Tympanic Perforations in Children: When to Propose Surgical Closure?

Marine Del Puppo, Anne Farinetti, Stéphane Roman, Marie-Eva Rossi, Claire Le Treut, Richard Nicollas, and Eric Moreddu

Department of Pediatric Otolaryngology Head and Neck Surgery, La Timone Children's Hospital, AP-HM, Aix Marseille Université, Marseille, France

Objective: This study aims to analyze the impact of age and other prognostic factors on the success of myringoplasty.
Study design: A retrospective case series.
Settings: Pediatric ENT department of a tertiary academic center.
Patients: Two hundred forty-one children (318 ears) aged 3 to 17 years with tympanic perforation.
Intervention: Myringoplasty performed between 2009 and 2019.
Main outcomes measures: The rate of tympanic closure, perforation recurrence, revision surgery, and audiometric gain were collected. The impact of age and anatomical and surgical factors was analyzed for each procedure.
Results: With a mean follow-up time of 1 year, the tympanic closure rate was 87.7%, the perforation recurrence rate was 18.6%, and 16.7% of ears required reoperation. The mean air–bone gap decreased from 21 dB preoperatively to 12 dB postoperatively ($p < 0.0001$). We did not find different anatomical and audiometric results for our three groups of patients classified according to age. Audiometric results were associated with the location of the perforation, intraoperative inflammation of the middle ear mucosa, and the surgical technique performed.
Conclusion: Myringoplasty in children is associated with excellent anatomical and functional results, even in the youngest patients. It can be proposed whatever the child's age if the patients are well selected before giving the indication.
Key Words: Age—Children—Hearing improvement—Myringoplasty—Prognostic factor—Surgical success—Tympanic perforation.

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INTRODUCTION

Tympanic perforations are a frequent reason for consultation and follow-up in otology and pediatric otology. Leading causes of tympanic perforations mainly occur in children and are perforation after acute otitis media, residual perforation after tympanostomy tube, or post-traumatic perforation.

Even if spontaneous closure is possible, the persistence of a tympanic perforation can have severe repercussions on the quality of life: contraindication to swimming, hearing loss, chronic otorrhea or epidermal inclusion, and transformation into a cholesteatoma. The occurrence of even a slight hearing loss in a child represents a barrier to learning and an added cause of tiredness in the context of the need for sustained concentration at school.

The treatment of this pathology is based on a surgical procedure, myringoplasty or type I tympanoplasty, first described in 1878. In France, in 2020, nearly 7,000 procedures were performed in the private sector alone in adults and children (1).

This surgery aims to restore the integrity of the eardrum and improve hearing. Although most studies show a high closure rate, close to 90%, after myringoplasty (2,3), it is essential to gather the best possible conditions to hope for success. There has yet to be a consensus on the significance of these prognostic factors in the studies already carried out on this subject, particularly on age (2,4–12). The reasons given by authors for a minimum age before surgery are based on the chronic inflammation of the upper airway and the immaturity of the Eustachian tube. (11).

The main objective of this study was to analyze, through a univariate and multivariate analysis, the impact of age on the success of myringoplasty in children and postsurgical hearing restoration. The secondary objective was to determine the role of other prognostic factors, such as the perforation size and location, the mucosal state of the operated and contralateral ear, and the operative technique.

MATERIALS AND METHODS

All myringoplasties performed in the pediatric ENT department of a tertiary academic center, over 10 years from

Address correspondence and reprint requests to Marine Del Puppo, Aix Marseille Université, Hôpitaux Universitaires de Marseille, 264 Rue Saint Pierre, 13005 Marseille, France; E-mail: marine.del-puppo@ap-hm.fr
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January 2010 to December 2019, were retrospectively collected. Among the 303 patients, 62 were excluded because of missing data, age over 18 years, the intraoperative discovery of a cholesteatoma, or loss to follow-up after the procedure. Each ear was considered separately. Data from 318 surgical procedures were analyzed, involving 241 children, 61 of whom had bilateral perforations. Fifty-five of the procedures were repeat surgeries after the first failed myringoplasty.

