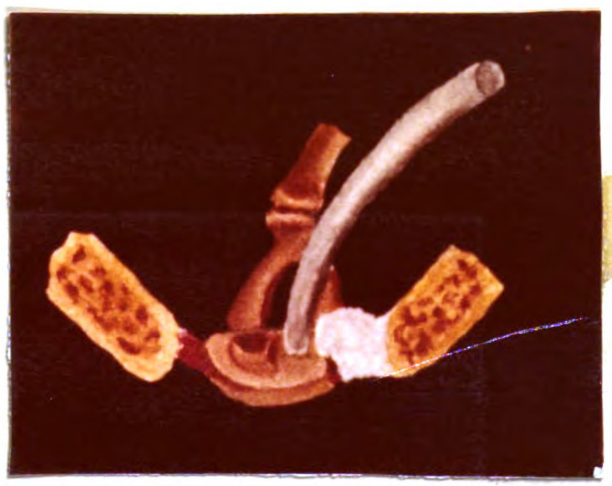

Figure 20. Direct method of mobilization, with pressure applied directly to the footplate.

House observes that when employing the direct method of mobilization, the most vulnerable area, ". . . seemed to

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[202]Goodhill, "Present Status of Stapedolysis," op. cit., p. 345.

[203]Ibid.

be in the posterior one-half of the footplate, especially in the region of the attachment of the posterior crus of the footplate."[204]

It is House's purpose to either free, or if necessary, fracture the stapes footplate, when employing the direct approach to stapes mobilization.[205]

House applies the mobilization force using either a manually manipulated needle, or the microvibrator. In regard to the manual needle approach, House states, ". . . manual needle manipulation is hazardous."[206] He explains:

> If considerable pressure is applied and the footplate suddenly fractures, there is a tendency for the needle to drop toward the vestibule before the manual pressure can be released.[207]

In regard to the use of the microvibrator, House explains:

> This hammer considerably lessens the hazard of dropping toward the vestibule after sudden fracture of the footplate occurs.. . . With the use of controlled pulsating pressures, as delivered through the pneumatic hammer, very few footplates were found that could not be fractured transversely or at the margins.[208]

Derlacki, Shambaugh and Harrison, combine the direct approach with the indrect method of mobilization, if a particular case warrants such action. These authors explain:

> If a stapes does not mobilize readily it may be advisable to loosen or free the margin of the footplate superiorly, anteriorly and inferiorly. . .

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[204]House, op. cit., p. 237. [205]Ibid.

[206]Ibid. [207]Ibid. [208]Ibid., p. 238.

> with special tiny angulated chisels prior to application of further pressure.[209]

The author observed that Schuknecht used both methods in all three operations witnessed. When employing the direct method of mobilization, Schuknecht used small chisels directed against the ankylosed area of the footplate. During the administration, Schuknecht placed and held the chisel, while the assisting nurse tapped the head of the chisel with a mental instrument.[210]

As a final attempt at mobilization, Goodhill states:

> . . . if neither probe nor microvibrator force application to the footplate region is effective, gentle needle curettage of the region is justified. Such curettage techniques will frequently loosen small areas of osteogenetic fixation and may allow footplate mobility which prior to that was impossible.[211]

Goodhill further adds:

> Up to the present time, footplate curettage remains the final step in stapedolysis techniques. If there is no audiometric evidence of lysis following footplate curettage, the procedure should be concluded.[212]

The determination of footplate mobilization. Surgical audiometry is probably the most favorable source, as far as the determination of footplate mobilization is concerned. However, there are visual and audible clues, that help the surgeon determine when the footplate has been mobilized.

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[209] Derlacki, Shambaugh and Harrison, op. cit., p. 436.

[210] Schuknecht, op. cit., April 27, 1957.

[211] Goodhill, "Present Status of Stapedolysis," op. cit., p. 346.

[212] Ibid.

These clues will be considered in the following discussion.

In reference to visual clues, House explains:

> As soon as footplate fracture occurs along its otosclerotic margins or by fracture of the footplate itself, a posterior tilting with a sagging of the stapedius tendon will be felt and observed.[213]

Therefore, as in the initial mobility test, the nature of the stapedius tendon is an important element to be observed by the surgeon, when determining the mobility of the stapes footplate.

According to Myers and Ronis, it is important that the surgeon observe not only the mobility of the stapes footplate, but the mobility of the entire ossicular chain, before terminating the mobilization procedure. Myers and Ronis list several ways to check the mobility of the ossicular chain:

> Observe the movement of the stapes tendon. When fixed, it is rigid. When the stapes is mobile, the tendon wrinkles. . . . Press on the incus and observe the stapes bobbing in and out. . . . If a drop of fluid or blood is in the round-window niche, a reflex movement can be observed there. . . . Press on the handle of the malleus in the inner aspect of the drum and watch the movement of the ossicular chain. . . . Palpate the crura of the stapes to determine if a fracture has occurred. . . . Observe and probe the incudostapedial articulation to make sure a separation did not occur.[214]

Audible clues that designate remobilization of the stapes, concern breaking of the ankylosis and spontaneous

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[213]House, op. cit., p. 240.

[214]Myers and Ronis, op. cit., p. 311.

verbal responses of the patient that sometimes take place when mobilization occurs, ". . . a slight audible crack and the voluntary statement by the patient that there was a change in auditory threshold."[215] may result. According to this author, common expressions made by the patients are, "'something just opened up,' 'I felt something snap,' 'I felt a loud noise in my ear'."[216]

House states that when mobilization occurs:

> . . . the patient often becomes aware of a change in the quality and intensity of his own voice and the voice of the operator. Slight vertigo and a change in tinnitus are also frequently noted.[217]

In regard to the determination of mobilization, Schuknecht stated, that if the patient hears his own and other voices as though they were being produced in a barrel, it is a good sign of mobilization.[218]

As previously stated, surgical audiometry is the most adequate method of determining footplate mobilization, however, the above described visual and audible clues are helpful in this decision. Surgical audiometry will be discussed in Section VI, of this chapter.

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[215] Goodhill, "Trans-Incudal Stapedolysis for Stapes Mobilization in Otosclerotic Deafness," op. cit., p. 707.

[216] Ibid.

[217] House, loc. cit.

[218] Schuknecht, personal observation, April 27, 1957.

Closure of the Tympanic Cavity

The closure of the tympanic cavity is the final phase of the stapes mobilization surgical procedure. This phase of surgery involves replacing the tympanic membrane and skin flap to their original positions, and the application of packing in the auditory canal portion of the surgical field.

Tympanic membrane and skin flap replacement. When the surgeon believes that mobilization attempts have produced results, or if he decides that further attempts at mobilization are fruitless in obtaining lysis, the operation is terminated and the tympanic membrane and skin flap are replaced. Goodhill explains:

> Upon the completion of the lysis maneuvers and the demonstrations of final audiometric status, regardless of success or failure, the operative wound is finally closed.[219]

Goodhill performs this procedure in the following manner:

> Meticulous removal of blood from the tympanic cavity is urgently indicated, and the tympanic membrane and posterior skin flap are gently replaced into their respective positions.[220]

Derlacki, Shambaugh, and Harrison state:

> . . . all blood is aspirated from the middle ear, including the niches of the oval and round windows, the meatal flap, and the tympanic membrane are replaced.[221]

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[219] Goodhill, "Present Status of Stapedolysis," op. cit., p. 347.

[220] Ibid.

[221] Derlacki, Shambaugh and Harrison, op. cit., p. 441.

The author learned that the procedures for replacing the tympanic membrane and skin flap are quite similar among all surgeons reviewed.

Packing and dressing application. Although the procedures discussed above are similar among the reviewed surgeons, such surgeons vary in their methods of applying packing and dressing.

Goodhill describes his method of performing this procedure:

> Upon replacement . . . the wound edges are carefully approximated to their preoperative positions and covered by strips of rayon gauze saturated in saline.[222]

He further adds:

> All of the raw areas are covered, as is the entire tympanic membrane. A cylindrical piece of nylon wool is impregnated with neomycis hydrocortisone "acetate F" ointment and placed within the lumen of the external auditory canal, and against the tympanic membrane, with concentric pressure against the rayon saline strips. . . . A dry cotton plug is inserted as a final dressing to close the meatus. No head dressing is deemed necessary.[223]

Derlacki, Shambaugh, and Harrison explain their technique:

> The meatal flap is held snugly but not tightly by small cotton ball packs moistened in gantrisin otic solution placed against a strip of surgical rayon to facilitate the removal. Should there be a perforation

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[222]Goodhill, "Trans-Incudal Stapedolysis for Stapes Mobilization in Otosclerotic Deafness," op. cit., p. 708.

[223]Ibid.

of the drum membrane, a sterile cigaret paper disc should be placed over it as a splint, and allowed to separate by itself a few weeks later.[224]

Myers and Ronis state:

The line of incision is covered with a layer of silk or nylon, and small cotton pellets are used to pack the ear. A small gauze dressing held by adhesive strips completes the operation.[225]

Myerson explains:

A piece of nitrofurazone (Furacin) gauze is placed over the line of incision as far inward as the tympanic membrane. No further dressing is necessary.[226]

Some surgeons do not apply any type of packing in the auditory canal. In this respect, House states, "The skin flap is allowed to heal without any packing being applied in the ear canal."[227] Scheer explains, "I have found that the use of packing in the external canal is unnecessary."[228] Both of these authors apply a mastoid head dressing, although they did not explain the characteristics of such a dressing.

When the packing and dressing have been applied, the stapes mobilization surgical procedure is terminated.

Possible operative complications and post-operative care will be discussed in Section VIII, and IX, of this chapter.

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[224]Derlacki, Shambaugh and Harrison, loc. cit.

[225]Myers and Ronis, op. cit., p. 312.

[226]Myerson, "Mobilization of the Stapes for Otosclerosis," op. cit., p. 90.

[227]House, op. cit., p. 241.

[228]Scheer, "Restoration of Hearing in Otosclerosis by Transtympanic Mobilization of the stapes," op.cit., p. 516.

VI. SURGICAL AUDIOMETRY

Surgical audiometry involves the audiometric testing of the patient's hearing during the stapes mobilization surgical procedure.

In regard to the importance of surgical audiometry, Goodhill and Holcomb state, "Surgical audiometry . . . is almost indispensible in the direct operation for Otosclerosis (Stapedolysis)."[229] Derlacki, Shambaugh, and Harrison describe stapes mobilization surgical audiometry, ". . . as a helpful and valuable adjunct to digital and visual evaluation of the degree of mobility achieved."[230]

Goodhill and Holcomb explain, "Because of the need for varying surgical approaches in stapedolysis, some guidance of force is required."[231] Surgical audiometry acts as this guide to the operating surgeon. Goodhill states, "The audiometric purpose is to obtain comparative threshold levels for guidance in manipulation . . . for stapedolysis."[232]

Because, the patient is given a local anesthetic, he remains conscious during the surgical procedure and is able to verbally respond during the audiometric testing procedures.

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[229]Goodhill and Holcomb, op. cit., p. 408.

[230]Derlacki, Shambaugh and Harrison, op. cit., p. 433.

[231]Goodhill and Holcomb, loc. cit.

[232]Goodhill, "Trans-Incudal Stapedolysis for Stapes Mobilization in Otosclerotic Deafness," op. cit., p. 701.

Surgical audiometry can be administered either through live-voice, or pure-tone testing methods. The following discussion will concern both live-voice and pure-tone audiometric testing, administered during the stapes mobilization surgical procedure.

