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Syed Faraz Kazim
Aga Khan University

Muhammad Shahzad Shamim
Aga Khan University

S. Ather Enam
Aga Khan University

Muhammad Ehsan Bari
Aga Khan University

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Microsurgical excisions of vestibular schwannomas: A tumor-size-based analysis of neurological outcomes and surgical complications

[Syed Faraz Kazim](#), [Muhammad Shahzad Shamim](#), [Syed Ather Enam](#), and [Muhammad Ehsan Bari](#)

Section of Neurosurgery, Department of Surgery, Aga Khan University Hospital, Karachi, Pakistan

Syed Faraz Kazim: farazkazim@gmail.com; Muhammad Shahzad Shamim: shahzad.shamim@aku.edu; Syed Ather Enam: ather.enam@aku.edu; Muhammad Ehsan Bari: ehsan.bari@aku.edu

* Corresponding author

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Abstract

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Introduction:

Vestibular schwannomas (VS) are benign tumors originating from Schwann cells in vestibulocochlear nerve. This study aimed at evaluating outcomes of microsurgical resections of VS based on tumor sizes in a South Asian country.

Methods:

The chart notes of 71 patients who underwent microsurgical resections of VS at a single academic center over a 20-year period (1990–2009) were reviewed, and relevant information was extracted. For analyzing outcomes, patients were divided into two groups based on tumor size at initial presentation: (1) Group A (tumor size \leq 4 cm) and (2) Group B (tumor size $>$ 4 cm).

Pearson's chi-square and Fisher's exact tests were used for comparison of proportions; the independent sample *t*-test was used for comparison of means.

Results:

The average tumor diameter was 4.1 ± 1.5 (range, 1–6.6) cm. Complete resection was achieved more frequently in patients in Group A ($P < 0.001$). Duration of hospital stay and cost of treatment were significantly higher in Group B patients ($P < 0.003$ and $P < 0.04$, respectively). The severity of postoperative facial nerve injury, assessed by House–Brackmann grading system, was significantly higher in Group B ($P < 0.01$). Cerebrospinal fluid (CSF) leak and lower cranial nerve deficits also occurred more frequently after resection in Group B ($P = 0.031$ and $P = 0.003$, respectively).

Conclusion:

We conclude that advanced stage tumors suggestive of delayed presentation are fairly common in Pakistan, and limit curative resection in the majority of patients. Postoperative morbidity is significantly higher in patients with tumor size > 4 cm.

Keywords: Acoustic neuroma, vestibular schwannoma, microsurgical resection, neurotological outcome, South Asia, tumor size

INTRODUCTION

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Vestibular schwannomas (VS) are benign, slow growing tumors which originate from Schwann cells at the oligodendrocyte–Schwann cell junction (i.e., the Obersteiner–Redlich zone), in the peripheral portion of superior and inferior vestibular as well as cochlear nerves. These tumors are frequently referred to as acoustic neuromas, but the preferred term to be used is VS because they are composed of Schwann cells, and more frequently originate in the vestibular portion of the eighth cranial nerve (CN).[4] These tumors comprise about 10% of primary intracranial tumors, 85% of tumors at the cerebellopontine angle, and 90% of intracranial schwannomas.[12,14]

Early in the twentieth century, the goal of treatment for VS was to prolong life with minimal operative mortality. However, by the end of the century, with improvement in neuroimaging modalities and with advent of microsurgical techniques and intraoperative monitoring tools, there was a paradigm shift toward excision of tumor with preservation of CN function.[16]

In developed countries, most VS are diagnosed early when they are still small in size but in developing countries such as Pakistan, where healthcare system is less refined, large VS are fairly common. Large tumors may be associated with compression of CNs, brainstem, and/or obstruction of cerebrospinal fluid (CSF) pathways causing life-threatening hydrocephalus, thus requiring urgent surgical treatment.[18,27] For large tumors, hearing preservation is generally not a consideration as most of the patients have poor or no hearing preoperatively.[27] In developing countries, most of the centers lack the facilities to perform intraoperative monitoring of facial nerves thus making its preservation even more difficult.

In this study, we have analyzed outcomes of microsurgical resections of VS in a South Asian country based on preoperative tumor sizes. The results are interpreted in the context of data from Western centers.

MATERIALS AND METHODS

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Study design

This was a retrospective descriptive study based on chart note review of all patients who underwent microsurgical resection of VS at the Aga Khan University Hospital (AKUH), Karachi, Pakistan over a 20-year period (1990–2009).

Case identification

Surgically treated cases of VS were identified by searching institution's medical record system based on ICD-9-CM (International Classification of Diseases, 9th revision with clinical modification) coding. The chart notes of all identified patients were retrieved and reviewed. All data were collected on a pro forma specifically designed for the purpose. Diagnosis of VS was based on clinical presentation, radiological imaging, and postoperative histopathology reports in all patients.

