INTRODUCTION

Chronic otitis media (COM) is a disease characterized by continuous or recurrent perforation of the eardrum and hearing loss following chronic inflammation of the middle ear cavity, ossicles, and mastoid cells. Eustachian dysfunction plays an important role in COM etiopathogenesis and postoperative prognosis. The determinants of postoperative prognosis are still being researched. This study aimed to research the prognostic value of acoustic rhinometry (ARM) and rhinomanometry (RMM) in COM surgery in terms of eradication of the infection after operation, graft success, and hearing gain in operated cases.

MATERIALS and METHODS: This study included 58 patients who underwent surgery with a diagnosis of COM. Patients were assessed in terms of age, gender, COM type, treatment methods used, eradication of infection, graft success, and hearing gain. ARM and RMM measurements were performed in the preoperative period. ARM and RMM values were statistically compared in terms of the existence of postoperative infection, graft success, and hearing gain.

RESULTS: In terms of ARM and RMM measurements, there was no statistically significant difference between cases where postoperative infection control was assured and cases with ongoing infection; successful and failed cases in terms of grafting; or successful and failed cases in terms of postoperative hearing. When preoperative and postoperative air-bone gap averages were compared, statistically significant differences were observed.

CONCLUSION: In the presence of a nasal obstruction in cases with chronic otitis, elimination of this situation is the first line of treatment. Infection control, graft success, and improvement of hearing will be possible to a greater extent in the postoperative period for patients with the nasal pathology remedied.

KEYWORDS: Chronic otitis media, acoustic rhinometry, rhinomanometry

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INTRODUCTION

Chronic otitis media (COM) is a disease characterized by continuous or recurrent perforation of the otorrhea, eardrum, and hearing loss following chronic inflammation of the middle ear cavity, ossicles, and mastoid cells [1]. Having a range incidence of 4–62% and prevalence of 2–52%, COM is a significant social problem in our country as in all societies [2]. In studies conducted in Turkey, COM prevalence is reported to be between 0.006 % and 2.6% [3].

Topical antibiotic drops and systemic antibiotics can be used for medical treatment in COM cases in the active period. Surgical treatment may be applied in cases not responding to medical treatment [1]. The main objective of COM surgery is to form a middle ear cavitation, which is well ventilated, provided with sound transmission, and remedied from inflammation. Many prognostic factors affecting hearing in cases with COM are discussed. Becvarovski and Kartush identified the key risk factors (discharge, cholesteatoma, tympanic membrane perforation, previous surgical history, granulation or effusion, smoking) for COM using the Middle Ear Risk Index [4]. As known, eustachian dysfunction plays an important role in COM etiopathogenesis and postoperative prognosis. It has been reported in literature that nasal obstruction plays a significant role in the formation of eustachian dysfunction [5]. In addition, it has been reported that eustachian dysfunction is frequently found in patients with turbinate and nasal septum deviation [6]. Pathologies of the nasal cavity are considered to adversely affect tympanoplasty and ossiculoplasty results, leading to eustachian dysfunction.

Acoustic rhinometry (ARM) and rhinomanometry (RMM) methods are most widely performed for the objective assessment of the nasal airway. RMM is a simultaneous measurement of nasal airflow and transnasal pressure. Pressure differences existing along the nose during nasal breathing create nasal airflow. Airflow can be measured by calculating the volume change either directly on nasal vestibule or indirectly on the thorax. A tube detecting the pressure in the active anterior RMM is fixed with a band in front of one of a nostril in such a manner so as to prevent air leakage. A mask covering the nose and mouth of the patient is placed on the face...
on the patient. Patient breathes through nose. As the patient will not
be able to breathe through the nostril with the pressure tube, the
pressure formed in the measurement tube is equal to the pressure
on the other nostril [8].

