Anatomical features of the straight sinus and its tributaries

Clinical correlations

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The authors report a variety of arrangements of the venous channels comprising the straight sinus (sinus rectus) and its connections during a continuing study of the cerebral sinuses and their tributaries. In approximately 85% of 131 specimens of dura mater with enclosed venous sinuses derived from fresh cadavers, the straight sinus was represented by a single midline tentorial channel whereas in the remaining 15%, segments of it were doubled and in a few, tripled. In addition to these aberrations in the development of the main trunk of this sinus, the venous patterns at the junctions of the inferior sagittal sinus, vein of Galen and straight sinus showed comparable developmental inconstancies. Also in no specimens were the patterns of venous channels in the leaves of the tentorium cerebelli alike. The course, size, and connections of all the tributaries of the straight sinus have been studied and consideration given to their potentials as collateral pathways in the event either the vein of Galen or the straight sinus itself were occluded.

KEY WORDS • dural sinuses • straight sinus • sinus rectus •
occluded straight sinus • occluded great vein of Galen •
straight sinus tributaries • vein of Galen tributaries

SAXENA, et al.,7,8 have reported their investigations of the variations of the straight sinus with particular reference to the frequency of doubling of this channel, the arrangements at its origin, the different courses it might run in the tentorium cerebelli, and its inconstant terminations at or near the confluence of sinuses. In addition to a review of these anatomical features of the straight sinus, we have observed inconstancies in the course, size, and connection of venous channels in the tentorium cerebelli that represent tributaries of the sinus; variations in arrangement of the venous branches that unite to form the vein of Galen; a venous lake in the falx cerebri constituting the caudal aspect of the inferior sagittal sinus, and not only doubling but tripling of segments of the straight sinus.

The information derived by us from dissection of a group of uninjected specimens and observations of Vinylite casts of the straight sinus and its tributaries have been drawn together and are presented in this paper. Clinical correlations of these anatomical findings are included. Knowledge of these
details should be useful to a neurosurgeon who anticipates the possibility of resecting a part of the straight sinus during removal of a meningioma attached to the dura mater at the junction of the falx cerebri and tentorium cerebelli.

**Materials and Methods**

Specimens including the total intracranial contents, exclusive of a median strip of dura mater at its base and the hypophysis, were obtained at autopsy. After removal of the brain with the dura mater, the superior sagittal sinus was divided at the junction of its middle and posterior thirds and the incision carried ventrorostrally leaving *in situ* the ventral two-thirds of the falx cerebri and the inferior sagittal sinus. The cerebral hemispheres dorsal to the lateral ventricles were sacrificed without disturbing the anatomical position of the internal cerebral veins, the basal veins of Rosenthal and the vein of Galen. The divided superior sagittal sinus was ligated and both transverse sinuses occluded by ligature at their respective knee. A Vinylite-acetone mixture was injected into the distal superior sagittal sinus and its tributaries. In most instances, there was good filling of the vein of Galen and its connecting channels, the inferior sagittal sinus, and the venous pathways within the tentorium cerebelli. Following completion of the injection, the entire specimen was immersed in 10% formalin for 2 days and then corroded in concentrated hydrochloric acid. The resultant casts were used for part of the study of the straight sinus and its tributaries.

A second group of uninjected specimens were probed and dissected with particular reference to the frequency of occurrence of multiple straight sinuses. Altogether 53 Vinylite casts of the venous channels under study and 78 uninjected specimens were critically reviewed. Lastly, previous observations made on material used in studies of the vasculature of the falx cerebri and tentorium cerebelli was drawn upon in the overall consideration of size, course, and connections of the tributaries of the straight sinus. Personal experience with a patient with a tentorial meningioma involving the midpart of the straight sinus is also reported.

**Observations**

We were able by dissection to identify the doubling of a segment of the straight sinus in nine of the 78 uninjected specimens. The anterior half of the sinus had this dual arrangement in seven and the posterior part in two. In those with doubling of the anterior part, the double barrel conformation extended to the junction of the vein of Galen with the straight sinus but did not involve the orifice of this vein. In the two specimens with doubling of the posterior part of the sinus, the distal part of the double barrel was united with regional sinuses in the area of the confluence.

