Endovascular approach and technique for treatment of transverse-sigmoid dural arteriovenous fistula with cortical reflux: the importance of venous sinus sacrifice

Andrew Phillip Carlson, Ali Alaraj, Sepideh Amin-Hanjani, Fady T Charbel, Victor Aletich

ABSTRACT

Background  Treatment of dural arteriovenous fistula involving the transverse-sigmoid region with cortical reflux is complex and treatment options may require sacrifice of the fistulous segment of the sinus.

Objective  To review our results in this subset of patients and describe current endovascular decision-making and approaches.

Methods  We reviewed cases of endovascular sinus sacrifice for dural fistulas at our institution from 2007 to 2012. Demographic, decision-making, technical and outcome data were collected.

Results  Seven patients were identified who underwent endovascular sinus sacrifice for treatment of dural fistula during this 4-year period. Determination of the fistulous sinus segment was based on the pattern of cortical drainage. Endovascular access to the sinus was achieved by transarterial, transvenous or via open surgery in one case. Complete cure of the target fistula was obtained in all cases. One patient had transient post-procedure headache. There were no hemorrhages, new neurological deficits or signs of increased intracranial pressure. Six of the seven patients had angiographic follow-up at least 6 months after treatment with no recurrence.

Conclusions  Fistulas of the transverse-sigmoid sinuses with cortical reflux may require sacrifice of the parent sinus for cure. Defining the fistulous segment and occluding this segment deliberately, completely and precisely is essential for cure. Several modalities and approaches can be used to achieve this. For properly selected patients, cure of the lesions can be achieved with this method with low risk of morbidity.

RESULTS

Seven patients who underwent endovascular sinus sacrifice for dural fistula treatment during the 4-year period of the review were identified (table 1). Age at presentation ranged from 46 to 63 years. One patient presented with hemorrhage and the remainder presented with headaches or represent a unique subset of dAVF where the venous drainage pattern may be complex involving both transverse sinuses. We present a series of these cases treated with sinus occlusion, integrating the lessons learnt from the previous era of predominantly transvenous treatment, with the current technical advances of Onyx (ethylene vinyl alcohol in DMSO; Ev3-Covidien, Irving, California, USA). In addition, we focus on the decision-making of sinus occlusion (approach and region to occlude) and technical nuances in order to clarify the optimal approach in the contemporary era where a large number of treatment modalities and techniques are available. We emphasize that (1) the direction of cortical venous drainage (not sinus flow direction) determines whether a sinus segment is functional; and (2) the occlusion should be performed deliberately, completely and precisely over the non-functional segment to avoid inadvertent occlusion of normal cortical drainage.

METHODS

The endovascular neurosurgery records for the Department of Neurosurgery at our institution were reviewed for diagnoses of dAVF over the period 2007–2011 using an approved Institutional Review Board protocol. These patients were then reviewed to determine those who underwent endovascular venous sinus sacrifice as part of the treatment. Angiographic data including treatment sessions, treatment modalities, angiographic cure and results of follow-up angiography were recorded. Clinical data including age, presentation, timing of treatment and clinical outcome were also noted. Individual illustrative cases were identified to highlight examples of the endovascular techniques used as well as factors involved in decision-making for sinus sacrifice. The decision-making and technical nuances were reviewed for each case to formulate the case illustrations and treatment paradigms (see Discussion for details).
other neurologic symptoms. All fistulas involved the transverse, sigmoid or jugular bulb and had cortical reflux, although one patient (number 7) had a complex fistula involving the contralateral sinus as well. Multiple treatment sessions were required for cure of the target fistula in all but two patients (3 and 7). Three patients underwent sinus sacrifice as the initial treatment (2, 3 and 7), while transarterial methods for feeder embolization were attempted initially in the remainder. In two of the three patients in whom sinus sacrifice was the initial treatment, this was the only procedure required. In general, transarterial methods were preferred initially to determine if the fistula could be cured without sinus sacrifice. Methods used for sinus occlusion included transarterial embolization with Onyx through arterial feeders and advanced into the sinus (n=1), a transarterial approach to coiling the venous sinus (n=1), transvenous coiling (n=4) and surgical access for coiling an isolated sinus segment (n=1). The illustrative cases describe the decision-making and technique for each approach.

