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The role of conservative management of vestibular schwannomas

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The role of conservative management of vestibular schwannomas

Although microsurgery is generally regarded as the conventional treatment of choice for most vestibular schwannomas, there remains a group of patients in whom a conservative management approach may be a desirable alternative. The aim of this study was to determine the natural history and outcome following the conservative management of 72 patients with unilateral vestibular schwannomas. The reasons for conservative management included poor general health, age, patient preference, small tumour size, minimal or no symptoms, and tumour in the only/better hearing ear. The mean duration of follow-up was 39.8 months (range 12–194 months). All patients underwent serial magnetic resonanace imaging (MRI) for assessment of tumour growth. Patients were deemed to have failed conservative management if there was evidence of continuous or rapid radiological tumour growth and/or increasing symptoms or signs. The mean tumour growth rate, according to the 1995 guidelines of the American Academy of Otolaryngology/Head and Neck Surgery, was 1.16 mm/year (range: 0.75–9.65 mm/year). Approximately 83% of tumours grew at < 2 mm/year. Significant tumour growth was seen in 36.4%, no or insignificant growth in 50%, and negative growth in 13.6% of tumours. The growth rate of CPA tumours (1.4 mm/year) was significantly greater than that of IAC tumours (0.2 mm/year) ($P = 0.001$). Failure of conservative management, in which active treatment was required, occurred in 15.3%. The outcome of these patients appeared to be as favourable to a comparable group who underwent primary treatment, without a period of conservative management. The mean growth rate of tumours in patients who failed conservative management (4.2 mm/year) was significantly greater than that in patients who did not fail (0.5 mm/year) ($P < 0.01$). No factors predictive of tumour growth or failure of conservative management were identified. Deterioration of mean pure tone average (0.5, 1, 2, 3 kHz) and speech discrimination scores occurred regardless of whether radiological tumour growth was demonstrated or not. This study suggests that in a select number of cases of vestibular schwannoma, a conservative management approach may be appropriate. Regular follow-up with serial MRI is mandatory. Deterioration of auditory function occurs even in the absence of tumour growth

Keywords *acoustice neuroma cerebellopontine angle magnetic resonance imaging non-surgical management vestibular schwannoma*

The first successful removal of a vestibular schwannoma (acoustic neuroma) was by Ballance in 1894.[1] In the early twentieth century, there was significant morbidity and mortality associated with the removal of vestibular schwannomas because by the time patients came to surgery the tumours were usually large with associated multiple cranial nerve palsies, cerebellar and brainstem compression and/or signs of raised intracranial pressure. In addition, the surgical techniques were relatively crude and they lacked the advantages of magnification. Tumour excision was often subtotal, mortality rates of $\approx$ 80% were reported,[2–5] and the facial nerve was almost

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Table 1. Published studies investigating the conservative management (i.e. natural history) of vestibular schwannomas

	Mirz *et al.* 1999	Niemczyk *et al.* 1999	Yamamoto *et al.* 1998	Levo *et al.* 1997	Deen *et al.* 1996	Charabi *et al.* 1995	Wiet *et al.* 1995	Strasnick *et al.* 1994	Jørgensen & Pedersen 1994	Rosenberg *et al.* 1993	Silverstein *et al.* 1993
No. of patients	50	15	12(13)	24	68	123(127)	53	50	19(20)	23	20
Mean age	53y	59.5y	58y	63.1y	67.1y	58.8y	66y	68y	55y	73y	73y
M : F	23 : 27	10 : 5	6 : 6	?	31 : 37	?	25 : 28	18 : 33	9 : 10	?	?
Follow-up											
Mean	3.5y	0.5y	1.4y	2y	3.4y	3.4y	2.13y	2.6y	4.5y	4.3y	4.7y
Range	6m–12y	4m–12m	3m–3.8y	1y–6y	6m–12y	3m–20y	5m–8.2y	6m–11y	1y–7y	8m–9.2y	1.8y–12y
NF-2	Included	Separated	Included	Separated	Excluded	Included	Excluded	Excluded	Included	Excluded	Excluded
Growth	33 (64%)	7 (43%)	6 (50%)	10 (42%)	20 (29%)	90 (74%)	21 (40%)	21 (42%)	10 (55%)	9 (56%)	?
No growth	11 (21%)	8 (57%)	4 (33%)	14 (58%)	48 (71%)	23 (18%)	32 (60%)	29 (58%)	8 (45%)	6 (37.7%)	?
Negative growth	8 (15%)	0	2 (17%)	0	0	10 (8%)	0	0	0	1 (6.3%)	?
Growth rate											
Overall group	0.7mm/y	?	?	0.35mm/y	0.72mm/y	3.2mm/y	1.6mm/y	1.1mm/y	1.1mm/y	1.7mm/y	?
Range	(−4.8 to 3.9)					(−3.2 to 30)		(0–11)	(0–4.8)		
Those needing Tx	1.3mm/y	?	?	?	3mm/y	6.7mm/y	4.2mm/y	3.5mm/y	?	6.8mm/y	?
Tumour diameter (dx)											
Overall group	12mm	?	?	10mm	12.2mm	?	9.8mm	10.3mm	12.7mm	12.9mm	?
Those needing Tx	?	?	?	?	11.7mm	?	8.8mm	19.8mm	?	21mm	
Those not needing Tx	?	?	?	?	12.3mm	?	10.5mm	7.7mm	?	8.2mm	
Failure of conservative Mx (those requiring Tx)	16 (33%) 16-Sx	?	6 (50%) 5-RS 1-Sx	3 (12.5%) 2-Sx 1-RT	10 (15%) 9-Sx 1-RS	49 (40%) 35-Sx 7-RS/Sh 7-Died	21 (40%) 14-Sx 4-RT 2-Observe	12 (24%) 11-Sx 1-RS	? 3 (16%) 3-Sx	3 (23%) 3-Sx	1 (5%) 1-Sx
Measurement of tumour diameter	Max. A-P diameter along pyramid	Tumour volume measured	Tumour volume measured	Not stated	Mean of max. A-P and M-L diameters	Sq. root of product of A-P and M-L diam. (and volume)	Max. A-P or M-L diameter	Mean of max. A-P and M-L diameters	Not stated	Max. diameter medial to the porus	Max. diameter outside the porus
Roles for conservative management	Yes (select)	Not stated	Yes (select)	Yes (select)	Yes (select)	Yes but limited	Yes (select)	Yes (select)	Yes (select)	Yes (select)	Yes (select)