Acoustic rhinometry is used to examine the nasal cavity geometry. The
amount and location of the stenosis is calculated by using intensi-
ity, phase, and the delay time of reflecting acoustic signals sent to
the nasal cavity [8]. The ARM device can calculate many parameters,
such as dimension, location, the transverse cross-sectional areas of
minimal cross-sectional area (MCA) in different distances from the
nostrils and the total volume of nose by using a field-distance curve
[7]. The horizontal segment prior to point “0” in the acoustic rhinogram
represents the nasal adapter. Two notching are observed following
this. The first collapse is located in the isthmus nasi location and is
named as notch “I”. The second collapse belongs to the front end
portion of the inferior turbinate and is named as notch “C”. Notch “I”
defines the geometric characteristics of the nasal valve area located
in the first 2 cm in the narrowest part of the nasal cavity. There is no
significant change in this part when applied topical decongestant.
Notch “C” is the second narrowest area. It reflects the geometric char-
acteristics of the top part of the inferior turbinate [9]. The ARM nasal
provocation test is sensitive to changes in the nasal mucosa, such as
effects of nasal cycle and to topical decongestants. It is proposed us-
ing the MCA value while assessing nasal affection by ARM [9].

In this study, ARM and RMM measures of the nasal cavity were made
in cases operated due to COM, and the results were assessed in terms
of postoperative eradication of the infection, graft success, and hear-
ing gain. Through these, this study aimed to research the prognostic
value of ARM and RMM in COM surgery.

MATERIALS and METHODS
Fifty-eight patients who underwent surgery with a diagnosis of COM
between the years 2009 and 2014 in our clinics were prospectively in-
cluded in this study. Patients were assessed in terms of age, gender,
COM type, treatment methods applied, eradication of infection, graft
success, and hearing gain. The COM type was detected by otoscopy
and oto-microscopic examination. Cases were classified according to
COM type as non-cholesteatomatous COM, cholesteatomatous COM,
or adhesive COM. The types of surgery performed on patients were re-
corded. Patients undergoing open cavity mastoidectomy (radical mas-
toidectomy) and patients with nasal pathologies such as nasal septum
forte deviation and nasal polyposis were excluded from study.

Patients underwent preoperative audiologic tests (Interacoustics
AC40; Denmark), and the pure tone threshold averages were deter-
mined in this way. Patients had a rest during 15-20 minutes for the
ARM and RMM measures, then appropriate probe leads, specifical-
ly and separately prepared for the right and left nostrils, were used.
Measures were performed by the SRE2000 (Rhinometrics A/S; Lynge,
Denmark) device, which produces an acoustic signal in the form of
two truncated impulses. The cross-sectional areas, distance between
them, and nasal cavity volume measurement results obtained from
the measurement curves were detected by version 2.6 of the Rhino-
socan software (Rhinometrics A/S; Lynge, Denmark). The absence
of any signal leakage during the measurements was assured by both
the measurement curves and acoustic signal noise changes occurring
during the measurement. Patients in a sitting position were asked to
silent breathe in through the mouth during the measurement
recordings. Excluding the curves over the standard deviation of 2%,
which was selected as an acceptable level, for the curves formed
during the acoustic measurements made for each nostril, at least
three calibration curves were obtained. The average value of the
curve obtained from these three curves was recorded as the values for
the relevant patient. The scales on the measurement curves detected
automatically by the device were, respectively, as follows: the small-
est cross-sectional area located within the first 2 cm from the nasal
vestibule (MCA1), the smallest cross-sectional area located within the
second or fifth cm from the nasal vestibule (MCA2), and the cross-sec-
tional area located within the fifth cm from the nasal vestibule (MCAS).
The cross-sectional area was in square centimeters (cm²).