Clinically, the three patients with pulsatile tinnitus (1, 3 and 4) improved after treatment. In the three patients presenting with headache (4, 6 and 7) the symptoms also improved after treatment. The two patients with visual symptoms at the time of presentation did not have any change in vision in the relatively short follow-up. The target fistula was angiographically cured in all seven patients, but there was residual fistula in the contralateral sinus in the one patient with complex bilateral fistulas. Six of the seven patients have undergone follow-up angiography at a minimum of 6 months after treatment (range 6–24 months). There was no sign of recanalization or fistula recurrence in any patient at 6-month follow-up. No new hemorrhage, venous infarction or new neurologic deficit was seen after the procedure.

Table 1  Summary of cases

| Patient no | Age | Presentation | Cognard type | Location of fistula | Number of sessions | TA/TV both | Sinus occlusion initial treatment? | Angiographic follow-up time (months) | Remained cured? | Clinical outcome | Clinical follow-up time (months) |
|------------|-----|--------------|--------------|---------------------|-------------------|------------|----------------------------------|-------------------------------------|----------------|-----------------|-------------------------------|
| 1          | 58  | Pulsatile tinnitus | IIB            | Left sigmoid sinus | 2                 | TA No      | Yes                             | 6                                   | Yes            | Improved        | 8                             |
| 2          | 62  | Intracerebral hemorrhage | IIB            | Left sigmoid sinus | 2                 | TA Yes     | Yes                             | 24                                  | Yes            | Mild headache, seizures, but working full time | 24               |
| 3          | 48  | Pulsatile tinnitus | IIB            | Left sigmoid sinus | 1                 | TV Yes     | Yes                             | 6                                   | Yes            | Improved        | 6                             |
| 4          | 62  | Headache, pulsatile tinnitus | IIB            | Left sigmoid sinus | 2                 | Both No    | Yes                             | 8                                   | Yes            | No symptoms      | 8                             |
| 5          | 46  | Pseudotumor cerebri, vision changes | IIB, III | Bilateral sigmoid sinus (Left treated with occlusion) | 11                | Both No    | L side yes, R remains            | 0                                   | na             | Unchanged, developed radiation induced dermatitis | 1                             |
| 6          | 59  | Headache, visual field deficit | IIB            | Right transverse sinus | 5                 | Both No    | Yes                             | 6                                   | Yes            | Headache improved, vision unchanged   | 6                             |
| 7          | 63  | Headache, progressive fistula on serial imaging for aneurysm | IIB            | Left jugular bulb | 1                 | TV Yes     | Yes                             | 12                                  | Yes            | No symptoms      | 13                            |

TA, transarterial; TV, transvenous.

Illustrative cases

Case 1: Transarterial intravenous sinus embolization with coils and liquid embolic agents

This 62-year-old patient presented with a left frontal intraparenchymal hematoma measuring 4 × 3 × 2 cm with mild aphasia and right-sided hemiparesis. Angiography revealed a large dural fistula located in the region of the left transverse sinus with massively dilated arterial feeders from the left external carotid artery (figure 1). In addition, there were large feeders from the right middle meningeal, bilateral meningohypophyseal trunks and a left posterior cerebral artery branch. There was evidence of steal angiographically from the left hemisphere as well as venous ectasia, dilation and extensive cortical reflux.