Live-Voice Surgical Audiometry

The author found no information regarding the administration of live-voice testing methods during the stapes mobilization operation. However, some surgeons, reviewed by the author, consider live-voice audiometric testing as inadequate. Goodhill states, in reference to live-voice testing:

> The surgeon usually relies upon the verbal response of the patient to spoken voice. This is at best a very crude and unreliable method. . .[233]

Myers and Ronis doubt the reliability of speech audiometry during surgery, because:

> The surgeon's whisper may actually be much louder in his anxiety to convince himself or the patient that a good result is being obtained.[234]

Therefore, it seems apparent to the author that because of the difficulty in controlling live-voice intensity, particularly in the atmosphere and pressure of the surgical situation, live-voice testing methods might be inferior to pure-tone testing.

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[233]Victor Goodhill, "Surgical Audiometry in Stapedolysis," A.M.A. Archives of Otolaryngology, 62:504, July-December, 1955.

[234]Myers and Ronis, loc, cit.

Pure-Tone Surgical Audiometry

The reliability of pure-tone audiometric testing may also be affected by the atmosphere of the operating room. Myers and Ronis explain:

> Sometimes the noise in the operating room, the anxiety of the patient to hear, and the operator's desire for success make the testing unreliable.[235]

According to these authors, reliability can also be affected by the fact that the testing is done on a, ". . . premedicated, tense person on the operating table."[236]

However, Goodhill explains in reference to the pure-tone audiometric threshold obtained during surgery, "These are relative and not absolute threshold values, such as might be obtained in an adequately sound-treated room"[237]

Not all surgeons, reviewed by the author, went into detail regarding their methods of pure-tone audiometric testing during the operation. However, from the information, it appears that all techniques are similar to those of Goodhill.

According to Goodhill's procedure, "The same audiologic technician who performed the preoperative tests. . ,"[238] administers the pure-tone aduiometric testing during surgery. In regard to the equipment used, Goodhill states:

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[235] Ibid.

[236] Ibid.

[237] Goodhill, "Trans-Incudal Stapedolysis for Stapes Mobilization in Otosclerotic Deafness," op. cit., p. 701.

[238] Goodhill, "Surgical Audiometry in Stapedolysis," op. cit., p. 504.

> Any calibrated and acceptable pure-tone audiometer capable of discrete frequency air-conduction audiometry is satisfactory. No special audiometer is needed for the test.[239]

Schuknecht used a small battery operated audiometer, called the "Otometer."* It is designed to test the following frequencies: 500, 1000, 2000, 4000, and 6000.[240] The author learned that the "Otometer," is used by other surgeons, also.

In his pure-tone audiometric procedure, Goodhill states:

> Thresholds are obtained for air conducted sound at frequencies of 500,1000, 2000, and 4000 cycles without masking of the opposite ear . . .[241]

When placing the air conduction receiver on the patient's ear, Goodhill explains:

> A sterile field cover is draped over the operative field. The audiologist places an air conductive receiver on the covered auricle and it is held in place by a sterile towel.[242]

The author had the opportunity to administer the pure-tone audiometric testing during the three operations performed by Schuknecht, which will be described in Section VII, of this chapter. Schuknecht instructed the author to place the

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[239]Ibid.

[240]Schuknecht, personal observation, April 27, 1957.

[241]Goodhill, "Trans-Incudal Stapedolysis for Stapes Mobilization in Otosclerotic Deafness," op. cit., p. 701.

[242]Ibid.

*Otometer, Ambco, manufactured by the Storz Instrument Company, 4570 Audubon Avenue, St. Louis 10, Missouri.

air conduction receiver in the same manner described by Goodhill in the above quotation.[243]

It seems apparent that the transmission of the pure-tone through the sterile field cover, will produce some amount of sound distortion. However, Goodhill explains:

> . . . the attenuation by the sterile field cover is a constant factor, and can be disregarded since the purpose is relative threshold determination for threshold shift only.[244]

When employing audiometric testing as a guide for mobilization techniques, Goodhill states:

> . . . it is necessary to test hearing at four specific steps in the surgical procedure, and these four steps constitute the minimum required for adequate threshold shift determination.[245]

The author learned that not all surgeons adhere to Goodhill's four step technique. Schuknecht, includes only two steps when employing pure-tone audiometry as a guide in the stapes mobilization surgical procedure.[246] However, in order that the reader can obtain a complete picture of the audiometric testing phase of stapes mobilization, Goodhill's four step procedure will be described.

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[243]Schuknecht, personal observation, April 27, 1957.

[244]Goodhill, "Trans-Incudal Stapedolysis for Stapes Mobilization in Otosclerotic Deafness," op. cit., p. 701.

[245]Goodhill, "Surgical Audiometry in Stapedolysis," op. cit., p. 505.

[246]Schuknecht, personal observation, April 27, 1957.

Step 1. The first step is performed after the completion of the incision, elevation of the tympanic membrane and skin flap, and the temporary replacement of these two components. Goodhill explains that the necessity for waiting until the middle ear has been opened and then temporarily closed is, ". . . to obtain a realistic audiometric graph of the traumatized tympanic membrane, and annular flap."[247]

Goodhill and Holcomb state:

> Step 1 usually measures well below preoperative air conduction due to edema (swelling) and occasional hemorrhagic infiltration of the drum layers.[248]

The results of the audiometric test administered during Step 1, are later compared with those obtained from Step 4, to determine the degree of staped mobilization gained from the various mobilization techniques, after the drum and skin flap have been replaced.

Step 2. After the reopening of the middle ear, following the Step 1 procedure, the Step 2 phase of surgical audiometric testing is administered. Goodhill says, "This is the step which will be used for comparison with critical Step 3."[249] Goodhill and Holcomb explain:

> Step 2, with the middle ear open and the tympanic membrane rolled back, is typically lower in response

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[247]Goodhill and Holcomb, "The Surgical Audiometric Nomograph in Stapedolysis," op. cit., p. 401.

[248]Ibid., p. 402.

[249]Ibid., p. 401.

> than Step 1 at the lower frequencies but higher at 2000 and 4000 cycles. Since the middle ear is opened, the loss of the lower frequencies would be expected.[250]

These authors further add:

> . . . the increased response which appears paradoxical at the higher frequencies is probably due to an effective change in the length of the cavity such that the resonant period or multiple thereof is approached by these higher frequencies.[251]

Step 3. This phase of the surgical audiometry, is considered the critical step by Goodhill.[252] He explains:

> Step 3 is performed immediately upon completion of an attempted lysis maneuver. . . . This may involve one or more maneuvers, but the step is done at a time when, in the judgment of the surgeon, sufficient motion has been produced to expect some change. The test may be made following responses of the patient to changes in intensity of the surgeon's voice or to room noise.[253]

As previously stated, the results of Step 3 are compared to those of Step 2, in order that any evidence of a threshold shift will be known to the surgeon. It is possible that Step 3 can be performed several times. Goodhill explains: "Step 3 may require several repetitions if there is only questionable evidence of stapediovestibular motion."[254]

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[250] Goodhill, "Surgical Audiometry in Stapedolysis," op. cit., p. 505.

[251] Ibid.

[252] Goodhill and Holcomb, "The Surgical Aduiometric Nomograph in Stapedolysis," op. cit., p. 401.

[253] Goodhill, "Surgical Audiometry in Stapedolysis," op. cit., p. 505.

[254] Ibid.

When comparing the results of Step 3, with those of Step 2, Goodhill states:

> A threshold shift of at least 15 db. is usually considered significant if it occurs in at least two of the lower three frequencies. A shift of 20 to 25 db. is more commonly encountered in successful stapedolysis maneuvers.[255]

Step 4. This phase of surgical audiometry is performed after the eardrum and skin flap have been permanently replaced. The results of this test are compared with those obtained from Step 1. Goodhill explains:

> In most of the successful stapedolysis cases a threshold shift of 25 to 35 db. will be seen in at least two of the three lower frequencies, accompanied by perhaps a lesser threshold shift in the third and possibly the fourth frequency.[256]

It is difficult to predict the actual posterative gain in hearing obtained through stapes mobilization for the results of Step 4. In this respect, Goodhill explains:

> Since all these tests are done under conditions other than ideal, it is difficult to equate the threshold in Step 4 with the threshold to be obtained later postoperatively when the tissues have healed and the edema has disappeared, and when the test is performed in the normal sound-treated audiometric room.[257]

Schuknecht's Surgical Audiometric Procedure

As previously stated, not all surgeons adhere to Goodhill's four step surgical audiometric method, during the stapes mobilization surgical procedure. Schuknecht includes only two steps in his procedure.[258]

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[255] Ibid. [256] Ibid., p. 506. [257] Ibid.

[258] Schuknecht, personal observation, April 27, 1957.

Step 1, in Schuknecht's procedure is administered after the eardrum and skin flap have been folded anteriorly and the tympanic cavity has been exposed.[259]

According to Schuknecht's method, Step 2 is administered after the stapes has been mobilized and the eardrum and skin flap have been replaced in their original positions.[260]

The three stapes mobilization operations, observed by the author, will be described in the following section.

VII. OPERATIONS OF DR. HAROLD F. SCHUKNECHT

On Saturday, April 27, 1957, the author had the opportunity to observe, and assist in, three stapes mobilization operations performed by Dr. Harold F. Schuknecht, at Henry Ford Hospital, in Detroit, Michigan. Dr. Schuknecht is an Associate Surgeon in the Division of Otolaryngology, at Henry Ford Hospital.

The following discussion will include descriptions of these three operations performed by Dr. Schuknecht. It should be mentioned here that like all types of surgery, stapes mobilization is not free from risks to the patient. It is possible that surgical complications may produce a greater hearing loss post-operatively than the patient had preoperatively. However, according to the claims of most of the reviewed surgeons, such surgical results occur in

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[259] Ibid.

[260] Ibid.

only a small percentage of cases. Surgical complications will be discussed in Section VIII, of this chapter.

It is the opinion of the author that the results of the following three stapes mobilization operations are generally representative of results that can be obtained from this surgical procedure. The first operation produced a greater post-operative hearing loss than the patient had preoperatively. The second operation produced favorable results and the third operation produced very favorable results. The results of these operations will be more thoroughly discussed following the narrative of each operation.

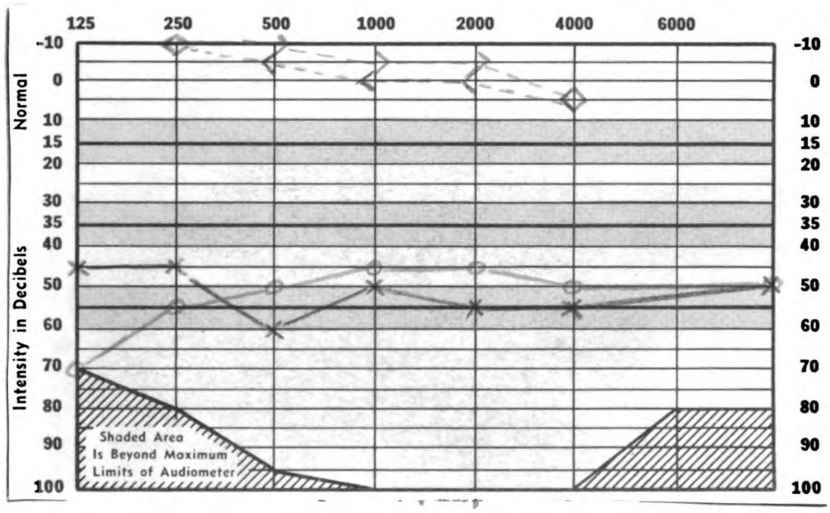
The following discussion will be limited to the results of the preoperative audiograms, a narrative of each surgical procedure, the results of the surgical audiometric procedures, and the results of the post-operative audiograms.

The First Operation

The first operation was performed on the left ear of a thirty-five year old male. Preoperative otoscopy revealed that this patient had dull and thick eardrums in both ears. No information regarding the history of this patient's hearing impairment was obtained by the author.