Inclusion criteria

All cases of VS who underwent microsurgical excision, and whose chart notes were considered complete with regards the required baseline information, were included in the study.

Exclusion criteria

Conservatively managed cases and patients with incomplete chart notes were excluded from the study.

Chart review

Information on following variables was extracted from hospital, laboratory, and radiology records: patient age and gender; signs and symptoms of VS; audiometric tests; laboratory and radiological investigations; tumor size at initial presentation; surgical approach and extent of resection; duration of stay and cost of treatment; and postoperative complications and outcome. The duration of follow-up (from surgery to last clinic visit) was also recorded.

The tumor size was measured (on computed tomography (CT) and/or magnetic resonance imaging (MRI) scan) in three axes, i.e. diameter parallel to the petrous ridge, diameter perpendicular to the petrous ridge, and the vertical diameter in the coronal slices. The size of VS was taken as the largest diameter in any one of the three axes. For analyzing outcomes, patients were divided into two groups based on tumor size at initial presentation: (1) Group A (tumor size ≤ 4 cm) and (2) Group B (tumor size >4 cm). Both pre- and postoperative tumor sizes were recorded. Tumor extension was described using the Hannover grading system:[\[15\]](#) : Class

T1, purely intrameatal; Class T2, intra- and extrameatal; Class T3a, filling the cerebellopontine cistern; Class T3b, reaching the brain stem; Class T4a, compressing the brain stem; Class T4b, severely dislocating the brain stem and compressing the fourth ventricle.

Facial nerve (FN) function was assessed using the House-Brackmann grade[8] (HB grade) and was classified as excellent (HB grade 1–2), intermediate (HB grade 3–4), and poor (HB grade 5–6). HB grade at last follow-up was used to analyze FN outcome.

Data analysis

We used Statistical Package for Social Sciences (SPSS) version 16.0 (© SPSS Inc., 1989-2007) for data entry and analysis. Continuous variables are reported as means (\pm standard deviation), with median (and range) also shown in the case of a skewed distribution. Pearson's chi-square and Fisher's exact tests were used for comparison of proportions; the independent sample t-test was used for comparison of means. For all comparisons, a P-value of <0.05 was considered statistically significant.

RESULTS

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General patient data

Between 1990 and 2009, seventy-eight consecutive patients with VS underwent microsurgical resection at authors' institution. Among these, 71 patients in whom the clinical and operative records were available were entered into the study. The average age of the patients was 43 ± 15 (range, 12–75) years. Thirty-nine (55%) patients were male and 32 (45%) were female. The most prevalent age was in the sixth decade [[Table 1](#)]. The average age of female patients was higher than that of male patients (43.25 *versus* 42 years), although this was not statistically significant. The average length of follow-up was 24.2 ± 35.8 months (range, 9 days to 225 months).

[Table 1](#)

Patients' age by decade and gender

Sixty-nine (97.2%) patients had unilateral tumors; 35 right-sided tumors and 34 left-sided tumors. Two patients (2.8%) had bilateral tumors (neurofibromatosis type-2). In one of these patients, bilateral surgery was performed and complete excision of the tumor was achieved on the side with larger tumor and a partial resection was done on the contralateral side after a period of time. This patient had a co-existing medullary astrocytoma which was also surgically excised. The other patient with bilateral VS underwent surgical resection for the left-sided tumor; the contralateral tumor was conservatively managed. This patient had co-existing trigeminal and olfactory nerve schwannomas and multiple dural meningiomas.

Previous surgery had been performed elsewhere in four patients. These patients underwent subtotal resection 9 months to 3 years before initial presentation at authors' institution. Three out of these four patients had lost hearing and FN in previous surgery and presented with facial paralysis.

Based on 58 available CT and/or MRI scans (discussed later), there were 32 (55.2%) patients in Group A (tumor size \leq 4cm) and 26 (44.8%) patients in Group B (tumor size $>$ 4 cm).

Clinical presentation

Varying degrees of hearing loss were found in 63 (88.7%) patients (28 in Group A and 24 in Group B, $P = 0.293$). Twenty-six (41.3%) out of these 63 patients had a completely deaf ear whereas 37 (58.7%) had variable hearing deficits. Hearing deficits were unilateral in 61 (96.8%) patients and bilateral in 2 (3.2%). Among the 46 patients in whom the character of hearing loss was recorded, 36 (78.3%) had a history of progressive hearing loss and 10 patients (21.7%) had an acute attack with total deafness.

