



## Prognostic significance of tympanosclerotic plaques localization and their morphological and histological characteristics for the outcome of surgical treatment

Prognostički značaj lokalizacije, morfoloških i histoloških karakteristika timpanosklerotičnih plakova na ishod operativnog lečenja

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### Abstract

**Background/Aim.** Tympanosclerosis is a sequela of inflammation of the middle ear usually causing conductive hearing loss. The aim of the study was to determine the significance of tympanosclerotic plaques localization in the middle ear and their morphological and histological characteristics for surgical treatment outcome. **Methods.** This retrospective study included a total of 73 patients operated on for tympanosclerosis in the Clinic for Otorhinolaryngology, Military Medical Academy (MMA) in a period 1996–2010. The results of surgical treatment as well as the last audiometry findings were analyzed, considering follow-up periods of 6 months to 8 years. The patients were divided into 4 groups according to tympanosclerotic plaques localization in the middle ear and the classification suggested by Wieling and Kerr. The patients were also divided based on intraoperatively noticed morphological characteristics of tympanosclerotic plaques, while the third division was done as per histological findings. Surgical success was assessed using the suggestions of the Japan Otological Society. **Results.** The analyzed results showed the surgical success especially in the group II according to Wieling and Kerr, while histological findings had no impact on the outcome of the surgery. **Conclusion.** Surgical treatment has good results especially in patients with the mobile stapes. Results are satisfactory in other localizations, while various morphological and histological characteristics do not have impact on the surgery outcome.

### Key words:

tympanoplasty; hearing disorders; audiometry; histology; prognosis.

### Apstrakt

**Uvod/Cilj.** Timpanoskleroza nastaje kao posledica upale srednjeg uva i najčešće izaziva konduktivni gubitak sluha. Cilj ovog rada bio je ispitivanje uticaja lokalizacije, morfoloških i histoloških karakteristika timpanosklerotičnih plakova u srednjem uvu na ishod operativnog lečenja timpanoskleroze. **Metode.** Retrospektivna studija sprovedena je na 73 bolesnika operisana zbog timpanoskleroze u Klinici za otorinolaringologiju VMA u periodu od 1996. do 2010. god. Posmatrani su rezultati hirurškog lečenja kroz nalaz zadnje dostupne audiometrije. Period praćenja bio je od 6 meseci do 8 godina. Bolesnici su bili podeljeni u četiri grupe u odnosu na lokalizaciju timpanosklerotičnih plakova u srednjem uvu prema klasifikaciji koju su predložili Wieling i Kerr. Druga podela učinjena je na osnovu intraoperativno uočenih morfoloških karakteristika timpanosklerotičnih plakova, a treća na osnovu histološkog nalaza. Procena operativnog uspeha izvršena je na osnovu predloga Japanskog udruženja otologa. **Rezultati.** Analizirani rezultati pokazali su operativni uspeh naročito u grupi II prema Wielinga i Kerr klasifikaciji dok morfološke karakteristike i histološki nalazi nisu imali uticaj na ishod operativnog lečenja. **Zaključak.** Hirurško lečenje timpanoskleroze daje dobre rezultate naročito u grupi bolesnika sa mobilnim stapesom. Zadovoljavajući rezultati postižu se i kod ostalih lokalizacija, dok varijacije morfoloških i histoloških karakteristika nisu imale uticaj na ishod operativnog lečenja.

### Ključne reči:

timpanoplastika; sluh, poremećaji; audiometrija; histologija; prognoza.

### Introduction

Tympanosclerosis is a consequence of inflammation of the middle ear often resulting in conductive hearing loss <sup>1</sup>.

When localized only in the tympanic membrane it refers to myringosclerosis and does not cause a significant hearing loss, while localized in the *cavum tympani* often affects the ossicular chain followed by hearing loss.

