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AEROMEDICAL REVIEWS

PROGRESS IN STAPES MOBILIZATION SURGERY

Aviation Medicine Implications

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 USAF AEROSPACE MEDICAL CENTER (ATC)
 BROOKS AIR FORCE BASE, TEXAS

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PROGRESS IN STAPES MOBILIZATION SURGERY

Aviation Medicine Implications

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Review 4-60

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PROGRESS IN STAPES MOBILIZATION SURGERY

Aviation Medicine Implications

Surgery for otosclerosis may restore hearing to a normal level but may necessitate the permanent "grounding" of flying personnel. While the otolaryngologist may possess a thorough knowledge of the physiology of hearing, have the delicate surgical skill necessary to perform the procedure, and be well grounded in the indications for surgery, he may fail to give adequate consideration as to how the ear will tolerate the stress of flying following a specific operation. Removal from flying status not only terminates the flying career but also may seriously affect the military career of flying personnel. Some of the factors that must be considered in the selection of a surgical procedure for otosclerosis in flying personnel will be presented in this paper.

Otosclerosis is the most common cause of progressive hearing loss of a conductive type in adults. Although it occurs more frequently in females, it is very often diagnosed in military otolaryngology clinics because of the extremely large number of male members of the Armed Forces who visit the clinics.

The diagnosis is readily established on the basis of history, examination, and audiometric tests. The history is characterized by the onset of a progressive hearing loss in the late teens or early twenties, often present in one ear only at the start. There is a negative history of otalgia and otitis media. The examination is remarkable for the absence of positive findings. There is no obstruction of the ear canal or visible abnormality of the tympanic

membrane and middle ear. There is no evidence of infection or fluid. The patient can perform the Valsalva maneuver with ease. Tuning fork tests reveal that bone conduction is greater than air conduction and the Schwabach test results are normal or prolonged in the involved ear or ears. The audiogram reveals essentially normal bone conduction and depression in the air conduction curve characteristic of a conductive-type hearing defect.

The pathology of otosclerosis has been described in detail by numerous investigators (1, 2, 3). When a hearing defect exists, the otosclerotic process involves the formation of new bone between the footplate of the stapes and the oval window resulting in ankylosis.

There is no medical treatment that will improve the hearing or prevent the hearing loss from becoming progressively worse. A surgical procedure which resulted in permanent and predictable improvement in hearing did not come about until Lempert (4) perfected the fenestration operation in 1938. Although useful hearing could be restored in approximately 90 percent of patients, the indications for the operation restricted its use to selected cases. The fenestration operation is a major operative procedure requiring a general anesthetic for two to five hours, depending on circumstances and the surgeon. Hearing, for the speech frequencies, is improved to 25 db on the average, following the procedure (5, 6). The surgically created cavity does not completely heal for 6 to 12 weeks and the patient must have the cavity cleaned at least once a year forever after. A fistula to the inner ear is present, necessitating limitation in the performance of certain types of hazardous activity. Because of these disadvantages a simpler and better procedure was sought by those interested in reducing patient morbidity and possible unpleasant sequelae of the fenestration operation.

The stapes mobilization operation was performed in the nineteenth century (7, 8). It was discontinued within a few years although the exact reason for this is not known. Interest in the stapes mobilization procedure was revived in 1953 when Rosen (9) reported his successful technic using the "indirect method." The technic was described as "indirect" since pressure was applied

through an instrument to the neck of the stapes and mobilization of the footplate occurred indirectly—that is, without manipulation of the footplate itself. Postoperative complications and patient morbidity were minimal following this procedure. The procedure could be performed under local anesthesia and hospitalization of only 2 or 3 days was required. Only one or two postoperative visits were necessary, to remove the small crust from the external ear canal. There were no restrictions placed on the patient's physical activities following the procedure.

Kos (10) developed an improved "indirect" method of stapes mobilization and reported this in 1955. This technic will be described briefly since it was used by the author from 1955 to January 1958. The author was extremely fortunate in having the opportunity of observing Dr. Theodore Walsh, Dr. Howard House, and Dr. Clair Kos demonstrate their technics of stapes mobilization during 1955.

The patient is prepared for surgery with a barbiturate at bedtime. An antibiotic is also administered the evening before surgery, and is usually continued for 5 days. Breakfast is withheld on the morning of surgery. Ninety minutes prior to surgery the barbiturate is repeated. Thirty minutes prior to surgery morphine gr. $\frac{1}{6}$ is given intramuscularly. After the patient is placed on the operating table, the Zeiss binocular microscope is brought into position and focused on the tympanic membrane. All the adjustments on the microscope are tightened and it is moved aside. A hearing test is then carried out. A speech reception threshold is obtained using a modified Mohawk reception repeater. This instrument has a range of 80 db. Attenuation can be carried out in 5 db steps. The cartridge of the instrument contains a W-1 word list on the tape.

