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Original Article

Cartilage Ossiculoplasty from Stapes to Tympanic Membrane in One-Stage Intact Canal Wall Tympanoplasty for Cholesteatoma

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OBJECTIVE: To report hearing results of cartilage interposition ossiculoplasty in one-stage intact canal wall (ICW) tympanoplasty for cholesteatoma with intact stapes.

MATERIALS and METHODS: A retrospective study of pre and postoperative hearing status was conducted at a tertiary referral otologic center in a series of 61 patients having undergone one-stage ICW tympanoplasty for cholesteatoma with intact stapes and cartilage ossiculoplasty during the same procedure.

RESULTS: In the preoperative period, the mean air conduction thresholds (AC), air-bone gap (ABG), and speech reception thresholds (SRT) were 35.3, 20.14, and 35.6 dB, respectively. Postoperatively, with a mean follow-up of 29 months, AC, ABG, and SRT were 27.8, 13.34, and 28.8 dB, respectively. Mean hearing gain was 6.8 dB and mean SRT improvement was 6.8 dB. Mean bone conduction thresholds for 1, 2, and 4 kHz remained stable after surgery (17.6 dB preoperatively vs. 18 dB postoperatively).

CONCLUSION: Cartilage ossiculoplasty from stapes to tympanic membrane in one-stage ICW tympanoplasty for cholesteatoma is a safe, reliable, easy, and effective procedure, with no additional cost.

Keywords: Ossiculoplasty, cartilage, stapes, cholesteatoma, tympanoplasty

INTRODUCTION

The double cartilage block ossiculoplasty for partial ossicular reconstruction in the presence of an intact stapes was described in 1987 by Luetje and Denninghoff [1]. This technique offers several advantages–it is easy to perform, uses well-tolerated autologous materials, and has no additional cost. Despite those advantages and encouraging hearing results, this interesting ossiculoplasty technique is not very popular among otologists.

For several years we have routinely used this technique at our institution, and we commonly refer to it as cartilage ossiculoplasty from stapes to tympanic membrane (COST). We decided to evaluate our results with this technique in a retrospective case-control study and to compare these to results published in studies dealing with other partial ossicular chain reconstruction techniques.

To obtain a homogenous series, we selected patients having undergone a COST during a one-stage intact canal wall tympanoplasty (ICW) for cholesteatoma, even if this condition is probably one of the worst for achieving good hearing results.

MATERIALS and METHODS

Among all surgical procedures performed at our institution for chronic otitis media between January 1999 and August 2006, we retrospectively selected the files of patients having undergone a COST during a primary one-stage ICW for middle ear and/or mastoid acquired cholesteatoma. We excluded ossiculoplasty procedures performed in case of chronic otitis media without cholesteatoma, canal wall-down tympanoplasties (CWD), ICW with staged ossiculoplasty, ossiculoplasties performed with other material than cartilage (incus, malleus head, hydroxyapatite, or titanium prosthesis), and cases where the stapes superstructure was missing. ICW included transcanal removal of a middle ear cholesteatoma and canal wall-up tympanoplasty.

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The study was approved by our Institutional Ethical Committee (CE_20160926_6_DAE), which did not request informed consent for this retrospective study.

All of the procedures were performed under general anesthesia via a postauricular incision. A large piece of tragal cartilage was harvested with its perichondrium through an additional incision at the posterior part of the tragus. The cartilage was not only used for the ossiculoplasty, but also to reconstruct the tympanic membrane and attic wall. The ossiculoplasty was performed at the end of the procedure after having removed the cholesteatoma and reconstructed the tympanic membrane and attic wall. After having stripped the perichondrium from both sides, one or two small pieces of cartilage, depending on the depth of the middle ear cleft, were prepared and interposed between the head of the stapes and the tympanic membrane (previously reinforced by cartilage). The placement of the cartilage plates was performed through the external auditory canal (Figure 1). When cholesteatoma involved the stapes, and even if the removal seemed complete, we usually interposed a sheet of silastic between the stapes and the cartilage. The aim of this additional procedure was to facilitate a potential revision surgery in case of residual disease, even if we were aware that interposing silastic makes the ossiculoplasty less stable.

