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Clinical Indications for Canal Wall-down Mastoidectomy in a Pediatric Population

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Abstract

Objective. To establish clinically derived indications for performing canal wall-up or canal wall-down surgery when treating children with cholesteatoma.

Study Design. Case series with chart review.

Setting. Tertiary care academic pediatric otolaryngology practice.

Subjects and Methods. Retrospective review of 420 children who underwent 700 procedures for cholesteatoma between 1996 and 2010.

Results. The canal wall was preserved in 89.5% of cases. Common reasons for removing the canal wall were to provide access to the disease, extensive erosion of key structures, and the desire to avoid further surgery. The mean pure-tone average (PTA) for the canal wall-up group was 30 dB, whereas the canal wall-down group had a mean PTA of 45 dB. A matched-pairs analysis demonstrated that the better performance of the canal wall-up group was independent of preoperative hearing levels. Furthermore, although the presence of the stapes did influence hearing results, the canal wall-up procedure yielded better results even when the condition of the stapes was taken into account. The number needed to treat with canal wall-up to prevent 1 case of hearing loss (ie, mean threshold $>$30 dB) would be around 6. The need for revision surgery was higher in the canal wall-up group (51%) compared with the canal wall-down group (21%).

Conclusion. In the setting of adequate follow-up and open access to surgical resources, most children with cholesteatoma can be managed with an intact canal wall technique. The authors believe that the better audiometric outcomes and easier postoperative care outweigh the need for revision surgery in this group.

Keywords

pediatric, cholesteatoma, surgery, modified radical mastoidectomy, canal wall

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The goals of cholesteatoma surgery are to eradicate disease, establish a dry ear, and restore or preserve serviceable hearing.[1] The means by which surgeons achieve these goals have varied historically and are more controversial in children than in adults. Those who advocate a canal wall-up (CWU) technique cite a maintenance-free ear, fewer activity restrictions, easier hearing aid fitting, and a more natural appearance as the advantages of this technique.[2,3] Proponents of the canal wall-down (CWD) technique maintain that its lower rate of recidivism and reduction in the total number of surgeries outweigh the advantages of the CWU technique.[4] Although as a whole, CWU procedures tend to result in better hearing,[5,6] some have concluded that middle ear factors such as condition of the mucosa and stapes superstructure are more important to hearing outcomes than the presence of the canal wall.[1,2,7,8] The recent development of hybrid and reconstruction techniques has been advocated to provide the intraoperative advantages of the CWD technique (ie, exposure) while maintaining the postoperative advantages of the CWU technique.[9,10] In the setting of relatively easy access to medical care, a uniform CWD approach is rarely adopted.

The CWU approach has often been advocated for children, especially because of their generally poor tolerance of mastoid cavity cleaning. Little has been published on the circumstances in which a CWD approach may be more appropriate for children. We review our surgical experience and clinical outcomes from a large series of pediatric cholesteatomas to determine the clinical indications for taking the canal wall down in children.

Methods

The Hospital for Sick Children Research Ethics Board approved this study. A retrospective review of all cases of cholesteatoma treated at The Hospital for Sick Children

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between 1996 and 2010 was conducted. A database was constructed to record appropriate patient information as well as relevant surgical details. This database was initiated retrospectively, with more recent patients added prospectively.

The extent of cholesteatoma was graded according to the Mills classification system.[11] Using this system, cholesteatomas are given points in 3 categories: stage (S), ossicular erosion (O), and complication (C) (outlined in **Figure 1**). For those cases where the canal wall was taken down, the operative reports were reviewed to discern the reasons for performing the CWD technique.

Pre- and postoperative air conduction hearing threshold was assessed from averaged pure-tone audiometry (PTA) at 500 Hz, 1 kHz, 2 kHz, and 4 kHz. Audiometric analysis was performed according to the guidelines of the American Academy of Otolaryngology—Head and Neck Surgery.[12] All statistical analysis was performed using appropriate parametric or nonparametric methods with significance defined as $P < .05$.

