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Evaluation of Middle Ear Ventilation after Tympanoplasty by Xe-133 Scintigraphy

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Aim: Eustachian tube is considered to have important role in the normal physiology of middle ear, as well as in the success of tympanoplasty operations. The study was designed prospectively to reveal the role of Xe-133 ventilation scintigraphy in the determination of eustachian tube (ET) function.

Materials and Methods: Thirteen patients who underwent successful tympanoplasty with intact graft and 5 healthy volunteers were included in this study. Xe-133 insufflation into nasopharynx was done using a polyethylene 7F catheter and the patient was asked to perform valsalva maneuver followed by swallowing. Time-activity curves were generated from the region of interest (ROI) corresponding to middle ears; uptake ratio and clearance half-time of xenon 133 were also calculated in this region.

Results: Decreased tracer uptake was demonstrated in the ears with tympanoplasty. Mean uptake value was 53.73 ± 15.73 in volunteers, 46.73 ± 15.28 in normal ears of operated patients and 39.99 ± 17.47 in operated ears. There was significant difference of uptake between the normal ears and ears with tympanoplasty ($P < 0.0.5$). However, there was no significant difference in the washout rate between normals and patients with tympanoplasty.

Conclusions: Xe-133 ventilation scintigraphy is a reliable method that gives objective and quantitative information about eustachian tube function. In the early postoperative period the uptake is less than normals.

Key Words: Xenon-133, ventilation scintigraphy, eustachian tube, tympanoplasty

Timpanoplasti Sonrası Orta Kulak Ventilasyonunun Xe-133 Sintigrafi ile Değerlendirilmesi

Amaç: Östaki tüpünün, hem orta kulağın normal fizyolojisinde hem de timpanoplasti operasyonlarının başarısında önemli rol oynadığı düşünülür. Bu çalışma, östaki tüpünün fonksiyonlarının değerlendirilmesinde, Xe-133 ventilasyon sintigrafisinin rolünü ortaya koymak için prospektif olarak planlandı.

Yöntem ve Gereç: Bu çalışmada başarılı timpanoplasti operasyonu geçiren ve greftleri intakt olan 13 hasta ve 5 sağlıklı gönüllü incelendi. Xe-133 nazofarinkse polietilen 7F kateter kullanılarak verildi ve kişiden yutkunmayı takiben valsalva manevrası yapması istendi. Orta kulak bölgesine uyan alandan zaman-aktivite eğrileri, tutulum oranı ve xenon 133 yarılanma zamanı hesaplandı.

Bulgular: Timpanoplastili kulaklarda azalmış tutulum gösterildi. Ortalama tutulum değeri gönüllülerde 53.73 ± 15.73, opere hastaların normal kulaklarında 46.73 ± 15.28 ve opere kulaklarında 39.99 ± 17.47 idi. Normal kulaklarla timpanoplastili kulaklar arasında tutulum açısından anlamlı fark belirlendi ($P < 0.0.5$). Bununla birlikte, normal ve timpanoplastili hastalar arasında yarılanma zamanı açısından anlamlı fark bulunmadı.

Sonuç: Xe-133 ventilasyon sintigrafisi, östaki tüpü fonksiyonlarının değerlendirilmesinde objektif ve kantitatif bilgiler veren güvenilir bir yöntemdir. Erken postoperatif dönemde tutulum normal kulaklara gore daha azdır.

Anahtar Sözcükler: Xenon-133, ventilasyon sintigrafi, östaki tüpü, timpanoplasti

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Introduction

Eustachian tube (ET), tubal connection between middle ear and nasopharynx, is opened actively by a group of muscles; tensor veli palatine and levator veli palatine, during swallowing. Its main function is the ventilation of middle ear cavity in order to equalize the middle ear pressure with that of the ambient. It also serves for mucociliary drainage and protection of the middle ear.

ET dysfunction may play role in chronic middle ear diseases and its functional status can be predictive in the long term success of middle ear surgery (1-3).

