Decision Making in the Wait-and-Scan Approach for Vestibular Schwannomas: Is There a Price to Pay in Terms of Hearing, Facial Nerve, and Overall Outcomes?

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BACKGROUND: The wait-and-scan modality has emerged as an important strategy in the management of vestibular schwannoma (VS) as it has been demonstrated that many tumors grow slowly or do not show any growth over long periods.

OBJECTIVE: To analyze long-term outcomes of wait-and-scan in the treatment of patients with VS, discuss the factors contributing to the decision making, determine the inherent risks of the policy, and compare our results with literature.

METHODS: In total, 576 patients with sporadic unilateral VS who were managed with wait-and-scan were reviewed retrospectively. Of these, a subset of 154 patients with 5-yr follow-up was separately analyzed. The tumor characteristics including patterns of growth, rate of growth, hearing outcomes, and likely factors affecting the above parameters were analyzed.

RESULTS: The mean period of follow-up was 36.9 ± 30.2 mo. The mean age was 59.2 ± 11.6 yr. Thirteen different patterns of tumor growth were observed. Eighty-four (54.5%) of 154 tumors with 5-yr follow-up showed no growth throughout 5 yr. Fifty-six (36.4%) tumors showed mixed growth rates. Only 57 (37%) patients had serviceable hearing at the start of follow-up, but 32 (56.1%) maintained it at the end of follow-up. One hundred fifty (26%) of the 576 patients who failed wait-and-scan had to be taken up for surgery.

CONCLUSION: While there may be no price to pay in wait-and-scan as far as hearing is concerned, this may not be the case for facial nerve outcomes, wherein the results may be better if the patients are taken earlier for surgery.

KEY WORDS: Vestibular schwannoma (VS), Wait-and-scan, Long-term outcomes, Tumor growth, Hearing outcomes, Protocol

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Until the mid-1980s, treatment for vestibular schwannomas (VS) involved surgery. Subsequently, radiotherapy (RT) emerged as a treatment option in small tumors.[1] In the following years, it was recognized that a percentage of VS followed an indolent path, which could allow the patient to escape surgery or RT. This was called the "wait-and-scan", "watchful waiting", or "expectant treatment" policy, and included observing the tumor growth with a systematic follow-up using magnetic resonance imaging (MRI). Recently, many reports on wait-and-scan have analyzed in detail the growth patterns and other characteristics of tumor. Most series point out to the fact that the majority of the tumors, especially small VS, show very little or no growth (NG)[2-4] (58%-71%).[5-10] Also, the percentage of patients on this strategy who escaped surgery or RT was between 66% and 92%.[7,11-14] However, there could be situations that are a dilemma to the treating clinician. For instance, in a patient with a small tumor, a "failure" of the wait-and-scan

ABBREVIATIONS: EM, extrameatal; **FG,** fast growth; **FN,** facial nerve; **HB,** House–Brackmann; **I,** involution; **IM,** intrameatal; **MRI,** magnetic resonance imaging; **NF,** neurofibromatosis; **NG,** no growth; **RT,** radiotherapy; **SDS,** speech discrimination score; **SG,** slow growth; **SNHL,** sensorineural hearing loss; **VS,** vestibular schwannoma

policy after a certain period would mean an increased risk of hearing loss or facial nerve (FN) dysfunction due to surgery on a larger tumor. Similarly, in an elderly patient, a failure would mean surgery or RT at an advanced age.

Most reports on wait-and-scan in the literature describe results of VS over different time periods and do not analyze a specific subset of tumors that have been followed-up for 5 yr or longer. This is exclusive to our study and gives valuable information. In this report, we discuss our selection criteria for wait-and-scan modality, present long-term outcomes, compare our results with the literature, and try to find an answer to the all-important question "is there a price to pay?" in wait-and-scan.

METHODS

Charts of 3547 VS that were managed at our center from December 1986 to May 2013 were evaluated. The wait-and-scan policy was clearly formulated since the mid-1990s with very few cases before then. However, even in the late 80s through the 90s, there were a handful of cases that were followed-up with wait-and-scan and they were incorporated into the study. The study population was defined using the following inclusion and exclusion criteria.

Inclusion Criteria

Patients with a radiological diagnosis of unilateral sporadic VS, who were assigned to the "wait-and-scan" modality were included in the study population.

Exclusion Criteria

Patients with neurofibromatosis (NF) type II, previously treated sporadic unilateral VS, patients with inadequate radiological and/or audiological records, and patients with less than 2 serial MRIs were excluded from the study population.

Protocol

The wait-and-scan policy was determined by taking into consideration the age, audiological symptoms, tumor size, and preferences of the patient. The protocol followed to designate the patients into wait-and-scan is shown in Figure 1. The decision to adopt a particular modality was taken at this center in consultation with the patient and not by the referring physician. Risks and benefits of all the 3 options for the management of VS, namely, wait-and-scan, surgery, and RT were discussed with the patients and thereafter it was the patients' decision to proceed with the wait-and-scan approach. The serial MRI protocols are also shown in Figure 1.[15] One mm thick slices were used for detection and follow-up of all VS to determine the growth of tumor up to 1 mm. It must be noted that the study population has a biased set of cases and it is inappropriate to extrapolate this analysis generally to all VS.

Tumors were defined as solid or cystic. Cystic VS are tumors with any degree of cystic changes due to degenerative changes inside the tumor and were defined and classified according to our recent publication on the topic.[16]

Tumor size was measured by linear measurements on MRI, of the largest extrameatal (EM) diameter in 2 dimensions. The tumors were then graded according to the paper published by the Tokyo Consensus Meeting on Systems for Reporting Results in Acoustic Neuroma[17] into the following grades: intrameatal (IM) tumor, grade 1 tumor (1-10 mm EM tumor diameter), grade 2 tumor (11-20 mm EM tumor diameter), grade 3 tumor (21-30 mm EM tumor diameter), grade 4 tumor (31-40 mm EM tumor diameter), and grade 5 tumor (>40 mm EM tumor diameter, also called giant VS).[15] We have been using volumetric measurements of tumor for the last 2 yr. However, since most of our patients were followed-up with linear measurements prior to this we decided to maintain the same for uniformity of reporting and analysis in this study.

Hearing was analyzed by noting the pure tone averages of air conduction at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz of the affected ear on each follow-up. The speech discrimination score (SDS) was also noted. The Modified Sanna classification was used to categorize hearing.[17] Classes A & B represented serviceable hearing.

