The transcallosal–transforaminal approach to the third ventricle with regard to the venous variations in this region

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Numerous approaches to the anterior and middle portions of the third ventricle have been described, including the transphenoidal,pterional–transsylvian, subfrontal, subtemporal, transcortical–transventricular, anterior transcallosal, and combined (pterional–transylvian and anterior transcallosal). The third ventricle cannot be exposed without traversing or manipulating neural structures, and in this respect, each approach features certain indications, limitations, and risks. For example, the transphenoidal approach provides access to the pituitary gland, but only permits visualization of the third ventricle in those cases in which the tumor has caused enlargement of the sella turcica. Using the subtemporal approach, tumors can be removed from the third ventricle, but actual entry into the ventricle is limited because of the angle of the approach and the important neural and vascular structures that are interposed.

Both the pterional–transylvian and subfrontal approaches provide exposure of the lamina terminalis, through which the anteroinferior portion of the third ventricle can be accessed. Using the transcortical–transventricular and the anterior transcallosal approaches, access is gained into the anterior and middle portions of the third ventricle. The combined approach (pterional–transylvian and anterior transcallosal) was introduced to ensure total removal of large tumors that extend inferiorly into the subchiasmatic–interpeduncular region and superiorly into the third ventricle with unilateral or bilateral occlusion of the foramina of Monro. The anterior transcallosal approach usually provides a direct and adequate pathway to the lateral ventricles, where the foramen of Monro serves as a natural entrance into the anterior and middle portions of the third ventricle, particularly when the foramen is dilated by tumor tissue. However, there are situations in which the midsuperior portion of the third ventricle is difficult to reach via the foramen of Monro. In these instances other techniques have been advocated, for example, the transforaminal exposure with unilateral sacrifice of the thalamostriate vein and the transchoroidal exposure with unilateral incision of the column of the fornix. The transforaminal exposure with unilateral incision of the column of the fornix.
Transcallosal–transforaminal approach

In this article we describe the anatomical variations of the subependymal veins of the lateral ventricle in the region of the foramen of Monro and analyze their significance in surgical exploration via a transcallosal–transforaminal approach. Based on the pattern followed by these venous variations, we propose enlargement of the foramen of Monro posteriorly, which allows adequate access to the anterior and middle portions of the third ventricle. An illustrative case describing the successful application of this technique is presented.

Materials and Methods

Twenty cadaveric brain specimens (40 hemispheres) were examined during this anatomical study. In 11, both the carotid and vertebral arteries as well as the jugular veins were perfused with saline solution, followed by injection with red and blue latex, respectively. The specimens were fixed in 10% formaldehyde solution for a minimum of 2 months. To simulate the anterior transcallosal approach, the superior portions of the cerebral hemispheres and the roof of the lateral ventricles were removed. This exposed both lateral ventricles, as well as both foramina of Monro. To improve our knowledge of the surgical anatomy in this complex area, we examined the neural and vascular structures in and around the third ventricle by using an operating microscope set at magnifications ranging from 6 to 40. Special attention was paid to the anatomical pattern and variations of the subependymal veins in the region of the foramen of Monro. The course followed by the anterior septal vein (ASV), thalamostriate vein, and internal cerebral vein (ICV) was studied. The proximity of the venous angle, the false venous angle, and the ASV–ICV junction to the posterior margin of the foramen of Monro was measured. In injected specimens, the diameter of the ASV, as measured adjacent to the ASV–ICV junction, was 1.92 mm (range 1–2.3 mm). In 39 (97.5%) of the 40 hemispheres the anterior caudate vein or veins and the superior choroidal vein were observed to join either the venous angle or the false venous angle (depending on which variation was present). In the remaining hemisphere (2.5%) a false venous angle was present, and the anterior caudate vein was found to join the ASV adjacent to the posterior margin of the foramen of Monro.