y = years; m = months. Sx = surgery; RS = radiosurgery; RT = radiotherapy; Sh = shunt; AP anteroposterior; ML = medial lateral.

always non-functional postoperatively.[6] By 1925, total tumour removal was eventually accomplished but the morbidity and mortality remained unacceptably high.[3] By the end of the Second World War, the results of vestibular schwannoma surgery were still so relatively unsatisfactory that many neurosurgeons were reluctant to recommend surgery unless the tumour was large and the intracranial pressure high.[7]

Over the past 40 years there have been many advances in the management of vestibular schwannomas which have resulted in a vastly improved surgical outcome. They include the use of the operating microscope, improved microsurgical techniques, intraoperative monitoring of cranial nerve function, improved neuro-anaesthesia and postoperative care. Possibly the single greatest advance was the development of the translabyrinthine approach to the cerebellopontine angle (CPA) in 1961 by William House.[8] The advantages included removal of the tumour with minimal cerebellar retraction and the consistent and early identification of the facial nerve in the internal auditory canal (IAC).

House also advocated the need for tumour removal by a joint neurotological/neurosurgical team, introduced the operating microscope to this surgery, and advanced the philosophy of early diagnosis and excision.[9] These advances allowing total tumour removal in 97–99% of patients, have led to anatomical facial nerve preservation rates of 94–97% for small tumours and 28–57% for large tumours, and a mortality rate less than 1%.[9–11] Although postoperative cerebrospinal fluid (CSF) leaks occur in $\approx$ 5–10% of cases, the reported incidence of lower cranial nerve palsies and brainstem/cerebellar injury is low (0.1%). In addition, refinements in suboccipital and middle cranial fossa approaches have resulted in 'hearing preservation' rates of 45–82% in select cases.[10] When surgery is performed, total tumour excision in a single stage is the preferred treatment.

Nedzelski *et al.* 1992	Anand *et al.* 1992	Bederson *et al.* 1991	Thomsen & Tos 1988, 1990	Wiet *et al.* 1989	Valvassori & Guzman 1989	Nedzelski *et al.* 1986 Kasset *et al.* 1986	Gardner *et al.* 1986 Clark *et al.* 1985	Laasonen & Troupp 1986	Silverstein *et al.* 1985	Wazen *et al.* 1985	Martin *et al.* 1985 (French)	Summary of studies
50 68.1y 16 : 34	13 (15) 55.8y 4 : 9	70 57y 31 : 39	21 59y 9 : 12	10 ? ?	35 ? 10 : 25	23 71y 6 : 17	6 71y 2 : 4	21(23) 46.5y 6 : 15	? 70.8y ?	4 74.7y ?	13 ?	730 patients 63.4y 1 : 1.5
3.5y 7m–12.7y	5.3y 1y–18y	2.2y 6m–7y	4.2y 1y–16y	? 1y–4y	? 8m–12y	3.8y 1y–10y	1.5y 3m–2.1y	1.25y 5m–2.6y	? 1y–6y	3.4y 1y–5y	?	6m–5.3y 3m–20y
Excluded	Included	Excluded	?	Excluded	Excluded	Excluded	Excluded	Included	Excluded	Excluded	?	
24 (48%) 17 (34%) 9 (18%)	2 (15%) ? ?	37 (53%) 29 (41%) 4 (6%)	3 (14%) 18 (86%) 0	5 (50%) ? ?	20 (57%) 15 (43%) 0	7 (30%) 16 (70%) 0	2 (33%) 4 (67%) 0	16 (mod) 7 (slow) 0	4 (57%) 3 (43%) 0	3 (75%) 1 (25%) 0	?	51.7% (14–75%) 43.3% (18–86%) 5% (0–18%)
1.1mm/y (−0.5 to 9)	?	1.6mm/y (−2 to 17)	?	?	?	2.2mm/y (−0.5 to 6.9)	0.5mm/y (0–1.5)	?	2mm/y	2mm/y (0–4)	?	1.42mm/y (−4.8 to 30mm/y)
?	?	7.9mm/y	?	?	?	?	?	?	?	?		4.77mm/y
10mm	?	27mm 21.3mm	?	?	?	21.7mm	8.9mm ? ?	? ? ?	12.8mm 16mm ?	? ? ?	?	12.1mm 17.4mm 12mm
12 (24%) 9-Sx 2-Sh 1-RS	2 (15%) 2-Sx	9 (13%) 9-Sx	3 (14%) 3-Sx	2 (20%) 2-Sx	?	6 (26%) 4-Sh 1-Sx 1-Both	0	?	1 (14%) 1-Sx	0	?	22.6% (0–50%)
Mean of max. A-P and M-L diameters	Not stated	Mean of max. A-P and M-L diameters	Not stated	Max. diameter medial to the porus	Not stated	Mean of max. A-P and M-L diameters	Max. diameter medial to the porus	Tumour volume measured	Not stated	Max. diameter medial to the porus	?	At least five different methods used to measure tumour diameter
Limited	Yes (select)	Yes (select)	Yes (select)	Yes (select)	Yes (select)	Debatable	Yes (select)	Yes but limited	Yes (select)	Yes (select)	Yes (select)	Yes: 20/26: Limited:5/26; Not stated: 1/26

Total tumour removal with preservation of normal facial function and, when indicated, an attempt at hearing preservation is best accomplished when the tumour is small.