Prior to RMM, patients undergoing nasal cleansing with normal sa-
line irrigation had a rest for 15–20 minutes in a room at a temperature
of 20±3 degrees, humidity 50%, not intensively exposed to sunlight.
It was important that they avoided taking exercise, drinking tea or
coffee, and smoking 2 hours prior to the test. In the active anterior
RMM measurements, the mask covered both the mouth and nose,
and a pressure probe was passed through, inserted into a nostril,
with a nasal flow probe inserted in the other nostril. While inserting
the probes, attention was paid not to deform the nostrils and to as-
sure the absence of any air leakage. Patients were asked to keep their
mouths closed and to breathe in through the nose. The individual
resistance of each nostril (Right and Left R) was calculated and then
the total inspiratory nasal resistance (Total R) was calculated.

After surgery, postoperative controls were performed within 4–6
months. The postoperative examinations of patients were performed
by otoscopy and automicroscopy, and the graft success and hearing
status were assessed according to the eradication of infection and
state of the tympanic membrane. Patients underwent a postopera-
tive pure tone audiometry test in intervals ranging from 3 months
to 4 years (average of 14 months), and by determining the preopera-
tive and postoperative air-bone gap of each patient it was observed
whether there was a statistically significant difference in the two or
not. In addition, in line with the proposals of the American Academy
of Otolaryngology-Head Neck Surgery (AAO-HNS), cases with a post-
operative air-bone gap of 20 dB and below were considered success-
ful in terms of hearing, while those with a postoperative air-bone gap
above 20 dB were considered unsuccessful.

Acoustic rhinometry and RMM measurement values of cases with
infection and without infection, successful (intact) and failed cases
(perforated) in terms of tympanic membrane graft, and successful
and failed postoperative cases in terms of hearing were statically
compared.

The present study was conducted based on the principles of the Decla-
reration of Helsinki and approved by the Ethics Committee of Canakk-
ale Onsekiz Mart University. Informed consent was obtained from
all adult patients and from both parents of child patients.

Statistical Analysis
Statistical Package for the Social Sciences 19 (SPSS Corp.; Chicago,
IL, USA) software was used for the statistical analysis. When evaluat-
and middle ear risk index are some of the proposed methods [4, 10, 11].

OOPSI (ossiculoplasty, outcome, parameter staging index), SPITE (surgery, prosthesis, infection, tissues, and eustachian tube), COM in 7 cases (12.1%), and cholesteatomatous COM in 5 cases (8.6%). Thirty-one cases (53.4%) underwent tympanomastoidectomy, 25 cases (43.1%) underwent tympanoplasty type 1, and 2 cases (3.5%) underwent open cavity modified mastoidectomy technique (modified radical mastoidectomy). Oil, tragal cartilage, temporal muscle fascia, fascia, and tragal cartilage graft were used simultaneously.

While infection was controlled in 56 cases (96.6%) in the postoperative period, 2 cases (3.4%) had signs of infection in the postoperative period. The postoperative graft success rate was 87.9%. While hearing gain was achieved in 38 cases (65.5%) in the postoperative period, there was no achievement in terms of hearing in 20 patients (34.5%).

The average preoperative air-bone gap was 30.00±11.54 dB, and the average postoperative air-bone gap was 20.71±11.09 dB, and it was detected that there was a statistically significant difference between the averages of the preoperative and postoperative air-bone gaps (p<0.05) (Table 1).

When the ARM and RMM measurements of cases with and without infection control in the postoperative period were compared, it was detected that there was no statistically significant difference between them (p>0.05) (Table 2).

In our study, no statistically significant difference was observed between ARM and RMM of the group with an intact graft and those whose postoperative infections were not controlled (p>0.05) (Table 3).

In successful cases, while the right nasal cavity resistance was 1.62±1.56, the left nasal cavity resistance was 2.96±5.95 and the total resistance was 0.67±0.33 in RMM in terms of postoperative hearing; in failed cases, the right resistance was 2.01±1.88, left resistance was 2.38±2.47, and total resistance was 0.91±0.58. No statistically significant difference was observed between ARM and RMM of the group with a hearing gain in the postoperative period and the group with failed cases (p>0.05) (Table 4).

