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Journal of the Chinese Medical Association 80 (2017) 508–514

www.jcma-online.com

Original Article

Learning curve for endoscopic tympanoplasty: Initial experience of 221 procedures

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Received September 9, 2016; accepted January 12, 2017

Abstract

Background: The learning curve for endoscopic tympanoplasty has never been quantitatively reported. The present study depicted the learning curve for endoscopic tympanoplasty and evaluated how many procedures an otologist requires to attain proficiency in this technique.
Methods: We reviewed the medical charts of consecutive patients who underwent endoscopic tympanoplasty between January 1, 2013 and June 1, 2015. We enrolled patients with simple perforations of the tympanic membrane and excluded those with ossicular chain disease. The main outcome was learning curves for endoscopic tympanoplasty, which illustrated changes in the mean operative time and graft success rate according to the patient numbers. We subsequently estimated and verified the threshold value using statistical methods.
Results: A total of 221 procedures were included. For the learning curve of the mean operative time, the time gradually decreased from 75 minutes to 55 minutes. After the 150th patient, the mean operative time stabilized to < 60 minutes. For the learning curve of the graft success rate, the rate sharply increased from 75% to 95%. After the 50th patient, the graft success rate reached a plateau and fluctuated between 85% and 100%. We subsequently verified that the 50th and 150th patients were appropriate threshold values. Moreover, the graft success rate of perforations < 50% was significantly higher than that of perforations > 50%.
Conclusion: These curves illustrate significant progress of the surgeon during the first 50 patients, considering the graft success rate, reaching an advanced level after the 150th patient, considering the mean operating time.

Keywords: endoscopy; learning curve; tympanic membrane; tympanoplasty

1. Introduction

Elucidating the learning curve for a new technique is essential. A learning curve for an operation refers to the number of patients required before achieving a stable operating time and surgical outcome.[1] Inexperienced surgeons can learn from the established learning curve and improve their learning process.

Since the 1950s, microscopic tympanoplasty has been the standard operation for repairing a perforated tympanic membrane.[2–4] The operation can be performed using three (postauricular, endaural, and transcanal) approaches. A postauricular incision facilitates greater visibility of the operating site, whereas the transcanal approach is reserved for patients with small tympanic perforations and a wide ear canal status.[3] Therefore, microscopic tympanoplasty through the postauricular approach has been performed worldwide.[3,4] Despite having a high graft take rate > 90%, this technique frequently requires hair shaving, deep postauricular incision, and general anesthesia.[3,4]

Conflicts of interest: The authors declare that they have no conflicts of interest related to the subject matter or materials discussed in this article..

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http://dx.doi.org/10.1016/j.jcma.2017.01.005

In addition to conventional microscopic tympanoplasty, endoscopic tympanoplasty has been an emerging technique since the late 1990s.[5–15] The number of related reports steadily increased, peaking in 2014.[6] The major difference between microscopy and endoscopy is the surgical view. The view during microscopic surgery is defined and limited by the narrowest segment of the ear canal. By contrast, transcanal endoscopy bypasses the narrowest ear canal and provides a wider view, even when a 0-degree endoscope is used.[7,8] Because of this advantage, endoscopic tympanoplasty can avoid canalplasty, postauricular incision, and general anesthesia, and therefore, is less invasive than the microscopic technique.[5–15]

Several studies have reported the learning curve for endoscopic tympanoplasty; however, none of them have quantitatively described those curves.[7,8,10] Therefore, the present study depicted the learning curve for endoscopic tympanoplasty and evaluated how many procedures an otologist requires to attain proficiency in this technique.

2. Methods

2.1. Study design and patients

The Joint Institutional Review Board of the Taipei Medical University approved our study protocol. The present study was a retrospective medical chart review of consecutive patients who had undergone endoscopic tympanoplasty between January 1, 2013 and June 1, 2015 at our hospital. We enrolled patients who had simple perforations of the tympanic membrane and excluded those with ossicular chain disease and cholesteatoma. Those patients were followed up at the clinic for at least 6 months. All operations were performed under local and intravenous anesthesia by the same surgeon in an outpatient setting. The surgeon had performed approximately 50 microscopic tympanoplasties before performing endoscopic tympanoplasty. This study included the surgeon's initial practice of endoscopic tympanoplasty.