Forty-one patients (51.7%) had headaches (18 in Group A and 19 in Group B, $P = 0.589$). Tinnitus was present in 12 (16.9%) patients (4 in Group A and 5 in Group B, $P = 0.98$). Vestibular deficits were noted in 36 (50.7%) (13 in Group A and 15 in Group B, $P = 0.291$). Varying degrees of facial paresis were observed in 35 (49.3%) (12 in Group A and 17 in Group B, $P = 0.129$). Three out of these 35 patients had facial paralysis after previous surgery for VS outside authors' institution. Trigeminal nerve deficits were present in 13 (18.3%) patients (4 in Group A and 6 in Group B, $P = 0.540$); altered sensation of face was identified in 10 (77%), diminished or absent corneal reflex in 9 (69.2%), weakness of muscles of mastication in 4 (30.8%), and neuralgia in 1 (7.7%) patient. Other CN deficits involved optic nerve in 7 (9.8%), oculomotor nerve in 1 (1.4%), glossopharyngeal nerve in 12 (16.9%), and vagus nerve in 9 (12.7%).

Cerebellar signs were present in 25 (35.2%) patients (8 in Group A and 14 in Group B, $P=0.193$). Twenty-two (88%) had gait disturbances, 7 (28%) had nystagmus, and 5 (20%) had ataxia. Clinically, raised intracranial pressure (ICP) was suspected in 23 (32.4%) patients (5 in Group A and 16 in Group B, $P < 0.01$). Clinical features suggesting raised ICP were headaches in all, nausea/vomiting in 16 (69.6%) patients, drowsiness in 4 (17.4%), and papilledema in 3 (13%) cases.

[Table 2](#) depicts the documented major clinical features along with their duration in 71 patients with VS.

Table 2

Preoperative cranial nerve and other neurological deficits in 71 patients with vestibular schwannomas

Preoperative diagnosis

Audiometric studies were performed in 17 (23.9%) patients. On pure tone audiometry (PTA), all had a “dead ear”. Brainstem evoked response audiometry was done in 4 (5.6%) patients. Latency of response waves and interauricular latency of greater than 0.2 ms was identified in all four cases.

Diagnostic neuroradiologic imaging was available in 58 patients, which included CT scan only in 8 (13.8%), MRI in 40 (69%), and both CT and MRI in 10 (17.2%) patients.

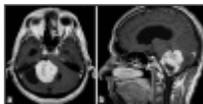
Tumor size and extension

The average preoperative tumor size was 4.1 ± 1.5 (range, 1–6.6) cm which was measured in the largest diameter on 58 available CT and/or MRI scans. Thirty-two (55.2%) patients had tumor size ≤ 4 cm (Group A) whereas remaining 26 (44.8%) patients had tumor size >4 cm (Group B). Tumor extension based on the Hannover grading system is demonstrated in [Table 3](#). Twenty-nine (50%) patients had a T4 tumor. Imaging reports documented hydrocephalus in 18 (31%) out of these 58 patients. Fourteen (53.8%) patients in Group B had hydrocephalus whereas only 4 (12.5%) in Group A developed hydrocephalus ($P = 0.001$). Preoperative extraventricular drains and ventriculoperitoneal shunts were placed in 10 (14.08%) and 12 (16.9%) patients, respectively.

[Table 3](#)

Tumor extension using the Hannover grading system determined from 58 available CT and/or MRI scans

[Figure 1](#) depicts the MRI scans of a VS patient with 4.2 cm and stage T4b tumor.



[Figure 1](#)

(a and b) Axial and sagittal, T1 weighted, post-contrast magnetic resonance imaging (MRI) brain scans of a patient with a 4.2 cm vestibular schwannoma (stage T4b)

Surgical procedure and extent of resection

Microsurgical resection was done using posterior fossa (suboccipital/retrosigmoid) approach in the majority ($n = 67$, 94.4%) of patients. Translabyrinthine excision of VS was performed in 3 (4.2%) cases; one (1.4%) resection was done using the middle cranial fossa approach. Surgical resections were performed by seven different neurosurgeons during a period of 20 years. An otolaryngeal surgeon was involved in three cases. Intraoperative facial nerve monitoring was done in eight patients.

Neuronavigation-guided craniotomy was done in one patient. Intraoperatively, tumor was found to be vascular in 32 (45%), adherent to adjacent tissues in 31 (43.6%), encapsulated in 8 (11.3%), cystic in 6 (8.45%), and hemorrhagic in 4 (5.6%) patients.

All tumors on histopathology received a diagnosis of benign schwannomas and none of the samples revealed any malignant change.

The extent of tumor resection as determined by the operative records and postoperative CT and/or MRI was as follows: complete resection in 34 (47.9%) and partial/subtotal resection in 37 (52.1%). Complete resection was done in 22 (71%) patients in Group A and in 1 (4.2%) patient in Group B ($P < 0.001$). The mean size of postoperative residual tumor calculated from 34 available scans was 2.1 ± 1.7 (range, 0–5) cm. The residual tumor size was significantly higher in Group B (3.4 ± 1.08 cm) as compared to Group A (0.8 ± 1.1 cm) ($P < 0.001$). In cases where the partial/subtotal resection was done, some portion of tumor adherent to the facial nerve or brain stem was left behind. A redo surgery was done after a period of time in 9 (12.67%) patients, 2 in Group A and 5 in Group B ($P = 0.309$).

