Interhemispheric Approach

Stephanie Anetsberger¹, Pablo Gonzalez– Lopez², Yasmeen Elsawaf¹, Alice Giotta Lucifero³, Sabino Luzzi³,⁴, Samer K. Elbabaa¹

¹ Department of Pediatric Neurosurgery, Arnold Palmer Hospital for Children, Orlando, Florida, ² Department of Neurosurgery, Hospital General Universitario de Alicante, Miguel Hernandez University, Alicante, Spain, ³ Neurosurgery Unit, Department of Clinical-Surgical, Diagnostic and Pediatric Sciences, University of Pavia, Pavia, Italy, ⁴ Neurosurgery Unit, Department of Surgical Sciences, Fondazione IRCCS Policlinico San Matteo, Pavia, Italy.

Abstract. The interhemispheric approach is the natural route to reach the parafalcine and paraventricular structures through the interhemispheric fissure. In this chapter, we report the main anterior and posterior corridors of the interhemispheric approach. (www.actabiomedica.it)

Introduction

The anterior and posterior interhemispheric approaches provide access to the deep midline parafalcine and paraventricular structures through the interhemispheric fissure. The first posterior interhemispheric transcallosal approach to the pineal region was originally described by Walter E. Dandy in 1915 with an animal model (1). Since the anterior and posterior interhemispheric approaches and their variations have been widely applied.

The anterior interhemispheric approach can be applied to access ruptured ACoA aneurysms, Tönnis first described this technique in 1936 (2).

Additionally, the anterior interhemispheric approach was applied to access the hypothalamic region in 1939 by William van Wagenen (3). This approach can also aid in the resection of medial hemispheric gliomas, metastases, AVMs, or lesions of the lateral or third ventricles from the contralateral side. In 1944, Bush described an anterior interhemispheric transcallosal interforniceal approach for the removal of anterior third ventricular tumors such as colloid cysts, hypothalamic hamartomas, and craniopharyngiomas (4).

A variation of this approach, the anterior inferior interhemispheric subcallosal approach, permits access to the suprasellar region. Here, an anterior midline skull base trajectory aids in resection of third ventricular lesions, large craniopharyngiomas or olfactory groove meningiomas, as well as distal aneurysms of the anterior cerebral artery. Pericallosal aneurysm resection depends on the location of the aneurysm relative to the genu of the corpus callosum. A low interhemispheric approach is preferred for aneurysms located below the genu to secure proximal vascular control.

The posterior interhemispheric approach is suitable for the removal of space-occupying lesions of the posterior third ventricle, posterior thalamic tumors, and pineal region masses with predominantly superior extension.

Anatomy

An understanding of the parasagittal venous anatomy is crucial for the execution of interhemispheric approaches (Figure 1).

Major topographic elements of the midline corridor:
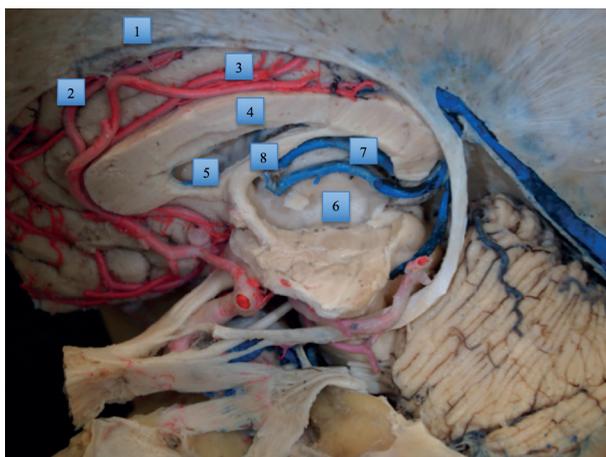
Figure 1: Dissection by Pablo Gonzalez-Lopez et al.; 1 Falx cerebri, 2 Callosmarginal artery, 3 Pericallosal arteries, 4 Corpus Callosum (Body), 5 lateral Ventricle, 6 III. Ventricle, 7 septal vein, 8 Fornix.