The ASV coursed medially from the tip of the frontal horn, curved posteriorly along the septum pellucidum and column of the fornix, and then passed above the foramen of Monro to join the ICV. The average diameter of the ASV, as measured adjacent to the ASV–ICV junction, was 1.02 mm (range 0.8–1.5 mm). The location of the ASV–ICV junction featured certain variations and we have classified these into four types according to their relationship with the venous angle or false venous angle (Table 1, Fig. 1). In 21 hemispheres (52.5%) from 17 (85%) of the 20 brain specimens studied, the ASV–ICV junction was located at the venous angle, which lies adjacent to the posterior margin of the foramen of Monro. This conforms to the classic anatomical description, and we have classified this as Type IA. In the remaining 19 hemispheres (47.5%) from 16 (80%) of the 20 brain specimens studied, the ASV–ICV junction was located beyond the venous angle. Type IB: the ASV joined the main stem of the ICV beyond both the foramen of Monro and the venous angle. This was observed in six (15%) of the hemispheres. Type IIA: the ASV joined the false venous angle, which lies beyond the foramen of Monro. This was observed in 10 (25%) of the hemispheres. Type IIB: the ASV joined the main stem of the ICV far beyond both the foramen of Monro and the false venous angle. This was observed in three (7.5%) of the hemispheres. These last three posterior locations of the

### TABLE 1

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<thead>
<tr>
<th>Location of the venous angle and false venous angle in 20 cadaveric brain specimens (40 hemispheres)</th>
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<tr>
<td>Structure</td>
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<td>venous angle</td>
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<td>false venous angle</td>
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### TABLE 2

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<tr>
<th>Location of the ASV–ICV junction in 20 cadaveric brain specimens (40 hemispheres)</th>
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<td>ASV–ICV Junction</td>
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<td>classic location (Type IA)</td>
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The lateral ventricle is approached posteriorly.

The MR venography demonstrated a more posterior location for the left ASV–ICV junction than the right, which suggested that the left foramen of Monro could be enlarged posteriorly (Fig. 5 center left and right). The tumor was explored via a right-sided combined approach. The exploration was begun transcortically. The left lateral ventricle was entered via a 10-mm incision in the corpus callosum made between the pericallosal arteries. The tumor adhesions to the choroid plexus and the ASV were dissected, and a small venous connection to the cystic wall of the tumor was coagulated and severed. The foramen of Monro was then enlarged 4 to 5 mm posteriorly by opening the choroidal fissure along the tenia choroidea as far as the posteriorly located ASV–ICV junction. This maneuver provided wider exposure for dissection and partial removal of the tumor from the wall of the third ventricle. Surgery continued via a right pterional–transsylvian approach, in which exploration followed parachiasmic arachnoid planes medial and lateral to the internal carotid artery, to dissect and remove the calcified subchiasmatic portion of the tumor. Finally, the lamina terminalis was opened to provide access to the remaining solid part of the tumor in the anterior portion of the third ventricle. This tumor had a large base originating from the pituitary stalk, which had become extremely flattened, resembling a transparent membrane, and which was resected to ensure complete removal of the tumor. The patient’s postoperative course was uneventful. Preoperative diabetes insipidus persisted but could be controlled by hormone-substitution therapy. Magnetic resonance imaging performed 10 days post surgery demonstrated total removal of the tumor (Fig. 5 lower left and right).

**Discussion**

Surgery of the third ventricle poses a considerable challenge, even for experienced neurosurgeons. The numerous publications describing various surgical approaches attest to the difficulties that are encountered when exploring this area. It was not until the 20th century that surgeons ventured to explore the third ventricle, when Dandy described a transcortical–transventricular approach to the third ventricle, partially resecting the frontal lobe to remove a colloid cyst. Later, many neurosurgeons used this approach, with the addition of a cortical incision, particularly in those patients presenting with ventriculomegaly. The lateral ventricle is approached via an incision into the right middle frontal gyrus, which offers good visualization of the ipsilateral foramen of Monro. The main disadvantages of this approach are the need for excessive brain excision and the inevitable neces-

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**Fig. 1.** Drawings showing variations in location of the ASV–ICV junction relative to the foramen of Monro (fin). Type IA: The ASV (asv) joins the ICV (icv) at the venous angle, which lies adjacent to the posterior margin of the foramen of Monro as is classically described (52.5% of hemispheres studied). Type IB: In the presence of a venous angle, the ASV joins the main stem of the ICV beyond the foramen of Monro (15% of hemispheres). Type IIA: The ASV joins the false venous angle, which lies beyond the foramen of Monro (25% of hemispheres). Type IIB: In the presence of a false venous angle, the ASV joins the main stem of the ICV far beyond the foramen of Monro (7.5% of hemispheres). tv = thalamostriate vein.
Transcallosal–transforaminal approach

