Otology & Neurotology
37:1565–1572 © 2016, Otology & Neurotology, Inc.

Outcomes of Drill Canalplasty in Exostoses and Osteoma: Analysis of 256 Cases and Literature Review

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Objective: 1) To describe the surgical technique of drill canaplasty for exostosis and osteoma and to evaluate our results. 2) To propose a new grading system for external auditory canal stenosis (EACS). 3) To review the recent literature.
Study Design: A retrospective review.
Setting: Quarternary referral center for Otology & Skull Base surgery.
Subjects and Methods: Two hundred seventeen patients (256 ears) with exostosis or osteoma were included in the study. Surgical and audiological parameters were evaluated.
Results: Mean age was 51.5 (±13.41) years. One hundred sixty nine cases were men and 48 women. Two hundred forty three (95%) cases were exostosis and 13 (5%) were osteomas. According to the proposed grading system, 81% ears had severe or complete stenosis. Seventy eight (30.5%) ears had a concurrent diagnosis of otosclerosis. Retroauricular approach was used in 245 (95.7%). Intraoperative complications included tympanic membrane (TM) perforation seen in four (2%) and mastoid cell exposure in two (1%). Postoperative stenosis/prolonged healing was seen in 11 (4%) patients and required revision in seven cases. Audiologic analysis available for 153 ears-showed the mean change in air-bone gaps (ABG) of 2.18 dB, pure tone averages (PTA) bone conduction (BC) (0.5–4 kHz) of 0.3 dB. Mean healing rate was available for 246 (96.1%) patients and was found to be 6.35 (4–16) weeks.
Conclusions: A systematically performed drill canalplasty via retroauricular approach, as described in this article, yields excellent postoperative outcomes as seen in our series. Notably, one-third of exostoses patients in this series, also suffered from otosclerosis. The proposed grading system for EACS enables the surgeon to objectively stage the disease.
Key Words: Drill canalplasty—Exostosis—External auditory canal stenosis—Grading—Osteoma—Surgical and hearing outcomes.

Otol Neurotol **37:**1565–1572, 2016.

Exostosis and osteomas are benign bony disorders that can effect any bone in the body but their incidence in the external auditory canal (EAC) in otological practice is 0.3 and 0.05%, respectively (1). The majority of cases of exostoses or osteomas do not present to medical care unless the canal stenosis approaches regarding 80% of normal (2) wherein they can give rise to recurrent otitis externa, conductive hearing loss, pain, and tinnitus (3). Surgery for external auditory canal stenosis (EACS), termed canalplasty, can be challenging. The development of the powered drill along with the microscope has led to the replacement of the chiseling technique that was used in the past to remove exostosis and osteoma. However, high incidences of tympanic membrane (TM) perforations and re-stenosis were reported in the past due to inconsiderate drilling techniques and lack of precise instrumentation. This prompted some authors to advocate the use micro-osteotomes as they argued that this decreased the chance of damage to the EAC skin, reduced the incidence of collateral sensorineural hearing loss and lessened the healing time (3–6). But recently published reports with large number of cases of canalplasty for exostosis and osteomas using the high speed motor drill have proven that drill canalplasty can give good results when performed correctly (3,7–10).

In this report, which is one of the largest series of exostosis and osteomas published in recent literature, we describe in detail the specific steps employed in our technique of drill canalplasty that has helped us achieve our successful postoperative outcomes.

MATERIAL AND METHODS

The charts of all patients with EACS who were treated at our center between June 1992 and January 2015 were

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The authors disclose no conflicts of interest.
DOI: 10.1097/MAO.0000000000001239

reviewed. Of them, 305 patients who underwent canalplasty were investigated. Patients who underwent canalplasty for exostosis and osteomas were included in the study. Patients who underwent surgery for infections, cholesteatomas, trauma, osteomyelitis, were excluded. Patients with follow-up of less than 6 months or those lost for follow-up were also excluded. This yielded a study population of 217 patients. Charts were analyzed for demographic and clinical features, grade of stenosis, audiometric outcomes, surgical details, follow-up, and complications. Hearing results were evaluated according to the Sanna classification of hearing for the evaluation of the results of treatment of hearing loss. Pure tone averages (PTA) for air conduction (AC) and bone conduction (BC) were calculated before and after surgery as the mean of 500, 1000, 2000, and 4000 Hz thresholds. Air-bone gaps (ABG) were calculated using AC and BC values determined at the same time (11,12). In case of bilateral stenosis, the ear with higher grade was operated first. The intraoperative and postoperative complications were noted and analyzed. Prolonged healing time was defined as a presence of granulation tissue or denuded EAC area for more than 8 weeks.

