Surgical Outcomes after Vestibular Schwannoma Surgery: Cystic Versus Solid Variants

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Original Article

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ABSTRACT

Introduction: This study aims at comparing the surgical resection and facial nerve outcomes between cystic and solid variants of vestibular schwannoma (VS).

Methods: All cases of VS surgically treated by an enlarged translabyrinthine approach over five years were included. Cases were divided into cystic and solid tumors based on the radiological evidence of presence or absence of a cystic component in the preoperative magnetic resonance imaging. 70 cases were included and divided in two groups: cystic tumors 31 patients and solid tumors 39 patients.

Results: Tumors were significantly larger in the cystic group (*p-value*= 0.0002), together with higher incidence of brainstem compression. Complete tumor removal was done in 18 out of 31 cystic VS (58%) and in 30 out of 39 solid VS (77%) with no statistical significance between the two groups (*p-value*= 0.2). On postoperative radiological evaluation, residual tumor was detected in 14 out of 70 cases (20%). Of those 14 cases, six (19%) cases were in the cystic group and 8(21%) were in the solid group (*p-value*= 1). The immediate postoperative facial nerve results showed significantly better results in solid tumors (*p-value*= 0.006), but at the end of the follow-up period, there was no difference regarding facial nerve outcomes between the two groups.

Conclusion: Cystic vestibular schwannoma is characterized by frequent facial nerve thinning over the surface of the tumor. Incomplete excision may be adopted in these cases to preserve facial nerve function.

Key Words: Cystic; facial nerve, schwannoma, solid, translabyrinthine approach, vestibular schwannoma.

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INTRODUCTION

Vestibular schwannoma (VS) is the most common neoplasm in the cerebello-pontine-angle (CPA), accounting for 80–90% of all its tumors[1-3]. Histopathologically, VS can be classified as Antoni type A or B. Type A has a core compact stroma mixed with bundles of long spindle cells arranged in palisades, while type B has a looser spongy texture with cyst formation[4]. The mechanism of cystic formation in VS has been attributed to coalescence of microcysts or tumoral degenerative changes[5]. Based on this, VS can be broadly categorized into solid and cystic[6,7]. There is a variable incidence of cystic variant of VS ranging from 11.3% to 48%[8-10].

Certain unique features were previously linked to cystic VS as being more aggressive, having shorter duration of symptoms, unpredictable behaviour and poor facial nerve and surgical results[5-7,11-15]. On the contrary, other reports showed no significant difference between solid and cystic VS regarding surgical outcomes[6,7,11,16]. To address this topic, we performed a comparative study between cystic

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and solid VS. The aim was to investigate the different clinical characteristics and to compare facial nerve (FN) and surgical resection results between the two variants.

PATIENTS AND METHODS

This study included patients diagnosed with unilateral VS and who underwent surgical excision via an enlarged translabyrinthine approach[17] in a tertiary referral center over a 5-year duration. Medical records of the studied cases were reviewed to extract and analyze patients' demographics, symptoms and signs at presentation, intraoperative and postoperative data after institutional review board approval. Participants were eligible if a one-year postoperative follow-up data were available. Exclusion criteria included patients with preoperative FN palsy, neurofibromatosis type II (NF II) and revision cases. A number of 70 patients were retrospectively analyzed and divided into two groups: cystic and solid tumors. The tumor was classified as cystic if there is a hypointense area on the preoperative magnetic resonance imaging (MRI) together with intraoperative identification of the cystic element[18-20].

Piccirillo's classification[7] was used to divide the cystic VS group into two subgroups; type A and type B. Type A represents central and thick-walled cysts and type B represents peripheral thin-walled cysts. Type A is further classified into three subtypes: A1 (polycystic multiple small cysts), A2 (polycystic multiple moderate-sized cysts) and A3 (monocystic, single large cyst). Type B had four subtypes according to the location of the cyst; B1 (anterior), B2 (medial), B3 (posterior) and a combination of them (B4).

Radiological estimation of tumor size was done by measuring the maximum extra-canalicular diameter. Tumor grading was described according to the following group classification: grade 0, intracanalicular tumor; grade one less than 1cm; grade two between 1cm and 2cm; grade three between 2cm and 3cm; grade four between 3cm and 4cm and grade five more than 4cm in greatest diameter[21]. Other radiological features including extension of the tumor to the fundus of internal auditory canal (IAC) and compression of the brainstem were also recorded.