For each procedure, the following data were collected: age at the time of surgery, personal history (syndrome, velopalatal cleft, or other), the status of the contralateral ear (perforation or other pathology), description of the perforation (location, estimated size in percentage of the tympanic membrane, marginal on the annulus, and marginal on the malleus), preoperative and postoperative audiometric test, and the intraoperative status of the fundus mucosa. The description of the tympanic perforation was based on the preoperative otoscopy picture. Four surgical techniques were used: the underlay technique, with the placement of either connective tissue (fascia temporalis or perichondrium) or cartilage under the remnants of the tympanic membrane; the butterfly technique, consisting of interposing a patch of tragal cartilage in the perforation; and the placement of a fat graft in the perforation. Age itself was not a criterion in the choice of surgical technique.

Patients were classified into three groups according to age at surgery: less than or equal to 6 years, between 7 and 10 years, and more than or equal to 11 years.

Outcomes were collected at the 2-year postoperative visit or the last available visit if follow-up was interrupted. The median duration of postoperative follow-up was 1 year and 4 months. The success of myringoplasty was assessed by tympanic closure at the end of the follow-up, the absence of perforation recurrence, and the absence of the need to repeat any surgery during the follow-up. These two rates differ because some postoperative reperforations could close spontaneously, whereas some ears had to be reoperated for other complications (retraction pocket, postoperative cholesteatoma …).

Audiometric tests were performed in soundproof rooms by trained professionals. Air and bone conduction thresholds were collected at five frequencies: 250, 500, 1000, 2000, and 4000 Hz. Unlike many studies, low frequencies were included in our data collection because they seem more affected in tympanic perforation cases (13). The audiometric air–bone gap (ABG) was calculated on these five frequencies. Postoperatively, results of an audiometric test were collected for each procedure. When bone conduction thresholds were unavailable postoperatively, bone thresholds at 5 dB were used to calculate the air–bone gap.

Postoperative hearing rehabilitation was defined as a mean air–bone gap 10 dB or lower on the last available audiogram.

Statistical analysis used MedCalc software for Windows, version 20.026 (MedCalc Software, Ostend, Belgium). Univariate analyses were performed using chi-squares tests for categorical data; Student's *t* test and analysis of variance for numerical data and then logistic and linear regression were used for multivariate analysis, respectively, for categorical and numerical data. The significance level was set for a p value lower than 0.05.

RESULTS

Patients

Characteristics of the studied population are presented in Table 1. The mean age at surgery was 8.9 years, with a median of 8 years and a range of 3 to 17 years. Of the 318 procedures analyzed, 26 (8.2%) were performed in syndromic children and 13 (4.1%) in children with velopalatal cleft. Another pathology of the contralateral ear (retraction pocket, serous otitis …) was found in 33 cases (10.4%). Etiologies of tympanic perforations were residual post-tympanostomy tube perforation (65.1%), postotitic perforation (28%), perforation of unknown cause (4.7%), and traumatic causes (3.5%). A preoperative computed tomography (CT) scan was performed for 104 of the procedures, which showed a middle ear effusion (mastoid and/or tympanic cavity) or a sclerotic mastoid in 50 cases.

Our three groups of patients were comparable concerning the description of the perforations, contralateral ear pathology, intraoperative mucosal inflammation, and preoperative audiometric Rinne. There was a significant difference between our groups regarding the surgical technique used (Table 1).

Figure 1 shows the distribution of the number of procedures performed for each age independently.

The preoperative audiometric Rinne was significantly correlated with the perforation size ($p < 0.0001$).

Anatomical Results

The results of the univariate analysis are presented in Table 2.

The tympanic closure rate at the last visit was 87.7%, whereas perforation recurrence and revision surgery rates were 18.6% and 16.7%, respectively.

In univariate analysis, no significant prognostic factors were found for tympanic closure rate and perforation recurrence rate among demographic and anatomical characteristics. Anatomical postoperative outcomes were similar for our three age groups. Of the patients, 104/303 (34.3%) underwent preoperative CT scanning of the middle ear. No association was found between CT images of chronic inflammation of the middle ear and surgical outcomes.

Regarding the rate of surgical revision, it depended significantly on the etiology of the tympanic perforation: it is higher in postotitis tympanic perforations (28.1%) and lower in post tympanostomy tube perforations (12.1%) and traumatic perforations (9.1%). Marginal perforations on the malleus were significantly associated with a higher rate of revision surgery.