Grading of EACS

At the Gruppo Otologico all the patients are documented preoperatively with photos of oto-endoscopy and the extent of EACS is graded as follows. The Gruppo Otologico grading system of EACS based on otoendoscopy and radiology as defined in Figure 1, A and B. In our classification, we use two parameters of assessment to achieve objectivity. Firstly, the size of the lesion is measured against the TM quadrants visible and thereby the area of the TM left exposed. The second parameter is radiological, wherein the degree of stenosis is calculated as a percentage of the maximum measurement available of the lesion against the maximum diameter of the EAC in axial and coronal cuts. If there was a doubt between two grades, we chose the lower grade.

Surgical Technique of Canalplasty for Exostosis and Osteoma

Simple transcanal approach is applicable only in Grade I or II EACS. In higher grades, a retroauricular-transcanal approach is used. After a classic post-aural incision, soft tissue flaps are elevated and temporalis fascia is harvested. The EAC incision is made lateral to the lesion (Fig. 2A). The skin over the EAC is carefully elevated using a round knife and cottonoid till the TM annulus (Fig. 2B). It is of paramount importance to preserve the skin of the EAC as much as possible to prevent postoperative stenosis. The meatal skin flap is protected with an aluminum foil taken from the cover of surgical sutures and cut to form an oval shape corresponding to the EAC with a small piece of cottonoid beneath the sheet. If the space medial to bony protrusions is insufficient to contain the detached skin, the skin covering the bony overhang is detached and folded toward the contralateral wall. Small pedunculated lesions can be excised using a simple curette (Fig. 2B). Drilling is then commenced from a medial to lateral fashion over the protruding bony overhangs, thereby creating space in the EAC as the drilling proceeds. With more space thus created, the meatal flap can be elevated further and manipulated away from the drilling site and towards the TM, using the aluminum foil to always protect the flap. In case of multiple lesions, the protrusions are drilled progressively from lateral to medial without continuously drilling blindly into any one of the lesions (Fig. 2C–E). The mastoid segment of the facial nerve (FN) runs in the vicinity of the posterior meatal wall, 2–3 mm posterior to the annulus (13,14). To avoid injury to the nerve, it is important to restrict the area of drilling around the meatal skin until the annulus of the TM is sufficiently visualized. The annulus serves as an indicator of the extent to which the bone must be removed. This is determined with the help of a round knife (Fig. 2F) and by replacing the meatal skin flap from time to time. Care is taken not to damage the temporomandibular joint anteriorly. Removal of the final bony overhang is better done using a small curette to prevent damage to the TM that can occur when a burr is used. After adequate canalplasty, the meatal flap is put back in place (Fig. 2G). If the remnant skin is inadequate to close the enlarged neo-canal, the skin is incised longitudinally (Fig. 2H) and temporalis fascia is used as an underlay in the canal to cover the exposed bone to ensure intimate lining on the bone. In case of accidental TM or meatal flap perforations, they are repaired using a temporalis fascia underlay graft. Likewise, accidental mastoid cell entry is dealt with by occluding it with tragal cartilage and fascia. In case the cartilaginous part is narrower than the enlarged bony part, a small conchoplasty is done. Gelfoam® (Pfizer Inc, NY) is placed in the EAC and the incision is sutured in layers. The patients were followed up with otoscopical evaluation at 3 months after surgery (Fig. 3).

In case of postoperative stenosis and granulations, the EAC was managed conservatively with antibiotic and steroid drops and aural toilet performed weekly under microscope till it healed completely. In intractable cases, the ear was taken up for a revision surgery. The Institutional Review Board of the hospital has approved this study.

RESULTS

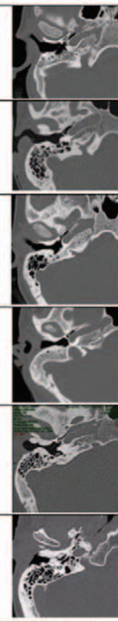
Two hundred seventeen patients with 256 ears (including 39 bilateral cases) underwent canalplasty for EACS secondary to exostosis and osteoma at our center. The mean age of the study population was 51.5 (±13.4) years, range (13–83 yr). One hundred sixty nine (77.8%) patients were men and 48 (22.2%) women.

