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REVIEW PAPER

# The intracranial bridging veins: a comprehensive review of their history, anatomy, histology, pathology, and neurosurgical implications

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**Abstract**
*Introduction* The intracranial bridging veins are pathways crucial for venous drainage of the brain. They are not only involved in pathological conditions but also serve as important landmarks within neurological surgery.
*Methods* The medical literature on bridging veins was reviewed in regard to their historical aspects, embryology, histology, anatomy, and surgery.
*Conclusion* Knowledge on the intracranial bridging veins and their dynamics has evolved over time and is of great significance to the neurosurgeon.

**Keywords** Bridging · Veins · Intracranial · Anatomy · Venous

## Introduction

Bridging veins were first mentioned in the scientific literature in association with subdural hematomas. Trotter was the first to attribute bridging vein trauma as a possible cause of subdural hematomas [1]. In 1934, John Leary stated that the majority of subdural hemorrhages result from "rupture of bridging veins, which cross the subdural space, or of veins on the surface of the arachnoid [2]." In 1940, Cabot et al. attributed subdural hematomas to "rupture" of the so-called bridging veins [3].

An intracranial bridging vein is defined as a vessel located in the subarachnoid space that empties into the dural venous sinuses [4, 5]. Three types of bridging veins have been investigated: cerebellar bridging veins, temporal bridging veins, and anterior frontal cortical bridging veins [6–9]. They are most often located near the superior sagittal sinus (SSS; Figs. 1, 2, 3, and 4) and anterior portion of the temporal lobe.

### Anatomy and histology of the bridging veins

During embryologic development, the venous drainage of the brain differentiates from the dural venous drainage. In the first 12 weeks of gestation, the primary venous anastomoses located between the pia and dura mater resorb, and the residual anastomoses evolve and mature into bridging veins [10]. The bridging veins develop varying cell wall thickness. Comparing the subdural and subarachnoid spaces, the subdural portion differs in thickness ranging from 10 to 600 μm, yet the subarachnoid space has a thickness of 50 to 200 μm [11]. However, in both spaces, a dense fibrous tissue layer wraps around the lumen surrounded by a fine loose connective tissue [11]. The bridging veins also have differing textures of collagen fibers. Comparing the subdural and subarachnoid spaces, the subdural space reveals a loose network of fibers, whereas the

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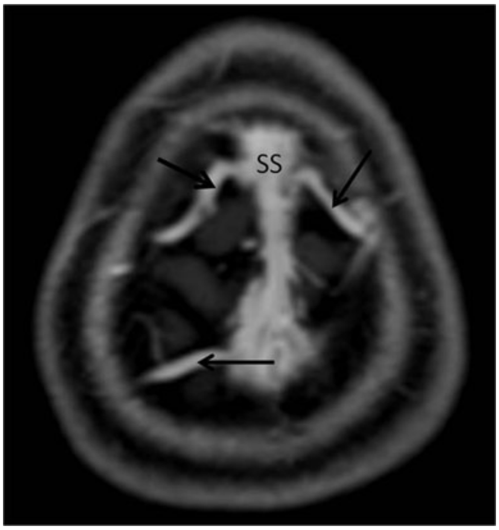


**Fig. 1** Axial T1-weighted MRI near the vertex of the skull illustrating bridging veins draining into the superior sagittal sinus (*SS*)

subarachnoid portion has a tighter network of fibers [5]. Electron microscopic data indicate that the subdural spaces of the bridging veins are tenuous in comparison to the subarachnoid portions [11]. Endothelial cells coat the lumen and are visible in contracted or flattened states [11]. Contracted endothelial cells joined by tight junctions contain a multitude of cytoplasmic projections merging into the subendothelial tissue, whereas the flattened endothelial cells show a smooth surface with elongated nuclei. Tight junctions join endothelial cells together.

