

Original Article

The outermost “dura-like membrane” of vestibular schwannoma

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Abstract

Background: The membranous structure of vestibular schwannoma is an important factor in its surgical treatment. Herein, we report intraoperative and microscopic findings relating to an outermost “dura-like membrane” in cases of vestibular schwannoma and the importance of these findings.

Methods: Intraoperative findings of 16 cases of vestibular schwannoma treated with an initial surgery were studied with an aim to determine if the cases had a dura-like membrane. Then we studied microscopic findings of the dura-like membrane using hematoxylin and eosin, Masson trichrome, and immunohistochemical staining in 2 cases.

Results: The dura-like membrane was observed in 8 out of 16 cases. The average tumor size of the cases that had a dura-like membrane was 30 ± 8.1 mm, and Koos grading 4 was in 7 out of 8 cases, and one was grade 3. In cases without a dura-like membrane, these values were significantly smaller, with an average tumor size of 12.8 ± 5.2 mm, and Koos grading 4 was only in 1 of 8 cases, grade 3 was in 2 cases, and other 5 cases were grade 2. The outermost dura-like membrane enveloped the vestibular schwannoma around the internal acoustic meatus and was continuous with the dura mater. Reactive angiogenesis was observed in the dura mater. Microscopic findings proved its continuity with the dura mater. In one case, the facial nerve was damaged before it was identified during subcapsular dissection. In that case, the dura-like membrane negatively affected our ability to identify the facial nerve.

Conclusions: A dura-like membrane sometimes envelops vestibular schwannoma around the internal acoustic meatus. Recognition of this membranous structure is important for the surgical preservation of facial and acoustic nerves.

Key Words: Acoustic neurinoma, acoustic neuroma, dura mater, operation, surgery, vestibular schwannoma

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**INTRODUCTION**

Preservation of the cochlear nerve and hearing capability remains challenging during surgery for large vestibular schwannoma, however, preservation of the facial nerve function is mandatory in this era. Recognition of the membranous structure and surgical cleavage plane of vestibular schwannoma is important for the preservation of function as well as intraoperative monitoring. The

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membranous structure of vestibular schwannoma has been reported by many authors to date.^[2,4-6] Especially, “is a vestibular schwannoma subarachnoid or epiarachnoid” has been well-discussed so far.^[2,4,6] To our knowledge, however, an outermost membranous structure that envelops the vestibular schwannoma around the internal acoustic meatus (IAM) has not been previously documented. We report a series of cases to examine the histologic and microanatomic features of this “dura-like membrane” along with the characteristics of vestibular schwannomas that manifest it.

MATERIALS AND METHODS

Intraoperative findings of 16 cases of vestibular schwannoma treated with an initial surgery using a lateral suboccipital approach (retrosigmoid approach) between February and March 2015 were prospectively studied with an aim to determine if the cases had a dura-like membrane. Cases of neurofibromatosis type 2 vestibular schwannomas were excluded. The tumor size, Koos grading, and existence of a contact between the dura mater of the petrous bone and the tumor were also studied by magnetic resonance imaging (MRI). All cases were operated upon in the prone-lateral or park-bench position. Facial nerve free-run and evoked electromyogram (EMG), facial nerve motor evoked potential (MEP), and acoustic brain stem responses (ABR) were monitored intraoperatively.

We studied the microscopic findings related to the dura-like membrane in two cases of vestibular schwannoma. In both the cases, the Koos grading of the tumor was 4, and the maximal tumor diameter was 37 mm [Figure 1]. Preoperative facial nerve function was intact, with a House–Brackmann (HB) grade of 1.

