

## ORIGINAL ARTICLE

# Functional Middle Ear and Mastoid Surgery ( FMMS )

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**Objective:** To present a new surgical concept, functional middle ear and mastoid surgery (FMMS), which is aimed to improve the results of chronic ear surgery in the 21st century .

**Setting:** Tertiary Care Center

**Study Design:** Clinical Prospective Study.

**Methods:** A surgical roadmap, based on a new clinico-radiological staging system (TMC) of middle ear cholesteatoma, is outlined.

**Patients:** 120 patients of tympanomastoid cholesteatoma were included in this study. They were preoperatively staged, operated by (FMMS) system, followed up and results reported.

**Results:** Anterior tympanotomy was done in all the cases. Intact canal wall mastoidectomy was done in 79 percent, while open mastoidectomy was performed in 11 percent, and no mastoidectomy was required in 10 percent of the cases. Residual and recurrent cholesteatoma was found in 6.7 percent (6/95) of cases, all after Intact canal wall (ICW) mastoidectomy. The overall (n=120) pre- and post-operative (at least 12 months after surgery) four frequency PTA-ABG were  $33.40 \pm 7.22$  dB and  $12.42 \pm 5.6$  dB.

**Conclusions:** Due to the changing trends in the presentations of chronic ear disease , as well as the advances in its diagnosis and treatment, FMMS presents a logical surgical solution for tympano-mastoid cholesteatoma in the 21st century It stresses the fact that the middle ear should be the primary target of otosurgeons to clear pathology and reconstruct the hearing mechanism. Mastoidectomy is performed, only if necessary, to approach the middle ear posteriorly and to clear pathology extensions if needed.

Submitted : 29 March 2012

Revised : 30 September 2012

Accepted : 02 January 2013

## Introduction

Mastoidectomy has classically been the treatment of middle ear cholesteatoma for more than one hundred years. In 1890, Zaufal introduced radical mastoidectomy to treat chronically draining ears. Modified radical mastoidectomy was introduced in 1910 by Bondy. In 1958, Sheehy and Jansen almost simultaneously, performed intact canal wall mastoidectomy. Since then, otologists argued the pros and cons of open versus closed mastoidectomy. There was no much concern whether mastoidectomy is needed in every case of cholesteatoma or not. <sup>[1-3]</sup>

Cholesteatoma is a middle ear disease in almost all the cases, and extends in varying percentages to the mastoid according to its pathological type. Mastoid involvement by cholesteatoma varies from 20 percent in the congenital type to 60 percent in secondary acquired and 80 percent in primary acquired types according to their site of origin and pathways of spread. On the other hand, residual cholesteatoma following open or closed cavity mastoidectomy occurs mostly in the middle ear (20 to 30 percent), and occasionally in 6 percent of the cases in the mastoid.<sup>[4-7]</sup>

Otosurgeons have long been trained that cholesteatoma surgery is “mastoidectomy”. They start the operation

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doing a meticulous mastoidectomy. By the time they reach the middle ear, where most of the cholesteatoma is, and important anatomical structures lie around e.g. ossicles and facial nerve, the surgeon is usually tired. The result is a perfect mastoid cavity, residual cholesteatoma in the middle ear and less than satisfactory functional restoration of hearing.

The 21<sup>st</sup> century brought many advances in the diagnosis and treatment of otitis media. Early diagnosis, the use of preventive measures like pneumococcal vaccination, increased rate of early myringotomy and grommet tubes, advanced imaging techniques and introduction of endoscopes, all lead to the diagnosis of retraction pockets and atelectatic eardrums, as well as cholesteatoma in its early stages, congenital cholesteatoma, secondary cholesteatoma to retraction pockets and atelectatic eardrums. Massive cholesteatoma with complications are uncommon now.<sup>[8,9]</sup>

Increased interest in temporal bone dissection courses as well as otology fellowships produced a new generation of well trained otosurgeons. The introduction of endoscopic ear surgery and the use of endoscopes for meticulous removal of pathology in inaccessible areas of the middle ear has definitely improved the results of chronic ear surgery in the 21<sup>st</sup> century.<sup>[10,11]</sup>

What we need now is a new concept emphasizing the middle ear approach first, to remove pathology as much as required, preserve middle ear mucous membrane and aeration, do mastoidectomy only when needed, and reconstruct the tympano-ossicular chain. This concept, we called Functional Middle ear and Mastoid Surgery "FMMS".

