

An ancient technique in the endoscopic era of otologic surgery: The Role of Refractive Index of Fluids

Endoskopik otolojik cerrahi çağında eski bir teknik: Sıvıların Kırıcılık İndeksi'nin rolü

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ABSTRACT

Objectives: This study aims to investigate the role of Refractive Index of Fluids (RIOF), an abandoned practical technique, in chronic otitis surgery.

Patients and Methods: This multi-center study included a total of 35 patients (18 females, 17 males; mean age 39.3±14.4 years; range 17 to 62 years) who were scheduled for surgery for chronic otitis media between July 2013 and August 2015.

Results: The left ear was affected in 18 patients, while the right ear was affected in 17 patients. Cholesteatoma and epithelium were successfully removed from the hidden anatomic areas with this technique. No recurrent or residual disease was observed during follow-up.

Conclusion: Our study results show that, although sophisticated techniques and fiber optic scopes enable extensive visualization of the recesses of the middle ear and mastoid today, RIOF is still a valid, effective, and cost-effective option.

Keywords: Endoscope; epithelium; hidden anatomic areas; law of refraction; microscope; middle ear; surgery.

ÖZ

Amaç: Bu çalışmada kronik otit cerrahisinde terk edilmiş bir uygulama tekniği olan Sıvıların Kırıcılık İndeksi'nin (RIOF) rolü araştırıldı.

Hastalar ve Yöntemler: Bu çok merkezli çalışmaya Temmuz 2013 - Ağustos 2015 tarihleri arasında kronik otitis media cerrahisi planlanan toplam 35 hasta (18 kadın, 17 erkek; ort. yaş 39.3±14.4 yıl; dağılım 17-62 yıl) alındı.

Bulgular: Hastaların 18'inde sol kulak ve 17'sinde sağ kulak etkilenmişti. Kolesteatom ve epitelyum, bu teknik ile gizli anatomik bölgelerden başarılı bir şekilde çıkarıldı. Takip sırasında nüks veya rezidüel hastalık görülmedi.

Sonuç: Çalışma sonuçlarımız, günümüzde gelişmiş teknikler ve fiber optik skopiler ile orta kulak ve mastoid girintilerinin etrafıca görüntülenmesi mümkün olsa da, RIOF'un halen geçerli, etkili ve maliyeti düşük bir seçenek olduğunu göstermiştir.

Anahtar Sözcükler: Endoskop; epitelyum; gizli anatomik bölgeler; kırılma yasası; mikroskop; orta kulak, cerrahi.

The tympanic cavity, probably one of the most complicated areas to study from both surgical and anatomic points of view, contains several hidden anatomic structures that the

surgeon cannot completely visualize with an oto-microscope during middle-ear surgery, potentially causing surgical failure. Therefore, surgeons are seeking new techniques in order



to better assess areas of the middle-ear that can hardly be seen.^[1-4]

One of the currently - proposed techniques is the use of endoscopic systems during middle ear surgery. Endoscopes provide a complete image of hidden areas of the middle ear that cannot be adequately visualized with a microscope.^[4-7]

Until the discovery of the endoscope, some outmoded but practical methods for exposition of hidden anatomic areas were routinely taught to trainees in otology courses. One such method used the law of light refraction with the refractive index of fluids (RIOF) under the oto-microscope. In this report, we aimed to refocus attention on this abandoned practical technique in chronic otitis surgeries.

PATIENTS AND METHODS

This study was conducted with a multicenter cooperative study of 35 patients (17 males, 18 females; mean age 39.3 ± 14.4 years; range 17 to 62 years) between July 2013 and August 2015.

Patients who underwent surgery for chronic otitis media were included in this study. Preoperative variables including gender, age, pathologic findings and types of operation were evaluated. All procedures were performed under general anesthesia.