FN function was graded according to the House–Brackmann (HB) grading system.[18]

Growth of tumor was calculated as the difference in tumor sizes between the latest follow-up and the previous one, which was recorded at each year of follow-up. Anything less than 1 mm can be attributable to interobserver variation and hence "growth" was defined as the change in tumor diameter by 1 mm. When there was no recordable growth in a year, this was considered as NG. Growth less than 3 mm (a maximum of 2 mm) per year was considered as slow growth (SG) and ≥3 mm per year was considered as fast growth (FG). When there was a contraction in tumor size of ≥1 mm per year it was considered as involution (I).[15] When a tumor was determined to be fast growing, the rate of growth was confirmed to be fast in a subsequent annual scan before embarking on active intervention.

Review of Literature

A detailed search of the peer-reviewed English literature was done from January 2005 to January 2013 to identify studies that evaluated the wait-and-scan modality in patients with unilateral sporadic VS. The cut-off of 2005 was chosen because we felt that most recognized centers had regularized their wait-and-scan policies by then. Reports with a study population of at least 100 cases were included. Data were collected regarding the cohort size, age of patients, protocol, and tumor features and outcomes.

Statistical Analysis

The data were processed using the SPSS version 21.0 statistics program (SPSS Inc, IBM, Armonk, New York). Chi-Square and Fisher's exact tests were used to compare nonparametric variables. Mean and standard deviation were calculated for parametric variables. The normality of the variables was analyzed by the Kolmogorov–Smirnov test. Independent-samples *t*-test (in the case of normal distribution) or Mann–Whitney *U*-test (in the case of non-normal distribution) was used to compare subgroups. Pearson's test was used for correlation with r-value. A *P* value less than .05 was considered as statistical significance.

RESULTS

Five hundred seventy-six of the 791 patients with VS who were wait-and-scanned met the inclusion criteria. The mean follow-up

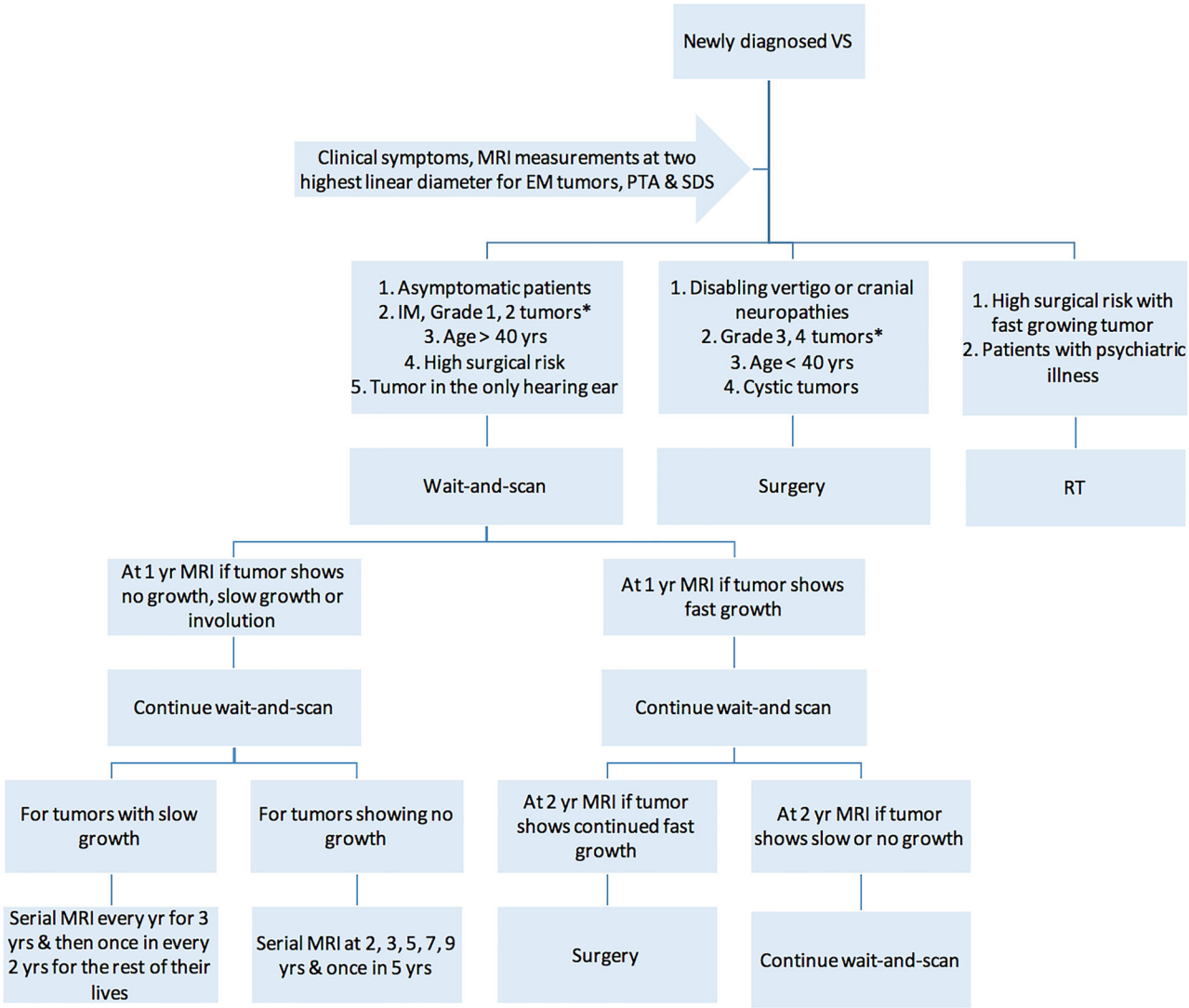

FIGURE 1. *Protocol followed at our center in the wait-and-scan modality. MRI, magnetic resonance imaging; EM, extrameatal; IM, intrameatal; PTA, pure tone audiogram; SDS, speech discrimination score; * Tumor grades according to the Tokyo Consensus Meeting on Systems for Reporting Results in Acoustic Neuroma[7]; IM, intrameatal.*

in this group was 36.9 ± 30.2 mo (range 12-216 mo). A separate analysis was made of a subset of 154 patients who had a follow-up of 5 yr and above. The overall mean follow-up for this subset was 77.9 ± 30.13 mo.

Demography and Symptomatology

The mean age of the population was 59.2 ± 11.6 (range 20-89 yr). Male:female ratio was 0.83:1 (Table 1). Forty-four (7.6%) patients were <40 yr of age, 231 (40.1%) between 40 and 60 yr, and 301 (52.3%) were >60 yr of age indicating a preponderance of an elderly population.

At diagnosis, 365 (63.4%) of the patients had unserviceable hearing (Class C, D, E, and F). Ninety-four (16.3%) patients presented with sudden onset-SNHL. Vertigo was present in 137(23.8%) of the patients.