After the surgeon scrubs, the auricle, canal, and surrounding exposed skin are prepared with Iphiohex and Zephiran and sterile drapes are applied. Local anesthesia is obtained by xylocaine[®] with adrenalin, injected into the skin of the external canal at the junction of the cartilaginous and bony meatus. An omega-shaped

incision is used. For the right ear it extends from "7 o'clock" to about "1 o'clock." The incision should be 6 to 7 mm. from the tympanic membrane at its mid-portion. The skin of the external canal is elevated from the bony canal wall down to the tympanic membrane which is then dissected from the annulus and reflected forward. The chorda tympani nerve can be visualized along the lower edge of the bony canal wall. It is then carefully dissected away from the canal wall so that it is not damaged when the lower edge of the canal wall is removed with a curet. Usually the microscope is brought into position at this point and the remainder of the operation carried out under 16 power magnification. The middle ear and round-window niche are inspected. A pick is then inserted into the capitulum of the stapes through the incudostapedial joint and the degree of fixation is determined by palpation. Mobilization is initiated with a gentle rocking motion at a right angle to the long axis of the footplate. The force applied is slowly increased until some motion is detected. The direction of the force applied is then directed toward the long axis of the footplate and finally *in* the long axis. Mobility is felt through the pick and can be observed visually. The mobility of the stapes is usually obtained gradually although it may at times occur suddenly. After the stapes is freely mobile, the tympanic membrane is returned to its normal position and the flap is replaced. The speech reception threshold is again obtained with the Mohawk message repeater. If the hearing improvement is satisfactory a pledget of Gelfoam soaked in thrombin is placed over the incision. If the hearing improvement obtained is not satisfactory, the flap and tympanic membrane may again be elevated and further manipulation carried out. No packing is used in the external canal. A piece of cotton is loosely applied to the external meatus. The patient is usually discharged from the hospital on the day following surgery. Since January 1958, the author has used chisels directly on the footplate when mobilization could not be accomplished by the technic just described. The use of chisels will be discussed later.

Because of the high incidence of failure to mobilize the stapes by the "indirect method," improved techniques were investigated. By 1957 most otologists were using the "direct method" to mobilize

the footplate. House (11) and Goodhill and Holcomb (12) used needles on the margin of the footplate. Heermann (13), Schuknecht et al. (14), and Derlacki et al. (15) explored the advantages of chisels and gouges on the footplate. Fowler (16) developed the technic of anterior crurotomy and Meurman (17) used serrated knives on the footplate. Portmann (18) developed a technic using a micro drill to perforate the otosclerotic focus.

Since an increased percentage of stapes were successfully mobilized by these "direct" methods, these procedures gained added proponents. Although the percentage of successful mobilizations using the direct method reached 70 percent or more by some surgeons, the passage of time brought the bad news that there was a regression of the auditory acuity in a high percentage of "initially-successful" cases. As a result, various newer procedures are being explored.

NEWER PROCEDURES

Shea (19) developed the following technic: A bilateral crurotomy was performed with excision of the superstructure of the stapes. He then fenestrated the footplate and covered the fenestra with a vein graft. If the footplate is thickened by otosclerosis he uses a micro drill and diamond burr to thin the footplate which is then fenestrated. A polyethylene prosthesis is used to bridge the gap between the vein graft and the incus. He was still using this technic in February 1960 (20).

Portmann (21) has developed a new procedure in which he does a stapedectomy. The oval window is covered with a vein graft and then the intact stapes, or the crura if the stapes has been fractured, is returned to the normal position.

When anterior and posterior or marginal otosclerosis is present, Juers (22) performs a bilateral crurotomy. He then nacerates the central portion of the footplate and transposes the posterior crus

so that it comes in contact with the macerated portion of the footplate. This technic is called stapedioplasty.

Schuknecht and Oleksiuk (23) use a similar technic; however, they remove the superstructure of the stapes immediately. After macerating the central portion of the footplate they insert a tantalum or stainless steel wire prosthesis, one end of which is placed against the footplate and the other clamped around the incus. A more conservative approach is used by House (24). When the otosclerotic lesion is limited to either the anterior or posterior portion of the stapes, he performs a crurotomy of the affected crura and fractures the footplate distal to the lesion. In bicrucial involvement he follows the technic of Shea as described above.