## Materials and Methods

The study was carried prospectively on 120 patients seen with middle ear cholesteatoma in the period from January 2005 to December 2010. The cases were clinically examined and CT was ordered for each case then it was staged according to TMC staging system suggested by Belal (2005).<sup>[12]</sup>

Functional middle ear and mastoid surgery (FMMS) was performed on all the cases according to the surgical roadmap outlined in Table 1. The roadmap correlates the type of the surgical procedure done according to the TMC stage of cholesteatoma. All the surgery was performed by the senior author (AB) as a single stage procedure.

30° and 70° endoscopes were utilized to control the disease in the anterior epitympanum and sinus tympani. Ossiculoplasty was performed with the patient's own ossicles (autograft). Middle ear and mastoid disease, age, sex, type of ossiculoplasty, pre- and post-operative audiograms, postoperative findings and follow up time were recorded.

Reviewed parameters were the graft take, change in PTA- ABG at each of four frequencies (0, 5, 1, 2, 4 KHZ) and complications such as reperforation, and recurrent cholesteatoma.

### **Surgical Technique:**

FMMS is done in 3 steps:

Proper exposure of the middle ear (anterior ± posterior) ± mastoid

Complete clearance of pathology

Functional restoration of the middle ear and hearing mechanism.

### **Step 1 : Proper Exposure**

Proper exposure of the middle ear and mastoid is crucial for proper clearance of pathology.

#### **A. Anterior Middle Ear Exposure:**

Anterior Exposure of the middle ear (Anterior Tympanotomy) is done by soft tissue and bone dissection. Soft tissue dissection is carried by either the classical tympanomeatal (TM) flap (Fig. 1) or by Extended Anterior Tympanotomy approach dissecting the TM flap from the periosteum of the malleus handle

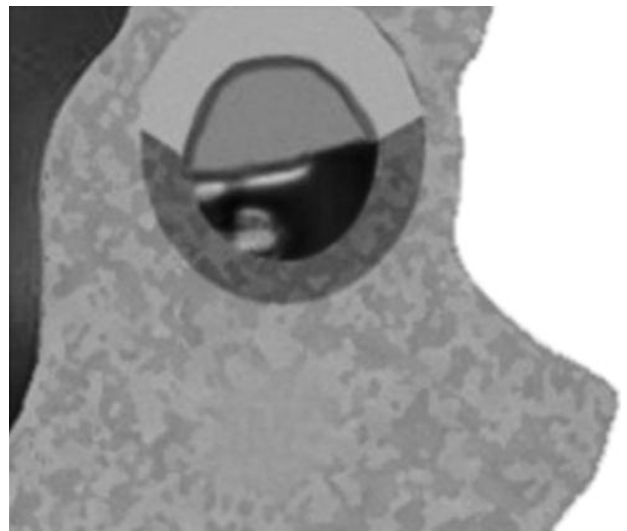


Figure 1. Anterior Tympanotomy

(Fig. 2). This extends the approach anteriorly to expose the protympanum and eustachian tube orifice. This is followed by (transcanal) bony dissection of the medial rim of the external canal (annulus attachment) to expose the middle ear. It includes: retro-tympanotomy, anterior atticotomy, anterior epi-tympanotomy and hypo-tympanotomy.

*Retro-tympanotomy*: is done by drilling the bony edge of the posterior auditory canal wall to expose the posterior tympanum. The limits of the exposure are the stapedius tendon, pyramidal eminence, round window and hypotympanic cell tract (Fig. 3).

*Hypo-tympanotomy*: will give additional exposure inferiorly (Fig. 4).