**DISCUSSION**

Despite various studies being conducted about the prognostic factors that play a role in achieving successful or failed results in chronic otitis surgery, there is no accepted standardization for all over the world. SPITE (surgery, prosthesis, infection, tissues, and eustachian tube), OOPSI (ossiculoplasty, outcome, parameter staging index), and middle ear risk index are some of the proposed methods [4, 10, 11].

As well as playing a role in COM etiopathogenesis, eustachian dysfunction is one of the most important reasons for postoperative failure. In the literature, it has been reported that development of the eustachian is linked to an effect of relevant nasal obstruction to the development of a nasomaxillary complex and skull base and that nasal obstruction plays an important role in eustachian dysfunction [5, 12]. In addition, it has been emphasized that eustachian dysfunction

### Table 1. The distribution of cases by preoperative and postoperative air-bone gap

<table>
<thead>
<tr>
<th>Air-bone gap</th>
<th>Preoperative number of patients (%)</th>
<th>Postoperative number of patients (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10 dB</td>
<td>0 (0)</td>
<td>9 (15.5)</td>
</tr>
<tr>
<td>11-20 dB</td>
<td>17 (29.3)</td>
<td>29 (50)</td>
</tr>
<tr>
<td>21-30 dB</td>
<td>14 (24.1)</td>
<td>11 (19)</td>
</tr>
<tr>
<td>31-40 dB</td>
<td>16 (27.6)</td>
<td>5 (8.6)</td>
</tr>
<tr>
<td>41-50 dB</td>
<td>9 (15.5)</td>
<td>3 (5.2)</td>
</tr>
<tr>
<td>&gt;50 dB</td>
<td>2 (3.4)</td>
<td>1 (1.7)</td>
</tr>
<tr>
<td>Total</td>
<td>58 (100)</td>
<td>58 (100)</td>
</tr>
<tr>
<td>dB: decibel</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 2. A comparison of rhinomanometry and acoustic rhinometry measurements in patients whose postoperative infections were controlled and those whose postoperative infections were not controlled**

<table>
<thead>
<tr>
<th>Infection absent</th>
<th>Infection present</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right R</td>
<td>1.82±1.72</td>
<td>0.99±0.66</td>
</tr>
<tr>
<td>Left R</td>
<td>2.86±5.13</td>
<td>1.78±0.03</td>
</tr>
<tr>
<td>Total R</td>
<td>0.78±0.46</td>
<td>0.60±0.28</td>
</tr>
<tr>
<td>Right MCA1</td>
<td>0.77±0.18</td>
<td>0.61±0.11</td>
</tr>
<tr>
<td>Right MCA2</td>
<td>0.57±0.31</td>
<td>0.48±0.26</td>
</tr>
<tr>
<td>Right MCA5</td>
<td>2.40±1.28</td>
<td>1.98±0.74</td>
</tr>
<tr>
<td>Left MCA1</td>
<td>0.78±0.18</td>
<td>0.62±0.37</td>
</tr>
<tr>
<td>Left MCA2</td>
<td>0.63±0.28</td>
<td>0.65±0.18</td>
</tr>
<tr>
<td>Left MCA5</td>
<td>2.39±1.32</td>
<td>2.32±0.40</td>
</tr>
</tbody>
</table>

R: resistance; MCA: minimal cross-sectional area

Statistically significant differences; significance level p<0.05

<table>
<thead>
<tr>
<th>Infection absent</th>
<th>Infection present</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right R</td>
<td>1.87±1.79</td>
<td>1.21±0.57</td>
</tr>
<tr>
<td>Left R</td>
<td>2.92±5.36</td>
<td>2.14±1.69</td>
</tr>
<tr>
<td>Total R</td>
<td>0.77±0.46</td>
<td>0.70±0.38</td>
</tr>
<tr>
<td>Right MCA1</td>
<td>0.76±0.18</td>
<td>0.79±0.20</td>
</tr>
<tr>
<td>Right MCA2</td>
<td>0.58±0.32</td>
<td>0.48±0.18</td>
</tr>
<tr>
<td>Right MCA5</td>
<td>2.39±1.34</td>
<td>2.38±0.61</td>
</tr>
<tr>
<td>Left MCA1</td>
<td>0.76±0.16</td>
<td>0.87±0.29</td>
</tr>
<tr>
<td>Left MCA2</td>
<td>0.65±0.29</td>
<td>0.48±0.08</td>
</tr>
<tr>
<td>Left MCA5</td>
<td>2.45±1.35</td>
<td>1.97±0.76</td>
</tr>
</tbody>
</table>