Tympanosclerosis is clinically characterized by hyaline changes or calcifications on the tympanic membrane, commonly in the shape of a horseshoe. They are caused by hyalinization of fibrous and elastic fibres in the lamina propria of the tympanic membrane. Similar changes can happen in the submucosal layer of the cavum. Collagen of the fibrous tissue loses its structure and merges with homogeneous mass. By the progression of the process calcium deposits causing ossification of the changes. Depending on the extent of calcification and localization of the process there comes to ossicular chain fixation and conductive hearing loss of various levels and, in rare cases, to deafness<sup>2</sup>. There are numerous controversies regarding etiology, pathogenetic and histological aspects of the disease as well as disagreement about surgical treatment and the choice of an optimal approach<sup>3</sup>. Some of the leading otologists, Austin, Sheehy, House, Tos advocate surgical treatment, while opponents, Schukhnecht, Morrison and Smyth, who even consider tympanosclerosis the last disease of the middle ear to be surgically managed<sup>4</sup>. There is a general agreement, however, only about nonspecificity of the process resulting from inflammation or infection of the middle ear.

The aim of the study was to determine the significance of tympanosclerotic plaques localization in the middle ear and histological findings for surgical treatment outcome.

## Methods

This retrospective study included a total of 73 patients with the diagnosed tympanosclerosis who had been operated on in the Clinic for Otorhinolaryngology, Military Medical Academy (MMA), in Belgrade within a period from 1996 to 2010. Postoperatively, the patients were followed up from 6 months to 8 years. Operative success was assessed by the means of the last available audiometry. The average follow-up period was 18 months, while the first audiometry was performed 3 weeks following the surgery. The study included patients with the primary operation no matter if tympanosclerosis was comorbide with a kind of chronic inflammation of the middle ear.

Regarding localization of tympanosclerotic process, the classification suggested by Wieling and Kerr<sup>5</sup> was performed: the group I – the process affects pars tensa intacta or perforated tympanic membranes, the group II – the process fixes the incudomalleolar complex while the stapes is mobile, the group III – fixed or absent stapes and the mobile incudomalleolar complex if there is one, and the group IV – a completely fixed ossicular chain.

Division of the patients regarding the noticed morphological characteristics was made in accordance with the recommendations given by Selcuk et al<sup>6</sup>.

The group I included causes similar to cholesteatoma matrix, of soft consistency easy to be surgically detached. Cheese-like characteristics are imputed to them due to their hardness and appearance.

The group II included moderately hard changes removed like a leaf from the bones of hearing, promontorium or some other localization in the cavum.

The group III consisted of extremely hard plaques that looked like osseous tissue difficult to be removed from the mucose in the cavum or the ossicular chain.

Based on histological examination of the sent material the 3 groups were also formed: the group I included connective tissue loss and fibroblast and collagen fibres proliferation with the appearance of rare calcium cristals.

The group II included changes characterized by further proliferation of fibroblasts and masses of irregular collagen fibres with focal calcification.

The group III included chondroblasts-like cells, round in form, localized in lacunae and the process of intense calcifications.

Preoperatively, hearing condition was determined on the basis of tone liminal audiometry in accordance with the suggestions of the Japan Otological Society. Only the values measured at 500 Hz, 1 000 Hz and 2 000 Hz were considered.

Postoperatively, surgical success was determined according to the same criteria that assumes tympanoplasty successful if one of the 3 conditions is met: air-bone gap less than 15 dB; hearing improvement of more than 15 dB; and postoperative air conduction hearing threshold less than 30 dB.

In case no of the 3 conditions fulfilled tympanoplasty is considered failed.

Old principles of middle ear surgery accepted in the Clinic for Otorhinolaryngology, MMA were applied in the surgical approach to tympanosclerosis.

In the group I classified according to Wieling and Kerr, myringoplasty was performed using a temporalis muscle fascia graft placed at underlay or inlay position.

Calcificates not affecting more than one quadrant of the tympanic membrane were not excised if not affecting the *annulus tympanicus* towards the atticus so as to fix a part of ossicular chain.

In the group II including the patients with lateral intact ossicular chain fixation and mobile stapes we performed ossicular chain mobilization, modelled incus interposition in case of second arm necrosis or partial ossicular prosthesis placement between the mobile stapes and tympanic membrane in cases of manubrium malleus absence.

Combined or transmeatal approach to the *cavum tympani* was used.

In the group III including the patients with fixed stapes, tympanosclerotic plaques were removed layer by layer and within the same act partial stapedectomy and partial stapedoplasty were performed stabilising the placed prosthesis by fibrous tissue or perichondrium.

In the group IV including patients with multicentric localization the prime aim was to preserve intact ossicular chain if present at all.