Clinical Features and Grading of EACS

The most common audiological manifestation of exostosis/osteoma was conductive hearing loss seen in 195 (76.2%) patients followed by recurrent otitis externa seen in 45 (17.5%) patients. The most common grades of

Grade	Severity of stenosis	Otoendoscopic findings	Radiological findings*	CT images	Descriptive figures	No of patients in our series	
Grade 0	No stenosis	All four quadrants of the pars tensa are perfectly visible. 100% of the pars tensa area is visible.	No narrowing of EAC			-	-
Grade I	Mild stenosis	One or more quadrants is/are partially visible. ≥ 75% of the pars tensa area is visible.	10 to 25% narrowing of EAC			0	0%
Grade II	Moderate stenosis	One of the quadrants is completely obscured. 50-75% of the pars tensa area is visible.	25-50% narrowing of EAC			7	2.7%
Grade III	Severe stenosis	Two of the quadrants are completely obscured. 25-50% of the pars tensa area is visible.	50-75% narrowing of EAC			42	16.4%
Grade IV	Near total stenosis	Three of the quadrants are completely obscured. 10-25% of the pars tensa area is visible.	75-90% narrowing of EAC			127	49.6%
Grade V	Total stenosis	None of the quadrants are visible. 0% of the pars tensa area is visible.	90-100% narrowing of EAC			79	30.9%

EAC: External Auditory Canal, *: the degree of stenosis is calculated as a percentage of the maximum measurement available of the lesion against the maximum diameter of the EAC in axial and coronal cuts.



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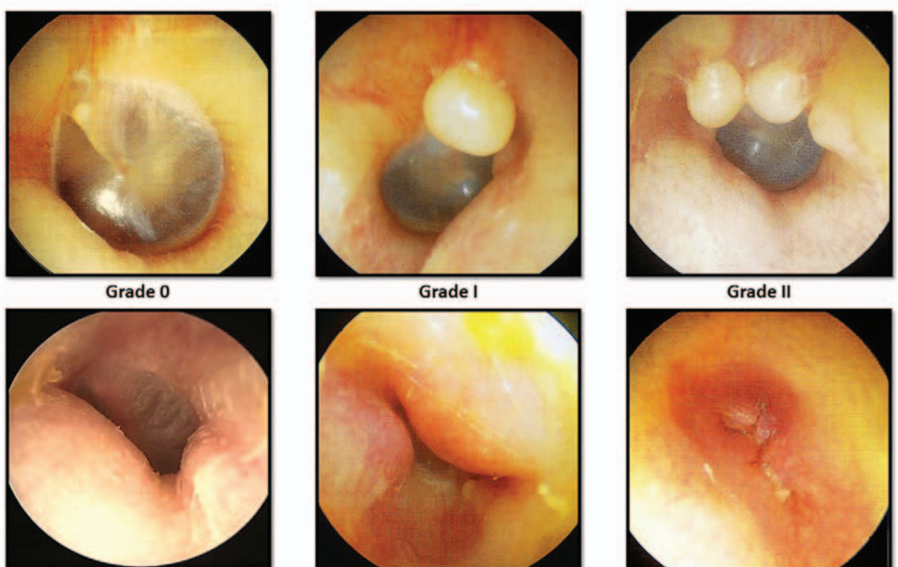

B

FIG. 1. *A*, Grading system of external auditory canal stenosis (EACS). *B*, Grades of EACS.

EACS stenoses were grade IV with 127 (49.6%) patients and grade V with 79 (30.9%) patients.

Surgical Results

As seen in Table 1, the important indication for canalplasty in this series was to deal with the manifestations of EACS secondary to exostosis/osteoma (143 patients, 55.8%). However, a substantial number of patients also underwent canaplasty in the setting of EACS as an approach for another middle ear condition (97 patients, 37.8%) like otosclerosis, ossicular fixation, or chronic otitis. Myringoplasties (10 patients, 3.9%) were done in the same stage but stapes surgeries (78 patients, 30.4%) and ossiculoplasties (nine patients, 3.5%) were done in a second stage. In the 39 (15.2%) bilaterally operated patients, the ear with the higher grade of EACS was operated first. Hence, the right ear was approached first in 16 cases and left ear in 23 cases. The retroauricular approach was used in 245 (95.7%) and the transcanal approach was used in 11 (4.3%) cases. Two hundred thirty six (92.2%) patients were operated under local anesthesia with sedation and the rest under general