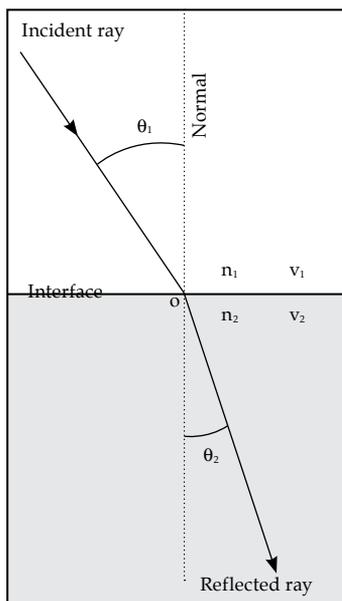


Figure 1. The law of refraction.

The study protocol was approved by the Istanbul University, Istanbul Medical Faculty Ethics Committee and written informed consent was obtained from each patient. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Technical note

The law of refraction states that the ratio of the sines of angles of incidence and refraction is equivalent to the ratio of phase velocities in two media (i.e. water and air), or equivalent to the reciprocal of the ratio of indices of refraction: $\sin\theta_1/\sin\theta_2=v_1/v_2=n_1/n_2$, with each θ as the angle measured from the normal of the boundary, "v" as the velocity of light in the respective medium, and "n" as the refractive index of the respective medium (Figure 1). Every substance has a specific bending ratio and the refractive indices for selected materials are shown in Table 1.^[8,9]

After filling fluid into the middle ear with a 22-gauge injector, refraction occurs while the microscope light passes through the air-fluid border owing to the difference between the two environments in terms of refraction index (Figure 2). In our cases, we only used saline solution (sodium chloride 0.9%).

Consequently, changing the incident ray angle and/or refraction index provides a greater refraction angle and allows visualization of hidden areas of the middle ear such as sinus tympani and facial recess. On the other hand, it should be kept in mind that readjustments of microscope focus become necessary after filling the middle-ear space with fluid using this technique.

Surgical note

Thirty-five patients with chronic otitis media were included in the study group.

Table 1. Refractive index of selected materials

Material	Index (Wavelength (0.4~0.8) μm)
Air (at 15 °C)	1.00027712
Alcohol, ethyl (grain)	1.3616
Glycerin	1.4700
Oil, microscope	1.515
Water (at 20 °C)	1.3270
Normal saline	1.5404

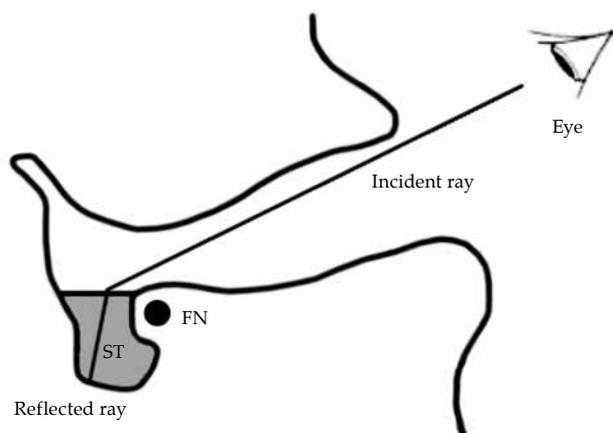


Figure 2. Refraction occurs while the microscope light passes through the air-fluid border. ST: Sinus tympani; FN: Facial nerve.

A retroauricular incision was performed for mastoidectomy and an endaural incision was performed for tympanoplasty. The decision of canal wall-down (CWD) or canal wall-up (CWU) mastoidectomy was made with respect to cholesteatoma invasion and squamous epithelium pathologies in the middle ear. This technique was used to ensure complete removal of the squamous epithelium and cholesteatoma, particularly in the hidden anatomic areas

(i.e., the sinus tympani, facial recess, anterior epitympanic space, hypotympanum) using tympanoplasty, CWD and CWU mastoidectomy approaches. Residual disease that could not be seen with the oto-microscope was removed with this technique.