Preoperatively, we used a video recording system to visualize the status of the tympanic membrane using an endoscope (Storz, Tuttlingen, Germany; 4.0 mm, 0-degree, 18-cm long lens). The recorded image was obtained to evaluate the perforation size of the tympanic membrane and condition of the middle ear mucosa. The tympanic membrane was divided into quadrants according to the position of the malleus handle, and each quadrant accounted for 25% of the tympanic membrane. The perforation size was evaluated and divided into three groups: < 10%, 10–50%, and > 50%; the perforation location was classified as anterior or posterior to the malleus handle. If an anterior perforation extended posterior to the malleus handle, it was considered central. Perforations were considered inferior if they were inferior to the umbus of the malleus. We defined the operating time as the duration between the start of local anesthesia and end of wound dressing. Graft success was defined as the presence of an intact graft evaluated using a 0-degree endoscope, whereas graft failure was a residual or recurrent perforation at 6 months postoperatively. The patients were chronologically numbered according to the operating date and were equally divided into 11 groups, each comprising 20 patients. The graft success rate and mean operating time were calculated for each group.

Data on patient age, sex, site, perforation size, graft success rate, operating time, air–bone gaps in audiograms, and hearing loss were extracted for analysis. We recorded preoperative and postoperative audiograms of patients at frequencies of 0.5 kHz, 1 kHz, 2 kHz, and 3 kHz to access the closure of the air–bone gap. When a threshold at 3 kHz was unavailable, the average of 2 kHz and 4 kHz was calculated.

The main outcomes were learning curves for endoscopic tympanoplasty. The first learning curve illustrated changes in the mean operating time according to the patient numbers. The second learning curve depicted changes in the graft success rate according to the patient numbers.

We determined the threshold value according to three criteria. First, we searched for an apparent deflection point on our depicted curves. Second, we verified the estimated threshold value by using statistical methods. For example, we compared the data before the estimated threshold value to those after the value by using sample t tests. Third, we compared the estimated threshold value to data from previous reports. For example, the graft success rate of type I tympanoplasty is typically higher than 90%.[3,4]

Because the perforation size generally affects the operating time and graft success rate,[3,4] we subsequently stratified these two factors according to the perforation size in the analysis.

2.2. Surgical techniques

Two Storz rigid endoscopes were used in our surgical techniques (4.0 mm, 0-degree, 18-cm long lens and 3 mm, 0-degree, 14-cm long lens).

Patient ears were prepared and draped under sterile conditions without hair shaving. Each patient was administered intravenous sedation (50 mg meperidine + 5 mg midazolam) 10 minutes preoperatively by an anesthesiologist. The periaural area and external ear canal were infiltrated with 2% lidocaine with 1: 100,000 epinephrine.

We used the temporalis fascia or tragal perichondrium as graft materials. For harvesting the temporalis fascia graft, a 2.5-cm incision near the hairline superior and posterior to the helix was made to expose the areolar tissue or temporalis fascia; this connective tissue was harvested and then pressed using a fascia clamp. After achieving hemostasis, the postauricular incision was closed with absorbable sutures. For harvesting the tragal perichondrium graft, a 1-cm incision was made 2–3 mm medial to the free border of the tragal cartilage, cutting through the skin and cartilage. The perichondrium was free of the cartilage and prepared as a graft. The incision was sutured with an absorbable material.

We used two surgical techniques: endoscopic simple underlay myringoplasty (without elevation of the tympanomeatal flap), and endoscopic type I tympanoplasty (with elevation of the tympanomeatal flap), as described by Furukawa et al.[11]

2.3. Endoscopic simple underlay myringoplasty

When the perforation size was < 50%, we performed endoscopic simple underlay myringoplasty. First, the perforation margin was circumferentially freshened using a pick. The middle ear cavity was tightly packed with Gelfoam (Pfizer, New York, USA) through the perforation. After being prepared 2 mm larger than the perforation size, the graft was pushed through the perforation and placed in an underlay manner. Gelfoam pledgets soaked with antibiotic drops (0.3% ofloxacin ear solution) were placed lateral to the graft in the external auditory canal.

2.4. Endoscopic type I tympanoplasty

When the perforation size was > 50%, we performed endoscopic type I tympanoplasty with elevation of the tympanomeatal flap. First, the perforation margin was circumferentially freshened with a pick. An incision was made from the tympanic annulus posteriorly to elevate the tympanomeatal flap. A prepared graft trimmed to an appropriate size was placed medial to the malleus handle to prevent graft lateralization. Gelfoam was packed in the middle ear cavity to support the graft from medialization. The tympanomeatal flap was subsequently replaced to its original position. The external auditory canal was packed with Gelfoam pledgets.