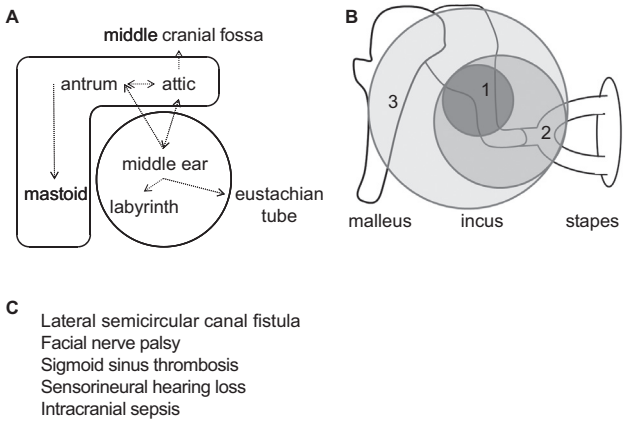

Figure 1. The Mills classification system for cholesteatoma (adapted from Saleh and Mills[11]). (A) Stage (S) score is calculated by adding 1 point for each labeled subsite involved with cholesteatoma. Arrows indicate routes of extension. (B) Ossicular erosion (O) score is calculated by adding 1 point for each ossicle eroded by cholesteatoma as indicated. (C) Complication (C) score is calculated by adding 1 point for each of the listed complications encountered.

Results

We reviewed 420 patients (435 total ears, 222 left) who underwent 700 procedures related to cholesteatoma. Two hundred eight patients had 1 procedure, and 26 patients were referred after having had a prior CWD procedure. Males were twice as abundant as females (289 vs 131), which is consistent with established incidence rates of cholesteatoma in children.[13] The age range was from 1 to 18 years of age. Congenital cholesteatoma was discovered incidentally in two 1-year-old children, one with pre–cochlear implant imaging and the other at tympanostomy tube placement during cleft palate surgery. The mean age at surgery was 10.8 years. There was no significant difference in the median ages of those patients who had CWU and CWD procedures (10.4 and 9.4 years, respectively, $P > .5$, Mann-Whitney test). Our average follow-up was 4.45 years.

There were 542 procedures in which cholesteatoma was present and the canal wall had not been taken down in prior surgery. The canal wall was preserved in 485 of these procedures, yielding an 89.5% rate of canal preservation. There were 57 CWD procedures in 56 patients, and thus 14.2% of patients ultimately received a CWD procedure. Of the 57 CWD procedures, the decision to remove the wall was made at the first surgery in 38 cases (9.7% of 390 first looks), on a second look in 13 cases (6.7% of 193 second looks), and on a third look in 6 cases (10.3% of 58 third looks). The median Mills stage score (S score) for cholesteatoma in CWU cases was 2 compared with 4 for CWD cases ($P < .001$, Mann-Whitney test); however, an S score of 4 has low predictive value for needing a CWD procedure (**Table 1**). The ossicular scores (O scores) were not significantly different (median, 1 for CWU and 2 for CWD, $P > .05$). In the 485 CWU cases, 24 cholesteatomas had a complication score (C score) of 1, whereas 13 of the 57 CWD cases had a C score of 1 ($P < .001$, Yates-corrected χ^2). Lateral canal fistula is often cited as an indication for CWD. However, we were able to remove the matrix from the membranous labyrinth in 9 instances with CWU without causing sensorineural hearing, although 2 individuals had profound sensorineural loss in the affected ear preoperatively.

As cholesteatoma extent by Mills score did not predict when a CWD procedure would be needed, we examined other factors that influenced this decision (**Table 2**). The most common reason for deciding to perform a CWD procedure was to improve poor access to the cholesteatoma, which was generally the result of an under-pneumatized mastoid coupled with an anterior sigmoid sinus and low tegmen.

We examined the rates of recidivism and the need for second surgeries in the CWU and CWD groups (**Table 3**). Of the 57 CWD procedures in our series, follow-up of at least 1 year was available for 53 and of at least 6 months for 55. In the CWU group, there were 352 first-look procedures. Three hundred twenty-one cases had 1-year follow-up, and 346 had a 6-month follow-up. Of these, 180 (51.1%) received a second look. Of the 159 second looks followed for at least 1 year, 52 (32.7%) received a third look. Of the 38 third looks followed for at least 1 year, 3 (7.9%) received a fourth look. The decision to defer a second look was based on clinical appearance and confidence of complete extirpation of disease at the first surgery. Magnetic resonance imaging (MRI) was not routinely used to monitor for disease recurrence.