The findings derived from the Vinylite cast were most conclusive. Complete injections of the distal superior sagittal, transverse, occipital, straight, and inferior sagittal sinuses with subsequent corrosion produced casts which demonstrated the details of even the small venous tributaries. Doubling of a segment of the sinus was present in 11 of the 53 injected specimens (Figs. 1–3).

In six the double segment was in the anterior half of the sinus, in three it was in the posterior half, and in two the doubling involved the middle part of the sinus. In three others, tripling of a substantial segment of the sinus was present (Fig. 4). In no instance with multiple straight sinuses, did the unusual development extend the full length from the orifice of the vein of Galen to the confluence of sinuses. Moreover, the double or triple segments communicated freely through orifices at the junction of their respective termination. In addition, as in the uninjected specimens, there were some with branching of
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The straight sinus just short of its junction with a transverse, superior sagittal and/or occipital sinus. In one specimen there were four such branches; one to the confluence of sinuses, one to either transverse sinus, and one to the distal superior sagittal sinus (Fig. 5).

Fig. 1. A lateral view of a cast showing doubling of the middle segment of the straight sinus. (A) confluence of sinuses; (B) right transverse sinus; (C) junction of superior sagittal and straight sinus; (D) doubling of the straight sinus at its midpart.

Another interesting feature of the casts was the great variety of tributaries, coursing in the tentorium cerebelli, that joined the straight sinus. In addition small channels in the falx cerebri coursed to the dorsal aspect of this sinus. Some of the tributaries in the tentorium connected the straight with one or the other superior petrosal sinus and still others, the straight with a transverse sinus (Figs. 6 and 7).

The vein of Galen varied in length, from 4 mm to 1.5 cm. Its position of attachment to the rostral aspect of the straight sinus was fairly constant. The orifice at the site of junction with the straight sinus was generally oval in shape and was usually guarded by a plica-like formation attached to the inner wall of the sinus. In two specimens a vein from the dorsum of the anterior vermis joined the sinus 1 cm caudad to the orifice of the vein of Galen. In all others, the vermian veins bypassed the trunk of the vein of Galen to join the basal vein of Rosenthal or the vein of Galen at its origin. The veins from the anteromedial occipital lobes and the medial temporal lobes, the pontile plexus and those from the mesencephalon all joined the basal veins of Rosenthal. Therefore, if the vein of Galen were occluded, retrograde flow would be through the following: the veins of the cerebellar vermis to the confluence of sinuses; the veins of the medial occipital cortices and medial temporal lobes to the cortical veins; the basal vein of Rosenthal through the deep vein of Sylvius across the island of Reil to the frontotemporal cortex; the frontal or orbital branches of the vein of Rosenthal to the ven-
FIG. 5. Dorsolateral view of a cast showing multiple terminal channels of the straight sinus. The posterior two thirds of this sinus has a double-barrel arrangement with each barrel forking before all four channels join area of confluence of sinuses (see text). (A) confluence of sinuses; (B) left transverse sinus; (C) right transverse sinus; (D) inferior sagittal sinus.

FIG. 6. Dorsal view of a cast showing a substantial tentorial channel connecting the posterior straight sinus with the left superior petrosal sinus just before the latter unites with the left transverse sinus. (A) confluence of sinuses; (B) right transverse sinus; (C) left transverse sinus; (D) straight sinus.

FIG. 7. Dorsal view of a cast showing a large tentorial channel on the left connecting the straight sinus with the left transverse sinus. (A) venous complex at area of confluence of sinuses; (B) right transverse sinus; (C) left transverse sinus; (D) stubs of vein of Galen and inferior sagittal sinus.