*Anterior Atticotomy*: is done by extending the bony exposure superiorly and forwards by removal of the scutum and exposure of the malleus head articulating with the incus body. Removal of the incus after separation of incudo-stapedial articulation is necessary to complete the atticotomy (Fig. 5).

*Anterior Epi-tympanotomy*: is done by further extension forward to expose the anterior epitympanic recess and eustachian tube orifice. This necessitates removal of the malleus head after cutting the tendon of the tensor tympani (Fig. 6).

*Bony Canaloplasty*: (posterior, superior and inferior) may be required if the bony external canal is narrow, or if additional exposure to the middle ear is required. Anterior

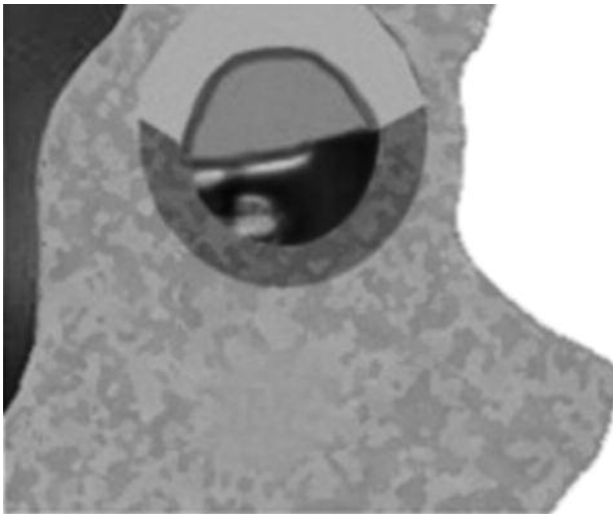


Figure 2. Extended anterior tympanotomy

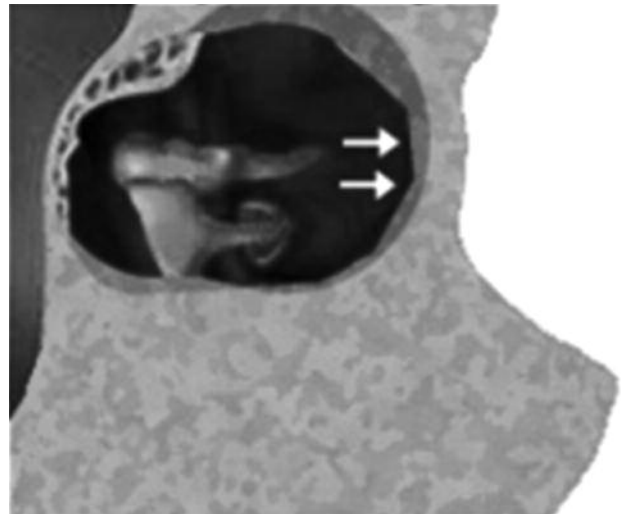


Figure 4. Hypo-tympanotomy

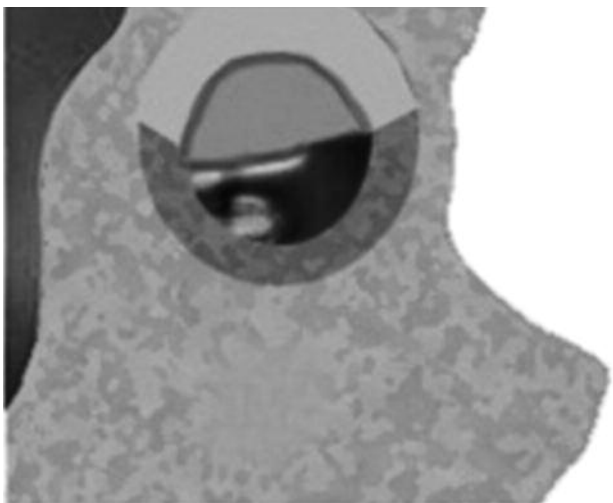


Figure 3. Retro-tympanotomy

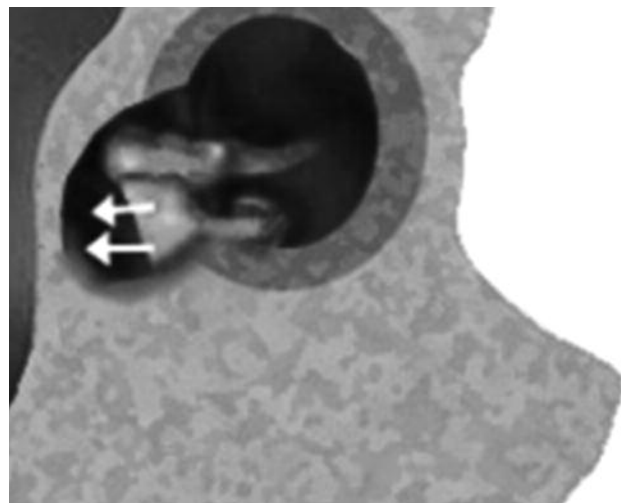


Figure 5. Anterior atticotomy

canaloplasty, after reflection of anterior canal skin upwards, may be required when grafting total perforations (Fig. 7).

**B. Posterior Exposure of the middle ear:**

This is done through mastoidectomy. Complete mastoidectomy is necessary in advanced mastoid disease according to the stage of the disease (M2). Limited mastoidectomy for exposure is done if the pathology is limited (M1). Intact canal wall (ICW) mastoidectomy is usually adequate for most of the cases. Open ( canal wall down ) technique is reserved for certain anatomical variations involving the sigmoid sinus and middle fossa dural plate, and in cases associated with intracranial

complications ( C2) or when the disease has destroyed the posterior canal wall. Posterior exposure techniques include:

*Posterior atticotomy:* is done by anterior extension of the mastoid approach to expose the attic from behind (Fig. 8).

*Posterior Epi-tympanotomy:* is done by extending the posterior atticotomy to expose the anterior epitympanic recess and eustachian tube orifice (Fig. 9).

*Posterior Tympanotomy (Facial recess approach):* is necessary to expose the facial recess from the mastoid side (Fig. 10).