Duration of stay and cost of treatment

The mean duration of hospital stay was 16.2 ± 17.8 (range, 3–102) days. The mean duration of stay in Group B (24.2 ± 20.2) was significantly higher than Group A (9.2 ± 5.3) ($P < 0.003$). Postoperatively, intensive care unit (ICU) stay was required in 27 (38%) patients. Seven out of 32 (21.9%) patients in Group A stayed in ICU whereas 14 out of 26 (53.8%) patients in Group B required ICU stay ($P < 0.01$). The average duration of ICU stay was 5.4 ± 4.6 (range, 1–10) days. The difference in mean duration of ICU stay between Groups A and B (2.7 ± 1.7 versus 7 ± 5.3) was approaching statistical significance ($P = 0.052$).

The average cost of treatment (including surgery and in-hospital stay) was Pakistan rupee (PKR) $205,755.54 \pm 26,059.86$ [United States dollars (USD) 2404.81 ± 304.58 , based on the current exchange rate, 1USD = 85.56 PKR]. The mean cost of treatment in Group B [PKR $307,165.52 \pm 38,825.42$ (USD $3,590.06 \pm 453.78$)] was significantly higher as compared to Group A [PKR $153,647.79 \pm 12,380.53$ (USD $1,795.79 \pm 144.70$)] ($P < 0.04$).

Facial nerve and hearing preservation

The frequency of new-onset FN injury was 38%. The HB grades of FN injury were significantly higher in Group B as compared to Group A ($P < 0.001$). Ten patients with facial weakness received gold weight lid implants, and four patients underwent facial-hypoglossal nerve anastomosis.

Hearing function was impaired in the majority (88.7%) of patients preoperatively. New-onset hearing loss was documented in two patients postoperatively (both in Group B). Overall, postoperative hearing was normal in nine (12.7%) patients only. None of the patients in Group B had normal hearing at last follow-up. However, it is difficult to comment about hearing preservation due to lack of objective evaluation (like audiometric tests) in the majority of patients.

Other neurological outcomes and surgical complications

Overall, CSF leak occurred in 13 (18.3%) patients, managed with lumbar drain in 12 (92.3%) patients. CSF leak was observed more frequently in Group B as compared to Group A ($P = 0.031$). Associated meningitis occurred in seven (9.9%) patients. Postoperative hydrocephalus developed in nine (12.7%) patients. CN IX, X, and XII deficits occurred in 10 (14.08%), 9 (12.67%), and 1 (1.4%) patients, respectively. Overall frequency of postoperative lower CN lesions was significantly higher in Group B than Group A ($P = 0.003$). The feeding tube was required in 11 (15.5%) patients including the nasogastric tube in 8 and PEG in 3 patients. The feeding tube was required more frequently in Group B as compared to Group A ($P = 0.014$). Tracheostomy was done in 8 (11.26%) patients and ventilatory support was required in 5 (7%) patients. The lower CN paresis improved significantly in the majority of patients on 6–8 weeks follow-ups. Varying degrees of postoperative hemorrhage occurred in 6 (8.5%) patients. Postoperative seizures were observed in 3 (4.2%) patients.

Mortality occurred in 3 (4.2%) patients, 1 in Group A and 2 in Group B ($P = 0.582$). First patient had aspiration pneumonia and later developed a lung abscess with *Enterobacter* species in the tracheal aspirate. This patient received ventilatory support and died on ninth postoperative day. Respiratory failure accounted for mortality in the second patient who died 1 month after the surgical excision of tumor. Aspiration pneumonia accompanied by the left-sided thoracic empyema was the cause of death in the third patient who died on 10th postoperative day.

[Table 4](#) depicts the comparison of extent of resection, FN outcome and postoperative morbidity, and hospital stay and cost of treatment between groups A and B.

[Table 4](#)

Comparison of extent of resection, facial nerve outcome and other postoperative neurological deficits and surgical complications, hospital stay and cost of treatment based on the tumor size[¶]

DISCUSSION

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The actual incidence and natural history of VS in Pakistani population is not known. Very little data are available on the topic.^[1] Our study has brought forth an important aspect of VS in Pakistan, i.e. delayed presentation with advanced stage tumors. Up to the best of our knowledge, no previous surgical series has reported such a large mean tumor size for VS patients. Inadequate screening and referral systems account for delayed presentation resulting in poor prognosis. Previous studies on other brain tumors in Pakistan have shown a similar trend.^[19] The fact that only 78 patients had VS surgery during a 20-year period at AKUH, one of the largest tertiary care hospitals in the country with a wide catchment both geographically and across social strata reflects the inaccessibility to expeditious health care provision to the majority of our population.