Hearing outcomes were available for 320 patients: 255 CWU and 65 CWD or revision CWD procedures (mean and median follow-up time 355 and 214 days, respectively; range, 39-1656 days). The mean and median PTA for CWD procedures were 46 dB and 51 dB, respectively, compared with 30 dB for CWU procedures ($P < .001$, Mann-Whitney test). Of CWU patients, 53.7% had a final PTA less than 30 dB—the same was true of 18.5% of CWD individuals ($P < .001$, χ^2 test). This equates to a number needed to treat of 5

Table 1. Stratification of Canal Wall-up (CWU) and Canal Wall-down (CWD) Procedures with Respect to Mills Stage (S) Score

S Score	CWU, No.	CWD, No.
≥4	93	39
≤3	392	18
Sensitivity, Specificity, and Predictive Value of Mills S Score ≥4 in Determining the Need for CWD		
	% Total (No.Total No.)	
Sensitivity	68.4 (39/[39 + 18])	
Specificity	80.8 (392/[392 + 93])	
Positive predictive value	29.5 (39/[39 + 93])	
Negative predictive value	95.6 (392/[392 + 18])	

Table 2. Factors Contributing to the Decision to Perform a Canal Wall-down (CWD) Procedure

Factor Contributing to CWD	No.[a]	%
Poor mastoid pneumatization, low tegmen, anterior sigmoid	27	42.9
Extensive disease resulting in erosion of the ossicular heads or the need for extensive atticotomy	23	36.5
Erosion of the posterior canal wall	13	20.6
Desire to avoid further surgery	8	12.7
Cleft palate or other reason for pervasive eustachian tube dysfunction	6	9.5
Rapid recurrence and aggressive disease	6	9.5
Poor follow-up	4	6.3
Complication from cholesteatoma	4	6.4
No reason given	5	7.9

[a]More than 1 reason was often given for each procedure, yielding more reasons in this table than total procedures. Total of 63 CWD procedures (57 with initial surgery at our institution and 6 revisions from an outside institution).

(ie, the number of cases in which a canal wall would have to be preserved to give 1 additional case of normal hearing). The best results were obtained in a CWU procedure with an intact stapes, whereas a CWD procedure with an absent stapes generally provided the least favorable hearing results (**Table 4**).

Results comparing preoperative and postoperative hearing of the CWU and CWD groups are shown in **Figure 2**. Postoperative hearing results for all individuals in our series correlated well with preoperative hearing (R = 0.56 overall, R = 0.52 CWU, R = 0.68 CWD, $P < .001$ for all) (**Figure 3**), as shown previously.[14] The CWD group had worse preoperative hearing than the CWU group, which might thus confound the comparison of postoperative hearing results between the CWU and CWD groups. To control for this preoperative hearing difference, we performed a matched-pair analysis between the CWD group and selected CWU patients matched for preoperative hearing, status of the ossicular chain, and extent of cholesteatoma. Matching was blinded to postoperative hearing thresholds, and there was no difference in preoperative hearing between the 2 subsets of patients (P = .54, Wilcoxon matched-pairs signed-rank test), indicating that our pairing algorithm was satisfactory. After matching, CWU patients had better postoperative hearing (median, 38 dB vs 51 dB, P = .004) and greater hearing improvement (median, 7 dB vs 0 dB, P = .004) than the CWD group (**Figure 2C**). Of the matched pairs, 11 of 36 (31%) patients had socially serviceable hearing (PTA <30 dB) after CWU surgery compared with 5 of 36 (14%) after CWD surgery (not significant; Fisher exact test). Power analysis of these matched-pair data indicates that a sample size of 246 would be required to achieve significance with this proportion (power = 0.9; α = 0.05), and if so substantiated, the number needed to treat would then be 6 cases of canal wall preservation for 1 additional case of normal hearing. Again, a significant difference in postoperative hearing (P = .02) and hearing improvement (P = .03) was seen between the CWU and CWD groups when the stapes was eroded; however, in the case of an intact stapes, results did not reach statistical significance (P = .1 for postoperative hearing and P = .1 for hearing improvement).