In 1949 Greenwood\textsuperscript{16} described an anterior transcallosal approach for the removal of a third ventricular colloid cyst. Because of the development of microneurosurgical techniques in the 1970s, the anterior transcallosal approach became widely used for the removal of third ventricular lesions.\textsuperscript{1,2,6,30,41,49,50} This approach offers natural anatomical planes for dissection and various anatomical landmarks that establish orientation. A cortical incision is not required; thus the risk of postoperative motor deficits and epileptic seizures is markedly reduced.\textsuperscript{1,3,8,15,16,28,35,37,40,41,45,49,50} Entry into the interhemispheric fissure is made in a stepwise fashion. Moist cotton balls of increasing size are placed at the anterior and posterior extent of the dissection to provide noninjurious retraction, thus avoiding the need for a self-retaining retractor.\textsuperscript{49} The appropriate length of bipolar forceps (1.5–13.5 cm) is essential because dissection proceeds from the surface to deep areas. Various tip sizes are necessary as well, from fine, for dissection of the arachnoid, to broader tips for tumor dissection and removal. A 10- to 20-mm-long incision into the corpus callosum, followed by fenestration of the septum pellucidum, ensures good visualization of both lateral ventricles as well as both foramina of Monro, regardless of the size of the ventricles. In cases of large suprasellar and intraventricular lesions, especially craniopharyngiomas, with occlusion of one or both foramina of Monro, the combined approach (pterional–transsylvian and anterior transcallosal) is recommended to achieve complete removal of these challenging lesions.\textsuperscript{49}

The postoperative cognitive deficits associated with the transcortical and transcallosal approaches for tumors of the third ventricle were compared in a study by Geffen, et al.\textsuperscript{15} They found better preservation of cognitive function following transcallosal exploration. In a review of their transcallosal surgery, Clark and Geffen\textsuperscript{9} reported that per-
sistent impairment of short-term memory tended to occur only in those patients in whom extracallosal damage had been inflicted, particularly to the fornix and its connections. Woiciechowsky, et al., confirmed that a callosotomy less than 22 mm in length does not result in persistent signs of interhemispheric disconnection in the late postoperative period.

Whether approaching the third ventricle via an anterior...
Transcallosal–transforaminal approach

The foramen of Monro is a unique natural opening leading from the lateral ventricle into the third ventricle. In most cases of third ventricular lesions, the exploration can be performed via a foramen of Monro that has been dilated by tumor. The senior author (M.G.Y.) applied the anterior transcallosal–transforaminal approach to explore lesions in 65 patients who presented with a tumor totally within the confines of the third ventricle. He used the combined approach to explore lesions in an additional 31 patients who presented with a craniopharyngioma located both extra- and intraventricularly with occlusion of one or both foramina of Monro. In these patients, fenestration of the septum pellucidum in the middle portion exposed both foramina of Monro and allowed bilateral exploration of the third ventricle and subsequent radical removal of the lesion.

When the foramen of Monro is not dilated by tumor, however, access to the midsuperior portion of the third ventricle is limited. Our modification of the transforaminal exposure, as described in this paper, permits access to the midsuperior portion of the third ventricle without causing damage to the surrounding vital structures. The location of the ASV–ICV junction relative to the foramen of Monro is the key to this exposure. When the ASV–ICV junction is located posteriorly, beyond the foramen of Monro, the neurosurgeon is confronted with certain limitations. Restricted by the confined working space and the proximity of vital neural and vascular structures, exposure of the third ventricle is deemed a delicate and complicated procedure.

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Monro (which was the case in 80% of the brain specimens studied), the transforaminal exposure can be adapted according to this particular aspect of the patient’s venous anatomy. The foramen of Monro, ipsilateral to the more posteriorly located ASV–ICV junction, can be enlarged along the choroidal fissure as far as the junction to provide a wide access to the third ventricle. The choroidal fissure can be opened in a similar fashion as in the transchoroidal technique (preferably) or the subchoroidal technique.