R: resistance; MCA: minimal cross-sectional area

Statistically significant differences; significance level p<0.05

### Table 3. A comparison of rhinomanometry and acoustic rhinometry measurements in patients with a postoperative intact graft or perforated graft

<table>
<thead>
<tr>
<th>Intact graft</th>
<th>Perforated graft</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right R</td>
<td>1.87±1.79</td>
<td>1.21±0.57</td>
</tr>
<tr>
<td>Left R</td>
<td>2.92±5.36</td>
<td>2.14±1.69</td>
</tr>
<tr>
<td>Total R</td>
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<td>Right MCA2</td>
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<td>0.48±0.18</td>
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<tr>
<td>Right MCA5</td>
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<td>2.38±0.61</td>
</tr>
<tr>
<td>Left MCA1</td>
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<td>0.87±0.29</td>
</tr>
<tr>
<td>Left MCA2</td>
<td>0.65±0.29</td>
<td>0.48±0.08</td>
</tr>
<tr>
<td>Left MCA5</td>
<td>2.45±1.35</td>
<td>1.97±0.76</td>
</tr>
</tbody>
</table>

R: resistance; MCA: minimal cross-sectional area

Statistically significant differences; significance level p<0.05
is found frequently in patients with turbinate and nasal septum deviation [16]. Low and Willatt [13] reported that middle ear pressure on the deviated side after septoplasty decreased significantly. Watson [14] detected that nasal obstruction on unilateral COM is important and that nasal airway resistance is higher at the side of the ear affected. Pathologies of the nasal cavity adversely affect tympanoplasty and ossiculoplasty results, leading to eustachian dysfunction. In our study, the anatomy and physiology of the nasal cavity were objectively assessed, and the prognosis effects on patients operated due to COM were researched. For this purpose, the results obtained from both postoperative otoscopic and microscopic examination, and the preoperative and postoperative hearing test results were compared with measurements of ARM and RMM. In this way, the prognostic value of the parameters, such as total nasal resistance, were assessed.

The cross-sectional area of the nasal cavity in tympanoplasty surgery was also discussed herein. ARM and RMM methods are most widely performed for the objective assessment of the nasal airway. RMM is a simultaneous measurement of nasal airflow and transnasal pressure [7]. Normally, inspiratory nasal airway resistance in non-decongestant noses ranges from 0.34–0.40 Pa/cm3/s (average, 0.39); and 0.25–0.30 Pa/cm3/s (average, 0.26) after decongestion per person. Even though each nasal cavity resistance changes during the day, total nasal resistance remains constant [7]. ARM was used to examine the nasal cavity geometry. The amount and location of the stenosis was calculated by using the intensity, phase, and delay time of reflecting acoustic signals sent to the nasal cavity [8]. Grymer et al. [15] observed MCA as 0.72–0.73 cm2 prior to topical decongestant application in asymptomatic persons; and as 0.92–0.95 cm2 after decongestantation [18].

Güçlü et al. [16] reported that the relationship between COM and nasal parameters was observed to be statically high at a significant level compared to nasal resistance in cases with COM. However, there was no statistically significant difference detected between the ARM values of these two groups. The fact that nasal resistance is different between two groups in RMM was linked to mucosal changes. However, in our study, when we considered the nasal cavity effect on prognosis in patients operated on due to COM, there was no statistically significant difference observed between the ARM and RMM measurements of cases with and without infection control. However, when successful and failed grafts and successful and failed cases in terms of hearing were compared in terms of ARM and RMM, there was no statically significant difference.

