

Tympanoplasty and Ossiculoplasty

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Abstract

Introduction: Since the first article about the reconstruction of the sound waves and the conduction of sound has been published continuous and restless effort in both measurement ways were included in reconstructive middle ear surgery.

Aim: In this review we will be discussing the outcomes of tympanoplasty operations and its outcomes as well as the factor influencing and affecting such operations.

Methods: We did a systematic search for tympanoplasty, procedural details and complications using PubMed search and Google Scholar search engine.

Conclusion: In summary, a very important point that the surgeons should be aware of is not to make any changes that can affect the sound transitions function while operating. From the view of surgeons, implementing a prosthesis require certain positioning and manipulation.

Keywords: Tympanoplasty; Middle Ear; Surgery

Introduction

The recent reviews on this topic have discussed biomechanics of the middle ear, of prostheses and prosthetic materials and of surgery as well as reconstruction techniques [1-3].

In this review we will be discussing the outcomes of tympanoplasty operations and its outcomes as well as the factor influencing and affecting such operations. The aim of this review is to identify and recognize the most important parameters that affect and influence the outcome of the tympanoplasty operations.

Methodology

We did a systematic search for tympanoplasty, and its procedural details and complications using PubMed search engine (<http://www.ncbi.nlm.nih.gov/>) and Google Scholar search engine (<https://scholar.google.com>). All relevant studies were retrieved and discussed. We only included full articles.

Quality assessment in reconstructive middle ear surgery

Recently, there have been increasing efforts to define new methods to assess the quality of reconstructive middle ear surgery. Besides the clinical and audiological outcomes after tympanoplasty, there has been increasing attention in patient-related aspects such as the health-related quality of life (HRQoL). In order to decide the success of the tympanoplasty, the patient must be able to manage his everyday life and to communicate successfully with others. But as the intraoperative and postoperative hearing assessment after tympanoplasty does not offer a complete statement about the outcome of the operation, more details about the quality of the everyday life after the operation is needed to determine the degree of success of the operation. The process chain that determines the quality tympanoplasty starts usually with the description of the preoperative situation, this includes the surgical technique and ends a long time after final wound healing at least one year after the surgery according to the clinical status of the patient.

Assessment parameters of tympanoplasty

Many functional tests are done to assess the success and surgical outcome after middle ear reconstruction. In addition to the pre- and postoperative status of the patient regarding the inflammation and the recurrences of the causative condition or the necessity of surgical revision or correction.

Audiological parameters

Regarding the functional aspects, pure tone audiometry is considered to be the most important instrument in determining the degree of success of middle ear reconstruction surgery, it also has the advantage of providing test that other tests can be compared and connected with, as the audiological tests are considered to be very accurate tools [4].

Air-bone gap (ABG) is defined as the difference in threshold between the air and bone tissue, ABG is usually is measured right after the surgical operations, as it is considered to be one of the best tests to assess the quality of the surgery. Many factors can affect the value of the ABG, it can be affected by any difference in the air conduction threshold, or the bone conduction threshold. Many previous studies have investigated the effect of the difference in bone conduction on the value of ABG [5]. However, in real life, the value of the ABG is calculated by calculating the difference between the postoperative air conduction threshold and the preoperative bone conduction threshold [6].

Speech audiometry is another test that is used to examine the functions after tympanoplasty. However, there are no recommendations regarding the way the test is done or the results are documented in order to use such a test to assess the functions after tympanoplasty [7]. Thus, such a test is rarely to assess the hearing functions after surgeries.

A previously published literature review identified more than 160 papers discussing the topic of hearing improvement surgery between 2005 and 2015; 41% of it did not provide the results as average with standard deviation; so it cannot be used in meta-analysis and further analysis. With more than 15% of it providing no data regarding the frequency range, and only 4% of it performed Speech audiometry. In order to make a fine comparison between several studies regarding the hearing results, it is essential to include data regarding the frequency range. So, the fact that many publications were published in peer-reviewed ENT journal which lacks such information [8].

