Is an Acoustic Neuroma an Epiarachnoid or Subarachnoid Tumor?

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BACKGROUND: There are arguments about whether acoustic neuromas are epiarachnoid or subarachnoid tumors.

OBJECTIVE: To retrospectively examine 118 consecutively operated-on patients with acoustic neuromas to clarify this point.

METHODS: Epiarachnoid tumors are defined by the absence of an arachnoid membrane on the tumor surface after moving the arachnoid fold (double layers of the arachnoid membrane) toward the brainstem. In contrast, subarachnoid tumors are characterized by the arachnoid membrane remaining on the tumor surface after moving the arachnoid fold. Based on this hypothesis, we used intraoperative views and light and electron microscopy to confirm the existence of an arachnoid membrane after the arachnoid fold had been moved.

RESULTS: The tumors were clearly judged to be subarachnoid tumors in 86 of 118 patients (73%), an epiarachnoid tumor in 2 patients (2%), whereas a clear judgment was difficult to make in the remaining 30 patients (25%).

CONCLUSION: The majority of acoustic neuromas are subarachnoid tumors, with epiarachnoid tumors being considerably less common.

KEY WORDS: Acoustic neuroma, Arachnoid membrane, Neurinoma, Surgery, Vestibular schwannoma

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In 1977, Yaşargil et al[1] described an acoustic neuroma occurring in the epiarachnoid space in the internal auditory canal (IAC) that pushed the arachnoid membrane toward the cerebellopontine cistern during growth. Since this description, many articles have been published that follow this concept,[2-4] and, as a consequence, many neurosurgeons consider acoustic neuromas to be epiarachnoid tumors. The reason that this concept is widely accepted is considered to be the presence of an arachnoid fold (double layers of the arachnoid membrane) seen on the tumor surface via a lateral suboccipital retrosigmoid or translabyrinthine approach. This arachnoid fold is one of the features every surgeon pays attention to and is also called arachnoidal duplication or double plane of the arachnoid.[1,3-10]

However, we often encounter cerebrospinal fluid intensity at the fundus on strong T2-weighted magnetic resonance imaging (MRI) in patients in which the fundus is not filled with an acoustic neuroma and also in patients with a healthy IAC (Figure 1).

In 2002, Lescanne et al[5] reported a cadaveric anatomic examination in which they proved that the arachnoid membrane covers the entire IAC including the fundus, leading them to conclude that an acoustic neuroma originating from a vestibular ganglion must be a subarachnoid tumor. There has been considerable debate as to whether acoustic neuromas are epiarachnoid or subarachnoid tumors.[5-10] In the current study, we focused on this question by performing a clinical study of patients with acoustic neuromas using both intraoperative observations and pathological methods.

ABBREVIATIONS: IAC, internal auditory canal

PATIENTS AND METHODS

We retrospectively examined 118 consecutive patients with acoustic neuromas who underwent surgery via the lateral suboccipital approach at Tokyo Metropolitan Police Hospital between February 2007 and May 2008 and verified whether the neuromas were

FIGURE 1. *Strong T2-weighted magnetic resonance images usually seen (left: healthy left side IAC, right: left acoustic neuroma). In both cases, the intensity of cerebrospinal fluid is clearly seen at the fundus acousticus.*

epiarachnoid tumors using operative views and light and electron microscopy. First, we made the following hypotheses (Figure 2). If an acoustic neuroma was classified as an epiarachnoid tumor, we observed no arachnoid membrane remaining on the tumor surface after the arachnoid fold had been drawn to the brainstem side. In contrast, if the acoustic neuroma was a subarachnoid tumor, the arachnoid membrane continued toward the IAC and remained on the tumor surface after the arachnoid fold had been moved. Therefore, if the arachnoid membrane on the tumor surface was confirmed either intraoperatively or pathologically, the acoustic neuroma was theoretically proven to be a subarachnoid tumor.

During the operation, we observed the tumor surface closely using the highest magnification of an operating microscope and determined whether the arachnoid membrane remained after moving the arachnoid fold toward the brainstem. In some cases, we also used the Valsalva method to prove the existence of a subarachnoid space on the tumor

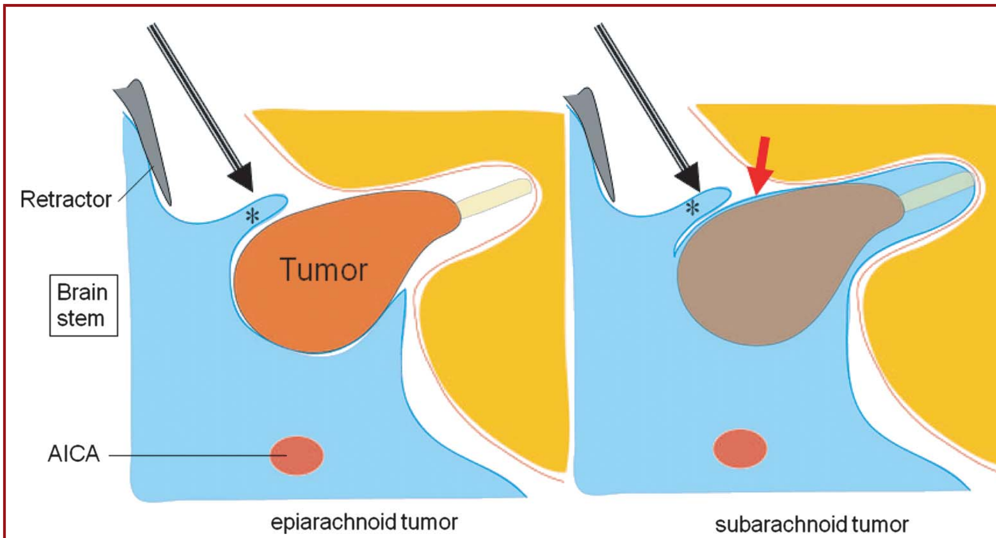

FIGURE 2. *Our hypotheses: schemas of a right acoustic neuroma approached by the lateral suboccipital approach in the park bench position (coronal view): epiarachnoid tumor (left) and subarachnoid tumor (right). A surgeon can recognize an arachnoid fold (*) after retraction of the cerebellum using a brain spatula. We consider that the tumor is a subarachnoid tumor when we identify an arachnoid membrane on the surface of the tumor (small arrow) after moving the arachnoid fold toward the brainstem (right). Large arrow, direction of the surgeon's view. AICA, anterior inferior cerebellar artery.*

surface. We judged a tumor as subarachnoid when we clearly observed the arachnoid membrane on the tumor surface after moving the arachnoid fold. When we identified a membrane structure on the tumor surface, which we were unable to confirm to be an arachnoid membrane, we judged the tumor as undetermined. Last, we judged a tumor as epiarachnoid when we found no membranous structures on the tumor surface after moving the arachnoid fold or when we found an arachnoid membrane covering the nerves in the meatus after dissecting the intrameatal part of the tumor. In all these cases, the procedures performed under the microscope were video-recorded and stored on DVDs.

Further, we conducted a pathological investigation to confirm that the arachnoid-like membrane remaining on the tumor surface was actually the arachnoid membrane. In 13 patients in whom we found that the arachnoid membrane remained on the tumor surface, we excised the tumor by cutting out a quadrilateral section containing the arachnoid membrane, thus preserving the surface without any electrocoagulation, and then sent the tissue sample to the Department of Pathology. In 11 of these patients, we also performed an electron microscopy examination of the tissue sample to confirm that the membrane was the arachnoid membrane.