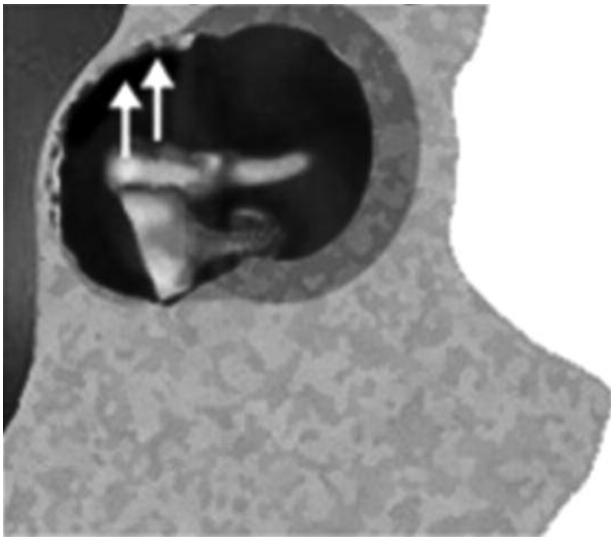


Figure 6. Anterior Epi-tympanotomy

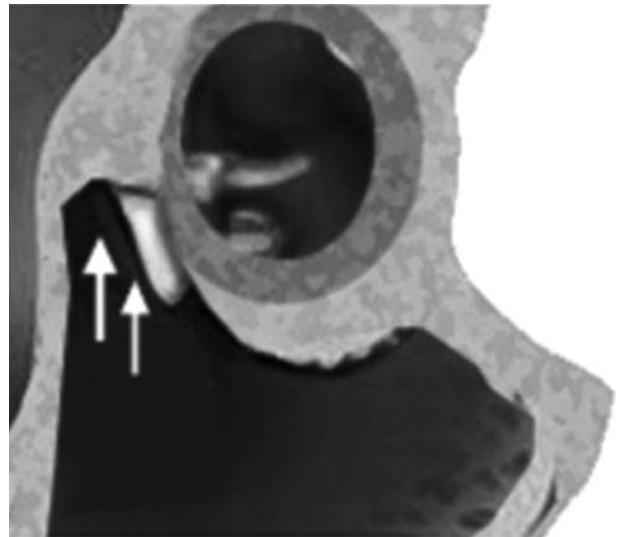


Figure 8. Posterior atticotomy

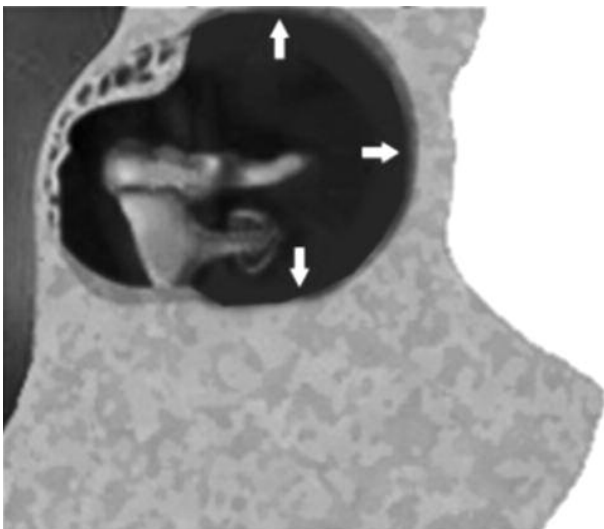


Figure 7. Canaloplasty

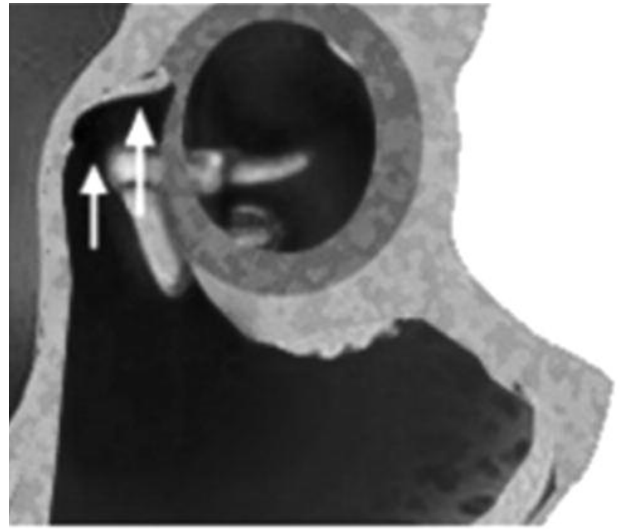


Figure 9. Posterior epi-tympanotomy

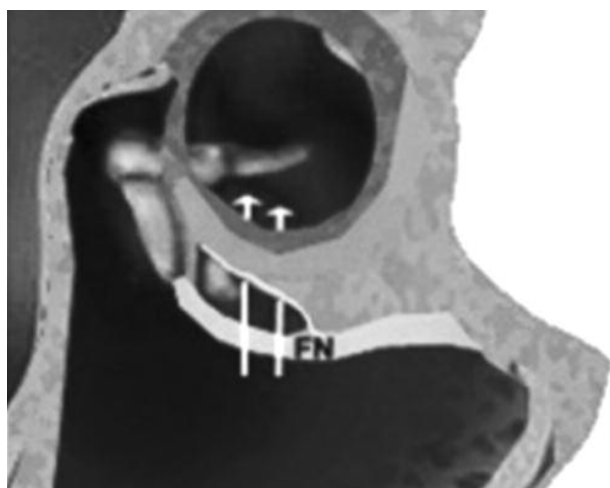


Figure 10. Posterior tympanotomy

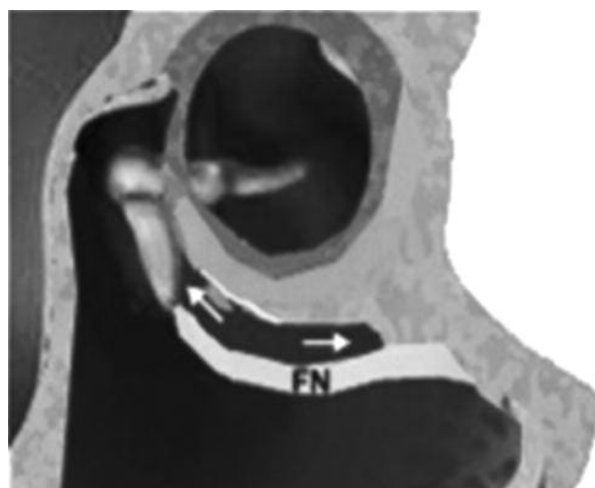


Figure 11. Extended posterior tympanotomy

*Extended posterior tympanotomy:* is done by further extension of the posterior tympanotomy superiorly (by removal of the incus buttress), or inferiorly (by cutting the chorda tympani) which may be required to expose the sinus tympani (Fig. 11).

### **Step 2 : Proper Extirpation of Pathology**

Cholesteatoma is primarily a middle ear disease with possible extension to other areas of the temporal bone or its surrounding structures. Proper clinio-radiological staging of the disease is necessary to outline a road map for the surgical treatment. Belal (2005) have proposed the TMC staging system of cholesteatoma (Fig 12).

The stage of the disease determines whether mastoidectomy is necessary , and whether open or closed technique should be done. In all the cases, proper anterior exposure of the middle ear should be done for proper visualization (microscopic and endoscopic) and identification of the middle ear anatomical structures including the ossicles, facial nerve, round window, eustachian tube orifice, tensor tympanic tendon and cochleariform process, pyramidal eminence and stapedius tendon, hypotympanic cell tract, and middle ear folds and recesses.