Intraoperative neurophysiological monitoring of the facial nerve was performed in all patients using a facial electromyographic device (NIM response 3.0 4-channel Nerve Integrity Monitoring System, Medtronics Xomed Surgical Products Inc., Jacksonville, FL, USA). Operation records were analyzed for anatomical identification of an intact FN and successful intraoperative electrical stimulation of the nerve. FN outcomes at different postoperative time points were compared. These included immediately postoperative, at the time of discharge, at six months, at one year and at the last follow-up visit. Good FN outcome was stated when the patient has a House-Brackmann (H-B) grade I, II or III. Poor FN function was defined as H-B grade IV, V or VI[22]. Pure tone audiometry charts were revised, and the mean degree of the preoperative hearing loss was calculated and classified using the American Academy of Otolaryngology-Head and Neck Surgery Foundation grading[23].

Tumor removal was graded into either total, near total or subtotal excision depending on the intra-operative surgeon's impression. Near total resection means that only a thin layer of tumor was left with a maximum measurement of 5×5×2mm. This thin layer was not removed due to strong adhesion to the cranial nerves, brainstem, or vascular structures. Subtotal resection is defined as a tumor remnant larger than these measurements[24]. All cases were done by the same experienced surgical team (J.G, L.L, JM.M). In our experience, near total resection is usually followed up by serial MRI images and the remaining layer rarely grows. Radiotherapy is considered only if significant growth was observed. In subtotal resection, early radiological follow-up, three to four months postoperatively, was done to assess the residual tumor followed by either a revision surgery or radiotherapy according to remanent size and patient preference[25].

A follow-up MRI was done after one year in all included cases to assess residual tumors. Any suspected residual enhancement usually appears as a lineal or nodular pattern. Lineal enhancements have less probability to be residual tumor and usually represent a scar tissue[24]. Accordingly, only nodular enhancements are categorized as residual tumor in this study. The correlation between subtypes of cystic VS and FN outcomes, extent of surgical resection and residual tumor was investigated.

Statistical Analysis

Data was fed to the computer and analyzed using R programming version 4.3.3. Quantitative data was described using mean, standard deviation, range (minimum and maximum), or median and interquartile range (IQR). Qualitative will be described using frequency and percentage. Mann Whiteny *U* test was used for non-parametric distributed quantitative variables to compare between two different samples. Monte Carlo test was used for correction for chi-square when more than 20% of the cells have expected countless than 5 (for lager than 2*2 tables). Chi square test was used for Correction for chi-square when less than 20% of the cells have expected countless than 5 and Fisher's exact test for Correction for chi-square when more than 20% of the cells have expected countless than 5 (for 2*2 tables). Significance was calculated at 5% level of significance and results were considered statistically significant at $p\text{-value} < 0.05$.

RESULTS

There were seventy patients included in the study, 31(44.3%) cases with cystic tumors and 39(55.7%) cases

with solid tumors. Mean age of the cystic VS group was 54.61±17.42 years while for the solid VS group, it was 50.3±14.7 years. The most common presenting symptom for both groups was hearing loss with an incidence of 71% followed by dizziness and tinnitus with an incidence of 10%. The duration of this main complaint was longer in the solid VS group (median= 24 months) than in the cystic VS group (median= 15 months). However, this difference was not statistically significant. The distribution of different symptoms among the two groups is presented in Table (1).

Apart from the significantly higher incidence of facial paresthesia in the cystic VS group, no other statistical difference was found regarding symptom distribution between cystic and solid VS.

In the cystic group, 12 patients (38.7%) had tumors less than 3 cm while 19 cases (61.3%) had larger tumors. This is in comparison to 79.5% and 20.5% of the solid group. This difference was statistically significant between the two groups (*p-value*= 0.004) with higher measurements of the maximum tumor diameter in the cystic group (*p-value*= 0.0002) (Table 2). Displacement of the fourth ventricle and/or compression of the brainstem were present in 45 out of 70 cases. Cystic VS group had higher incidence of compression of brainstem, 26(84%), than solid VS group, 19(49%) reaching statistical significance. Solid tumors had more centred orientation to the IAC, 28 patients (72%), than cystic tumors, 15 patients (48%), but there was no significant difference regarding occupancy of the fundus of the IAC by the tumor between the two groups.