After removal, the tissue was fixed in 20% buffered formalin and embedded in paraffin. Careful attention was paid during embedding to ensure that the tumor surfaces could be clearly differentiated from the surgically cut planes. The tissue was sliced into 3-μm-thin sections using a microtome at a plane perpendicular to the marked surface. Several levels of each specimen were taken to ensure adequate sampling. The cut sections were then deparaffinized and stained with standard hematoxylin and eosin. To further elucidate the nature of the connective tissue observed in the proximity of the tumor surface, we performed immunohistochemistry using a Histostainer 36A (Nichirei Bioscience, Tokyo, Japan) and antibodies against S100 protein (H0805; Nichirei, Tokyo, Japan), epithelial membrane antigen (EMA, M0613; Dako, Glostrup, Denmark), and progesterone receptor (PgR, A621A; Nichirei Bioscience). The pathological features of all the sections were analyzed under both high- and low-power magnification. In the electron microscopy study, small parts of the specimens were fixed with 2.5% glutaraldehyde, post-fixed in 1% osmium tetroxide, and embedded in Epon 812. Ultrathin sections were prepared and stained with uranyl acetate and lead citrate and observed under Hitachi 7200 and 7500 transmission electron microscopes (Hitachi, Tokyo, Japan).

The number of patients in whom we performed pathological investigation was relatively small. However, the focal investigation in this study was that of the intraoperative microsurgical findings, and we considered it sufficient to simply prove the existence of the arachnoid membrane on the tumor surface in the complementary pathological approach.

RESULTS

In 86 of the 118 patients (73%), the tumors were clearly judged to be subarachnoid tumors, whereas in 2 patients (2%), the tumors were classified as epiarachnoid tumors. In the remaining 30 patients (25%), most of whom had large tumors, it was difficult to ascertain the tumor type (Table). The Koos grading system[11] was used to divide the tumors into 4 size-based categories in the Table. In addition, we classified the tumors into the following 3 categories based on the degree of extension of the tumor into the IAC: type A (the most common type observed in acoustic neuromas), extending into the lateral one third of the IAC; type B, extending into the middle one third of the IAC; and type C, extending slightly into the medial one third of the IAC (medial type). In all cases, tumors categorized under Koos I and II were classified as subarachnoid tumors. However, a very small number of Koos III cases and 40% of Koos IV cases were categorized into the undetermined group. Therefore, we concluded that most of the small tumors were classified as subarachnoid tumors, whereas the large tumors were likely to be classified either as subarachnoid tumors or undetermined. Further, no significant differences were observed between subarachnoid tumors and tumors in the undetermined group in relation to factors such as the age and sex of the patients, laterality, the degree of tumor extension into the IAC, and the number of neurofibromatosis type 2 patients.

The reasons for the subarachnoid tumor classifications were as follows: (1) apparently existing in the subarachnoid space (Figure 3), (2) definite confirmation of the arachnoid membrane remaining after moving the arachnoid fold (Figures 4-6), and (3) identification of a subarachnoid space on the tumor surface proven by inflow of cerebrospinal fluid during the Valsalva method (Figure 7).

On the other hand, in the 2 patient with tumors judged to be epiarachnoid tumors, the tumors did not extend to the fundus,

TABLE. Summary of This Study[a]

	Subarachnoid Tumor, n = 86	Undetermined, n = 30	Epiarachnoid Tumor, n = 2
Age	14-76 y (mean, 43.4 y)	22-71 y (mean, 44.5 y)	55 and 38
Sex	M: 39 F: 47	M: 13 F: 17	M: 1 F: 1
Laterality	Right: 45, Left: 41	Right: 16, Left: 14	Right: 2, Left: 0
Tumor size (Koos classification[11])	I: 3, II: 13, III: 28, IV: 42	III: 2, IV: 28	III and IV
Extension into the IAC[b]	A: 63, B: 14, C: 9	A: 24, B: 4, C: 2	B: 1, C: 1
Number of NF2 patients	3	2	0

[a]IAC, internal auditory canal; NF2, neurofibromatosis type 2.
[b]Type A: extending into the lateral one third of the IAC; type B, extending into the middle one third of the IAC; type C, extending into the medial one third of the IAC.

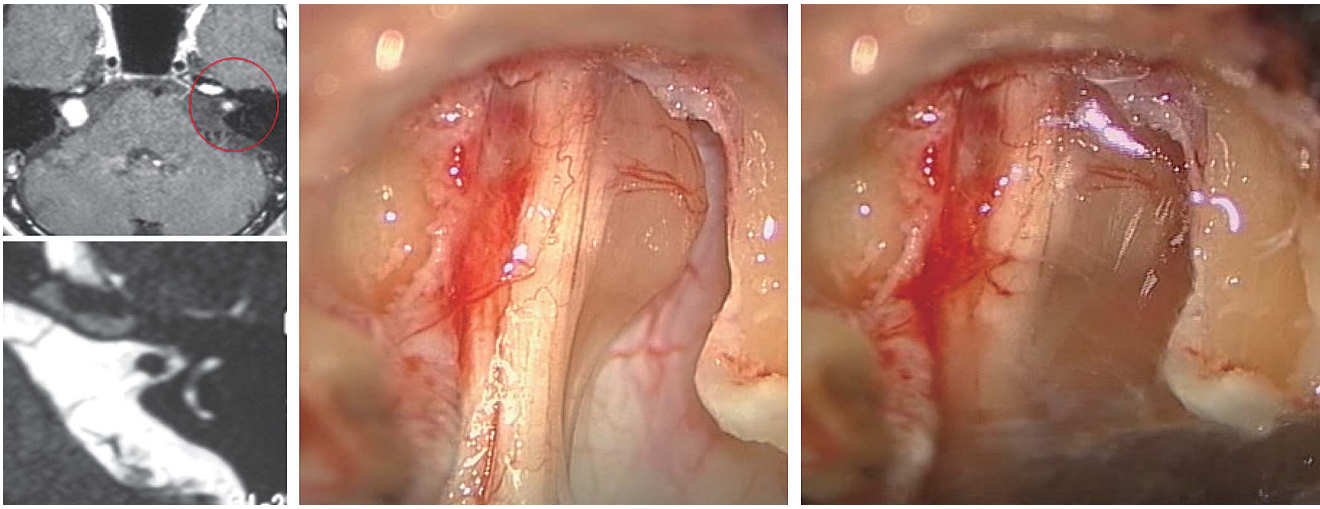

FIGURE 3. *Case of a very small intrameatal left acoustic neuroma that was clearly diagnosed as a subarachnoid tumor by preoperative magnetic resonance imaging (lower left). In this case of bilateral acoustic neuromas of a neurofibromatosis type 2, we first operated on the left smaller tumor using the lateral suboccipital approach to preserve hearing acuity. The operative findings revealed no arachnoid fold and that the tumor was covered by a normal arachnoid membrane and was located in the subarachnoid space in the internal auditory canal (center), which was shown by pulsation to be filled with cerebrospinal fluid (right).*

and after dissecting the intrameatal part of the tumor, the nerves were observed to be covered by the arachnoid membrane behind the tumor (Figure 8). The first patient was a 55-year-old male with an acoustic neuroma of maximum diameter 17 mm, which extended into the cistern. He had a 4-month history of tinnitus and hearing loss in the right ear (pure tone average: 45 dB; speech discrimination score: 70%). The second patient was a 38-year-old female with a 24-mm acoustic neuroma. She had an 8-year history of right tinnitus (pure tone average: 18.8 dB; speech discrimination score: 100%). In these 2 patients, the superior and inferior vestibular nerves were partially outside the subarachnoid space in the IAC, respectively. We were unable to clearly evaluate the relationship between the arachnoid fold and the tumor surface in the cerebellopontine angle cistern. In both patients, the