The choice of surgical technique showed a significant result on the management outcome. The butterfly surgical technique was associated with a better rate of tympanic closure (96.7%), a lower rate of reperforation (8.2%), and surgical revision (6.6%). Conversely, the fat graft was associated with poorer results.

TABLE 1. *Patients' characteristics in the function of the age*

	Patients, n = 318	≤6 yrs, n = 70	7–10 yrs, n = 157	≥11 yrs, n = 91	*p*
Mean age (±SD) (yrs)	9 (±3)	5 (±1)	8 (±2)	13 (±2)	
Mean size of the perforation	31% (±16)	33% (±16)	29% (±15)	33% (±18)	0.15
Localization (%)					
Anterior	150 (47.2)	35 (50)	75 (47.8)	40 (44)	
Posterior	54 (17)	7 (10)	33 (21)	14 (15.4)	
Median	114 (35.8)	28 (40)	49 (31.2)	37 (40.6)	0.21
Marginal (%)					
On the annulus	42 (13.2)	12 (17.1)	17 (10.8)	13 (14.3)	
On the malleus	115 (37.1)	25 (35.7)	54 (34.4)	36 (40)	0.64
Pathological contralateral ear (%)	33 (10.4)	7 (10)	16 (10.2)	10 (11)	
Intraoperative inflammatory	n = 251	n = 63	n = 114	n = 74	
middle ear mucosa[a] (%)	67 (26.7)	13 (20.6)	29 (25.4)	27 (36.5)	0.69
Surgical technique (%)					
Underlay with connective tissue	188 (59.1)	46 (65.7)	88 (56.1)	54 (59.3)	
Underlay with cartilage	49 (15.4)	2 (2.9)	28 (17.8)	19 (20.9)	
Butterfly	61 (19.2)	18 (25.7)	32 (20.4)	11 (12.1)	
Fat graft	20 (6.3)	4 (5.7)	9 (5.7)	7 (7.7)	**0.02**
Mean preoperative air–bone gap	21 (±9)	20 (±9)	20 (±9)	22 (±8)	0.3

[a]Missing data.
Data in bold correspond to significant results.

A multivariate analysis was conducted using logistic regression to specify the results of our first analysis (Table 3). We considered age and the only significant factors in univariate analysis: etiology of the perforation, surgical technique, and presence of contact with the malleus. It was found that no prognostic factor was found on our three criteria of anatomical success.

Audiometric Results

The postoperative audiogram was performed between 1 month and 5 years after surgery, with an average delay of 1 year. The hearing was normalized postoperatively in 39.7% of the cases (122 ears) out of all 318 procedures performed. The mean postoperative Rinne was significantly improved with a mean of 12 dB compared with 21 dB preoperatively ($p < 0.0001$).

In univariate analysis (Table 4), demographic prognostic criteria, including age, did not show significance in normalizing or improving hearing. The postoperative audiometric outcome was significantly different depending on the location of the perforation. The Butterfly technique and using a fat graft showed the best results in normalization (58.5% and 58.8% of cases) and hearing improvement (mean postoperative Rinne of 9 and 10 dB). Hearing results were significantly worse when intraoperative inflammation of the middle ear mucosa was found.

As for anatomical results, a multivariate study was conducted using logistic and multiple linear regression (Table 5). We included in this analysis the location of the perforation, the operative technique, and the presence of intraoperative mucosal inflammation, when they were significant in univariate analysis.

DISCUSSION

The prognostic factors of the success or failure of myringoplasty remain a subject of debate. With one of the largest sample sizes to date, our series of 318 procedures allows us a detailed exploration of these factors. Despite age being frequently cited as a determinant for surgical success,

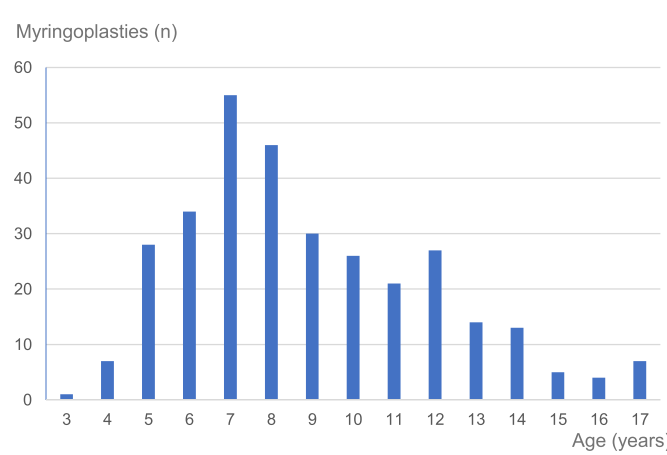

FIG. 1. Number of myringoplasties (*y* axis) for each age group (*x* axis).