Discussion

Our study of 420 children with cholesteatoma has allowed us to complete a detailed analysis of the factors that influenced our decision to perform CWU or CWD pediatric tympanomastoid surgery. We prefer a CWU approach to pediatric cholesteatoma and were able to preserve the canal wall in 89.5% of cases in which cholesteatoma was present. This approach is widely practiced in children, particularly

Table 3. Rates of and Reasons for Revision Surgery in the Canal Wall-down (CWD) and Canal Wall-up (CWU) Groups

	No.	% Total (No./Total No.)	% Stage (No./Total No.)
CWD procedures	57		
Required revision	12	21.1 (12/57)	
Reason for revision			
Recurrent cholesteatoma	4		
Pearl	4		
Web	2		
Fluid accumulation	1		
Dysosteosclerosis	1		
CWU procedures			
First looks	352		
Second looks	180	51.1 (180/352)	
Recidivism	106	30.1 (106/352)	58.9 (106/180)
No cholesteatoma	74		
Third looks	52	14.8 (52/352)	28.9 (52/180)
Recidivism	25	13.9 (25/180)	48 (25/52)
No cholesteatoma	27		
Fourth looks	3		
No cholesteatoma	3		

Table 4. Hearing Results of Canal Wall-up (CWU) and Canal Wall-down (CWD) Procedures

	Mean PTA, dB	% with PTA <30 dB
CWU	30.7	53.7
CWD	45.4	18.5
CWU with stapes	25.8[a]	68.1
CWU without stapes	36.7[a]	36.8
CWD with stapes	40.5[b]	23.8
CWD without stapes	47.7[b]	15.9

Abbreviation: PTA, pure-tone audiometry.
[a]Comparison of these groups demonstrates a statistically significant difference ($P < .001$).
[b]Comparison of these groups demonstrates a statistically significant difference ($P < .05$).

because of their greater difficulty with management of the open mastoid cavity (with respect to aural toilet and swimming) and the hope that middle ear function may improve with age to yield a healthy, stable ear.[1,15] We did not find a significant difference in age between children who received a CWU or CWD procedure; however, older children generally tolerate cleaning of mastoid cavities better than young children, so we favor a CWU approach in younger children. If a CWD procedure is required when the child is older, the decision can be made with the patient's input and understanding that ongoing office debridement would likely be required.

The main disadvantages of the CWU technique are a higher rate of recidivism and need for a second surgery. However, it is important to note that recidivism and revision surgery are not unique to the CWU approach. Approximately one-fifth of CWD cases require revision, and a review of the literature presented by Dodson et al[1] demonstrates an overall rate of residual and recurrent disease of 22% in CWD procedures. Revisions of CWD surgery are often minor, permeatal procedures, and only 4 of 12 cases had frank recurrence requiring complete revision. In young children, minor revisions and even cleaning can require general anesthetic. We feel the financial and emotional costs of second-look CWU surgery are offset somewhat by avoidance of unpleasant cavity management. Intraoperative use of laser and endoscopes to reduce residual disease rates, as well as the use of MRI as a radiologic "second look," has the potential to reduce the need for second-look surgery. Use of laser and endoscopy has increased over the study period. This, coupled with the increase in surgeons' experience, may have contributed to a slight increase in the proportion of CWU cases with time, but we are unable to separate and control for these factors in our analysis.

The CWD approach does lead to lower rates of recidivism and revision and thus remains indicated in those who