Overall Tumor Characteristics

The mean tumor size at diagnosis and at the end of follow-up was 8.26 ± 5.4 mm and 10.81 ± 7 mm, respectively, for the

TABLE 1. Relation Between Demography and Clinical Presentation of the Study Population (n = 576)

	n = 576	Total (No; %)	Sensorineural hearing loss* (No; %) Serviceable hearing (Class A-B) n = 211	Sensorineural hearing loss* (No; %) Unserviceable hearing (Class C-F) n = 365	Vertigo/imbalance (No; %) n = 137	Tinnitus (No; %) n = 46
Sex	Males	**262 (45)**	93 (35)	169 (65)	65 (25)	17 (7)
	Females	**314 (55)**	118 (38)	196 (62)	72 (23)	29 (9)
Age	20-30 yr	**11 (2)**	4 (36)	7 (64)	4 (36)	1 (9)
	31-40 yr	**33 (6)**	15 (45)	18 (55)	8 (24)	4 (12)
	41-50 yr	**80 (14)**	47 (59)	33 (41)	27 (34)	10 (13)
	51-60 yr	**151 (26)**	59 (39)	92 (61)	33 (22)	14 (9)
	61-70 yr	**218 (38)**	70 (32)	148 (68)	46 (21)	15 (7)
	71-80 yr	**73 (12)**	14 (19)	59 (81)	17 (23)	2 (3)
	81-90 yr	**10 (2)**	2 (20)	8 (80)	2 (20)	–

*Tumor grades according to the Acoustic Neuroma Consensus Systems for Reporting Results.[33]

TABLE 2. Mean Annual Growth Rate of IM and EM Tumors

	IM (mm)	EM (mm)
1st yr	1.14 ± 2.70	1.54 ± 2.83
2nd yr	0.90 ± 2.23	1.16 ± 3.07
3rd yr	0.78 ± 1.70	0.66 ± 1.83
4th yr	0.74 ± 1.72	0.47 ± 1.37
Overall	1.07 ± 2.17	1.40 ± 2.22

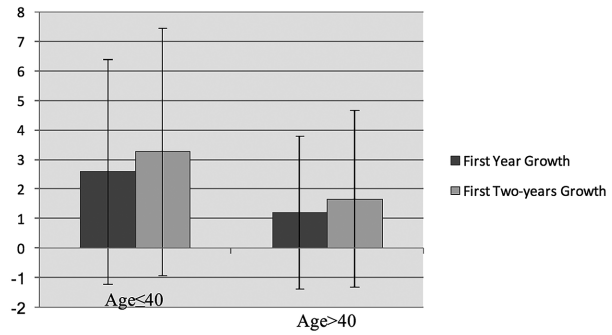

FIGURE 2. *Graph showing the mean tumor growth in first year and first 2 yr in relation to age.*

entire cohort. Of the 576 tumors at presentation, 333 (57.8%), 162 (28.1%), 80 (13.9%), 1 (0.2%), 0(0%) were IM, grade 1, 2, 3, and 4 tumors, respectively.

Annual Growth Rates

The annual mean growth rate for the cohort was 1.21 ± 2.2 mm. While solid tumors demonstrated a mean annual growth rate of 2.86 ± 2.6 mm, cystic tumors demonstrated a mean annual growth rate of 6.08 ± 3.10 mm. IM tumors and EM tumors showed mean annual growth rates of 1.07 ± 2.17 mm and 1.40 ± 2.22 mm, respectively (Table 2), the difference not being statistically significant ($P = .142$).

The mean annual growth rate in patients ≤40 yr and >40 yr in the first year was 2.59 ± 3.8 mm and 1.2 ± 2.6 mm, respectively, and the difference was significant statistically ($P = .001$). Similarly, in the first 2 yr, this was, respectively, 3.26 ± 4.2 mm and 1.67 ± 3.0 mm (Figure 2), the difference being statistically significant ($P = .0022$) but not thereafter. IM tumors showed mean annual growth rates of 2.05 ± 3.05 mm and 0.96 ± 2.02 mm in patients ≤40 yr and >40 yr, respectively. Similarly, EM tumors showed annual growth rates of 2.92 ± 2.64 mm/yr and 1.33 ± 2.18 mm/yr in patients ≤40 yr and >40 yr.

Patterns of Tumor Growth

This analysis was carried out on the subset of 154 patients with greater than 5-yr follow-up. Thirteen diverse growth patterns were observed (Table 3). Eighty-four (54.5%) tumors demonstrated NG for 5 yr, 12 (7.8%) demonstrated SG for 5 yr, and 2 (1.3%) tumors demonstrated FG for 5 yr. The remaining 56 (36.4%) tumors demonstrated mixed growth patterns. Growth pattern like NG + I, NG + SG, SG + NG, NG + SG + NG, and SG + I were favorable to wait-and-scan. Hence, overall, 134 (87%) tumors determined growth patterns that can be considered favorable for the policy of wait-and-scan.[15]

In tumors that did not grow, delayed onset growth was seen as late as at 5-, 8-, and 13-yr follow-up. Significantly, all 4 cystic tumors on follow-up demonstrated FG and had to be taken off the wait-and-scan policy.

Patterns of Tumor Growth in Relation to Tumor Grades (Sizes)

This analysis was carried out on the subset of 154 patients with greater than 5-yr follow-up (Table 3, Figure 3).

TABLE 3. Relation Between Tumor Growth Patterns and Tumor Grade for a 5-yr Follow-up (n = 154)

		Grade of tumor at diagnosis* (No; %)				
n = 154		IM tumors	Grade 1 tumors	Grade 2 tumors	Grade 3 tumors	Grade 4 tumors
NG throughout 5 yr		59 (70%)	13 (16%)	12 (14%)	–	–
SG throughout 5 yr		7 (58%)	3 (25%)	2 (17%)	–	–
FG throughout 5 yr		1 (50%)	1 (50%)	–	–	–
Mixed growth patterns	NG + SG	8 (57%)	4 (29%)	2 (14%)	–	–
	NG + FG	7 (70%)	1 (10%)	2 (20%)	–	–
	NG + SG + NG	3 (100%)	–	–	–	–
	NG + SG + FG	1 (100%)	–	–	–	–
	NG + FG + NG	1 (100%)	–	–	–	–
	NG + I	–	3 (60%)	2 (40%)	–	–
	SG + NG	5 (36%)	8 (57%)	–	1 (7%)	–
	SG + FG	2 (33%)	1 (33%)	–	–	–
	SG + I	–	2 (100%)	–	–	–
	FG + SG/NG/I	1 (33%)	2 (33%)	–	–	–
Total		95 (61%)	38 (25%)	20 (13%)	1 (1%)	–

NG, no growth; SG, slow growth; FG, fast growth; I, involution; IM, intrameatal tumor; No, number; %, percentage.
*Grades according to the Acoustic Neuroma Consensus Systems for Reporting Results.[33]