## Cerebellar bridging veins

In a recent study, Ueyama et al. examined 14 cadaveric heads to identify particular bridging veins within the brain

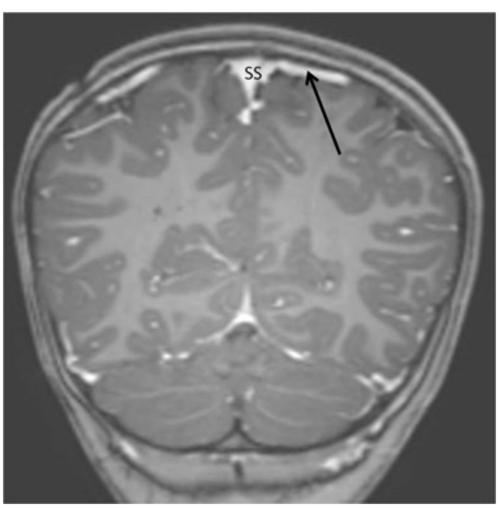


**Fig. 2** Coronal T1-weighted MRI showing a contrasted bridging vein entering into the superior sagittal sinus

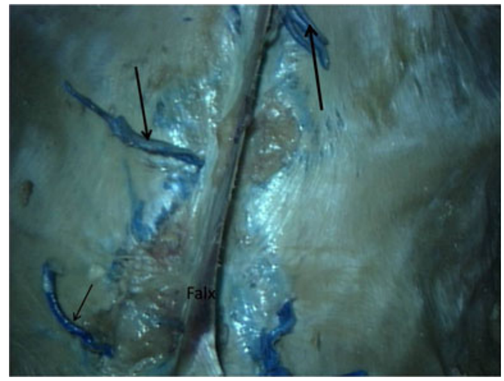


**Fig. 3** The undersurface of the exposed calvaria from a cadaveric specimen. The brain is removed demonstrating the bridging veins draining medially into the superior sagittal sinus

[6]. The area between the superior surface of the cerebellum and tentorium cerebelli was divided into two types: vermian/midline and hemispheric/lateral groups. The vermian bridging veins emptied into the confluence of sinuses and were found in the midline [6]. The hemispheric bridging veins emptied into the tentorial sinuses and were found on the hemispheric surface of the tentorium cerebelli.

The *vermian bridging veins* group is comprised of two inferior vermian veins [1]. At times, the vermian bridging veins' tributaries are an exception because they can drain directly into the confluence without merging with the inferior vermian vein [6]. The paravermian vein is what the inferior vermian vein is called if it travels in the posterior aspect of the inferior paravermian sulcus and empties 5 to 10 mm from the midline, into the sinus near the confluence.

The *cerebellar hemispheric bridging veins* form a network with the veins of the primary, postdeclival, and horizontal fissure. Ueyama et al. found 44 hemispheric bridging veins from 26 cadaveric sides [6]. There was an average of 1.69 bridging veins per hemisphere. Ueyama et al. classified three types of hemispheric bridging veins [6]. Type 1 was

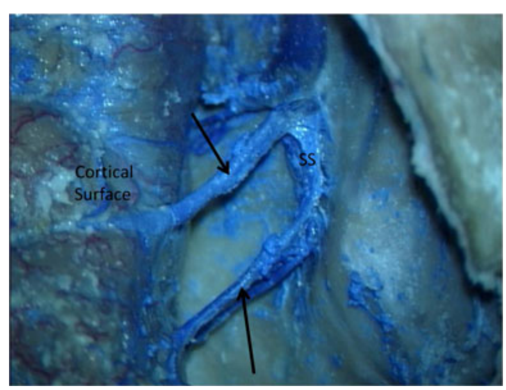


**Fig. 4** Intracranial view of a cadaveric skull with brain in place. Note the bridging veins leaving the cortical surface to drain superiorly into the superior sagittal sinus (*SS*)

formed by the union of superior and inferior hemispheric veins. Type 2 was formed by the union of superior hemispheric veins only. Type 3 was formed exclusively by the union of inferior hemispheric veins. Both, the superior and hemispheric veins, merge to form type 1 hemispheric bridging veins, while type 2 are classified by the merger of exclusively superior hemispheric veins [6]. Additionally, the inferior hemispheric veins exclusively merge to form type 3 hemispheric bridging veins (Fig. 5) [6].