The postauricular incision was covered with a gauze dressing, whereas the tragal incision was packed with a cottonoid ball placed in the orifice of the external auditory canal. No mastoid dressing was required. The patients were discharged on the day of surgery.

2.5. Postoperative follow-up

Each patient was prescribed systemic antibiotics (first-line cephalosporins or antibiotics according to preoperative culture results). At 1-week postoperatively, stitches and aural dressings were usually removed, and Gelfoam fragments were aspirated, thus allowing the graft to be visualized. Each patient was scheduled regular follow-up visits at 2 weeks and 3 weeks as well as 2 months, 3 months, 6 months, and 12 months and underwent endoscopy and audiometry at 3 months, 6 months, and 12 months postoperatively.

2.6. Statistical analysis

Statistical analysis was performed using SPSS version 16.0 for Windows (SPSS Inc., Chicago, IL, USA). The study results are expressed as mean ± standard deviation for continuous variables. A sample t test was used to compare the differences between groups that had continuous variables. The differences between groups were considered significant at $p < 0$ .05.

3. Results

Over the 30-month study period, the surgeon consecutively performed 234 procedures of endoscopic type I tympanoplasty. Of these patients, 13 were excluded because of an inadequate follow-up period of 6 months, and the remaining 221 were included in this analysis.

There were 110 (50%) male and 111 (50%) female patients, with a mean age of 51.3 years (18–86 years). Furthermore, 106 (48%) right and 115 left (52%) ears were operated upon. The mean follow-up period was 10.4 ± 7.6 months.

The main outcome of this study was the learning curves for endoscopic tympanoplasty. Figure 1 illustrates the learning curve of the mean operating time according to the patient numbers. The mean operating time gradually decreased from 75 minutes (10th patient) to 55 minutes (150th patient). After the 150th patient, the mean operating time stabilized to < 60 minutes, which is comparable to the duration of tympanoplasty in the literature.[16] The mean operating time before the 150th patient was significantly longer than that after the 150th patient (Table 1). Based on the criteria mentioned in the Methods, we determined the 150th patient as the threshold value according to the curve of the mean operating time (Fig. 1). Figure 2 depicts the learning curve of the graft success rate according to the patient numbers. The graft success rate sharply increased from 75% (10th patient) to 95% (50th patient). After the 50th patient, the graft success rate reached a plateau and fluctuated between 85% and 100%; this rate is consistent with the overall success rate of tympanoplasty of 90%.[3,4] The graft success rate before the 50th patient was significantly lower than that after the 50th patient (Table 1). Based on the criteria mentioned in the Methods, we determined the 50th patient as the threshold value according to the curve of the graft success rate (Fig. 2).

When the patients were divided by the perforation sizes (< 10%, 10–50%, and > 50%), the proportions of the perforation size were 15.4%, 50.2%, and 34.4%, respectively. The mean operating times, graft success rates, and postoperative air–bone gaps were significantly different when they were stratified by the perforation size (Table 2). No significant difference was found in the distribution of patients stratified by the perforation size (Table 3).

A total of 13 patients developed postoperative otorrhea for > 3 weeks, which resolved after they received otic and oral antibiotic treatments. Two patients experienced postoperative hemorrhage because of postauricular incision; however, the bleeding stopped after direct compression. All operations were completed through the endoscopic method, and none converted to the microscopic method. No patients reported sensorineural hearing loss.

4. Discussion

Although endoscopic tympanoplasty has been increasingly reported recently,[5–15] its learning curve has never been quantitatively reported. This study is the first to plot learning curves for endoscopic tympanoplasty.

Learning curves for endoscopic procedures have been reported.[17–21] The learning curve was 30 cases for sialendoscopy,[18] 40 for endoscopic septoplasty,[21] and 60 for endoscopic thyroidectomy.[17] Regarding the learning curve for microscopic tympanoplasty, Liu et al[16] reported that 29