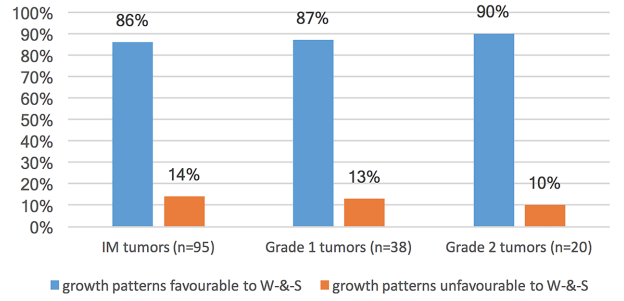

FIGURE 3. *Bar diagram showing the relation between tumor grade and growth pattern.*

Eighty-six percent of the IM tumors (n = 95) showed growth patterns favorable for wait-and-scan. Of these, 59 (62.1%) tumors showed NG for 5 yr. Eighty-seven percent of the grade 1 tumors (n = 38) showed patterns favorable for wait-and-scan. Of these, 13 (34.2%) showed NG for 5 yr. Ninety percent of the grade 2 tumors (n = 20), showed patterns favorable for wait-and-scan. Of these, 18 (90%) showed NG for 5 yr. Of the 84 tumors showing NG, 59 (70.2%) were IM tumors.[15]

The data for tumor progression is displayed in a Kaplan–Meier plot (Figure 4). The clinical progression-free survival is depicted in Figure 5.

Overall Hearing Outcomes

Serviceable hearing was seen in only 211 (36.6%) of the 576 patients. Of 57 patients with serviceable hearing and long-term follow-up, 32 (56%) maintained it.

Relation Between Age and Hearing

In the 154 patients with long-term follow-up, Figure 6 shows that the incidence of serviceable hearing at presentation decreased as the age increased (62% for 20-40 yr, 40% for 40-60 yr, and 30% for >60 yr). This could be attributed to the synergistic effects of SNHL by VS and the setting of presbyacusis in that age group. The deterioration in hearing during the follow-up period was more pronounced in the 20-40 yr age group when compared >40 yr, but was not significant statistically ($P = .356$). This difference could be attributed to the slow rate of growth of the tumors in the older age group when compared to the younger age group.

Relation Between Tumor Grade and Hearing

When hearing was analyzed in relation to tumor grade it was seen that IM tumors had better serviceable hearing at presentation (45.3%) than grade 1 (28.4%) and grade 2 tumors (16.3%) (Table 4 and Figure 7).

Relation Between Tumor Growth Patterns and Hearing

We analyzed the 154 tumors with a 5-yr follow-up to see if the patterns of tumor growth (NG, SG, and FG) had any effect on hearing during the period of follow-up (Table 5 and Figure 8). Of the 84 tumors that showed NG, 34 (40.4%) had serviceable hearing (Class A & B) at the beginning of follow-up and 24 (28.6%) continued to preserve serviceable hearing at the end of follow-up. Of the 3 patients that began with serviceable hearing and showed SG in follow-up, 0 (0%) had serviceable hearing at the end of follow-up. Both the FG tumors had unserviceable hearing at the start of follow-up. Of the 56 tumors that showed mixed growth patterns, 20 (35.7%) began

