Analysis of Temporobasal Vein with Short Subdural Segment for Anterior Transpetrosal Approach

Ryota Tamura, Masahiro Toda, Yukina Morimoto, Mizuto Sato, Takenori Akiyama, Kazunari Yoshida

■ BACKGROUND: **The anterior transpetrosal approach (ATPA) is applied to petroclival and brainstem lesions. Although neurosurgeons need to minimize the risk of neurologic complications, brain retraction is necessary for procedures of ATPA. Bridging veins (BVs) limit mobility of the temporal lobe. In the present study, BVs around the petrous bone were analyzed, focusing on the dural entrance and termination points.**

■ METHODS: **The relationship between subdural and meningeal segments of temporobasal veins (TBVs) was analyzed by preoperative computed tomography venography in 102 patients who underwent ATPA. TBVs were classified by the dural entrance and termination points.**

■ RESULTS: **TBVs mainly entered the transverse sinus and rarely entered transverse-sigmoid sinus (T-S) junction and superior petrosal sinus (SPS). TBVs entered a dural sinus either directly or indirectly through a meningeal vein. The changes in vascular diameter of the lumen, shape, and course were identified between the subdural and meningeal segments. Generally, BVs with long subdural segment do not limit mobility of the temporal lobe. TBVs draining into the T-S junction and SPS tended to be shorter than those draining into the transverse sinus. Furthermore, a few TBVs indirectly entered the dural sinuses through the meningeal vein (early dural entrance). The subdural segment of these TBVs was much shorter.**

■ CONCLUSIONS: **TBVs entering the T-S junction or SPS with short subdural segment may limit the mobility of the temporal lobe. Changes in vascular diameter, shape, and course were detected by computed tomography venography, which was helpful to detect the subdural-meningeal transition.**

INTRODUCTION

The subtemporal approach (STA) was first described by Naffziger in 1928, and it is an effective approach for upper-middle clival tumor, epidermoid cyst, and aneurysm of the basilar tip or trunk.[1] STA provides excellent exposure of the posterior cranial fossa and shortens the working distance between the surface of the skull and the cerebellopontine angle compared with the posterior approach.[1-10] In 1985, Kawase et al. described a modification of the extended middle fossa approach for the treatment of low-lying basilar aneurysms, which is one of the STAs and named the anterior transpetrosal approach (ATPA).[7,11-13]

Although neurosurgeons need to minimize the risk of neurologic complications, brain retraction is necessary for procedures using ATPA. Bridging veins (BVs) that drain into the adjacent dural sinus often limit mobility of the temporal lobe during operation.[14-18] BVs are pivotal to determine the surgical corridor and approach for skull base lesions.[19] Because BVs serve as the final pathway for venous drainage of the brain, sacrificing BVs sometimes results in severe disturbance of venous return, subsequent brain edema, and hemorrhage.[20-22] To prevent BV-related complications, we must take care with the direction of brain retraction. However, BVs sometimes rupture because they

Key words
- Anterior transpetrosal approach
- Bridging vein
- Dural sinus
- Meningeal vein
- Subtemporal approach
- Temporobasal vein

Abbreviations and Acronyms
ATPA: Anterior transpetrosal approach
BVs: Bridging veins
CTV: Computed tomography venography
DSV: Digital subtraction venography
MRV: Magnetic resonance venography
SMCV: Superficial middle cerebral vein
SPS: Superior petrosal sinus
STA: Subtemporal approach
TBV: Temporobasal vein
T-S junction: Transverse-sigmoid sinus junction

Department of Neurosurgery, Keio University School of Medicine, Tokyo, Japan

To whom correspondence should be addressed: Masahiro Toda, M.D., Ph.D.
[E-mail: todam@keio.jp]