Preoperative audiogram. Audiogram 4 reveals the pre-operative pure-tone audiometric results of the first patient, obtained on October 11, 1956. The audiogram reveals a wide

air-bone gap of 52 db. According to Schuknecht's previously stated criteria, such a wide air-bone gap may be indicative of severe stapes ankylosis. Dr. Schuknecht stated, "The wider the bone-air gap the less likely is stapes mobilization to succeed, because the magnitude of the gap is an indication of the degree of ankylosis."[261]



Audiogram 4. Preoperative audiometric results of the first patient.

When analyzing the results of the bone conduction test, it seems apparent that there is no nerve damage involved in this case. Therefore, this patient has a case of uncomplicated stapes ankylosis.

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[261]Schuknecht, personal correspondence, July 18, 1957.

In regard to the possibility of this patient or any patient receiving successful results from the stapes mobilization operation Schuknecht said, "The patients are all told that their chances are about 50-50."[262]

Narrative of the surgical procedure. The following will concern a narrative of the first surgical procedure, as the author observed it, and as Dr. Schuknecht explained it. The operation was performed on the patient's left ear. Dr. Schuknecht was assisted by one nurse, and the author. The surgery proceeded as follows:

> 9:00 A.M. The surgical field was cleansed and inspected. It was observed that the patient had a small ear canal, with a difficult angle. The inner hairs of the canal were clipped, and a suction was used to remove the clipped hairs and particles of wax that remained in the canal.
>
> 9:05 A.M. The Ziess binocular microscope was adjusted and the ear speculum was inserted into the auditory canal.
>
> 9:08 A.M. Novocain was injected into the anterior and posterior surfaces of the auditory canal wall.
>
> 9:13 A.M. A scalpel was used to make the initial incision in the posterior canal wall producing a retangular flap. The flap was then elevated. The surgeon found that the patient's skin was very fragile. At this point, the eardrum was perforated. The surgeon stated that the drum would heal without difficulty.
>
> 9:15 A.M. The eardrum was reflected forward and lifted out of its sulcus. It was stated that this is a critical point in the surgical procedure, because the drum can be permanently perforated if this maneuver is not accomplished carefully.

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[262] Ibid.

9:17 A.M. Entrance was made into the tympanic cavity.

9:18 A.M. The surgeon observed that it would be necessary to remove some bone from the inner posterior canal rim, because the stapes footplate could not be seen. The bony canal rim was then removed with a curette. While removing the bone it was necessary to use suction to keep the bone chips from the surgical field. Because the bone chips kept filling up the suction, it was necessary to change suction tips frequently.

At 9:25 A. M. the author was instructed to administer Step 1 of the surgical audiometric procedure. The instrument used was the Otometer. Frequencies 500,1000, 2000, 4000 and 6000 were tested. Dr. Schuknecht placed a sterile towel over the patient's left ear and the air-conduction receiver was placed on the towel. Another sterile towel was placed over the receiver and Dr. Schuknecht held it on the patient's ear, while the author performed the test. As in standard audiometric testing, the patient responded verbally when he heard the pure-tone.

The results obtained from Step 1 of the surgical audiometric procedure are as follows:

Frequency . . .	500	1000	2000	4000	6000
Step 1 results.	55db	55db	40db	40db	40db

Because the surgical audiometric procedure is administered through a towel with an inexpensive audiometer and performed in an inadequate acoustic environment, and the preoperative pure-tone audiometric test is administered under ideal conditions using a properly calibrated audiometer, a comparison of the results of these two tests would not reveal significant differences.

After the Step 1 results had been obtained, the surgical procedure continued as follows:

> 9:33 A.M. The initial mobility test was performed at the head of the stapes. The palpation test revealed that the ankylosis was solid. At this point, the mobilization force was directed against the stapes footplate, with a needle. The needle moved the footplate when pressure was applied to its superior margin. The surgeon felt that the footplate would mobilize, but stated that caution should be used to avoid disarticulating the stapes from the incus.
>
> 9:41 A.M. While the mobilization force was being directed in the area of the footplate, a hole was made in the footplate. Perilymphy leaked out and a piece of jel-foam was placed over footplate hole. The surgeon then proceeded with mobilization applying pressure on the anterior and posterior margins of the footplate. Mobilization was then discontinued and the surgeon prepared to remove the blood from the tympanic cavity.
>
> 9:45 A.M. The eardrum and skin flap were replaced in their original positions. At this point a piece of rayon was placed over the hole in the eardrum in preparation for the final audiometric test.

At 9:48 A.M. the author was instructed to administer Step 2 of the surgical audiometric procedure. The audiometric test was performed in the same manner as it was during Step 1.

A comparison of the results obtained from Step 2, and those obtained from Step 1, is as follows:

Frequency.	500	1000	2000	4000	6000
Step 1 results . .	55db	55db	40db	40db	40db
Step 2 results . .	35db	35db	30db	55db	50db
Difference	20db	20db	10db	-15db	-10db

It is noted that the Step 2 results indicate an increase in hearing at the 500, 1000 and 2000 frequency levels. According to Dr. Schuknecht, the reason for the greater loss

at the 4000 and 6000 frequency levels is caused by an increase in "mass" of the tympanic membrane, called a "mass lesion" due to edema (swelling) of the eardrum. Such "mass lesions" affect the high frequencies.[263]

At 9:56 A.M., Dr. Schuknecht applied the packing and dressing. The operation was terminated.

Post-operative audiometric results. The post-operative audiogram was obtained on June 3, 1957, which was thirty-seven days after the operation. A comparison of the results obtained from the post-operative audiometric test, and those obtained from the preoperative audiometric test is as follows:

Frequency	125	250	500	1000	2000	4000	8000
Preoperative results	45db	45db	60db	50db	55db	55db	55db
Post-operative results	65db	65db	70db	65db	65db	75db	70db
Difference	-20db	-20db	-10db	-15db	-10db	-20db	-15db

As the post-operative audiometric results indicate, this stapes mobilization operation was a failure. According to Dr. Schuknecht this patient, "Improved for two weeks and then his hearing dropped."[264] The exact reason for this is unknown at this time. However, Dr. Schuknecht feels that perhaps this is a case of post-operative reankylosis and mild labyrinthitis (inner ear infection).[265]

Dr. Schuknecht informed the author that the eardrum that was perforated during surgery healed perfectly.[266]

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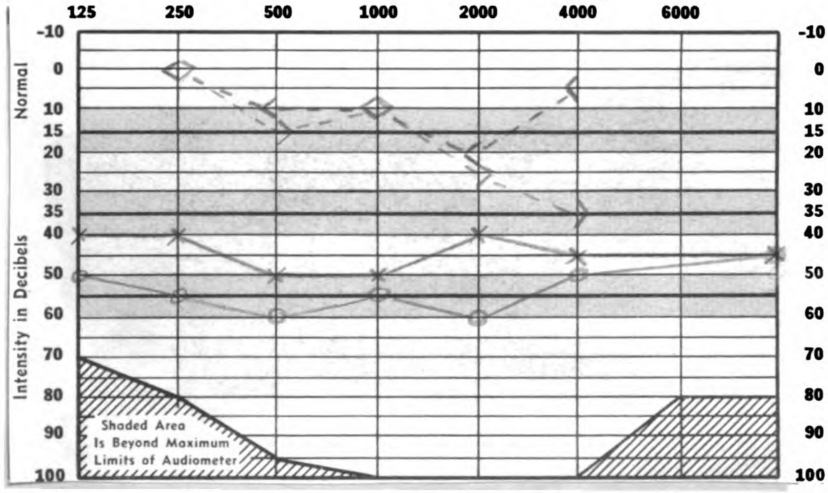
[263] Ibid. [264] Ibid. [265] Ibib. [266] Ibid.

The Second Operation

The second operation observed by the author was performed on the right ear of a thirty-seven year old woman. Her case record revealed that she had been aware of her hearing impairment for two years.

Preoperative audiogram. The preoperative audiometric results reveal some nerve impairment in the higher frequencies in the patient's right ear. This indicates a slight case of complicated stapes ankylosis, as far as nerve impairment is concerned.



Audiogram 5. Preoperative audiometric results of the second patient.

There is a 45db difference between air conduction and bone conduction which indicates severe ankylosis, according to Schuknecht's criteria.

Narrative of the surgical procedure. After the first patient had been removed from the operating room the second

patient was brought in. She was placed on the operating table, on her back, with her head turned in such a manner that her right ear faced the ceiling.

While two nurses prepared the surgical instruments for the operation, Dr. Schuknecht talked with the patient cautioning her not to move her head at any time during the surgical procedure, as he tells all of his patients. When the instruments had been properly placed, the surgery proceeded as follows:

> 10:15 A.M. The ear canal and surrounding field was cleansed. It was noted upon inspection that there was no abnormal canal angle. It was not necessary to clip the internal hairs. The suction was used to remove excess fluid left in the canal from the cleansing procedure.
>
> 10:22 A.M. The Ziess binocular microscope was adjusted and the ear speculum was inserted into the auditory canal.
>
> 10:30 A.M. Novocain was injected into the anterior and posterior surfaces of the canal wall.
>
> 10:35 A.M. The incision was made by scalpel in the posterior canal wall.
>
> 10:40 A.M. The eardrum and skin flap were elevated and folded anteriorly. The middle ear was exposed.
>
> 10:43 A.M. Because the footplate of the stapes could not be seen, bone was chipped away from the posterior rim of the auditory canal.

At 10:45 A.M., the author was instructed to administer Step 1 of the surgical audiometric procedure. The audiometric test was performed on the patient's right ear, in the same manner as previously described in the testing procedure involving the first patient.

The results obtained from Step 1 of the surgical audiometry procedure are as follows:

Frequency. . . .	500	1000	2000	4000	6000
Step 1 results .	55db	70db	75db	55db	55db

After the Step 1 results had been obtained, the surgical procedure continued as follows:

10:55 A.M. The results of the initial mobility test indicated that the footplate was firmly ankylosed. Otosclerotic bony areas could be seen around the footplate margin that looked severe. It was decided to apply the mobilization force directly to the footplate region. The force was applied through the use of a small chisel. The chisel was placed in the appropriate area and while the surgeon held the chisel the nurse tapped its head with a metal instrument.

11:02 A.M While the mobilization force was being applied the patient jerked her head. The surgeon asked the patient if she had heard a loud noise. The patient stated that she had and that there was now a ringing in her ear. It was then stated that tinnitus was the first sign of acoustic trauma. It was stated that perhaps the patient had heard a loud noise resembling a "sonic boom."

11:08 A.M. The application of force to the footplate was concluded and the stapes was palpated for mobility. The palpation revealed that the footplate was loose. The patient stated that she was dizzy. At this point the blood was removed from the tympanic cavity and the eardrum and skin flap were replaced in their original positions.

At 11:11 A.M. the author was instructed to perform Step 2 of the surgical audiometric procedure.

A comparison of the results obtained from Step 2 and those obtained from Step 1 is as follows:

Frequency.	500	1000	2000	4000	6000
Step 1 results . . .	55db	70db	75db	55db	55db
Step 2 results . . .	45db	50db	50db	60db	70db
Difference	10db	20db	25db	- 5db	-15db

It appears that the differences between Step 1 and Step 2 involving the second patient are similar to those between Setp 1 and Step 2 involving the first patient. The gain indicated at the 500, 1000, and 2000 frequency levels and the loss indicated at the 4000 and 6000 frequency levels were not definitely explained. However, Schuknecht felt that perhaps the loss at the higher frequencies was due to acoustic trauma suffered during the operation, or possibly a "mass" effect.[267]

The surgical procedure continued as follows:

> 11:15 A.M. The tympanic cavity was exposed for a final observation of footplate mobility. The surgeon stated that this footplate was a "difficult" one to mobilize, but thought that it was very well mobilized. However, it was possible that the incus had almost been separated from the stapes. A condition called "subluxation."
>
> 11:20 A.M. Packing and dressing were applied. The operation was terminated.