The cerebellar hemispheric bridging veins consist of the superior and inferior hemispheric veins that travel transversely along the fissures while moving longitudinally on the surface. The postdeclival fissure vein, the most common transverse vein, can occasionally serve as the junction between the hemispheric bridging veins because it intersects with the bridging veins. However, if no hemispheric bridging vein was present, the transverse vein would bridge both the vermian bridging vein and superior petrosal vein. The primary fissure vein, a secondly common transverse vein, is also united with the hemispheric bridging vein. One of the inferior vermian vein's tributaries, the declival vein, served as a significant intersection with the superior vermian vein, primary fissure vein, postdeclival fissure vein, hemispheric veins, and contralateral veins. The great horizontal fissure vein is normally the largest transverse vein that either empties near the superior petrosal vein or medially near the vermian veins. This vein can also serve as an attachment between the hemispheric bridging veins and is adjoined to the inferior hemispheric veins that travel longitudinally. Commonly, the inferior hemispheric veins that travel longitudinally may medially connect with the inferior vermian vein at the inferior portion of the suboccipital surface [6].

There tends to be many collateral pathways for the hemispheric bridging veins. Types 1 and 3 veins have collateral pathways that usually join at the inferior portion of the suboccipital surface with the inferior vermian vein. Type 1 hemispheric veins usually have one major collateral pathway, while type 2 veins typically have multiple smaller collateral pathways [6].

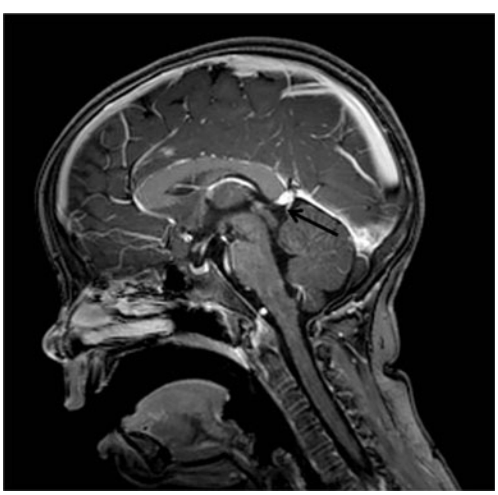

**Fig. 5** Contrasted sagittal T1-weighted MRI demonstrating a cerebellar vein draining into the junction of the vein of Galen and straight sinus


**Fig. 6** Lateral exposed cadaveric brain illustrating the veins of Labbe and Trolard, which are injected with blue latex

## Temporal bridging veins

Sakata et al. identified the temporal bridging veins in ten cadaveric brains [7]. Each temporal bridging vein was identified by the location of its "entry complex" and categorized into one of the following: the transverse sinus group, the tentorial group, and the petrosal group. An entry complex was designated because each temporal bridging vein terminated in one of two ways: the candelabra or separated types. The candelabra type was defined as "multiple venous complexes" merging into one vein, while the separated type was defined if "veins enter(ed) the same area but independently [7]." There was a total of 44 entry complexes found among the 20 cadaveric heads [7]. The temporal bridging veins traveled over the temporal lobe laterally [12] and veins can be divided into a mediodorsal group that enters into the superior sagittal sinus and a posteroinferior and middle cerebral group that opens into the lateral sinus [13]. The transverse sinus is the primary source of drainage, while the sigmoid sinus drains the hemispheres [12]. The vein of Labbé is the largest of the inferior cerebral veins and crosses from the sylvian fissure to the transverse sinus [14]. This vein was found in each cadaver and was predominately found entering the transverse sinus entry complex, and only 19 % of the specimens' vein of Labbé (Fig. 6) entered the tentorial complex [12]. The vein of Labbé is noted to often be larger on the dominant hemisphere, whereas the vein of Trolard is more often larger on the non-dominant hemisphere [15]. The vein of Trolard typically enters the postcentral region of the SSS [16]. Also, superficial cerebral veins extend from the sylvian fissure to penetrate the sphenoparietal sinus [14]. Tubbs et al. found that among 15 cadaveric brains, 10 had temporal veins that emptied into the sphenoparietal sinus from the anterior temporal tip [17].