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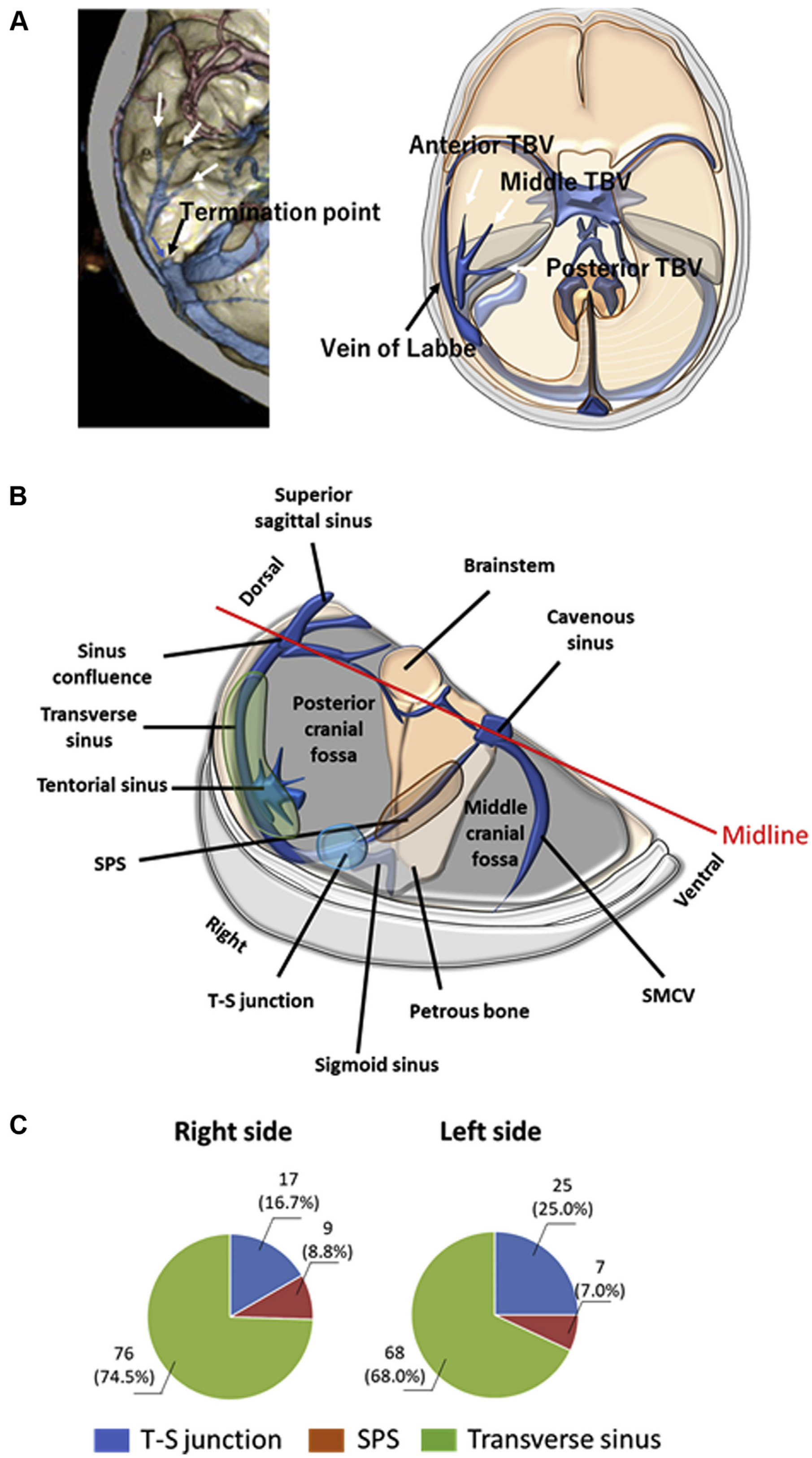

A
Termination point
Anterior TBV
Middle TBV
Posterior TBV
Vein of Labbe
B
Superior sagittal sinus
Dorsal
Brainstem
Cavenous sinus
Sinus confluence
Transverse sinus
Posterior cranial fossa
Tentorial sinus
Middle cranial fossa
Midline
SPS
Ventral
Right
T-S junction
Petrous bone
SMCV
Sigmoid sinus
C
Right side
Left side
17 (16.7%)
9 (8.8%)
76 (74.5%)
25 (25.0%)
7 (7.0%)
68 (68.0%)
T-S junction
SPS
Transverse sinus

have many different patterns of their course, length, and diameter.[23-26] Generally, BVs with long subdural segment do not limit mobility of the temporal lobe.

Most of the temporal veins, which drain the temporal convexity, terminate in the transverse, lateral tentorial sinus, or in the vein of Labbé. The temporobasal veins (TBVs), which mostly drain the inferior surface of the temporal lobe, commonly end in the transverse sinus through the lateral tentorial sinus.[16,27] Although TBVs have not been fully discussed, these inconspicuous veins are important for risk avoidance, because they are short and often out of working operative field in ATPA.

In the present study, TBVs around the petrous bone were analyzed, focusing on the dural entrance and termination points. TBVs with short subdural segment (early dural entrance) have particularly limited mobility, which could be evaluated by the preoperative radiographic neuroimages. If these TBVs can be preoperatively evaluated, ATPA (and STA) can be more safely performed.

MATERIALS AND METHODS

The current study was approved by our institutional review board. We also obtained written informed consent from all patients. For this retrospective analysis, we collected computed tomography venography (CTV) of 102 patients who underwent surgery via ATPA at our hospital from January 2009 to December 2018 (31 male and 71 female patients; age range, 6—78 years; mean age, 52 years). We investigated the venous circulation around petrous bone with junction of the superior petrosal sinus (SPS), transverse sinus, and sigmoid sinus, which may play a key role in the ATPA.