Absence of the stapes suprastructure required, except for mobilization, both partial stapedectomy and stapedoplasty. A total ossicular replacement prosthesis (TORP) was placed in one case.

## Results

Table 1 shows the frequency of some tympanosclerotic plaques localizations in a group of 73 patients.

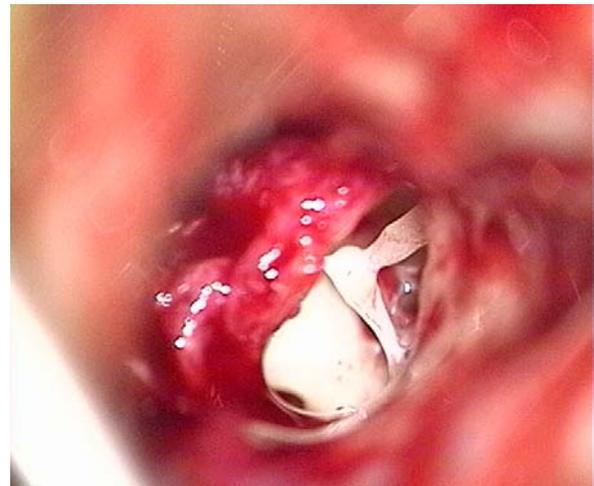
**Table 1**  
**Tympanosclerotic plaques localizations**

Localization	Patients [n (%)]
Tympanic membrane	5 (6.8)
Lateral attic	37 (50.7)
Oval window and stapes	18 (24.7)
Multicentric localisation	13 (17.8)

Each of the 5 patients in the group with tympanic membrane plaques had open type tympanosclerosis audiometrically characterized by air-bone gap up to 20 dB. The patients with lateral fixation (n = 37) (50.7%) were dominant in the studied series. Hearing damage in this group was classified in the group with air-bone gap of more than 30 dB, and in the group with air-bone gap between 20 and 30 dB. In the group of patients with stapes fixation the highest number of patients had hearing damage with air-bone gap of more than 30 dB. Table 2 shows the frequency of intraoperatively found morphological characteristics of tympanosclerotic plaques. Table 3 shows the histological plaque distribution, and Table 4 pre- and postoperative hearing condition regarding localization of tympanosclerotic process.

Analysis of operatively seen morphological characteristics revealed that a higher number of the patients in the

groups 1 and 2 were characterized with the absence or the beginning of the process of calcification. Histological findings in the majority of cases confirmed operatively seen characteristics of plaques (Figures 1 and 2).

**Fig. 1 – Erosion of the second arm caused by tympanosclerotic process****Table 2**  
**Intraoperative morphological characteristics of tympanosclerotic plaques**

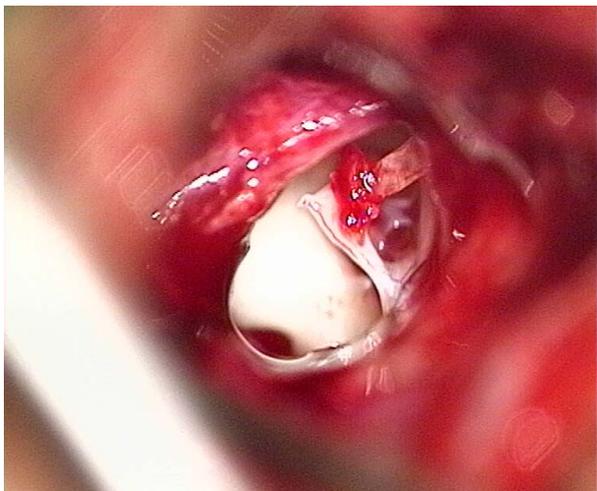
Intraoperative morphological characteristics	Patients [n (%)]	Preoperative hearing condition (dB)	Postoperative hearing condition (dB)
Soft cheese-like plaques similar to cholesteatoma matrix	25 (34.25)	Air 50.8 ± 6.2	Air 38.6 ± 3.8
		Bone 27.3 ± 6.4	Bone 23.7 ± 4.4
Leaf-like moderately hard plaques	29 (39.7)	Air 61.5 ± 10.5	Air 38.6 ± 4.3
		Bone 25.7 ± 5.6	Bone 20.7 ± 2.4
Bone-hard calcified plaques	19 (28.1)	Air 65.2 ± 8.5	Air 44.8 ± 7.3
		Bone 28.7 ± 3.7	Bone 25.8 ± 3.2