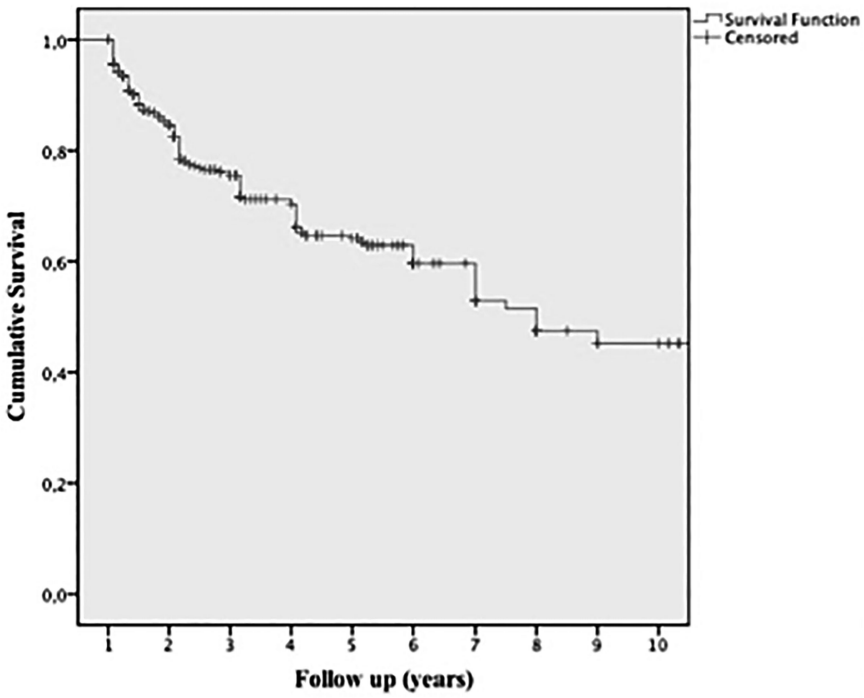

FIGURE 4. *Kaplan–Meier plot showing tumor progression.*

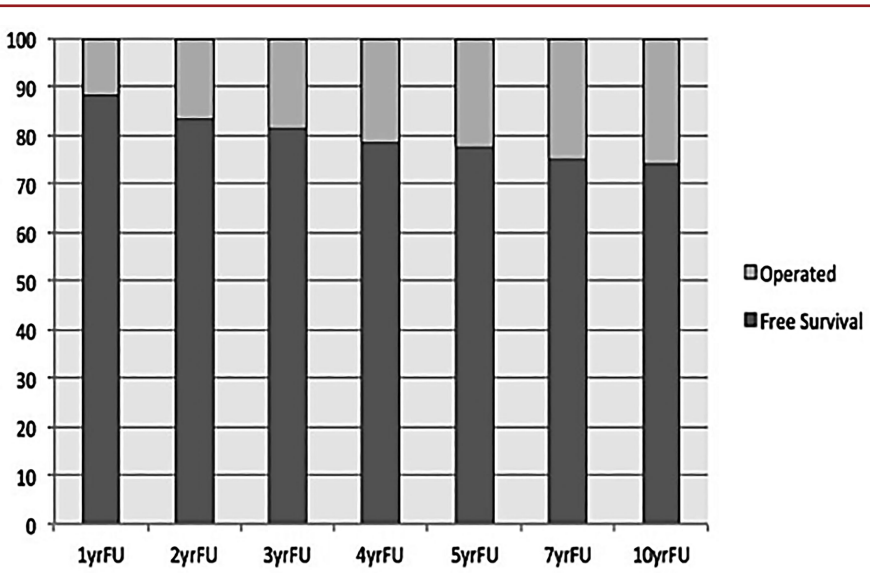

FIGURE 5. *Graph showing clinical progression-free survival.*

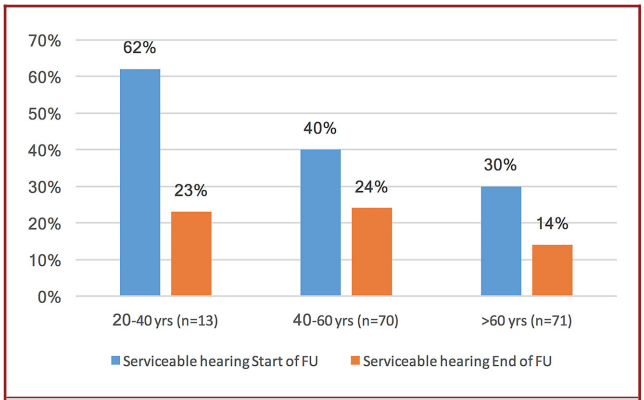

FIGURE 6. *Bar diagram showing the relation between age groups and progression of hearing loss (n = 154).*

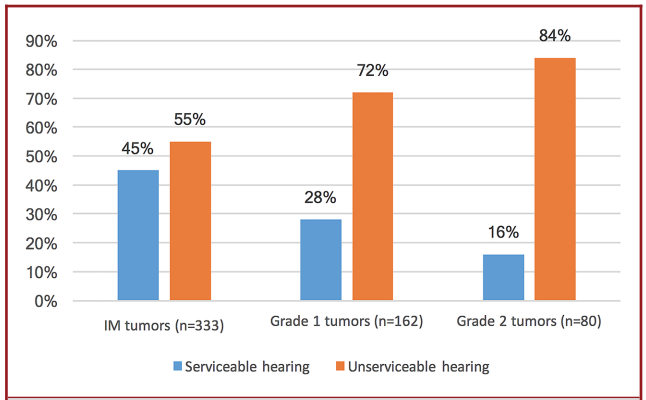

FIGURE 7. *Bar diagram showing the relation between tumor grade and hearing status at the time of presentation.*

with serviceable hearing at the beginning of follow-up and 8 (14.3%) preserved hearing at the end of follow-up. Although the above data show that growing tumors had a tendency to cause progressive hearing loss, this was not statistically significant ($P = .240$).

Failure of Wait-and-Scan

One hundred fifty (26%) in the overall group of 576 patients and 32 (20.7%) in the subgroup of 154 patients who were followed up for 5 yr failed wait-and-scan and were taken up for surgery. The number of patients failing wait-and-scan each year is shown in Figure 9. One hundred and five (70%) patients failed the wait-and-scan policy in the first 2 yr. The main causes of failed wait-and-scan were progressive growth in 133 (88.7%) patients, vertigo in 18 (12%), patient preference in 10 (6.7%), FN palsy in 1 (0.7%), and midline shift in 1 (0.7%) patient. Some patients had more than 1 reason for failure. The initial tumor size and the final tumor size in the patients who continued wait-and-scan were 7.99 ± 5.2 mm and 8.88 ± 5.6mm, respectively. The initial tumor size and the final tumor size in the patients who failed wait-and-scan were 9.02 ± 5.8 mm and 16.29 ± 7.6 mm, respectively (Figure 10).

FN Outcomes After Surgery in Failed Wait-and-Scan

In patients who underwent surgery after failed wait-and-scan, FN outcomes were good (HB grade I and II) in 69 (93.2%) of IM tumors, 22 (75.8%) of grade 1 tumors and 28 (63.6%) of grade 2 tumors. When this was compared with our results of FN in whom surgery was done as a primary treatment modality,[5] it was found that there was no statistical significance between any groups (Table 6). This indicates that there is no increased risk of injury to FN due to wait-and-scan per se over initial surgery between similar sized tumors. However, the risk of poor FN result exists due to the increase in size of the tumor.

DISCUSSION

The wait-and-scan policy has evolved over the last decade. In the past, faulty selection criteria and biases, differences in estimating tumor sizes and grading them, differences in defining NG, SG, and FG, had led to a lot of confusion about the outcomes of this policy.[6,9,15,19] We at our center have

TABLE 4. Relation Between Tumor Sizes (Grades) and Hearing Status at the Time of Diagnosis (n = 576)

	Serviceable hearing			Unserviceable hearing				
(n = 576)	Class A	Class B	Total (No; %)	Class C	Class D	Class E	Class F	Total (No; %)
IM tumors (n = 333)	71	80	151 (45%)	42	87	47	6	182 (55%)
Grade 1 tumors (n = 162)	17	29	46 (28%)	22	57	26	11	116 (72%)
Grade 2 tumors (n = 80)	3	10	13 (16%)	7	26	29	5	67 (84%)
Grade 3 tumors (n = 1)	–	1	1 (100%)	–	–	–	–	
Grade 4 tumors (n = 0)	–	–	–	–	–	–	–	
Total (n = 576)	91	120	211 (37%)	71	170	102	22	365 (63%)

IM, intrameatal; No, number.
Tumor grades according to the Acoustic Neuroma Consensus Systems for Reporting Results.[33] Hearing classified according to Modified Sanna Classification for hearing.

TABLE 5. Relation Between Tumor Growth Patterns and Hearing Through a 5-yr Follow-up

	Serviceable hearing						Unserviceable hearing					
	Class A (No; %)		Class B (No; %)		Class C (No; %)		Class D (No; %)		Class E (No; %)		Class F (No; %)	
(n = 154)	Start of FU	End of FU	Start of FU	End of FU	Start of FU	End of FU	Start of FU	End of FU	Start of FU	End of FU	Start of FU	End of FU
NG throughout 5 yr (n = 84)	18 (22%)	8 (9%)	16 (19%)	16 (19%)	10 (12%)	17 (20%)	22 (26%)	15 (18%)	17 (20%)	24 (29%)	1 (1%)	4 (5%)
SG throughout 5 yr (n = 12)	2 (17%)	–	1 (8%)	–	3 (25%)	4 (33%)	4 (33%)	4 (33%)	1 (8%)	3 (25%)	1 (8%)	1 (8%)
FG throughout 5 yr (n = 2)	–	–	–	–	–	–	2 (100%)	1 (50%)	–	1 (50%)	–	–
Mixed growth patterns (n = 56)	8 (14%)	2 (4%)	12 (21%)	6 (11%)	2 (4%)	9 (15%)	20 (36%)	10 (18%)	10 (18%)	20 (36%)	4 (7%)	9 (16%)
Total (n = 154)	28 (18%)	10 (7%)	29 (19%)	22 (14%)	15 (10%)	30 (19%)	48 (31%)	30 (20%)	28 (18%)	48 (31%)	6 (4%)	14 (9%)

NG, no growth; SG, slow growth; FG, fast growth; FU, follow-up.
All hearing classes classified according to Modified Sanna Classification for hearing.