Computed Tomography Venography

Dynamic CTV images were procured using a 320-detector row dynamic volume CT scanner (Aquilion ONE; Toshiba Medical Systems, Tochigi, Japan). Scans were angled parallel to a line drawn from the posterior margin of the foramen magnum to the superior margin of the orbita. Patients underwent a helical acquisition high-resolution, non-enhanced CT scan with 0.5-mm slice thicknesses before the administration of intravenous contrast media. Then, we obtained a volume acquisition that was used as a mask acquisition. Volumetric data from the mask were subtracted from the volume data subsequently acquired, essentially providing a 3-dimensional volumetric subtraction angiogram to obtain vessel-specific images.

Data Analysis

Transverse sinus, sigmoid sinus, vein of Labbé, SPS, tentorial sinus, and veins coursing along the middle cranial fossa floor, including anterior, middle, and posterior TBVs were evaluated in each case. To avoid the possibility of biasing the results, a retrospective review of radiographic images of 102 patients was performed blinded by 3 authors who independently studied the scans. Surgical data were retrieved from operation reports and videos, and all other perioperative information was collected from hospital medical records.

The χ^2 test was used to compare the distribution of several types of TBVs in each side. Analyses were performed with IBM SPSS statistics (IBM Corp., Armonk, New York, USA). A P value of <0.05 was considered significant.

RESULTS

Venous Circulation of TBVs

CTV was used to evaluate TBVs of all 102 patients. Anterior, middle, and/or posterior TBVs were detected, forming a common trunk (Figure 1A). A common trunk of TBVs drained into the transverse sinus directly or indirectly through the tentorial sinus, transverse-sigmoid sinus junction (T-S junction), and SPS (Figure 1B). T-S junction was defined as the transitional zone where the transverse sinus ended by the vertical descending segment of the sigmoid sinus. In most cases, TBVs drained into the transverse sinus (right: 74.5%, left: 68.0%) (Figure 1C). There was no significant difference in distribution of the drainage sinus between the right and left sides ($P = 0.48$).

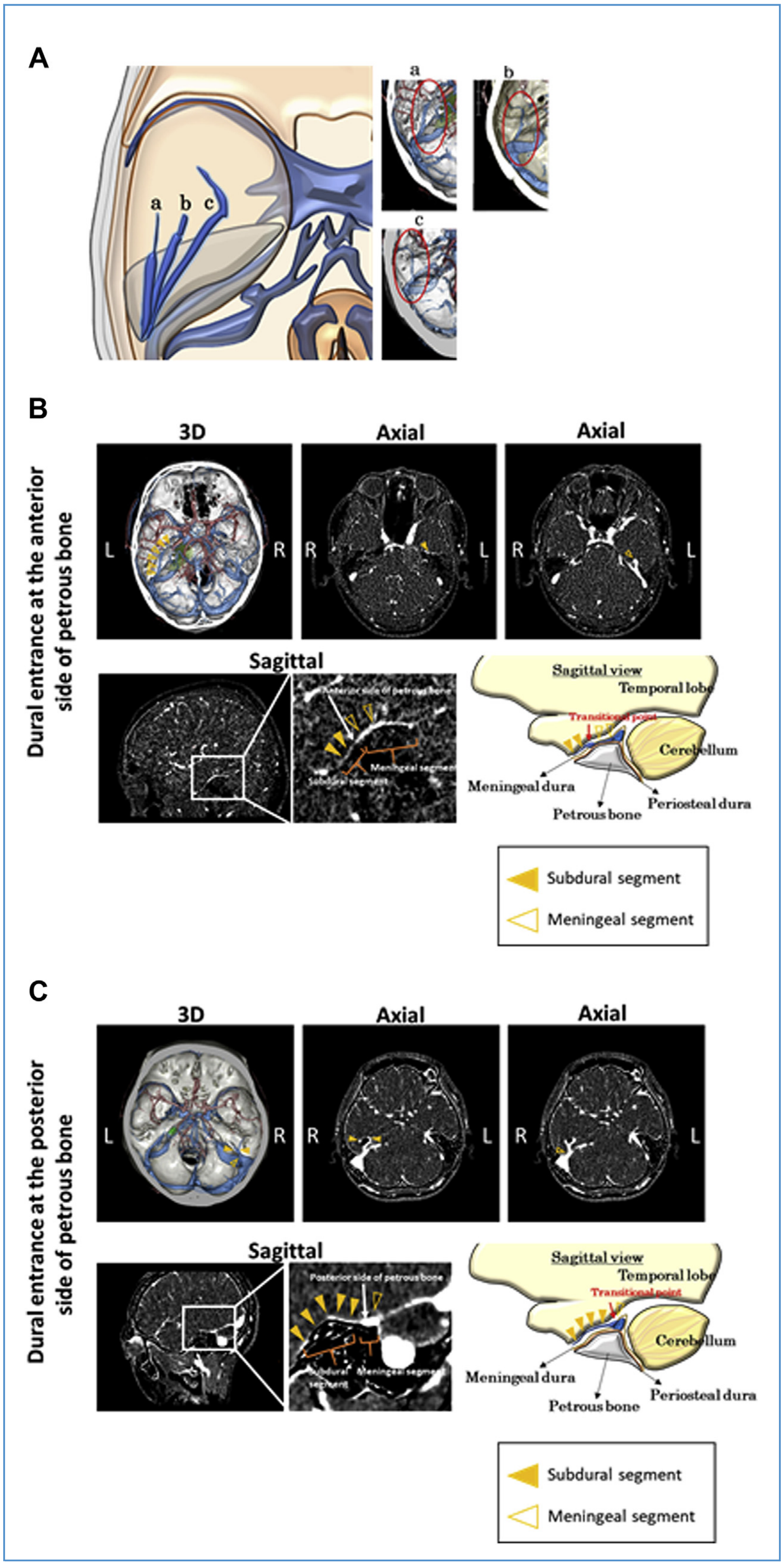
Detection of Dural Entrance Point on CTV