One object of tympanoplasty operations is to form a closed self-ventilated cavity. Demirpehlivan et al. [17] reported the graft attachment success in the tympanoplasty surgery of type 1 as 97.7% in the group using palisade cartilage; 79% in the group using an island graft of perichondrium cartilage; and 80.6% in fascia group; with the average of the three groups reported as 85% . Coelho et al. [18] detected the success rate in patients having cartilage tympanoplasty surgery as follows: 92.9% in a smoking group; 90.6% in a non-smoking group. Hod et al. [19] detected the graft success rate in the inlay butterfly cartilage tympanoplasty technique as 92.5% [19]. In our study, there was a group of solely fascia, solely cartilage, and a heterogeneous group with fascia and cartilage used simultaneously. In our study, the graft attachment success rate was 87.9%, regardless of the graft material used. In our study, there was no significant difference between the ARM and RMM measurements of groups with intact graft or a perforated graft in the postoperative period.

In conclusion, according to data obtained when comparing ARM and RMM measurements of cases where postoperative infection control was assured and cases with ongoing infection, no statistically significant difference was observed. Similarly, no significant difference was observed between the ARM and RMM measurements in successful and failed graft cases. This finding is in fact an expected condition because if the patients undergoing ear surgery have upper respiratory tract pathologies, the treatment should be applied accordingly. In addition, the elimination of this situation in the presence of nasal obstruction in patients with chronic otitis is the first line of treatment. We believe that the attention paid to the selection of patients led to this result. However, when comparing successful and failed cases in postoperative hearing, no significant difference was observed between the ARM and RMM measurements in successful and failed graft cases. Nevertheless, when comparing preoperative and postoperative air-bone gap averages, a statically significant difference was observed (p<0.05). Considering these findings, it is understood that better results can be obtained in postoperative hearing in patients with a more advanced eustachian function and nasal anatomy and physiology, according to the objective nasal measurement results.

### Table 4. A comparison of rhinomanometry and acoustic rhinometry measurements of groups with a hearing gain in the postoperative period and the group with failed cases

<table>
<thead>
<tr>
<th></th>
<th>Postoperative hearing gain</th>
<th>Postoperative hearing failed</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right R</td>
<td>1.62±1.56</td>
<td>2.01±1.88</td>
<td>0.167</td>
</tr>
<tr>
<td>Left R</td>
<td>2.96±5.95</td>
<td>2.38±2.47</td>
<td>0.314</td>
</tr>
<tr>
<td>Total R</td>
<td>0.67±0.33</td>
<td>0.91±0.58</td>
<td>0.195</td>
</tr>
<tr>
<td>Right MCA1</td>
<td>0.76±0.18</td>
<td>0.76±0.20</td>
<td>0.722</td>
</tr>
<tr>
<td>Right MCA2</td>
<td>0.59±0.32</td>
<td>0.51±0.27</td>
<td>0.387</td>
</tr>
<tr>
<td>Right MCA5</td>
<td>2.54±1.32</td>
<td>2.01±1.02</td>
<td>0.121</td>
</tr>
<tr>
<td>Left MCA1</td>
<td>0.78±0.17</td>
<td>0.74±0.20</td>
<td>0.545</td>
</tr>
<tr>
<td>Left MCA2</td>
<td>0.62±0.26</td>
<td>0.61±0.28</td>
<td>0.574</td>
</tr>
<tr>
<td>Left MCA5</td>
<td>2.34±1.16</td>
<td>2.40±1.46</td>
<td>0.993</td>
</tr>
</tbody>
</table>

R: resistance; MCA: minimal cross-sectional area
Statistically significant differences; significance level p<0.05
Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Çanakkale Onsekiz Mart University / 2014-01 08.01.2014

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Peer-review: Externally peer-reviewed.


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Conflict of Interest: No conflict of interest was declared by the authors.

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