- Superior and inferior sagittal sinus
- Parasagittal veins
- Gyrus cinguli
- Corpus callosum
- Pericallosal arteries
- Fornices
- Septum pellucidum
- Cisterna veli interpositi with the internal cerebral veins
- Lateral and third ventricles and the anterior superior aspect of the suprasellar region

The cerebrovascular structures in each dissection level should be carefully preserved. Preservation of the sagittal sinus and their venous tributaries, as well as the diencephalic veins, is vital during interhemispheric exposure to avoid surgical morbidity. Specific risks involve the combination of brain retraction and venous occlusion, which may result in extended venous infarction and hemiparesis (Table 1).

Preoperative Considerations

Imaging/Preoperative MRI

Consideration must be made for the specific underlying pathology resected; supply of a vascular lesion or tumor location regarding surrounding structures requires surgical planning. For the interhemispheric approach location of the superior sagittal sinus and the corresponding bridging veins, as well as the pericallosal and callosomarginal arteries should be assessed. If necessary magnetic resonance venogram or a CT-angiogram should be performed. For the surgery of vascular lesions and aneurysms, a digital subtraction angiography (DSA) is helpful.

Neuronavigation aids in accurate orientation in the midline and localization of the lesion. Intraoperative neurophysiological monitoring should be used to prevent postoperative neurological deficits. For vascular procedures, transcranial doppler should be employed.

CSF-Drainage

For large tumors, CSF drainage over an external ventricular drain or lumbar drain facilitates brain relaxation and mobilization of the tumor.

Anterior Interhemispheric Approach

Positioning

With careful positioning and head-rotation, gravity assisted self-retraction of the brain, combined with CSF drainage, widens the interhemispheric fissure allowing for atraumatic surgical dissection without rigid

Table 1: Anatomical structures accessible through the anterior interhemispheric transcallosal approach (5).

Ipsilateral	Midline
Medial part of the frontal lobe	Superior sagittal sinus
Ipsilateral cingulate gyrus	Anterior cerebral falx
Frontal horn of the lateral ventricle	Distal (A3, A4) segments of anterior cerebral artery
Cella media of the lateral ventricle	Anterior corpus callosum
Foramen of Monro	Velum interpositum
Septal vein, thalamostriate vein,	Third ventricle
Choroid plexus	Interpeduncular fossa
	Tip of the basal artery
	Opposite cingulate gyrus
	Lateral aspect of the contralateral ventricle

brain retraction. Patients may be placed in supine or lateral position; the former may allow for improved orientation, while the lateral positioning employs gravity assisted retraction to mobilize the ipsilateral hemisphere.

The Head and operating table should be elevated to approximately 15° to provide sufficient venous drainage.

The head should be anteflexed approximately 15° to 45° and rotated about 10° to 30° as well as lateroflexed to the side of the craniotomy. Lateroflexion and rotation of the head aid in a significant relaxation of the frontal lobe, which by this move, depresses from the Falx cerebri, permitting access to the interhemispheric space with or without minimum retraction of the hemispheres.

An ipsilateral interhemispheric approach requires lateroflexion of 30° and rotation of 10°. A contralateral approach requires lateroflexion of 10° and a rotation of 10° (Figure 2).

Figure 2: Patient positioning for anterior interhemispheric approach.

Incision

With the use of neuronavigation, a bone flap is tailored to the venous anatomy to avoid sacrificing the bridging veins. The borders of trephination should be extended over the midline to gain control over the superior sagittal sinus. After defining the craniotomy, a curvilinear incision behind the hairline or a horseshoe incision one-third behind and two-thirds anterior to the coronal suture and across the midline is made. Then subcutaneous tissue is mobilized, the galea aponeurotica and the periosteal layer are incised in a curvilinear fashion and retracted towards the midline. If necessary, this flap can be utilized for water-tight dural closure.

Craniotomy

For a paramedian craniotomy, two burr holes are placed over the superior sagittal sinus; the first burr hole is made at the frontal-medial corner of the craniotomy, and the second parietally at the posterior-medial corner. Subsequently, an additional 1-2 paramedian burr holes are made. The dura is separated from the inner table of the calvarium over the sinus and deep to the planned craniotomy with a Penfield dissector. The bone cut is made by sawing away from the sagittal sinus. The craniotomy should measure 2.0 to 3.0 cm. By undercutting the bone, the angle for visualization can be increased which facilitates the use of micro-instruments within the limited craniotomy. After removing the bone flap the sinus should be covered with Gelfoam, Surgicel, or Cottonoid.