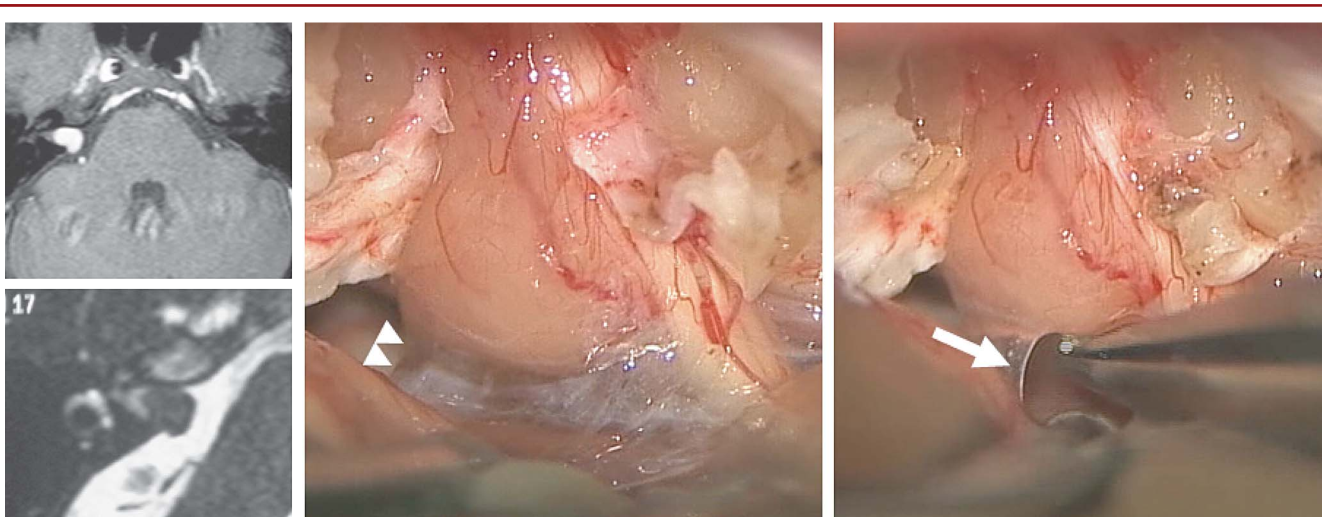

FIGURE 4. *Case of a small right acoustic neuroma operated on via the lateral suboccipital approach. The arachnoid fold was not identified, and we recognized the margin (arrowheads) of the arachnoid membrane, which covered the tumor like a cone from the fundus toward the brainstem (center). After opening, the membrane was confirmed to be an arachnoid membrane (right, arrow).*

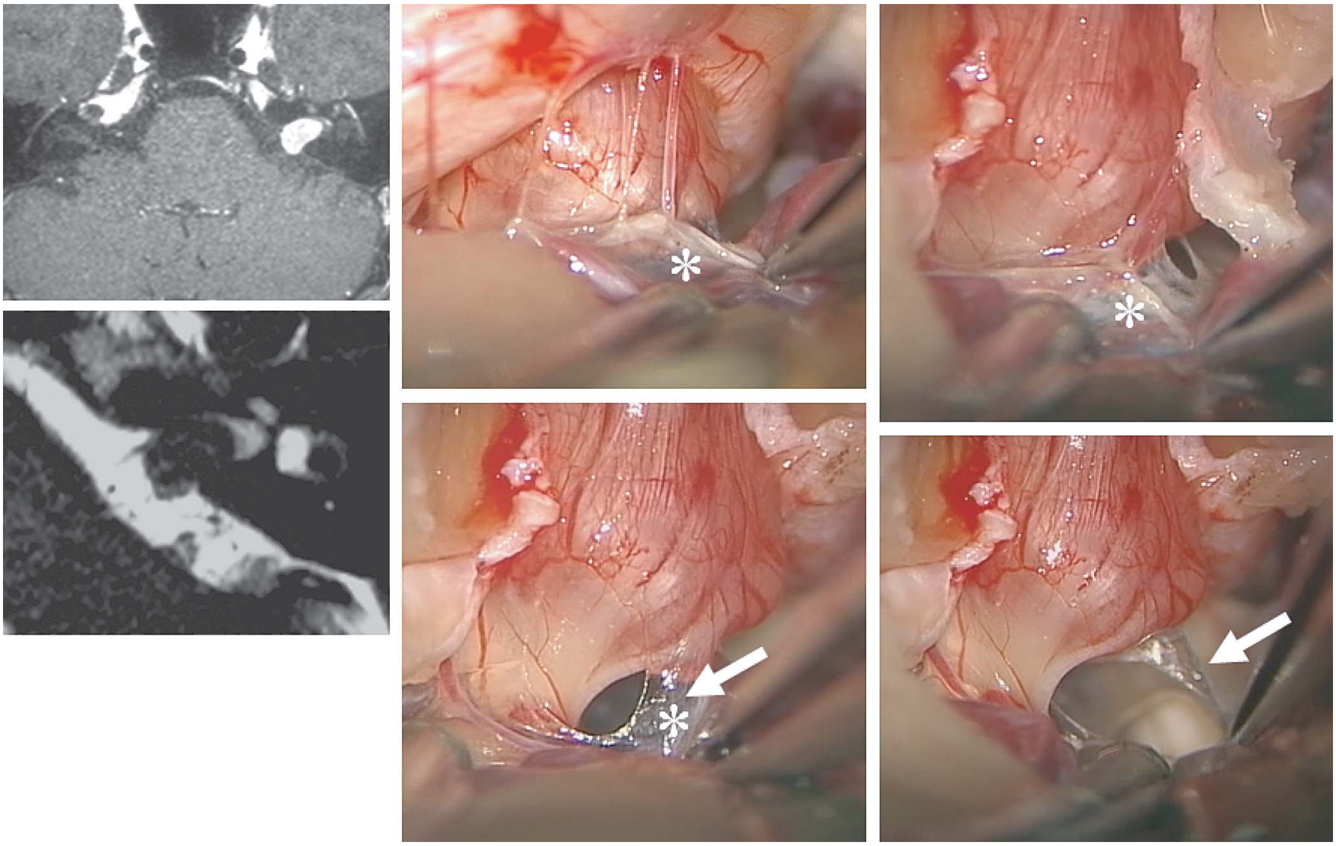

FIGURE 5. *Despite a small left acoustic neuroma, the arachnoid fold (*) was recognized intraoperatively via the lateral suboccipital approach. After we moved this arachnoid fold toward the brainstem, the arachnoid membrane (arrows) was found to cover the tumor and continued from the arachnoid fold toward the internal auditory canal.*