Excellent studies have been published describing the deep venous system of the brain and defining the venous variations in the region of the foramen of Monro. They all emphasize that, in most instances, the thalamostriate vein and the ICV form a characteristic U-shaped junction adjacent to the posterior margin of the foramen of Monro, which is termed the venous angle. This junction has also been observed beyond the posterior margin of the foramen of Monro and in these instances is termed the false venous angle. Based on angiographic criteria, the incidence of a false venous angle is reported to vary between 14% and 26%. However, Lang observed this structure in 39% of the hemispheres in his anatomical study, and we observed it in 32.5% of the hemispheres in our study. The ASV usually joins the ICV (ASV–ICV junction) at the venous angle, which is located adjacent to the posterior margin of the foramen of Monro. Posterior locations of the ASV–ICV junction, beyond the foramen of Monro, have also been noted by many authors, but they quote no specific statistics. Their observations were made based on cerebral angiograms obtained during the pre–computerized tomography era for the investigation and diagnosis of intracranial mass lesions. Because of the inherent difficulty in determining the exact location of the foramen of Monro on angiographic studies, accurate radiographic measurements are not available. In our anatomical study, the ASV–ICV junction, which is the limit of enlargement of the foramen of Monro, was found to be located 3 to 13 mm (average 6 mm) posterior to the foramen of Monro in 47.5% of the hemispheres (80% of brain specimens). Our definition and classification of the various locations of the
ASV–ICV junction and the surgical significance of this particular aspect of the venous anatomy have not been described previously.

Preoperative neuroradiological studies, cerebral angiography, MR imaging, and MR venography in particular, reveal the location of the ASV–ICV junction and indicate which foramen of Monro can be enlarged to provide the widest access to the third ventricle. These neurological studies contribute to precise surgical planning and subsequent successful application of the transforaminal exposure (Fig. 6). We strongly recommend preoperative MR venography for all third ventricular lesions, because this will clearly show the anatomical relationships of the subependymal veins. When such a study is unavailable, an anterior transcallosal approach followed by fenestration of the septum pellucidum will expose both foramina of Monro, and the decision regarding which foramen to enlarge can be made at the time of surgical exploration.

When posterior enlargement of the foramen of Monro is prevented because the ASV–ICV junction is located bilaterally at the venous angle (Type IA; 20% of brains in our study), the transforaminal exposure can be combined with the transchoroidal exposure. However, combining these techniques introduces the possibility of damage to the ASV, which is formed primarily from tributaries originating in the deep white matter near the frontal pole; relatively little blood drains from the septum pellucidum itself.20,34,42,65,61 There is no evidence of adverse sequelae resulting from unilateral occlusion of the ASV, possibly because of connections among the deep medullary veins.20 Yamamoto, et al.48 reported that they frequently sacrificed the ASV to expose the opposite lateral ventricle and foramen of Monro, and they did not observe increased morbidity resulting from this technique. We do not recommend sacrifice of the ASV, but when confronted with such a choice, it is usually preferable to sacrificing the thalamostriate vein or injuring the column of the fornix. A foramen of Monro dilated by tumor is usually adequate to reach the anterior and middle portions of the third ventricle. As demonstrated in our study, the ASV–ICV junction is located posteriorly in most cases. This allows enlargement of the foramen of Monro and adequate access to a lesion. The need to sacrifice the ASV, therefore, will be very rare.

Transforaminal Exposure With Unilateral Sacrifice of the Thalamostriate Vein

Delandsheer, et al.,12 and Hirsch, et al.,17 reported that to enlarge the foramen of Monro posteriorly the thalamostriate vein could be sacrificed without causing postoperative deficits in the patient. Lavyn and Patterson25 sacrificed the thalamostriate vein and/or the ASV to enlarge the foramen of Monro posteriorly and to approach the middle portion of the third ventricle between the thalamus and ipsilateral ICV. The thalamostriate vein is one of the largest subependymal veins and receives blood from the deep medullary veins of the caudate nucleus, the lenticular nuclei, the internal capsule, and the deep white matter of the posterior frontal and anterior parietal lobes, but it does not receive venous blood from the thalamus.23,42,46,48 Occlusion of the thalamostriate vein at the foramen of Monro may cause drowsiness, hemiplegia, mutism, hemorrhagic infarction of the basal ganglia, or death. A patient will only tolerate this occlusion when sufficient communication is present among the thalamostriate, direct lateral, and deep medullary veins. There is currently no way to determine which patients have adequate collateral venous outflow.