The decision whether to perform the craniotomy ipsilateral or contralateral to the pathology is made preoperatively after a thorough analysis of the preoperative imaging. According to the keyhole concept, deep-seated lesions are best exposed through a contralateral interhemispheric approach. This approach offers more flexible working angles for lesions extending laterally.

Dura Opening

The C-shaped dura opening is based towards the superior sagittal sinus. The dura-flap is fixed with

two sutures. Subsequently, the superior frontal gyrus should be carefully dissected from the midline. Bridging veins running within the dura or the falx cerebri before entering the superior sagittal sinus should be dissected away from the dura and the arachnoid adhesions. If a bridging vein is injured or must be sacrificed, cerebral retraction in this area should be minimized to prevent cerebral infarction and postoperative brain edema from compression of the venous anastomosis.

Opening of the interhemispheric fissure and dissection

After mobilization of the frontal lobe and the falx cerebri, the interhemispheric fissure is carefully opened. Thorough CSF drainage is necessary to gain space in the interhemispheric fissure. After further dissection within the interhemispheric fissure and retraction of the cingulate gyrus, the corpus callosum is approached. The cingulate gyri may be adherent; thus, careful differentiation from the corpus callosum is vital. The ipsilateral callosomarginal arteries may serve as landmarks to define the midline dissection planes and avoid subpial injury until the pericallosal arteries can be defined. The corpus callosum is subsequently exposed in the midline between the paired pericallosal arteries. Neuronavigation guidance aids in planning the precise location of the 1-2cm callosotomy; tailored to the needs of surgery with as limited as possible. After reaching the goal of surgery, the subdural space and ventricles, if breached throughout the procedure, should be filled with artificial CSF before the dura is closed in a watertight fashion. The coverage on the superior sagittal sinus with Gelfoam or Surgicel should not be removed. After accessing the ventricular system, a ventricular catheter may be required briefly during the postoperative period *f* (6).

Variations of the Anterior interhemispheric approach

Anterior superior trans-callosal interhemispheric approach for intraventricular exposure

Interhemispheric approach to the lateral ventricles
Lesions of the lateral ventricles located medially within the ventricular chamber can be exposed through an ipsilateral interhemispheric approach. Optimal positioning of the head enables exposure of the lateral ventricle after gentle mobilization and retraction of the hemisphere through a limited callosotomy. Lesions located laterally in or adjacent to the lateral ventricle, especially within the dominant hemisphere, should be exposed via a contralateral trans-callosal approach.

Interhemispheric approach to the third ventricle

The third Ventricle can be entered via an interfornical, sub-choroidal, trans-choroidal, or trans-foraminal route using an interhemispheric trans-callosal approach. Applying for the inter-fornical access, manipulation, and contusion of both fornices may result in severe postoperative permanent memory loss. Unilateral impairment may cause minor deficits, especially on the nondominant side. Therefore, to avoid the risk of memory loss, the sub-choroidal or trans-choroidal approaches are more favorable for third ventricular access.

Anterior inferior subcallosal interhemispheric exposure for the skull base pathologies

The anterior inferior interhemispheric approach is one of the most frequently employed techniques for lesions of the anterior cranial fossa; via this approach extended lesions of the frontal skull base and the anterior plane of the supra-sellar region can be effectively accessed.
Preoperative planning of the craniotomy should consider the relationship between the skull base and the corpus callosum, as well as the relationship between the genu and rostrum of the corpus callosum.
Through a mid-positioned craniotomy, the anterior plane of the supra-sellar region can be accessed. The rostrum corpus callosum, the lamina terminalis, and the third ventricle can be approached via a basal approach (Table 2).

Surgical technique of the anterior inferior interhemispheric approach

Patient Positioning
The patient should be placed in the supine position with the head elevated above the thorax, facilitat-

Table 2: Anatomical structures approached through the different variants of the anterior inferior subcallosal interhemispheric approach (5).