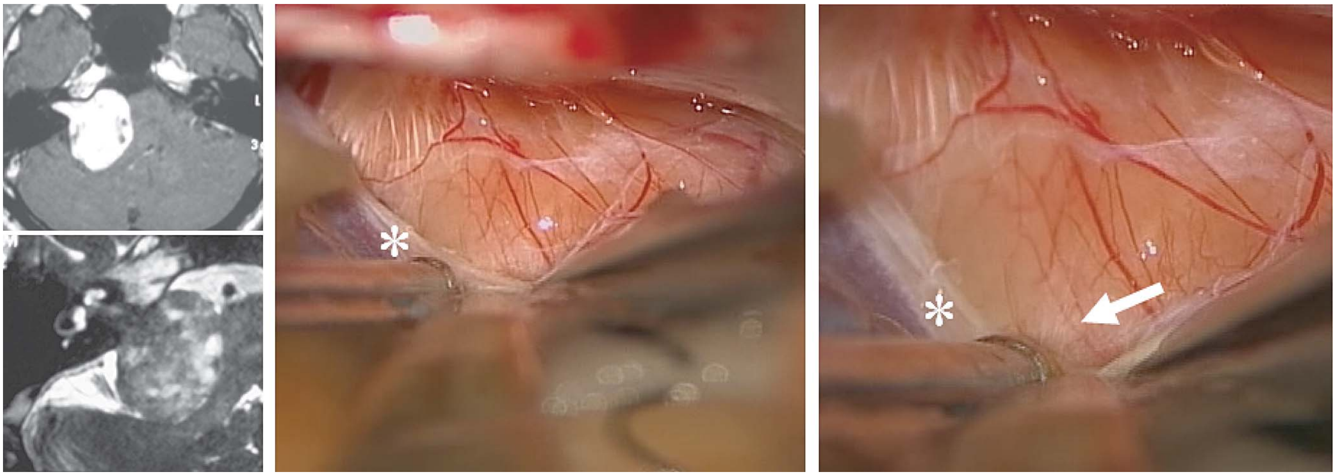

FIGURE 6. *In the case of a larger right acoustic neuroma, after we moved the arachnoid fold (*) toward the brainstem, the arachnoid membrane (arrow) was recognized on the tumor surface continuing from the arachnoid fold.*

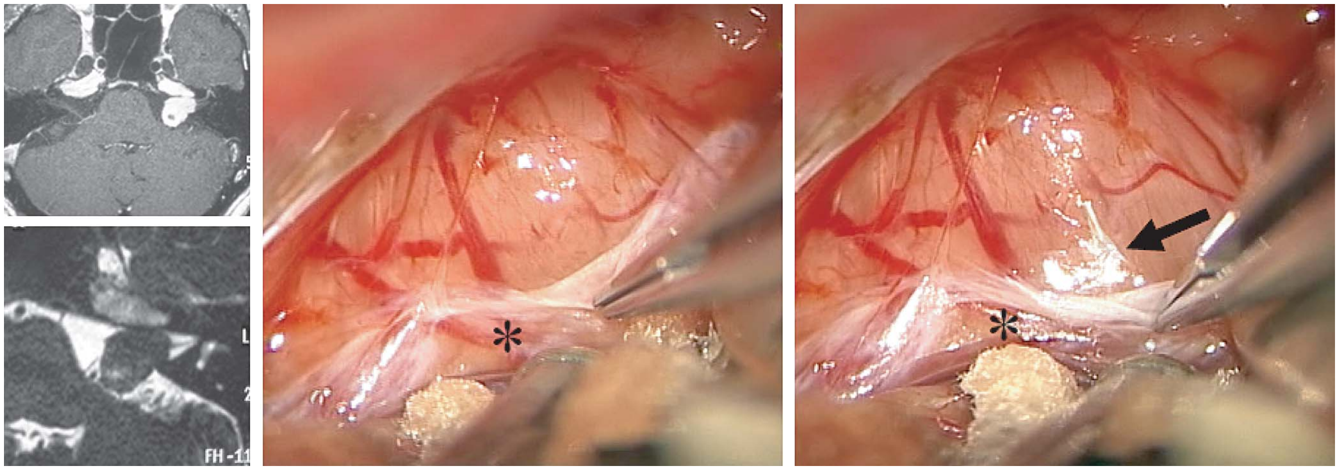

FIGURE 7. *In the case of a small left acoustic neuroma, after we moved the arachnoid fold (*) toward the brainstem using forceps, cerebrospinal fluid flowed in under the arachnoid membrane (arrow) by the Valsalva maneuver, which proved the existence of a subarachnoid space on the tumor.*

pathological findings of the tumors revealed that they were a mixture of Antoni type A and B schwannomas. These findings were consistent with those of other acoustic neuromas.

Of the 118 patients, the microscopic operative findings for 5 patients with neurofibromatosis type 2 did not reveal any specific differences from those of the nonhereditary common acoustic neuromas.

Light Microscopic Findings

In 10 of 13 cases, those we submitted the specimen of the tumor surface to optical microscopic examination, we confirmed that the surface had a membranous structure, with all 4 specimens adding immunostaining showing S100 negative and epithelial membrane antigen–positive cells on immunohistochemistry. Accordingly, these surfaces were classified as an arachnoid

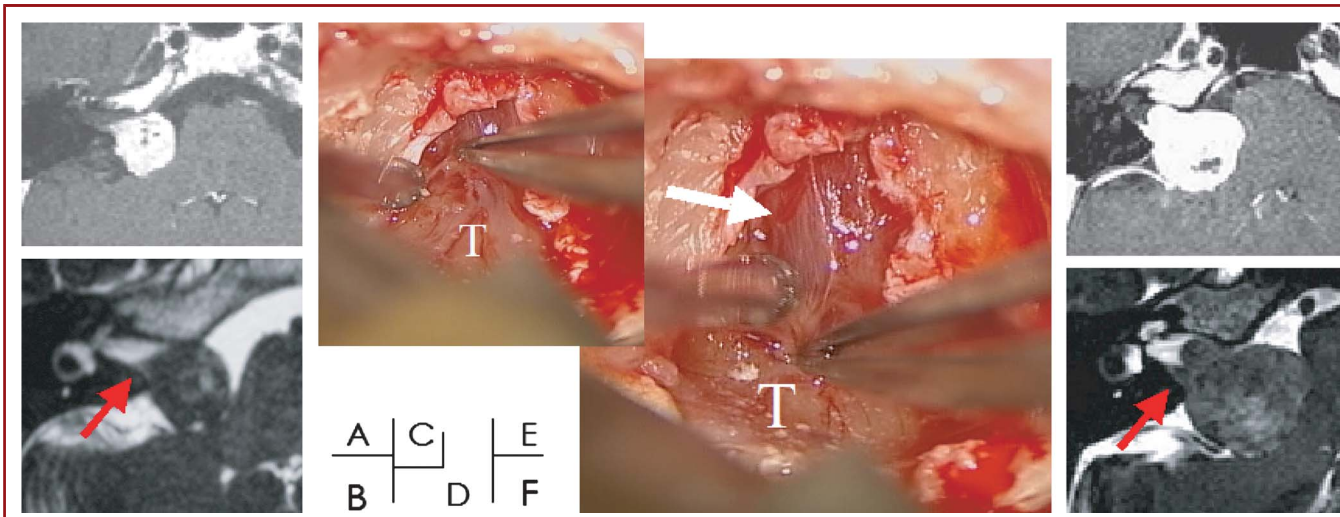

FIGURE 8. *Preoperative magnetic resonance and intraoperative images of 2 patients whose acoustic neuromas were classified as epiarachnoid tumors (a 55-year-old man [***A-D***] and a 38-year-old women [***E***,* ***F***]). Preoperative magnetic resonance imaging scans (***A***,* ***B***,* ***E***,* ***F***) showed similar findings: the tumor did not extend to the fundus acousticus, and the tumor was distributed along the posterior wall of the internal auditory canal (IAC) (red arrows). After dissection of the tumor (T) in the IAC via the lateral suboccipital approach, we found an intact arachnoid membrane (white arrow) behind the tumor, covering the nerves running through the meatus (***C***,* ***D***).*

