Prevalence and Surgical Implications of Dural Enhancement at the Porus Acusticus in Vestibular Schwannomas

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Abstract

Objective. Demonstrate the association of radiographic dural enhancement with increased tumor adherence at the porus acusticus, which may influence completeness of resection and facial nerve outcome.

Study Design. Case series with chart review.

Setting. Academic referral center.

Subjects and Methods. A total of 205 consecutive patients with histopathologically confirmed vestibular schwannoma (VS) were evaluated. Patients with tumors exhibiting dural enhancement on postgadolinium T1-weighted magnetic resonance imaging were identified and compared with matched controls. Completeness of resection, intraoperative details, and facial nerve outcomes were analyzed.

Results. Excluding strictly intracanalicular tumors (n = 32, 16%) and those with NF2 (n = 10, 4.9%), the presence of dural enhancement was radiographically confirmed in 16 (9.8%) cases. Paired analysis did not reveal significant baseline differences between cases and controls. Subtotal resection was performed in 5 (31%) of the 16 patients with tumors exhibiting dural enhancement, in contrast to 1 (3%) of the matched controls (P = .01). Four (25%) demonstrated increased tumor adherence at the porus acusticus intraoperatively, compared with 1 control (3%, P = .04). Long-term facial nerve function was similar between cases and controls (81% vs 84% House-Brackmann I-II function, P = 1.00).

Conclusion. Dural enhancement is present in approximately 10% of extracanalicular VS. Dural enhancement at the porus acusticus may represent hypervascularity, dural reaction, or infiltration, and portends increased tumor adherence and greater likelihood of subtotal resection to preserve facial nerve function. To our knowledge, this is the first series that reports the prevalence of this phenomenon in VS and the potential surgical implications. Recognition preoperatively may be valuable toward patient counseling.

Keywords

acoustic neuroma, vestibular schwannoma, skull base, cranial base, neurotology, meningioma

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Consistent with the guiding tenets of skull base surgery, microsurgical resection of vestibular schwannoma (VS) centers on the balance between functional outcome and tumor control.1 Excluding large tumors compressing the brainstem or causing obstructive hydrocephalus, surgeon and patient tolerances for cranial nerve injury are exceedingly low, especially in the era of radiosurgical or purely observational approaches to tumor management. Subtotal resection (STR) due to unfavorable facial nerve or tumor-brainstem adhesion is not only frustrating but carries a significant likelihood of recurrence necessitating further treatment.2 While some of these intraoperative hazards may not be identifiable preoperatively, high-resolution magnetic resonance (MR) imaging has permitted the correlation of outcomes with various intrinsic tumor characteristics and relationships to nearby structures. For example, the advent of heavy T2-weighted MR sequences—such as fast imaging employing steady-state acquisition or constructive interference in steady state—has allowed surgeons to estimate the likelihood of hearing preservation by determining whether the tumor has impacted the fundus3 and,
in some cases, the precise nerve of origin.\textsuperscript{4,5} With regard to facial nerve outcomes, tumors with unfavorable anterior or caudal displacement, oval shape, or large extrameatal diameters have been correlated with worse immediate postoperative facial function.\textsuperscript{6} As well, a recent study demonstrated a trend toward worse outcomes with firmer tumors, based on differences in T2 signal intensity, with firmer tumors being hypointense.\textsuperscript{7}

Initially described in \textsuperscript{1989},\textsuperscript{8} the radiographic dural “tail” sign has often been used as a factor to distinguish meningiomas from other tumors of the cerebellopontine angle (CPA), including VS. This sign is represented by a fusiform tapering of dura surrounding the meningeal tumor origin or attachments, which exhibits hyperintensity on contrast-enhanced T1 MR sequences. Thickened dura with histopathologic evidence of tumor has been reported,\textsuperscript{8} but more recent series contend that in most cases the dural tail represents local edema and hypervascularity.

We have anecdotally observed peritumoral dural enhancement (DE) at the porus acusticus in preoperative contrast-enhanced T1 MR sequences obtained for CPA masses subsequently proven to be VS. Herein we present evidence of this phenomenon, the frequency with which it may be encountered, and the potential impact on microsurgical resection.