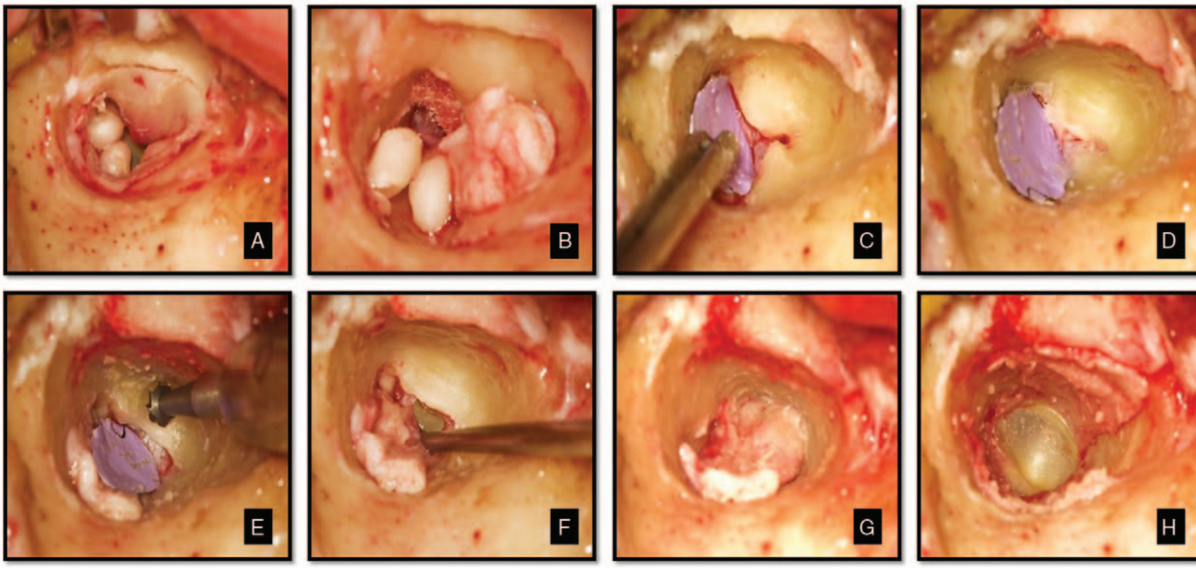

FIG. 2. Surgical steps in canalplasty.

anesthesia. Eleven cases underwent a transcanal approach. Of them, five patients had grade I, two had grade II, and four had grade IV EACS. Six of the 11 patients who underwent transcanal approaches also underwent stapedotomies in a second stage. Intraoperatively, TM perforation and mastoid cell entry occurred in four (1.5%) and two (0.8%) patients, respectively. Damage to FN, temporo-mandibular joint, or lateral malleolar process was not encountered in this series. The mean duration of procedure was found to be 82.5 minutes.

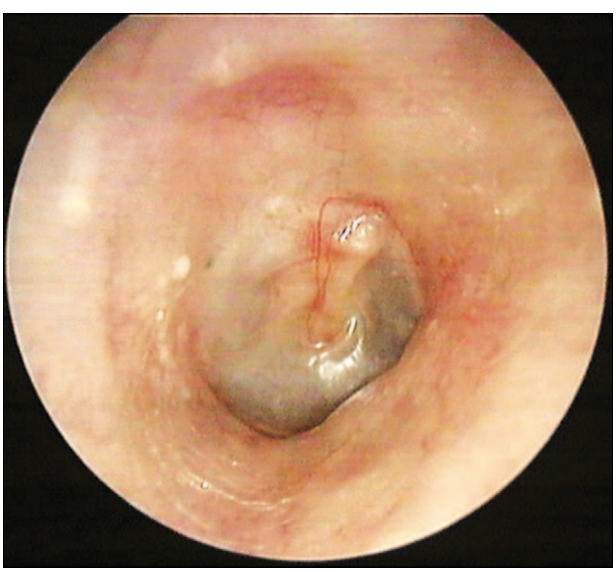

FIG. 3. Postoperative result after canaplasty in the same patient as in Figure 2 seen after 6 months. Note that all the canals are well calibrated and the quadrants of the tympanic membrane are visualized clearly.

Audiological Results

Audiological analysis was performed in 137 cases after excluding 78 cases of stapedotomy, 10 cases of myringotomy, nine cases of ossiculoplasty, and six cases of incomplete audiogram. The improvements in the mean ABG and AC after surgery were 2.18 and 2.5 dB, respectively and they were statistically significant ($p \leq 0.02$; $p \leq 0.05$; paired *t* test, respectively). Change (worsening) in the mean BC was 0.3 dB and was not statistically significant ($p > 0.05$, paired *t* test). Only two (0.8%) patients showed a worsening of BC between 10 and 20 dB HL at all PTA frequencies. We then analyzed mean BC at the single frequency of 4 kHz because drilling is known to affect higher frequencies. At 4 kHz, the mean BC was found to be −0.7 dB (worsening). This was not statistically significant ($p = 0.09$, paired *t* test). At 4 kHz, one (1%) and 12 (8%) patients had improvement of BC between 20–35 dB HL and 10–25 dB, respectively. Likewise, four (3%) and 15 (10%) patients had worsening of BC between 20 to 35 dB HL and between 10 to 20 dB HL, respectively. The mean improvement in ABG in all patients who were operated with no concurrent middle pathology (only for EACS) was marginal. We really have no explanation for this finding other than the fact that the characteristics of the tympanic membrane could have played a role.