Other surgical options have included subtotal removal[12,13] and ventriculo-peritoneal (V-P) shunting of CSF for obstructive hydrocephalus. Silverstein *et al.*[12] and Rosenberg[13] recommend that asymptomatic patients over 65 years are followed with yearly imaging studies to determine the tumour growth rate. Subtotal resection (> 90% tumour removal) is recommended if neurological deterioration or rapid tumour growth (> 5 mm/year) occurs. As some tumour is invariably left on the facial nerve or brainstem, it is imperative that the patient is followed with annual imaging studies.

Improved scanning techniques, in particular magnetic resonance imaging (MRI) with gadolinium enhancement (fine axial cuts), have enabled the diagnosis of vestibular schwannomas as small as 2–3 mm. Paradoxically, this in itself has created further clinical dilemma. As the natural history of these small intracanalicular vestibular schwannomas is unclear, it is not known whether to advise some form of active treatment or a 'wait-and-rescan' policy in these patients. Nevertheless, some surgeons routinely advise surgery in most patients at the time of diagnosis with either no or, at best, a very limited role for conservative management.[14–21] Moffat and Hardy,[16] for example, justify the early diagnosis and excision of vestibular schwannomas in terms of reduced morbidity and mortality, as well as in financial terms. Delayed surgery results in greater expense because larger tumours have greater morbidity. The consequent need for state financial support, in situations where the patient is unfit to return to work and where nursing care is required should the patient become dependent, increases costs.

Unfortunately, despite the technical advances over the past 40 years microsurgical excision is still associated with sig-

nificant morbidity and impaired quality of life,[22–25] even in the best of hands. The presence of self-help groups, such as the Acoustic Neuroma Association, is testament that not everyone has a good result and that problems do exist. This is thought to be one reason for the increasing popularity of stereotactic radiosurgery for the treatment of these tumours, especially in the USA.[26] Although, it is reported that radiosurgery provides good long-term tumour control, it too has complications. These include facial weakness, trigeminal neuropathy, hearing loss, iatrogenic hydrocephalus and the potential for malignant transformation also exists. Also, if the tumour recurs after radiosurgery, subsequent removal without injury to the seventh and other cranial nerves is reported to be more difficult.[27]

Conservative management of vestibular schwannomas

Since 1985, there have been many reports in the literature investigating the role of conservative management of vestibular schwannomas (Table 1).[12–14,19,23,28–51] Improved imaging techniques, in particular MRI, and increased awareness of the natural history of these tumours have improved our ability to follow them conservatively.

RATIONALE FOR A CONSERVATIVE APPROACH

1. They are oncologically benign and usually slow growing tumours.[30,32,36,39,41,44,47–49,51] Eighty per cent grow at less than 2 mm/year.[13,19,30,44] Nevertheless, there is a wide individual variation in tumour growth.
2. They have been known to involute spontaneously.[13,19,40,46,49,51]
3. The risks of surgery and radiosurgery, which include both functional and psychological morbidity, and mortality, are often underestimated.[22–24]
4. Increasingly smaller, often incidental, tumours are being diagnosed (especially intracanalicular), many of which are asymptomatic or minimally symptomatic.
5. Delay in treatment does not necessarily result in an adverse neurological outcome.[40]

PROPOSED INDICATIONS FOR A CONSERVATIVE APPROACH

1. Those with serious medical problems, likely to increase the operative risk.
2. Advanced age (> 65 years), where the tumour is perceived unlikely to grow to such an extent as to require excision in the lifetime of the patient (i.e. those with limited longevity).
3. Patient preference, i.e. treatment is refused or deferred.
4. Small tumours, especially intracanalicular tumours with minimal symptoms.
5. Minimal or no symptoms
6. Tumours in the only or better hearing ear
7. Bilateral vestibular schwannomas (neurofibromatosis type 2: NF-2).
8. Various combinations of these reasons.

Accordingly, the aim of this study was to determine the natural history and outcome following the conservative management of a group of patients with unilateral vestibular schwannomas.

Materials and methods

STUDY GROUP

The authors conducted a retrospective review of all patients with a radiological diagnosis of unilateral vestibular schwannoma who were managed conservatively by the Departments of Otolaryngology and Neurosurgery, University Health Network, Toronto General and Western Hospitals, University of Toronto between 1987 and 1998.

ANALYSIS OF TUMOUR SIZE AND GROWTH RATE

All patients underwent neurotological examination every 6 months. Radiological assessment of tumour size and growth rate was primarily undertaken with high resolution MRI using 2–3-mm slices (combination of T1 weighted MRI (gadolinium enhancement and T2 weighted MRI) or computed tomography (CT $\pm$ enhancement) early in the series. Imaging was carried out at 6-monthly intervals in the first year after radiological diagnosis. The scanning interval after the first year was dictated by the clinical status of the patient, the tumour growth rate in the first year and the size of the tumour. The duration of follow-up was defined as the interval between the first scan and the final scan. The same neuroradiologist (AK) reviewed all scans.

The tumour size was determined according to the 1995 guidelines of the American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS).[52] The extracanalicular component of CPA tumours was determined as follows. The axial image with the largest extracanalicular tumour diameter was selected and the maximum antero-posterior (A-P) and medial-lateral (M-L) tumour diameters were calculated with a micrometer, or in more recent cases calculated on screen by computer. The A-P measurement was calculated parallel to the posterior surface of the petrous temporal bone and the M-L measurement was calculated perpendicular to it. The size of the tumour was calculated as the square root of the product of these two diameters.