**Methods**

Following Institutional Review Board approval (Mayo Clinic approval 15-001365), a retrospective review was performed from a database of adult patients who underwent microsurgical resection of histopathologically confirmed VS from 2000 to 2010 at a single tertiary care academic referral center. With the observer blinded to outcome data, 2 controls per case were randomly selected from the database and subsequently matched by tumor size (within 0.5 cm), surgical approach to resection (ie, retrosigmoid, middle fossa, or translabyrinthine craniotomy), and age (within 10 years). The surgical approach utilized was retrosigmoid in 9 patients (56%) and translabyrinthine craniotomy (n = 115, 71%) and translabyrinthine craniotomy (n = 115, 71%) and translabyrinthine craniotomy (n = 115, 71%) and translabyrinthine craniotomy (n = 115, 71%). Patients without pretreatment T1 contrast-enhanced MR imaging available for review were excluded from analysis.

The presence of DE was evaluated through postcontrast T1-weighted MR studies in the axial and coronal planes, based on the criteria set forth by Goldsher et al for assessment of dural tails in meningioma.\textsuperscript{9} The contralateral posterior petrous ridge and region of the porus acusticus were used as an internal control, since a small percentage of patients may exhibit physiologic linear DE without the presence of a tumor. In all cases where positive DE was found at the porus acusticus surrounding a VS with extracanalicular extension, the contralateral skull base required absent or less enhancement by comparison. To confirm the presence or absence of abnormal DE, imaging was reviewed independently by a neurotologist (M.L.C.) and a neuroradiologist (J.I.L.).

Tumor size was measured and reported in accordance with American Academy of Otolaryngology—Head and Neck Surgery Foundation guidelines.\textsuperscript{10} Outcomes analyzed included completeness of resection, intraoperative adherence at the porus acusticus (based on intraoperative impression), and facial nerve function. Completeness of resection was defined as follows: gross total resection (GTR) with no evidence of residual tumor at conclusion of resection, near-total resection (NTR) with no more than a small remnant tumor pad (5 × 5 × 2 mm) left on the facial nerve or brainstem to preserve neurologic integrity, and STR with anything greater than NTR left in situ.\textsuperscript{2} Completeness of resection was confirmed on the first postoperative MR imaging study, routinely obtained 3 months after surgery, where no nodular enhancement was seen following GTR or NTR. Preoperative, nadir postoperative, and long-term postoperative facial nerve function was graded with the House-Brackmann scale\textsuperscript{11} and compared with preoperative function. Unacceptable facial nerve function was defined as House-Brackmann grade 3 or worse.

Comparisons of categorical variables were performed with Fisher’s exact test. Continuous variables were summarized with medians and interquartile ranges (IQRs). Similarity between groups was determined via a paired \( t \) test or Wilcoxon signed-rank test for nonnormally distributed data based on all 3 pairings to maintain matched pair analysis (ie, DE group vs control group 1, DE group vs control group 2, and control group 1 vs control group 2). \( P \) values <.05 were considered statistically significant.

**Results**

**Overall Patient Population**

A total of 205 consecutive patients (median age = 51 years, 53% female) with histopathologically confirmed VS and available preoperative MR imaging were evaluated (Table 1). Ninety-four (46%) patients had preoperative nonserviceable hearing (class C or D). Excluding patients with neurofibromatosis type II (n = 10, 4.9%) and subsequently eliminating those with purely intracanalicular tumors (n = 32, 16%), median tumor size at diagnosis was 2.0 cm (IQR = 1.3-2.6 cm, n = 163). Surgical approaches utilized included retrosigmoid craniotomy (n = 115, 71%) and translabyrinthine craniotomy (n = 48, 29%). GTR was achieved in 108 patients (66%), NTR in 28 (17%), and STR in 27 (17%).