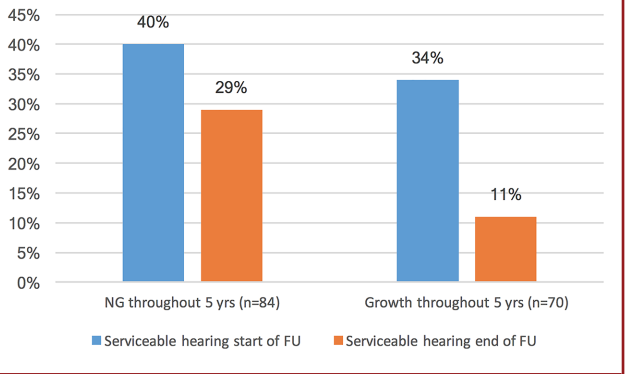

FIGURE 8. *Bar diagram showing the relation between patterns of growth and hearing.*

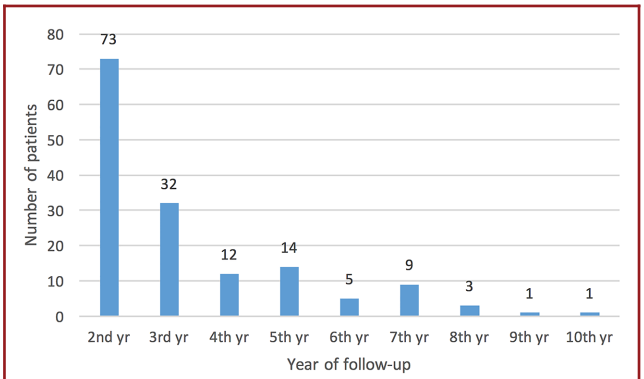

FIGURE 9. *Number of patients failing wait-and-scan during each year of follow-up.*

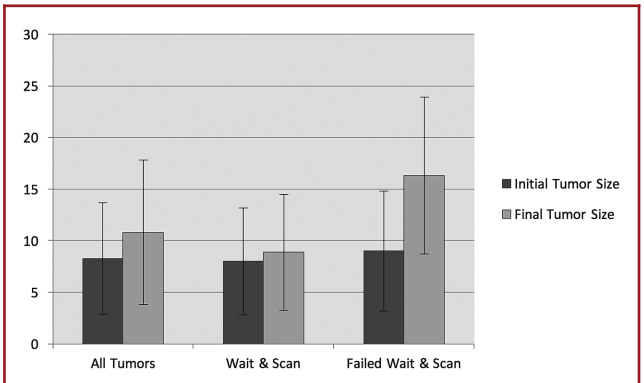

FIGURE 10. *Graph showing the comparison of initial and final tumor size. (Mean and standard deviations are marked in the range of 95% confidence interval).*

TABLE 6. FN Outcomes in the Group That Underwent Surgery

	Good		Intermediate	Poor			
	HB I No (%)	HB II No (%)	HB III No (%)	HB IV No (%)	HB V No (%)	HB VI No (%)	Total
FN outcomes after surgery in failed wait-and-scan (n = 150)							
Intrameatal tumors	52 (70)	17 (23)	5 (7)	–	–	–	**74**
Grade 1 (1-10 mm)	15 (52)	7 (24)	3 (10)	2 (7)	1 (3)	1 (3)	**29**
Grade 2 (11-20 mm)	16 (37)	12 (27)	8 (18)	7 (16)	–	1 (2)	**44**
Grade 3 (21-30 mm)	–	–	1 (50)	1 (50)	–	–	**2**
Grade 4 (31-40 mm)	–	–	–	1 (100)	–	–	**1**
Total	**83**	**36**	**17**	**11**	**1**	**2**	**150**
Facial nerve outcomes after primary surgery without wait-and-scan (n = 1742)[34]							
Intrameatal tumors	165 (83)	20 (10)	13 (7)	2 (1)	0 (0)	0 (0)	200
Grade 1 (1-10 mm)	341 (73)	45 (10)	71 (15)	7 (2)	1 (0.2)	0 (0)	**465**
Grade 2 (11-20 mm)	227 (44)	71 (14)	163 (32)	18 (3)	7 (1)	30 (6)	**516**
Grade 3 (21-30 mm)	85 (23)	46 (13)	176 (48)	28 (8)	9 (2)	21 (6)	**365**
Grade 4 (31-40 mm)	28 (20)	7 (5	55 (39)	17 (12)	4 (3)	30 (21)	**141**
Total	**852**	**191**	**508**	**75**	**24**	**92**	**1742**

formulated an effective strategy of wait-and-scan (Figure 1) and this is represented by the fact that only 26% of our patients failed the strategy.[15] Careful patient selection in our series also leads to a biased set of population leading to good results. Hence the results analyzed in this paper must not be generalized to all cases of VS. The factors that influence decision making in wait-and-scan are discussed below.

Age

Our study, like most others on the subject, had a study population with a mean age of around 60 yr, making this modality an important option for the elderly.[6,7,10,11,20] This study also showed that the rate of growth of tumors in the elderly was slower compared to younger individuals that makes the policy of wait-and-scan an appropriate option for the elderly. In younger patients, the subset of IM tumors can also be subjected to wait-and-scan as they show a higher tendency to remain without growth (NG) when compared to larger tumors.

Tumor Growth Patterns

Overall, 13 definite patterns of tumor growth were demonstrated in our series (Table 3). Such a detailed growth description in wait-and-scan for VS has not been described previously in the literature.[15] According to the literature, about 45% to 75% of tumors do not grow during observation.[1,6,9,14,20,21] This wide range may be due to the disparity in the selection criteria applied by the authors. In our series, we have not only demonstrated an incidence of NG (54%) but also an additional subset of tumors (32%) that showed growth patterns that were favorable to wait-and-scan (SG or a combination of NG/SG/I). Only 14% of tumors were FG over a 5-yr follow-up. Another important observation was that 64% of tumors showed the uniformity of growth pattern over 5 yr which implies that most tumors have a fairly predictable growth pattern.[15] Like others, our results too demonstrated that IM tumors show more dormancy when compared to EM tumors[7,9,10,14,21] and hence can be ideal for wait-and-scan. It is well known that cystic tumors grow faster than solid tumors, sometimes showing spurts in growth requiring more careful observation and if required immediate intervention.[1,15,16]

Many authors have shown growth rates of tumors decreasing over time, and some even recommend discontinuation of radiological follow-up; we have seen a few cases of tumor growth after over 10 yr of follow-up and we advise follow-up over the patient's life time while increasing the interval between follow-ups.[22-24,6,7] Also, patients who did not fail wait-and-scan also showed radiological evidence of tumor growth and it is imperative that these patients receive treatment a few years down the line.