Follow-up and Complications

The mean follow-up was 20.4 months (6–180 mo). The mean healing rate was 6.35 (±1.28) weeks. The correlation between stenosis and healing rate was positive but not significant ($r = 0.54$). In four cases the healing process was prolonged (mean 12.5 wk). Eight (3.1%) patients developed cicatricial stenosis and all of them underwent a revision surgery 3 to 6 months postoperatively. Five of the eight cases had cicatricial

TABLE 1. *Indications and complications of canalplasty*

		No.	Percentage
Indications			
To deal with manifestations of exostosis/osteoma		143	55.8%
Approach for another middle surgery	Otosclerosis (with second stage stapes surgery)	78	30.4%
	Middle ear disease (with same stage myringoplasty)	10	3.9%
	TTE of the ossicles (with second stage ossiculoplasty)	9	3.5%
Hearing aid fitting		16	6.3%
Complications			
Intra-operative			
Tympanic membrane perforation		4	1.5%
Mastoid air cell entry		2	0.8%
Total		6	2.3%
Postoperative			
EAC stenosis	Cicatricial stenosis	5	1.9%
	Cicatricial and bony stenosis	2	0.8%
EAC infection		6	2.3%
Prolonged healing time		4	1.6%
Tinnitus		2	0.8%
Worsened BC[a]		2	0.8%
De-epithelialization of the EAC requiring surgery		1	0.4%

[a]In patients with no middle ear pathology in all PTA frequencies (in both cases the postoperative BC was between 10 and 20 dB HL).
BC indicates bone conduction; CHL, conductive hearing loss; EAC, external auditory canal; TTE, transtympanic exploration.

stenosis and two had mixed cicatricial and bony stenosis with optimal results 4 to 6 weeks later. In another case, there was denuded area with granulation in the posterior canal wall which was repaired using a temporalis underlay graft. There were no cases of external auditory canal or middle ear cholesteatoma (Table 1). Of the 17 cases with delayed healing (cicatricial stenoses, infection, and prolonged healing), concurrent diabetes mellitus was seen in four cases. However, when analyzed statistically, the association was not significant ($p = 0.5$)

DISCUSSION

In 1763, François Boissier de Sauvages first described a patient with EAC exostosis (15). The earliest attempts to remove the lesion were with chiseling using an osteotome (15). Although William Dalby and Arthur Mathewson were the first to use the motor drill for removal of an exostosis, it was George Field who had a large series thereby popularized this technique for exostosis (15). Though exostoses and osteomas are often categorized together as a single clinical entity due to the similarities in clinical presentation and surgical management, they are actually pathologically distinct entities. Exostosis is considered to be a reactive inflammatory response to an external stimulus, like prolonged exposure to cold water and wind (6,16–19). It is characterized by concentric, dense layers of subperiosteal bone that presents as new bony growth in the osseous portion of the EAC. It is usually multiple, bilateral, and broad-based (20). Osteoma on the other hand is a true benign tumor of the bone (21) often arising from the along the tympanomastoid or tympanosquamous suture lines. Microscopically, it consists of mature bone trabeculae, separated by medular spaces with fibrovascular tissues. They are usually single, unilateral, and pedunculated. Although the two entities differ in their gross appearance, debate remains in the medical literature as to whether basic histopathology can distinguish osteoma from exostoses (21,22).

Occurrence and Associations

Exostoses occurs more frequently in middle aged men, and has never been reported in black people in English literature (17,22). Osteomas are rarer and no such demographic or racial predilection has been established. In our review of literature, the men preponderance is clearly established with a male:female ratio that ranged from 3.5:1 to 139:1 (Table 2). The predilection of exostoses is similar to otosclerosis, another bony entity afflicting the middle ear that is often seen associated in patients with exostosis. Like in our series, Timofeev et al. (23), and House and Wilkinson (10), also observed a high incidence of otosclerosis in patients with exostosis. In fact, otosclerosis was the main indication for exostosis removal in 30.5% our series. There are other similarities between the two temporal entities. Both produce extrabone as a response to different trigger. The incidence of exostoses (0.6%) and otosclerosis (0.3–0.5%) is similar (17). Both have a high predilection for the Caucasian population (23,24).

Grading of EACS

EACS, one of the principal features of exostoses and osteomas, leads to many symptoms in later stages. It is important to grade EACS to determine the extent of the disease and also to standardize reporting in literature. Many grading systems have been proposed for grading of EACS (3,4,9,10). But none of them have been able to provide an adequate objective assessment of the grades of stenosis. Ambiguous terminologies like ''obliterative'' or ''less than obliterative'' (3), minimal, moderate or severe (4,9,25) exostosis have been used to describe the degree of EACS. In our classification, we use both clinical and radiological parameters of assessment to achieve objectivity. This ensures that there is no inter-observer variability in documentation and reporting.