Kos (25) has developed a new technic which appears very promising. It incorporates the better features of several of the procedures already discussed. The middle ear is exposed by means of the tympano-meatal flap, described above. A complete stapedectomy is performed. A 5-0 stainless steel wire is tied around a section of vein 1 by 3 mm. in dimensions. This vein "plug" is packed into the oval-window niche. The other end of the wire is crimped around the distal end of the incus — similarly to the Schuknecht procedure. The air-bone gap can be completely closed with this procedure.

AVIATION MEDICINE IMPLICATIONS

The exact incidence of otosclerosis in the Air Force flying population is not known. In one major Air Command waivers have been granted for failure to meet Flying Class II audiometric requirements at the rate of 5.6 per thousand flying population, or 0.56 percent. These waivers were granted for all types of hearing defects and not otosclerosis specifically. A review of the consultation reports of all flying personnel referred to the ENT Branch, USAF School of Aviation Medicine, who failed the audiometric requirements for Flying Class II, reveals otosclerosis was the etiology of hearing loss in 28.5 percent. This is an indication that approximately 2.0 per thousand or 0.2 percent of rated flying personnel

have otosclerosis to the degree that they fail the Flying Class II audiometric requirements. These requirements as stated in AFM 160-1 are as follows:

	250 cps	500	1000	2000	4000	8000
Better ear	20 db	20	20	20	No requirement	
Worse ear	20	20	40	40	No requirement	

This is fairly consistent with the incidence of otosclerosis in flight-line personnel. An evaluation of flight-line personnel with Class C hearing revealed 22 percent to have otosclerosis (26). Class C hearing, as defined in AFR 160-3, means that there is an average loss for *either* ear of 20 db or more in the speech frequencies.

When a diagnosis of otosclerosis is made on an aircrew member who is on flying status, serious consideration of numerous factors must be given before surgical treatment is recommended. First, consideration must be given to *why* the operation is recommended. Performing the operation simply for the reason that the patient may attain the audiometric qualifications for Flying Class II is not necessary, since AFM 160-1, par. 127c, provides that anyone who *fails* the Flying Class II audiometric requirements may be given an in-flight hearing test, and if he performs satisfactorily a waiver may be considered without the necessity of any operative procedure. I have never seen — nor do I ever expect to see — an aircrew member with a conductive-type hearing loss due to otosclerosis who cannot, in the presence of aircraft cockpit noise, hear as well as a person with normal hearing. The hearing defect induced by otosclerosis does not, of itself, interfere with the performance of flying duties.

A second and most important consideration is: Does the hearing defect interfere with the performance of *nonflying* duties? This will depend not only upon the degree of hearing loss but also on the type of ground duties which the individual is required to perform. Aircrew members usually have to participate in group discussions as occur in briefings, lectures, conferences, etc. These

individuals may be seriously handicapped in the accomplishment of the nonflying phases of their flying duties.

It must be kept in mind that any treatment recommended should not unnecessarily jeopardize the aircrew member's physical qualifications for flying. This is imperative for two principal reasons. First, the cost of training a pilot to combat-ready status in jet bomber aircraft has been conservatively estimated at \$300,000. When a crew member is removed from flying duties, a replacement must be provided. Second, when an aircrew member is removed from flying status his career is likely to be seriously affected if not stymied, since most command positions require an officer be fully qualified, professionally and physically, for flying duties.

Of all patients with hearing defects those with otosclerosis receive the most satisfactory benefits from a hearing aid. These devices are available to Air Force personnel under the provisions of AFR 160-37. Dozens of aircrewmembers are among the millions of satisfied users of hearing aids in the United States today. If a hearing aid fails to satisfy the hearing requirements of certain aircrew members, because of unusual circumstances in their nonflying duties, such as participating in group conferences and briefings, surgical correction may be considered.

The fenestration operation is ordinarily considered disqualifying for flying duties because of the danger of incapacitating vertigo although a waiver may be granted by the Surgeon General, USAF, in individual instances. To my knowledge no specific policy has been formulated concerning physical qualification for flying following fenestration of the footplate of the stapes or stapedectomy, followed by a graft of vein, fat, fascia, or plastic over the oval window with or without reconstruction of the ossicular chain by polyethylene or metal prosthesis.

Complications which could seriously compromise in-flight performance following these procedures are not unknown. Partial degeneration of the cochlea has occurred, resulting in a perceptively-type hearing loss. Occasionally labyrinthitis develops and as a

result complete degeneration of the cochlea and peripheral vestibular system occurs. The patient must then go through a period of compensation while the remaining vestibular apparatus undergoes a period of readjustment due to lack of inhibition from the destroyed labyrinth. During this phase of recovery from sequelae the patient may be completely incapacitated because of vertigo and impairment of balance. This period of compensation may require more than 80 days. The compensation may be adequate for maintaining balance and orientation on the ground but whether it is adequate to enable a pilot to maintain coordination and orientation in the air cannot be predicted.