Superior variant	Mid variant	Inferior variant
Anterior third of the SSS	Anterior superior SSS	Inferomedial frontal lobe
Anterior third of the falx cerebri	Anterior third of the falx cerebri	Anterior third of the falx cerebri
Frontal skull base	Frontal skull base	Rostrum of the corpus callosum
Tuberculum sellae	Tuberculum sellae	Lamina terminalis
Christa Galli	Christa Galli	Anterior third ventricle
Olfactory groove, lamina cribrosa	Sella turcica, diaphragma sellae	Optic nerves and chiasm
Superior ethmoidal cells	Medial part of the frontal lobe	ICA, A1, ACoA, A2, incl. perforators
Sphenoid sinus	Genu of the corpus callosum	
Medial part of the frontal lobe	Gyrus rectus	
Genu of the corpus callosum	Rostrum of the corpus callosum	
Olfactory bulbs, olfactory tracts	Olfactory tracts	
A3, A4 Segments of the ACA	Optic nerves and chiasm	
	Pituitary	
	ICA, A1, ACoA, A2, A3 incl. perforators	

ing cranial venous drainage. The head is flexed according to the level of the approach. The more inferiorly the craniotomy is performed, the more retroflection is needed. In order to expose the sellar and supra-sellar area, a retroflection of 10° to 20° is sufficient. In lesions accessed via the superior variant of the approach, the head is Antero-flexed approximately 10°. For approaching structures like the lamina terminalis, the rostrum corpus callosum, or the anterior third ventricle, flexion of 30° to 45° is applied. The head is rotated approximately 10° towards the side of the craniotomy to allow the frontal lobe to reduce away from the falx cerebri.

Posterior interhemispheric approach for lesions of the posterior segment of the third ventricle and the pineal region

With a posterior interhemispheric approach, the posterior part of the tentorial incisura can be exposed via a supratentorial route. This region is located posterior to the midbrain and corresponds to the area of the quadrigeminal cistern. Through this approach, the splenium, pineal gland, mesencephalic tectum, upper part of the vermis, and complex neurovascular structures can be overlooked. Such complex neurovascular structures include the internal cerebral veins, the vein of Galen, the branches of the posterior cerebral and the superior cerebellar arteries, and the trochlear nerve (Table 3).

Preoperative Considerations

Again, a careful study of the venous anatomy in

Table 3: Anatomical structures exposed through the posterior interhemispheric approach(5).

Supratentorial	Infratentorial
Posterior part of the superior sagittal sinus	Splenium of the corpus callosum
Posterior part of the falx	Vein of Galen
Straight sinus, tentorium	Basal vein of Rosenthal
Medial surface of the occipital lobe	Internal cerebral vein
Splenium of the corpus callosum	Pineal gland
posterior part of the inferior sagittal sinus	Cisterna veli interpositii
Posterior periocallosal artery	Quadrigeminal plate
Distal segment of the PCA	Upper vermis
Vein of Galen	CN IV
	Distal segments of the PCA and SCA

preoperative MRI is crucial, as it provides information regarding the location of the internal cerebral veins, veins of Rosenthal and Galen in relation to the pathology and aids in the determination of the pathway of dissection between and around the internal cerebral veins.

Posterior Interhemispheric approach

Positioning

In principle, the same technique applies to the anterior interhemispheric approach. The patient may be positioned supine or lateral, more neck flexion is required as compared to an anterior transcallosal approach. The patient may also be positioned prone or semi-sitting with anteflexion of the head which allows for optimal venous drainage but carries the risk for air embolism. The patient´s head and thorax are elevated ca. 15° for better venous drainage. To bring the tentorium into a horizontal plane the head may be Antero-or retroflexed up to approximately 45° depending on the course of the straight sinus and the location of the planned craniotomy. If the straight sinus is more perpendicular, less retroflection is required and craniotomy can be placed next to the occipital protuberance. With a slight head rotation of approximately 10°, the occipital lobe falls away from the falx cerebri allowing access to the deep structures with minimal brain retraction.

Surgery

To access midline pathology, a 5-6 cm long bone flap is created on the right side of the skull. Resection of paramedian pathology requires the bone flap to be placed on the ipsilateral side, centered either in the coronal suture or one-third anterior and two-thirds posterior to the coronal suture. An extended posterior approach places the sensorimotor cortex at risk of compromise; further, all parasagittal veins in this area must be preserved. The exact location of the craniotomy is dependent upon the individual shape of the tentorium and the straight sinus, as well as on the individual pathoanatomical situation. The craniotomy is performed as outlined in the anterior interhemispheric approach section.