The size of tumours limited to the IAC was calculated as the length of the tumour along the long axis of the canal, from the fundus to the porus. No attempt was made to measure tumour volume. Tumours in the CPA were categorized as small (< 15 mm), medium (15–30 mm) or large (> 30 mm).

The annual growth rate (mm/year) was calculated as the change in tumour size between the first and last scan, divided by the duration of follow-up in months, and multiplied by 12. Total tumour growth greater than 1 mm was considered significant, as originally defined by Nedzelski *et al*.[19] In those tumours that demonstrated growth, the intervening scans were also analysed to determine when the growth had taken place. Tumours were described as solid/cystic/mixed and any necrosis or calcification was noted. The following tumour effects were also noted: brainstem/cerebellar compression, displacement of the fourth ventricle and hydrocephalus. Patients were deemed to have failed conservative management if there was evidence of continuous or rapid radiological tumour growth and/or increasing symptoms or signs suggestive of tumour growth.

AUDIOMETRIC ASSESSMENT

Audiometric assessment was carried out during the period of conservative management. The mean pure tone average (PTA) (0.5, 1, 2, 3 kHz) and speech discrimination score (SDS) were recorded in accordance with AAO-HNS guidelines (1995).[52]

DATA PRESENTATION AND STATISTICS

The data are presented as a mean $\pm$ SD. Statistical analysis was performed using the Student's *t*-test (two-tailed) with a 95% significance level ($P \leqslant 0.05$).

Results

STUDY GROUP

Ninety-three patients with a radiological diagnosis of vestibular schwannoma were managed conservatively between 1987 and 1998. Patients with a follow-up period after radiological diagnosis of less than 1 year ($n = 10$), NF-2 patients ($n = 9$), and those who moved out of the province ($n = 2$), were excluded resulting in a study group of 72 patients. There were 32 men and 40 women with a mean age of 60.8 years at presentation (range 36–78 years) (Table 2). The mean duration of follow-up was 39.8 months (range 12–194 months) (Table 2).

CLINICAL PRESENTATION

The presenting symptoms were unilateral sensorineural hearing loss (98.6%), tinnitus (62.5%), unsteadiness/vertigo (38.9%), facial nerve or trigeminal nerve symptoms or signs (8.3%), lower cranial nerve (IX-XII) symptoms or signs (2.7%), and various combinations of these (80.5%). No patients presented with signs of cerebellar/brainstem compression or raised intracranial pressure. One patient died of unrelated causes during the observation period.

REASONS FOR CONSERVATIVE MANAGEMENT

The reasons for conservative management included advanced age (48.6%), small tumour size (45.8%), patient preference (43%), poor general health (19.4%), no or minimal symptoms (2.8%), tumour in the only hearing ear (1.4%), and various combinations of these (62.5%).

TUMOUR DIAMETER

There were 54 CPA and 18 IAC tumours. The mean tumour diameter at diagnosis for the overall group was 9.4 ± 5.1 mm, 9.8 ± 5.4 mm for CPA tumours and 7.8 ± 3.4 mm for tumours confined to the IAC (Table 2). At the time of diagnosis, 68 of the tumours were small CPA or intracanalicular tumours, four were medium-sized and none was large.

TUMOUR GROWTH

Total group

The mean tumour growth rate for the overall group was 1.16 ± 2.2 mm/year (range: 0.75–9.65 mm/year) (Table 2). Eighty-three per cent of all tumours had a growth rate <

Table 2. Study group characteristics

	Total group	CPA group	IAC group
No.of patients	72	54	18
Age at diagnosis (years)	60. 8 (36–78)	61.9 (36–78)	57.8 (38–71) ($P = 0.15$)
Male : Female	32 : 40	24 : 30	t8 : 10
Follow-up (months)	39.8(12–194)	39.1(12–194) ($P = 0.7$)	421(3–108)
Tumour diameter at diagnosis (mm)	9.4 ± 5.1 (3–24.4)	9.8 ± 5.4 (3–24.4)	7.8 ± 3.4(3–16)
Tumour growth rate (mm/year)	1.16 ± 2.2 (−0.75–9.65)	1.44 ± 2.5 (−0.75–9.65) ($P = 0.001$)	0.21 ± 0.5 (0–1.85)

2 mm/year (Fig. 1). Significant tumour growth (> 1 mm) was seen in 36.4%, no or insignificant growth (0–1 mm) in 50%, and negative growth (< 0 mm) in 13.6% of tumours (Table 3). Neither the age of the patient nor the mean tumour diameter at diagnosis was predictive of tumour growth, i.e. there was no significant difference between the mean age of patients ($P = 0.59$) nor between the mean tumour diameter at diagnosis ($P = 0.75$) with and without tumour growth (Table 4).

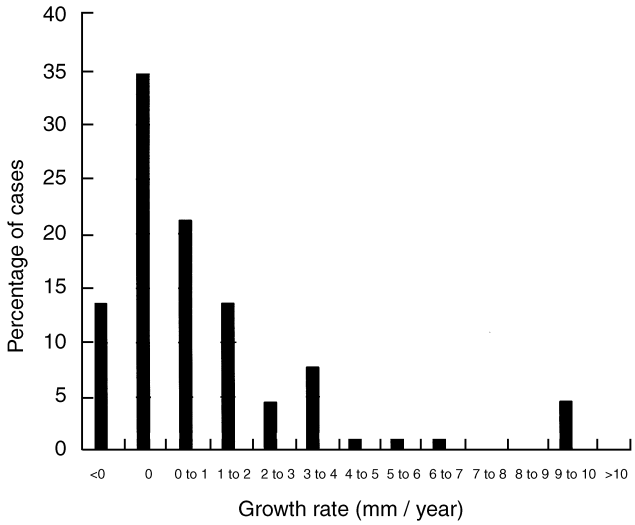

Figure 1. Growth rate of vestibular schwannomas.