There are several methods such as; manometric tests (i.e. forced-response test and pressure equilibration test), perfusion pressure test, Valsalva's manoeuvre and sonotubometry to assess the ventilation function. In clinical practice tympanometry is the most commonly used test for the evaluation of ventilation function. However, none of these tests give quantitative data, plus manometric tests require either a perforated ear drum or a ventilation tube (4-7). Postoperative evaluation of ET is even more challenging in patients undergoing tympanoplasty, and it would be more reliable to use a quantitative and minimally invasive test.

Advances in gamma camera technology and computer software programs made a great contribution to nuclear medicine in the assessment of regional functions quantitatively. Radioactive xenon gas can be used for this purpose and lung ventilation scintigraphy is the main clinical application. First studies of the ear and the paranasal sinuses with Xe-133 were reported by Kirchner in 1974 (8). Since then, several studies have been published in the field of otorhinolaryngology (9-14). By noninvasive administration of radioactive gas into tympanic cavity via ET; objective, functional and quantitative assessment of middle ear ventilation can be achieved. However, there have been few efforts for the evaluation of middle ear ventilation using scintigraphic methods by means of calculating uptake or washout rate of radioactive gas in the middle ear (8,9,14).

The goal of this study was to identify the assessibility of ET function in patients who underwent successful tympanoplasty operation with intact tympanic graft, and to determine the value of Xe-133 ventilation scintigraphy in this setting.

Material and Methods

Patients: The study population included those who underwent surgery for chronic otitis media and normal controls. The decision for surgery was made by an otorhinolaryngologist, on the basis of medical history, otoscopic findings and audiogram. Tympanoplasty with or without mastoidectomy was performed in all patients. In the postoperative period, potential complications and healing were monitored at regular intervals. Those with intact graft were referred to scintigraphic evaluation at their 8^{th} to 12^{th} postoperative week. In all patients, allergy, systemic diseases and sinusitis-polyposis were excluded. Otoscopic examination, tympanometry and audiometry were performed prior to scintigraphy. The study was performed with the approval of the local ethical committee and all patients gave their informed consent prior to inclusion.

Thirteen patients who underwent tympanoplasty for chronic otitis media, and 5 normal controls were included in the study. Three study groups were designed: group-1 consisted of ten normal ears of 5 controls, group-2 consisted of contralateral normal ears of 9 operated patients, group-3 consisted of operated ears of 13 patients. Group-3 was subdivided into 2 as follows: group-3a consisted of operated ears of patients with unilateral chronic otitis media (n = 9), and group-3b consisted of operated ears of patients with bilateral chronic otitis media (n = 4).

Tracer application and imaging: Fifteen MBq xenon 133 dissolved in 20 ml air was directly given to the nasopharyngeal space. A 50 ml syringe and a 15 cm long 7F size polyethylene catheter were used. The catheter was introduced through one nostril and extended to the posterior choana after topical anesthesia. The gas-air mixture was taken into the syringe and administered in one attempt, in the sitting position. During the application the patient held his/her breath, while the opposite nostril and mouth were closed. After the gas insufflation, the patient performed Valsalva maneuver 3 times, each followed by swallowing.

A single head gamma camera equipped with a high resolution collimator was used. Sequential imaging was obtained immediately after the gas application. While the patient was in supine position, camera head was positioned under the head of the patient. Imaging was performed at 60 seconds intervals for 20 minutes in a 64 x 64 matrix. Images were interpreted visually by a nuclear medicine specialist (HO), in terms of absence or presence of radioactivity in the middle ear cavity of the operated site. Additional quantitative analyses were performed. Regions of interest (ROI) were drawn over the middle ear area and background correction was made drawing a ROI over the corresponding brain region. Time-activity curves were generated from the ROIs and Xenon-133 uptake and clearance rate were calculated for each ear.

Statistics: All statistical analyses were performed with SPSS software. All results are expressed as median and range as well as mean ± sd. Mann-Whitney U test was used for data comparisons, $P < 0.0.5$ was considered as statistically significant.