BVs entered the dural sinus either directly or indirectly through a meningeal vein. A previous study demonstrated that changes between the subdural and meningeal segments in vascular density, shape, course, and diameter of the lumen were identified.[28] This transitional point of the TBVs could be visualized by CTV. In particular, the changes in vascular shape, diameter, and course were helpful in detecting the subdural-meningeal transition (Figure 2A). The change from a round lumen in the subdural segment to a flat lumen in the meningeal segment was identifiable. In addition, veins in the meningeal segment tended to show a larger diameter than those in the subdural segment. When the diameter of veins is small, rapid change of the vascular course provided some indication. The dural entrance point was defined based on the anterior or posterior side of petrous bone in the present study that was easily evaluated on sagittal view of CTV. The sagittal view of CTV showed the following 2 patterns: short subdural segment (early dural entrance) (Figure 2B), and long subdural segment (late dural entrance) (Figure 2C) that directly entered the dural sinus.

Classification of TBVs

All dural entrance points could be assessed by changes in vascular diameter, shape, and course between subdural and meningeal segments on CTV. TBVs were classified into 3 types based on the

Figure 1. Distribution of termination points in the common trunk of temporobasal veins (TBVs). (**A**) Typical example of anterior, middle, and posterior TBVs (*white arrows*) are shown. (**B**) There are 3 termination points of TBVs: transverse sinus through tentorial sinus, T-S junction, and SPS. (**C**) Proportion of termination points. There was no significant difference in distribution of the termination points between the right and left side. Most TBVs drained into the transverse sinus on both sides. SPS, superior petrosal sinus; T-S junction, transverse-sigmoid sinus junction; SMCV, superficial middle cerebral vein.


A
a
b
c
B
Dural entrance at the anterior side of petrous bone
3D
Axial
Axial
L
R
R
L
R
L
Sagittal
Sagittal view
Temporal lobe
Transitional point
Cerebellum
Meningeal dura
Petrous bone
Periosteal dura
Subdural segment
Meningeal segment
C
Dural entrance at the posterior side of petrous bone
3D
Axial
Axial
L
R
R
L
R
L
Sagittal
Posterior side of petrous bone
Sagittal view
Temporal lobe
Transitional point
Cerebellum
Meningeal dura
Petrous bone
Periosteal dura
Subdural segment
Meningeal segment

drainage termination sinus and dural entrance points detected by CTV. Type 1a TBVs directly entered the T-S junction (long subdural segment pattern), and Type 1b indirectly entered the T-S junction through the meningeal vein (short subdural segment pattern) (Figure 3A). Type 2a TBVs directly entered the SPS (long subdural segment pattern), and Type 2b indirectly entered the SPS through the meningeal vein (short subdural segment pattern) (Figure 3B). Type 3 TBVs directly or indirectly entered the transverse sinus (Figure 3C). Although Type 3 TBVs sometimes showed indirect patterns, all dural entrance points were identified in the tentorium.

Figure 4A shows the distribution of each pattern. Short subdural segment types (Type 1b and Type 2b) rarely existed (Type 1b: 4.9%, Type 2b: 2.5%, total 7.4%). Dural entrance points detected by CTV were traced into the skull base illustration (Figure 4B–C). The earliest dural entrance point of Type 1b and Type 2b TBVs was located on the anterior side of petrous bone (Figure 4B–C). There was no significant difference in existence ratio of Type 1b and 2b between the right and left side ($P = 0.76$).

Operative Image of TBVs with Short Subdural Segment

Figure 5 shows actual operative images of 2 cases. CTV showed Type1b TBVs on the right side (Figure 5A) and left side (Figure 5C), suggesting change of shape, course, and diameter. Intraoperative images showed TBVs between temporal lobe and middle cranial fossa floor dura matters (Figure 5B–D). As CTV indicated, these TBVs indirectly entered the T-S junction through the meningeal vein (short subdural segment pattern). Dural entrance point was clearly observed during operation, limiting the mobility of the temporal lobe (Figure 5B–D).