Most patients in our study sought treatment for varying degrees of hearing loss, which was found in 88.7% of patients at the initial examination. This is consistent with Western data where reported incidence of hearing loss in patients with VS ranges from 80%

to 96%.[\[9,18,26\]](#) However, 16.9% of our patients reported tinnitus in contrast to 40–90% documented by others.[\[15,26\]](#) Also, many more patients in our series (51.7%) complained of headaches compared to 5–30% reported by others.[\[1\]](#) Both these findings can be attributed to late presentation and larger tumor size. An inverse association has been suggested between tinnitus and tumor extension; patients with smaller tumors have higher rates of tinnitus.[\[1,15\]](#) Our study further corroborates the evidence.

As tumor enlarges and extends to the cerebellopontine angle, other CNs and structures may become involved. The sensory division of the trigeminal nerve is usually the first CN affected other than the vestibulocochlear nerve.[\[1\]](#) FN shows resilience even under extreme pressure and stretching with sensory division getting involved first.[\[1\]](#) Other authors have reported deficits of CN V as 20% and CN VII as 6–33% which is in congruence with our data.[\[15,24,26\]](#)

In contrast to certain Western settings where signs of raised ICP and cerebellar dysfunction are rarely the presenting features, [\[10,11\]](#) many of our patients had clinical evidence of raised ICP (32.4%) and/or cerebellar deficits (35.2%) at the time of admission. It may also be related to delayed presentation in our series. These large tumors caused brain stem compression and obstructive hydrocephalus in many of our patients (Group B > Group A). Preoperative ventriculoperitoneal shunts were required in 16.9% patients in our series. The frequency of preoperative shunt has been reported as 8.3% in a recent study from India.[\[9\]](#)

Microsurgical resection of VS can be accomplished via three operative approaches: translabyrinthine approach, middle fossa or temporal approach, and posterior fossa (retrosigmoid/suboccipital) approach.[\[13,17\]](#) We used the posterior fossa (retrosigmoid/suboccipital) approach in the majority (94.4%) of our patients. In the literature on microsurgical experience, complete resection of tumors has been achieved in 96–98% patients and FN function has been preserved in 65–100% patients.[\[3,13,16\]](#) The rate of hearing preservation ranges from 13 to 82% with the posterior fossa approach.[\[3,13,16,20\]](#)

Complete resection could be achieved in less than half (47.9%) patients in our series which is lower than the Western reports.[\[3,13,16\]](#) However, the rate of complete resection was markedly higher (71%) for tumors ≤ 4 cm.

In our study, the facial nerve could only be preserved in 34.6% patients with tumor size >4 cm. Large VS are associated with a worse functional facial nerve outcome as reported by Tos *et al.*[\[23\]](#) and by Grey *et al.*[\[7\]](#) Ojemann[\[16\]](#) in his series of 410 patients reported that HB grade 1 or 2 FN function was achieved in 98% of small tumors, 96% of medium tumors (1.0–1.9 cm), 75% of medium-large tumors (2.0–2.9 cm), 56% of large tumors (3.0–4.0 cm), and 56% of giant tumors (>4.0 cm). Somers *et al.*[\[21\]](#) also reported that FN functional outcome is dependent on tumor size, with HB grade 1 or 2 function being the rule (92%) for small tumors (<1.0 cm), still attainable (82%) for medium tumors (1.1–2.5 cm), but less common (56%) for large tumors (>2.6 cm). However, most of these papers are reports of a single surgeon's experience whereas our series presents results of microsurgical resections performed by seven different neurosurgeons over a period of 20 years with many of them performing a maximum of 12 surgeries over a period of 5 years. Thus the concept of a learning curve for VS surgery[\[22\]](#) cannot be applied to our series. According to Whittaker and Luetje[\[25\]](#) a surgeon operating less than 12 cases per year cannot expect to get equal results in large series. The preoperative size of tumor is an essential factor determining the FN preservation rate. As reported by others, a reciprocal relationship between tumor size and FN preservation rate was observed in our study. Also, a lack of intraoperative

facial nerve monitoring may have adversely affected FN preservation rate. Such monitoring is highly warranted especially for resections of large-size tumors.[\[27,28\]](#)

Several studies also suggest that hearing preservation is more likely with smaller tumors with good preoperative hearing.[\[5,9\]](#) Ebersold *et al.*[\[3\]](#) have reported no postoperative hearing in any of their patients with preoperative tumor size >4 cm. Our study further corroborates the evidence that hearing preservation is very poor for tumors >4 cm.

CSF leak remains an important issue in the surgical treatment of VS. The reported frequency ranges between 0 and 30%, with an approximate average rate of 12%, however, making comparisons between various published series are difficult because of methodological issues.[\[2,9\]](#) In this study, frequency of CSF leak was 18.3% (18/71 patients) with 12 patients requiring lumbar drain; the frequency is in congruence with the series published by Fishman *et al.*[\[6\]](#) Brennan *et al.*[\[2\]](#) have reported a significant effect of tumor size on the leakage rate after retrosigmoid resection of VS which is at par with our findings. The frequency of associated meningitis in our series (9.9%) was slightly higher as compared to some of the recent series (between 3.7% and 9.2%).[\[9,11\]](#)

Microsurgical resection of VS is associated with a concomitant risk of lower CN injuries in large size tumors which can complicate postoperative course and may lead to increased morbidity and mortality.[\[9\]](#) The 21% (15/71 patients) frequency of lower CN injuries in our series is higher than the 1.5–6.8% reported incidence in published reports.[\[12,15\]](#) Nonetheless, the majority of lower CN injuries in our study were noted in Group B (tumor size > 4 cm).