**Tumors with DE at the Porus Acusticus**

Baseline characteristics and findings of comparison with matched controls are summarized in Table 1. Sixteen tumors were identified as exhibiting DE at the porus acusticus on contrast-enhanced T1 MR sequences. This figure represents 9.8% of tumors with CPA extension that met study inclusion criteria and underwent surgery during the study period. There were 2 primary types of DE identified: nodular enhancement at the porus (Figure 1) and/or a linear enhancement pattern extending from the porus along posterior fossa dura (Figure 2). Median age (51.5 years, IQR = 37.8-58.3 years) and tumor size (1.8 cm, IQR = 1.4-2.1 cm) were similar to the sourced population (n = 163) of histopathologically proven VS described above (\( P = .76 \) and .30, respectively). The surgical approach utilized was retrosigmoid craniotomy in 9 patients (56%) and...
translabyrinthine craniotomy in 7 (44%). GTR was achieved in 9 patients (56%), NTR in 2 (13%), and STR in 5 (31%).

Control Group

Thirty-two patients (53% female) without peritumoral DE were matched to cases with DE in a 2-to-1 fashion as described in the Methods. The median age of controls was 49 years (IQR = 41.3-52.8), and the median tumor size was 1.75 cm (IQR = 1.5-2.3 cm). Paired analysis did not reveal any differences between median age and tumor size at diagnosis between cases and controls ($P > .05$).

Intraoperative Findings and Outcomes Comparing Tumors with DE and Controls

Of the 16 patients with tumors exhibiting DE at the porus, increased tumor-dura adherence (Figures 2 and 3) was reported in operative notes by the operating neurotologist-neurosurgeon team more frequently than among controls (4 vs 1, $P = .04$). GTR was more difficult to achieve in these tumors (STR in 5 cases vs 1 control, $P = .01$). Nadir facial nerve function in the immediate postoperative period, as recorded in postoperative hospital progress notes, was considered poor (House-Brackmann grade 3 or worse) in 5 of 16 cases (31%) and 7 of 32 controls (22%, $P = .5$). Poor long-term facial nerve function was present in 3 cases (19%) and 5 controls (16%, $P = 1.0$) at a median follow-up of 42.5 months (IQR = 11.3-74.5 months) for cases and 38.5 months (IQR = 22.3-80.8 months) for controls.

Discussion

In this report, we demonstrate radiographic evidence of peritumoral DE at the porus acusticus in 16 cases of VS with extracanalicular growth. This phenomenon and its correlation to intraoperative findings and outcomes may provide helpful diagnostic and prognostic information. The present study estimates the prevalence of VS exhibiting radiographic DE at the porus acusticus to be roughly 10%. This relatively frequent occurrence suggests that DE should not necessarily bring into question the diagnosis of VS if all other imaging and clinical findings are consistent with the diagnosis. By comparison, dural tails seen with meningioma are generally circumferential with greater nodularity than those cases with VS seen in the current study.

Since tumor adherence at the porus may be greater with VS that exhibit DE, patients should be informed that GTR

Table 1. Baseline Characteristics, Intraoperative Findings, and Outcomes among Patients with VS Exhibiting DE and Matched Controls.

<table>
<thead>
<tr>
<th>Feature</th>
<th>VS with DE (n = 16)</th>
<th>Controls (n = 32)</th>
<th>$P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographics</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Females</td>
<td>6 (63)</td>
<td>17 (53)</td>
<td>.76</td>
</tr>
<tr>
<td>Surgical approach</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Retrosigmoid</td>
<td>9 (56)</td>
<td>18 (56)</td>
<td>1.00</td>
</tr>
<tr>
<td>Translabyrinthine</td>
<td>7 (44)</td>
<td>14 (44)</td>
<td></td>
</tr>
<tr>
<td>Age at diagnosis, y</td>
<td>51.5 (37.8-58.3)</td>
<td>49 (41.3-52.8)</td>
<td>.20</td>
</tr>
<tr>
<td>Tumor size at diagnosis, cm</td>
<td>1.8 (1.4-2.1)</td>
<td>1.75 (1.5-2.3)</td>
<td>&gt;.5b</td>
</tr>
<tr>
<td>Duration of follow-up, mo</td>
<td>42.5 (11.3-74.5)</td>
<td>38.5 (22.3-80.8)</td>
<td>&gt;.3b</td>
</tr>
<tr>
<td>Operative findings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tumor adherence at porus acusticus</td>
<td>4 (25)</td>
<td>1 (3)</td>
<td>.04</td>
</tr>
<tr>
<td>Completeness of resection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross total</td>
<td>9 (56)</td>
<td>24 (75)</td>
<td>.01c</td>
</tr>
<tr>
<td>Near total</td>
<td>2 (13)</td>
<td>7 (22)</td>
<td></td>
</tr>
<tr>
<td>Subtotal</td>
<td>5 (31)</td>
<td>1 (3)</td>
<td></td>
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<tr>
<td>Facial nerve function</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative HB 1 or 2</td>
<td>16 (100)</td>
<td>31 (97)</td>
<td>1.0</td>
</tr>
<tr>
<td>Preoperative HB 3 or worse</td>
<td>0 (0)</td>
<td>1 (3)</td>
<td></td>
</tr>
<tr>
<td>Nadir immediate postoperative</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HB 1 or 2</td>
<td>11 (69)</td>
<td>25 (78)</td>
<td>.5</td>
</tr>
<tr>
<td>HB 3 or worse</td>
<td>5 (31)</td>
<td>7 (22)</td>
<td></td>
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<tr>
<td>Long term (at most recent follow-up)</td>
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</tr>
<tr>
<td>HB 1 or 2</td>
<td>13 (81)</td>
<td>27 (84)</td>
<td>1.0</td>
</tr>
<tr>
<td>HB 3 or worse</td>
<td>3 (19)</td>
<td>5 (16)</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: DE, dural enhancement; HB, House-Brackmann; VS, vestibular schwannoma.