One week after presentation the patient was taken for embolization. Initially, the very large dilated segment of vein entering the junction of the transverse-sigmoid was catheterized transarterially. An attempt was made initially to preserve the sinus, and coiling of the dilated venous segment was initiated at the junction with the sinus. After deploying 36 coils and n-butyl cyanoacrylate (n-BCA) through this segment, it was noted that there were several vessels still filling distally directly into the sinus. Two further large pedicles were then embolized with coils and n-BCA glue. A second embolization session was undertaken 6 days later via a large dilated arterial feeder. Although initial attempts were made to preserve the patency of the sinus, there was persistence of the fistula feeding directly into the sinus. At this point an Echelon microcatheter (Ev3-Covidien) was advanced transarterially through the fistula into a dilated vein and Onyx was delivered into the sinus in the region of the two distal coiled arterial feeders resulting in complete occlusion. Control angiography revealed no further filling via any of the vessels and no cortical reflux.
Figure 1  Illustrative case of patient 2. (A) Lateral view of left external carotid injection demonstrating the complex fistula involving the transverse-sigmoid junction. There are multiple large dilated feeders from middle meningeal branches as well as the occipital artery (narrow arrows) and reflux into several cortical veins (wide arrows). Early drainage into the sigmoid sinus is seen. (B) Right anterior-posterior external carotid injection showing middle meningeal feeders crossing the midline to the point of fistulization at the left sigmoid sinus. (C) Diagram of the fistula demonstrating feeders which drain both directly into a venous varix as well as into the sigmoid sinus. The arrows show the direction of flow with red being arterialized, purple mixed and blue normal venous drainage. (D) Left vertebral anterior-posterior projection showing feeding into the fistula from distal superior cerebellar and meningeal branches. (E) Unsubtracted radiograph showing the coil, Onyx and n-BCA mass in the region of the feeding vessels and sinus. The arrow shows a microcatheter in a distal middle meningeal branch which was used to inject Onyx into the coil mass to complete the occlusion of the sigmoid sinus and fistula. (F) Left common carotid artery injection venous phase showing no early venous drainage and occlusion of the left transverse-sigmoid junction. There is stasis in the feeding vessels from the external carotid artery (arrows). (G) Diagram showing the coil mass in the region of the fistula with restoration of normal venous drainage and preservation of the vein in the left transverse sinus. The catheter is shown pushing the liquid embolic into the sinus.

The patient recovered well from the hemorrhage and has undergone multiple follow-up diagnostic angiograms and been followed clinically for 24 months with no sign of recurrence.

Case 2: Transvenous sinus embolization with coils
This 48-year-old patient presented with pulsatile tinnitus and was found to have a dural fistula involving the distal transverse sinus with complete occlusion of the sigmoid sinus distal to the fistula. Feeding vessels were primarily from the left external carotid artery with smaller branches from the right external carotid and vertebral arteries (figure 2). There was evidence of cortical reflux into a large temporo-occipital vein with direct connection to a large superior convexity vein draining into the superior sagittal sinus. Several other refluxing veins were also noted, however a transition in the medial portion of the transverse sinus was noted where there was normal anterograde cortical drainage. This was thought to represent the transition into the functional segment of the sinus.

Sinus occlusion was considered the first-line treatment for this fistula, which clearly involved the sinus itself. A diagnostic catheter was positioned in the left external carotid artery. The right internal jugular was then catheterized from the femoral vein and a 6 F 80 cm Shuttle sheath (Cook Medical, Bloomington, Indiana, USA) was positioned. A Neuron 0.053 (Penumbra, Alameda, California, USA) guide catheter was then advanced across from the right to the left transverse sinus due to distal left sigmoid occlusion.

An Echelon-14 (eV3 Neurovascular) microcatheter was then advanced through the sigmoid sinus and into the dilated temporo-occipital vein, sufficiently distal to the point of fistulization that complete disconnection of that vein could be achieved. A total of 48 coils were then deployed in order to pack this segment of the sinus tightly as well as each of the origins of the cortical veins. Control arterial angiography showed no further filling of the fistula after embolization with preservation of the normal venous drainage into the medial transverse sinus.

The patient’s tinnitus resolved; there was temporary worsening of headache after the procedure which resolved within 1 week and the patient remained asymptomatic at 7-month follow-up with no sign of recurrence angiographically.

Case 3: Transvenous sinus embolization with coils of isolated sinus segment using surgical sinus access
This 62-year-old patient presented with headache and progressive left pulsatile tinnitus. The patient was found to have a left-sided transverse-sigmoid dural fistula fed primarily from left external carotid artery branches and feeders from the posterior cerebral artery branches were also noted (figure 3). The sinus was found to have near occlusion proximally and distally to the segment of sinus with extensive cortical reflux. The feeding vessels clearly involved this segment of the sinus but were too small to achieve adequate complete transarterial embolization of the involved sinus segment.