TABLE 2. *Anatomical results in univariate analysis*

Cases' Characteristics	Tympanic Closure (%)	*p*	Reperforation (%)	*p*	Revision Surgery (%)	*p*
Total interventions	87.7		18.6		16.7	
Demographic data						
Age						
≤6 yrs	90		20		17.1	
7–10 yrs	87.3		19.1		18.5	
≥11 yrs	86.8	0.80	16.5	0.82	13.2	0.56
Medical history						
Syndrome	80.8	0.26	15.4	0.67	11.5	0.46
Velopalatal cleft	100	0.17	7.7	0.3	15.4	0.9
All history	83.1	0.22	23.7	0.26	23.7	0.11
Perforation's etiology						
Post-tympanotomy tube	88.9		15.9		12.1	
Postotitis	84.3		23.6		28.1	
Traumatic	100		9.1		9.1	
Unknown cause	80	0.37	33.3	0.18	20	**0.012**
Pathological contralateral ear	84.8	0.59	15.2	0.6	15.2	0.81
Anatomical data						
Size						
≤20%	87.3		20		15.5	
30–40%	88.1		16.6		14.6	
50–60%	81.5		29.6		33.3	
≥70%	88.9	0.82	22.2	0.44	17.6	0.06
Location						
Anterior	86.7		19.3		17.3	
Posterior	90.7		20.4		16.7	
Median	87.7	0.74	16.7	0.8	15.8	0.95
Marginal perforation						
On the annulus	88.1	0.94	23.8	0.35	23.8	0.18
On the malleus	87	0.84	20	0.72	22.6	**0.046**
Surgical data						
Intraoperative inflammatory middle ear mucosa	86.6	0.75	16.4	0.78	19.4	0.41
Surgical technique						
Underlay with connective tissue	87.8		19.7		17.6	
Underlay with cartilage	83.7		18.4		20.4	
Butterfly	96.7		8.2		6.6	
Fat graft	70	**0.011**	40	**0.014**	30	0.05

Data in bold correspond to significant results.

our multivariate analysis did not corroborate its negative impact on the tympanic membrane closure rate.

Some studies report that age is an essential factor to consider before indicating myringoplasty, without a consensus on a minimum age (5–8,10). Kumar et al. (7), Rozendorn et al. (5), and Ben Gamra et al. (8) report poorer postoperative results before 8, 9, or 12 years of age, respectively, whereas Kessler et al. (10) describes a higher rate of reperforation in children under 6 years of age. Other studies report that age does not influence surgical anatomical or audiometric outcome (4,9,13). Knapik and Saliba (6) found a higher pre- and postoperative bone conduction loss at high frequencies in children over 12 years of age explained by the chronicity of the perforation, exposing the ear to a risk of repeated infections and impact on the inner ear and motivating the author not to delay surgery unnecessarily.

TABLE 3. *Anatomical results in multivariate analysis*

Cases' Characteristics	Tympanic Closure, *p*	Reperforation, *p*	Revision Surgery, *p*
Age	0.57	0.74	0.54
Perforation's etiology	0.46	0.09	0.08
Marginal perforation on the malleus	0.84	0.77	0.06
Surgical technique	0.62	0.63	0.57

The reasons given by authors for a minimum age before surgery are based on the chronic inflammation of the upper airways related to adaptive disease and the Eustachian tube immaturity and dysfunction (12). The Eustachian tube has three essential functions: pressure balance and ventilation of the middle ear, mucociliary evacuation of middle ear secretions, and protection of the middle ear against pathogens from the nasopharynx (15). Eustachian tube dysfunction may manifest as full ear sensations, tinnitus, or hearing impairment. These symptoms are rarely expressed in children, especially before 10 years. The search for tubal dysfunction in young children is based on clinical examination with otoscopy that can reveal tympanic retraction, middle ear effusion, or recurrent acute otitis media. The tympanogram can be helpful, revealing a type C curve, shifted toward negative pressures. The status of the contralateral ear is a reflection of the tubal function and an important prognostic factor (4,9,14). Our results indicate the absence of link between tubal dysfunction and surgical outcome, but this is due to the selection of the patients eligible for myringoplasty (healthy contralateral ear, absence of