Post-operative audiometric results. The post-operative audiogram of the second patient was obtained on June 21, 1957. The time span between the operation and the post-operative audiometric test was fifty-five days.

A comparison of the results obtained from the post-operative audiometric test and those obtained from the pre-operative audiometric test is as follows:

Frequency.	125	250	500	1000	2000	4000	8000
Preoperative results. . . .	50db	55db	60db	55db	60db	50db	45db
Post-operative results. . . .	20db	20db	35db	35db	45db	35db	40db
Difference	30db	35db	25db	20db	15db	15db	5db

[267] Ibid.

As the post-operative audiometric results indicate, the patient received favorable results from the stapes mobilization. However, when averaging the results obtained at 500 cps and 1000 cps, it was learned that preoperatively the patient had an average loss of 57 db in her right ear. Post-operatively, the patient had an average loss of 35 db in her right ear. This indicates an average 22 db increase in hearing gained in the right ear. But, the patient's hearing in her right ear still doe not fall within the -10 db to 30 db range of practical hearing.

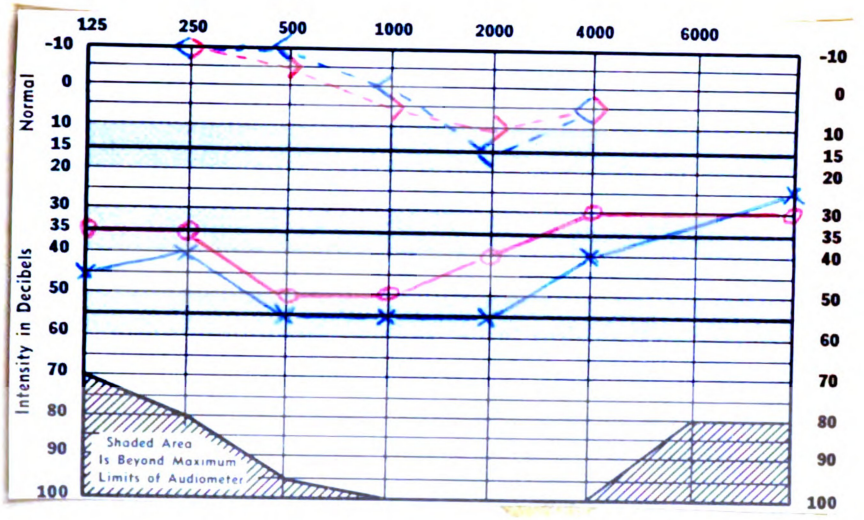
The Third Operation

The third operation was performed on the left ear of a fifty-seven year old woman. She had been aware of her hearing impairment since 1939, however, her record stated that she had never worn a hearing aid.

Preoperative audiogram. The results of the third patient's preoperative audiogram reveal a wide air-bone gap of 50 db, which is indicative of severe ankylosis, according to Schuknecht.

The bone-conduction curve reveals that there is no nerve impairment.

From the results of the preoperative audiogram it appears logical to predict that this patient may receive favorable results from the stapes mobilization surgical procedure.



Audiogram 6. Preoperative audiometric results of the third patient.

Narrative of the surgical procedure. The third operation did not directly follow the second operation because the operating room had been scheduled for another type of surgical procedure. However, in the afternoon the third patient was brought into the operating room and surgery proceeded as follows:

2:30 P.M. The surgical field was cleansed and the ear canal was inspected.

2:32 P.M. The Ziess binocular microscope was adjusted and the ear speculum was inserted into the auditory canal.

2:35 P.M. Novocain was injected into the anterior and posterior surfaces of the auditory canal wall.

2:40 P.M. A scalpel was used to create the incision in the posterior surface of the canal wall.

2:42 P.M. The skin flap and eardrum were dissected and reflected anteriorly. It was necessary to remove the posterior bony rim of the ear canal with a curette so that the stapes footplate would be visible. The tympanic cavity and stapes footplate were exposed.

At 2:55 P.M. the author was instructed to administer Step 1 of the surgical audiometric procedure.

The results obtained from Step 1 of the surgical audiometric procedure are as follows:

Frequency. . . .	500	1000	2000	4000	6000
Step 1 results .	60db	55db	70db	50db	40db

After the Step 1 results were obtained, the surgical procedure continued as follows:

> 3:00 P.M. Otosclerotic bone masses were seen around the anterior margin of the footplate. The results of the initial mobility test revealed that the crura were fragile and "willowy." Pressure was applied to various areas of the footplate with a small needle. No perilymph leaked out. Pressure was then applied to the head of the stapes. At this point, the surgeon felt the stapes wiggle and noticed some movement of the footplate. Upon closer inspection it was observed that the footplate had been cracked anteriorly.
>
> 3:03 P.M. While palpating the stapes the surgeon talked to the patient. The patient's vocal responses appeared louder as palpation proceeded. The surgeon stated that the stapes was mobilized. The patient stated that she felt dizzy.

At 3:05 P.M., the author was instructed to administer Step 2 of the surgical audiometric procedure.

A comparison of the results obtained from Step 2 and those obtained from Step 1, is as follows:

Frequency.	500	1000	2000	4000	6000
Step 1 results . .	60db	55db	70db	50db	40db
Step 2 results . .	25db	30db	45db	35db	35db
Difference	35db	25db	25db	15db	15db

The general characteristics of the results of the Step 2 and Step 1 comparison in the third operation are unique from those in the first and second operations, in

that all frequency results of Step 2 indicate positive differences. In the first and second operations, only the results obtained at the 500, 1000 and 2000 frequency levels in the Step 2 phase, indicated positive differences.

The surgical procedure continued as follows:

> 3:10 P.M. The patient responded dramatically to the voices of those persons in the operating room. She repeatedly stated, "I keep hearing voices."
>
> 3:12 P.M. Packing and dressing were applied. The operation was terminated.

Post-operative audiometric results. The post-operative audiogram was obtained on May 22, 1957. The time span between the operation and the post-operative audiometric test was twenty-five days.

A comparison of the results obtained from the post-operative audiometric test of the patient's left ear and those obtained from the preoperative audiometric test of the patient's left ear, is as follows:

Frequency	125	250	500	1000	2000	4000	8000
Preoperative results . . .	45db	40db	55db	55db	55db	40db	25db
Post-operative results . . .	25db	25db	25db	20db	15db	20db	25db
Difference. . . .	20db	15db	30db	35db	40db	20db	0db

As the post-operative audiometric results indicate, the patient received very favorable results from the stapes mobilization operation. By comparing the decibel averages at the 1000 and 2000 frequency levels, preoperatively and post-operatively, it is learned that the patient has gained a 38 db average increase in hearing. Her average threshold,

post-operatively, is 17 db, which places her hearing within the range of practical hearing (-10 db to 30 db).

VIII. OPERATIVE COMPLICATIONS

It is possible that surgical accidents will occur during the stapes mobilization operation. Such accidents may cause operative complications that produce negative post-operative results. However, in some instances it is possible for the surgeon to correct such complications during surgery.

Operative complications that may result during stapes mobilization surgery will be considered within this section of the study. These complications will involve, crural fractures, luxation of the incudostapedial joint, facial nerve injury and inner ear complications.

Crural Fractures

One type of operative complication involves the fracture of one or both of the stapes crura. In this respect, Goodhill, states:

> In the application of force to the incudostapedial area it is inevitable that crural damage will be inflected in some cases. Such is the case in all present techniques.[268]

This author adds:

> Such injuries may range from a partial greenstick fracture of one crus to complete fracture of both crura and ablation of the capitulum and crura from the footplate remnant.[269]

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[268] Goodhill, "Present Status of Stapedolysis," op. cit., p. 348.

[269] Ibid.

It is possible that crural fractures will heal, and therefore, post-operative complications will not result. Goodhill says, "Undoubtedly healing does occur in many cases but it is not the rule probably."[270] In many cases, after a fracture has occurred during surgery, the surgeon can take measures to aid healing. According to Goodhill, ". . . attempts should be made to replace the fragments in such positions that healing will be encouraged."[271]

House states that when crural fractures result in cases involving otosclerotic bone growth in the anterior footplate margin:

> . . . the posterior crus often seems to reunite with the footplate. The anterior crus does not seem to heal after fracture. This may be due to the fracture sites being in contact with the otosclerotic bone.[272]

When crural fractures do not heal, post-operative results may be negative. Scheer says, "Fracture of the crura of the stapes is the most frequent cause of failure."[273]

The author found no information regarding the incidence of crural fractures during stapes mobilization surgery.

Luxation of the Incudostapedial Joint

Luxation of the incudostapedial joint concerns the displacement of the lenticular process of the incus from the head of the stapes.

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[270] Ibid. [271] Ibid. [272] House, op. cit., p.238.

[273] Scheer, "Restoration of Hearing in Otosclerosis by Transtympanic Mobilization of the Stapes," op. cit., p.516..

Incudostapedial joint dislocation can occur when the mobilization force is applied in any area of the ossicular chain, depending upon the stability of the joint. Goodhill explains:

> Such dislocations appear to be even more frequent following lysis attempts via the stapedial neck, according to the Rosen technique.[274]

Goodhill further states, "When dislocation occurs, it usually is of no significance providing the forces are not great. . ."[275]

When considering the effect of incudostapedial joint dislocation upon post-operative hearing, House says:

> This complication with dislocation of the incudo-stapedial joint does not seem to interfer with the ultimate hearing result, providing the incus is replaced on the capitulum at the time surgery is completed.[276]

In this respect, Meurman and Meurman explain, ". . . it is often possible to place the joint surfaces in the right positions."[277] Goodhill says, "It is usually quite simple to reapply the lenticular process to the capitulum of the stapes and obtain very good contact and union. ."[278]

Incudostapedial joint dislocation can be serious if accompanied by dislocations of other joints in the ossicular chain. Goodhill states:

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[274]Goodhill, "Present Status of Stapedolysis," op. cit., p. 347.

[275]Ibid.

[276]House, op. cit., p. 241.

[277]Meurman and Meurman, op. cit., p. 170.

[278]Goodhill, loc. cit.

> In some cases, incudo-stapedial dislocation is probably accompanied by some degree of incudo-malleolar joint disruption, and perhaps by partial detachment of the malleus handle from its tympanic membrane attachment. This. . . seriously impairs the mechanical advantage of the middle ear mechanism, and may even create an obstructive lesion.[279]

No information was found concerning the incidence of this complication during the stapes mobilization operation.

Perforations of the Tympanic Membrane

Meurman and Meurman state, "Another accident, which is not rare, is rupture of the tympanic membrane. Most of them are small ones."[280]

Such an accident may occur at anytime during the surgical procedure, but occurs most frequently during the initial elevation of the tympanic membrane and skin flap. According to Goodhill:

> It is not unusual to perforate or simply tear the tympanic membrane in the posteri-inferior quadrant, particularly a very transparent atrophic tympanic membrane, during the enucleation. . . . This is not a serious occurrence since healing of the perforation almost always occurs.[281]

In the event that eardrum perforations do occur, it is possible for the surgeon to place the torn edges in such a manner that healing is aided. House says, "If marginal perforations occur at the time of surgery, simple approximation will usually result in successful hearing."[282]

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[279] Ibid., pp. 347-348. [280] Meurman and Meurman, loc.cit.

[281] Goodhill, "Present Status of Stapedolysis," op. cit., p. 350.

[282] House, op. cit., p. 242.

In regard to the effect of eardrum perforations upon post-operative hearing, Scheer explains:

> Perforation of the tympanic membrane will not appreciably alter a good result, provided that the skin flap is sufficient to hold the drum in place, when it is put back into position.[283]

However, permanent eardrum perforations will affect hearing. When considering the incidence of permanent eardrum perforations, House says, "Fortunately, permanent eardrum perforations are indeed rare."[284]

Facial Nerve Injury

The transverse portion of the facial nerve extends along the wall of the tympanic cavity, close to the margin of the oval window. It is protected by a thin layer of bone.