The Relationship Between TBVs and Perioperative Complications

In the present study, postoperative hemorrhage in the temporal lobe was observed in 5 of 102 cases. The superficial middle cerebral vein (SMCV) was preserved in all the cases. Of the 5 cases, 2 showed early dural entrance (Type 1b and 2b). According to the operative records, venous bleeding was observed in 4 cases from the subdural space on the posterior side of the craniotomy after the brain retraction. Of 4 cases, 3 cases showed early dural entrance (Type 1b). However, it is difficult to conclude that these perioperative complications were associated with TBVs because TBVs are short and often out of the working operative field in ATPA.

DISCUSSION

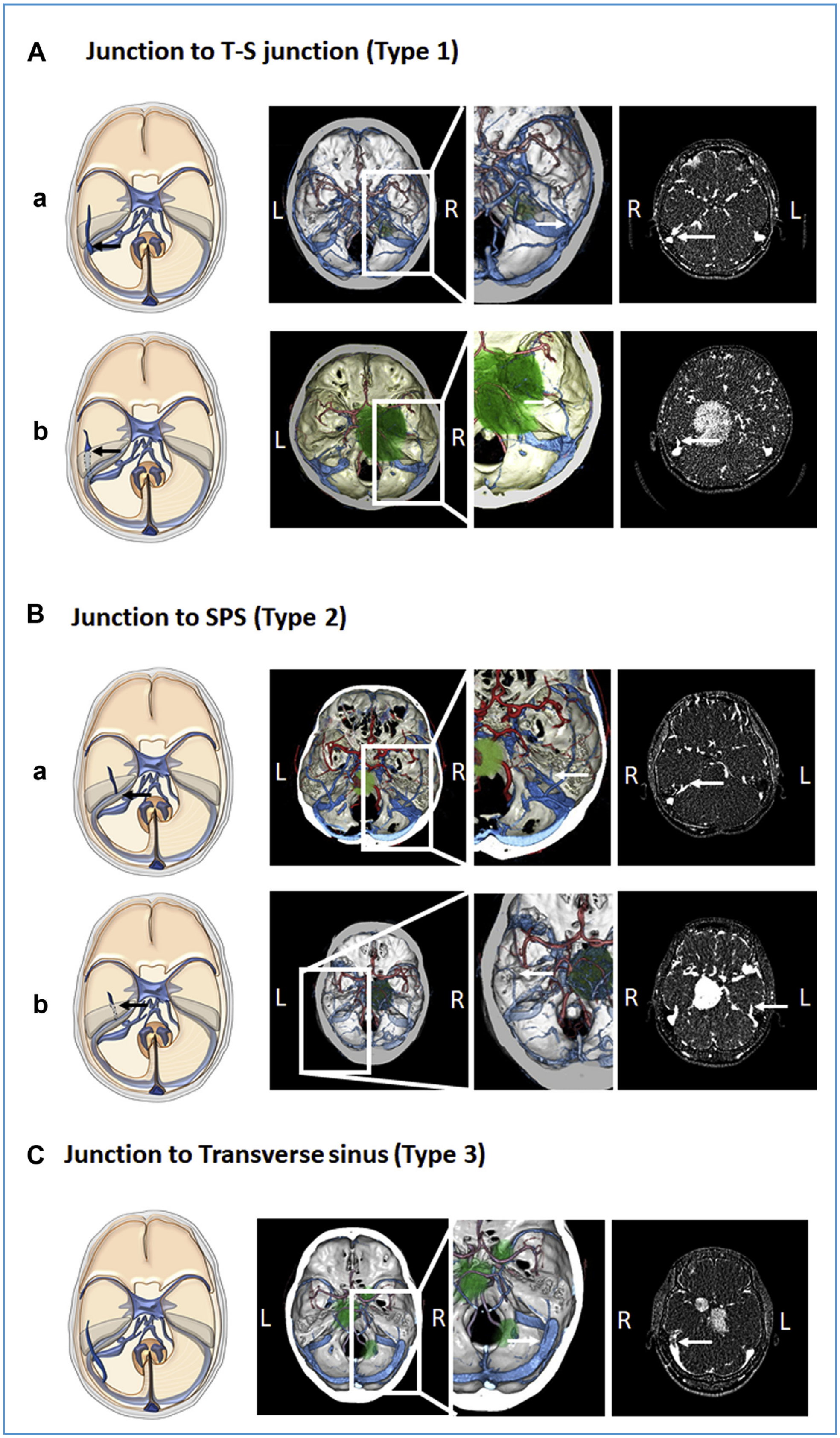
Because damage to BVs could cause disturbance of venous return and brain edema or venous infarction, preoperative evaluation is needed to manage BVs during an operation. In a previous study, the dural entrance points of the BVs in the middle cranial fossa were grouped into 4 areas: along the lesser sphenoid wing, cavernous area, floor of the middle cranial fossa, and petrosal area. The majority of the dural entrances were detected in the anterior cavernous area and lesser sphenoid wing area of the cadaver's head. These entrances were larger in diameter and more likely located in the anteromedial area.[13] Some draining veins of the temporal lobe, including the vein of Labbé, are known to be the origins of BVs, contributing to difficulty gaining adequate access during an operation.[29,30] In comparison, TBVs have not been fully evaluated in the imaging literature.