RESULTS

Table 2 demonstrates the descriptive results of the patients. In 25 patients who required tympanoplasty for posterior marginal perforation, when checking the middle ear with RIOF before microscopic graft material placement (i.e. cartilage, perichondrium), squamous epithelium was found in the aditus ad antrum (n=6), facial recess (n=4), and sinus tympanum (n=2). These patients were able to avoid mastoidectomy due to complete removal of squamous epithelium, which was made possible under RIOF. However, partial attic dissection (n=3) and minimal scutum removal (n=2) was needed for the complete eradication of epithelium in five patients. In the remaining seven patients, RIOF permitted delicate removal of epithelium from hidden areas without drilling. The mean follow-up was 11.4 ± 3.4 . There was no recurrent or residual disease.

Table 2. This table demonstrates the descriptive results of the patients

Patients	Tympanoplasty (n=25)		Mastoidectomy (n=10)		
	n	Mean±SD	CWU (n=7)		CWD (n=3)
			n	n	n
Age (years)		39.3±14.4			
Gender					
Males	11			6	
Females	14			4	
Ear side					
Right	13			4	
Left	12			6	
Pathology localization					
Epitympanum			7		3
Mesotympanum					3
Hypotympanum					3
Facial recess	4		2		3
Sinus tympanum	2		5		3
Aditus ad antrum	6		7		3
Mastoid cells			7		3

CWU: Canal wall up; CWD: Canal wall down; SD: Standard deviation.

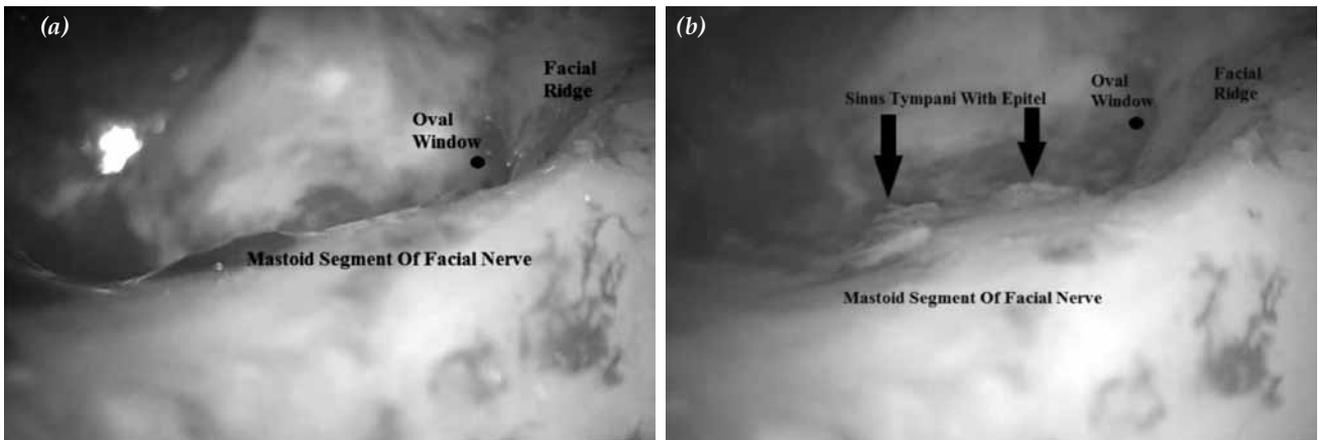


Figure 3. (a) After canal wall-down mastoidectomy, no residual epithelium was detected with microscopic view. (b) Residual epithelium shown in the sinus tympani using RIOF, the law of refraction.

Canal wall up mastoidectomy was performed in seven patients with epitympanic cholesteatoma extending into the mastoid cells. Using RIOF allowed better visualization of the hidden areas; the sinus tympanum (n=5) and facial recess (n=2) contained concealed cholesteatoma. In the other three patients, CWD mastoidectomy was performed for invaded cholesteatoma through the epitympanum, mesotympanum, and mastoid cells. Using RIOF allowed sufficient exposition, especially in the sinus tympanum (n=3) for total removal of the disease (Figure 3). The mean follow-up was 13.3 ± 3.8 months and there was no recurrent or residual disease.