Table 3. Tumour-growth characteristics;

	Total group	CPA group	IAC group
Growth (> 1 mm)	36.4%	45%	6.7%
No or insignificant growth (0–1 mm)	50%	37.3%	93.3%
Negative growth (< 0 mm)	13.6%	17.7%	0

Table 4. Comparison of tumour-growth and no-growth groups

	Tumour-growth group	No-growth group
Patients (%)	36.4%	63.6%
Age (years)	61.7 ± 11.4	60.2 ± 10.06; ($P = 0.59$)
Follow-up (months)	25.4(6–67)	45.2(12–194)
Tumour diameter at diagnosis (mm)	9.1 ± 6.05	9.55 ± 4.4; ($P = 0.75$)
Treatment required	35%	6.5%

CPA and IAC tumour groups

The mean growth rate of tumours which extended into the CPA (1.44 ± 2.5 mm/year) was significantly greater than that of tumours limited to the IAC (0.21 ± 0.5 mm/year) ($P = 0.001$) (Table 2). This could not be attributed to a difference in length of follow-up of the two tumour types (39.1 months vs. 42 months; $P = 0.7$) (Table 2).

In the CPA group, 45% showed significant growth, 37.3% had no or insignificant growth, and 17.7% demonstrated negative growth while only 6.7% of tumours confined to the IAC showed significant growth and 93.3% demonstrated no or insignificant growth (Table 3).

TYPES OF GROWTH PATTERN

Four different types of growth pattern were recognized, as previously described by Charabi *et al.*[46]: 30.4% showed continuous growth, 50% no or insignificant growth, 6% no or insignificant growth followed by a period of continuous growth, and 13.6% negative growth (Table 5).

FAILURE OF CONSERVATIVE MANAGEMENT

Eleven patients (15.3%) failed conservative management and required treatment after a mean duration of 23.8 months (range 6–67 months) (Table 6). The reasons for failure were

Table 5. Tumour-growth patterns

Growth pattern	Tumours (%)
Continuous growth	30.4%
No or insignificant growth	50%
No or insignificant growth followed by continuous growth	6%
Negative growth	13.6%

Table 6. Failure of conservative management (treatment group)

No. of patients requiring treatment	11 (15.3%)
Time to failure (months)	23.8 (6–67)
Reasons	
Tumour growth	8
Increasing symptoms and signs	9
Patient preference	2
Combination of the above	6
Treatment	
Microsurgery	5
Translabyrinthine approach	3
Retrosigmoid approach	2
Ventriculo-peritoneal shunt	1
Radiotherapy	4
Gamma knife	3
Linear accelerator (LINAC)	1
Undecided	1

continuous or rapid radiological tumour growth ($n = 8$), increasing symptoms or signs suggestive of tumour growth (such as headache, trigeminal neuropathy, balance disturbance) ($n = 9$), or a combination of these ($n = 6$) (Table 6). Two patients expressed a strong desire to undergo treatment despite the fact that there was no evidence of significant tumour growth.

The growth rate of tumours in patients who failed conservative management (4.2 ± 3.8 mm/year) was significantly greater than that in patients who did not fail (0.5 ± 2.2 mm/year) ($P < 0.01$) (Table 7). Neither the age of the patient nor the mean tumour diameter at diagnosis was predictive of the eventual need for treatment (failure of conservative management), i.e. there was no significant difference between the mean age of patients ($P = 0.5$) nor between the mean tumour diameter at diagnosis of patients ($P = 0.9$) who required treatment and those who did not (Table 7). Thirty-five per cent of patients who demonstrated radiological tumour growth required treatment while only 6.5% of patients without tumour growth needed treatment (Table 4).

TREATMENT AND OUTCOME OF PATIENTS WHO FAILED CONSERVATIVE MANAGEMENT

Five patients underwent microsurgical excision (translabyrinthine approach: three; suboccipital (retrosigmoid) approach: two); four underwent radiotherapy (gamma knife stereotactic radiosurgery: three; linear acceleration (LINAC): radiotherapy: one); and one patient is currently deciding on which treatment option to proceed with (Table 6). One patient with hydrocephalus who was too unwell to undergo microsurgery had a V-P shunt inserted. Tumour removal was total in all cases except for a 77-years-old lady with a medium-sized vestibular schwannoma and an associated arachnoid cyst who underwent subtotal removal and decompression of the cyst.

The mean duration of follow-up following treatment was 18.6 months (range 2–51 months). All patients are alive. There has been no evidence of recurrence in those tumours that were totally excised nor increased growth in those patients who were managed by subtotal removal or V-P shunting. To date, tumour control has been achieved in the four patients who underwent radiotherapy. A transient grade 2/3 facial weakness (House and Brackmann grading system) occurred in three patients following surgery. All three reverted to a grade 1 ultimately. No attempt was made to preserve hearing in the two patients whose tumour was excised via the retrosigmoid approach as the hearing was not serviceable preoperatively. Four patients experienced mild balance disturbance. Of the six patients who were working prior to treatment, three have returned to work. There were no serious intracranial or lower cranial nerve complications.