Intraoperative electrophysiological monitoring and Neuronavigation are essential. Compared to the frontal and parietal areas, prominent bridging veins are uncommon in the occipital region. Sufficient CSF drainage is also of paramount importance.

Callosotomy should be planned with neuronavigation, most of the splenium must be spared to prevent the risk of disconnection syndrome. In tumor surgery, the endoscope is a helpful tool to inspect the operative blind spots below the splenium and laterally under the corpus callosum for residual tumor (7).

Pitfalls

Incorrect positioning and insufficient surgical planning with inadequate intracranial exposure.
Risk and Complications

Complications may arise via vascular structure compromise, injury of the superior sagittal sinus should be packed immediately. Venous infarction can occur through injuries of the superior sagittal sinus or due to occlusion of large bridging veins coursing into the sinus. The bone flap should be fixated without compression of the superior sagittal sinus to avoid sinusoidal thrombosis.

Aggressive retraction of both cingulate gyri can cause akinetic mutism; thus, fixed retractors must be avoided. The hemisphere should be mobilized via gravity assisted positioning, dynamic retraction, and CSF drainage. There have been suggestions that sectioning of the anterior aspect of the corpus callosum is not associated with severe distinct symptoms, although it can cause a decrease in the spontaneity of speech ranging from a mild slowness in initiating speech to mutism. A posterior and complete callosal section has demonstrated a broad array of postoperative behavioral abnormalities. Therefore, the commissural section should be restricted to surgical necessity.

After intraventricular procedures, the intraventricular and intradural space should be filled with normal saline at body temperature to avoid severe pneumatocephalus. Soleman et al. assessed the risk and morbidity of the interhemispheric approach in 26 patients undergoing 28 procedures. Approach-related morbidity occurred following 7 anterior interhemi-

spheric approaches and one posterior interhemispheric approach including pseudomeningocele (7.1%), persistent subdural effusions (10.7%), epidural bleed (3.6%), and infections (3.6%). In this series, there were no CSF leaks, supplementary motor area syndrome, seizures, or subdural hematomas. None of the approach-related complications led to permanent morbidity or mortality (8).

Case Illustration

Case # 1 Cavernous Malformation in the Gyrus Rectus After Radiation Therapy of a Bifocal Germinoma

Presentation

A 15-year old girl with a history of a bifocal germinoma treated by biopsy and adjuvant therapy including proton therapy, presented with an acute headache. Imaging demonstrated a large hemorrhagic brain mass in the left gyrus rectus. The previous imaging depicted remission of the germinoma as well as a small lesion in the same location of the hemorrhage suggestive of a cavernous vascular malformation; Because of suspected recurrent bleeding and rapid growth of the cavernoma within one-year, resection of the cavernoma was recommended (Figure 3A).

Surgery

The patient, under general anesthesia, was placed in the supine position, with her head side fixed in the Mayfield clamp, elevated at approximately 15°, and slightly extended and rotated 25° to the left side. Baseline SSEPS and MEP neurophysiologic monitoring were obtained. Intraoperative Neuronavigation was registered using preoperative MRI, and craniotomy and incision were planned. A left frontal butterfly incision was made behind the hairline with a slight extension across the midline to the right side. Three burr holes were made; two were performed over the superior sagittal sinus in the midline, in the anterior and posterior corner of the planed craniotomy, and a third was performed over the left frontal bone. The underlying dura over the superior sagittal sinus and the left frontal lobe was bluntly dissected free from the bone and a craniotomy connecting the three burr-