Although the middle and inner ear seem to tolerate the grafts and prostheses, surgeons who reconstruct the oval window in this way warn that only the passage of time will reveal the eventual outcome (23, 25). What might be the effect of repeated atmospheric pressure changes within the middle ear cavity on the graft or footplate of the stapes by a prosthesis? It can be postulated that the graft may develop a perforation due to pressure necrosis as the prosthesis is forced against the graft or footplate with recurrent tympanic membrane movements; the prosthesis may enter the labyrinth and mechanically stimulate the saccule in such a circumstance; the perilymph may escape from the inner ear with resultant degeneration of the membranous labyrinth or labyrinthitis. One investigator found, to his surprise, that the saccule was torn in three of ten cats in which the footplate of the stapes was fenestrated (23).

Most jet aircraft are flown at altitudes of 30,000 feet or higher. These aircraft cabins are ordinarily pressurized to a much lower altitude. For instance, while the flight altitude may be 30,000 feet, the cabin altitude will be 12,000. Failure of this pressurization system may occur at any time, resulting in violent pressure changes and some tympanic membrane movement. The atmospheric pressure at 34,750 feet is 180 mm. Hg, or one-fourth atmosphere. If the aircrew member is unable to ventilate the middle ear on rapid descent from this altitude the ear that has had one of these procedures will have to tolerate a relative negative pressure of 580 mm. Hg within the middle ear. We are all familiar with the

"fistula phenomenon." When a fistula to the labyrinth is present, either positive or negative pressure induced in the ear canal by a Siegle's otoscope will cause nystagmus and vertigo due to mechanical stimulation of the sensory receptors in the labyrinth. The induced vertigo may be of such severity that the patient is completely incapacitated. This factor could lead to disastrous results if it happened to a pilot making an emergency descent, as described.

I sincerely hope that all of these factors will be considered by the otolaryngologist before a stapes mobilization procedure is contemplated for flying personnel with hearing defects due to otosclerosis.

I do not feel that the benefit of good hearing should be denied anyone, least of all an aircrewman whose responsibilities in nonflying duties require acute hearing. It would be wrong to condemn *all* surgical procedures devised to improve hearing. However, it would seem wise at this time to use conservative techniques which will not unnecessarily jeopardize the aircrew member's physical qualification for flying, and which do not offer serious compromise of the labyrinthine functions essential to flying safety.

In twenty-six "stapes mobilization operations" on eighteen aircrewmen I have employed the original Koa technique or the use of a chisel on the footplate. Everyone of these individuals has returned to full flying duty within 30 days. None of them have suffered any adverse effects or sequelae from the operation. It is extremely gratifying to observe the increased effectiveness of these patients in the performance of their nonflying duties.

I should like to emphasize that all of the procedures described in this paper are called "stapes mobilization procedures." These procedures are all performed by means of the same surgical approach to the middle ear cavity. One cannot, by examining the external ear canal and tympanic membrane after surgery, determine what the surgical procedure was or what, if any, prosthesis was inserted. It is essential to have an operation report to determine exactly what was done to, and with, the stapes and oval window

at the time of surgery. Only by careful examination of the report and clinical evaluation of the patient can the physician properly assess the implications of the surgical treatment of otosclerosis in the patient required to participate in aerial flights.

SUMMARY

Otosclerosis is the most common cause of progressive hearing loss of a conductive type in adults. Stapes mobilization effected by the direct method was revived in 1953. Recent procedures involve fenestration of the footplate, the use of a vein graft, and reconstruction of the stapes with tantalum or stainless steel wire or a polyethylene prosthesis. Fenestration of the horizontal semi-circular canal is ordinarily considered permanently disqualifying for flying duties and a waiver can be granted only by the Surgeon General, U. S. Air Force. An Air Force policy has not been formulated with regard to fenestration of the footplate of the stapes. Aviation medicine principles should be considered in the choice of a surgical procedure for otosclerosis performed on an aircrew member. Mobilization of the stapes achieved conservatively by manipulation of the head of the stapes or occasionally by chisels is recommended and has been demonstrated not to have adversely affected the performance of flying duties by aircrewmen. Until it has been definitely determined that the middle ear can tolerate fenestration or removal of the footplate, addition of grafts and prostheses, without compromising the integrity of the inner ear while being subjected to the inevitable, repeated bouts of severe atmospheric pressure changes encountered in military aircraft, it would seem wise to refrain from using these procedures on flying personnel.

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