The *transverse sinus group* is found 1 cm medially to the transverse sinus [7]. The transverse sinus group was associated with 52 % of all 44 complexes. Amongst all cadaveric hemispheres, the transverse sinus group of temporal bridging veins was found in each case [7]. The majority of these bridging veins included the posterior temporobasal vein, the middle temporal vein, and the posterior temporal vein. The majority of the above-mentioned bridging veins traveled medial to the transverse sinus while travelling "1 cm posterior to the sinodural point" and ultimately emptying into the sinus [7].

The *tentorial group* is found posterior to the sinodural point and was associated with 23 % of all 44 complexes and 50 % of all hemispheres. These bridging veins empty into the transverse sinus and form the tentorial sinus [7].

The *petrosal group* is found anterior to the sinodural point and next to the petrous ridge. In general, this group drains the "anterior part of the brainstem and cerebellum" while emptying into either the superior or inferior petrosal sinuses [18]. The superior petrosal vein, also known as Dandy's vein, courses with the trigeminal nerve anteriorly and laterally while it enters the superior petrosal sinus [18]. Following sacrifice, complications such as peduncular hallucinosis have been reported [19]. Sakata et al. found the petrosal group to be associated with 25 % of all 44 complexes [7]. In 55 % of the cadavers, the petrosal bridging vein was found to exit the temporal lobe and enter the petrosal group. It was found that among 55 % of these particular cases, the superior petrosal sinus was formed by this petrosal bridging vein, and among 18 % of the cases, the petrosal bridging vein traveled between the transverse and sigmoid sinuses [7]. In 27 % of the remaining cases, the petrosal bridging vein traveled medial into the superior petrosal sinus and ultimately into lateral tentorial sinuses to empty into transverse sinus [7].

## Frontal bridging vein

Sampei et al. completed a study examining the anatomy of the anterior frontal cortical bridging veins from 21 cadaveric heads [8]. Among these cadavers, a total number of 34 frontal cortical bridging veins were located. There were three major drainage areas found from the anterior frontal cortical bridging vein: lateral convexity, medial surface, and basal surface [8]. In 41.2 % of cadavers, only the convexity side was drained, yet only one specimen drained either the basal or medial areas. Among 18 of the 21 cadaver brains, these vein drained into two areas. However, in 8.8 % of the specimens, drainage occurred in all three areas [8]. These authors classified the veins into two groups: types 1 and 2. A positive linear relationship was found between the diameter of the vein and the distance from the frontal pole to the merger of the SSS and the frontal cortical bridging vein [8]. One type of frontal cortical bridging vein stems from the anterior and middle frontal area and moves along the interhemispheric fissure posteriorly and drains into the posterior frontal region of the SSS. Normally, these veins are known as the middle and posterior frontal veins [8].

*Frontal cortical bridging veins type 1* drains into the SSS through one venous trunk. Of the veins, 67.6 % were classified as type 1. The merger of the frontal cortical bridging vein with the SSS was measured to be on average 30.5 mm from the frontal pole and had a mean diameter of 1.9 mm [8].

*Frontal cortical bridging vein type 2* drains into the SSS through two or more venous trunks. Of the veins, 32.4 % were classified as type 2 [8]. The merger of the frontal cortical bridging vein with the SSS was measured to be 32.5 mm from the frontal pole and had a mean diameter of 3.2 mm [8].

Brockmann et al. used computed tomography venography to analyze deviations of the SSS and bridging veins [9]. They found that among 30 brains, 120 were found, and the majority of them drained distal to the coronary suture yet near the SSS [9]. These veins tended to drain antidromic, while the majority of the bridging veins, which drain 3 cm anterior to the coronary suture, have an orthodromic inflow direction [9]. The most plausible reason for varying inflow patterns into the SSS, and in particular the retrograde direction, is the way the brain and its vascular system develops [9].