Transforaminal Exposure With Unilateral Incision of the Column of the Fornix

Dandy14 introduced the technique of unilateral incision of the column of the fornix to enlarge the foramen of Monro anteriorly. This technique was considered useful and acceptable by some authors,1,11,16,22,27,32,37,38,41,47,48 for exploration of a deeper portion of the anterior part of the third fornix. The fornix is a major efferent pathway connecting the hippocampus to other limbic and diencephalic structures that play an important role in the function of human memory.13,18 Following unilateral incision of the column of the fornix, persistent13,14,18 and transient5,20 memory deficits have been reported. Incision of the ipsilateral column of the fornix can cause severe memory problems, particularly if the contralateral fornix has been compromised by tumor or by brain retraction.13,35 Furthermore, there is a danger of damaging the anterior commissure because of its proximity to the column of the fornix. Insufficient access to the mid superior portion of the third ventricle is the significant limitation of the trans foraminal exposure, and unilateral incision of the fornix does not solve this problem.

Interforniceal Exposure

In 1944 Busch described a technique of interforniceal exposure of the third ventricle via the transcortical approach. Apuzzo and colleagues modified this technique of interforniceal exposure by substituting the anterior transcallosal approach and introducing the application of microtechniques. It has since become a widely accepted method of exposure.19,22,25,37,47,48 The interforniceal exposure takes advantage of a natural plane between the fornices that opens into the roof of the third ventricle. It is important that the interforniceal division be made exactly in the midline, and this is best initiated with a blunt hook.6,17,22 It is imperative that the incision not be made beyond the region of the interface between the column of the fornix and the anterior commissure.3,47 Postoperative transient memory loss has been reported, which was considered to be the result of bilateral damage to the fornices.2,4,9,19,45

Subchoroidal Exposure

This technique involves opening the choroidal fissure along the tenia choroidea and retracting the choroid plexus and the body of the fornix in a lateral to medial direction to expose the velum interpositum, which is then opened between the thalamus and the ipsilateral ICV to expose the middle portion of the third ventricle.10,47 The main disadvantage of the subchoroidal exposure concerns opening the choroidal fissure along the tenia choroidea between the choroid plexus and thalamus, because this involves the risk of damage to the thalamus, the stria medullaris thalami, the superior and/or anterior thalamic
veins, the thalamostriate vein, and the choroidal arteries.37,47

Transchoroidal Exposure

Nagata, et al.,33 have described a technique for exposing the middle portion of the third ventricle. The choroidal fissure is opened along the tenia fornicis, and the body of the fornix is displaced to the opposite side. The layers of the tela chooroidea are split in the interval between the two ICVs to enter through the roof of the third ventricle.33,37,47,48 We agree with Nagata, et al.,33 that fewer difficulties are encountered when opening the choroidal fissure along the tenia fornicis as opposed to opening it along the tenia chooroidea, because no choroidal arteries or major ventricular veins pass through the tenia fornicis.

Conclusions

Given the inherent advantages and disadvantages of all the various exposures used in exploration of the third ventricle, posterior enlargement of the foramen of Monro along the choroidal fissure offers direct and adequate access to the anterior and middle portions of the third ventricle without causing damage to vital neural and vascular structures. The successful application of this technique by the surgeon is reliant on an absolute familiarity with the venous variations in this region. Our study demonstrates a high incidence of posteriorly located ASV–ICV junctions, which allows the foramen of Monro to be enlarged along the choroidal fissure as far as the junction. This technique proved particularly appropriate in our patients with third ventricular tumors, in whom the aperture afforded by the foramen of Monro was inadequate to dissect and remove these lesions. Since the advent of improved cerebral angiography, MR imaging, and MR venography, variations in the subependymal veins of the lateral ventricle and their relationships to the foramen of Monro can be determined preoperatively. Such information plays an important role in planning an effective and precise surgical approach. Our modification of the transforaminal approach to the third ventricle, posterior enlargement of the foramen of Monro was inadequate to dissect and remove these lesions. Since the advent of improved cerebral angiography, MR imaging, and MR venography, variations in the subependymal veins of the lateral ventricle and their relationships to the foramen of Monro can be determined preoperatively. Such information plays an important role in planning an effective and precise surgical approach. Our modification of the transforaminal approach to the third ventricle, as described in this paper, is a procedure that allows successful exploration of these formidable lesions and avoids sacrifice of any vital neural or vascular structures.

Acknowledgments

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