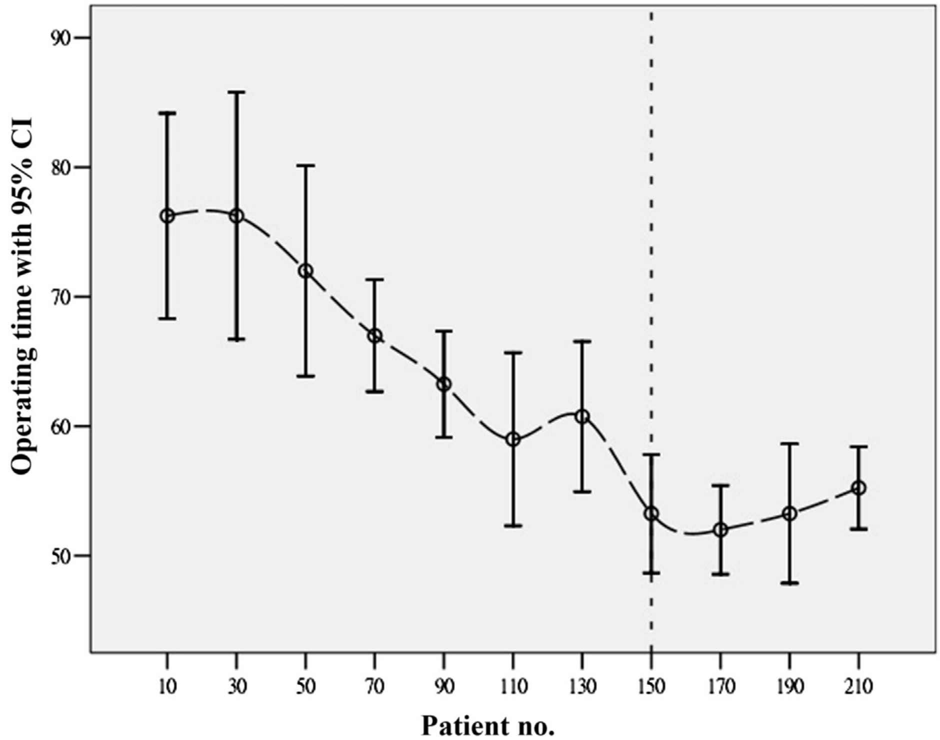

Fig. 1. Changes in the mean operating time according to patient numbers. CI = confidence interval.

Table 1
Mean operating time and graft success rate before and after the threshold value: the 50th and 150th patients.

Patient no.	No. of patients	Mean operating time (min)	Mean graft success rate
< 50	50	74.2 ± 18.1	0.80 ± 0.40
> 50	171	59.1 ± 12.7	0.96 ± 0.20
		$p < 0.01$	$p < 0.01$
< 150	150	62.1 ± 16.0	0.92 ± 0.27
> 150	71	54.0 ± 9.0	0.92 ± 0.27
		$p < 0.01$	$p = 0.96$

patients were operated upon to achieve a success rate of 96%, with a mean operating time of 76 minutes. In this study, 50 patients were operated upon to reach a success rate of 95%, with a mean operating time of 72 minutes.

For analysis, we stratified the mean operating time and graft success rate by the perforation size. When the mean operating time was stratified by the perforation size, we found that the durations for these three groups were significantly different (Table 2). The larger the perforation, the longer the mean operating time. All three of these curves showed a decreasing trend of the mean operating time according to the patient numbers (Fig. 3). When the graft success rate was stratified by the perforation size, we found that the rates for these three groups were significantly different (Table 2). The graft success rate of perforations < 50% was significantly higher than that of perforations > 50%. Regarding perforations < 10%, the curve showed no learning process (Fig. 4). Regarding the perforation sizes between 10% and 50%, the curve became stabilized after the 50th patient (Fig. 4). On the basis of these findings, we suggest that inexperienced surgeons start performing endoscopic tympanoplasty on patients who have a perforation size < 50%, because it is easy to achieve a high success rate and shorten the operating time.

Several surgical techniques facilitate determining the mean operating time and graft success rate. First, we prevent the formation of hemorrhagic bulbs in the ear canal when injecting local anesthesia. Also, we prevent erosions in the ear canal caused by the friction against the endoscope and instruments. Bleeding from hemorrhagic bulbs and erosions blurs the surgical field and endoscopic tip. Achieving hemostasis and cleaning the endoscopic tip are time consuming in the endoscopic technique. Second, we have become sophisticated in using this one-handed technique for endoscopic tympanoplasty. In this technique, the endoscope is held in the nondominant hand, whereas most of the surgery is performed using the dominant hand. This procedure is particularly challenging when a surgeon elevates the tympanomeatal flap or places a graft medially. Third, we have become familiar with the monocular view of endoscopy. This monocular view causes a loss of depth perception, compared with the binocular view of microscopy.[3,7,10] However, once the surgeon is sufficiently proficient with the endoscopic technique, considerable time is saved during surgery, particularly because no soft-tissue approach is required and the ear need not be closed following surgery.[12] Similarly, our findings reveal that the mean operating time decreased from the initial 75 minutes to a final duration of 55 minutes (Fig. 1).