BVs on the middle cranial fossa often are associated with tentorial sinuses. Tentorial sinuses are venous channels that are divided into medial and lateral groups. They drain into the anterior side of the transverse sinus. The lateral tentorial sinuses are formed by convergence of the veins draining the basal and lateral surface of the temporal and occipital lobes. Furthermore, the veins draining into the lateral tentorial sinuses can be divided into the medial and lateral branches. The lateral branches include the vein of Labbé and the anterior, middle, or posterior temporal vein. The medial branches include the occipitobasal veins and the anterior, middle, or posterior TBVs.[31]

The common trunk of anterior, middle, and posterior TBVs is known to drain into the transverse sinus either directly or indirectly through the tentorial sinus, which is detected by CTV in the present study. The entry into the transverse sinus is usually located in the lateral third.[28,31-36] TBVs form a small venous lake and drain into the sinus. BVs draining into the transverse sinus are known to difficult to lengthen by dissecting away from the dural mater, because the subdural segment of the BVs in that region is not long.[31-36]

In the present study, some TBVs drained into not only transverse sinus but also the T-S junction and SPS, which tended to be shorter, and was interrupted by the retraction of brain and by the incision of the tentorium and the middle cranial fossa dura mater. In the cadaver's head, a small cluster of dural entrances was located around the posterior end of the SPS.[28] Furthermore, a few TBVs indirectly entered the dural sinuses through the meningeal vein (short subdural segment pattern). The subdural-meningeal transitional point was detected by CTV. Type 1b and 2b TBVs entered a dural sinus indirectly through a meningeal vein. Subdural segment of these TBVs was much shorter, requiring

Figure 2. Subdural and meningeal segment visualized by computed tomography venography (CTV). The subdural-meningeal transitional point of the temporobasal veins could be visualized by CTV. In particular, the changes in vascular diameter (a), shape (b), and course (c) were helpful in detecting the subdural–meningeal transition (**A**). The change from a round lumen in the subdural segment to a flat lumen in the meningeal segment was identifiable. In addition, veins in the meningeal segment tended to show a larger diameter than those in the subdural segment. When the diameter of veins is small, rapid change of the vascular course provided some indication. The dural entrance point was defined based on the anterior or posterior side of petrous bone in the present study that was easily evaluated on sagittal view of CTV. The sagittal view of CTV showed 2 patterns: short subdural segment (early dural entrance) (**B**), and long subdural segment (late dural entrance) (**C**) that directly entered the dural sinus. 3D, three-dimensional; L, left; R, right.


A Junction to T-S junction (Type 1)
a
b
L
R
B Junction to SPS (Type 2)
C Junction to Transverse sinus (Type 3)