Hearing Outcomes

Very few studies have systematically analyzed hearing results of patients that were on long-term follow-up. In our series, we observed that the incidence of SNHL in VS increased as age advanced, which could be due to the fact that the hearing loss caused by the tumor can act synergistically with the onset of presbyacusis in this age group. A detailed study of this phenomenon, although desirable, is outside the scope of this study. When compared to the literature, our study shows that the percentage of patients with good functional hearing at presentation is less than reported elsewhere. This is perhaps because the Modified Sanna classification of hearing that we have used in this study takes into account SDSs apart from the pure tone audiogram levels to classify serviceable hearing. Many studies have shown a positive correlation between tumor growth and hearing loss.[10,25,26] In our study, although hearing deterioration was the rule among all patterns of growth including NG, the hearing was relatively better preserved in tumors that showed NG when compared to growing tumors (Figure 8). However, hearing deterioration occurred even in static (NG), tumors as

observed in other studies.[1,12] Many other studies that have also shown that a good percentage of patients (42%-73%) maintain hearing upon wait-and-scan,[9,10,27] which was also reflected in our series (56%). Nevertheless, only 37% of patients presented with serviceable hearing at the start of follow-up and 21% remained with serviceable hearing at the end of the 5-yr follow-up. Since the wait-and-scan policy is focused on the older age group, it is to be expected that a majority of them will have poor hearing on presentation when compared to younger patients. But those in the older group who do present with good hearing are likely to preserve it over a long follow-up. The opinion that tumors are more indolent in older patients may be a reason for this.[10,14] These observations further justify the application of wait-and-scan in elderly patients.

FN Outcomes

The FN has been seen to be fairly resistant to stretching by VS and hence the onset of palsy occurs at a much-delayed stage. FN preservation ranges from 65% to 100% in wait-and-scan series.[10,11,28] All but 1 of the 154 patients in our series presented with and maintained HB grade I at the end of the 5-yr follow-up. Hence, FN status on presentation is not a significant consideration that has to be taken into account in deciding to observe a patient. This has been corroborated by other studies.[10,11,29] However, in case of failure of wait-and-scan and subsequent surgery, the progression in tumor size might mean a poorer postoperative FN outcome as compared to outcomes with surgery performed earlier.[30,31] It is well known that larger VS have worse FN injury outcomes after surgery in general. Yet, in this context of a wait-and-scan approach, this fact might not be relevant as it is very much possible that the wait-and-scan strategy will lead to overall lower incidence of FN damage given that, as seen in this series, only 20.7% of those patients, when the cohort is chosen carefully, end up being operated.

In large tumors, many recent studies have reported excellent FN preservation rates by going in for near-total or subtotal resections.[32,33] Anaizi et al[33] reported that good long-term FN function (HB I-II) was achieved in 94% of their gross-total, 92% of their near-total, and 91% of their subtotal resections. Similarly, Monfared et al[32] reported that good CNVII function was achieved in 81% at 1-yr using the same philosophy. They also observed that immediate FN function was better associated with smaller tumor size and the percentage of tumor left behind on MRI.

In small tumors (IM and grade I tumors), it can be argued that RT can be a good option as surgery in this set of tumors is associated with a 7% to 20% risk of damage to the FN. However, in small tumors where the hearing is generally well preserved, it is also true that RT is associated with a 30% to 40% incidence of hearing loss. Added to this, IM tumors being the slowest growing of all grades of tumors. Hence we recommend wait-and-scan for this subset of tumors. However, in small tumors, less surgically experienced teams should be more biased towards RT.

Review of Literature

Table 7 shows that our series has the longest follow-up of 6.5 yr when compared to other large studies in the last decade. The age of the study population of all the studies ranges from 56 to 71 yr. The annual growth rates ranged from 0.6 mm/yr (present study) to 4 mm/yr. The incidence of NG ranged from 45% to 75%. The percentage of failed wait-and-scan ranged from 9% to 58%. Most series have noted a slower rate of growth in IM compared to EM tumors. However, only 6 of the 14 studies used international reporting guidelines to document tumor growth and hearing.

Reporting of results on wait-and-scan in VS must eliminate discrepancies. The guidelines laid down in the report of the Tokyo Consensus Meeting on Systems for Reporting Results in Acoustic Neuroma[17] has been widely accepted and has proven to achieve standardization.[15,34,35] It is important not to mix NF II tumors while reporting on the results of unilateral sporadic VS. Growth must be documented in grades of 1 mm as any growth less than 1 mm cannot be reliably and consistently documented. A tumor growing at a rate of <3 mm/yr can be considered as SG and ≥ 3 mm/yr as FG. Therefore, an SG tumor has a documented growth of only 2 mm/yr as growth is measured in grades of 1 mm.[15] Most series accept that a growth of 2 mm is considered SG.[14] While volumetric analysis is desirable to measure tumor dimensions until protocols are standardized to do this, it is appropriate to measure tumors in the 2 greatest dimensions on MRI and take the higher value of the 2. Reduction of bias, development of consensus in reporting, and homogenization of wait-and-scan protocols needs to be achieved as soon as possible (Table 7).

Role of RT

Most reports on RT as a treatment option for VS do not address the benefits of wait-and-scan. In view of the fact that a considerable section of tumors does not grow or show SG, the successes claimed of RT may be at least partially contributed to the nature of tumor itself. Hence there is a need to revaluate the results of RT in the light of these observations. Radiotherapists and skull base surgeons must be a part of an interdisciplinary team that must consider the benefits of all the three options: wait-and-scan, surgery, and RT before deciding upon the best modality of treatment for the patient.