Hearing results were evaluated by comparing the preoperative hearing test, usually performed the day before surgery, and the last available postoperative hearing test following the guidelines of the American Academy of Otolaryngology - Head and Neck Surgery [2]. Pure-tone audiometry was used to report the mean postoperative air-bone gap (ABG), the hearing gain, and the status of the inner ear. The mean postoperative ABG was calculated as the difference between the postoperative air conduction (AC) and bone conduction (BC) thresholds at frequencies of 0.5, 1, 2, and 3 kHz. The postoperative ABG was reported in the following categories: less than 10 dB, 11 to 20 dB, 21 to 30 dB, and greater than 30 dB. The average hearing gain (number of decibels of closure of the ABG) was calculated as the difference between the preoperative and the postoperative ABG at frequencies of 0.5, 1, 2, and 3 kHz. The status of the inner ear was determined as the preoperative minus the postoperative high pure-tone BC average at 1, 2, and 4 kHz. Overclosure yields positive numbers and postoperative inner damage yields negative numbers, and these were arbitrarily considered significant when ≥10 dB. Results of speech audiometry were reported using the Speech Reception Threshold at 50% (SRT_{50} expressed in dB).

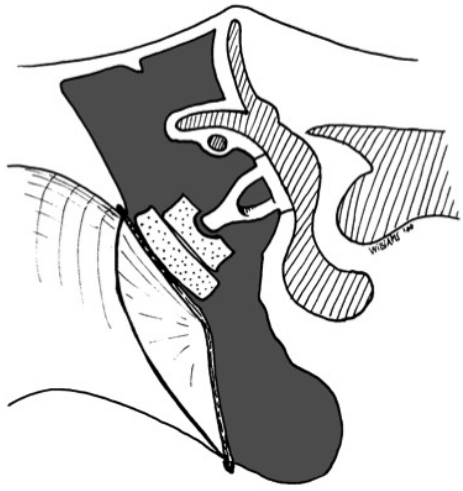

Figure 1. Drawing of COST, with two pieces of cartilage interposed between the stapes capitulum and tympanic membrane (courtesy of M.T Williams, MD, Department of Medical Imaging, Fondation A. de Rothschild, Paris, France)

Postoperative follow-up was based on repeated otoscopic and audiometric evaluation, and postoperative imaging evaluation, which was performed between 12 and 18 months after the procedure. During the study period, particularly at the beginning, CT scan was the first-line imaging modality [3], according to a previously published algorithm [4]. All patients underwent CT scan, and some underwent MRI with special protocols to detect cholesteatoma when CT scan was not conclusive (delayed postcontrast T1 and/or diffusion weighted MR imaging), except one who was lost of follow-up after 3 months. Indications for revision surgery were selected according to clinical, audiometric, and radiological data.

For reporting hearing results in case of revision surgery, we took into account the last available audiometric data if primary cartilage ossiculoplasty was not modified, and we took into account the pre-revision audiometric data in case of ossiculoplasty revision.

Hearing results were reported for the whole cohort and for two subgroups according to the ventilation status of postoperative tympanomastoid cavities found on CT scan (completely aerated vs. partial or complete opacity).

Statistical Analysis

Chi^2 test and Fischer's exact test were used for statistical analysis. The criterion for statistical significance was set at $p<0.05$.

RESULTS

Sixty-one patients (61 ears) were included in the study (38 men and 23 women; mean age of 41.7 years at the time of surgery ranging from 6 to 74 years old). The mean follow-up was 29 months, ranging from 3 to 82 months.

There were no cases of cartilage ossiculoplasty extrusion.