## Parietal bridging veins

Some of the parietal veins functionally serve as bridging veins but are not anatomically classified as such. The vein of Trolard drains the "anterior part of the supramarginal gyrus and superior parietal lobule and the posterior part of the postcentral gyrus [20]." The paracentral, anteromedial, and posteromedial parietal veins are ascending veins that join together and empty into the SSS [20].

## Surgical significance of the bridging veins

Bridging veins are especially important in head trauma. The slightest head trauma can result in bridging vein rupture if the brain has already undergone cortical atrophy. Cortical atrophy causes the veins to become stretched and in turn more susceptible to rupture [21]. Rupture may lead to a subdural hematoma. In particular, the junction between the SSS and bridging veins functions as an important fulcrum of the force in head injury [22]. In 2006, Delye et al. found the possibility of a critical elongation criterion of 5 mm and a strain criterion of 25 % for an acute subdural hematoma to be caused by a bridging vein rupture [22]. In 2006, Depreitere et al. discovered a specific tolerance level for bridging vein rupture in correspondence to falls [23]. The study utilized human cadaveric head impact tests in order to analyze the critical magnitude of rotational acceleration from head trauma and found a suggested 10,000 rad/s for pulse durations under 10 ms [23]. This information is pertinent because short pulse durations are seen for falls on firm surfaces and acute subdural hematomas have been found to happen most often due to a fall, rather than a motor vehicle accident [23]. The flow capacity velocity of an individual bridging vein has been calculated among elderly adults to be 5 cc/min, which indicates the severity of a bridging vein rupture [24].

Ehrlich et al. found the frequency of bridging vein ruptures from head trauma to be greatest with impacts towards the frontal area [25]. However, at other sites, roughly a third of the impacts resulted in bridging vein rupture. The only exception was temporal impacts, which caused more rupture towards parietal bridging veins than those in the frontal area [25].

Beside their role in subdural hematomas, the bridging veins serve as landmarks for specific locations within the brain during neurosurgery. Furthermore, identification of the bridging veins during surgery makes the neurosurgeon aware of avoiding damage to them in order to prevent venous infarction secondary to iatrogenic occlusion of these veins. Neurosurgeons may follow the rule of thirds to minimize the risk of neurological complications. If the anterior 1/3 of the SSS or all tributary bridging veins are obstructed, there is less than a 1/3 risk for severe complications. If the middle 1/3 of the SSS is obstructed, there is up to a 2/3 risk of severe complications, whereas if the posterior 1/3 of the SSS is obstructed, there is more than a 2/3 risk for severe complications.

### Hemispheric/vermian bridging veins

Neurosurgeons should be knowledgeable about the location of the various bridging veins within the brain. The cerebellar bridging veins are most often injured from a median infratentorial supracerebellar surgical approach. Injury of these bridging veins can lead to cerebellar venous infarction [6].

### Temporal bridging veins

Neurosurgeons must understand the anatomy of the temporal bridging veins and their respective draining patterns. In particular, the anatomy and termination point of the vein of Labbé is pertinent in many lateral cranial base approaches because it is the largest posterior cerebral anastomotic vein [7].

### Anterior frontal cortical bridging veins

The anterior frontal cortical bridging vein should be understood especially in the anterior interhemispheric approach [8]. Previously, destruction of frontal cortical veins was thought to be relatively unimportant because of their small size. However, Sampei et al. showed frontopolar veins drain three sides (convexity, medial, and basal), which increases the risk of venous infarction [8]. Yasui showed that the anterior interhemispheric approach is successful when the bridging vein is at a minimum of 16 mm from the craniotomy lower edge [26]. Among 71.4 % of patients, the interhemispheric transcallosal approach with cortical bridging vein ligation resulted in postoperative hemiparesis [27].

### Parietal bridging veins

Ligation of parietal bridging veins has resulted in seizure and hemiparesis [28].

## Conclusions

Knowledge on the intracranial bridging veins and their dynamics has evolved over time and is of great significance to the neurosurgeon. A thorough understanding of their anatomy is necessary to insure safe intracranial surgery.

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