In this study, we consecutively performed endoscopic tympanoplasty on the first 234 patients, and we did not select our patients because of disease severity. Table 3 also

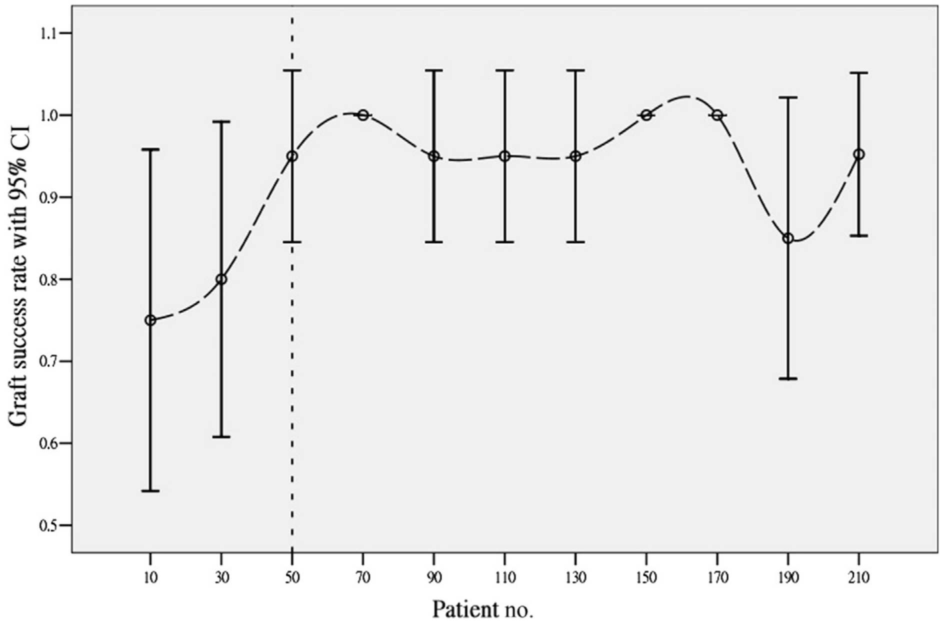

Fig. 2. Changes in graft success rate according to patient numbers. CI = confidence interval.

Table 2
Mean operating time, graft success rate, and postoperative ABG stratified by perforation size.

Perforation size	No. of patients	Mean operating time (min)	Graft success rate	Postoperative ABG
< 10%	34	50.9 ± 16.2	1.0 ± 0.0	8.0 ± 10.5
10–50%	111	60.5 ± 12.0	0.95 ± 0.23	8.5 ± 10.7
> 50%	76	70.8 ± 15.1	0.86 ± 0.35	13.5 ± 14.5
		$p < 0.01$	$p < 0.05$	$p < 0.05$

ABG = air-bone gap.

demonstrates that no significant difference was found in the distribution of patients stratified by the perforation size. The surgeon had practiced three procedures of endoscopic ear surgery (ossiculoplasty) other than type I tympanoplasty or myringoplasty during this period. None of these procedures required converting to the microscopic method from the endoscopic method. Over these procedures, the surgical technique was modified according to our experience. For example, the temporal fascia was initially used as the graft material more frequently than the perichondrium. However, the temporal fascia was subsequently used as the graft material less frequently. Although we used two distinct graft materials in our study, research has not found that this affects graft success rates.[22]

The present study had three limitations. First, only one surgeon contributed to this learning experience. Second, this study was a retrospective chart review, which might have caused a recall or measurement bias. Third, the learning curve may have been affected by the surgeon's surgical experience. For example, a resident's learning curve differs from that of a visiting staff member. This observation may influence the generalization and external validity of our results. Because no study of this type exists in the literature, the value of this study is its novelty. Future studies should extend our work from a retrospective design to a prospective one and from a single surgeon's experience to that of several surgeons.

For beginners to shorten their learning period for endoscopic tympanoplasty, we have several suggestions. It is often most favorable to start with patients who have a perforation size < 50%. In addition, a training course of endoscopic temporal bone dissection may equip surgeons with the skills and techniques necessary for using this technique.[23] Moreover, surgical video clips of endoscopic tympanoplasty from open resources, such as YouTube, might play a role in shortening the learning period.