Health-related quality of life (HRQoL)

Recently, there has been an increasing interest in the instrument that helps measure the quality of life-related to the various health issues (HRQoL), and as an outcome of the surgery, it is becoming more and more important [9]. Such interest in the quality of life is heavily outlined in the outcomes of the different otology operations [10]. The HRQoL is considered to be consisted of multiple factors that cover 4 main outlines: the physical complaints of the patient, the overall physical status of the patient, the effect of disorder on his life, and its effect on his relations with his environment. As every different disease has its own different symptoms, HRQoL must be assessed differently for every single disease. Regarding the field of otology [11].

Factors influencing the hearing result

There are many other factors that affect the final hearing outcomes after tympanoplasty, other than the outcomes of the actual surgery, like middle ear ventilation, any underlying pathology, the condition of the ear mucosa and many other factors. After tympanoplasty, while assessing the outcomes of the surgery most publications focus on three: assessing the surgical technique, the condition and outcome of the operation comparing to similar cases, and the prognosis if the cases [13].

Right now, many assessment systems exist that focus on different aspects such as Wullstein classification that focuses on the postoperative hearing results, Bellucci's assessment system depends on the liability to develop middle ear infection, and Wullstein described a system that assesses the outcomes of the surgery according to the surgical reconstruction technique [14].

Quality control in reconstructive middle ear surgery

Due to the anatomy and physiology of the middle ear, the surgeon has so limited ways to assess the quality of the tympanoplasty and to detect any possible cause of failure. Intraoperative, an assessment system depends on electromagnetic stimulation and laser vibrometry, allows the surgeon to adjust and tune the reconstruction process. While postoperative, different imaging technologies are used to identify the cause of any residual conductive hearing loss.

Intraoperative assessment of the reconstruction quality

During the surgery, real-time feedback can be very important and can prevent many possible complications. In some cases, ossiculoplasty operations are formed under local anesthesia, allowing the patient to give direct feedback during the ossicular reconstruction. Allowing further intraoperative adjustment and manipulation of the prosthesis such as change of the coupling, length or position between the ossicular remnants or the reconstructed eardrum which can lead to a better outcome of the surgery.

In cases of operations performed under general anesthesia, the surgeon can assess the quality of his work depending on a combination of a mechanical stimulation and an optical measurement (LDV) of the ossicular vibration [15].

Real-time feedback and ossiculoplasty monitoring

During operations, surgeons can rely on a series of mechanical stimulation of the ossicular chain combined with electromagnetic stimulation to assess the quality of his work, allowing him to make minor changes and manipulations to the prosthesis with real-time feedback [16,17].

Postoperative quality control by means of imaging

Postoperatively, the evaluation of conductive hearing loss is considered to be challenging, as the reconstructed area cannot be accessed. Many postoperative complications such as prosthesis dislocation. In such cases, surgical exploration and correction are considered to be the best possible choice [18].

Many studies recognize computed tomography to be the best pre- and post-operative imaging technique to assess the status of the middle ear. In cases of metallic middle ear prostheses, the significance of CT is considered to be limited due to the radiological impermeability of metals [19]. In such cases, non-metallic hydroxyl apatite prostheses to allow visibility when using CT [20]. Other non-invasive radiological modalities used are Rotational tomography (RT) and cone-beam tomography (CBT). Such modalities allows better visual angles to access the ossicles without the disadvantages of regular conventional CT [21].

Postoperative RT can be used for assessing the quality of the surgery postoperatively, it can provide information about the state and position of the prosthesis.

Development of functional elements for middle ear prostheses

The middle ear serves many other purposes other than transmitting the sound waves, such as adjusting air pressure variations. Many anatomical components that participate in regulating the air pressure (the eardrum, the ossicles, and the ligaments) are removed in cases of prosthetic middle ear reconstruction. In such cases, the removed components are replaced with titanium prosthetic parts as titanium allows excellent sound transmission.

Malleus (manubrium) prostheses

The malleus hand (manubrium) has a very important effect on the postoperative hearing results. There have been huge efforts to construct prosthetic manubrium for cases with destroyed manubrium [22]. Malleus is usually replaced using titanium replacement prosthesis that is fixed into the bone part of the auditory canal. Such a technique of replacement minimizes the risk prosthesis dislocation.