CONCLUSION

In a well-selected population, the successes of wait-and-scan can be very high. The wait-and-scan modality is an optimal strategy for management of unilateral solitary VS in the elderly population and also in younger age groups with IM tumors. While there may be no price to pay in wait-and-scan as far as hearing is concerned, this may not be the case for FN outcomes wherein the results may be better if the patients are taken earlier for surgery. The role of RT as a primary treatment modality for

TABLE 7. Systematic Analysis of Important Literature Reports of Outcomes of Wait-and-Scan and Comparison With Present Series

Author	Cohort size	Follow-up* (yr)	Age* (yr)	Tumor size* (mm)	IM:EM (%)	Reporting standard	Measurement criteria	Outcomes			Comments/ recommendations
								Growth	Hearing change	% failed W&S	
Hoistad et al[13] 2001	102	2.4	64	NA	65:35	–	LM(−IM)	NG:53%, G:44%, I:3% AGR:2.17 mm	NA	37%	Growth predictors: none
Stangerup et al[21] 2006	729	3.6	59	NA	42:58	CMSRRAN	LM(−IM)	NG:75%, G:24%, I:1% AGR(IM):10.3 mm/1st yr & 0.9 mm/4th yr AGR(EM):4.9 mm/1st yr & 0.8 mm/4th yr	37% deteriorated 59% unchanged	15%	83% of IM showed NG. EM showed more tumors with growth than IM. FUP: 1, 2, 3, 4, 5, 7, 9, and 14
Al Sanosi et al[27] 2006	197	3.4	60.8	8.7	63:37	–	LM(+IM)	NG:69%, SG:24%, FG:4%, I:3%	NA	9%	–
Battaglia et al[14] 2006	111	3.2	71	8.9	41:59	Jackler[36]	LM(−IM)	NG:51%, G:49% AGR:0.7 mm	NA	10%	Growth & growth rate of IM tumors < EM tumors
Ferri et al[9] 2008	124	4.8	61.1	11	48:52	–	LM(+IM)	NG:60%, G:35%, I:5% AGR:0.3 mm	27% deteriorated 73% unchanged	20%	70% IM & 60% of EM tumors showed NG Growth predictor: Tinnitus FUP: 0.5, 1, 2, 3 & annually in NG FUP: Every 6 mo in case of growth
Solares et al[10] 2008	110	2.6	62.4	6.9	29:71	CMSRRAN	LM(−IM)	NG:69%, G:21%, I:10%	NA	11%	5 yr NG was 90% for IM tumors, 74% for grade I tumors & 45% for grade II tumors
Bakkouri et al[7] 2009	325	NA	58	NA	45:55	CMSRRAN	LM(−IM)	NG:58%, SG:29%, FG:12%, I:1% AGR(IM):0.7 mm AGR(EM):1.15 mm	NA	24%	AGR of IM < EM FUP: 1, 2, 3, 4, and 5 for growth/symptoms 1, 3, 5, 7, and 9 for NG/asymptomatic
Martin et al[1] 2009	276	3.6	NA	NA	NA	–	LM	NG/I:73%, G:22% AGR:4 mm	NA	NA	FUP: 0.5, 1, 2, 4, 9, and 13 (lifelong)
Malhotra et al[11] 2009	202	2.5	60	9	NA	–	LM(+IM)	NA	48% deteriorated	9%	Predictor of failure of W&S: Dysequilibrium FUP: 1, 2, 3, 5, 7, 9, 12, and 15
Suryanarayanan et al[35] 2009	327	5.1	60.5	5.1	47:53	CMSRRAN	LM(−IM)	NG:68%, G:30%, I:2% AGR:1.1 mm	NA	25%	Growth predictor: initial tumor size
Agrawal et al[8] 2010	180	2.7	61	10	64:36	–	LM	NG:63%, G:37% AGR:1.1 mm	NA	35%	Growth predictors: initial tumor size & tinnitus
Moffat et al[6] 2012	381	4.2	60.9	10	62:38	NA	LM(+IM)	NG:59%, G:33%, I:8% AGR:0.7 mm	NA	58%	Max growth <3 yr, growth after 5 yr in 7%, faster AGR for IM tumors, Growth predictors: None FUP: 0.5, 1, 2, 3, 5, 7, 9, 12, 15, and 18
Varughese et al[35] 2012	178	3.6	56.3	NA	NA	–	VA	NG:45%, G:29%, I:26% AGR:0.7 mm	NA	NA	No growth predictors FUP: 1, 2, and 5
Current series, 2014	154	6.5	57.6	3.62	62:38	CMSRRAN	LM(−IM)	NG:54%, SG:8%, FG:1%, MG:37% AGR:0.6 mm	37% had serviceable hearing at start & 21% at end of FU	21%	AGR of tumors was higher in ≤40 yr when compared to >40 yr for the 1st 2 yr Growth predictors: None FUP: 1, 2, 3, 5, 7, 9, 14, and 19 (lifelong) in NG & 1, 2, 3, 5, 7, 9, and 11 (lifelong) in NG

W&S, wait-and-scan; IM, intrameatal; LM, linear measurement (−IM is when the IM diameter is not taken into account and +IM is when IM diameter is taken into account); VA, volumetric analysis; NG, no growth; G, growth; I, involution; GR, growth rate; FU, follow-up; FUP, follow-up protocol (in years); CMSRRAN, report of the Consensus Meeting on Systems for Reporting Results in Acoustic Neuroma[15]; NA, not available; AGR, annual growth rate (in years).

*In mean, median, or average as reported by author.

VS needs to be revaluated and redefined, taking into consideration the results of this study and many others on the topic.

Disclosure

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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COMMENT

This is a very well written paper discussing the groups extensive experience with the wait-and-see approach of treatment for VS. The authors should be congratulated on amassing a great deal of data, analyzing it in a meaningful fashion, and presenting it in a simple and effective way. They report of 576 patients who were placed on the wait-and-see part of their treatment algorirthm wherein they seem to be getting yearly MRI scans. The mean tumor size was 8.3 mm and the mean annual rate of growth observed was 1.2 mm overall and 2.9 mm in growing tumors. Cystic tumors grew, on average, 6.1mm annually while extrameatal tumors tended to grow somewhat faster than purely intrameatal tumors, without any statistical signifcance in the difference. Mean growth rates were statistically higher in patients younger than 40 years of age both for the first and second year of observation. The majority of patients lost serviceable hearing by the end of observation, even without evidence of tumor growth; however, tumor growth as well as larger size were factors associated with increased likelihood of hearing loss. Twenty-six percent of the patients officially failed the wait-and-see strategy and underwent surgical resection; however even the ones who did not, on average, showed some growth. Of the 154 patients who were followed for at least 5 years, the majority showed no growth with the remaining showing a number of different patterns of growth with all the various combinations of no, slow, and fast growth as well as involution over the years of follow-up. In all, about 11 of those patients exhibited fast growth following no or slow growth and an additional 10 patients showed involution following some evidence of earlier growth.

One should be cautious in the interpretation of these results as the group of patients reported as other published natural history studies

include mostly smaller, asymptomatic tumors. Any generalization to all acoustic neuromas at initial presentation is not accurate. As the authors also note, linear measurements have significant limitations in accurately representing growth of tumors and we have gone away from using them, instead utilizing volumetric measurement which I think should become the standard. Finally, it should be noted that some of the patients have shown radiographic evidence of progression and although they had not per se failed the wait-and-scan process they may well fail in the future. All in all, however, I would say that this is an important addition to the literature and prompts one to consider continued radiographic imaging for many asymptomatic smaller tumors.

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