**Table 3****Histological findings in tympanosclerotic plaques**

Histological finding	Patients [n (%)]	Preoperative hearing condition (dB)	Postoperative hearing condition (dB)
Connective tissue loss, proliferation of fibroblast and collagen fibres	29 (39.7)	Air 52.8 ± 8.2	Air 39.6 ± 5.8
		Bone 28.3 ± 8.4	Bone 22.7 ± 4.6
Focal calcification of irregularly distributed collagen fibres	27 (37.0)	Air 62.5 ± 12.5	Air 38.6 ± 4.3
		Bone 26.7 ± 3.6	Bone 21.7 ± 1.6
Chondroblastoma-like cells and calcifications	17 (23.3)	Air 65.5 ± 12.5	Air 42.8 ± 8.2
		Bone 29.7 ± 2.8	Bone 24.7 ± 2.2

**Table 4****Preoperative hearing condition and postoperative success regarding localization of tympanosclerotic process**

Localization	Preoperative hearing condition (dB)	Postoperative hearing condition (dB)
Tympanic membrane	Air 32.8 ± 6.12	Air 15.8 ± 4.6
	Bone 16.4 ± 13.5	Bone 14.6 ± 3.4
Attic	Air 52.3 ± 6.12	Air 39.1 ± 12.5
	Bone 26.6 ± 12.7	Bone 24.8 ± 9.8
Oval window	Air 65.5 ± 12.5	Air 58.5 ± 13.2
	Bone 38.2 ± 14.6	Bone 35.2 ± 11.74
Multicentric localizations	Air 62.6 ± 14.3	Air 57.3 ± 15.6
	Bone 35.4 ± 16.62	Bone 31.8 ± 12.9



**Fig. 2 – Ossiculoplasty by mastoid cortex plasty**

### Discussion

There have been many controversies regarding etiology, pathogenesis, diagnostics and the treatment of tympanosclerosis since the beginning. The use of surgical microscope that has made middle ear surgery possible contributed especially to dilemmas about surgical treatment. The questions about the need at all to surgically manage tympanosclerosis then about surgical technique in cases that have to be surgically managed have been put.

A long-standing experience in middle ear surgery in the Military Medical Academy, Belgrade led to the attitude that tympanosclerosis need to be surgically managed sticking to a certain extent to the modified basic otosurgery principles, including firstly, eradication of pathological process as a whole, and secondly restitution of the transmission apparatus. Considering that just a small number of patients with tympanosclerosis show symptoms such are otorrhea, instability in walking, that might disturb daily activities of patients with tympanosclerosis, hearing improvement by the use of surgical treatment should be the major aim. Especially if we consider the fact that tympanosclerotic process does not complicate as other forms of chronic inflammatory processes, such are active squamous ones, for example. The basic motive for the group of 73 patients to present to the doctor was a hearing improvement possibility.

Tympanosclerosis open type localized only to the tympanic membrane damage hearing less than other three groups. Calcificates on the tympanic membrane that need annulus should be removed in the same way as those that affect more than a half of the tympanic membrane, thus considerably disturbing its mobility. According to our experience, temporalis muscle fascia is the best material available for perforation reconstruction, the ideal position being that between the cutane layer and lamina propria which, however, is not always easy to realize. In the 3 patients of this group perforations required posterior quadrants that is a precondition for this so-called inlay fascia position. In other patients fascia was placed below the remnants of the tympanic membrane. According to the criterion of the Japan Otological So-

ciety, surgical treatment of all of the 5 patients was classified as successful. They, also, met more strict evaluation criterion that assumed only air conductivity of less than 30 dB as socially acceptable hearing.

Lateral atticotomy and mobilization of the ossicular chain lead to surgical success in case of incudomalleolar complex and intact ossicular chain mobilization. It is a known fact that immediate postoperative results are good tending, however, to refix due to the formation of scarf tissue in a period up to 2 years following the surgery. Prevention is possible by placing silastics or gel foams onto the potential contact sites, that was applied in the group of the studied patients in all the cases in which refixation was considered possible. Topical application of corticosteroid drops and the use of various laser types (argonne, CO<sub>2</sub>) have also been presented in papers of many authors<sup>3, 7-11</sup>. When it was impossible to mobilize the ossicular chain to a certain satisfying extent or when the chain was disrupted, we applied disarticulation of the incudomalleolar joint and interposition of previously modelled incus.