In 60 patients (1 case was lost of follow-up at 3 months), recurrent cholesteatoma occurred in seven cases (10.6%), with five residual cholesteatomas and two relapsing cholesteatoma. Except for the two cases of relapsing cholesteatoma occurring through a recurrent retraction pocket of the attic, the 58 other cases had good anatomical results, with closed and unretracted tympanic membrane and stable cartilage reconstruction of the atticotomy.

Pre and postoperative hearing results are presented in Table 1. A less than 20dB ABG was observed postoperatively in 85.2% compared to 59% preoperatively. No dead ears were encountered postoperatively.

The cohort included 9 children (<18 years old) and 52 adults. Results of the two subgroups are presented in Table 2. Statistical analysis showed a significant difference when comparing preoperative ABG in the two subgroups (p=0.0077). Otherwise, no difference was observed between the two subgroups for the other data.

Table 1. Summary of pre and postoperative hearing results

	Preoperative data	Postoperative data
Mean ABG (0.5-1-2-3 kHz)	21 dB [5–46.9]	13 dB [0.6–42.5]
Pure tone postop gain		8 dB
ABG=0 – 20 dB	36/61 59%	52/61 85.2%
ABG=21 – 30 dB	13/61 21.3%	4/61 6.6%
ABG > 30 dB	12/61 19.7%	5/61 8.2%
SRT_{50}	36 dB	29 dB
Speech postop gain		7 dB
Mean HF-BC (1-2-4 kHz)	17 dB	18 dB

ABG: air-bone gap; SRT: speech reception thresholds; HF-BC: high-frequency bone conduction

Table 2. Pre and postoperative results in children (<18 years old) and adults (≥18 years old)

	Children (n=9)		Adults (n=52)	
	Preop	Postop	Preop	Postop
Mean ABG	13	10	22	14
Pure tone gain		3		8
ABG 0-20	9	9	27	43
ABG 21-30	0	0	13	4
ABG > 30	0	0	12	5
SRT50	20	14	39	31
Speech gain		6		8
HF-BC 1-2-4	7	6	19	20

ABG: air-bone gap; SRT: speech reception thresholds; HF-BC: high-frequency bone conduction

Table 3. Postoperative ABG in well-aerated and poorly aerated tympanomastoid cavities (TMC)

Postoperative ABG	Well-aerated TMC	Poorly aerated TMC
0 – 20 dB	26	24
> 20 dB	1	8
Total	27	32

ABG: air-bone gap; TMC: tympanomastoid cavity

Analysis of tympano-mastoid cavities was made on 59 patients: 27 were totally aerated (45.7%) and 32 presented a complete or partial opacity of the cavity (54.3%). Postoperative hearing results are summarized in table 3. A less than 20 dB postoperative ABG was observed in 96% of the well-aerated group versus 75% of the group with complete or partial opacity. The difference was statistically significant (p=0.03).

DISCUSSION

Numerous ossiculoplasty procedures using either synthetic or autologous materials have been previously described and the results have been widely reported in the literature. Several synthetic prostheses are available, but nowadays hydroxyapatite and titanium are the most often used. Autologous material mainly consists of ossicles (incus or malleus head) or cortical bone. Results are roughly the same whatever the material used, particularly in the presence of a mobile stapes. Autologous material offers two major advantages over synthetic prostheses– better tolerance and no additional cost. On the other hand, ossicles are not always available and the proper surgical technique is more complex, which are limitations in performing ossiculoplasty with autologous bone, particularly for less experienced surgeons.

