Retrolabyrinthine transsigmoid approach to complex parabrainstem tumors in the posterior fossa

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OBJECTIVE The surgical management of large and complex tumors of the posterior fossa poses a formidable challenge in neurosurgery. The standard retrosigmoid craniotomy approach has been performed at most neurosurgical centers; however, the retrosigmoid approach may not provide enough working space without significant retraction of the cerebellum. The transsigmoid approach provides wider and shallower surgical fields; however, there have been few clinical and no cadaveric studies on its usefulness. In the present study, the authors describe the transsigmoid approach in clinical cases and cadaveric specimens.

METHODS For the clinical study, the authors retrospectively reviewed the medical records and operative charts of patients who had been surgically treated for parabrainstem tumors using the transsigmoid approach between 1997 and 2019. They analyzed patient demographic and clinical data, as well as surgical and clinical outcomes. In the cadaveric study, they compared the surgical views obtained in different approaches (retrosigmoid, presigmoid, retrolabyrinthine, and transsigmoid) and measured the sigmoid sinus width at the level of the endolymphatic sac and the distance between the anterior edge of the sigmoid sinus and the endolymphatic sac on 35 sides in 19 cadaveric specimens.

RESULTS A total of 21 patients (6 males and 15 females) with a mean age of 42.2 (range 15–67) years were included in the clinical study. Eleven patients had meningioma, 7 had vestibular schwannoma, 2 had hemangioblastoma, and 1 had epidermoid cyst. Gross-total, near-total, and subtotal removal were achieved in 7 (33.3%), 3 (14.3%), and 11 (52.4%) patients, respectively. In the cadaveric study, 19 cadaveric specimens were used. The sigmoid sinus was cut in the middle, and the incision was extended from the retrosigmoid to the presigmoid dura. The dura was then retracted upward and downward like opening a door. The results indicated that this technique can widen the operative field anteriorly by approximately 2 cm as compared to the retrosigmoid approach and provides a better view anterior to the brainstem.

CONCLUSIONS The transsigmoid approach is useful for complex parabrainstem tumors in the posterior fossa because it provides a wider and shallower operative view with less retraction of the cerebellum. This enables safer tumor removal with less damage to important structures in the posterior fossa, resulting in better operative and clinical outcomes.

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rior to the brainstem without retraction. This reduces the risk of damaging important structures and, consequently, the risk of intra- and postoperative complications. This technique contributes to patient safety and improves outcomes. There have been only a few clinical studies of this approach \(^1-12\) and, to the best of our knowledge, no cadaveric studies.

In the present study, we describe the transsigmoid approach, investigate its feasibility for the treatment of posterior fossa tumors in a clinical study, and compare it to other surgical approaches in a cadaveric study.

**Methods**

**Ethical Considerations**

The study protocol was reviewed and approved by the institutional review boards of all participating hospitals. The requirement for informed consent was waived in this study; however, informed consent was obtained from all patients at the time of treatment.

**Clinical Study**

For the clinical study, we retrospectively reviewed the medical records and operative charts of patients who had been surgically treated for parabrainstem tumors using the transsigmoid approach between 1997 and 2019 at the following hospitals: Duke University Hospital, Durham, North Carolina; Shinkomonji Hospital, Fukuoka, Japan; Mobara Hospital, Chiba, Japan; Koto Memorial Hospital, Shiga, Japan; Minami Tohoku General Hospital, Fukushima, Japan; Atago Hospital, Kochi, Japan; Tessekai Hospital, Osaka, Japan; Fukushima Takanori Memorial Clinic, Chiba, Japan; and Tokyo General Hospital, Tokyo, Japan. We excluded patients with jugular foramen tumors because the approach to this area is different from our transsigmoid approach and the sigmoid sinus is frequently occluded prior to surgery. The decision to apply the transsigmoid approach was made at the discretion of the senior surgeons. We analyzed patient demographic and clinical data, as well as surgical and clinical outcomes. Extent of resection was classified into three groups as gross-total resection (GTR) with microscopic removal and no residual lesion on postoperative images, near-total resection (NTR) with no microscopic removal and no residual lesion on postoperative images, and subtotal resection (STR) with no microscopic removal and residual lesion on postoperative images.