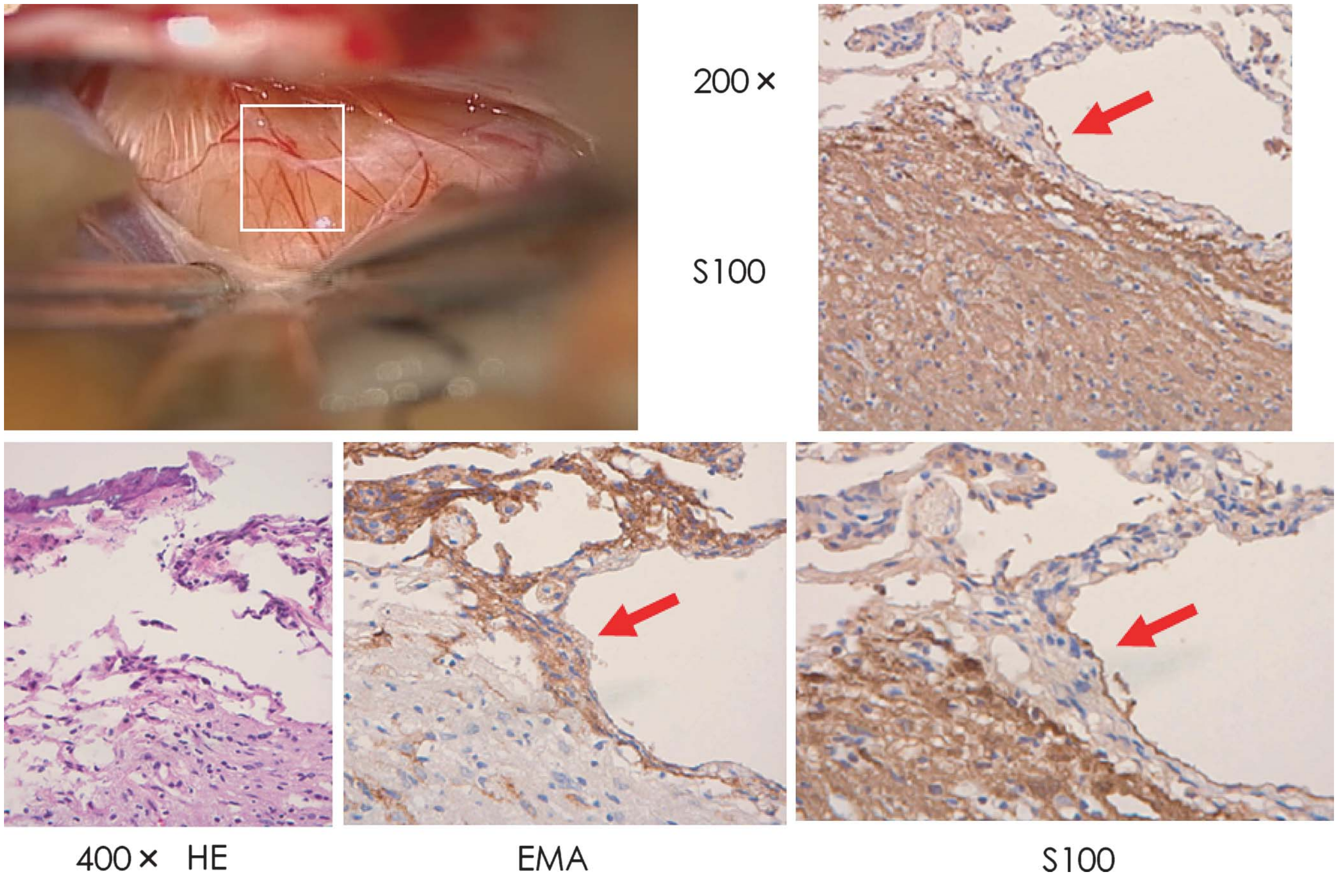

FIGURE 9. *Light microscopic findings of a tumor surface. The sample was taken from the upper left. A cell group (arrow) positive for the epithelial membrane antigen (EMA) and negative for S100 protein was observed and considered to be the arachnoid membrane (lower). HE, hematoxylin and eosin.*

membrane (Figure 9). In 2 of these 4 cases, we also carried out immunostaining for the progesterone receptor and observed positive staining—a finding that corroborated the presence of the arachnoid membrane.

Electron Microscopic Findings

Arachnoidal cells and membrane were observed in only 4 of the 11 cases examined using an electron microscope (Figure 10) although in 10 of the 11 cases, precut light photomicrographs showed a membranous structure considered to be an arachnoid membrane on the dens layer, which was suspected of being the perineurium of the vestibular nerve (Figure 10).

DISCUSSION

Previous Arguments

Since the description of Yaşargil et al,[1] acoustic neuromas have generally been considered to be epiarachnoid tumors.[2-4] This concept is based on the presence of the usually identifiable arachnoid fold (double layers of the arachnoid membrane), with the tumor being exposed after drawing this arachnoid fold toward the brainstem by using the lateral suboccipital or translabyrinthine approach. However, in recent years, this concept has been reconsidered with popularization of MRI and advancement of techniques such as microneurosurgery. Ohata et al[9] published their original concept using many schemas that acoustic neuromas originate subarachnoidally and grow epiarachnoidally. Nevertheless, their explanation of a tumor with a subarachnoid origin that grows epiarachnoidally is somewhat difficult to understand. Lescanne et al[5] performed a cadaveric study on 44 IACs and demonstrated that the arachnoid membrane covers the entire IAC, including the fundus and vestibular ganglion where acoustic neuromas occur and that all vestibulocochleofacial complexes exist in the subarachnoid space (acousticofacial cistern). In the same issue, there was a very interesting argument between Lescanne et al and Yaşargil.[10] Yaşargil commented that it was possible that their study on cadavers may have included conditions different from the actual pathological type, whereas Lescanne et al insisted