Table 1 shows the surgical road map for the different stages of cholesteatoma, as outlined by the TMC system.

### **Step 3 : proper restoration of function**

Restoration of middle ear function includes reconstruction of the attic, tympano-ossicular reconstruction, and reconstruction of the middle ear space. Reconstruction of the attic wall is usually done by a semilunar piece of autogenous tragal or conchal cartilage and is meant to prevent post-operative retraction of the graft. Bone cement has been used for the same purpose.

Tympano-ossicular reconstruction is usually done in the same stage using autograft ossicles, fascia or perichondrium. Periosteum may be used in revision cases . The use of autogenous ossicles in cases of cholesteatoma is controversial <sup>[13,14]</sup>, but the use of prostheses in primary operations is not advised due to the high rate of extrusion since graft healing in these cases is not stable.<sup>[15,16]</sup>

Aeration of the middle ear is usually done by lateralizing the handle of the malleus, repositioning of malleus with section of tense tympani tendon to put it in alignment with the stapes to facilitate ossicular reconstruction. Atelectatic parts of the eardrum are removed.

The use of thick silastic sheets in the middle ear is only done if excessive removal of mucous membrane is done to remove polypi or granulations.

### **Results**

The present series consisted of 57 men and 63 women. The mean age was 45.5 years (range 25 – 66 years).