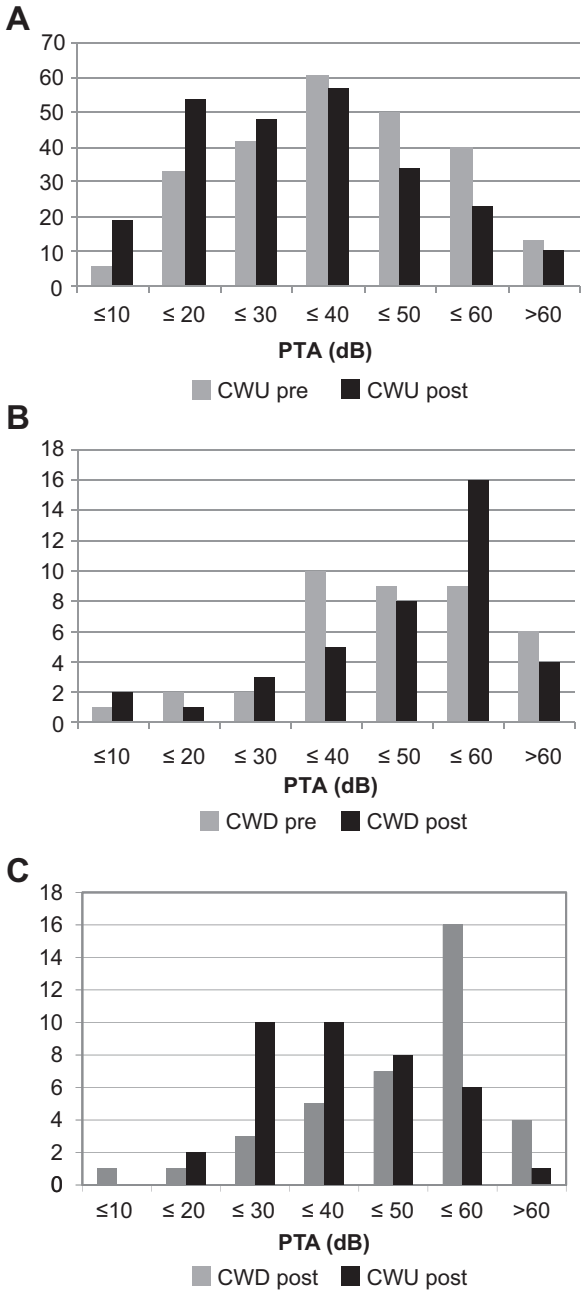

Figure 2. Bin analysis of preoperative and postoperative hearing levels. Histograms demonstrate the absolute number of patients with pure-tone audiometry (PTA; dB) in the indicated range. Bin analysis of preoperative and postoperative hearing results for (A) CWU and (B) CWD groups are shown. The postoperative hearing bin results for the CWD cases and the matched CWU cases used in the matched-pair analysis are shown in (C).

desire to avoid additional surgery and in those who have poor follow-up. We also performed the CWD approach when the child's medical comorbidities put them at a high anesthetic risk. Although the situation did not arise in our series, the lower rates of recurrence and revision surgery are also the reasons that a CWD procedure is often advocated in the case of cholesteatoma in an only-hearing ear.

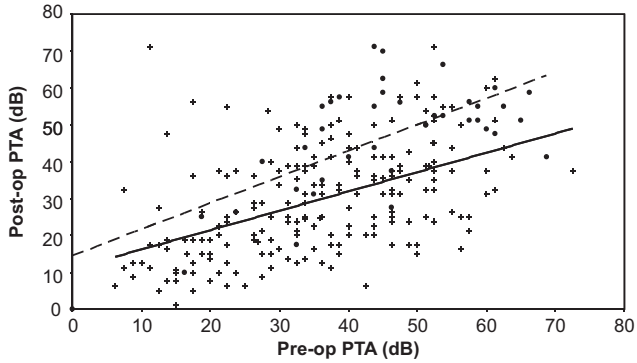

Figure 3. Postoperative hearing is correlated with preoperative hearing. Postoperative hearing is graphed with respect to preoperative hearing for the canal wall-up (CWU; +) and canal wall-down (CWD; •) groups. Trend lines for the CWU (solid) and CWD (dashed) data sets are shown. PTA, pure-tone audiometry.

Our hearing results are better after the CWU procedure, even when controlling for disease severity. This is true regarding either the mean pure-tone average or the number of patients with socially serviceable hearing (PTA $\leq$30 dB hearing level [HL]). Other studies have shown conflicting results on whether CWU provides better hearing outcome.[2,6-8,16] The conclusion that has been drawn from these studies is that other factors such as the condition of the middle ear mucosa or stapes superstructure have a greater influence on hearing outcome than the presence of the canal wall. Our results support the conclusion that the absence of the stapes significantly worsens hearing results in both the CWU and CWD cases; however, our stratified results demonstrated that the condition of the stapes alone did not account for the differences seen in the hearing results.

Our results support the notion that preoperative hearing remains an important predictor of postoperative hearing.[14] Even given equal preoperative hearing, however, the CWU group still shows better postoperative hearing and greater improvement in hearing than the CWD group. This effect did not reach significance when the stapes was intact, possibly because of the small number of individuals in the CWD group who had an intact stapes. It is likely that with a larger sample of matched pairs, the difference would reach significance given the observed trend. Furthermore, it is important to remember that this holds true only for a subset of patients in whom the preoperative hearing was relatively poor. In individuals with good preoperative hearing, we would particularly recommend a CWU procedure when possible to maximize the chances of obtaining a good postoperative hearing result. Similarly, in the presence of an intact ossicular chain, a CWU approach is indicated to preserve the ossicular chain and optimize postoperative hearing thresholds.