holes was performed. The superior sagittal sinus was covered, and the dura was opened in a C-shaped manner. It was then reflected over the midline with two sutures. After sharp dissection of arachnoidal planes, CSF was drained using suction and cottonoid patties until the left cerebral hemisphere was relaxed. An anterior interhemispheric parafalcine approach was performed until the pericallosal arteries were appreciated
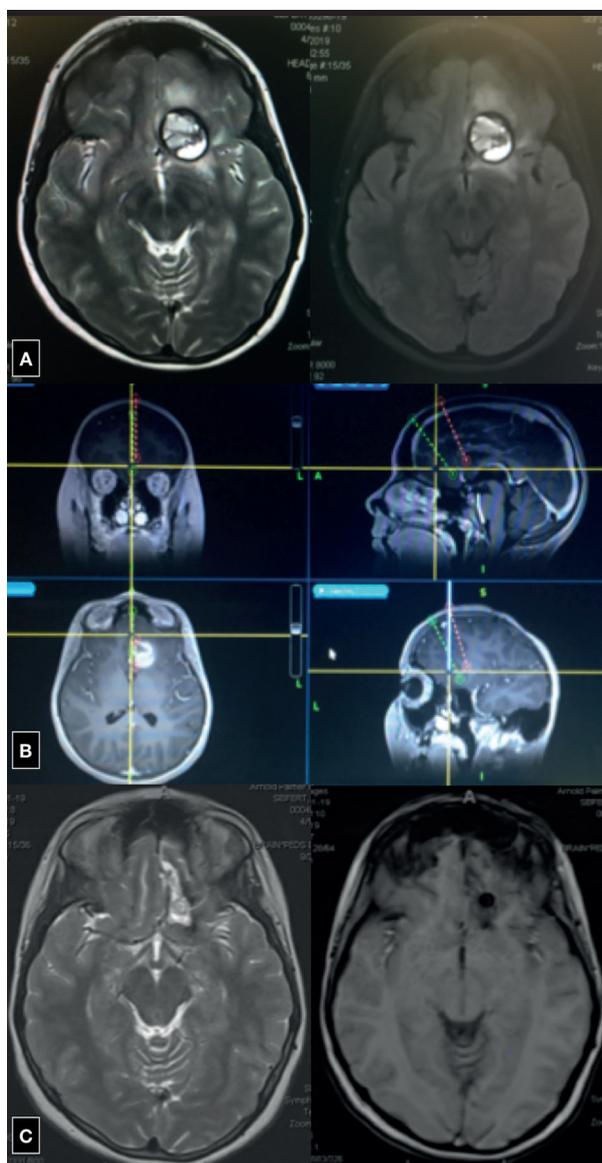
Figure 3: (**A**) Preoperative axial T2-weighted and FLAIR MRI showing a left gyrus rectus cavernoma. (**B**) Intraoperative neuronavigation showing the surgical trajectory to the target. (**C**) Postoperative axial T2-weighted and FLAIR MRI revealing the complete removal of the cavernoma.

and continued until edema in the left frontal lobe was noted due to the underlying hemorrhagic mass. Significant adhesions in the interhemispheric fissure were sharply dissected while protecting the branches of the pericallosal arteries. The corticectomy and entry to the cavernous mass were planned using neuronavigation. The edema was managed by repeated CSF drainage, mannitol, and hyperventilation. With bipolar electrocautery and microscissors, a horizontal corticectomy was performed. With the assistance of neuronavigation and under careful suction, the cavernoma hemorrhagic mass was entered. An immediate expression of a large amount of fresh and old blood products and hemosiderin resulted in a relaxation of the left frontal lobe. The cavernoma mass was circumferentially bluntly dissected first with cottonoid patties, then with a Penfield dissector #5; the associated developmental venous anomaly was preserved. Heavy staining of hemosiderin of the cavernoma resection bed was carefully dissected free with the Sonopet aspirator until there was healthy surrounding white matter circumferentially. A thorough inspection of the resection cavity revealed no residual cavernoma. Careful hemostasis was performed using a combination of thrombin-soaked Gelfoam and Flowseal. All hemostatic agents were irrigated until irrigation was clear. Dura was closed using interrupted Nurolon 4-0 sutures, followed by Onlay Duragen Plus and Tisseal sealant agent. Cranioplasty was performed using the native bone flap. There were no SEEP or MEP changes throughout the case (Figure 3 B, C).

Case # 2 Ruptured Flow Aneurysm of Left Pericallosal Artery with Associated AVM Grade 3

Presentation

A 12-years-old boy fell unconscious during a soccer match. His admission GCS was 8 and he was intubated and a CT scan revealed a fronto-basal midline hematoma (Figure 4A).