Tumor excision was total in 18 out of 31 cystic VS (58%) and in 30 out of 39 solid VS (77%). Incomplete removal, near total and subtotal, was found in 13(41.9%) and 9(23.1%) of the cystic and solid groups, respectively. Incomplete removal was carried out in these cases for preservation of the anatomical integrity of important neurovascular structures, particularly the facial nerve. The statistical difference between the two groups was not significant (*p-value*=0.2). On postoperative MRI, residual tumor was detected in 14 out of 70 cases (20%), 6(19%) in the cystic VS group and 8(21%) in the solid VS group

Table 1: Demographic and basic clinical data of the included patients:

Characteristic		Overall, *N*= 70	Cystic, *N*= 31	Solid, *N*= 39	*p*-value
Gender	female	37 (53%)	16 (52%)	21 (54%)	> 0.05 (0.9)
	male	33 (47%)	15 (48%)	18 (46%)	
Age	Median IQR Range	51.50 (40.00, 65.00) [15.00 - 82.00]	60 (39.50, 69.50) [18.00 - 82.00]	50 (42.00, 60.50) [15.00 - 76.00]	> 0.05 (0.2)
Side	Lt	37 (53%)	17 (55%)	20 (51%)	> 0.05 (0.8)
	Rt	33 (47%)	14 (45%)	19 (49%)	
Comorbidities	HTN	16 (22.85%)	10(32.26%)	6(15.4%)	> 0.05 (0.4)
	Asthma	5 (7.14%)	2(6.45%)	3(7.7%)	
	Thyroid	6 (8.57%)	3(9.68%)	3(7.7%)	
	GERD	1 (1.43%)	1(3.23%)	0(0%)	
Main complaint	Hearing loss	50 (71%)	23 (74%)	27 (69%)	> 0.05 (0.4)
	Dizziness	7 (10%)	3 (9.7%)	4 (10%)	
	Altered facial sensation	1 (1.4%)	1 (3.2%)	0 (0%)	
	headache	5 (7.1%)	3 (9.7%)	2 (5.1%)	
	tinnitus	7 (10%)	1 (3.2%)	6 (15%)	
Duration of the main complaint (months)	Median IQR Range	24.00 (12.00, 36.00) [1.00 - 150.00]	15.00 (7.00, 30.00) [3.00-72.00]	24.00 (12.00, 48.00) [1.00 - 150.00]	> 0.05 (0.10)
Prevalence of complaints	Vertigo	21 (30%)	10 (32%)	11 (28%)	> 0.05 (0.7)
	Dizziness	50 (71%)	23 (74%)	27 (69%)	> 0.05 (0.6)
	Tinnitus	43 (61%)	19 (61%)	24 (62%)	> 0.05 (1)
	Hearing loss	67 (96%)	30 (97%)	37 (95%)	> 0.05 (1)
	Ear fullness	19 (27%)	11 (35%)	8 (21%)	> 0.05 (0.2)
	Altered facial sensation	15 (21%)	12 (39%)	3 (7.7%)	< 0.05* (0.002)
	Headache	32 (46%)	18 (58%)	14 (36%)	> 0.05 (0.064)

Lt: Left; Rt: Right; HTN: Hypertension; GERD: Gastroesophageal reflux disease; IQR: Interquartile range.

Table 2: Radiological, intraoperative and postoperative data of the studied population:

Characteristic			**Overall, *N*= 70**	**cystic, *N*= 31**	**solid, *N*= 39**	***p*-value**
Maximum Diameter		Median	30	34	26	< 0.05*
		IQR	(9)	(9)	(8)	(0.000212)
		Range	[15: 54]	[20: 54]	[15: 53]	
Grade		2	14 (20%)	3 (9.7%)	11 (28%)	< 0.05 (0.004)*
		3	29 (41%)	9 (29%)	20 (51%)	
		4	17 (24%)	11 (35%)	6 (15%)	
		5	10 (14%)	8 (26%)	2 (5.1%)	
IAC		Centered	43 (61%)	15 (48%)	28 (72%)	< 0.05 (0.008)*
		Not centered	27 (38.57%)	16 (51.6%)	11 (28%)	
Reaching Fundus of IAC			55 (79%)	24 (77%)	31 (79%)	> 0.05 (0.8)
Compression of brainstem			45 (64%)	26 (84%)	19 (49%)	< 0.05 (0.002)*
Tumor origin		IV	16 (23%)	7 (23%)	9 (23%)	> 0.05 (0.7)
		SV	3 (4.3%)	2 (6.5%)	1 (2.6%)	
		uncertain	51 (73%)	22 (71%)	29 (74%)	
Cochlear nerve preservation			8 (11%)	3 (9.7%)	5 (13%)	> 0.05 (1)
Successful electrical facial nerve stimulation at the end of surgery			62 (89%)	26 (84%)	36 (92%)	> 0.05 (0.5)
Tested at mA		Median	0.04	0.04	0.03	> 0.05 (0.9)
		IQR	0.0275	0.03	0.02	
		Range	(0-0.1)	(0-0.1)	(0-0.1)	
Surgical excision		Total	48 (69%)	18 (58%)	30 (77%)	> 0.05 (0.2)
		Near total	18 (26%)	10 (32%)	8 (21%)	
		Subtotal	4 (5.7%)	3 (9.7%)	1 (2.6%)	
hospital stay(days)		Median	7.00	7.00	7.00	> 0.05 (0.14)
		IQR	(3.00)	(2.00)	(1.50)	
		Range	[5.00, 30.00]	[6.00, 20.00]	[5.00, 30.00]	
Facial nerve function postoperatively	Immediately	Good	44 (63%)	14 (45%)	30 (77%)	< 0.05 (0.006)*
		Poor	26 (37%)	17 (55%)	9 (23%)	
	At time of discharge	Good	39 (56%)	14 (45%)	25 (64%)	> 0.05 (0.11)
		Poor	31 (44%)	17 (55%)	14 (36%)	
	At 6 months	Good	53 (76%)	20 (65%)	33 (85%)	> 0.05 (0.051)
		Poor	17 (24%)	11 (35%)	6 (15%)	
	At 1 year	Good	61 (87%)	25 (81%)	36 (92%)	> 0.05 (0.2)
		Poor	9 (13%)	6 (19%)	3 (7.7%)	
	At the last follow-up	Good	65 / 70 (93%)	28 / 31 (90%)	37 / 39 (95%)	> 0.05 (0.6)
		Poor	5 / 70 (7.1%)	3 / 31 (9.7%)	2 / 39 (5.1%)	

IQR: Interquartile range; IAC: Internal auditory canal; IV: Inferior vestibular nerve; SV: Superior vestibular nerve.

Table 3: Comparison between the two types of cystic vestibular schwannoma regarding main postoperative outcomes:

		Type A cystic VS (*N*=15)	**Type B cystic VS**	**(*N*= 16)**	***p*-value**
Postoperative facial nerve function at one year	Good (*N*=25)	12	13		0.9
	Poor (*N*=6)	3	3		
Surgical excision	Total (*N*=18)	11	7		0.09
	Near total (*N*=10)	2	8		
	Subtotal (*N*=3)	2	1		
MRI postoperatively	No residual (*N*=25)	14	11		0.08
	Residual tumor (*N*=6)	1	5		

VS: Vestibular schwannoma; MRI: Magnetic resonance imaging.

(*p-value*= 1). No postoperative adjuvant treatment was given to the patients undergoing near total resection, while three cases with subtotal resection had radiosurgery postoperatively.

Facial nerve assessment after surgery at different time intervals is reported in Table (2). It was anatomically preserved in all included cases, and successful electrical stimulation at the end of the surgery was achieved in 62(89%) cases with a median of 0.04mA. This percentage was not significantly higher in cystic VS when compared with solid tumors (*p-value* >0.05). However, the immediate facial nerve results postoperatively showed significantly better results in the solid group. Notably, in surgery of cystic tumors, surgeons described the FN as being thinned or ribboned, even if it is anatomically intact, in a high number of cases. Among the eight cases with no intraoperative electrical facial nerve response, six cases had a reinforcement by greater auricular nerve graft in the same setting[26]. "Great auricular nerve reinforcement was done in six, out of eight, cases with failed intraoperative electrical nerve stimulation. Based on that, its usage was understandably linked to the immediate postoperative poor facial nerve function in all the six cases. At the one-year follow-up evaluation four cases (66.6%) had good facial nerve outcomes (all of them in the cystic group) while two cases (33.3%) had poor facial nerve outcomes, one in cystic and one in the solid group. This clinical difference between the good and poor facial nerve functions was not statistically significant. Also, the difference between the cystic and solid groups regarding this point was not statistically significant at the one-year follow-up.