*aValues presented as n (%) or median (interquartile range).
*bTo maintain matched analysis, a pairwise comparison was performed for each possible combination (as described in Methods), and the minimum $P$ value is reported.
*cGross total or near-total versus subtotal resection.
may be more challenging. Adherence of the tumor–facial nerve interface and facial nerve splaying at the porus acusticus are the most common reasons for adverse facial nerve outcomes or the need for less-than-complete resection.\textsuperscript{12,13} When faced with unfavorable tumor adherence at the porus, our group tends to prioritize facial nerve function over complete tumor removal. This paradigm may be responsible for the increased frequency of STR among tumors with DE, with a similar rate of normal postoperative facial nerve function. We hypothesize that facial nerve outcomes among tumors exhibiting DE may have been worse in the current study, had the degree of resection been pushed to match the control group.

The precise etiology of abnormal DE surrounding a benign intracranial tumor is controversial. Wilms et al reported 7 cases of meningioma exhibiting this phenomenon in 1989, with the advent and more widespread use of MR imaging with gadolinium. In 2 cases, histopathology of dura in the periphery of the tumor demonstrated neoplastic tissue, suggesting that direct tumor extension and infiltration of dura were responsible for enhancement on MR.\textsuperscript{8} One year later, Goldsher et al examined gadolinium-enhanced MR imaging over a 14-month interval to determine the prevalence of the dural tail sign among intracranial tumors.\textsuperscript{9} The sample consisted of 30 meningiomas, 7 large acoustic neuromas, and several other benign and metastatic lesions. Of the 30 meningiomas, 18 exhibited linear enhancement extending away from the tumor along the dura. Interestingly, none of the other tumors, including VS, demonstrated similar enhancement in their series. While only conjecture, this difference may be attributable to the fact that Goldsher and colleagues utilized less developed scanning protocols in 1990 that may have lacked the sensitivity required to see more subtle patterns of peritumoral DE. Most current MR protocols of the internal auditory canal or CPA employ a slice thickness $\leq 3$ mm. Thinner slices are less prone to volume averaging of adjacent tissues and more likely to correctly characterize DE adjacent to an extra-axial lesion. With wider availability of 3-dimensional volumetric T1-weighted images with slice thickness $<1$ mm, the incidence of DE associated with VS may be expected to increase.\textsuperscript{14} Utilization of a fat saturation technique (Figure 1) will also increase the conspicuousness of DE. The authors theorized that increased vascularity or edema, rather than tumor infiltration specifically, may produce enhancement with contrast administration. However, a definitive conclusion was not drawn due to the small number of patients with radiologic-pathologic correlation.\textsuperscript{9}

A number of subsequent case reports and small series have expanded the types of intracranial neoplasms that may exhibit a dural tail, eventually including a number of benign\textsuperscript{15-24} and malignant primary tumors,\textsuperscript{25-37} metastatic lesions,\textsuperscript{38-44} facial nerve schwannoma,\textsuperscript{45} and VS.\textsuperscript{46-49} While many of these tumors occur at other intracranial locations, a number of malignant primary CPA tumors exhibiting a dural tail have been reported, including glioblastoma,\textsuperscript{34,37} medulloblastoma,\textsuperscript{31} and melanoma.\textsuperscript{30} In the case of CPA medulloblastoma, the authors commented on histopathologic evidence of dural tumor invasion. One may conclude that the inherent predilection for infiltration that a malignancy possesses would logically manifest in dural contrast enhancement.