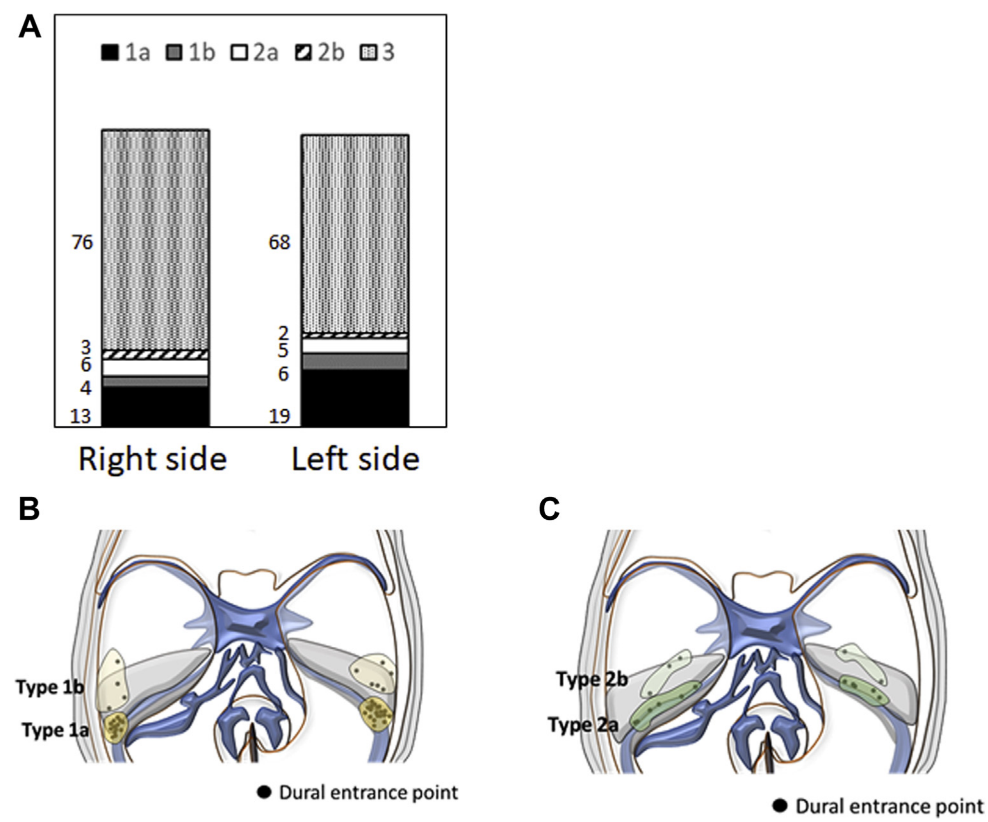


Figure 4. Distribution of temporobasal vein (TBV) types. (**A**) Distribution of TBV types in the right and left side. Short subdural segment types (Type 1b and Type 2b) rarely existed (Type 1b: 4.9%, Type 2b: 2.5%, total 7.4%). (**B** and **C**) Dural entrance points of Type 1 and 2 were traced into the skull base illustration.

particularly careful brain retraction. The present study showed actual operative cases with limited mobility of the temporal lobe caused by the TBVs with early dural entrance. Type 3 TBVs also showed relative short subdural segment pattern; however, all dural entrance points were in the tentorium. The length of subdural segment for Type 3 TBVs was longer than Type 1b and 2b TBVs.

The dural entrance point between the subdural and meningeal segments could be evaluated by CTV. In a previous study, the dural entrance point was identified on neuroimages such as CTV, magnetic resonance venography (MRV), or digital subtraction venography (DSV). The SMCV was carefully investigated to detect the dural entrance point. Han et al.[14,37] systematically compared anatomic features of the dural entrance point of BVs into the superior sagittal sinus, the transverse sinus in the cadaver's head, DSV, CTV, and MRV. Histologic features of the meningeal segment demonstrated that its inferior wall was thin with less supporting tissues. Therefore, the dural entrance point of BVs showed changes of the course, diameter, and intensity between

Figure 3. Classifications of temporobasal veins (TBVs). These illustrations focus only on termination point and dural entrance point to avoid confusion, because it is difficult to clearly detect all 3 TBVs (anterior, middle, and posterior) in some cases. In addition, some cases showed dural entrance before the formation of the common trunk. These 2 points are most important for preoperative radiographic evaluation in the present study. Type 1a TBVs directly entered the transverse-sigmoid sinus junction (T-S junction), and Type 1b TBVs indirectly entered the T-S junction through the meningeal vein (**A**). Type 2a TBVs directly entered the superior petrosal sinus (SPS), and Type 2b indirectly entered the SPS through the meningeal vein (**B**). Type 3 TBVs directly or indirectly entered the transverse sinus (**C**). Type 1b and Type 2b TBVs showed changes in vascular diameter, shape, and course of the lumen between subdural and meningeal segments on computed tomography venography images. TBVs draining into the T-S junction and SPS tended to be shorter than those draining into the transverse sinus. Furthermore, a few TBVs in Type 1 and 2 indirectly entered the dural sinuses through the meningeal vein (Type 1b and 2b). The subdural segment of these TBVs was much shorter, requiring particularly careful brain retraction. *White arrow* indicates the dural entrance point. L, left; R, right.