Type A cysts were found in 15 cases and 16 cases were type B. Type A was divided into 3(9.7%) cases in subtype A1, 7(23%) in A2 and 5(16%) in A3. Two cases (6.5%) were classified as type B1, 5(16%) type B2, 3(9.7%) type B3 and 6(19.4%) type B4. A comparison between the two groups regarding facial nerve outcome at one year, extent of surgical excision and presence or absence of a residual tumor is presented in Table (3) with no significant difference between the two cystic subtypes.

Overall, 14/70 patients (20%) had severe headache requiring analgesia and 3 cases (4.3%) had refractory headache (not responding to usual analgesic medications) with no statistically significant difference between the two groups. Cerebrospinal fluid fistula occurred in two cases and was treated conservatively. Wound granulation/ infection or dehiscence affected 10% of the patients (13% cystic, 7.7% solid), which was not statistically significant. Pnumocephalus was present in 5.7% of the cases (6.5% cystic, 5.1% solid), with a *p-value* of 1. Disturbed conscious level, seizures, or stroke occurred in 8.6% of the patients (13% cystic, 5.1% solid), with a *p-value* of 0.4. Venous sinus thrombosis affected 1.4% of the cases (3.2% cystic, 0% solid), with a *p-value* of 0.4. Meningitis occurred in 2.9% of the patients (3.2% cystic, 2.6% solid), with a *p-value* of 1. Other temporary cranial nerve injury in the form of abducent paralysis and trigeminal paresthesia occurred in 5.7% of the cases (3.2% cystic, 7.7% solid), with a *p-value* of 0.6.

For the cystic VS group, mean PTA was 60.54±16.8 for the VS side and 17.25±4.8 for the normal side whereas for the solid VS group, mean PTA was 64.67±16.52 for the VS side and 22.15±10.1 for the normal side. According to speech discrimination score, 3(4.3%) cases out of 70 had slight difficulty, 5(7.1%) had moderate difficulty, 13(19%) had poor score, 27(39%) had very poor score and 22(31%) had normal discrimination. Two (3%) cases were categorized as class A, 13(19%) were class B, 26(37%) were class C and 29(41%) were class D. No statistically significant difference was detected between both groups regarding hearing results.

DISCUSSION

The incidence of VS in the cerebello-pontine angle is about 80% accounting for the most common tumor in this location[5,7,14,15]. The incidence of the cystic variant ranges in the literature between 4 and 48%[14,16,27,28]. There is no definitely known pathogenesis for cyst formation within VS, however, several suggestions were postulated in previous reports. One of these theories, is related to coalescence of small cysts in Antoni type B VS[15,28,29]. Enlargement in these cases is mainly due to cystic expansion rather than actual tumor growth[29,30]. Cyst expansion usually owed to fluid collection by a direct osmotic effect or extravasation of serum proteins through the blood brain barrier[27]. Another theory for cyst formation is the repeated intratumoral haemorrhage and degeneration forming intra-tumoral cysts. This was evidenced by presence of hemosiderin-laden macrophages in these tumors[15,19,29]. Large VSs have a higher rate of degeneration and necrosis than smaller tumors. Accordingly, cyst formation is thought to be more frequently encountered in large and giant VSs[31].

Cystic VS were thought to be different from solid VS on a clinical, radiological, and surgical basis. Initial atypical presentations are more common with cystic tumors like facial pain, paraesthesia or facial palsy unlike the usual clinical picture of a progressive hearing loss. Vestibular schwannoma-related facial pain or paresthesia are attributed to trigeminal neuropathy which occur from direct tumor pressure on the trigeminal nerve with subsequent nerve demyelination or from a growing tumor pushing trigeminal nerve to come in contact with an artery[32]. In our series, nearly 39% of the cystic group presented with facial pain or numbness which was statistically higher than the solid group. However, the most common initial symptom in the two groups remained hearing loss (96%). This is in accordance with the incidence reported by Benech *et al*.,[5] who had a percentage of 81% as the initial symptom.