The primary aim of our article was to determine the clinical indications for performing a CWD procedure within the context of a health care system and clinical preference that support CWU procedures. Understanding this context is important—in our catchment area, health care is universally

funded, which supports unimpeded access to operating rooms and expertise. The fulcrum upon which many surgical decisions are made is resource availability, and a greater predominance of CWD surgery may be appropriate in other health care systems.[17] On occasion, the decision to perform a CWD procedure is made preoperatively based on patient factors (such as desire to avoid further surgery or anesthetic risk), but usually, the decision to take the canal wall down is made intraoperatively. An important point therefore is the complete communication of this possibility with the family at the time of obtaining consent.

The most common reason for performing a CWD procedure was to provide access to the cholesteatoma for complete removal. A low tegmen tympani or anteriorly extending sigmoid sinus restricts access to the attic and posterior mesotympanum. Removing the canal wall in these cases may be the best way to exenterate disease. In many cases, the cavity created by externalizing an under-pneumatized mastoid leads to an ideally small and maintenance-free cavity. A low-lying tegmen in itself is not necessarily a reason to remove the canal wall. We have been able to avoid taking the canal wall down in many cases where a low tegmen was present by performing an atticotomy to access the cholesteatoma and then using cartilage or bone pate to reconstruct the defect, as reported by others.[18,19] Endoscopic surgery also facilitates removal of cholesteatoma behind anatomical obstructions and is helpful in preserving the canal wall or ossicular chains for disease in the posterior mesotympanum and medial epitympanum.[20,21]

Destruction of the ossicular heads, or their removal to adequately access the cholesteatoma, or the presence of a large atticotomy leads to a high likelihood of recurrence if the canal wall is left intact and the scutum is not adequately reconstructed. Accordingly, extensive disease of this sort is frequently treated with a CWD procedure and cited as a contributing factor in approximately half of CWD cases. Extensive disease in and of itself is not necessarily an indication to remove the canal wall. Even disease extending to the sinus tympani is not necessarily best treated with a CWD approach as removing the canal wall provides only modest additional visualization and access to this space. We commonly use endoscopes, occasionally with the retrofacial approach, to address sinus tympani disease. Insofar as it might represent aggressive disease, extensive disease may serve as an indication for removing the canal wall. This assessment should be made on an individual basis: extensive disease found on the first surgery might be treated differently from extensive disease found on a second look 6 months after an initial surgery.

We graded the cholesteatomas in our series using the classification system described by Saleh and Mills.[11] Although there was a significant difference between the S score of the cholesteatomas that were treated with CWD and CWU approaches, the S score in and of itself is not an accurate predictor of who will need the CWD approach. This reinforces our assertion that disease extent alone should not dictate the approach.

A component of the Mills grading system, the complication or C score, was significantly higher in individuals who required a CWD approach. Although a lateral canal fistula is often cited as an indication to perform a CWD approach, we were often able to remove the matrix from the membranous labyrinth, preserving the canal wall. Accordingly, we feel that a horizontal canal fistula does not necessarily mandate a CWD approach, and the protection, caloric and otherwise, that an intact canal wall provides might be beneficial in these cases.[22,23]

Conclusions

In a setting of adequate follow-up and excellent access to operative resources, we have been able to treat the vast majority of cases of cholesteatoma in our practice with a CWU procedure. In our series, hearing results are better with the CWU procedure, even when the status of the stapes is taken into account. We feel that the better hearing results and easier postoperative care justify the higher rate of recurrence and the increased need for revision surgery. Multiple patient-related factors such as the need to avoid further surgery or recalcitrant eustachian tube dysfunction, anatomic factors such as a low tegmen or anterior sigmoid, disease characteristics such as aggressive disease and erosion of key structures (eg, posterior canal wall), and surgeons' preference and experience ultimately influence the decision to take the canal wall down. A patient-centered approach demands that the decision is based on careful consideration of these factors for each individual, rather than a strict protocol.

Author Contributions

Alexander J. Osborn, study design, data analysis, manuscript preparation, final approval of manuscript; **Blake C. Papsin**, study design, data acquisition, manuscript preparation, final approval of manuscript; **Adrian L. James**, study design, data acquisition, manuscript preparation, final approval of manuscript.

Disclosures

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