Clinical Features

As seen in most series, exostoses and osteomas manifest their symptoms only when they occlude a considerable portion of the EAC. We prefer not to operate on exostoses and osteomas, even with higher grades of EACS, if they are asymptomatic. In our series we had no cases of Grade I and only seven (2.7%) of cases of Grade II that required surgery. Having an extremely narrow opening of the external canal typically allows sound waves to provide sufficient air conduction to the tympanic membrane. Hence, often surgery is not necessarily done for conductive hearing loss but to address other manifestations of a narrow canal like recurrent otitis externa or wax retention. However, asymptomatic lesions may be operated upon as an approach to other middle ear conditions like chronic otitis, ossicular chain pathology or otosclerosis, or for hearing aid fitting. Although House and Wilkinson (10), performed stapes surgery in the same sitting, we prefer to perform any middle ear surgery (except for a routine TM perforation repair) in a second stage. In Table 2, the most common indication for canalplasty in literature was hearing loss (42–83%) and recurrent otitis externa (18–63%).

Surgical Technique

Both the drill canalplasty and osteotome techniques are well-accepted techniques in the surgical management of exostoses and osteomas. Both techniques are not easy to master and the surgeon may lose his way if the procedure is not followed orderly (3). The success of any surgical technique is defined by the shape of the ear canal (which should be conical at the end of the surgery), minimum healing time and minimal collateral damage to the TM, ossicular chain (more commonly the malleus), FN, and the temporomandibular joint. The proponents of the osteotome canalplasty argue that the technique is safer than the drill canalplasty as there is less chance of damage to the important structures. However, most authors using the osteotome use the transcanal approach which results in working in a narrow operating field. The use of a hand held osteotome and gouge is not safe in the immediate vicinity of the TM, especially in the setting of bleeding in the canal. In such situations, authors have reported allowing an assistant to hit the osteotome with a gouge while the surgeon's hands hold a suction and an osteotome (3).

The drill canalplasty is usually done via a retroauricular approach that allows a full view of the EAC and hence reduces the risk of complications. Damage to important structures can be avoided by taking care to address key areas like careful elevation of EAC skin, protecting the meatal flap with a piece of aluminum foil, incremental and circumferential drilling of the lesions without going too deep at any point, the use of fascia to cover the skin defects, and of course, a thorough knowledge of the anatomy of the area.

There have been suggestions to leave behind part of the lesions on the posterior wall not to put to risk the FN thereby achieving a subtotal removal (26). Although it is not compulsory to remove all the bony lesions, this philosophy is unwarranted for in modern surgery as all lesions can be removed completely with negligible complications. Injury to the FN can be avoided by circumferential drilling and refraining drilling blindly when the TM is not visible. We had no trouble removing exstosis/osteoma without the use of FN monitor and we do not advocate using the same for canalplasty. There was no event of a FN injury in our series.

Complications

A comparison of results (Table 1) shows that the highest incidence of TM perforations has occurred in the series with osteotome canalplasty. Other complications with the osteotome is fracture of the anterior canal wall (3,4) that has not been reported with the drill and higher incidence of TMJ prolapse. However, the range of EAC stenosis (0.1–6%) as seen in Table 2 was higher in the drill canaplasty group. This could be explained by the fact that retroauricular approach involves a wider exposure of the EAC and therefore there is a tendency to drill more bone than osteotome canalplasty which is via a transcanal approach. The drilling obviously leaves behind a wider and conical EAC than before and the original skin is almost always insufficient to be plastered against all the surfaces of the neocanal. To address this issue, we cut the canal skin longitudinally and use an underlay temporalis fascia to cover the defect. This has led to a low stenosis rate of 2.7% in our series.

It also appears that a certain degree of SNHL is also inevitable with drill canalplasty although this cannot be said conclusively as SNHL results have not been analyzed in detail by all authors. However, this is rarely higher than 10 dB and is limited to high frequencies as seen in our series (9,10).

CONCLUSION

A systematically performed drill canalplasty via retroauricular approach yields excellent postoperative outcomes as seen in our series. A new grading system incorporating clinical (otoscopical) and radiological observations has been proposed to reduce inter-observer variability. We would like to conclude by agreeing with James Sheehy's thoughts on which approach is better; the retroauricular or transcanal. He asked ''Do you believe you can see well enough transmeatally to totally remove the lesion? Or are you concerned regarding making the operation a 'big one' with a post auricular approach?''