DISCUSSION

The complex anatomy of the middle ear creates difficulty for the management of chronic middle-ear disease. The posterior wall of the tympanic cavity, also known as the retrotympanum, contains four important recesses, the sinus tympanum, lateral tympanic sinus, posterior tympanic sinus, and facial recess that have an important place in surgery for chronic otitis media. Cholesteatoma and squamous epithelium frequently invade to the retrotympanum, and recurrent or residual disease is also very frequently seen in parallel in this area.^[10-12]

The pathogenesis of acquired cholesteatoma continues to be controversial. One of the theories proposes migration of squamous epithelium from the external ear canal and/or

the tympanic membrane through a perforation of the tympanic membrane into the middle ear.^[11,12] Karmody and Northrop^[13] have presented histologic findings and supported the migration theory that cholesteatomas are formed by medial migration of the stimulated squamous epithelium of the tympanic membrane. The majority of our findings in cases with marginal perforation are in accordance with migration theory. Additionally, we noticed that squamous epithelium was detected in the middle ear in 48%^[12] of patients who required tympanoplasty for marginal perforation. Therefore, we suggest that surgeons should routinely inspect hidden areas for residual disease using visualization methods in surgery especially for posterior marginal perforations of tympanic membrane.

The approach to hidden areas such as the retrotympanum determines whether the surgeon can use a conservative approach with regards the posterior ear canal, as approach options include CWD or CWU procedures. Visualization methods for hidden areas are more frequently required in CWU procedures. One of the methods that the surgeon can use is to visualize the retrotympanum indirectly by means of tiny mirrors using the technique of Zini, who described this approach as "indirect microtympanoscopy".^[1]

The endoscope is becoming a popular instrument in many aspects of middle ear surgery. Based on the endoscopic view of the

middle ear, accurate anatomic and pathologic diagnosis can be achieved. Thus, low rates of complications and residual disease in middle ear surgery have been obtained with minimal invasive surgery.^[6,14-18]

Badr-el-Dine et al.^[17] found that after completion of primary surgery for middle-ear disease with oto-microscope, the overall incidence of intraoperative residual disease detected with endoscopy was 22.8%; the sinus tympani was the most common place for intraoperative residual disease in both the CWU and CWD groups. At second-look explorations with the endoscope, recurrence was identified in 8.6% of cases. Alicandri-Ciufelli et al.^[18] reported on the value of endoscopy in long-term results of attic cholesteatoma surgery and found that 68% of patients were disease free in the postoperative period. The mean follow-up was 64.3 months.

In the literature, several authors have suggested that endoscopy assisted routine middle ear surgery has several disadvantages. The disadvantages include one-handed manipulation, loss of depth perception, the need for new surgical instruments, bleeding is harder to manage, difficulty in passing instruments past endoscopes through the external ear canal, fogging, and the need for training.^[14-17]

The limitations of this study include the relatively small numbers of patients enrolled and the short follow-up period for the assessment of residual or recurrent disease. Diffusion-weighted magnetic resonance imaging could have been used for investigating residual or recurrent disease in the follow-up period. Different fluids that are not ototoxic could be used for obtaining more refraction. However, as the present work describes a practical technique that provides visibility in hidden places of the middle ear, we did not aim to compare endoscopic techniques.

In conclusion, the current study describes the RIOF technique for the visualization of hidden anatomic areas using the law of refraction in the middle ear space, which enables three-dimensional views of hard-to-reach places using no additional instruments. We wanted to remind physicians of this technique, which we used successfully in chronic otitis surgery.

Today it is possible to obtain extensive visualization of the recesses of the middle ear and mastoid with better lighting, better options, and fiber optic scopes, which makes this refraction technique somewhat antiquated; however, it remains available, effective and inexpensive.

Declaration of conflicting interests

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