Review Article

Evolution of Stapes Surgery

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Abstract

Otosclerosis is a hereditary localized disease of the otic capsule which is characterized by alternating phases of bone resorption and formation, as a result of which there is removal of mature lamellar bone by osteoclasts and the subsequent replacement by woven bone of greater thickness, cellularity and vascularity in the active stage, and later this is followed by sclerosis and hardening, leading to ankylosis of the stapes foot plate and conductive deafness. The surgical management of this condition has been the subject of much debate and several controversies over the course of more than a century of study, with several stalwarts of the field of Otorhinolaryngology taking opposing points of view in regard to this. Beginning with Kessel in the late 1800s, stapes surgery began with the era of stapes mobilization, which progressed to the era of stapes fenestration following the introduction of the operating microscope into otologic practice, and finally reached the era of stapedectomy in the 1950s. Advances in surgery have come as a result of the introduction of laser, microdrills and now, robotics into the field of stapes surgery and brought us to where we are now. Even still, the basic principles of stapes surgery deduced by the pioneers of the profession still hold true today, albeit with few changes.

Key Words: Stapes surgery, Otosclerosis, Stapedotomy

Introduction

Otosclerosis is a genetically-mediated primary metabolic bone disease of the otic capsule and ossicles, causing ossicular fixation and hence resulting in conductive or mixed hearing loss and is mediated via autosomal dominant transmission with incomplete penetrance and complex, not clearly defined triggering mechanisms[1]. It is a disease of young patients, mainly females, who are handicapped by progressive hearing loss for no apparent reason. The diagnosis is usually straight forward and is made on clinical grounds. These patients can be nicely and effectively rehabilitated by modernized hearing aids or surgery, which is the best option in the expert's hands[2].

Discovery of Otosclerosis

Ludwig van Beethoven (1770-1827) was considered to have mixed hearing loss attributed to otosclerosis. Beethoven first admitted his deafness at the age of thirty-one when writing to a friend complaining of progressive worsening of his hearing. His deafness drove him to social isolation and his last public performance was at the age of forty-four[3].

Antonio Valsalva in 1704 was the first person to describe the stapes ankylosis as a cause of hearing loss when describing bony obliteration of the oval window in a patient of acquired deafness[3]. In 1841, Toynbee described fixation of the stapes to the margins of the oval window in 136 of 1000 temporal bone dissections. Politzer demonstrated the histology of otosclerosis and he identified the disease as an otic capsule disorder, characterized by abnormal new bone formation[4].

In 1872, Anton von Tröltsch coined the term otosclerosis, but did not make any difference between otosclerosis and tympanosclerosis[5]. Politzer, in 1894, recognized otosclerosis as the final stage of the disease with sclerotic plaques in the otic capsule[6].

Development of Surgical Management of Otosclerosis
Surgery for otosclerosis has developed through three distinct eras:
1) The mobilization era
2) The fenestration era
3) The stapedectomy era

The Mobilization Era
Prosper Meneire first reported mobilization of the stapes in 1842. In the late 1800s, Kessel attempted stapes mobilization without ossicular reconstruction in cases with ossicular fixation, thereby ushering inthe mobilization era. Kessel described a case in the mid-1800's wherein hearing improvement was noted following a skull fracture in a young man with otosclerosis. Unfortunately the patient expired due to complications of head injury, and postmortem examination of his temporal bones revealed a fracture running through the horizontal semicircular canal. Based on this

observation, Kessel tried to create a similar fistula in patients with otosclerosis using a hammer and gauge and hence, he is considered to be the actual founder of stapes surgery[7].

In 1891, Jackin Boston, USA, left the oval window open after removing the stapes. At the time, eminent contemporaries condemned the procedure due to its inherent risk off atal complications. The techniques introduced by Kessel and Jackdid not employ middle ear amplification structures, but allowed increased transmission of sound through the oval window. Also, any gains in hearing were frequently temporary because of refixation of any remaining stapes footplate.Fatal cases of meningitis were reported as occurring secondary to intraoperative exposure of perilymph to bacteria[8].