Initial attempts were made to access the fistulous segment of the sinus from the left internal jugular and then from the left transverse sinus via the right internal jugular. Despite attempts to probe through the occluded segments, it proved...
impossible to access the sinus segment draining the fistula. Direct access to the fistulous segment was therefore gained via a craniotomy, with a sheath placed directly into the sinus. A 5 F guide catheter was then passed into this sheath and an Echelon microcatheter was advanced into the sinus. The entire segment of isolated sinus was tightly packed with a total of 43 coils. Control angiography revealed no further filling and there was no further retrograde venous drainage.

The patient’s symptoms completely resolved and follow-up angiography at 8 months showed no filling of the fistula.

DISCUSSION

Treatment of cranial dAVF depends on the anatomic features of the fistula and the patient’s clinical symptoms. Cognard/Borden type I fistulas involve only the dural sinus with normal anterograde flow and no cortical reflux. Treatment is typically considered for symptom (pulsatile tinnitus) amelioration only. Cognard type II fistulas directly involve the sinus: type IIA with retrograde sinus flow and normal cortical drainage; type IIB with anterograde sinus flow but with cortical reflux; and type II a+b with retrograde flow in the sinus with cortical reflux. The Borden and Dindjian systems both classify any fistulous segment as type II. Since cortical reflux is the most important risk factor for subsequent hemorrhage, treatment is aimed at eliminating this reflux. The key concept for treatment of dAVF is interruption of the exiting venous channel at the earliest point after fistulization, and in general agrees with the overall approach as previously outlined. Fistulas involving the transverse-sigmoid region with cortical reflux, however, represent a challenging subset to treat safely and completely and are the focus of this series.

Figure 2  Illustrative case of patient 3. (A) Oblique external carotid angiogram showing early drainage into the transverse-sigmoid junction fed by multiple external carotid artery feeders. There is extensive cortical reflux (wide arrows) and distal occlusion of the sinus (large arrow). A small vein in the mid transverse segment was draining anterograde (narrow arrow), defining the fistulous segment. (B) Diagram of the fistula. The arrows demonstrate the direction of flow, showing the transition zone of the transverse sinus from non-functional to functional drainage. The grey area indicates occlusion of the sinus. (C, D) Anterior-posterior and lateral venous phase angiograms. A guiding catheter extends up the right jugular, across the torcula and into the most distal dilated cortical vein. (E) Completed coil mass occluding the region of the sinus. (C, D) Anterior-posterior and lateral venous phase angiograms. A guiding catheter extends up the right jugular, across the torcula and into the most distal dilated cortical vein. (E) Completed coil mass occluding the region of the fistula at the transverse-sigmoid junction. Note the packing of coils into the origins of the refluxing veins (arrows) to ensure occlusion. (F) Venous phase of the left common carotid artery angiogram showing no filling of the sinus but with drainage of the previously refluxing veins via cortical anastomoses. Note the preservation of the normal vein in the mid transverse segment (arrow) seen on the original angiogram. (G) Diagram of the region of coil mass occluding the sinus with coils extending into the previously refluxing veins and normal venous (blue) flow the remainder.

Two major paradigm shifts have characterized the endovascular treatment of dAVF. Initial endovascular treatment included a variety of transarterial methods including injection of Polyvinyl alcohol (PVA), silk suture or liquid embolic, but were primarily performed prior to surgical intervention and did not result in long-lasting cure. The advent of detachable coils and detachable balloons allowed for more precise control of embolization and transvenous routes of access became more standard therapy. These series firmly established the concept that only the fistulous segment of the sinus should be sacrificed. While this concept was clearly described, only sporadic series including patients with direct sinus fistulas with cortical reflux were reported, and the largest of which by Urtasun et al12 reported a 70% cure rate in 10 such patients. Other smaller series reported cure in 1/4 patients, 1/1 patient and 4/5 patients.