Postoperatively, no difference in the sound transferring function have been recorded after malleus replacement operations. Furthermore, after replacement operations, better sound transferring function have been recorded due to the properties of titanium. The use of titanium prosthesis have many other advantages like the additional stabilization of the prostheses [23].

Head plate

Usually, the head palate prosthesis is connected to the strut and the tympanic membrane, in order to ensure functional sound transition function and avoid dislocation of the prosthesis from the tympanic membrane, the connection of the head palate connection to the surrounding parts could be needed [24].

Due to the dynamic nature of the connection between the implanted eardrum and the middle ear, the implanting process of an eardrum requires an optimized middle ear prosthesis. The angle between the reconstructed eardrum and the vertical stapes axis rarely amounts to the 90° that is manufactured between the prosthesis stem and the head plate [25]. In such a situation, during the process of wound healing, the head plate passively adapts with the dynamic changes, thus, changing the position of the eardrum. Furthermore, such change has a positive on the atmospheric pressure gradient. Many clinical trials confirmed the results of the previously mentioned experiment [26]. In cases of total prostheses using, the further challenge of fixing an opponent with angular variability which makes establishing a stable position during the operation very difficult. In such cases, many studies recommended the use of centering devices [27].

Prosthesis strut

Another solution to avoid any solid connection between the eardrum and the footplate, and to prevent any pressure variation is to insert a joint in the prosthesis strut [28]. In such cases we replace the static prosthesis stem with a resilient joint influenced from the middle ear of birds that contains a columella which in cases of pressure changes shifts to the inside protecting the inner ear from ant pressure induced damage [29]. Some recent experiments found that the use of silicone in the joints which provides a resilient joint with reset effect and suggest a very promising results [30].

Prosthesis foot

The connection between the ossicles and the implanted prosthesis have significant effects on the outcome of the surgery, it can provide a stable connection which helps avoiding any prosthesis dislocation. On the other hand, the angular connection provide a connection with the eardrum that ensure effective transmission of sound waves. One side effect of such model is the possibility of fractures is high especially with intensive pressure. The solution of this problem is to use a connection that provides distribution of the pressure on a larger surface [27].

Influence and properties of the annular ligament

All of the previous components and techniques are used to maintain the function of keeping the atmospheric the pressure balanced in the middle ear. In cases of connections with balanced atmospheric pressure and a tight connection between the eardrum and the stapes rehabilitation programs must be started to regain the function of sound wave transmission and regain hearing function. Some studies recommend the use of a prosthesis longer than the anatomical requirement in order to prevent any risk of dislocation following the surgery or during the process of tissue healing [3].

On the other hand, a prostheses implant that is too long may lead to increasing the tension on the annular ligament and the eardrum. A too long prostheses may also lead to impaired transmission of sound and vibrations through the middle ear [32]. Thus the only way to achieve the optimal fit is to insert the prostheses and then adjusting the fit according to the resulting transmission properties measured intraoperative. Better transmission function was also reported with longer a higher prosthesis fixation.

Recent studies investigated the connection between the prosthesis length and the development of annular ligament and tympanic membrane stiffness, and found that the longer distance between the eardrum and the footplate is associated with low tympanic membrane stiffness over longer distances [33]. The increased tension on the annular ligament have a negative effect on the sound transmission function [31].

A point to pay attention to, is that all the above mentioned tests and investigations were performed on human corpse. We still have no idea how the human body will adapt with the tension in the annular ligament on the course of time. There is a possibility that the living human body will adapt and remodel the arrangement of the collagen fibers in the ligament, or even develop a new resting position for the ligament with the optimal tension required for the function of sound transmission. Another point to take into consideration is that the eardrum is usually covered with a cartilaginous membrane after being reconstructed. This could change its elastic functions and affect its ability to transmit sound waves comparing to the natural tympanic membrane.

Conclusion

In summary, a very important point that the surgeons should be aware of is not to make any changes that can affect the sound transitions function while operating as any impairment in the transmission function can be enhanced with the process of healing and adapting. From the view of surgeons, implementing a prostheses require certain positioning and manipulation. Thus, a certain level of unavoidable tension could be performed on the different tissues and components. Surgeons must be wear of such risk and take it into consideration.

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