Results

Initially 18 patients were taken into the study, however 13 of them were able to be successfully imaged by scintigraphy. Five of the patients in whom no image was obtained, due to either patient noncooperation or technical problems, were excluded.

Patients' group consisted of 8 men and 5 women. Their ages ranged from 14 to 47 years, with a mean of 22 years. The control group consisted of 5 volunteers without any ear disease, and with a normal tympanogram (3 women and 2 men; median age, 29 years; range, 23 to 40 years). Otoscopic and pneumootoscopic examination revealed intact non-mobile graft in all operated patients. Type B tympanogram was obtained in the operated ears of all patients.

Visual evaluation: All volunteers demonstrated radioactivity accumulation in both middle ears. In patients with one-sided chronic otitis media, decreased activity accumulation on operated ears was demonstrated but normal ears of these patients did not demonstrate significant difference from the volunteers (Figure 1, 2). In patients with bilateral chronic otitis media , visual appearance of radioactive accumulation in operated ears appeared to be similar to patients operated for unilateral disease.

Quantitative evaluation: Representative time-activity curve of volunteers demonstrated an initial fast decrease of the activity during first 2-3 minutes and then a slow washout phase (Figure 3). The time-activity curves of patients showed lower initial uptake than normals. The clearance half-time showed different curves between patients and normals. Quantitative results in all patients are given in Table 1, 2. Mean uptake value was 53.73 ± 15.73 in group-1, 46.73 ± 15.28 in group-2, and 39.99 ± 17.47 in group-3. When we compared the Xe-133 uptake between controls and normal ears of the patients, no significant difference was found ($P < 0.05$). The

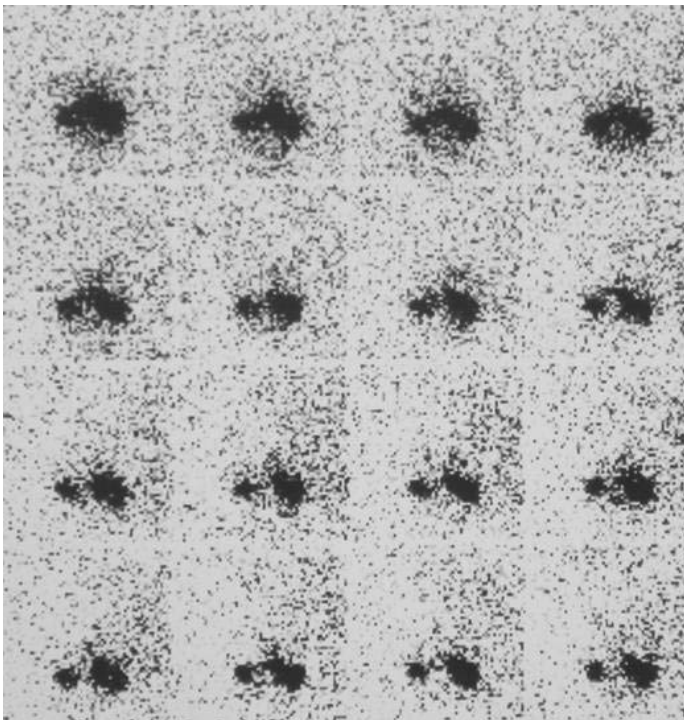

Figure 1. Dynamic posterior images after the insufflation of Xe-133 through a polyethylene nasal catheter. Both middle ear regions can be clearly delineated on all frames.