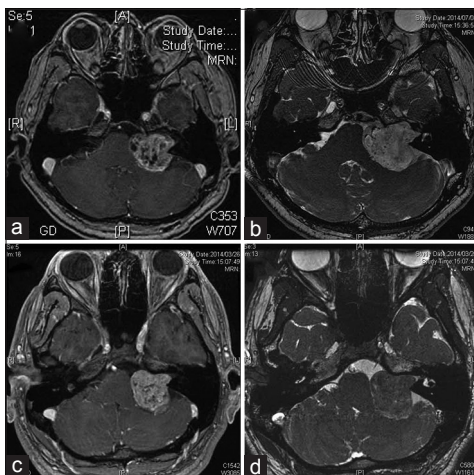


Figure 1: (a) Gadolinium-enhanced T1-weighted image of the first case. (b) Constructive interference in steady state image of the first case. (c, d) Respective images of the second case

A continuous sheet of the dura-like membrane was taken from the dura mater on the petrous bone just behind the IAM to the tumor surface, and was used as a specimen for microscopic examination.

Microscopic findings of the dura-like membrane were studied on a paraffin-embedded specimen, using classical hematoxylin and eosin (H and E), Masson trichrome (MT), and immunohistochemical staining. S-100, myelin basic protein (MBP), neurofilament (NF), and epithelial membrane antigen (EMA) stains were used for the first case. S-100 and MBP stains were used for the second case. The specimens were sectioned in a plane perpendicular to the dura-like membrane surface to contain the posterior wall side and the tumor side in each section.

This study was conducted in accordance with the ethical standards of the ethics committee of Keio University School of Medicine and with the Helsinki Declaration of 1975, as revised in 2000 and 2008.

RESULTS

Characters of cases with the dura-like membrane

The dura-like membrane was observed in 8 of 16 cases. The average tumor size of the cases that had a dura-like membrane was 30 ± 8.1 mm, and Koos grading 4 was in 7 out of 8 cases, another one was grade 3. In cases without a dura-like membrane, these values were significantly smaller, with an average tumor size of 12.8 ± 5.4 mm ($t(N = 16) = 5.15, P < 0.01$) and Koos grading 4 was only 1 in 8 cases, grade 3 was in 2 cases, and other 5 cases were grade 2. All the tumors with the dura-like membrane were Koos grade 3 or 4 and larger than 24 mm. The dura-like membrane existed in all 6 cases (100%), in which a contact between the dura mater of the petrous bone and the tumor was confirmed in MRI, however, this membrane was observed in only 2 out of 10 cases (20%) that had no such contact.

Intraoperative findings related to the dura-like membrane

Intraoperative findings showed that the outermost dura-like membrane enveloped the tumor around the IAM, but it was not fully circumferential in most of the cases. The size of the enveloped area varied among cases [Figures 2 and 3]. The surface appearance of the dura-like membrane was also different among cases; it was typically less dense than the dura mater, however more similar to the dura mater than the tumor surface. The dura-like membrane appeared to be continuous with the dura mater, and it appeared as if this connective tissue layer was derived from the dura mater and trailed over the tumor. The membrane contained microscopic vessels, which appeared to provide vascular supply to the

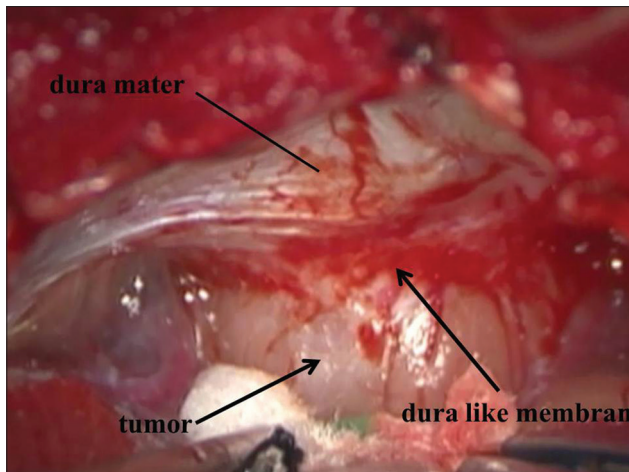


Figure 2: A representative case of the dura-like membrane. The membrane, tumor, and the dura mater of the petrous bone are shown

tumor. Angiogenesis was also observed on the contiguous portion of the dura mater in 7 out of 8 cases that showed a dura-like membrane. There were no findings of angiogenesis on the contiguous dura mater in the other 6 cases in which there was no dura-like membrane.