Several French otolaryngologists performed mobilization of the stapes, including Boucheron and Miot. In 1890, Miot published a series of 200 cases of stapes mobilizations, applying the antiseptic principles of Lister with cleansing of the ear canal and sterilization of instruments. The results of Miot's stapediolysis were quite good, with hearing improvement in 59% of ears. Schwartze and Lucae from Germany[9], Ferrari from Italy, Blake10 and Jack[8] from USA and Sexton[11] and Alderton[12] from New York carried out stapes mobiliza tion and removal of the stapes. Adam Politzer, Siebenmann and Moure, who were theleading otologists of their time, declared that stapes surgery was useless, dangerous and unethical at the 6th International Otology Congress in London[9].

The Fenestration Era

Passov suggested the promontory fenestration in 1897, and in 1899 Floderus suggested an opening of the vestibular labyrinth. This was described by Jenkins in London in 1913 as a fenestration of the lateral semicircular canal. In the 1920s, Nylen in Sweden was the first to use a microscope for ear surgery[13].

With the advent of the operating microscope, the fenestration era beganin 1923, when Gunnar Holmgren (who is considered the Father of fenestration surgery) created a fistula in the lateral semicircular canal and sealed it immediately with periosteum[14]. This procedure worked by allowing preferential sound conduction via the fistula instead of the ossicular chain. Holmgren's procedure was popularized during the 1930's by Sourdille in France, who developed a three-stage technique which was widely published[15]. A one-stage technique for horizontal semicircular canal fenestration was developed by Julius Lempert in New York, which went on to achieve international recognition after it proved to improve hearing. However, the seresults were fleeting as the fenestra often resealed with bone and the technique was further refined by others[16]. These surgeries were aided by the development of improved anaesthesia, lighting,operating microscopes, antiseptic techniques and antibiotics.John House described the double blue line technique to avoid drilling directly over the fenestra.

The Stapedectomy Era

The stapedectomy era was ushered in prior to the end of the fenestration era. It was in 1952 when Samuel Rosen from New York, tested the mobility of the stapes using a transcanal approach before a semicircular canal fenestration and hence, rediscovered that stapes mobilization causes hearing improvement[17]. John Shea Jr. later came to the conclusion that it must be possible to replace an otosclerotic stapes with a prosthesis. In collaboration with Treace, an engineer, he created a stapes prosthesis made of the biocompatible material Teflon. In a female patient with otosclerosis, after removal of the stapes and covering the oval window with a vein graft, he used this Teflon prosthesis for the first time on 1st May 1956 with complete success. After the Teflon stapes, Shea used a hollow polyethylene tube for a certain period of time, but this sometimes caused inner ear fistulae. Later,he used a piston made entirely of Teflon which is still used today by many surgeons[18]. In 1958, Shea advocated total stapes footplate removal when using the polyethylene strut prosthesis and a vein graft to seal the oval window. Shortly, thereafter Schuknecht advocated the use of wire and fat prosthesis[19].

Portmann and Claverie in 1957 and Zangemeister in 1958 suggested that the suprastructure of the stapes should be left in situ and one of the stapes crura used as an interposition. The advantages of this is that no foreign material is implanted. In 1960, Zollner replaced the extracted stapes with an autologous cortical bone chip whereas Pflatz made a graft with a cartilage chip. In 1960, Schuknecht developed a steel wire-adipose tissue prosthesis made directly during the operation, which had the disadvantage of lateral displacements of the wire[20].