During stapes mobilization surgery, it is possible that this nerve may be injured, causing post-operative facial paralysis. Scheer states, that in his experience with stapes mobilization, "Trauma to the facial nerve has been completely avoided and should never occur if proper care is exercised."[285] However, House explains:

> Permanent injury of the facial nerve has been known to occur due to instrumental injury of the transverse portion of the facial nerve.[286]

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[283]Scheer, "Restoration of Hearing in Otosclerosis by Transtympanic Mobilization of the Stapes," op. cit., p. 517.

[284]House, op. cit., p. 242.

[285]Scheer, "Restoration of Hearing in Otosclerosis by Transtympanic Mobilization of the Stapes," op. cit., p. 517.

[286]House, loc. cit.

This author adds further:

> Temporal facial involvement may occasionally occur from the local infiltration of the local anesthetic on the anterior and inferior walls of the ear canal.[287]

Kos says:

> Temporary paresis or paralysis may result from an intent to infiltrate the anesthetic agent too widely and too deeply . . . but it can be avoided if carelessness and incompetence can be eliminated.[288]

In regard to the incidence of facial paralysis, House reports from a review of 1,091 mobilization cases, "Facial paralysis, which was temporary, occurred in .3 per cent, probably from infiltration. . ."[289]

Inner Ear Complications

It is possible that the inner ear may be damaged due to surgical accidents. House says, "The inner ear may be damaged due to surgical trauma . . . or post-operative inner ear infections."[290]

Trauma to the inner ear can be induced by excessive mobilization force in the area of the stapes footplate. In this respect Schuknecht and Trupiano state:

> The injudicious use of hammer blows to a rigid stapedial footplate can create an acoustic impulse of sufficient intensity to injure the organ of Corti in the basal turn.[291]

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[287] Ibid.

[288] Symposium, op. cit., p. 748.

[289] Ibid., p. 762.

[290] House, loc. cit.

[291] Harold F. Schuknecht and Samuel Trupiano, "Some Interesting Middle Ear Problems," The Laryngoscope, 67:399, May, 1957.

The author found no information regarding the exact cause of inner ear infections but assumes that such infections may be caused by footplate performations or the tearing of the annular ligament during mobilization.

When speaking of the incidence of inner ear complications, House says, "Fortunately, the complications seem to occur in less than 0.5% of the cases."[292]

Other Complicating Factors

There are other operative complications that might occur during the stapes mobilization surgical procedure besides the ones previously described.

The author could find little information regarding the nature of post-operative bleeding and its effect upon post-operative results, however, this complication had occurred in some cases.[293]

Another operative complication that can result during surgery is injury to the chorda tympani nerve. As previously stated, if the chorda tympani nerve is injured the patient's sense of taste will be affected.

It would appear to the author that perforations of the footplate would be considered in the category of operative complications. In this respect, Schuknecht stated, "We

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[292]House, loc. cit.

[293]Goodhill, "Present Status of Stapedolysis," op. cit., p. 349.

don't worry about this so long as we get it loose and get an intact crus to the footplate."[294]

According to Scheer, some surgeons intentionally perforate the footplate when the stapes footplate has been found too firmly fixed for mobilization. In this way a new window is made in the footplate. In this respect Scheer explains:

> Theoretically, the hearing obtained is unphysiological because there are now two windows exposed within the middle ear without preferential deliverance of sound.[295]

Incidence of Permanent Complications

Generally speaking, the incidence of permanent complications resulting from surgical accidents during the stapes mobilization operation is not serious. Kos says, ". . . the likelihood of residual damage or injury to the ear structurally or functionally is a very remote one."[296]

Kos further adds:

> While they are rare, the risks and complications seem to be directly proportional to the ability, training and experience of the surgeon. He should be qualified and prepared to give definitive otological treatment, and to accept the responsibility of managing any problem that may arise in connection with his efforts.[297]

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[294]Schuknecht, personal correspondence, July 18,1957.

[295]Scheer, "Observations of Five Hundred Cases of Transtympanic Mobilization of the Stapes," op. cit., p. 252.

[296]Symposium, op. cit., p. 747.

[297]Ibid.

IX. POST-OPERATIVE CARE

Post-operative care proceeding the stapes mobilization surgical procedure is not extensive, when compared to that of the fenestration operation. Derlacki, Shambaugh and Harrison state, "Postoperative care is minimal in comparison to that of the post-fenestration patient."[298]

This section of the study will concern a discussion of the various factors involved in the post-operative treatment of the stapes mobilization patient. Such factors are: ambulation, the alleviation of pain, antibiotic administration, alleviation of vertigo and nystagmus, hospital dismissal, dressing and packing removal, healing of the surgical field, and post-operative audiometric test.

Ambulation

Patients are not required to spend a great length of time in bed before they are allowed to be ambulatory (not confined to bed). In this respect, Goodhill says, "The patient is allowed to be ambulatory as soon as the effects of the barbiturate medication have worn off."[299] Myers and Ronis state, ". . . the patients are immediately ambulatory . . ."[300] Rosen and Bergman explain, "The patient is ambulatory the day of operation. . . "[301]

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[298] Derlacki, Shambaugh and Harrison, loc. cit.

[299] Goodhill, "Present Status of Stapedolysis," op. cit. p. 351.

[300] Myers and Rois, op. cit., p. 309.

[301] Rosen and Bergman, "Mobilization of the Stapes for Otosclerotic Deafness," op. cit., p. 200.

Alleviation of Pain

Due to the fact that the auditory canal and tympanic membrane suffer some trauma during the surgical procedure, some patients may suffer from pain post-operatively. Scheer says, "Most patients do not complain of any pain."[302] Goodhill states, "There is slight pain following this surgical procedure, but it is relieved by the use of aspirin, codein or demerol."[303] Schuknecht gives the patient aspirin if there is any pain proceeding the operation.[304]

Antibiotic Administration

Antibiotics are administered to the patient as a preventative action against any possible post-operative infections of the external ear, middle ear or inner ear.

Some surgeons administer antibiotics before and after the operation. In this respect, House states:

> An oral antibiotic of choice is prescribed at the time the patient is admitted and is continued for three postoperative days, as a precautionary measure.[305]

Scheer explains:

> Penicillin is given the day of the operation and before discharge from the hospital the next day. One of the oral antibiotics is then given for the next four days.[306]

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[302]Scheer, "Restoration of Hearing in Otosclerosis by Transtympanic Mobilization of the Stapes," op. cit., p. 517.

[303]Goodhill, "Trans-Incudal Stapedolysis for Stapes Mobilization in Otosclerotic Deafness," op. cit., p. 708.

[304]Schuknecht, personal interview, April 27, 1957.

[305]House, op. cit., p.241.

[306]Scheer, loc. cit.

Goodhill says:

> If the patient has no antibiotic sensitivities, it is our practice to administer Bicillin 600,000 units intramuscularly on the morning of the operative day, and to follow this with oral tetracycline 250 mgm. t.i.d. for five days. In allergic patients, other antibiotics or sulfonamides are employed.[307]

Other surgeons administer antibiotics only post-operatively. Myers and Ronis say, "Each patient is given an antibiotic for a five-day period postoperatively."[308] Rosen and Bergman state, "Antibiotics are given for five days after the operation, when dressing is removed."[309]

Alleviation of Vertigo and Nystagmus

Some surgeons have reported cases in which the presence of vertigo and nystagmus (an involuntary oscillation of the eyeball) was noted post-operatively.

Goodhill states:

> Some patients will experience immediate slight or moderate vertigo and in some instances nystagmus may be observed. Such vertigo is usually self limited within a few hours. If it is annoying it may be alleviated by small doses of Dramamine by mouth, occasionally by injection.[310]

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[307] Goodhill, "Present Status of Stapedolysis," op. cit., p. 350.

[308] Myers and Ronis, loc. cit.

[309] Rosen and Bergman, "Mobilization of the Stapes for Otosclerotic Deafness," op. cit., p. 200.

[310] Goodhill, "Present Status of Stapedolysis," op. cit., p. 351.

Myers and Ronis state from their experiences:

> There were only six patients with marked nystagmus and vertigo immediately postoperatively. These patients were given cyclizine lactate (Marezine), 1 cc., intramuscularly. In all patients the vertigo subsided within an hour or two and did not recur.[311]

The author found no information regarding the possible cause of vertigo, however, Myers and Ronis state in reference to the possible cause of nystagmus, "This nystagmus is probably due to the sudden mobilization of the labyrinthine fluids. The fact that it subsided immediately would speak against a labyrinthosis."[312]

Hospital Dismissal

The amount of time the patient is required to spend in the hospital post-operatively appears to be the same, no matter which surgeon performed the surgical procedure.

Scheer allows the patient to be discharged from the hospital the day following the operation.[313] According to Rosen's instructions, the patient ". . . leaves the hospital the following morning."[314] Derlacki, Shambaugh and Harrison say, "The patient returns home the day following surgery and may then return to work."[315] Schuknecht dismisses his

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[311]Myers and Ronis, loc. cit. [312]Ibid.

[313]Scheer, "Restoration of Hearing in Otosclerosis by Transtympanic Mobilization of the Stapes," op. cit., p. 517.

[314]Rosen and Bergman, "Mobilization of the Stapes for Otosclerotic Deafness," op. cit., p. 200.

[315]Derlacki, Shambaugh and Harrison, op. cit., p. 442.

patients from the hospital the day following the operation.[316]

House dismisses his patients the day following the operation and gives them the following three instructions:

1. Avoid blowing the noise.
2. Avoid air travel.
3. Avoid getting water in the ear canal for a period of three weeks.[317]

Dressing and Packing Removal

Most surgeons reviewed by the author remove the dressing on the first post-operative day. Scheer states, "The mastoid dressing is removed on the first postoperative day and the external canal is cleaned."[318]

As previously explained, Scheer does not apply packing to the patient's external ear canal during surgery, however, after the dressing is removed, ". . . cotton is put into the external canal and the patient is advised to change it as often as necessary."[319]

Goodhill explains his procedure for packing removal:

> The cellulose sponge and rayon packing is usually removed about the sixth day, after preliminary application of a detergent such as phisoderm or acidolate. This allows easy removal of the packing without bleeding. If bleeding occurs, the packing is undisturbed for another few days.[320]

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[316]Schuknecht, loc. cit. [317]House, loc. cit.

[318]Scheer, "Restoration of Hearing in Otosclerosis by Transtympanic Mobilization of the Stapes," op. cit., p. 517.

[319]Ibid.

[320]Goodhill, "Present Status of Stapedolysis," op. cit., p. 351.

Derlacki, Shambaugh and Harrison say, "At one week the cotton ball packs are removed. . ."[321]

The author found no further information regarding methods of dressing and packing removal.

Healing of the Surgical Field

It appears that little time is required for the skin flap and tympanic membrane to heal from trauma suffered during the surgical procedure. In this respect, Derlacki, Shambaugh and Harrison state, at one week post-operatively:

> The drum membrane and flap will vary in appearance at this time from near normal to a still bruised look. . . . At the second postoperative visit at one month the drum membrane and canal appear quite normal.[322]

Scheer explains:

> A coagulum of blood seals over the area of the incision. This hardens to form a hard crust, which can be readily removed between the third and fourth weeks. The tympanic membrane assumes a normal appearance between the second and third weeks. When healing is complete, the skin of the external canal is normal. There is no scar visible where the original incision was made.[323]

Goodhill says:

> When the packing has been completely removed it will usually be observed that the flap is well healed, the tympanic membrane appears mobile, and in most instances is translucent. No further dressing is employed after the packing has been removed. It is rarely necessary to treat the canal with any type of medication.[324]

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[321]Derlacki, Shambaugh and Harrison, loc.cit. [322]Ibid.