The higher frequency of postoperative complications in Group B led to a higher duration of hospital stay and thus increased cost of treatment in these patients. Early detection when the tumor is of small size can not only result in better outcome but may also lead to reduction in cost of treatment.

CONCLUSION

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Advanced stage tumors suggestive of a delayed presentation are more common in Pakistan. Postoperative morbidity including FN injury, hearing loss, lower CN deficits, and CSF leak are significantly higher in patients with tumor size > 4 cm leading to higher cost of treatment in these patients. We infer from our results that reduction in postoperative morbidity in our part of the world can be achieved with early detection of tumor emphasizing the need of effective screening and referral system.

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Commentary

[Regunath Kandasamy](#) and [Jafri Malin Abdullah](#)

Regunath Kandasamy, Neurosurgical Division, Department of Neurosciences, Hospital Universiti Sains Malaysia, 16150, Kubang Kerian, Kota Bharu, Kelantan, Malaysia E-mail: brainsciences@gmail.com;

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Developments in the field of microneurosurgery coupled with adjunctive technologies have altered therapeutic goals in vestibular schwannoma surgery. From the mortality rates of 40%, 100 years ago, the current published mortality rate stands at less than 1%. [28,29] The preservation of useful hearing has superseded facial nerve preservation in recent times. Although complications associated with surgery are widely reported, the rate of complication tends to vary widely. The low published complication rates as that reported by Samii and Matthias in the Hannover series are the norm in well-equipped and highly trained facilities in the West.[29] However, in South Asia the complication rates do not always parallel that of the West. In developing nations technologies such as latest imaging or neuromonitoring, facilities may not always be present.

In the article “Microsurgical excisions of vestibular schwannomas: a tumor size-based analysis of neurologic outcomes and surgical complications,” the authors present a retrospective review of the experience in the Aga Khan University in Karachi, Pakistan, over a 20-year period. The authors have collected data in a retrospective manner to elucidate if the size of the vestibular schwannoma has a bearing on the postoperative complication rates. Case records of a total of 71 patients were reviewed and they were divided into 2 groups according to tumor size. The analysis noted that large tumors (>4 cm in size) were associated with significantly higher rates of complications, such as severe facial nerve palsy, cerebrospinal fluid leaks, and lower cranial nerve lesions.

There are a number of issues to be noted: The data collected for this article represents a heterogenous group of patients who were operated on by seven different neurosurgeons in the above-stated duration. The level of experience and prior number of cases that were operated on by each of these surgeons were not described. Audits have proven that improvement in outcomes of Vestibular Schwannoma surgery occur mainly between the 40th and the 100th operated cases. This difference could contribute to variations in complication rates due to difference in the surgical learning curves.[30]

Radiologic studies that were utilized being either magnetic resonance imaging or computed tomography scan were done in only 58 patients. No description was given on how the tumor size was evaluated in patients without imaging. Furthermore, the measurement of tumor size itself was also questionable as the maximum size measured in any one of the planes was taken to represent to size of the tumor. The variation of size in each plane may have different contribution to surgical complications, and thus needs to be considered separately.

From the surgical standpoint, the authors have described in general the approaches that were used for tumor excision. Further description of the microsurgical process may have yielded some simple but significant variations that may contribute to the differences in outcome. Over the 20-year period in which the patients described in this article presented, there have been developments in surgical techniques as well as the use of adjuncts, such as neuromodality monitoring. Outcomes in preservation of facial nerve function and hearing specifically have benefitted most from the use of these.[31] In the authors' center, baseline investigations such as audiometry and facial nerve monitoring were only done in a small number of patients.

This review can be considered as an acceptable preliminary report describing the outcomes of vestibular schwannoma surgery in the authors' center. However, the heterogeneity of the sample is such that no confirmative conclusions can be made with regard to the outcome predictors described in the series. The shortcomings of this series reflect common problems seen in many developing nations, especially in South Asia and South East Asia. The authors' outcomes were nearly similar to our series of cases with the same pathology seven years ago with approximately similar outcomes. Thus far with the presence of intraoperative brain stem, Somatosensory Evoked Potential, Electromyographic facial nerve monitoring, image-guided surgery, and endoscopes, our morbidity for small- to moderate-sized lesions has decreased tremendously. The availability of stereotactic radiosurgery has given the opportunity for our neurosurgeons to be able to improve functional outcome in moderate and a small number of larger tumors after surgery in our institution. The technique of surgery, the knowledge of anatomy, and good neurosurgical skills are needed to achieve good results reported in the literature.[30–32]

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Commentary

[Gerardo Guinto](#)

Gerardo Guinto, Department of Neurosurgery, Hospital de Especialidades, Centro Médico Nacional Siglo XXI, México City, México E-mail: guinto@prodigy.net.mx.