**Transsigmoid Operative Technique**

Preoperative assessment of venous sinus flow is the crucial element for this approach. The transverse sinus, sigmoid sinus, and superior petrosal sinus should be examined using MR venography. In cases of a hypoplastic sigmoid sinus, the transsigmoid approach is probably safe. When the sigmoid sinus is dominant, we perform a two-stage surgical intervention. The first stage includes only the extradural approach, and an aneurysm clip is placed over the sigmoid sinus without the measurement of venous pressure. The patient is clinically monitored for 1–2 days to confirm their condition is stable; CT scanning is also performed. In the second stage, the sinus is ligated and tumor resection is performed.

After induction of general anesthesia and placement of a lumbar drain catheter, patients are placed in a lateral position with the head supported with a 3-pin head clamp or are placed in the supine position with the head lateral on an ear, nose, and throat pillow. Pin headrest fixation is optimal. A C-clamp or L-clamp is attached to the side arm of the Mayfield head holder to fixate a self-retaining spatula holder. A 2-mm tapered malleable brain spatula is used to support the cerebellum, preventing it from sagging into the operative field.

**Skin Incision.** A curve-shaped scalp incision of 2 inches (5 cm) is made 2 inches (5 cm) behind the ear, extending from the asterion to just below the digastric groove at the inferior nuchal line.

**Craniotomy.** A transmastoid retrolabyrinthine exposure is done using a high-speed drill. The presigmoid dura is exposed by removing the bone lateral, posterior, and superior to the semicircular canals, using drill bits of various sizes. It is not necessary to completely skeletonize the facial nerve, but the bone up to the fallopian canal should be removed. The translabyrinthine approach can be added to expand the surgical view in patients who have already lost their hearing. The bone over the sigmoid sinus is removed, and a retromastoid craniotomy is performed (3 × 3 cm).

**Dural Incision.** A dural incision is made anterior and posterior to the sigmoid sinus (Fig. 1A). The sigmoid sinus is double ligated with 3-0 Nuron sutures in its midportion, and the sinus is cut at its middle. This dural incision is extended into the retrosigmoid to the presigmoid dura through the sigmoid sinus. The sutures are retracted upward and downward like opening a barn door (Fig. 1B).

This H-shaped dural incision is recommended to achieve a wide opening and provide more anterior exposure than the standard retrosigmoid approach. It is completely different from the transsigmoid approach for jugular foramen tumors.\(^13\) When a jugular foramen tumor occludes the sigmoid sinus, the tumor is removed by opening the sinus. Our technique is used for resecting tumor anterior to the brainstem without retraction and preserving flow from the superior and inferior petrosal sinuses.

**Closure.** Bone wax is applied to the mastoid air cells,
and the craniotomy defect is filled with abdominal fat in order to prevent CSF leakage. Fat and fascia are placed in the middle ear to prevent CSF from leaking through the eustachian tube. The dural defect is patched with the fascia harvested in the surgical field before craniotomy or from the abdomen at the time of harvest.

**Cadaveric Study**

In the cadaveric study, we compared the surgical views obtained from different approaches (retrosigmoid, presigmoid, and transsigmoid) in 19 cadaveric specimens (Fig. 2). We also measured the width of the sigmoid sinus at the level of the endolymphatic sac and the distance between the anterior edge of the sigmoid sinus and the endolymphatic sac on 35 sides (Fig. 3).

**Statistical Analysis**

The parameters measured in the cadaveric study were compared between the right and left sigmoid sinuses using the t-test. Microsoft Excel (Microsoft Corp.) was used for the analysis. A p value less than 0.05 was considered statistically significant.
Results

Clinical Study

Patient Characteristics

Between 1997 and 2019, the transsigmoid approach was performed for treatment of parabrainstem tumors in 21 patients (6 males and 15 females) with a mean age of 42.2 (range 15–67) years. There were 11 patients with meningioma, 7 with vestibular schwannoma, 2 with hemangioblastoma, and 1 with epidermoid cyst (Table 1).