**Tympanic cavity involvement**

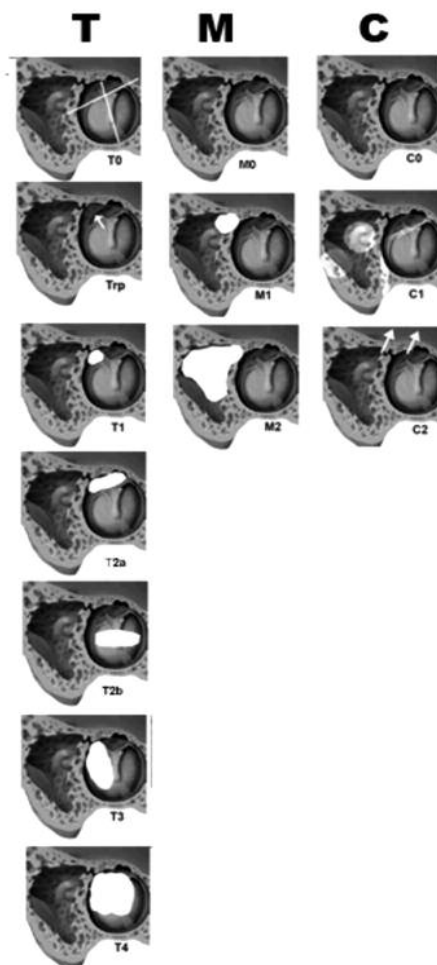
- T0: No tympanic cavity involvement
- Trp: Retraction pocket (pre-cholesteatoma)
- T1: Cholesteatoma involving one side of one region
  - T1a: One side of epitympanum
  - T1b: One side of mesotympanum
- T2: Cholesteatoma involving both sides of one region
  - T2a: Both sides of epitympanum
  - T2b: Both sides of mesotympanum
- T3: Cholesteatoma extending from one region of the middle ear to another (Vertical spread)
- T4: Holotympanic cholesteatoma filling the whole middle ear
- Regions (epity or meso, and hypotympanum)
- Sides (anterior or posterior in relation to a line along handle of malleus)

**Mastoid cavity involvement**

- M0: No mastoid cavity involvement
- M1: Cholesteatoma extending to mastoid antrum only
- M2: Cholesteatoma extending to mastoid cavity

**Complications**

- C0: Un complicated cholesteatoma
- C1: Cranial or extracranial complication
- C2: Intracranial complications



Stages				
1	2	3	4	5
Trp M0 C0	T2 M0 C0	T3 M0 C0 Trp M1 C0	T4 M0 C0 Any T M2 C0 Any T any M C1	Any T any M C2

T: Tympanic M: Mastoid C: Complication rp: Retraction pocket

**Figure 12.** TMC Classification of tympano-mastoid cholesteatoma.<sup>[12]</sup>

The mean follow-up period was 42 months (range 12-72 months). Of the 120 procedures, all the cases had anterior tympanotomy, 114 cases had atticotomy, 95 had intact canal wall (ICW) mastoidectomy and 13 had open mastoidectomy. In 10 cases no mastoidectomy was required. Table 2 summaries the surgical procedures performed in the present series.

Graft take was achieved in 112 patients (93.5 percent). In 4 patients, there was a residual anterior perforation. The rate of residual or recurrent cholesteatoma was 6.7 percent (6/95), all after ICW mastoidectomy. The overall (n = 120) pre- and postoperative (at least 12 months after surgery) four frequency PTA - ABG were 33.40 ± 7.22 dB and 12.42 ± 5.16 dB.

**Table 1.** Surgical Roadmap for the different stages of cholesteatoma. T: Tympanum M: Mastoid C: Complication ME: Middle ear Mast : Mastoidectomy Tympan: Tympanotomy ICW : Intact canal wall.

Stage of Cholesteatoma	T	M	C	Surgical Procedures ME	M	Additional
1	Trp	0	0	Atticotomy	-	-
	T1a	0	0	Atticotomy		
	T1b	0	0	Anterior Tympanot	-	-
2	T2a	0	0	Atticotomy	-	-
	T2b	0	0	Anterior Tympan		
3	T3	0	0	Anterior Tympan & Atticotomy	-	-
				Anterior Tympan	ICW mast	-
4	T4	0	0	Anterior Tympan	-	-
	Any T	M1	0	Ant Tympan		
	M2	0	Ant Tympan	ICW mast		
	Any T	Any M	C1	Ant Tympan	ICW mast	Management of cranial or extra-cranial complications eg. Facial nerve decompression.
5	Any T	Any M	C2	Ant Tympan	Open mast	Management of intracranial complications. Eg. Evacuation of extra-dural abscess.