Table 7. Comparison of treatment and no-treatment groups

	Treatment group	No-treatment group
Patients (%)	11 (15.3%)	71 (84.7%)
Age (years)	62.6 ± 8.1	60.5 ± 11; ($P = 0.5$)
Time to treatment	23.8 (6–67)	
Follow-up (months)		41.9 (12–194)
Tumour diameter at diagnosis (mm)	9.1 ± 6.8	8.7 ± 4.7; ($P = 0.9$)
Growth rate (mm/year)	4.2 ± 3.8 (0–9.6)	0.5 ± 2.2 (−0.75 to 4.95); ($P < 0.01$)

AUDIOLOGICAL RESULTS

Total, CPA and IAC tumour groups

Twenty-one patients had audiological measurements available for comparison at the time of diagnosis and last follow-up. At the time of diagnosis, the mean PTA (0.5, 1, 2, 3 kHz) for the overall group was 47.6 ± 19.9 dB and the mean SDS was $60.4 \pm 36\%$ (Table 8). A significant deterioration in the mean PTA and the mean SDS occurred for the total group (Table 8). There was no significant difference in the mean PTA between the CPA and IAC groups ($P = 0.5$) nor in the mean SDS between the CPA and IAC groups, at the time of diagnosis ($P = 0.07$).

Growth vs. no-growth groups

A significant deterioration in the mean PTA (0.5, 1, 2, 3 kHz) and SDS occurred following conservative management in both the radiological tumour-growth and no-growth groups (Table 9). There was no significant difference in the change in mean PTA between the tumour-growth and the no-growth groups ($P = 0.4$) (Table 9). There was also no significant difference in the change in mean SDS between the tumour-growth and the no-growth groups ($P = 0.2$) (Table 9). These findings suggest that audiological deterioration occurs regardless of whether tumour growth takes place or not.

Treatment (failure of conservative management) group

Of those patients who failed conservative management ($n = 11$), three went from being suitable for a hearing preservation operation (Mean PTA < 50dB; SDS > 50%; diameter < 1.5 cm) at the time of initial diagnosis to a nonhearing preservation operation. The remaining eight patients were not suitable for a hearing preservation operation at the time of diagnosis.

Discussion

COMPARISON WITH STUDIES INVESTIGATING THE NATURAL HISTORY OF VESTIBULAR SCHWANNOMAS

There are at least 26 published studies investigating the role of conservative management (i.e. natural history) of vestibular

Table 8. Mean pure tone average (PTA) (0.5, 1, 2, 3 kHz) and speech discrimination score (SDS) (first and last audiograms)

	Mean PTA (dB) First audiogram	Last audiogram	Mean SDS (%) First audiogram	Last audiogram
Total group	47.6 ± 19.9 ($P < 0.05$)	62.5 ± 28 ($P < 0.05$)	60.4 ± 36	37.4 ± 36.7
CPA group	50.6 ± 21.8 ($P = 0.06$)	68.6 ± 29.1 ($P = 0.07$)	53 ± 37	29 ± 33
IAC group	40.7 ± 13.5 ($P = 0.4$)	48.7 ± 21.3	77 ± 28 ($P = 0.3$)	56 ± 40

Table 9. Change in the mean pure tone average (PTA) (0.5, 1, 2, 3 kHz) and mean speech discrimination score (SDS) in tumour-growth and no-growth groups (first – last audiogram)

	Tumour-growth group	No-growth group
Change in mean PTA(dB)	(+) 20.3 ± 15.64 ($P < 0.05$) ($P = 0.4$)	(+) 13.4 ± 21.0; ($P < 0.05$);
Change in mean SDS (%)	(–) 49 ± 36.7 ($P < 0.05$) ($P = 0.2$)	(–) 20.5 ± 21.1; ($P < 0.05$)

schwannomas (Table 1).[12–14,19,23,28–38,40,42,44–51] The results of these studies share many similarities with this report. The mean age of patients in these studies was 63.4 years and there was a female : male preponderance of 1.5 : 1 (Table 1). The number of patients per study ranged from four to 123 and the duration of follow-up ranged from 6 months to 5.3 years. Eight studies included NF-2 data.

TUMOUR GROWTH RATE AND DIAMETER

From these studies, tumour growth (usually defined as total growth > 1 mm)[19] occurred in 51.7% (range of means 14–75%) of patients managed conservatively, no growth in 43.3% (range of means 18–86%) and negative growth in 5% (range of means 0–18%) (Table 1). The mean annual growth rate of all tumours was 1.42 mm/year (range of means 0.35–2.2 mm/year) and there was considerable variation in individual tumour growth rates (– 4.8 to 30 mm/year). In contrast, the mean annual growth rate for tumours that required treatment (failed conservative management) was considerably higher at 4.77 mm/year (range of means 1.3–7.9 mm/year), a finding that was also evident in this study.

This study confirms the view that the majority of vestibular schwannomas grow slowly. In general, most (80%) grow at less than 2 mm/year,[13,19,30,44] although there is wide individual variation in tumour growth rates[19,40,53] and, indeed, within the lifespan of a particular tumour. The large discrepancy between the incidence of vestibular schwannomas diagnosed at autopsy (≈1%, range 0.8%[54]–2.7%[55]) and clinically during the life-time of the patient (7.8[56]–12.4[57] per 1000 000) can be explained partly by their slow growth. Many remain silent and will not reach a size that will require surgery. The recently reported increase in the incidence of vestibular schwannomas[57] is probably explained by greater awareness amongst otolaryngologists and GPs of the diagnosis of vestibular schwannoma and improved access to MRI.

Although most tumours are slow growing, there is a subset of patients who demonstrate rapid tumour growth, either due to rapid cell mitosis, cyst formation, haemorrhage, or oedema. Deen *et al.*[47] reported two distinct patterns of growth in the first year of conservative management. Those that did not require intervention (85%) had a growth rate of 0.36 mm/year while those requiring intervention had a growth rate of 3 mm/year. Using tumour volume, Laasonen and Troupp[32] and Yamamoto *et al.*[49] also reported two distinct growth rates.