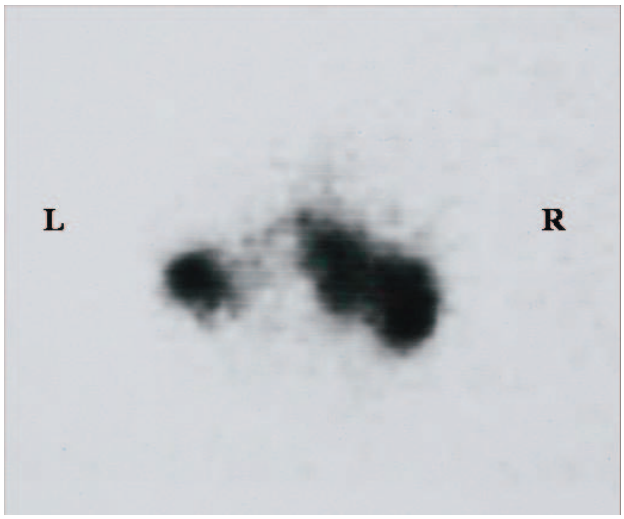

Figure 2. Decreased uptake of Xe-133 in left tympanic cavity compared to right side in a patient who underwent left tympanoplasty, R: right, L: left.

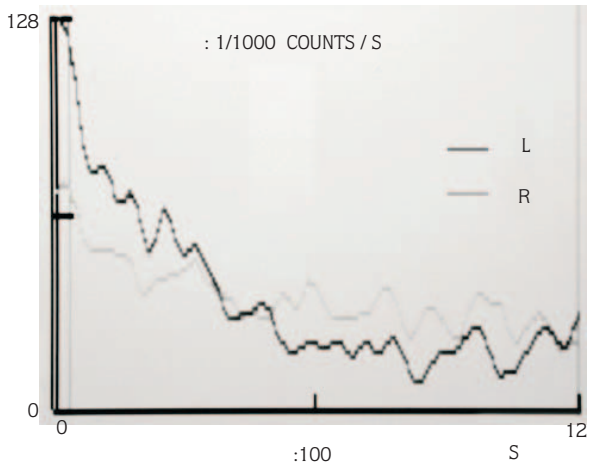

Figure 3. Representative time-activity curves over 20 minutes in normal subjects. An initial fast decrease of the activity during first 2-3 minutes and then a slow washout phase during ensuing minutes. R: right, L: left.

Table 1. Middle ear uptake of Xe-133 in all groups.

	Mean uptake ± sd	Median (min-max)
Group-1 (n = 10 ears) 5 normals	53.73 ± 15.73* †	48.90 (36.96-86.59)
Group-2 (n = 9) Normal ears of patients	46.73 ± 15.28*	47.43 (27.34-75.06)
Group-3 (n = 13) Ears with tympanoplasty	36.99 ± 17.47†	32.45 (22.32-73.78)

* No significant differences (P < 0.05), group-1 vs group-2
† P < 0.05, group-1 vs group-3

Table 2. Washout rate of normal subjects and patients.

	HALF-TIME (minute)	
	median	min-max
Group-1 (n = 10 ears) 5 normals	61*†	11-312
Group-2 (n = 9) Normal ears of patients	67*	25-250
Group-3 (n = 13) Ears with tympanoplasty	58†	40-72

* No significant differences (P < 0.05), group-1 vs group-2.
† No significant differences (P < 0.05), group-1 vs group-3.

comparison of the tracer uptake of the normal ears with that of the operated ears, revealed significantly lower uptake in the latter (P < 0.05). Group-3a and group-3b did not show any differences with respect to the uptake ratio in the middle ear.

We also evaluated the washout rate (%) of Xe-133. In 10 ears of 5 healthy subjects, the median clearance half time was 61 min (range 11-297 min). In 13 ears of patients with tympanoplasty, the median clearance half time was 58 min (ranging from 40 to 72 min). There

were no significant differences in the washout rates between normals and ears which had undergone tympanoplasty.

Discussion

Main functions of eustachian tube are ventilation, drainage and protection of the middle ear. Pathologic conditions and surgery of middle ear can alter these functions. Sufficient ventilation of tympanic cavity can be considered as a predictive factor for the success of surgery for chronic otitis media. Therefore, demonstrating the ventilation of middle ear can give objective information about ET function. Clinically most popular method is tympanometry, which gives indirect information, but the data obtained is not quantitative (15, 16).