TABLE 2. *Review of literature and comparison of results in canalplasty for EACS*

Author	No. of Patients, No. of Surgeries	Pathology Causing EACS and No. of Cases	M:F Ratio	Indications for Canalplasty	Canalplasty Technique	Approach and No. of Patients	Details of Complete Healing (In wk)	Surgical Complications	Audiometric Complications
Sheehy (1)	80; 100	Exostoses (84); Osteomas (16)	19:1; 3:1	HL: 64%; ROE: 40%	Drill	TC (43); RA (57)	Osteoma: 83% in 3 weeks; Exostoses: 75% in 6 weeks	TMP: 12%; FNP: 1%; St: 6%; residual: 1%; RS: 6%	NA
Fisher et al. (27)	102; 127	Exostoses (123); Osteomas (4)	5.8:1	HL: 67%; ROE: 63%; ME access: 10%	Drill	TC (87); EA (36); RA (4)	≤8 in 80%	TMP: 0.4%; Gr: 6%, St: 6%, TMJP: 1%; RS: 2%	SNHL: 1%
Vasama (8)	136; 182	Exostoses (182)	11.4:1	NA/NC	NA	EA (182)	NA	TMP: 3%; Inf: 3%; St: 0.1%; EACC: 0.5%; TMJP+EACF: 0.5%; RS: 4%	SNHL: 2%
Hetzler et al. (3)	140; 221	Exostoses (221)	139:1	HL: 100%	Osteotome (179); Osteotome + drill (42)	TC (221)	3.5 (mean)	EACF: 2%; TMJP: 1%; TMP: 13%; Inf: 2%	SNHL: 1% (at individual freq)
House and Wilkinson (10)	327; 401	Exostoses (401)	45.7:1	HL: 55%; ROE: 42%	Drill	RA (397); TC (4)	≤12 in 96%	Inf: 1.5%, St: 1%; TMP: 0.2%; TMJP: 0.2%; RS: 0.5%	SNHL: 0.4% (all freq 4.4% (4kHz)
King et al. (6)	61; 83	Exostoses (83)	29.5:1	NA	Drill (10); Osteotome + drill (61); Osteotome (4); NA (8)	RA (80); TC (3)	Prolonged healing time by several weeks in 17.5%	St: 6%; Gr: 4%; Inf: 2.5%; TMP: 1%; RS: 6%	NA
Hempel et al. (28)	30; 35	Exostoses (26); Osteomata (4)	29:1	HL: 57%; Wax: 47%; REO: 40%	NA	EA (33); RA (2)	NA	Inf: 9%; St: 3%; RS: 6%	SNHL: 9% (NC)
Barrett et al. (5)	78; 92	Exostoses (92)	77:1	HL: 58%; ROE: 61%; Otalgia-24%	Drill (21); Osteotome + drill (38); Osteotome (33)	EA (92)	NA	Inf: 9%; TMP: 5%;	SNHL (56 pts): 3.5% (drill)
Moss et al. (9)	34; 41	Exostoses (41)	34:1	NA	Drill	RA (41)	<8 (prolonged healing; >8 wks in 3%)	Inf: 13%; Hematoma / seroma: 8%; canal swelling: 15%; TMP: 2%; Mast CE: 2%	SNHL (>3 kHz): 9%
Ghavami et al. (4)	106; 138	Exostoses (138)	14.1:1	NA	Osteotome	TC (138)	<3 in 80%	TMP: 6.5%; EACF: 0.7%	No SNHL
Present study	217, 256	Exostoses (243); Osteomas (13)	3.5:1	HL: 83%; ROE: 18%; ME access: 38%	Drill	RA (245); TC (11)	6.4 (mean); (prolonged healing >8 wks in 2%)	St: 3%; Inf: 2%; TMP: 2%; Mast CE: 1%	SNHL (all freq): 0.4%; SNHL (4 kHz): 7%

EA indicates endaural; EACC, external auditory canal cholesteatoma; EACF, external auditory canal fracture; EACS, external auditory canal stenosis; FNP, facial nerve paralysis; Gr, granulations; HL, hearing loss; Inf, infections; Mast CE, mastoid cell entry; NA, not available; NC, not clear; RA, retroauricular; ROE, recurrent otitis externa; RS, revision surgery; SNHL, sensorineural hearing loss; St, stenosis; TC, transcanal; TMJP, temporomandibular joint prolapse; TMP, tympanic membrane perforations.

His answer was ‘‘There is no question that the lesion can be removed totally by the transmeatal approach, but I believe this is doing the operation the hard way. The retroauricular approach is easier and safer for the surgeon if his objective is performing a definitive operation’’ (1).