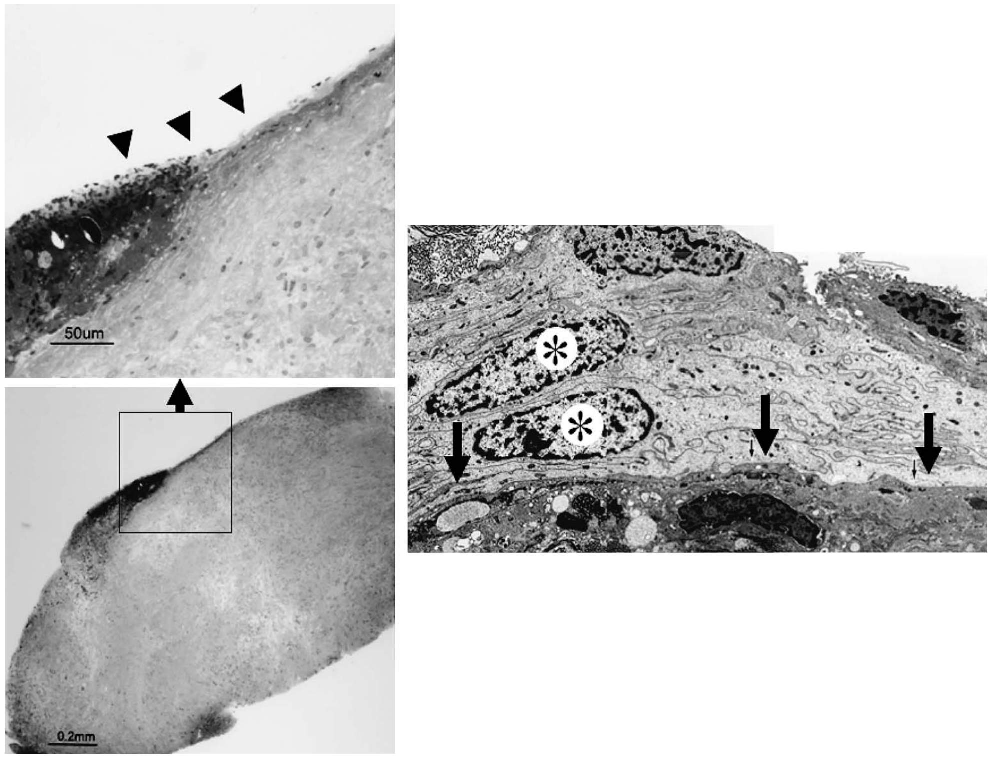

FIGURE 10. *Electron microscopic findings of a sample of the tumor surface. A membranous structure, considered to be the arachnoid membrane (arrowheads), was observed on the dens layer, suspected to be the perineurium of the vestibular nerve on the precut light microscopy photographs (left). Electron microscope view demonstrating the cell group considered to be meningothelial cells (*) in the membranous structure on the tumor surface. These cells have complicated cell projections that form interdigitations between adjoining cells. Moreover, various junction equipment like tight junctions, gap junctions, and desmosomes are visible, with abundant middle filaments existing in the cytoplasm. As for these cell layers, an articulated section with tumor cells is seen clearly (arrows).*

that acoustic neuromas be considered subarachnoid tumors irrespective of the part of the vestibular nerve in which the tumor occurred. However, they were not able to study and comment on the double layers of the arachnoid membrane because their study included patients with normal anatomy. Thereafter, they performed a cadaveric study by using temporal bones from 18 patients with acoustic neuromas; they were unable to identify any layer between the tumor and the intrameatal contents. Therefore, they concluded that these observations contradicted the descriptions concerning the epiarachnoid origin of acoustic neuromas.[7]

Regarding operative findings, Neely[12] stated that there was no cleavage between the cochlear nerve and the tumor, whereas Luetje et al[13] stated that the surgical plane between the facial nerve and the tumor was difficult to locate. In addition, cell-level intermingling was pathologically confirmed between the tumor and nerves other than the nerve where the tumor had originated.[12-14] These reports provide evidence that there are no arachnoid membranes between tumors and the cranial nerves VII and VIII, which is compatible with the findings obtained with subarachnoid tumors. Furthermore, these findings are observed routinely by surgeons during daily operations.

Our research therefore provides additional information by using operative videos, photographs, pathology, and, in particular, electron microscopy.

Pathology of Acoustic Neuromas

Many articles have been published about light microscopy findings on acoustic neuromas.[15-17] Stewart et al[17] reported there was no clear capsule formation in the circumference of 5 acoustic neuromas with diameters of 4.5 mm or less that were discovered by chance in the IAC of pathology specimens obtained at autopsy. The photographs in their article showed no relationship between each tumor and the arachnoid-like membrane in the IAC, with this finding being considered evidence of a subarachnoidal origin of the acoustic neuromas. Neely et al[16] reported that the tumors and nerves from which the tumor originated were covered by a thin perineurium in the small acoustic neuroma and that these 2 structures were separated by a delicate fibrous tissue except for a partial borderless area.

Kuo et al[15] performed pathological examinations of the surface of acoustic neuromas collected at surgery, and described that the tumors were covered with a 3–5-μm-thin membrane. They suggested that this was an arachnoid membrane, expressing "a particular attractive explanation for its origin was draping of arachnoid sheets." Ohata et al[9] described that the tumor surface was covered by "floss," which they suspected to be reactive tissue from the dura mater, although they did not provide any pathological verification. According to our results, we suspect that this "floss" covering the tumor surface seen by Ohata et al may actually be a thinned arachnoid membrane. We therefore consider our concepts and those of Ohata et al to be fundamentally based on the same operative findings. As a reference, spinal neuromas have quite different tumor surface structures as evidenced by the findings of Hasegawa et al,[18] who showed that the tumor capsule consisted of 3 layers containing the nerve.

Regarding the electron microscopy findings, although Neely[12] and Sterkers et al[19] paid attention to both tumors and nerves, they provided no description of tumor surfaces. In our study, although a membranous structure was recognized on the layer considered to be the perineurium on the tumor surface in 10 of the 13 cases examined by light microscopy, arachnoidal cells and membrane were observed in only 4 of the 11 cases examined by electron microscopy (Figure 10). We therefore suspect that it is possible that the arachnoid membrane may be peeled off and lost when superthin samples are made when there is only weak adhesion between the tumor and the arachnoid. This emphasizes the fact that light microscopic examination is more suitable than