Surgical outcome for cystic VS is still a matter of debate. Many studies have demonstrated a less favorable outcome than that of solid tumors of comparable size, while other papers support a contradicting opinion[5,6,12,20,27,30,33-36]. Despite these conflicting views, it is agreed that initial debulking of the tumor, by ultrasonic aspirator, is easier and quicker in cystic VS than in solid tumor. It has been reported by Lunardi *et al*.,[37] that simple aspiration of the cystic content facilitated recognition and preservation of the FN yielding a more favorable prognosis. Nonetheless, the risk of FN damage at the porus of the IAC is greater in the cystic variant. This is attributed to stretch of the FN over the tumor surface with difficult dissection from the cyst wall. Charabi *et al.,*[28], reported higher risk of accidental FN injury in surgery of cystic than in solid tumors. However, in the same report, all patients with anatomical preservation of the FN, either cystic or solid, showed similar FN outcomes at the 1-year results.

On the average, postoperative FN function in our series of cystic VS is comparable with published data[12,27]. FN function at the one-year assessment was good (HB grade I-III) in 87% of patients. This is in accordance with results present in literature, in which good function was observed in 60-80% of patients[7,14,15]. The relatively high incidence of good FN function in the present study is attributed by the authors to the fact that, intraoperatively we prefer to leave a very thin layer of the firmly adherent cyst capsule over the brainstem and FN, instead of pursuing complete tumor removal. However, the immediate postoperative facial function is statistically worse in patients with cystic VS. This is explained by the authors by the difficulty in dissection in the arachnoidal plane in these cases due to strong adhesions between the FN and tumor surface. Moreover, there was a high percentage of patients in the cystic VS group where the nerve was described as very thinned and ribboned, which can be easily more affected with excessive manipulation during surgery.

Jones *et al.,*[16] stated that the poor FN results following cystic VS surgery were due to the large size of the tumor rather than the presence of the cyst itself. The rate of anatomical FN preservation with total tumor resection was found to be 93% in solid tumors versus 88% in cystic ones by Samii *et al*.,[35]. This gives an impression that total tumor resection, together with preservation of the FN function is technically more difficult in cystic variants[15]. Though total tumor resection is an optimal overall goal, incomplete excision may be justified in cystic VS to protect neural integrity. In the present series, total excision of the tumor was accomplished in 69% cases, which is comparable to several previously published series[7,14,15,31]. On evaluating post-operative radiological images, residual tumors can be either monitored for growth over consequent scans or sent for radiosurgery if a large residual is remaining or rapid regrowth is observed.

According to Muzumdar *et al*.,[30], multicystic tumors show a more difficult dissection between the tumor and FN in comparison with monocystic tumors. Piccirillo *et al*.,[7] reported that subtotal resection is frequently advocated in type B cysts, leaving a thin part of the cyst wall on important adherent structures. He also mentioned that posteriorly located and type A cysts have a higher possibility of complete surgical resection than other types. However, no significant difference between the two types of cystic VS was encountered in the present study.

Limitations of this study include relatively low number of cases for comparison especially between the two cystic subgroups. Added to that, we didn't include the histological criteria for diagnosing cystic VS. Moreover, it has been reported that there is a higher potential of rapid re-growth of the remanent tumor and subsequently, the need for a revision surgery in cystic VSs than solid tumors[36]. Based on that, long-term follow-up for the residual tumor need to be addressed in future studies.

CONCLUSION

Cystic VS is considered a distinct category of VS with characteristic features such as short duration of symptoms with possible sudden onset deterioration and frequent facial nerve thinning by the expanding cystic component. Facial nerve outcome was not different between type A and B cystic vestibular schwannoma. Special attention must be given to FN preservation during resection knowing that, in most cases, it will be technically challenging. Extensive intraoperative nerve manipulation to dissect in the tumor-nerve plane results in poor FN outcomes and incomplete excision may be ideal in these cases to preserve facial nerve integrity.

CONFLICT OF INTERESTS

There are no conflicts of interest.

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