Operation and clinical course

The dura mater of the petrous bone just behind the IAM was peeled off, and then “the posterior wall of the IAM was carefully drilled into. We usually try to confirm the location of the facial nerve by facial EMG monitoring at the IAM and identify a border between the tumor and the facial nerve. A specimen of the dura-like membrane was taken after confirmation that there was no nerve just under the specimen in two cases [Figure 4].

We usually perform a subcapsular dissection of vestibular schwannoma. The outer layer of the tumor forms a “capsule” that is derived from the tumor origin nerve, and this capsule is usually not removed at our institution in order to preserve nerve function.

Facial nerve function was preserved in 75% (6 of 8) of the cases with the dura-like membrane. In one of the cases used for microscopic observation, the facial nerve was severed before it was identified during subcapsular dissection around the IAM. The presence of the dura-like membrane would negatively affect the surgical outcome in this case. The dura-like membrane was fibrous and surrounded the other structures. The facial nerve and the tumor were tightly attached to the dura-like membrane, and hence it was difficult to recognize the facial nerve. We were unable to confirm the facial nerve by EMG stimulation until tumor removal was finished, at which point a distal edge of the severed facial nerve was confirmed. The patient complained of HB grade 6 facial paralysis immediately following the surgery. Another HB grade 3 facial paralysis was observed in a case after the

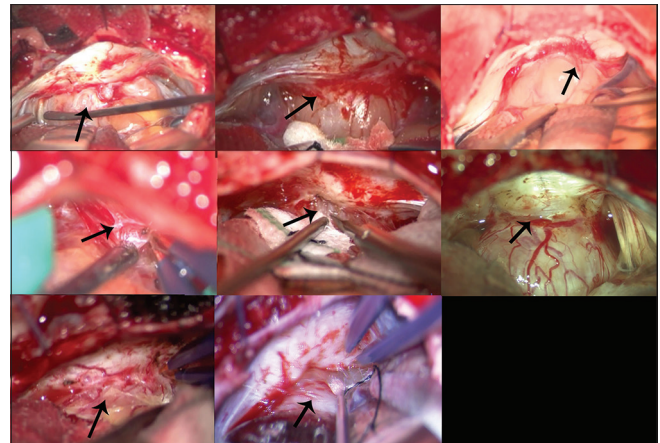


Figure 3: Photographs of operative views of the “dura-like membrane” as seen in all 8 cases (black arrow). Angiogenesis is also visible on the contiguous dura mater in most cases. Cases shown in g and h underwent microscopic observation

surgery. The facial nerve and its function were completely preserved in the other 6 cases. The capsule of the tumor remained, however, near-total resection was achieved in 6 cases.

Microscopic findings of the dura-like membrane in two cases

H and E, MT, S-100, MBP, NF, and EMA stains were used for case 1. MT stains myelin (shown in red), NF and MBP stain vestibular nerve fibers, and the schwannoma was stained by S-100. The vestibular schwannoma and vestibular nerve fibers are seen in the middle of the specimen in these stains [Figure 5]. The tumor and nerve fibers were covered by a very thick connective tissue layer (>500 μm), which was stained blue using MT staining, and this connective tissue layer was apparently far thicker than normal outer thin connective tissue layer that was thought to be the perineurium in a previous report.^[5] This thick connective tissue layer was continuous with the dura mater of the IAM posterior wall. This connective tissue layer was the dura-like membrane that enveloped the vestibular schwannoma around the IAM, and it also contained vessels around the tumor. The same microscopic findings for H and E, S-100, and MBP staining were seen in case 2 [Figure 6].