FIG. 8. Lateral view of straight sinus to show the fusiform, bulbous arrangement of the anterior half of the straight sinus. Note the several venous tributaries joining this enlarged segment. (A) superior sagittal sinus and connecting network of veins in the dura mater; (B) right transverse sinus; (C) confluence of sinuses with attached occipital sinus; (D) stub of inferior sagittal sinus.

tromedial frontal lobe of the brain; the internal cerebral veins through the subependymal veins, choroidal veins, and transcerebral veins to the cerebral cortex.

A bulbous formation of the caudal end of the inferior sagittal sinus and/or the rostral aspect of the straight sinus was present in approximately 30% of all specimens of dural sinuses. The size of a venous pool of this complex did not seem to be influenced by the size of the inferior sagittal sinus. Neither did the dimensions of the joining vein of Galen appear to have a bearing on the size of such a venous cavity. All tributaries of these lakes were veins (Fig. 8). Other aberrant arrangements at the unions of the inferior sagittal sinus, the vein of Galen and the anterior straight sinus were viewed as developmental variations (Fig. 9).

Clinical Observations

We have found only two recorded cases where the straight sinus in man was occluded and/or resected during the removal of a tentorial meningioma. Castellano and Ruggiero reported one case from Olivecrona’s clinic. The operation had been a difficult one due to hemorrhage, and the patient died on the operating table shortly after the straight sinus was ligated. The time elapsing from occlusion of the straight sinus to death was not stated. Merli and Carteri reported a case of a 51-year-old woman who had a right-sided
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Fig. 9. Lateral view of a cast showing the straight sinus and its tributaries. Note the triangular arrangement at the anterior aspect of the sinus. We presume that this represents a variant of doubling of the anterior part of the straight sinus. (A) superior sagittal sinus; (B) confluence of sinuses; (C) (arrow) distal end of the vein of Galen; (D) inferior sagittal sinus.

Fig. 10. Dorsal view of a cast showing multiple venous channels in the tentorium cerebelli that join the straight sinus. These are often more numerous in the posterior half of the tentorium than in its anterior half. (A) confluence of sinuses; (B) left transverse sinus; (C) right transverse sinus; (D) stub of inferior sagittal sinus.

supra- and infratentorial meningioma successfully removed with a segment of the involved straight sinus, leaving the vein of Galen and internal cerebral veins intact. There were no postoperative complications attributed to the ablation of a part of the straight sinus. The right occipital lobe had been removed to give exposure to the mass. Two years postoperatively a left homonymous hemianopsia was still present. Her general health had been good.

Case Report

Our patient was a 40-year-old man. He was admitted to a small outlying hospital with a history of sudden loss of consciousness. On admission he was in coma; he had choked disc, moderate fever, and decerebrate attitude. Transfer to a facility where immediate surgical treatment could be carried out was urged, and he was admitted to the Brooklyn Hospital in coma. A ventriculogram disclosed shift of the ventricular system consistent with a mass lesion in the right occipital fossa. Within an hour, a bone flap was turned which uncovered a dark dura. With incision of the dura, a relatively large unmeasured quantity of clotted blood spontaneously extruded. The dome of a meningioma was exposed and approximately two-thirds of the interior of the mass removed by loop-cautery. The attachment of the tumor to the dura mater was then brought into view and found to be at the junction of the falx cerebri and the tentorium. Attempts to remove the remaining mass resulted in brisk hemorrhage. The sinus was occluded and the tumor totally removed. The patient was able to walk with assistance by the sixteenth postoperative day. Typical features of parkinsonism were evident. One year following operation a moderate grade parkinsonian syndrome remained unchanged. He was lost to follow-up.

Comment

One could only speculate on the causative factor for the development of Parkinson's syndrome. The decerebrate posture was present for at least 8 hours prior to surgery. The pathophysiological mechanism for this may have been the same as that which produces cerebral changes that result in parkinsonism.

Discussion

It is evident that surgical experiences with occlusion of the straight sinus and/or the vein of Galen in man are too few for one to draw any conclusion from them. Sudden blockage of the rostral part of the straight sinus and/or the vein of Galen in man apparently is a dangerous procedure.