The unpredictable growth pattern of vestibular schwannomas is illustrated in another study in which five different growth patterns were identified: continuous growth (40%), no growth (18%), no growth followed by continuous growth (18%), negative growth (8%) and a variable growth pattern (16%).[46] Four distinct growth patterns similar to the above were also seen in this study. In view of the fact that continuous growth can occur after a period of quiescence, close monitoring of tumour growth is required if a conservative management approach is adopted. In contrast to these findings, Nedzelski *et al.*[19] used two methods to measure tumour growth, one which took into account any variation in yearly growth within the total follow-up time, the other did not. He reported a growth rate of 1.1 mm/year for both methods, implying that a constant pattern of growth occurs regardless of the rate and that it is sufficient to measure the first and final diameter to arrive at the mean tumour growth rate.

The analysis of tumour diameter and tumour growth rates from these studies should be treated with some caution, however, as at least five different methods of measuring the radiological tumour diameter were used and the method used was not stated in at least seven studies (Table 1). Also, intra-

canalicular tumours were often included and their diameter was not measured.42 We used the now standard AAO-HNS guidelines (1995).52 From the published studies to date, the mean extra-canalicular tumour diameter at the time of diagnosis was 12.1 mm (range of means: 8.9–21.7 mm) (Table 1). This compares with a mean of 12 mm (range of means 7.7–21.3 mm) for those tumours that did not ultimately require treatment and contrasts with a mean of 17.4 mm (range of means 8.8–27 mm) for those tumours that did require treatment. The mean tumour diameters in this study were considerably smaller than those from the published studies to date. This is probably due to the relatively large number of intracanalicular tumours included in the study.

Tumour size is thought to be best expressed as an exact measurement of tumour volume as it is almost certainly the change in volume that gives rise to the development of clinical symptoms. Four studies have attempted to measure tumour volume, two from a formula employing the maximal antero-posterior and medial-lateral diameters,[46,49] the other two from volumetric programmes built-into the scanner.[32,50] However, no significant difference has been reported between the analysis of tumour growth estimated by volume to that calculated by diameter.[46]

PREDICTIVE FACTORS OF TUMOUR GROWTH

The ability to predict the growth potential of a tumour would help greatly in the selection of patients for a conservative management strategy. The studies of the natural history of vestibular schwannoma have attempted to identify factors predictive of tumour growth. It has been reported that the growth rate measured during the first year of observation is predictive of growth in the following year[19,40,44] and a strong predictor of the eventual need for treatment.[47] However, most authors would now agree that the growth of vestibular schwannomas is unpredictable, i.e. rapid growth can occur several years after a period of no growth.[46] Therefore, if vestibular schwannomas are managed conservatively follow-up must be for life. There is no correlation between the size of the tumour at diagnosis and tumour growth.[45,51] Although, it has been reported that there may be a significant correlation between the patients age and tumour growth,[39] this has not been found in other studies.[40,44–46,51,58] Neither the patient's age nor the initial tumour diameter were found to be predictive of tumour growth in this study.

Charabi *et al.*[46] reported that tumour growth is greater in patients with a short duration of symptoms, a cystic tumour-radiological architecture and in NF-2 tumours. There have been sporadic reports of a high tumour growth in fertile women.[59] There have been numerous immunohistochemical,[53,60] DNA flow cytometry,[61,62] and chromosomal studies[63] of vestibular schwannomas in an attempt to identify predictors of growth. None has produced a reliable and reproducible predictive parameter. As yet, there is no single reliable clinical, radiological, audiological or histological feature that predicts tumour growth in a prospective manner.[32,37,47] Currently, the most reliable method of monitoring tumour growth is with regular clinical assessment and serial MRI.

FAILURE OF CONSERVATIVE MANAGEMENT

Conservative management failed in 0–50% of patients (mean 22.6%) in the published studies investigating the conservative management of vestibular schwannomas, although the relatively short duration of follow-up (mean 3.0 years) must be taken into account when interpreting this result (Table 1). The commonest form of intervention was microsurgery, followed by stereotactic radiosurgery (more recently) and V-P shunting. The fact that 15.3% required some form of intervention in this study underscores the need for careful monitoring.

Nedzelski *et al.*[19] advise intervention where the tumour growth rate exceeds 2 mm/year. Twenty per cent of patients required surgical intervention within one third of their expected survival time and all patients who required surgery had tumours measuring 2.5 cm in greatest dimension.[14] Bederson *et al.*[40] compared the outcome of patients who underwent initial surgery ($n = 108$) with those who required surgery after a period of conservative management ($n = 9$). Although, there is a large discrepancy in the size of the two groups, they did not report any difference in the postoperative neurological outcome, suggesting that the delay in their surgery (14 ± 5 months) did not adversely affect the outcome, a finding that was also seen in this study. In the study by Strasnick,[44] the average time from presentation until surgical intervention was 2.3 years. However, there was a wide range (6–74 months) and the mean duration of follow-up was only 2.6 years.

HEARING RESULTS

There is precious little published data of the change in hearing that occurs following the conservative management of vestibular schwannomas. In the study by Charabi *et al.*,[46] 21 patients (75%) lost their eligibility for a hearing preservation operation (Mean PTA $\leqslant$30dB, SDS (70%, tumour diameter $\leqslant$15 mm) during the observation period either because of deterioration of hearing level or tumour growth. Applying the 50 dB PTA/50% SDS rule, 23 patients (62%) lost their candidacy for hearing preservation surgery. In contrast, Yamamoto *et al.*[49] reported that neither tumour growth nor deterioration in auditory acuity occurred in five of 12 patients. In another study, the patient's hearing thresholds deteriorated despite the fact 'that their medical condition was unchanged.[23] It has recently been reported that there is a significant risk of loss of useful hearing with conservative management of vestibular schwannomas, although only 10 patients were included in this study.[64] In our study, deterioration of audiological function occurred regardless of whether tumour growth took place or not.