[323]Scheer, "Restoration of Hearing in Otosclerosis by Transtympanic Mobilization of the Stapes," op. cit., p. 517.

[324]Goodhill, "Present Status of Stapedolysis," op. cit., p. 351.

During the healing process a serous fluid may accumulate in the surgical field. Goodhill says, ". . . serous effusion is encountered only rarely postoperatively and usually subsides spontaneously."[325]

Presence of serous fluid may affect postoperative hearing to some extent. Scheer explains:

> Patients who heard well immediately after surgery may state that within the next few hours a definite drop in the hearing has taken place. This is completely relieved when the serosanguineous fluid is removed with a suction tip. . .[326]

Post-operative Audiometric Testing

In order that the post-operative hearing of the stapes mobilization patient can be properly evaluated, it is necessary that it be tested periodically over a considerable span of time. Only one surgeon, reviewed by the author, mentioned in his publication the amount of time required for periodic post-operative audiometric testing. House says, "A post-operative audiogram is obtained at three weeks, four months and one year following surgery."[327]

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[326]Scheer, "Restoration of Hearing in Otosclerosis by Transtympanic Mobilization of the Stapes," op. cit., p. 517.

[327]House, loc. cit.

CHAPTER VI

EVALUATION OF STAPES MOBILIZATION

Within the time span of five years from Rosen's revival of stapes mobilization in 1952, to its current status today, many otologic surgeons have performed this operation, evaluated and reported their results and expressed their opinions regarding the value of stapes mobilization as a surgical treatment for otosclerotic deafness.

This chapter of the study will concern the evaluation of the stapes mobilization surgical procedure in light of some of its successes and failures, and the personal opinions of some of the surgeons who have performed this operation.

The discussion will be divided into the following three sections: evaluation criteria, review of some stapes mobilization results, and some personal opinions of surgeons regarding stapes mobilization.

I. EVALUATION CRITERIA

Evaluation criteria concern the various standards set forth by the operating surgeon to aid him in his judgment of the success or failure of a particular stapes mobilization operation.

Such standards are generally stated in terms of pure-tone air conduction acoustic thresholds. For instance, the standard for "normal hearing" would be a pure-tone air conduction acoustic threshold ranging from -10 db to 15 db. The author learned that most surgeons who were reviewed state the values of acoustic thresholds as being an average of the two best air conduction thresholds of either the 500, 1000, or 2000 frequency levels. Therefore, in the following discussion regarding evaluation criteria this formula has been used in arriving at the various criteria thresholds.

The following information concerns the various evaluation criteria used by operating surgeons in determining stapes mobilization results as being successful, producing partial gains, or indicating operation failures.

The author learned that such criteria are not standard among the various otologic surgeons.

Success Criteria

When considering the success of a stapes mobilization operation it is necessary that the state of the patient's preoperative hearing be taken into account. Generally speaking, a patient with a complicated case of stapes ankyosis (accompanying nerve impairment) will seldom, if ever, obtain as favorable a post-operative gain in hearing as the patient with an uncomplicated case of stapes ankylosis. When speaking of a favorable hearing gain, the author is referring to a post-operative gain in hearing by air

conduction that falls within the range of normalcy (-10 db to 15 db) or falls within the range of social adequacy (-10 db to 30 db). As previously mentioned, the amount of hearing gain that can be obtained from the stapes mobilization operation is greatly dependent upon the state of the cochlear nerve. In this respect, Goodhill says:

> . . . in all fairness, the title of "success" in stapedolysis surgery must be a dual concept, and must include either the achievement of the 30 db. level or the elimination of the conductive block, as evidenced by an eradication of the bone-air gap.[1]

Achievement of the 30 db level. As previously stated in this study, the 30 db level indicates the most extreme air conduction pure-tone threshold one can possess and still be within the range of social adequacy.

The author learned that most otologic surgeons use the attainment of a 30 db acoustic threshold as one criterion in judging the success of a stapes mobilization operation. Some surgeons allow 5 db more and set the success criterion as being the attainment of a 35 db threshold level.

Derlacki, Shambaugh and Harrison state that stapes mobilization successes include, ". . . all cases that were at or above the 30 db limit of practical hearing at the most recent test one month to 24 months after operation."[2]

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[1]Goodhill, "Present Status of Stapedolysis," op. cit., p. 354.

[2]Derlacki, Shambaugh and Harrison, op. cit., p.443.

Scheer evaluates a stapes mobilization operation as being a success if post-operatively, ". . . the air conduction reaches the 30 db. level or better in the speech frequencies."[3]

Myers and Ronis consider an operation a success if the post-operative hearing falls, ". . . within the 25-35 db level, which could be considered on the border line of practical serviceable hearing."[4]

Eradication of the air-bone gap. In regard to the eradication of the air-bone gap, Goodhill evaluates a stapes mobilization operation as being a success providing the patient's, ". . . last postoperative air conduction is above the level, at the same level or not more than 7.5 db below preoperative bone conduction."[5]

Derlacki, Shambaugh and Harrison state:

> Cases are also included as successes when the last test was within 5 db of the prediction for fenestration (20 db. below preoperative bone conduction), or when it exceeded this prediction by 10 db (within 5 db. of eradication of the preoperative air-bone gap).[6]

According to Scheer's method of evaluation, a successful result is a "Group A" result. A "Group A" result is one in which the 30 db level had been attained or:

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[3]Scheer, "Observations of Five Hundred Cases of Transtympanic Mobilization of the Stapes," op. cit., p. 245.

[4]Myers and Ronis, op. cit., p. 312.

[5]Goodhill, "Present Status of Stapedolysis," op.cit., p. 355.

[6]Derlacki, Shambaugh and Harrison, loc. cit.

> . . . one where the air-conduction comes within 20 db. of its bone-conduction potential. . . . This general classification is necessary because cases with varied levels of bone-conduction are accepted for surgery.[7]

In explaining the above statement, Scheer says:

> For example, a case with bone-conduction at or slightly below the 30 db. level may obtain a post-operative air-conduction level at 35 or 40 db. after a gain of 30 db. This certainly must be classified as a successful mobilization.[8]

Partial Gain Criterion

Goodhill was the only author among those reviewed who established a "partial gain" criterion in evaluating stapes mobilization results. Goodhill states that a "partial gain" is one in which, ". . . the last postoperative air conduction is 7.5 db or more above the preoperative air conduction, but less than 'success'."[9]

Failure Criteria

According to the criteria set forth by Derlacki, Shambaugh and Harrison, operations were considered failures if they:

> . . . failed to reach the 30 db level and were within 10 db of the preoperative level (no change); that were more than 10 db. below the preoperative level (worse), and then gained more than 10 db but failed to come within 5 db of the predicted result of fenestration.[10]

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[7]Scheer, "Observations of Five Hundred Cases of Transtympanic Mobilization of the Stapes," op. cit., p. 245.

[8]Ibid.

[9]Goodhill, "Present Status of Stapedolysis," op.cit., p. 355.

[10]Deerlacki, Shambaugh and Harrison, loc. cit.

Goodhill classifies his operation failure as either "no change," or "losses." This author states that "no change" in indicated, ". . . where the last postoperative air conduction level is within plus or minus 5 db of preoperative air conduction."[11] According to Goodhill, "losses" are indicated, ". . . where the last postoperative air conduction level was 7.5 db or more below preoperative air conduction."[12]

Over-all Evaluation Criteria

It should not be assumed that the authors quoted above are the only surgeons who evaluate their stapes mobilization results according to a particular set of criteria. The above mentioned authors were included only because they had made specific comments regarding stapes mobilization evaluation criteria. However, it appears that such comments are generally representative of most evaluation standards employed by surgeons in judging the results of their stapes mobilization operations.

The author determined the evaluation criteria of other surgeons by reviewing their stapes mobilization results.

The most consistent criterion for stapes mobilization success that appeared among the reviewed surgeons, is the attainment of at least a 30 db pure-tone acoustic threshold

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[11]Goodhill, "Present Status of Stapedolysis," op. cit., p. 355.

[12]Ibid.

All authors felt that a considerable closure of the air-bone gap is significant towards success, although the exact amount of closure required varied.

II. REVIEW OF STAPES MOBILIZATION RESULTS

The review of stapes mobilization results that will be considered in this section of the chapter will concern specifically, the operation results obtained by various surgeons reviewed by the author.

Results Obtained by Goodhill

The results of 189 stapes mobilization operations performed by Goodhill will be considered in the following discussion. These operations were performed between November, 1954, and December, 1955.[13]

When reporting his results, Goodhill divided the entire one-hundred and eighty-nine cases into two groups. The first group included the first one-hundred patients operated upon and the second group included the remaining, or most recent, eighty-nine patients operated upon. Goodhill says, "This somewhat arbitrary division into two groups is based upon both chronological order and technical change".[14] He did not explain the nature of his change of technique, nor did he explain the significance of basing the division upon chronological order.

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[13]Goodhill, "Present Status of Stapedolysis," op. cit., p. 353.

[14]Ibid.

As previously stated, Goodhill used two evaluation criteria when judging the results of his stapes mobilization operations. Such criteria being either the achievement of the 30 db air conduction acoustic threshold level, or an eradication of the air-bone gap to at least 7.5 db of pre-operative bone conduction. All of the results that are reported include the judgment of success or failure using one or both of these criteria.

Results of Goodhill's first one-hundred cases. In regard to the results of the first one-hundred cases, Goodhill reports:

> . . . a total of 39 per cent of the cases in the first 100 may be classified as successes by one or both of the criteria of success; 14 per cent showed useful gains but were below the criteria necessary for success, and 47 per cent could be classified as failures (no change or losses) . . . 15 per cent losses, 32 per cent no change . . .[15]

Results of Goodhill's second, or most recent group of eighty-nine cases. According to Goodhill the results of his second, or most recent group of eighty-nine cases as compared to those of the first one-hundred cases are as follows:

> The feature of greatest importance . . . is the increase in the percentages of successes from 39 per cent to 56.2 per cent, with partial gains of 11.2 per cent. . . . . The no change category has been reduced from 32 per cent to 23.6 per cent. . . the losses encountered . . . are reduced from 15 per cent to 9 per cent.[16]

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[15] Ibid., p. 360. [16] Ibid.

Goodhill further states:

> It is of interest to note that the increase in successes is more marked in the group with bone-air gap eradication rather than in the 30-db. level group. This may reflect a definite improvement in technique.[17]

Goodhill's over-all results. In order that the reader may obtain an over-all picture of Goodhill's reported results involving all one-hundred and eighty-nine of his stapes mobilization cases, the author computed the percentages of these results as they appeared in each of his above mentioned categories. The over-all percentages are as follows:

Successes	47%
Partial gains	12.6%
No change	28%
Losses	12.1%

Goodhill did not mentioned the time span between the operation and the post-operative audiograms upon which these results are based.

Results Obtained by Derlacki, Shambaugh and Harrison

Derlacki, Shamgaugh and Harrison report the results of four-hundred and forty stapes mobilization operations performed by them during the twenty-five month period between September, 1954, and November, 1956.[18] They have divided the group of four hundred and forty cases in the following four groups:

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[17] Ibid.

[18] Derlacki, Shambaugh and Harrison, op. cit., p. 420.

> . . . the first 54 operations in which Rosen's technique was largely employed; the next 26 cases where a sharp pointed mobilizer was used for applying force in various directions according to the method of Kos; a third group of 48 cases where the procedure was controlled by direct visualization of the footplate under 16-X magnification; and the most recent group of 312 cases under direct visualization of the footplate, the blunt ended (Derlacki) mobilizer and the sharp pointed mobilizer were used, applying force in various directions but especially directly inward.[19]

Success criteria used by these authors concerns either the establishment of at least a 30 db air conduction acoustic threshold, or the eradication of the air-bone gap to at least 20 db less than the preoperative bone conduction.