*a Paired Samples t test, b Wilcoxon Sign Rank test.*

**Table 2.** Surgical Procedures done in this series.

Procedure	Stage Of Disease	No of cases	%
Atticotomy	All Stages		95%
Anterior Tympanotomy	All Stages	120	100%
Canaloplasty	All Stages	60	50%
ICW mastoid	T2 a (2)	95	79%
	M1 (39)		
	M2(46)		
	C1(11)		
Posterior Tympanotomy	T4	6	5%
Open mastoidectomy	M2 (8)	13	11%
	C1 (3)		
	C2 (2)		
Additional Procedures		11	9%
Closure of fistula	C1	7	6%
Facial nerve decompression	C1	2	1.5%
Sigmoid sinus drainage	C2	2	1.5%

## Discussion

There are three ways that determine the surgical strategy of cholesteatoma. First, patient's factors like bilaterality, and hearing level in diseased and contralateral ear. Second, surgeon's choice that depends on his practice and experience. This choice obviously changes from time to time according to his added experience. The third choice, is the most logical in our view, depends on pathology of cholesteatoma, namely its site of origin, ways of spread, biological behavior and growth rate, and histological characteristics.

TMC staging system (Belal, 2005) outlines a simple clinico-radiological staging of the disease that allows us to have a road map for the surgical approaches meant to remove completely the pathology and reconstruct the hearing mechanism. We have called this surgical approach system, which is based on pathological staging: Functional Middle ear and Mastoid Surgery (FMMS). It is meant to replace mastoidectomy as the classical surgical approach to remove cholesteatoma. It emphasizes the fact that cholesteatoma almost always starts in the middle ear, then spreads in the temporal bone according to its site of origin, biological behavior and lines of least resistance. This means that we need to clear the middle ear first by proper anterior exposure that may include canaloplasty, retro-tympanotomy, hypotympanotomy, anterior atticotomy and anterior epi-tympanotomy.

Then, the decision of doing mastoidectomy is taken based on pre-operative staging of the disease as well as intra-operative findings. In most of the cases, intact canal wall mastoidectomy suffices to completely clear mastoid disease as well as to approach the middle ear from the posterior route. This includes posterior atticotomy and posterior epi-tympanotomy. Posterior tympanotomy was only done in six cases in this series, probably because of proper anterior clearance of the disease from the facial recess with the help of endoscopes.

Open mastoidectomy was done in 13 of the cases in the present series. It was done in four cases for anatomical reasons e.g. far forward sigmoid sinus, low middle fossa dura, and in nine cases for pathological reasons because the disease destroyed the posterior wall of the external auditory canal, and in advanced cases of cholesteatoma with intracranial complications.

Endoscopic ear surgery has been introduced in the late eighties. While the role of the endoscopes in pre- and intra-operative examination of the middle ear has added much to the anatomic knowledge and diagnostic capabilities of the otologist, the use of endoscopes in otosurgery was handicapped by the single handed approach and the continuous need for drilling and irrigation.<sup>[10,11]</sup> In the present study, the endoscope was used during microscopic ear surgery to enhance the vision during certain steps of the operation.

In FMMS, in view of the meticulous middle ear dissection and emphasis on the use of endoscopes to explore all the possible sites of pathology like anterior epi-tympanic recess, sinus tympani and stapes area, staging for the possibility of residual or recurrent cholesteatoma was not done. Staging was done in 4.1 percent (5/ 120) for revising ossicular reconstruction, or to remove a silastic sheet put to provide aeration in the middle ear.

## Conclusion

Due to the changing trends in the presentations of chronic ear disease, as well as the advances in its diagnosis and treatment, FMMS presents a surgical roadmap for tympano-mastoid cholesteatoma. It stresses the fact that the middle ear should be the primary target of otosurgeons to clear pathology and reconstruct the hearing mechanism. Mastoidectomy is performed, only if necessary, to approach the middle ear posteriorly and to clear pathology extensions if needed.

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