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Vestibular schwannoma (VS) is the most frequent tumor of the cerebellopontine angle (CPA), and represents 6-8% of all intracranial tumors. The first description occurred in 1777 in an autopsy case published by Edward Sandifort. Sir Victor Horsley was the first surgeon who reported a surgical resection of this tumor. At the beginning of the 20th century, success in VS surgery was defined only based on patient's survival because of the high mortality rate, which ranged between 67 and 84% of the cases. It

was not until 1939 when Olivecrona demonstrated for the first time that the facial nerve could be preserved. Currently, by using novel microsurgical techniques and intraoperative neurological monitoring, it is possible to get a mortality index close to zero, with global functional facial nerve preservation over 90%. In this paper, Kazim, *et al.* present a series of 71 patients with VS who were surgically treated in one institution during a 20-year period. One of the most remarkable topics of this article is the inclusion of tumors proportionally bigger than other similar series published. This fact corroborates what is relatively common in developing countries, where most of the people do not have prompt access to medical attention. When patients arrive to the specialist, tumors are usually very huge and difficult to remove. By analyzing the clinical manifestations reported in this series, it is possible to find that the great majority of patients begun with sensitive alterations, such as hypoacusia, deafness, tinnitus, vertigo and dizziness. Affections on the motor system were very rare and they usually appeared during the later stages of the clinical course. This supports the neurophysiological bases that sensitive fibers work like an alarm system to protect motor functions. In VS, it is very common to find giant lesions as presented here, but with integrity on facial movements, in spite of obvious displacement and distortion on the VII cranial nerve. Considering that most of the patients with VS who are good candidates for open surgery already have an important auditory deficit, the most important goal of microsurgery, besides surgical resection of tumor, must be preservation of facial nerve function. According to the masters on this kind of surgeries, tumors of size <4 cm diameter can be totally removed with an excellent facial function preservation (House-Brackmann grades 1-2) in over 80% of the cases. In the Kazim *et al.* series, this facial integrity was obtained in 65.6%, which is acceptable, mostly considering that surgeries were performed by seven different neurosurgeons. However, it calls the attention that 42.3% of the patients with large tumors (>4 cm) presented a severe postoperative functional deficit even though in only one of them could a total resection of the tumor be achieved. When a surgeon decides on making a partial resection of the VS, it is with the main intention to preserve the facial nerve. One of the most frustrating situations after this procedure is getting an incomplete resection of the tumor, leaving the patient with severe facial dysfunction. In my opinion, the main explanation of this problem in Kazim's series is that they performed the intraoperative facial nerve monitoring in only eight cases. It has been clearly demonstrated that this monitoring is mandatory in terms of getting an acceptable result in facial function.[\[32\]](#) Finally, another remarkable finding on the analysis of the results is that none of the patient presented postoperative hematomas, which is one of the most frequent complications reported in big CPA tumors that cause the patient's death. This is an evidence of the meticulousness of the surgeons during closure. The cause of death in the three patients of this series was related to respiratory problems, this evidence supporting the fact that these patients have to be submitted to a strict vigilance on respiratory parameters for at least 3 days after surgery, especially in those cases in which the lower cranial nerves were manipulated. This paper is very useful in giving valuable information about VS surgery, and it is an excellent example of the rational use of the technological resources available. It is also another proof that, in developing countries, it is possible to obtain excellent results in complex surgeries.

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Commentary

[Abbas Amirjamshidi](#)

Abbas Amirjamshidi, Prof. Neurosurgery, Department of Neurosurgery, Tehran University of Medical Sciences (TUMS), Tehran, Iran E-mail: abamirjamshidi@yahoo.com;

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I read with interest this report about a survey of surgical outcome of large vestibular schwannomas (VSc). The authors have tried to find a correlation between the tumor size and surgical outcome defined as preservation of the function of the cranial nerves. Surgery has been done in a setting similar to the situation available in most of the countries coined as the “Third World”! That conveys the situation wherein microsurgical technique and surgeon's expertise plus a good neuroanesthesiologist are all armamentarium to survive a tough case. We work in the same situation and are familiar with the problems and limitations.

On the other hand, this case series has all the limitations of a retrospective study and that is the issue that most of the reports coming from similar context suffer from and should be clarified for the younger researchers intending to bring up evidences in their institutes. I am not going to analyze all the results of the analysis made by the authors even though many of them can be criticized because of derangements in data collection plus the way they have been put together; but on the whole, all of them transfer a good way of thinking about the problem and are good to be published.