Results of technique #1. According to Derlacki, Shambaugh and Harrison, Technique #1, produced thirteen (24%) successes and forty-one (76%) failures.

Among the thirteen successes the post-operative hearing of eight cases reached the significant level of 30 db. The remaining five cases were proven successful according to a significant eradication of the air-born gap.

Of the forty-one failures, one case obtained a post-operative gain, but this gain was not significant according to the evaluation criteria. Thirty-eight cases resulted in no change. The remaining two patients received a post-operative air conduction threshold that was 10 db or more worse than their preoperative air conduction.[20]

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[19] Ibid., pp. 443-444.

[20] Ibid., p. 443.

Results of technique #2. Technique #2, produced ten (39%) successes and sixteen (61%) failures.

Among the ten successes, eight cases were proven successful according to the post-operative 30 db air conduction threshold criterion. The remaining two cases achieved a significant eradication of the air-bone gap.

Of the sixteen failures, four cases obtained post-operative gains, but such gains were not significant according to the evaluation criteria. Twelve cases resulted in no change. There were no cases in this group that received a more severe post-operative loss than they had preoperatively.[21]

Results of technique #3. Technique #3, produced twenty-six (54.5%) successes and twenty-two (45.5%) failures.

Of the twenty-six successes, seventeen cases obtained a post-operative 30 db air conduction threshold, or more, and the remaining nine cases were evaluated as successful according to the significance of the air-bone gap eradication.

Among the twenty-two failures, two cases received post-operative gains that were not considered significant enough to be classified as successes. Seventeen cases resulted in no change. The remaining three cases received post-operative air conduction results that were 10 db or more worse than their preoperative air conduction.[22]

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[21] Ibid., p. 444.

[22] Ibid.

Results of technique #4. Technique #4, produced one-hundred and seventy-seven (56%) successes and one-hundred and thirty-five (44%) failures.

Among the one-hundred and seventy-seven successes, one-hundred and thirty-eight cases obtained post-operative 30 db air conduction thresholds, or better, and the remaining thirty-nine cases were evaluated as successful according to the significance of their post-operative air-bone gap eradications.

Of the one-hundred and twenty-five failures, eighteen cases received post-operative gains that were not considered significant enough to be classified as successes. One-hundred and six cases resulted in no change. The remaining eleven cases received post-operative air conduction results that were 10 db or more worse than their preoperative air conduction.[23]

Over-all results of Derlacki, Shambaugh and Harrison. The following information was obtained from the above authors' report of results and compiled by the writer.

There were two-hundred and twenty-six (51.3%) successes and two-hundred and fourteen (48.7%) failures in the entire over-all group of stapes mobilization operations performed by Derlacki, Shambaugh and Harrison

Among the two-hundred and twenty-six successes, one-hundred and seventy-one cases obtained post-operative 30 db,

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[23] Ibid., p. 445.

or better, air conduction thresholds and the remaining fifty-five cases were evaluated as successful according to the significance of their air-bone gap eradications.

Of the two-hundred and fourteen failures, twenty-five cases obtained gains that were not considered significant enough to be classified as successes. One-hundred and seventy-three cases resulted in no change. The remaining sixteen cases received post-operative air conduction results that were 10 db or more worse than their preoperative air conduction.

In regard to the permanence of the above reviewed results, Derlacki, Shambaugh and Harrison state, "These results are preliminary, and their permanence is entirely a matter of conjecture."[24]

Results Obtained by Scheer

The following review will concern the results of 500 stapes mobilization operations performed by Scheer, published in 1956.[25] Scheer says:

> The first case was done in March, 1954, two and one-half years ago. Since then, a total of 500 operative cases have been performed and observed, so that now certain conclusions can be fairly definitely established.[26]

As previously stated, Scheer classifies a successful stapes mobilization result as a "Group A" result. A "Group

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[24] Ibid., p. 447.

[25] Scheer, "Observations of Five Hundred Cases of Transtympanic Mobilization of the Stapes," op. cit., p. 245.

[26] Ibid.

A" result being one that reaches the 30 db level of practical hearing, or a significant eradication of the air-bone gap.

Scheer reports the following results:

> There were 176 Group A results obtained in this series of 500 cases. One hundred thirty had air conduction at or above the 30 db. level in the speech frequencies. Forty-six cases obtained Group A results by our bone-conduction potential standard but did not obtain the 30 db. level because of their poorer bone conduction preoperatively.[27]

However, after a period of time post-operatively, Scheer states:

> There has been a reccurrence of the hearing loss in 35 (20%) of the Group A losses. The air conduction in these cases returned approximately to its preoperative level. The majority of these patients lost their initial result within five to six weeks.[28]

Scheer performed second stapes mobilization operations on nineteen of the above mentioned thirty-five patients whose hearing had regressed to its approximate preoperative level. In regard to the amount of fixation observed by Scheer during these second operations, he explains:

> All cases that were revised (19 patients) were found to have as equal or greater degree of fixation when compared with that at the original mobilization.[29]

Of the nineteen patients who received a second operation, Scheer reports the following results:

> Eight patients have had a permanent return of a Group A result following revision. If the revision is successful, the hearing gained has little tendency to deteriorate.[30]

Scheer offers the following conclusions:

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[27] Ibid. [28] Ibid., p. 246. [29] Ibid. [30] Ibid.

> The percentage of Group A results that can be obtained(36%) was established early in the course of this work. It has not been possible to improve upon this figure using the present operative technique. There is a recurrence of the hearing loss in 20% of cases, approximately half of which are improved when a revision is done.[31]

Results Obtained by Rosen

The following is a review of the results of Rosen's stapes mobilization operations. These operations involved two-hundred and eleven cases operated on between April, 1952 and August, 1954.[32]

Rosen divided the two-hundred and eleven cases according to their preoperative bone conduction. Rosen's divisions are as follows:

> . . . Class A cases (maximum pre-operative loss of 10 db. by bone conduction in the speech frequencies). . . . Class B cases (maximum pre-operative loss of 20 db. by bone conduction in the speech frequencies). . . . Class C cases (maximum pre-operative loss of 30 db by bone conduction in the speech frequencies). . .[33]

Rosen and Bergman report the following over-all results:

> If the percentages of improved patients in the C category (generally less suitable) are added to those of A and B, 37 per cent reached levels of 35 db. or better by pure tones. . . while 30 per cent reached a level of 30 db. or better by pure tones. . .[34]

Rosen and Bergman did not report any successful results evaluated according to significant air-bone gape eradication criteria.

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[31] Ibid., p. 253.

[32] Rosen and Bergman, "Restoration of Hearing in Otosclerosis by Mobilization of the Fixed Stapedial Footplate. An Analysis of Results," op. cit., p. 23.

[33] Ibid., pp. 255-256. [34] Ibid., p. 256.

In regard to operation failures, Rosen and Bergman state, "In none of the unsuccessful cases did the hearing fall significantly below the pre-operative level."[35]

Results Obtained by Meurman and Meurman

Meurman and Meurman report the results of sixty-three stapes mobilization operations. The report was published in 1954. Meurman and Meurman state:

> The operations were performed by both of us, about an equal number by each, five by Dr. Rosen, and five by Docent Vaheri. The age of the patients varied from 20 to 74 years . . .[36]

These authors divided the cases into the following three groups:

> Group A, the pure-tone audiogram showed an air conduction between 30 and 60 db. Bone conduction was not lower than 25 db . . . in Group B, the air-conduction hearing loss did not as a rule exceed 60 db. Between 2000 and 4000 cps bone conduction declined to 30 db. or somewhat lower, being, however, distinctly higher than air conduction. The cases of Group C showed an air-conduction curve lower than 60 db. The loss in bone conduction was greater than in Groups A and B, and there was a greater decline toward the higher frequencies.[37]

According to the results reported by Meurman and Meurman they obtained good improvement in all groups. A total of 58.7% of the cases were improved. Among these, 39.6% obtained good improvement, and 19.1% obtained slight

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[35] Ibid.

[36] Meurman and Meurman, op. cit., p. 167.

[37] Ibid.

improvement. There were 41.3% of the cases that remained unchanged. Meurman and Meruman did not specifically state what criteria determined good improvement, slight improvement, or cases that remained unchanged.[38]

Results Obtained by Myers and Ronis

Myers and Ronis published the results of their experience with stapes mobilization in 1956. This experience involved one-hundred and thirty-nine patients on whom one-hundred and sixty-one stapes mobilization operations were performed over a period of eighteen months. Myers and Ronis state, "In some cases a revision was done; in some the other ear was done."[39] The revisions concerned a later operation on the same ear.

The results of these operations reveal that there were sixty-five patients, or 47% of all patients involved, who obtained post-operative improved hearing.[40] Myers and Ronis state:

> These patients had a total of 77 operations, or 48% of the total number of operations. . . . Of the 77 successful results, 14 or 18.1%, had the hearing restored to the 0-15 db. level, or approximately normal hearing; 47, or 61%, had levels of 15-25 db., and 16, or 21%, had final results within the 25-35 db. level, which could be considered on the border line of practical serviceable hearing.[41]

Myers and Ronis further state:

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[38] Ibid.

[39] Myers and Ronis, loc. cit.

[40] Ibid.

[41] Ibid.

> The unsuccessful cases numbered 74 (53%), on whom 84 operations were done. On three patients bilateral operations were done without result. The unsuccessful cases were chosen with the same care as were the successful ones. In the main, they represented ideal patients for surgery.[42]

Myers and Ronis did not report any successful results that were evaluated according to significant air-bone gap eradication criteria.

Results Obtained by House

The following information concerns a review of the results obtained by House in a series of stapes mobilization operations involving four-hundred patients. House published these results in 1956.[43]

House states in reference to successful results obtained by ideal cases:

> In ideal cases with a bone-conduction loss of 10 db. or less in the three speech frequencies, approximately two-thirds of the patients mobilized . . . reached the 30 db. level, or better, by air conduction and maintained their improvement for one year or more.[44]

House further adds:

> Considering other than the ideal cases, where the bone-conduction curve was depressed below the 10 db. level, the following results may be reported: (a) Approximately one-half of the cases with a bone-conduction loss of 11 to 20 db. at the 500 and 1000 frequencies and 30 db. or less at the 2000 frequency achieved the 30 db. level postoperatively. (b) Approximately one-fourth of the cases with a bone-conduction loss of 20 to 30 db. at the 500 and 1000 frequencies and with a loss of 30 db. or more at the 2000 frequency reached the 30 db. level postoperatively.[45]

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[42] Ibid., p. 32.

[43] House, op. cit., p. 235.

[44] Ibid., p. 243.

[45] Ibid.

In regard to closure of the air-bone gap, House reports:

> (1) 67% of the cases operated on closed the bone-air gap 25% or more. (2) 33% closed the bone-air gap by 50% or more. (3) 25% closed the bone-air gap by 75% or more. (4) 11% of the cases operated on closed the bone-air gap completely.[46]

Among the unsuccessful cases, there were some cases whose post-operative air conduction results were worse than their preoperative air conduction. House explains:

> Five per cent of the cases operated on were worse by 10 db. or more in the three speech frequencies four months after surgery. Of this 5%, 4% were worse by 10 to 20 db. and 1% of the cases operated on were worse by more than 20 db. in the three speech frequencies.[47]

Review of Significant Trends

Because of the variety of methods the above surgeons employed in reporting their results, it is possible only to approximate the current trends.

It seems apparent that the above surgeons are receiving from approximately 30% to 56% successes in their stapes mobilization operations.

The period of time between the operation and the stability of hearing gained from the operation, appears significant in evaluating post-operative results. As Scheer reported, some patients who were considered to have obtained successful results after a short period of time following the operation, lost some, or all, of the hearing gained after a longer period of time had lasped post-operatively.