REFERENCES

1. Sheehy JL. Diffuse exostoses and osteomata of the external auditory canal: a report of 100 operations. *Otolaryngol Head Neck Surg* 1982;90:337–42.
2. Whitaker SR, Cordier A, Kosjakov S, Charbonneau R. Treatment of external auditory canal exostoses. *Laryngoscope* 1998;108:195–9.
3. Hetzler DG. Osteotome technique for removal of symptomatic ear canal exostoses. *Laryngoscope* 2007;117:1–14.
4. Ghavami Y, Bhatt J, Ziai K, Maducdoc MM, Djalilian HR. Transcanal micro-osteotome only technique for excision of exostoses. *Otol Neurotol* 2016;37:185–9.
5. Barrett G, Ronan N, Cowan E, Flanagan P. To drill or to chisel? A long-term follow-up study of 92 exostectomy procedures in the UK. *Laryngoscope* 2015;125:453–6.
6. King JF, Kinney AC, Iacobellis SFJ2nd, et al. Laterality of exostosis in surfers due to evaporative cooling effect. *Otol Neurotol* 2010;31:345–51.
7. Sanna M, Russo A, Khrais T, Jain Y, Augurio AM. Canalplasty for severe external auditory meatus exostoses. *J Laryngol Otol* 2004;118:607–11.
8. Vasama JP. Surgery for external auditory canal exostoses: a report of 182 operations. *ORL* 2003;65:189–92.
9. Moss WJ, Lin HW, Cueva RA. Canalplasty for exostoses with maximal skin preservation with temporoparietal fascia grafting and use of bone wax for skin flap protection: a retrospective case series. *Ann Otol Rhinol Laryngol* 2015;124:978–86.
10. House JW, Wilkinson EP. External auditory exostoses: evaluation and treatment. *Otolaryngol Head Neck Surg* 2008;138:672–8.
11. Sanna M, Karmarkar S, Landolfi M. Hearing preservation in vestibular schwannoma surgery: fact or fantasy? *J Laryngol Otol* 1995;109:374–80.
12. Sanna M, Mancini F, Russo A, Taibah A, Falcioni M, Di Trapani G. *General Features of Acoustic Neurinomas. Atlas of Acoustic Neurinoma Microsurgery*. Stuttgart: Georg Thieme Verlag; 2011. 1–3.
13. Adad B, Rasgon BM, Ackerson L. Relationship of the facial nerve to the tympanic annulus: a direct anatomic examination. *Laryngoscope* 1999;109:1189–92.
14. Lavy J, Fagan P. Canalplasty: review of 100 cases. *J Laryngol Otol* 2001;115:270–3.
15. Mudry A, Hetzler D. Birth and evolution of chiselling and drilling techniques for removing ear canal exostoses. *Otol Neurotol* 2016;37:109–14.
16. Cooper A, Tong R, Neil R, Owens D, Tomkinson A. External auditory canal exostoses in white water kayakers. *Br J Sport Med* 2010;44:144–7.
17. DiBartolomeo JR. Exostoses of the external auditory canal. *Ann Otol Rhinol Laryngol Suppl* 1979;88:2–20.
18. Harrison DF. The relationship of osteomata of the external auditory meatus to swimming. *Ann R Coll Surg Engl* 1962;31:187–201.
19. Hutchinson DL, Denise CB, Daniel HJ, Kalmus GW. A reevaluation of the cold water etiology of external auditory exostoses. *Am J Phys Anthropol* 1997;103:417–22.
20. Kemink JL, Graham MD. Osteomas and exostoses of the external auditory canal - medical and surgical management. *J Otolaryngol* 1982;11:101–6.
21. Carbone PN, Nelson BL. External auditory osteoma. *Head Neck Pathol* 2012;6:244–6.
22. Granell J, Puig A, Benito E. [Osteoma and exostosis of the external auditory meatus: a clinical diagnosis]. *Acta otorrinolaringol Esp* 2003;54:229–32.
23. Timofeev I, Notkina N, Smith IM. Exostoses of the external auditory canal: a long-term follow-up study of surgical treatment. *Clin Otolaryngol Allied Sci* 2004;29:588–94.
24. Arnay-de-la-Rosa M, Velasco-Vazquez J, Gonzalez-Reimers E, Santolaria-Fernandez F. Auricular exostoses among the prehistoric population of different islands of the *Canary archipelago*. *Ann Otol Rhinol Laryngol* 2001;110:1080–3.
25. Moore RD, Schuman TA, Scott TA, Mann SE, Davidson MA, Labadie RF. Exostoses of the external auditory canal in white-water kayakers. *Laryngoscope* 2010;120:582–90.
26. Longridge NS. Exostosis of the external auditory canal: a technical note. *Otol Neurotol* 2002;23:260–1.
27. Fisher EW, McManus TC. Surgery for external auditory canal exostoses and osteomata. *J Laryngol Otol* 1994;108:106–10.
28. Hempel JM, Forell S, Krause E, Müller J, Braun T. Surgery for outer ear canal exostoses and osteomata: focusing on patient benefit and health-related quality of life. *Otol Neurotol* 2012;33:83–6.