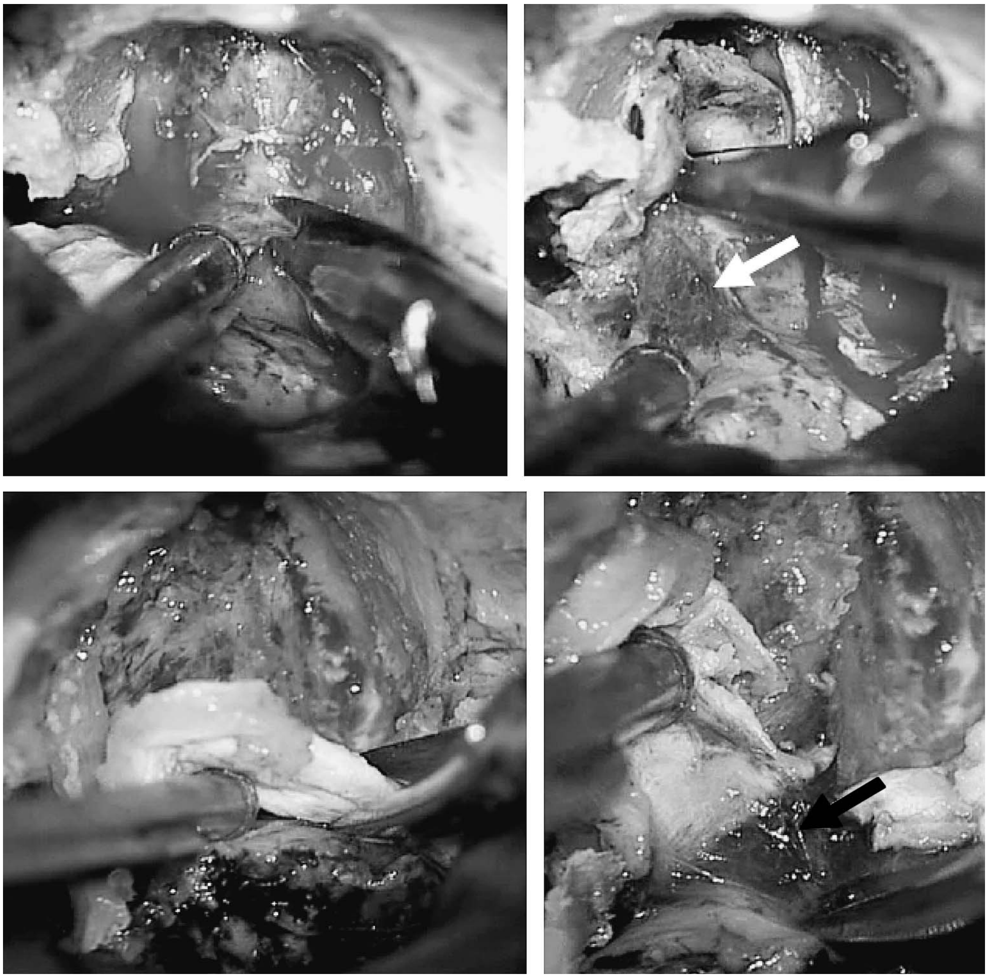

FIGURE 11. *Adhesion between the tumor and the arachnoid membrane and also the arachnoid membrane and the dura mater (arrows) was sometimes observed when we cut and opened the dura mater of the internal auditory canal (upper and lower, different cases).*

electron microscopy for identifying the arachnoid membrane on tumor surfaces.

Mechanism of Forming an Arachnoid Fold

Ohata et al[9] proposed their idea that the keys for the formation of an arachnoid fold were a brain retractor as well as adhesion between the tumor and the arachnoid membrane at the porus acousticus. According to their theory, an acoustic neuroma occurs in the subarachnoid space in the IAC and grows gradually, adhering to the arachnoid membrane mainly at the porus acousticus. The adhesion then moves toward the brainstem as the tumor grows, resulting in the formation of an overlap of the arachnoid membrane. Finally, retraction of the cerebellum by a brain spatula in the operative field results in a surgeon recognizing the arachnoid membrane as a double layer (arachnoid fold) on the tumor in the cerebropontine cistern. Intraoperatively, we often observe adhesion between not only the tumor and the arachnoid membrane, but also between the dura mater and the arachnoid membrane at the porus acousticus (Figure 11). In agreement with the concept of Ohata et al, we speculate that movement of this adhesion toward the brainstem as the tumor grows exposes the arachnoid fold (Figure 12). In our study, there was a tendency for this adhesion and arachnoid fold to be smaller in small tumors and larger in large tumors.

Surgical Procedures and Techniques

Based on the results of our study, changes in surgical strategy, procedures, and techniques are not necessary in acoustic neuroma surgery. First of all, in common with the practice of most neurosurgeons, we grasp the arachnoid fold and move it toward the brainstem and then cut the tumor surface and decompress the tumor. After reduction of the tumor volume, we continue moving the arachnoid fold toward the brainstem. By this method, tumor dissection is performed without injuring the nerves and vessels in the subarachnoid space. However, the arachnoidal fold cannot be kept throughout, and there is a point when we enter the subarachnoid space as described by Ohata et al.[9] We consider that this point is the moment for breaking the continuity between the arachnoid fold and the arachnoid membrane on the tumor surface.

Is an Acoustic Neuroma an Epiarachnoid or Subarachnoid Tumor?

From our results, the majority of acoustic tumors are subarachnoid tumors, although we were not able to make a definitive classification in 25% of the cases. However, we experienced 2 cases in which the acoustic neuroma originated from the epiarachnoid space, although the fundus acousticus was vacant on the preoperative MRI (Figure 8). In both these cases, the MRI scans showed tumor distribution along the posterior wall of the IAC without extension of the tumor to the fundus acousticus; although this is interesting, we have not yet been able to explain these findings. The authors can only describe that there are rare cases in which the vestibular nerve runs partially exterior to the subarachnoid space.

Therefore, our clinical study proved theoretically that most acoustic tumors occur subarachnoidally and also that there are some exceptions to the conclusion of Lescanne et al[5-7] from a cadaveric study that the arachnoid membrane covers the entire IAC in all cases.

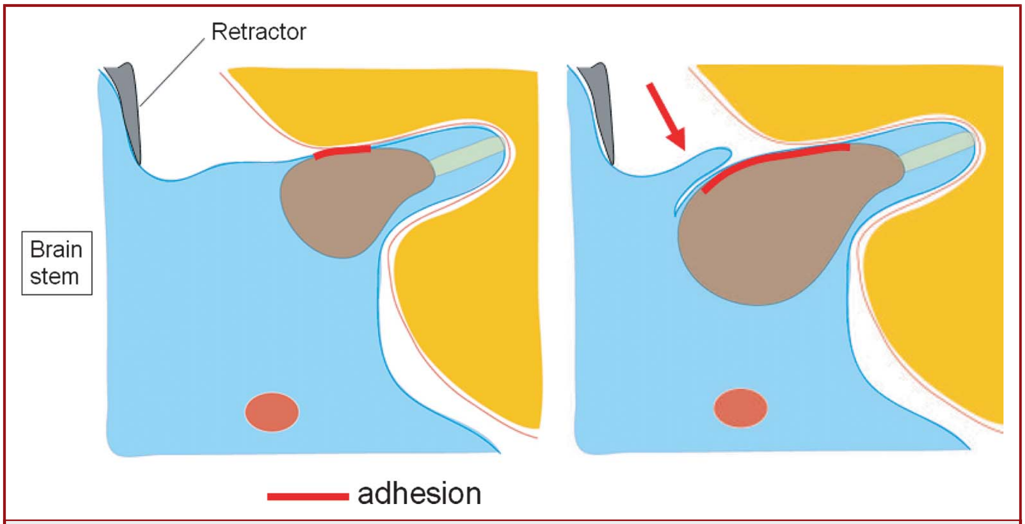

FIGURE 12. *Hypothesis regarding the formation of an arachnoid fold. An acoustic neuroma occurs in the subarachnoid space in the internal auditory canal, grows gradually, and adheres to the arachnoid membrane mainly at the porus acousticus (left), and the adhesion moves toward the brainstem as the tumor grows. This results in the formation of the overlap of the arachnoid membrane (right), and after adding retraction of the cerebellum by the brain spatula in the operative field, surgeons recognize the arachnoid membrane as an arachnoid fold (arrow) on the tumor in the cerebropontine cistern.*

CONCLUSION

From the results of intraoperative and pathological findings in our study, the majority of acoustic neuromas are considered to occur in the subarachnoid space and grow subarachnoidally. The formation of the arachnoid fold is considered to be caused by adhesion between the tumor and the arachnoid membrane around the porus acousticus. Surgical procedures and techniques need not be modified, and it is important to grasp and move the arachnoid fold toward the brainstem to avoid injury to nerves and vessels.