An ICP probe was inserted in the left frontal lobe. ICP initially was normal. A digital subtraction angiography was obtained showing a ruptured flow aneurysm descending from the left pericallosal artery pointing towards the left cingulate gyrus as the source of the hemorrhage. This artery, anterior to the caudate nucleus, was feeding a small grade 3 AVM draining into the

septal vein. Emergent hematoma evacuation, resection of the AVM as well as clipping of the associated aneurysm, was performed after a challenging attempt at endovascular interventional occlusion.

Surgery

General anesthesia was continued. The patient was positioned in a supine position lying on the left side with an elevation of the right shoulder. The head was fixed in the Mayfield Clamp elevated about 15°, extended, and rotated approximately 30° towards the left side. Craniotomy and incision were planned. A left frontal butterfly incision was made behind the hairline with a slight extension across the midline to the right side. Three burr holes were made, two were performed over the superior sagittal sinus in the midline, and a third was performed over the left frontal bone. The dura was bluntly dissected free from the tabula interna of the bone and a craniotomy was performed. The superior sagittal sinus was covered, and the dura
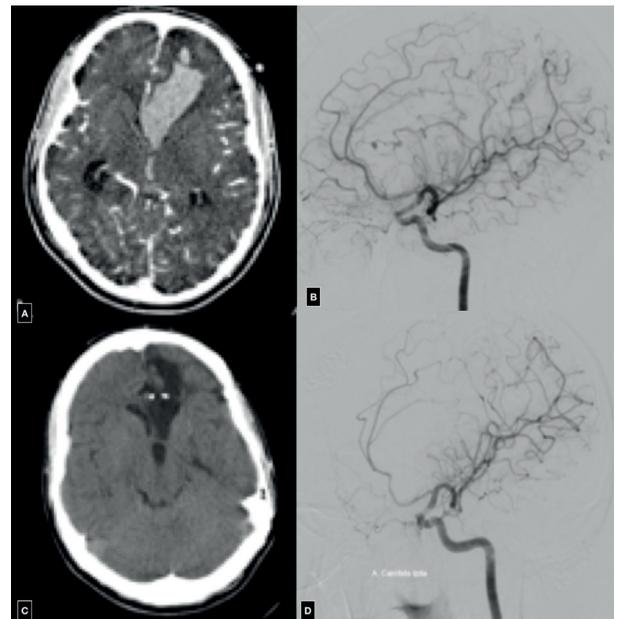
Figure 4: (**A**) Pre-operative contrast-enhanced CT scan revealed a fronto-basal midline hematoma. (**B**) Lateral projection digital subtraction angiography, obtained after the injection of the left internal carotid artery, and showing a small anterior interhemispheric AVM (grade 3) associated with a flow-related left pericallosal artery aneurysm. (**C**) Postoperative axial CT scan showing the complete removal of the hematoma. (**D**) Lateral projection post-operative digital subtraction angiography confirming the complete exclusion of the AVM.

was opened in a C-shaped fashion and reflected over the midline with two sutures. After sharp dissection of arachnoidal planes, the CSF of the interhemispheric fissure was drained until the brain was relaxed. The interhemispheric approach was continued until the left callosomarginal artery was identified and followed. The hematoma was entered and the left pericallosal artery was appreciated. The hematoma was carefully evacuated, and the proximal feeding artery of the flow aneurysm was dissected and clipped. Afterwards the dissection was continued laterally towards the nidus, which was circumferentially devascularized followed by clipping of the drainage vein into the septal vein.

Careful hemostasis was performed, the subdural space was filled with normal saline. Dura was closed in a watertight fashion. Cranioplasty was performed using the native bone flap (Figure 4 B,C,D).

Conflict of Interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

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Sabino Luzzi M.D., Ph.D.
Neurosurgery Unit, Department of Clinical-Surgical, Diagnostic and Pediatric Sciences, University of Pavia, Pavia, Italy.
Polo Didattico "Cesare Brusotti",
Viale Brambilla, 74 - 27100, Pavia, Italy;
Phone numbers: Secretary: +39 0382502780
Office: +39 0382502781
E-mail: sabino.luzzi@unipv.it