Slow progressive partial to complete occlusion of the sinus at its middle or caudal levels by an invading tumor presents a different set of circumstances. A priori, one
would expect under these conditions at least partial establishment of substitute venous pathways before the patient came to surgery. Such conditions may have been present in the case reported by Merli and Carteri. In our case the involvement of the straight sinus was at its midpoint and the gross findings at operation indicated that the sinus was not completely occluded by tumor growth preoperatively. This raises the question of potential collateral circulation from the rostral aspect of the straight sinus to regional great sinuses by way of the irregularly occurring channels in the tentorium cerebelli and/or more rarely, the falx cerebri. Saxena, et al., reported on the frequency of multiple straight sinuses, and found nine of 86 specimens with communications with the cavernous sinus. It would appear from the configurations demonstrated in the Vinylite casts of our material that venous channels are larger and found in greater abundance between the leaflets of the tentorium in its posterior half (Fig. 10). However, in some, these channels are present in sufficient size and numbers in the anterior half of the tentorium cerebelli to offer adequate substitute pathways for venous outflow if the straight sinus were occluded at its midpoint or at other levels in its course from this site to the confluence of sinuses. These speculations are a poor substitute for hard experience. In view of our defective knowledge of the rapidity of establishment and functional effectiveness of collateral circulation following occlusion of the vein of Galen and/or the straight sinus, it appears unwise to boldly apply in clinical practice the conclusion reached by Hammock, et al., that the vein of Galen might be sacrificed in man with fewer untoward consequences than previously imagined.

As reported in the literature, surgical ligation of the great vein of Galen, in both the dog and the monkey, has minimal consequences. No significant alterations of cerebral function of the animals were observed subsequent to clipping of this vein at any level. Among these contributors, only Dandy reported hydrocephalus in one of 10 dogs in which the vein of Galen had been ligated. He remarked that numerous channels establish a free anastomosis between the "intra- and extracerebral venous circulation," but did not comment on the channels involved. Bedford reported his observations on the effects of experimental occlusion of the great vein of Galen in both the dog and rhesus monkey. In sum, they showed the absence of hydrocephalus.

Schlesinger reported that hydrocephalus did not develop after occlusion of the great vein of Galen in either the monkey or the rabbit. He demonstrated the "intra-cerebral anastomatic veins," termed transcerebral veins by Kaplan, which were regarded by him as the main connections between the great vein of Galen and the veins on the surface of the brain. Also, it was observed that the tributaries of the great vein of Galen and the large cerebral cortical veins overlap to a very large extent in widely separated areas.

Hammock, et al., reported their observations in 16 rhesus monkeys submitted to surgical clipping of the great vein of Galen at its origin. Care was exercised during the procedure to preserve what they termed bridging veins in the region of the vein of Galen. Immediately following occlusion of the vein of Galen, dilatation of the internal cerebral veins was demonstrated by angiographic examination. One week later angiography revealed engorgement of the internal cerebral veins, superior and inferior sagittal sinuses, and straight and transverse sinuses, and this persisted until the animals were sacrificed at the end of 6 months. Hydrocephalus did not develop in a single instance. They concluded that the vein of Galen might be sacrificed in man with fewer untoward consequences than previously imagined.

Some of the pathophysiological alterations of the venous system of the brain that implicate the caudal aspect of the Galenic system in man are poorly understood. Two of these deserve brief consideration as they relate to blood flow through the vein of Galen and/or the straight sinus. The first is that primary thrombosis of the straight sinus which results from inflammatory disease is rare, consequently cerebral dysfunction caused by thrombophlebitis of venous channels of this region may be due to implication of pathways joining the straight sinus rather than diminution or absence of blood flow in the sinus itself. Second, a developmental vascular malformation resulting in dilatation of the vein of Galen, commonly termed aneurysm of this vein, is often varied and complex. Dilatation of other vessels of the implicated area are numerous, whereas in
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many the enlarged vein of Galen merely represents a conduit for outflow of the anteriovenous mix from a regional arteriovenous malformation. Under either circumstance, ablating the so-called aneurysm of the vein of Galen is not comparable to occluding a relatively normal vein of Galen and/or the anterior straight sinus.

References


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