Disclosure

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

REFERENCES

1. Yaşargil MG, Smith RD, Gasser JC. Microsurgical approach to acoustic neurinomas. In: Krayenbuhl H, et al., eds. *Advance and Technical Standards in Neurosurgery*. Vol 4. New York, NY: Springer-Verlag; 1977:93-129.
2. Tarlov E. Development in the neurosurgical treatment of acoustic neuroma. *Lahey Clinic Found Bull*. 1978;27:41-50.
3. Tarlav E. Total one-stage suboccipital microsurgical removal of acoustic neuromas of all sizes: with emphasis on arachnoid planes and on saving the facial nerve. *Surg Clin N Am*. 1980;60(3):565-591.
4. Rosenwasser RH, Buchheit WA.Suboccipital approach. In: Apuzzo MJL, ed. *Brain Surgery*. New York, NY: Churchill Livingstone; 1993:1743- 1772.
5. Lescanne E, Velut S, Lefrancq T, Destrieux C. The internal acoustic meatus and its meningeal layers: a microanatomical study. *J Neurosurg*. 2002;97(5):1191-1197.
6. Lescanne E, François P, Velut S. Cerebellopontine cistern: microanatomy applied to vestibular schwannomas. *Prog Neurol Surg*. 2008;21:43-53.
7. Lescanne E, François P, Bakhos D, Velut S, Robier A, Pollak A. Vestibular schwannoma dissection of the tumor and arachnoid duplication. *Otol Neurotol*. 2008;29(7):989-994.
8. Pellet W, Roche PH: Microsurgery of vestibular schwannoma: persisting questions. *Neurochirurgie*. 2004;50(2-3 Pt 2):195-243.
9. Ohata K, Tsuyuguchi N, Morino M, et al. A hypothesis of epiarachnoidal growth of vestibular schwannoma at the cerebello-pontine angle: surgical importance. *J Postgrad Med*. 2002;48:253-259.
10. Yaşargil MG, Lescanne E, Velut S. The internal acoustic meatus. *J Neurosurg*. 2002;97:1014-1017.
11. Koos WT, Day JD, Matula C, Levy DI. Neurotopographic considerations in the microsurgical treatment of small acoustic neurinomas. *J Neurosurg*. 1998;88(3):506-512.
12. Neely JG. Gross and microscopic anatomy of the eighth cranial nerve in relationship to the solitary schwannoma. *Laryngoscope*. 1981;91(9 Pt 1):1512-1531.
13. Luetje CM, Whittaker CK, Callaway LA, Veraga G. Histological acoustic tumor involvement of the VIIth nerve and multicentric origin in the VIIIth nerve. *Laryngoscope*. 1983;93(9):1133-1139.
14. Jaaskelainen J, Paetau A, Pyykko I, et al. Interface between the facial nerve and large acoustic neurinomas: immunohistochemical study of the cleavage plane in NF2 and non-NF2 cases. *J Neurosurg*. 1994;80(3):541-547.
15. Kuo TC, Jackler RK, Wong K, Blevins NH, Pitts L. Are acoustic neuromas encapsulated tumors? *Otolaryngol Head Neck Surg*. 1997;117(6):606-609.
16. Neely JG, Britton BH, Greenberg SD. Microscopic characteristics of the acoustic tumor in relationship of its nerve of origin. *Laryngoscope*. 1976;86(7):984-991.
17. Stewart TJ, Liand J, Schuknecht HF. Occult schwannomas of the vestibular nerve. *Arch Otolaryngol*. 1975;101(2):91-95.
18. Hasegawa M, Fujisawa H, Hayashi Y, Tachibana O, Kida S, Yamashita J: Surgical pathology of spinal schwannomas: a light and electron microscopic analysis of tumor capsules. *Neurosurgery*. 2001;49(6):1388-1393.
19. Sterkers JM, Perre J, Viala P, Foncin JF. The origin of acoustic neuromas. *Acta Otolaryngol*. 1987;103(5-6):427-431.

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COMMENTS

This study of the microanatomy of the arachnoidal coverings of the acoustic tumors is relevant for microsurgery. The subject has been extensively disputed between prominent neurosurgeons in recent years. This article indicates that extra-arachnoid is the dominating type of growth. This does not resolve the debate, but adds important new data obtained with optical and electron microscopy on the position of arachnoid in relation to acoustic schwannoma. The possibility of inaccuracies could result from the existence of both intra- and extra-arachnoid growth of the tumor, but also from the retrospective character of the analysis of video-recorded surgical procedures, which does not comply with the methodological consistency in all cases and could be a source of artifacts.

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This is a well-written article on the issue of whether vestibular schwannomas (VSs) are in principle subarachnoidal or epiarachnoidal tumors. The authors performed a well-done study with 118 consecutive cases of VSs and concluded that in the majority of the cases, these tumors are located at the subarachnoidal space. This finding is not a surprise because there are several indicators for this assumption. The authors mentioned some of them, and another one might be the not uncommon finding of associated hydrocephalus despite small VSs caused by increased protein content in cerebrospinal fluid of these VS patients. Surprisingly, the authors found epiarachnoidal VSs in tumors distant to the fundus of internal auditory canal (IAC). Because the arachnoid membrane is supposed to accompany the vestibular nerves up to the fundus of the IAC, it remains unclear why these particular cases are epiarachnoidal. Further studies must clarify this aspect in future.

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In 1976, Yasargil et al[1] detailed the arachnoid membranes in relation to the surface of VSs and stated that VSs originate extra-arachnoidally in the internal auditory meatus and push the arachnoid membrane of the cerebellopontine cistern medially, thereby causing an arachnoid duplication (or even a triplication) between the tumor and the brainstem. This superposition of layers creates a surgical cleavage plane. The original description of Yasargil et al remains a major reference and is still found in numerous textbooks on surgical technique. However, in 2002, Lescanne et al[2] performed a microanatomical cadaver study and challenged the concept that VSs are extra-arachnoidal tumors. The current study by Kohno et al is designed to address this issue.

The study is a retrospective study of 118 consecutive patients with VS, which is quite a sizable population. The authors contrast the 2 classic hypotheses, namely, that a VS is a subarachnoidal tumor or an extra-arachnoidal tumor.

The authors made their conclusions based on direct intraoperative microscopy in the majority of cases. In all the patients, the operations performed under a microscope were routinely recorded on DVDs. After observing the presence of the arachnoid membrane on the tumor surface, the tumor surface was carefully studied before beginning to operate on the tumor. Retrospective analysis was possible by viewing the surgical procedure recorded on the DVDs.

The VSs were determined to be subarachnoidal in 86 patients, extra-arachnoidal in 2, and indeterminable in 30 patients using this technique. Only in 13 cases (presumably out of the 30 indeterminable cases) were specimens sent to pathological examination with specific focus on the membranous surface. It is somewhat unclear from the text how many of these 13 cases ended up being classified as extra-arachnoidal.

The study by Lescanne et al[2] showed that the arachnoidal layer doubles the dura mater of the meatus along its entire length. As a result, the vestibular and cochlear nerve fibers penetrate the arachnoid very early, as soon as they enter the meatus. This fixes the position of the vestibular ganglion in the subarachnoid space. Neuromas that arise at this level are thus all contained in the acousticofacial cistern. The current study by Kohno et al support these findings, and the authors go on to illustrate this with a nice drawing.

The authors focus on the majority of patients in whom the VSs were subarachnoidal, but fall short of presenting an explanation for the ones that were either deemed to be extra-arachnoidal or indeterminable. The authors stress that the results of their current study do not warrant a change in the surgical technique.

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1. Yasargil MG, Smith RD, Gasser JC. Microsurgical approach to acoustic neurinomas. In: Krayenbuhl H, et al., eds. *Advances and Technical Standards in Neurosurgery*. Vol 4. New York: Springer-Verlag; 1977:93-129.
2. Lescanne E, Velut S, Lefrancq T, Destrieux C. The internal acoustic meatus and its meningeal layers: a microanatomical study. *J Neurosurg*. 2002;97:1191-1197.