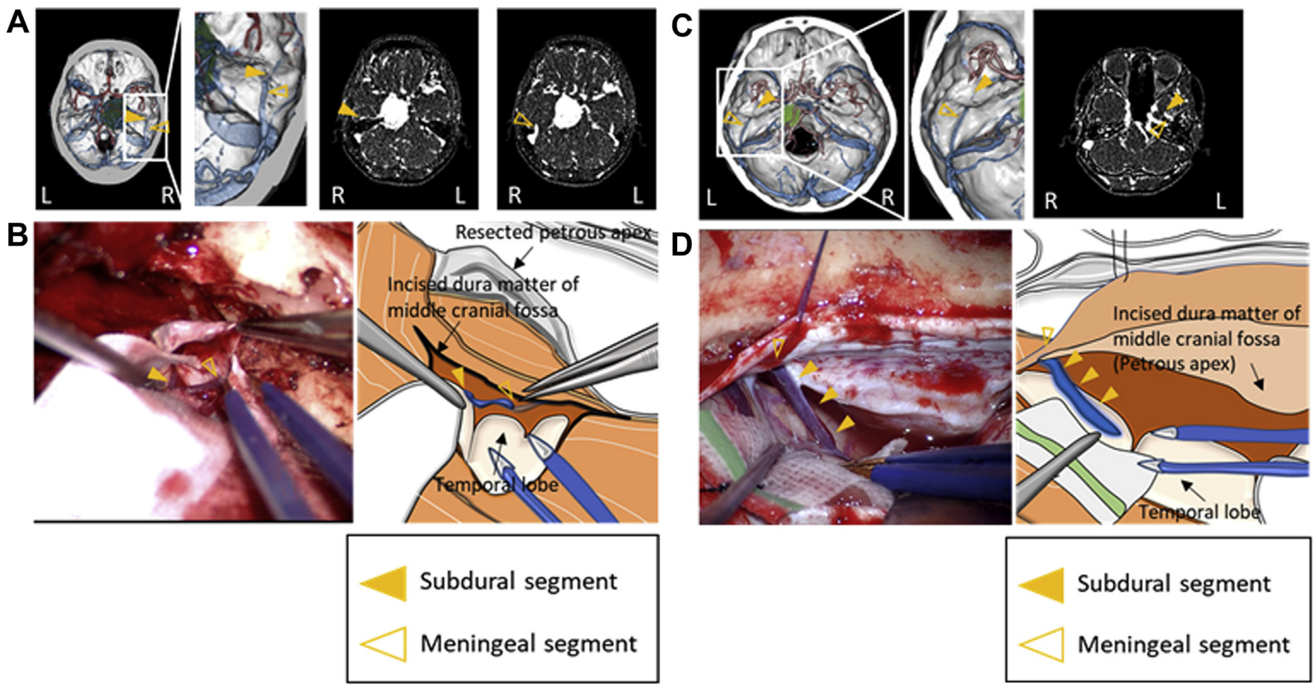


Figure 5. Temporobasal vein (TBV) with short subdural segment detected during the operation via the anterior transpetrosal approach (ATPA). Type 1b TBVs with short subdural segment were detected on the right (**A**) and left (**C**) side by preoperative computed tomography venography. (**B**–**D**) Operative views during ATPA. Early dural entrance point was detected after opening dura matter of middle cranial fossa floor. This problematic TBV with short subdural segment limited the mobility of the temporal lobe. L, left; R, right.

the subdural and meningeal segment on neuroimaging. In total, 80% of dural entrances of large veins, such as SMCV, could be identified in MRV. However, small BVs around petrous bone were still difficult to identify by MRV because of the current low sensitivity of the imaging modalities. Although the dextroscope was recommended to enhance magnetic resonance of the head to intuitively show temporal bridging veins, this was not a common modality.[14,38] Some authors considered DSV a better way to learn, because MRV of brain sometimes has false-negative results that may mislead neurosurgeons. However, DSV is an expensive and invasive examination.

In the present study, small draining veins of the temporal lobe, such as TBVs, could be clearly detected by CTV. The dural entrance points were confirmed. Particular attention should be paid to TBVs around petrous bone. Although the anteromedial area could be identified during operation via ATPA, the posterolateral area containing TBVs was often out of the working surgical field.

The present study has some limitations. The resolution of neuroimages must be discussed. In a previous study, there were more dural entrances detected in the cadaver's head than that detected in the CTV, MRV, and DSV in the middle cranial fossa, because the diameter of the dural entrances depicted by the neuroimages was larger than that in the cadaver's head.[14,28,38] Therefore, careful monitoring during an operation is necessary, even if critical TBVs are not detected by CTV. Furthermore, it is difficult to fix patterns of venous drainage because venous drainage highly depends on the nature, location, and vascularity of the tumor. In addition, we must carefully evaluate how these TBVs are highly and solely critical for the success of surgical procedure, and perioperative complications, such as brain edema and hemorrhage. The present study showed operative cases with limited mobility of the temporal lobe caused by the TBVs with early dural entrance. However, the actual tolerability of these TBVs against brain retraction during ATPA should be evaluated in greater detail using a large number of patients and/or cadaver's heads. SMCV is associated with severe postoperative complications, such as brain edema and hemorrhage, requiring careful preoperative evaluation. However, TBVs are not major veins because TBVs are short and often out of working operative field in ATPA. It is not clear whether the sacrifice of TBVs plays a role in the outcome. Further studies using a larger number of patients are warranted to confirm the findings and assess the relationship of TBVs with the success of the surgical procedure and postoperative complications.

CONCLUSIONS

Some TBVs drain into the T-S junction and SPS with short subdural segment, and these may particularly limit mobility of the temporal lobe. Changes in vascular diameter, shape, and course were detected by CTV, which was helpful to detect the subdural–meningeal transition.

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