Radioisotope methods for the measurement of middle ear ventilation with Xe-133 have previously been studied in both healthy subjects and patients with middle ear disease. The technique in these studies was invasive which involved either transnasal catheterization of ET or myringotomy for the administration of gas. There are also few reports about noninvasive scintigraphic studies (12,13). Brenner et al compared different methodological approaches and concluded that, Xe-133 gas administration through a nasal olive was a noninvasive and easy way (12). In our study, we performed a modification of this method. We used a polyethylene nasal catheter and a syringe and directly transferred the gas into nasopharynx. According to patient compliance or technical disabilities, we were able to demonstrate Xe-133 middle ear uptake in 72% (13/18) of the patients. Our success rate is comparable to that in the literature, and Brenner et al reported it to be 70% (12). Non-visualization of air in the middle ear in some patients may be due to inability to open the ET during Valsalva maneuvers as reported by Thullen (3). Possibly, upright position is the most suitable for the opening of the tube, therefore Valsalva maneuvers were performed in the upright position in all our patients.

The number of relevant studies is limited in the literature, and there is also no consensus about which parameter of Xe-133 study should be used for the measurement of ventilation. Brenner reported that Xe-133 uptake should be considered to reflect this function rather than Xe-133 washout (12). We evaluated both parameters in our study. We used 2 min-4 min images for the evaluation of uptake by excluding the scatter activity from nasal and paranasal regions which was dominantly too high at the first few minutes. We found the uptake ratio to be significantly lower in patients than normals. This low uptake rate may be due to reversible or irreversible results of surgery as well as structural problems of ET, which might have played role in the pathogenesis of middle ear disease. As we did not perform ventilation scintigraphy prior to surgery; we can not say that tympanoplasty altered the situation. Comparable studies before and after surgery may be needed for more accurate explanation of this issue.

Many reports pointed out that gas exchange in the middle ear cavity occurs not only via ET but also through the middle ear mucosa (17-19). There is diffusion of gas through the surrounding mucosa into the circulation in the middle ear and ET serves to admit gas in order to equalize middle ear pressure with that of the ambience. Brenner et al. suggested that Xe-133 clearance primarily depends on the blood flow and increase in clearance should be expected in case of inflammation. However, they could not find any difference in Xe-133 clearance between the healthy subjects and the patients with middle ear pathology (12). Yamashita et al studied gas dynamics in the middle ear and showed that gas was absorbed mainly by surrounding tissue. In their study, the washout of Xe-133 was 40% in 1 hour with a patulous tube, 30% in an occluded tube and 8% in normal, leading to the hypothesis that the pathologic ear mucosal absorption rate might be greater than that of normal (20). In another study, authors did not take this gas diffusion into consideration and they used retention per cent of Xe-133 for eustachian ventilation measurement (13). In our study, when we compared the washout rates, there was no significant difference between the normals and patients, and it did not support the hypothesis of increase in blood flow would result in increased washout rate. Morphological and physiological factors, which affect the washout of Xe-133 from the middle ear cavity, are not known completely. It can be argued that washout may reflect the drainage function of ET. However, there seems to be an overlap of mucosal absorption and ET drainage of gas. Due to the complexity of this situation the use of uptake of Xe-133 rather than washout seems

to be the most accurate parameter for the evaluation of ventilation function. We still assume that washout may give an idea about the drainage function of the tube.

We also obtained postoperative tympanograms, which showed a type B pattern in almost all patients. This may be due to thickness and low elasticity of the graft in the early postoperative period. Therefore we consider that tympanogram is not a valuable method for the follow-up of middle ear and ET status especially in the early postoperative period. On the other hand, as it is shown in Yamashita's study, thickened ear drum can result in decreased uptake of gas into the middle ear cavity (20). This may be an independent factor that plays role in the decreased uptake irrespective of the ET dysfunction. Mid to long-term studies would better clarify this situation.

The preliminary data collected from this study showed that Xe-133 uptake can be used for the quantitative evaluation of ET ventilation function after tympanoplasty. Our method is reliable, accurate, and reproducible. The use of this method in long-term randomized prospective studies may be used to assess the role of ET function in the success of tympanoplasty.

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