We have experience with 108 cases of VSc, all larger than 4cm in the greatest diameter. The use of neuronavigation and intraoperative facial nerve monitoring and the impact of these factors on the outcome of the function of the cranial nerves, especially the facial nerve in similar cases, have been debated by many neurosurgeons. Surgical outcomes of gross total excision of VSc have steadily improved over the last decade in our hands and the primary goal of the surgical treatment today is yet to remove the tumor completely, while preserving the cranial nerve functions. Refinement in microsurgical technique and perhaps the intraoperative monitoring tools, and improvement in imaging studies bestowed more chances on neurosurgeons to achieve this goal. However, it is still difficult to accomplish a successful surgical outcome in large tumors mainly because of the progressive thinning and stretching of the adjacent cranial nerves, especially the facial and cochlear nerves, and subsequently their tight adhesion to the tumor surface. Virtually, there are no ways to visualize or predict the anatomy of the displaced cranial nerves preoperatively using contemporary diagnostic techniques, especially in large VSc. Thus, during the microsurgical resection, it is critical to identify the nerves with their anatomic relationship to the tumor as early as possible. In this context, information regarding the anatomy of the displaced cranial nerves detected by the experienced VSc surgeons preoperatively, can offer practical value. To date, there are a limited number of surgical series, which describe the exact location and course of those cranial nerves displaced in large VSc with their practical reference value. And it is necessary that such delicate perioperative studies be completed.

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Commentary

[Leonidas M. Quintana](#)

Leonidas M. Quintana, Department of Neurosurgery, Faculty of Medicine, Valparaíso University, Valparaíso, Chile E-mail: leonquin@gmail.com;

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Vestibular schwannomas (VSs) are benign neoplasms that are caused by an overproliferation of Schwann cells on the vestibular branches of the vestibulocochlear nerve.[37]

Macroscopically, VSs appear as lobular, well-encapsulated solid tumors. The nerves are stretched over the tumor surface by tumor growth.[37] In addition, surrounding blood vessels, such as the anterior inferior and posterior inferior cerebellar arteries, may also be adherent to the tumor capsule. Tumor consistency varies from very soft to firm and adherent.[37]

The wide variety of symptoms is due to different stages of tumor growth. The evolution comprises four different stages. Initially, the tumor produces otological symptoms such as high-frequency sensorineural hearing loss, tinnitus, vertigo, and instability. This stage is also known as the intracanalicular stage. As the tumor grows out from the porus acusticus, worsening of the auditory symptoms is observed together with the onset of headache and facial hypoesthesia due to trigeminal compression, when the tumor reaches 2 cm in size. The third stage is characterized by filling of the cerebellopontine cistern, compressing the brainstem, ultimately involving the facial nerve, the cerebellum, and the lower cranial nerves. Finally, the tumor causes a shift of the fourth ventricle and obstructive hydrocephalus.[35]

According with these clinical pictures, patients are classified regarding the tumor extension as follows: T1, purely intrameatal; T2, intra- and extrameatal; T3a, filling the cerebellopontine cistern; T3b, reaching the brainstem; T4a, compressing the brainstem; and T4b, severely dislocating the brainstem and compressing the fourth ventricle (Hannover classification).[34,36]

The treatment options comprises clinical and radiological observation, surgery, and radiotherapy. Patients are advised of all treatment modalities and the choice is made together with the medical team, according with the clinical picture of presentation

The method employed by the authors, at the Aga Khan University Hospital, was the review of the chart notes of 71 patients who underwent microsurgical resections of VS in this hospital over a 20-year period (1990–2009). For analyzing outcomes, patients were divided into two groups based on tumor size at initial presentation: (1) Group A (tumor size \leq 4 cm) and (2) Group B (tumor size $>$ 4 cm).

In my opinion the methodology employed was correct, but I'm not sure if the cut between both groups was properly elected, choosing 4 cm of linear dimensions, because a tumor, or any space-occupying mass that is similar or approaches the lobular or the ellipsoid form, should be carefully analysed, taking into account the volumetric dimensions. For example, a mass just with only 1 cm of diameter difference occupies more the double volume, e.g.: a mass with 4 cm of diameter occupies approximately a volume of 32 cc, but a mass with 3 cm diameter occupy a volume proximal to 14 cc. This is very important inside the all calvarium, but specially interesting and important at the posterior fossa level, and the structures that anatomically are related with the tumor at the cerebello-pontine angle.[33]

A volume of 15-20 cc at the posterior fossa is very important because it produces severe alterations at the microcirculation over the encephalic surrounding structures, the brain stem and cerebellar hemispheres, and also, the cranial nerves. However, this affects the results.

In this series, the average tumor diameter was 4.1 ± 1.5 (range, 1–6.6) cm. The better results, and the minor complications were obtained when the size was about 4 cm, but probably much better if the size was less than 4 cm.

The authors conclude that advanced stage tumors suggestive of delayed presentation are fairly common in Pakistan, and limit the management to curative resection in the majority of patients. I agree completely with them, and suggest to analyse the tumors of 3 cm or less in size.

Footnotes

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