In conclusion, our learning curves for endoscopic tympanoplasty illustrate a significant progress of the surgeon during

Table 3
Distribution of patients stratified by perforation size.

Patient no. group	10	30	50	70	90	110	130	150	170	190	210
Perforation size < 10%	6	2	3	5	2	4	2	4	3	3	0
No. of patients (%)	(30)	(10)	(15)	(25)	(10)	(20)	(10)	(20)	(15)	(15)	(0)
Perforation size 10–50%	8	11	10	10	12	8	8	10	10	11	13
No. of patients (%)	(40)	(55)	(50)	(50)	(60)	(40)	(40)	(50)	(50)	(55)	(62)
Perforation size > 50%	6	7	7	5	6	8	10	6	7	6	8
No. of patients (%)	(30)	(35)	(35)	(25)	(30)	(40)	(50)	(30)	(35)	(30)	(38)
Total	20	20	20	20	20	20	20	20	20	20	21
(%)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)
										$p = 0.83$	

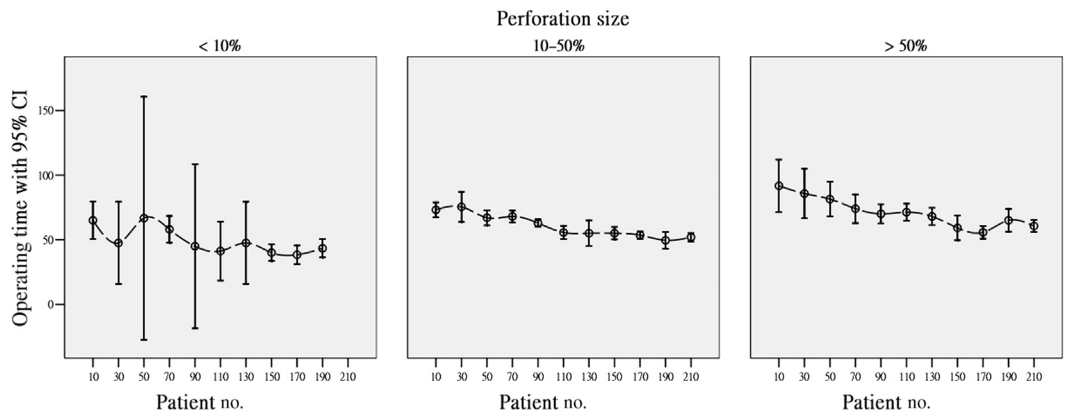

Fig. 3. Changes in mean operating time according to patient numbers stratified by perforation size. CI = confidence interval.

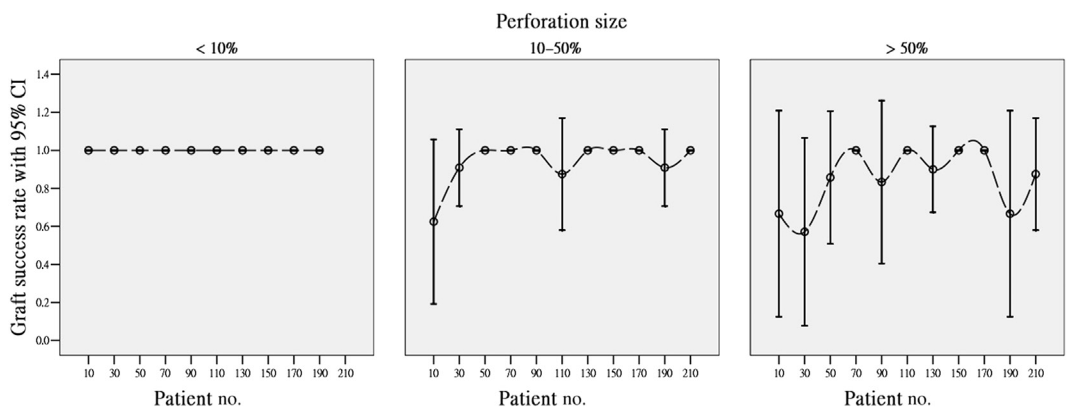

Fig. 4. Changes in graft success rate according to patient numbers stratified by perforation size. CI = confidence interval.

the first 50 patients considering the graft success rate, reaching an advanced level after the 150th patient considering the mean operating time. Moreover, we suggest that inexperienced surgeons start performing endoscopic tympanoplasty on patients who have a perforation size < 50%; thus, they can shorten their learning curve for this technique.

Acknowledgments

The authors thank Professor Winston W. Shen for his constructive criticism of the manuscript.

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