In the case of VS, the etiology of DE is most likely vascular or inflammatory given that the tumor is neither malignant nor derived from meningeal tissue. In 4 cases (25%) of tumors exhibiting DE in the present series, increased tumor

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**Figure 1.** Nodular dural enhancement at the posterior margin of the porus acusticus (arrow) in a patient with a 1.2-cm vestibular schwannoma with extracanalicular extension.

**Figure 2.** A 2.0-cm left-sided vestibular schwannoma exhibiting abnormal enhancement at the porus acusticus extending along the posterior fossa dura (arrow).
adherence at the porus was noted intraoperatively. In 1 of these 4 cases, the tumor had grown 7 mm in maximum posterior fossa dimension over a 4-month imaging interval (Figure 3). Given this patient’s history of breast cancer, this raised concern for malignancy. She underwent retrosigmoid craniotomy and NTR of her CPA mass, which was consistent with VS on histopathologic analysis. Recent studies of VS tumor biology have shown a relationship between growth rate and inflammation or neovascularization. It is possible that this may be responsible for the rapid growth of the tumor in question and, potentially, hypervascularity or inflammation of the surrounding dura at the porus (Figure 4). Since many of the other tumors exhibiting DE (including those with increased adherence noted intraoperatively) were not observed for a period prior to microsurgical resection given the baseline size, it is difficult to draw conclusions regarding the effect of growth rate.

To our knowledge, only 1 series exists that estimates the prevalence of DE in VS. Haque et al reported a 27% rate of MR evidence of dural tails among 42 cases of VS. The authors noted that these were “consecutively selected patients referred for the evaluation of CP Acoustic Schwannoma.” However, the authors also remarked that only 60% of tumors were histopathologically proven to be consistent with the imaging diagnosis. If other CPA tumors were included in analysis, it is possible that this figure represents an overestimation.

Several study strengths and limitations warrant mention. This represents the first estimate of the prevalence of DE
among a large consecutive sample of histopathologically proven VS. Paired analysis to matched controls permitted the determination of important prognostic information that may play a role in preoperative counseling and intraoperative decision making. Some degree of subjectivity in the interpretation of imaging findings is unavoidable, as an accepted definition of abnormal DE in VS does not exist. Inherent to the study of a rare phenomenon, the small absolute number of tumors exhibiting DE limits the ability to draw conclusions regarding tumor behavior and outcomes. Given its retrospective nature, the analysis of intraoperative findings and outcomes is limited by the completeness of the medical record, and future validation of these findings may require prospective analysis.

Conclusion

DE at the porus acusticus is seen in approximately 10% of extracanalicular VS. The precise etiology of this phenomenon is unclear but may be related to hypervascularity or tumor inflammation. Less-than-complete resection resulted more frequently among tumors with DE than their matched control counterparts, which may be related to increased adherence of tumor to the facial nerve at the porus acusticus. Similarity in facial nerve function between groups likely represents the prioritization of facial nerve function over GTR in the subset that exhibited DE. These findings may be of considerable clinical value in preoperative patient counseling.

Author Contributions

Neil S. Patel, study design, data collection, manuscript preparation, revision, figures; Kathryn M. Van Abel, study design, data collection, manuscript preparation, revision; Michael J. Link, study design, manuscript preparation, revision; Colin L. W. Driscoll, study design, manuscript preparation, revision; Jamie J. Van Gompel, study design, manuscript preparation, revision, figures; Brian A. Neff, study design, manuscript preparation, revision; John I. Lane, study design, manuscript preparation, revision; Matthew L. Carlson, study design, manuscript preparation, revision.

Disclosures


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