In the 1960s, Plester suggested the technique of partial stapedectomy in which only the posterior third of the foot plate was removed. In 1961, the piston concept was introduced in which a cup or piston prosthesis was used with connective tissue graft of vein to seal the oval window. The classic cup/piston prosthesis was fabricated of 316 L stainless steel, an alloy that is inert in living tissues and is non magnetic.[21]

In 1962, Shea et al and Marquet and Martin made a small opening in the middle of the footplate into which the prosthesis piston fitted exactly, in order to reduce the inner ear risk. This initiated the era of "stapedotomy" which has continued till the present time. Reverse Stapedotomy was popularized by Fisch and involved insertion of a prosthesis before removal of suprastructure of stapes. The advantage of this technique was that the ossicular chain remained very stable during insertion of prosthesis. Intact tendon stapedotomy preserves blood supply to lenticular and long process of incus, prevents slipping of the prosthesis and protects the inner ear against loud noise. House and Greenfield[22] later advocated the use of wire with absorbable gelatin sponge (gelfoam) prosthesis. Use of wire/gelfoam or wire/fat prosthesis necessitated total removal of footplate for the wire prosthesis to function satisfactorily. Moon[23] advocated cup/piston prosthesis with areolar tissue. Glasscock[24] and Sheehy[25] and their associates Lippy and Schuring[26,27]advocated leaving the oval window neomembrane intact and undisturbed, if possible, in revision cases, to reduce the risk of severe SNHL. Feldman and Schuknecht[28], Pearman and Dawes[29], and Derlacki[30] reported opening the

neomembrane to identify the vestibule and ensure correct prosthesis placement.

Newer Advances And The Future Of Stapes Surgery

Perkins in 1980 performed laser surgery inotosclerosis for the first time. Laser Stapedotomy provides pinpoint accuracy and instantaneous cauterization minimising tissue trauma. The Argon laser has been more commonly used in stapedotomy because it has a visible wavelength and better accuracy which helps to prevent inner ear damage and also causes photo coagulation. Poe in 2000 advocated for laser-assisted endoscopic stapedectomy, which provides a better view of the surgery[31].

Laser stapedectomy minus prosthesis (LASER STAMP) is a physiological stapedectomy done in early cases of Otosclerosis involving the fissula ante fenestrum. In this procedure, the anterior crus is vapourised using Argon laser and the anterior third of the otosclerotic footplate is separated from the remaining stapes. Here, the posterior part of the footplate with the posterior crus and the incudostapedial joint, acts like a piston[32]. Most recently, Rothbaum et al from John Hopkins, Baltimore, have published a report on robot-assisted stapedotomy, specifically concerning the use of robot ics for micropick fenestration of the stapes surgery[33].

Conclusion

Stapes surgery has come a long way since its inception in the 1800s thanks to the efforts of the pioneers mentioned above, and many of the techniques developed by them persist today, albeit with many variations. However, the fundamental principle of re-establishing a mobile link between the tympanic membrane and vestibule has remained the objective of surgery for patients with otosclerosis. Although certain challenges linger, such as patients of otosclerosis with sensorineural hearing loss and vertigo, for now, the future looks bright for further development of surgery of the stapes.

The authors declare no conflict of interest.

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Fasting Unnecessary for Lipid Profile

Excluding Denmark, all other countries of the world require the patients to fast for at least 8 hours before undergoing tests for cholesterol and other components of lipid profile. In Denmark, non-fasting samples have been in use for lipid profile since 2009. The problem with fasting samples is one of compliance, particularly from children, senior citizens, diabetic patients and patients on certain drug therapies. Besides, Insistence on fasting makes it difficult to do population screening. Now an expert group representing the European Atherosclerosis society (EAS) and the European Federation of Clinical Chemistry and Laboratory Medicine (EFLM) have recommended that non-fasting samples are adequate for majority of the patients for the estimation of cholesterol and other lipid components. This recommendation comes after careful evaluation of research done in USA, Canada and Denmark covering well over 300,000 study subjects. However, fasting sample is required when triglyceride levels are more than 440/dL (5 mmol/L) (European Heart Journal, doi: 10. 1093/eurheartj/ehw152, published online26 April 2016).

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