Clinical and Operative Outcomes

GTR, NTR, and STR were achieved in 7 (33.3%), 3 (14.3%), and 11 (52.4%) of the 21 patients, respectively. Postoperative complications were noted in a total of 4 patients: hearing loss in 3 (14.3%), facial palsy in 2 (9.5%), facial hypesthesia in 1 (4.8%), and diplopia in 1 (4.8%). The postoperative neurological deficits were related to the pathological resection. No complications due to venous infarction were observed in our series.

Illustrative Cases

Case 1. A 29-year-old woman complained of right facial numbness, hearing loss, and mild diplopia due to a right abducens nerve palsy. Brain MRI revealed a right-sided petroclival meningioma (Fig. 4). Surgery was performed using the transsigmoid approach. We obtained a wide and shallow surgical view. Although the right abducens nerve was involved with the tumor, all arteries and nerves were preserved. STR was achieved because a thin tumor layer was left on the surface of the brainstem and basilar artery perforating vessels because of adhesion. The patient was discharged without any new deficits.

Case 2. A 67-year-old man complained of left facial palsy and ataxia. MRI showed a left-sided petroclival meningioma (Fig. 6A). The sigmoid sinus on the left side was noted on the preoperative image (Fig. 6B). The first stage of the surgery was conducted to place an aneurysm clip over the sigmoid sinus 1 day prior to the second surgery (Fig. 6C). The patient had no symptoms caused by the temporary occlusion of the sigmoid sinus. The second stage of the surgery was performed using the transsigmoid approach. GTR was achieved (Fig. 6D). The patient was discharged without any new symptoms.
FIG. 6. Case 2. A: Preoperative T1-weighted MR image showing a left-sided petroclival meningioma. B: Preoperative 3D CT scan. C: CT scan after the first surgery. D: Postoperative T1-weighted MR image showing GTR of the meningioma. Figure is available in color online only.

Cadaveric Study

In the cadaveric study, we used 19 cadaveric specimens (35 sides). As shown in Fig. 2, the retrosigmoid and presigmoid approaches provide a narrow operative view. In contrast, the transsigmoid approach (Fig. 2D–F) provides a wide operative view to the cerebellopontine angle. The cranial nerves (V–XI) can be seen without retraction of the cerebellum (Fig. 2F). There were no significant differences in the measured distances between the right and left sigmoid sinuses (Table 2 and Fig. 3). Our results indicated that the transsigmoid approach can widen the operative field anteriorly by approximately 2 cm as compared to the retrosigmoid approach.

Discussion

The conventional retrosigmoid approach limits the surgeon’s ability to resect tumors anterior to the brainstem. The presigmoid approach provides narrow surgical fields with access to the front of the brainstem. The transsigmoid approach provides a wider space and more anterior access than those provided by the retrosigmoid approach.

The transsigmoid approach was initially performed in the early 20th century. However, the procedure was abandoned because of the high mortality due to excessive blood loss. In the modern era, the first paper detailing the use of this approach was published by Hitselberger and House in 1966. They used this approach in 10 cases of tumors with a two-stage surgery. The surgery failed in 1 patient because of increasing pressure in the posterior fossa, but it went well in the remaining 9 cases. Giannotta and Maceri reported 3 cases of the transsigmoid approach applied for basilar trunk aneurysms in 1988. All patients were discharged and returned to their previous activities. This approach has been applied for tumors and aneurysms.