TABLE 4. *Audiometric results in univariate analysis*

Cases' Characteristics	Air–Bone Gap Closure Rate (%)	*p*	Mean Postoperative Air–Bone Gap (dB)	*p*
Total interventions	39.7		12 (±8)	
Demographic data				
Age				
≤6 yrs	31.7		14 (±8)	
7–10 yrs	45.2		12 (±9)	
≥11 yrs	36.7	0.16	12 (±8)	0.27
Medical history				
Syndrome	42.9	0.76	14 (±10)	0.33
Velopalatal cleft	30	0.52	14 (±9)	0.63
All history	37.5	0.73	14 (±9)	0.1
Perforation's etiology				
Post-tympanotomy tube	32.8		12 (±8)	
Postotitis	42.7		12 (±9)	
Traumatic	22.2		14 (±10)	
Unknown cause	38.5	0.62	13 (±6)	0.9
Pathological contralateral ear	53.6	0.11	12 (±9)	0.29
Anatomical data				
Size				
≤20%	45.7		11 (±8)	
30–40%	34.3		13 (±9)	
50–60%	37.5		13 (±7)	
≥70%	43.8	0.38	11 (±8)	0.31
Location				
Anterior	30.7		13 (±9)	
Posterior	27.8		14 (±8)	
Median	43	**0.041**	11 (±8)	0.07
Marginal perforation				
On the annulus	26.3	0.07	14 (±7)	0.22
On the malleus	40.2	0.69	12 (±7)	0.33
Surgical data				
Preoperative inflammatory middle ear mucosa	23.3	**0.03**	15 (±9)	**0.04**
Surgical technique				
Underlay with connective tissue	33.1		13 (±8)	
Underlay with cartilage	34.8		14 (±9)	
Butterfly	58.5		9 (±6)	
Fat graft	58.8	**0.005**	10 (±10)	**0.002**

Data in bold correspond to significant results.

otorrhea and otitis for more than 1 year, and absence of local inflammation), which excludes most patients with tubal dysfunction. By relying solely on the selection criteria, without considering age, we were able to include 70 patients 6 years or under and compare them with older children. This allowed us to confirm that age in itself is not a factor in failure. Among these, children under the age of 5 years were very few, often with atypical clinical histories. For example, one of the patients was operated on at 3 years old because of purulent otorrhea due to tympanic perforation, which contraindicated liver transplantation for biliary atresia.

Intraoperative inflammation of the operated ear represents an adverse prognostic factor in hearing recovery.

TABLE 5. *Audiometric results in multivariate analysis*

Cases' Characteristics	Air–Bone Gap Closure ≤10 dB, *p*	Mean Postoperative Air–Bone Gap, *p*
Age	0.88	0.2
Localization	**0.01**	–
Intraoperative inflammatory middle ear mucosa	**0.03**	**0.03**
Surgical technique	**0.03**	0.08

Data in bold correspond to significant results.

Myringoplasty on an inflammatory ear can likely recreate the conditions for a middle ear effusion and, thus, conductive hearing loss. Denoyelle et al. (4) reported middle ear inflammation as a prognostic factor in the anatomical success of myringoplasty. On the other hand, Hosny et al. (16), in a prospective study comparing the results of myringoplasty on dry and wet ears, did not find any influence of inflammation on the tympanic closure rate or the audiometric gain. Imaging can reveal stigmata of chronic middle ear inflammation, such as filling or sclerosis of the mastoid, effusion, or mucosal thickening of the tympanic cavity. CT scanning is not systematically performed preoperatively for a myringoplasty and is reserved for children with comorbidities or an inflammatory middle ear. This patient selection explains the absence of a significant link between the imaging analysis and the surgical outcome.