For several decades, cartilage has been the material of choice for middle ear surgery. It is mainly used for reconstructing the tympanic membrane or the external auditory canal. Surprisingly, this easily available autologous material has not been shown the same interest for ossicular reconstruction. The lack of stiffness of the cartilage is the major reason for the poor interest in ossiculoplasty. This is probably true for total ossicular reconstruction, but some papers showed promising and reliable results in partial ossicular reconstruction [5, 6]. In 1987, Luetje and Denninghoff reported the double cartilage block ossiculoplasty as an alternative to a partial ossicular replacement prosthesis (PORP), particularly in CWD procedures [1]. They found better hearing results in the cartilage group than in the PORP group, with closure of the ABG to within 20 dB in 79% and 56% of patients, respectively. No extrusion was observed with the cartilage technique, while two PORPs (8%) extruded. Harvey and Lin [7] reported a small series of CWD and double cartilage block ossiculoplasty with less favorable hearing results. Closure of the ABG to within 20 dB was achieved in only 50% of their series. Nevertheless, the series was made of aggressive middle ear diseases (active draining at the time of surgery in 83% and revision procedures in 74%) with poor hearing prognosis. They also reported no cases of extrusion. In 2007, Kyrodimos et al. [8] presented their experience of the so-called "type III cartilage shield tympanoplasty," which consisted of repairing large tympanic membrane perforation and ossicular discontinuity with one piece of full thickness conchal cartilage shaped as a shield. They used the cartilage shield to replace the entire tympanic membrane and reconstructed sound transmission by placing the cartilage on the head of the stapes. They reported a successful graft take in 100% of the patients and a closure of the ABG to within 25 dB in 78.8%. Malafronte et al. [9] modified the original double cartilage block ossiculoplasty by leaving the perichondrium attached to the cartilage surface in contact with the tympanic membrane to improve adhesion between these two structures. With this slightly modified technique, the success rate was 81.1% with no cases of extrusion. In an exclusive large pediatric cohort, Nevoux et al. [10] reported the results of the cartilage shield tympanoplasty technique. Unlike Kyrodimos et al. [8], Nevoux et al. [10] interposed two additional pieces of cartilage between the stapes capitulum. At 1 year, closure of the ABG to within 20 dB was achieved in 62.2% of the cases, which is an interesting result in children taking into account the frequent onset of otitis media with effusion in the pediatric population. Once again, no cases of extrusion occurred. With no cases of extrusion and an 85.2% rate of ABG closure to within 20 dB, our results are in accordance with other published series.

Reconstructing sound transmission in case of intact stapes and missing or eroded incus can be done with various materials other than

cartilage, including autologous ossicles (mainly the incus), autologous cortical bone, or synthetic prostheses, nowadays almost exclusively represented by hydroxyapatite and titanium [11]. Among these materials, none has clearly demonstrated its superiority over the others. According to the literature, closure of the ABG to within 20 dB ranges from 60% to 85% with incus interposition [12-14], from 57% to 84% with hydroxyapatite [11], and from 60% to 81% with titanium [15-18]. Most papers comparing hearing outcomes of various ossiculoplasty materials have come to similar conclusions [19-24]. In 2014, Querat et al. [25] compared the results of cartilage ossiculoplasty and partial titanium ossiculoplasty with intact stapes in canal wall-up procedures for cholesteatoma and did not find any significant difference between the two materials.

The type of material used and the correct location of the ossiculoplasty are not the only factors affecting hearing results. Thanks to imaging follow-up, we found that closure of the ABG to within 20 dB was achieved in 96% of cases in which the tympanomastoid cavities were aerated and in 75% of cases in which the tympanomastoid cavities were filled with soft tissue. This difference was statistically significant. Unfortunately, because of the retrospective design of our study and the small size of the subgroups, we were unable to split the non-aerated subgroup into middle ear or mastoid or middle ear+-mastoid. Merchant et al. [26] and Chien et al. [27] found larger postoperative ABG in case of stapes fixation or nonaeration of the middle ear. Other authors also demonstrated the major role of aeration of the middle ear, or at least aeration around the stapes, in achieving better postoperative hearing results [28, 29].

CONCLUSION

Cartilage ossiculoplasty in intact canal wall tympanoplasty with intact stapes is a safe, simple, reliable, and effective procedure. Hearing results are at least as good as with other materials. Compared to synthetic prostheses, cartilage ossiculoplasty offers better biocompatibility and no additional cost.

Ethics Committee Approval: The study was approved by our Institutional Ethical Committee (CE_20160926_6_DAE).

Informed Consent: Our institutional ethical committee did not request informed consent for this retrospective study.

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