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[46] *Ibid.*, p. 243. [47] *Ibid.*

Of the operation failures reported by some of the surgeons, a small percentage of the patients received post-operative air conduction results that were 10 db or more worse than their preoperative air conduction.

By improving their stapes mobilization techniques, some surgeons have increased their percentages of operation successes.

III. PERSONAL OPINIONS OF SURGEONS REGARDING STAPES MOBILIZATION

This section of the chapter will concern a review of the various opinions of the surgeons reviewed by the author, regarding the stapes mobilization surgical procedure as a cure for otosclerotic deafness.

The review will be divided into the following three parts: general opinions, comparison of stapes mobilization to the fenestration merit, and future prospects of stapes mobilization.

General Opinions

This review of general opinions will include those regarding the current status of stapes mobilization, success determinants, and causes of operation failures.

Current status of stapes mobilization. In a paper read by Goodhill at the meeting of the Western Section, American Laryngological, Rhinological and Otological Society, San Francisco, January 21, 1956, he stated:

> Stapedolysis is an approach requiring varying techniques to cope with pathological variations. . . . Precise microsurgical technique controlled by surgical audiometry is necessary. . . . The technically complex and delicate surgical approach is, nevertheless, benign for the patient; it is quite free of operative and postoperative dangers.[48]

House said in a paper read before the Annual Meeting of the Pacific Coast Oto-Ophthalmological Society, Phoenix, Arizona, in April, 1956:

> I routinely advocate stapes mobilization as the surgical approach of choice in patients with clinical otosclerosis. . . . There are many different techniques being employed at the present time in mobilization. . . . The more experience one has in this type of surgery, the more one realized that the word "simple" should never be attached to this procedure. Stapes mobilization is a very painstaking surgical procedure, not without the possibility of complications.[49]

Meurman and Meurman stated before a meeting of the Finnish-Oto-Laryngological Society, October 30, 1954:

> We. . . advocate stapes mobilization in cases of otosclerosis. On the other hand, we realize that, as regards the number of cures, this operation has not so far given as good results as might be desired.[50]

Scheer stated in a paper read before the Eastern New York Eye, Ear, Nose and Throat Association, Schenectady, New York, January 6, 1955, "The fact that this transtympanic technique can restore hearing to patients with otosclerosis is established. . ."[51]

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[48]Goodhill, "Present Status of Stapedolysis," op. cit., pp. 333,380.

[49]House, op. cit., p. 243.

[50]Meurman and Meurman, op. cit., pp. 164-172.

[51]Scheer, "Restoration of Hearing in Otosclerosis by Transtympanic Mobilization of the Stapes," op. cit., p.534.

In 1955, Rosen and Bergman stated:

> Audiologic evidence indicates that hearing improvement following mobilization of the footplate of the stapes has already been maintained for periods up to two years.[52]

In 1956, Goodhill said:

> A significant number of successful results have been observed for periods of six to 12 months as stable gains. Further long range observation is essential.[53]

In a paper read before the Middle Section Meeting of the American Laryngological, Rhinological and Otological Society, Cleveland Ohio, January 10, 1957, Derlacki, Shambaugh and Harrison stated:

> . . . stapes mobilization is a relatively new procedure, with little or nothing known as yet concerning the ultimate duration of the hearing improvement.[54]

Success determinants. Derlacki, Shambaugh and Harrison explain the various factors that determine post-operative stapes mobilization success in the following manner:

> Our present discussion offers the patient a 40 to 50 per cent chance of initial success. . . . We bring out the fact that the success of mobilization depends as much upon the extent and pattern of the otosclerotic involvement of the footplate as upon the surgical technique, so that the outcome of this procedure in a particular patient cannot be predicted until the stapes has been exposed and examined.[55]

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[52]Rosen and Bergman, "Mobilization of the Stapes for Otosclerotic Deafness," op. cit., p. 205.

[53]Goodhill, "Present Status of Stapedolysis," op. cit., p. 380.

[54]Derlacki, Shambaugh and Harrison, op. cit.,p. 422.

[55]Ibid.

Causes of failures. As previously discussed, stapes mobilization failures, those results that fail to meet the criteria for success, indicate no gain in hearing or reveal post-operative air conduction as being worse than pre-pperative air conduction.

In reference to failure causes, Goodhill states:

> In the final analysis, except for the 10 per cent of immediate re-ankyloses, it seems that simple lysis failure is the main cause of "immediate operative failures."[56]

Myers and Ronis explain:

> It is difficult to assign specific causes for failure. We do not believe it is only due to fracture of the strapes crura, because we can usually determine this. It is amazing how much pull can be exerted before the crura fracture. Possibly, after the stapes is mobilized, the simple fracture at the footplate become healed, or perhaps the ragged edges of the fracture lock and fix the stapes again. Unless we have oppprtunity of evaluation after reoperation, we will be unable to know the reason for failure.[57]

When considering the causes of post-operative air conduction results being worse than preoperative air conduction, Derlacki, Shambaugh and Harrison state:

> Some of these are accounted for by fracture of the crura, increasing the conductive loss; but others are the result of cochlear damage as evidenced by a drop in bone conduction acuity, due probably to hemorrhage into the labyrinth, or to concussion from use of the pneumatic hammer.[58]

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[56]Goodhill, "Present Status of Stapedolysis," op. cit., p. 364.

[57]Myers and Ronis, op. cit., p. 320.

[58]Derlacki, Shambaugh and Harrison, op. cit., p. 446.

Comparison of the Value of Stapes Mobilization and Fenestration

As previously stated, both stapes mobilization and the fenestration operation are surgical procedures administered as treatments for otosclerotic deafness. This part of the section will involve various comments made by experienced surgeons comparing the value of stapes mobilization with that of fenestration, in the alleviation of otosclerotic deafness.

When comparing these two procedures, Kinney states in regard to stapes mobilization:

> While the technique required to do this operation is more delicate than that required to do a fenestration, the time consumed is shorter, and certainly the post-operative care of the patient is reduced considerably.[59]

Meurman and Meurman explain in reference to results obtained from the stapes mobilization operation, "The improvement in many cases exceeds that attained by fenestration."[60] In this respect, Bellucci says:

> Excellent results have been obtained more frequently with the mobilization procedure. More consistent good results, however, are obtained with the fenestration operation.[61]

Scheer explains:

> If the mobilization were a major procedure, like the fenestration there would be no point in attempting

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[59]Charles E. Kinney, "Statistical Analysis of the Stapes Mobilization Procedure," The Laryngoscope, 66:1345, October, 1956.

[60]Meurman and Meurman, op. cit., p. 171.

[61]Richard J. Bellucci, "Present Status of the Operation for Mobilization of Stapes," The Laryngoscope, 66:292, March, 1956.

> it first when only 36% good results are obtained, but the fact that it is uncomplicated, requiring an overnight stay in the pospital, modifies this thinking.[62]

At this point, the author feels it necessary to emphasize the fact that other surgeons are obtaining more favorable results than those referred to by Scheer in the above quotation.

Goodhill states in regard to the significance of his present results obtained from stapes mobilization:

> These encouraging results seem to indicate that stapedolysis is a justifiable first choice in the surgical treatment of otosclerosis. In the event of failure, recourse to a successful fenestration is still possible.[63]

In the event of stapes mobilization failure and a fenestration operation is performed, House states, "My experience indicates that a previous mobilization attempt in no way interferes with the subsequent fenestration results."[64]

When considering the employment of the stapes mobilization operation in place of the fenestration operation, Derlacki, Shambaugh and Harrison say, "In no way should stapes mobilization be presented as a substitute or alternative to fenestration."[65] These authors further explain:

> . . . we refer to stapes mobilization as a preliminary exploratory operation, to be followed by fenestration

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[62]Scheer, "Observations of Five Hundred Cases of Transtympanic Mobilization of the Stapes," op. cit., p. 253.

[63]Goodhill, "Present Status of Stapedolysis," op. cit., p. 380.

[64]House, loc. cit.

[65]Derlacki, Shambaugh and Harrison, op. cit.,p. 422.

six months later when the extent of otosclerotic involvement prevents mobilization or causes refixation.[66]

As a final opinion in regard to the comparison of the value of stapes mobilization and fenestration, Scheer states:

> Mobilization and fenestration must be considered as partners in the surgical treatment of otosclerosis. It should not be a question of competition as to which technique is to be used or preferred.[67]

The Future Prospects of Stapes Mobilization

As previously stated in this study, there was much skepticism among otologic surgeons regarding the value of stapes mobilization shortly after Rosen revived the surgical procedure in 1952. However, with the advent of more improved mobilization techniques producing a greater percentage of favorable gains in hearing, attitudes are changing. Derlacki, Shambaugh and Harrison explain:

> Our changing attitude toward mobilization is evidenced by our preoperative discussion of surgery with our patients with otosclerosis. Two years ago we discouraged patients who expressed interest in stapes mobilization. If the patient wished to try this experimental procedure we would do it, but did not advise it.[68]

Kinney is of the opinion that future developments in mobilization techniques may increase the value of stapes mobilization surgery. This author states:

> There is good reason to believe that some additional refinements in the technique of the actual mobilization

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[66] Ibid.

[67] Scheer, "Observations of Five Hundred Cases of Transtympanic Mobilization of Stapes," op. cit., p. 253.

[68] Derlacki, Shambaugh and Harrison, loc. cit.

will be developed which will certainly increase the chances of any one person obtaining a successful result.[69]

House says in reference to future standardization of the stapes mobilization surgical procedure:

> Because of the variation in the anatomy of the stapes crura and footplate and the variation in the histopathology of otosclerosis, I do not feel any standard routine technique will be developed for this procedure. Each case presents its individual problems, which must, of necessity, tax the ingenuity of the otologic surgeon.[70]

Schuknecht stated:

> I am now using the Heerman chisels on the footplate on all cases. I strive to get the footplate loose and to have one or both crura in continuity with a part or all of the footplate. Our results are better, but we still have a long way to go.[71]

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[69]Kinney, op. cit., p. 1344.

[70]House, loc. cit.

[71]Schuknecht, personal correspondence, July 18, 1957.

CHAPTER VII

CONCLUSIONS

This study was undertaken with the purpose of determining the current status of the stapes mobilization surgical procedure as a treatment for otosclerotic deafness.

After reviewing and analyzing the published materials regarding the various aspects of stapes mobilization and observing and assisting in three stapes mobilization operations, the author offers the following conclusions in reference to diagnosis and candidate selection, the operation and post-operative results.

I. DIAGNOSIS AND CANDIDATE SELECTION

1. A thorough otologic examination and audiometric testing battery are necessary in the diagnosis of stapes ankylosis.

2. Post-operative results cannot be predicted accurately. A stapes mobilization candidate classified as "ideal" cannot be guaranteed a successful post-operative result.

II. THE OPERATION

1. The stapes mobilization surgical procedure is not a standard operation. Surgical methods that are employed

depend upon the otologic surgeon performing the operation.

2. Stapes mobilization surgery is not "simple," its administration requires a skilled otologic surgeon.

3. Surgical audiometry is essential as a guide to aid the surgeon in determining the effectiveness of his mobilization techniques.

4. Preoperative and post-operative care are minor.

III. POST-OPERATIVE RESULTS

1. Stapes mobilization has restored normal hearing in some cases.

2. Operative complications can produce post-operative hearing losses more severe than preoperative hearing losses.

3. Immediate post-operative successful results have regressed, in some cases, to their preoperative level over a period of time following the operation.

4. The time span between the operation and post-operative audiogram is significant when evaluating post-operative results. The amount of time necessary, before a post-operative gain in hearing will stablize, is unknown at this time.

5. Stapes reankylosis can result post-operatively. However, if this occurs, another stapes mobilization operation on the same ear, or a fenestration operation on the same ear, can be performed.

6. Recent improvements in mobilization techniques have increased the percentages of successful results.

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