CONCLUSION OF STUDIES

Twenty of 26 studies investigating the natural history of vestibular schwannomas conclude that there is a role for the conservative management of a select group of patients with this tumour (Table 1). Five studies conclude that this role is very limited[14,19,32,34,46] and in one other it was not stated[50] (Table 1). The one drawback of all of these studies is the relatively limited duration of follow-up (mean 3 years). To answer all of the questions concerning the validity of the conservative management of vestibular schwannomas, a long-term (10–20 years) prospective study is required. Until such time, the conclusions drawn from current studies should be treated with some caution.

DRAWBACKS OF THIS STUDY

Our study can be faulted because of the relatively short follow-up period (3.31 years), especially in view of the fact that these are usually slow growing tumours. Also, different imaging techniques (T1 MRI $\pm$ contrast; T2 MRI; CT $\pm$ contrast) and different scanners were used throughout the study. This is partly a reflection of the evolution of imaging technology during the study period. In addition, the ideal method of measuring tumour size and growth rate would have been by volumetric analysis rather than two-dimensional assessment. Unfortunately, the facilities to calculate tumour volume were not available to us. Finally, the study has all the inherent disadvantages of a retrospective study. Only one of the published studies to date, investigating the role of the conservative management of vestibular schwannomas, was performed prospectively.[49] However, in an attempt to make our study more robust, a minimum period of follow-up of 1 year was used, and those patients with NF-2 and those who moved away from the province were excluded. NF-2 tumours are known to behave differently to unilateral vestibular schwannomas, i.e. more rapid growth.[32,65]

CONSERVATIVE MANAGEMENT

The successful treatment of patients with vestibular schwannomas continues to be best accomplished by early diagnosis. The management of vestibular schwannomas should take into account the patient's age, overall health, symptoms, bilateral hearing, patient preference and tumour diameter.[12] The treatment of choice for most vestibular schwannomas is surgery, with total excision in a single stage the preferred option (although stereotactic radiosurgery is becoming increasingly popular as the first line of treatment in some Neurosurgical centres in the USA). However, as surgery carries some risk even in experienced hands, as most of these tumours are slow growing, and as increasingly smaller tumours with fewer symptoms are being diagnosed because of improved radiological techniques, this would suggest that there may be a role for the conservative management of at least a select number of these patients.

The perceived advantages of a conservative approach are the avoidance of treatment (microsurgery or stereotactic radiosurgery) and its: (1) potential morbidity (facial paralysis, loss of hearing, balance disturbance, CSF leak, trigeminal nerve injury, lower cranial nerve palsy, brainstem/cerebellar injury, stroke); (2) impaired quality of life (unable to continue work, psychological problems);[22–25] (3) mortality; and (4) risk of malignancy following radiosurgery. These complications may be all the more difficult to accept in patients whose only preoperative disability was unilateral hearing loss.

The disadvantages include: (1) the potentially poorer surgical outcome in terms of facial nerve function and hearing preservation (conversion from a hearing preservation to a nonhearing preservation operation) should the tumour grow and microsurgery be required. However this is contested by some authors;[40] (2) the cost of the annual clinical assessment and MRI scan for the rest of the patient's life; and (3) the rather disconcerting thought to some patients that their 'brain tumour' is being simply watched.

Conclusions

Most neurologists and neurosurgeons would agree that the conventional treatment of choice for the majority of vestibular schwannomas is microsurgery, with total excision in a single stage the preferred option. This study, in conjunction with the published studies investigating the natural history of vestibular schwannomas, suggests that a conservative approach may be appropriate in the management of a select number of patients with a vestibular schwannoma. However, the results of all current studies must be treated with some caution in view of their relatively short duration of follow-up. We believe that the following criteria may represent suitable indications for a conservative management approach: poor general health; advanced age (although some authors would dispute this); [65,66] patient preference; small tumour size (especially intracanalicular tumours with minimal symptoms); minimal or no symptoms; tumour in only or better hearing ear; NF-2 and a combination of the above (most common indication). Each patient must be assessed and before such a policy is adopted the growth rate of the tumour must be established.[19] The patients are monitored closely for both clinical and radiological evidence of tumour progression. We recommend a follow-up MRI scan initially at 6 months and 1 year and then at yearly intervals thereafter. If continuous or rapid radiological tumour growth and/or increasing symptoms or signs are demonstrated, then intervention is recommended.

- The majority of vestibular schwannomas are slow growing. In this study, 83% of tumours grew at <2 mm/year. The mean growth rate was 1.16 ± 2.2 mm/year (range: 0.75–9.65 mm/year).

- Only 36.4% of tumours showed significant growth (> 1 mm) and 63.6% of tumours had insignificant, no, or negative growth.
- The growth rate of those tumours extending into the CPA (1.44 ± 2.5 mm/year) was significantly greater than those tumours confined to the IAC (0.21 ± 0.5 mm/year) ($P = 0.001$).
- Monitoring should continue even if the tumour diameter does not increase in size as growth can occur after a period of no growth. This occurred in 6% of patients in this study.
- Failure of conservative management, in which active treatment was required, occurred in 15.3%. The outcome of these patients appeared to be as favourable as those patients who underwent primary treatment, without a period of conservative management. The growth rate of tumours in patients who failed conservative management (4.2 mm/year) was significantly greater than that in patients who did not fail (0.5 mm/year) ($P < 0.01$).
- No factors predictive of tumour growth or failure of conservative management were identified.
- Deterioration of audiological function occurred regardless of whether radiological tumour growth was demonstrated or not.

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