DISCUSSION

The dura-like membrane enveloped a section of the vestibular schwannoma around the IAM, and this fibrous layer was tightly attached to the tumor. Vestibular schwannoma usually originates from the inferior or superior vestibular nerve. The facial and cochlear nerves are pressed against the wall of the IAM, and these nerves cling closely to the exterior of the enlarged tumor in the cerebellopontine angle (CPA) cistern part. Thus, the facial and cochlear nerves are usually the most laterally

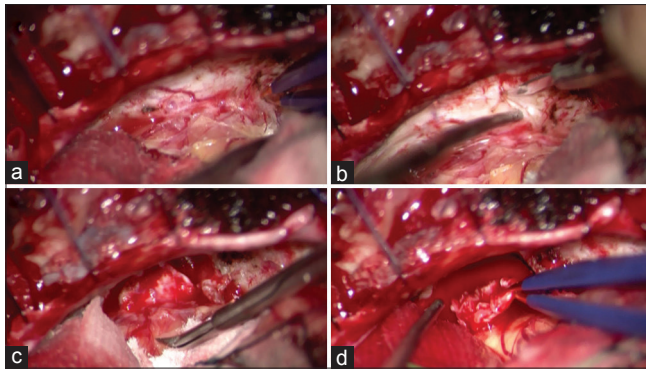


Figure 4: Photographs of operative procedures for harvesting a specimen of the “dura-like membrane” in the first case. (a) The outermost dura-like membrane envelops a part of the tumor around the internal acoustic meatus (IAM) (black arrow). The dura-like membrane appears to be an extension of the dura mater, and this layer seems to trail over the tumor. The membrane contains numerous microscopic vessels, and it appears to provide vascular supply to the tumor. Angiogenesis is also observed on the contiguous dura mater (white arrow). (b-d) A specimen of the dura-like membrane is taken from the dura mater, consisting of a continuous sheet from the surface of the posterior wall of the IAM to the tumor surface (black arrow)

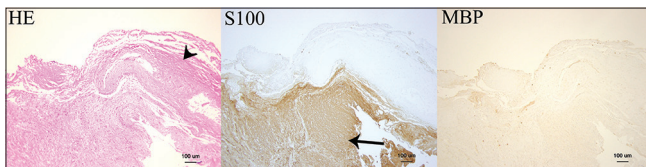


Figure 6: Microscopic findings seen in the second case ($\times 100$). Hematoxylin and eosin, S-100, and myelin basic protein (MBP) stains are shown. The tumor is stained with S-100 (arrow), and it is covered by an S-100-negative thick connective tissue layer referred to as the “dura-like membrane” (arrow head). MBP staining is slightly positive at the border between the tumor and the dura-like membrane

located structures in this surgery. However, the dura-like membrane was located outside of these nerves. This dura-like membrane continued from the dura mater of the petrous bone and enveloped the complex of tumor and nerves from the outside [Figure 7]. There was a tight adhesion between the dura-like membrane and the tumor or nerves, which made preservation of the nerves more challenging at the beginning of the subcapsular dissection. It becomes more difficult to identify correct layer for dissection when the dura-like membrane envelops the tumor and nerves. Thus, the dura-like membrane could be a risk factor in vestibular schwannoma surgery.

Sasaki *et al.* reported their subcapsular dissection method for vestibular schwannoma surgery.^[5] Although a very small amount of tumor remains as a capsule in this strategy, this subcapsular dissection has a theoretical advantage for facial and cochlear nerve preservation. Thus, we performed a similar surgery. Recognition of a correct subcapsular layer is the most important in the first step of the subcapsular dissection. However,