In the study we did not compare postoperative success between mobilization and interposition. Considering data of other authors, e.g. Albu et al.<sup>4</sup>, however, there is no statistically significant difference, although the results are slightly better in the group of patients with mobilization. This agrees with our attitude to keep intact ossicular chain whenever it is possible. It was the most frequent localization in the studied group (n = 37, 50.7%) of the patients. There was a significant correlation found between this localization and surgical success, explained by the significance of the intact and mobile stapes in sound transmission.

There are the most pronounced controversies regarding surgical approach to tympanosclerosis, no matter if there are suprastructures of the stapes or not. The question remains if mobilization of the fixed stapes plate is enough or if there is a need for stapedectomy, i.e. stapedoplasty.

Tos et al.<sup>7</sup> suggest in case of fixed plate and intact ossicular chain to keep it along with mobilization of the stapes. They approve stapes ligaments resection in case of uneasy approach to the oval niche during removal the plaques, but with no fenestration of the plate nor its removal. In case of the stapes suprastructures absence and if the plaques fix the plate they recommend stapedoplasaty in 2 acts: in act 1 to remove plaques from the plate, and in act 2 to do stapedotomy and stapedoplasty. Numerous authors share the same opinion, advocating mobilization, too, agreeing with Tos et al.<sup>7</sup> that its highest advantage is one act performance, while Smyth<sup>8</sup> disagrees with that, thinking that the possibility of damaging the inner ear during mobilization either with hydric blast or perilymphatic fistula is very great, leading together to sensorineural hearing damage. In his serie he reports that it ranges up to 36%. Giddings and House<sup>9</sup> has the same opinion giving the priority to stapedectomy in managing tympanosclerosis of the stapes. There is not the small number of authors who accept both attitudes, documenting no difference between mobilization and stapedectomy or stapedoplasty<sup>10</sup>, but who do differentiate stapedotomy from stapedectomy in favor of the second due to better results in

speaking discrimination and hearing condition in stapedectomy. Tiefert and De La Cruz<sup>3</sup> make a difference between mobilization and stapedectomy. In their series of 73 patients, too, followed up within a longer time period (average 1.6 years) they report equally good results for both procedures giving more significance to the surgeon skill than to the choice of the method.

In a part of the patients of our series with the fixed stapes we performed fenestration of the stapes footplate and stapedoplasty along with the use of various types piston stapes prosthesis (Fisch, House, Kurtz). Of the whole group, in one patient there was a more serious sensorineural damage requiring hearing amplification.

In the group with multicentric localization we performed the principles common for the two previous groups. Removal of plaques and mobilization of the chain if intact is the primary aim which we obtained in the 6 out of the 13 patients. The process in the medial attic requires disarticulation of the incudomalleolar joint and reconstruction of the chain<sup>11</sup>. The procedure of a modelled incus interpositioning between the manubrium malleus and stapes suprastructures, if any present, gives good results. In one case we placed a total ossicular replacement prosthesis (TORP), and the result of the most recent audiometry 12 months following the surgery was not satisfactory according to the requirements of the Japan Otological Society.

Statistical data analysis of histological changes in tympanosclerosis by the use of the  $\chi^2$  test did not reveal any statistically significant dependence regarding the success of surgical treatment. A possible explanation is the fact that histological changes characteristic for all the three groups could be found in one patient suggesting dynamic process and a long evolution of the disease. According to data of other authors<sup>4</sup> immediate postoperative results are better in a group of patients with proliferation of fibroblast and collagen fibers. At the same time, in each patient there is a higher possibility of conductive hearing loss recurrence than in a group of patients with more pronounced calcification.

### Conclusion

Surgical treatment of tympanosclerosis leads to good results regardless location and the extent of the process affecting the middle ear, however, especially good results are obtained in a group of patients with the mobile stapes footplate and suprastructures present. The variety of morphological changes seen intraoperatively in the studied series of patients did not show a statistically significant correlation with the success of surgical treatment. The same conclusion applies to the results of pathohistological findings which, in spite of the obvious differences, do not influence the outcome of surgical treatment.

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