The criteria for safe ligation and resection of the sigmoid sinus are not precisely known. Several methods have been reported to determine whether the sigmoid sinus can be cut safely. Rosenberg et al. reported that adequate collateral venous sinus flow can be determined by viewing the size of the contralateral transverse sinus and the influence of the transverse sinus on a preoperative catheter angiogram or MR angiogram. If the sinus is temporarily occluded and the sinus pressure does not increase, this would indicate that there is adequate collateral flow through the opposite transverse sinus. Spetzler et al. found that if the intravenous pressure does not increase by more than 7 mm Hg with temporary clamping of the sigmoid sinus, then the patient has adequate collateral flow. The sinus cannot be safely ligated with pressure increases of more than 10 mm Hg. Cantore et al. also stated that venous pressure should not exceed 10 cm H2O. Day et al. reported that an increase in intravenous pressure of less than 5 mm H2O with temporary occlusion can be considered safe. Hwang et al. reported that the identification of brain swelling after intraoperative test clamping of the sigmoid or transverse sinuses for more than 30 minutes was a reliable indicator. Shitara et al. concluded that a venous pressure increase of less than 10 mm Hg during an endovascular balloon occlusion test or intraoperative sinus clipping occlusion test portends a safe ligation.

In an experimental study, Kanno et al. showed that the unilateral sigmoid sinus or transverse sinus in a monkey can be safely occluded if the vein of Labbe, superior petrosal sinus, and bilateral transverse sinuses are readily visible on preoperative angiograms. Fortunately, we did not encounter venous congestion, venous infarction, or brain swelling in our series.

The cadaveric study showed that the transsigmoid approach provided a wide operative view anterior to the brainstem. As a result, there is an advantage in the angle at which surgeons are looking and the degree to which it allows surgeons to look more to the other side of the clivus without retraction of the brainstem. The retrosigmoid approach is often used by neurosurgeons, except in cases of large parabrainstem tumors with a large component anterior to the brainstem and no posterior component to naturally retract the cerebellum. Viewing the tumor anterior

| Table 2. Cadaveric data on the sigmoid sinus and presigmoid dura |
|------------------|------------------|------------------|
| Variable         | Rt Side (n = 16) | Lt Side (n = 19) | p Value |
| A                | 10.6 ± 1.2       | 10.1 ± 1.4       | 0.16    |
| B                | 8.7 ± 0.9        | 8.3 ± 1.1        | 0.10    |
| C                | 19.4 ± 1.7       | 18.4 ± 1.9       | 0.06    |

A = width of sigmoid sinus at endolymphatic sac level; B = distance from anterior edge of sigmoid sinus to endolymphatic sac; C = A + B. Values are expressed as the mean ± standard deviation in millimeters, unless indicated otherwise. There were no significant differences in any of the measured parameters between the right and left sigmoid sinus.

References

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to the brainstem would require dangerous retraction. The operative field of the presigmoid approach is very narrow. The transsigmoid approach enables less retraction of the cerebellum and is much safer. The limitation of the transsigmoid approach compared to other approaches is the risk of sinus occlusion.

The limitations of this study include its retrospective design and small sample size. Hence, the generalizability of our findings is limited. However, careful selection of cases suitable for this approach will help neurosurgeons perform a safer surgery for complex parabrainstem tumors. Future studies are warranted to establish a standard method for cutting the sigmoid sinus safely.

Conclusions

The transsigmoid approach is useful for complex parabrainstem tumors in the posterior fossa because it provides a wider and shallower operative view. This enables less cerebellar retraction and reduces the risk of damage to important structures in the posterior fossa, resulting in better operative and clinical outcomes.

References


Disclosures

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

Author Contributions

Conception and design: Kinoshita, Fukushima. Acquisition of data: Kinoshita, Sato, Carter, Bawornvaraporn, Fukushima. Analysis and interpretation of data: Kinoshita. Drafting the article: Kinoshita. Critically revising the article: Zomorodi, Friedman, Nakamura, Fukushima. Reviewed submitted version of manuscript: Friedman, Fukushima. Statistical analysis: Kinoshita. Administrative/technical/material support: Zomorodi, Friedman, Nakamura, Fukushima. Study supervision: Friedman, Nakamura, Fukushima.

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