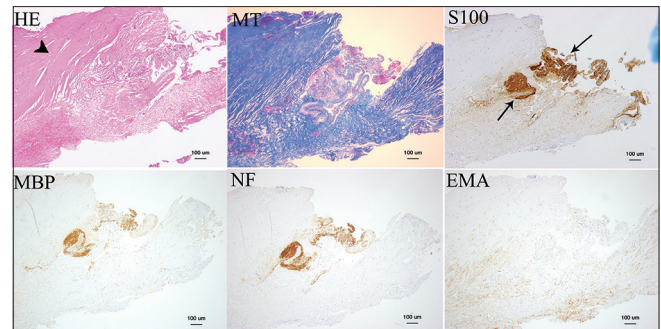


Figure 5: Microscopic findings seen in the first case ($\times 100$). Hematoxylin and eosin, Masson trichrome, S-100, myelin basic protein, neurofilament, and epithelial membrane antigen stains are shown. The thick connective tissue layer is the “dura-like membrane” that envelops the vestibular schwannoma (arrow head). S-100 stain showed the tumor (arrow)

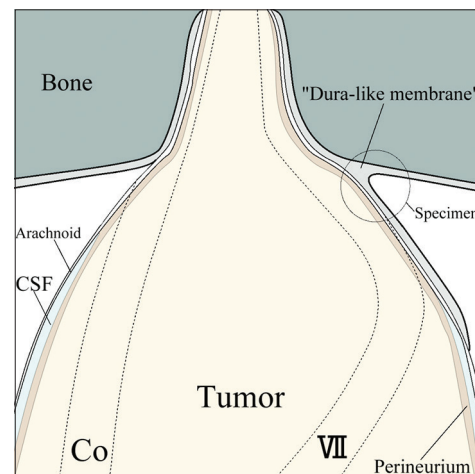


Figure 7: Schema of the “dura-like membrane” and other membranous structures of the vestibular schwannoma

because the dura-like membrane adhered to the capsule and nerves from the outside, it made the first step difficult. Unfortunately, the facial nerve was injured before confirming it in our first case of microscopic study.

The dura-like membrane was apparently continuous with the dura mater, and it appeared to be derived from the contiguous dura mater. Our 8 cases with a dura-like membrane had tumors that were large enough (>24 mm, and Koos grade 3 or 4) to adhere tightly to the dura mater. This contact between the dura mater and the tumor was observed in all cases where the dura-like membrane was seen, and it would thus be one of the required conditions for dura-like membrane origin. A preoperative MRI finding regarding whether there is contact between the dura mater and the tumor was considered a predictive factor for the presence of the dura-like membrane. Reactive angiogenesis within the surrounding dura mater was seen in all cases with a dura-like membrane, and this was apparently

induced by the tumor. Koutsimpelas *et al.* reported that vestibular schwannomas showed expression of vascular endothelial growth factor (VEGF) and basic fibroblast growth factor at both the mRNA and protein levels.^[3] This finding might indicate angiogenic and neurotrophic influence of these factors and possible involvements in growth of the tumor and the dura-like membrane formation. Migration of the membranous tissue that trails over the tumor from the dura mater would strongly contribute to the formation of the dura-like membrane.

Our colleague reported a similar pseudocapsule formation that covered both a trigeminal neurinoma and the trigeminal nerve fibers after gamma knife radiosurgery.^[1] The capsule was composed of thick connective tissue, and it was directly continuous with the dura of the posterior fossa. The macroscopic and microscopic findings of that capsule were similar to the dura-like membrane presented in this article. The trigeminal nerve fibers were covered, and adhered tightly to the pseudocapsule. Although there is a difference between this capsule and the dura-like membrane, in that this capsule formation was likely caused by an irradiation-mediated response, the most important finding is that both of these membranes were a continuation of the dura mater. Both the dura-like membrane and this capsule were thought to be derived from the dura mater, and we hypothesize that this may be due to a reactive change induced by the tumor itself, inflammation, or an irradiation-mediated response. Further investigation is needed to reveal the origin of the dura-like membrane.

CONCLUSION

A “dura-like membrane” was sometimes found to envelop a vestibular schwannoma around the IAM. Recognition of this membranous structure is important in vestibular schwannoma surgery, especially for the surgical preservation of the facial and acoustic nerves.

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Nil.

Conflicts of interest

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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