The etiology of tympanic perforation appears to be a prognostic factor of the risk of revision surgery in univariate analysis, with a higher rate of revision surgery in cases of postotitis perforation, probably linked to ischemia and necrosis of the tympanic membrane due to inflammation, leading to a more fragile tympanic membrane. On the other hand, traumatic perforation, or post-tympanostomy tube perforation, where the tympanostomy is instrumental and preferentially in the axis of the tympanic fibers, is of better prognosis. These data are not consensual; Knapik and Saliba (6) did not find any influence of the etiology of the perforation on the results of myringoplasty.

The role of the size and location of the perforation is unclear (4–10). In our series, contact of the perforation with the malleus is associated with a higher rate of revision surgery in the univariate analysis. In the multivariate analysis, the perforation location retains an influence on some audiometric results, with better results on median perforations. Anterior perforations are more challenging to operate in children, but we need to explain the poor results regarding posterior perforations. Kumar et al. (7) also describes poorer anatomical and audiometric results with anterior perforations. Still, most authors found no influence of the perforation location on the postoperative results (4–6,8,10).

The choice of surgical technique depends on the patient's comorbidities and the inflammatory state of the ear, which de facto explains the differences in age observed according to the surgical technique used (Table 1). Cartilage grafts are preferred in cases of reperforation after the first surgery, the appearance of a retraction pocket, or in cases of comorbidity such as a velopalatal cleft. Patients selected to receive a fascia temporalis graft have fewer risk factors for failure, which explains the similar results of the two techniques. Fat graft showed the poorer closure rate, with a 40% reperforation rate; this result is consistent with the literature (17). This technique is preferred in small perforations where preoperative ABG is less important. This explains why the average postoperative ABG is better with this graft, despite the higher rate of graft failure. The butterfly myringoplasty showed the best results. This technique has been widely used for small (20–30% of the tympanic surface) and nonmarginal perforations since its description by Eavey (18) in 1998, with success rates between 87.7% and 96% and an average postoperative air–bone gap between 8 and 15 dB (19–21). Some authors also propose this technique for subtotal or marginal perforations with excellent results (20). Endoscopic or microsurgical, the approach does not impact the success rate (21).

The success of myringoplasty is mostly estimated by the tympanic closure rate and hearing improvement (2–10). The tympanic closure rate is 87.7% in our series. This is consistent with the literature, with values ranging from 70.1% to 93.5% (2–10). Variations in results must be balanced with the length of follow-up; the longer the follow-up, the higher the risk of reperforation or the appearance of another complication (6). Perforation recurrence rates or the need for revision surgery are not well described in articles. Still, they are essential to consider when considering the surgery's success. The surgical revision rate, for example, reflects all the events or complications that can occur postoperatively (recurrence of perforation, the appearance of seromucous otitis media or retraction pocket, iatrogenic cholesteatoma, etc.).

Analysis of the air–bone gap was the only audiometric data considered to analyze hearing improvement. Although the air–bone gap closure rate (39.5% for all procedures) may seem disappointing, the average postoperative audiometric Rinne is 12 dB, which is still very close to normal. In the literature, the air–bone gap closure rate less than or equal to 10 dB is estimated to be between 67.5% and 63.2% (4,5,8). The difference with our results can be explained by the use of arbitrary bone thresholds at 5 dB when bone conduction thresholds were not available, and there was no sign of inner ear damage at the consultation; the air–bone gap calculation can then easily exceed 10 dB, even with normal air conduction threshold values between 15 and 20 dB. Furthermore, unlike our study, most studies do not consider audiometric values at low frequencies (250 Hz), which are more affected by tympanic perforation (13). Of the 318 procedures, a postoperative air–bone gap of less than or equal to 20 dB, a value used in some studies (6,10), was found in 237 ears (74.5% of cases).

The risk of inaccuracy and missing data related to the retrospective nature of our study represents its main limitation. The short follow-up of some patients may lead to biases in the results, as complications may have needed more time to occur. However, among our series of 318 procedures, the follow-up was more than 1 year for 202 cases. An analysis of prognostic factors in this population might be of interest, as might the evolution of early and late audiometric results.

CONCLUSION

Myringoplasty in children is associated with excellent anatomical and audiometric results, regardless of age. The selection of the patients eligible to surgery remains essential to obtain the best possible result. Despite the Eustachian tube's pathophysiological role in myringoplasty's success, we did not find any difference in outcome in the youngest patients of our series. The choice of surgical technique according to the preoperative assessment is another key to the success of this surgery.

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