The second major shift occurred in the mid-2000s with the availability of Onyx, which allowed for distal penetration into the fistula without a wedged position and has largely revolutionized the endovascular treatment of dAVF. Onyx allows for penetration into multiple feeding vessels; however, it may act more unpredictably when transitioning from the arterial feeders into the fistula and unless the venous anatomy and fistulous segment is carefully evaluated. In addition, it may be more difficult to achieve complete cure of the fistula using only the transarterial approach with Onyx. Recent series with Onyx support this observation. Natarajan et al10 reported cure in only 2/5 direct sinus fistulas with cortical reflux involving the transverse-sigmoid sinus with transarterial Onyx. The series reported by Abud et al12 supports the observation that sinus occlusion is usually required for this type of fistula, noting that...
sinus occlusion was required in 65% of fistulas directly involving the sinus. The series included 10 patients with transverse-sigmoid fistulas with cortical reflux, but the results were not reported separately for these patients. Cognard et al.26 reported an 80% overall cure rate with transarterial Onyx embolization in 30 patients, 10 of whom had direct sinus fistulas with cortical reflux although this subset was not reported separately. Other small series suggest wide variability with cure rates ranging from 50%24 to 100%27,28 in patients with direct sinus fistulas and cortical reflux.

Our overall approach and treatment strategy for dAVF of the lateral sinuses with cortical reflux involves defining the involved or non-functional segment of the sinus and ensuring complete, deliberate and precise embolization of that segment. This approach builds on the experience with transvenous embolization but, with the addition of Onyx to the treatment armamentarium, a more complete cure rate can be achieved. Defining the fistulous segment

Fistulas that directly involve the sinus typically require sinus occlusion for complete cure. That said, there are probably a subset of cases where there is a parallel venous channel within the sinus29 which is the point of fistulization, or the fistula may involve a cortical vein very close to the sinus. These two reasons are likely to explain why a minority of fistulas reportedly involving the sinus have been reported to be cured by transarterial embolization without sinus sacrifice.25 For this reason, a transarterial approach may be considered first (as it was in most of our cases) to determine if the fistula can be filled with liquid embolic without obstructing the sinus. If, in fact, the fistula can be cured with a parallel venous channel occlusion, this is preferable but may be considered functionally to be closer to a type III fistula (with the point of fistulization into a cortical vein).

In most cases of true type II fistula, the segment of sinus where there is a fistula must be completely occluded to ensure cure.13,16,21 The defining feature of the fistulous segment of the dural sinus is the direction of cortical drainage rather than the direction of flow within the sinus.16 The entire segment of sinus where there is cortical reflux defines the region that can be safely sacrificed since these veins are not draining via that segment, even if their ultimate route of drainage is not clear angiographically. If there is cortical reflux, the drainage is

![Image of patient 4. (A, B) Anterior-posterior and lateral left external carotid angiograms showing early venous drainage into the transverse-sigmoid. There is a very fine network of arterial feeders with cortical reflux. The small arrows show the retrograde flow in the cortical veins and the large narrow arrow shows the left hemisphere draining to the right transverse sinus. The sinus proximal and distal appears to be nearly occluded. (C) Diagram of the fistula showing the occluded segments (grey) proximal with cortical reflux. The arrows demonstrate the direction of flow. (D, E) Anterior-posterior and lateral views of the sheath showing the guiding catheter (arrow) secured in the fistulous segment and the multiple refluxing veins as well as the collateral pathway of drainage into the superior sagittal sinus. (F, G) Anterior-posterior and lateral unsubtracted views showing the coil mass within the fistulous segment. The artifact of the previously attempted transarterial Onyx embolization is also visualized, showing the inability to penetrate into the tiny feeding vessels (arrows). (H) CT scan showing the coil mass occluding the region of the fistula. The cranial defect is also seen where the guide catheter was inserted. (I, J) Anterior-posterior and lateral left external angiograms showing no evidence of early venous drainage. (K) Diagram demonstrating the cranial opening (dotted circle) for coiling of the transverse-sigmoid fistula. The grey areas show the occluded segments.](image-url)
mining the direction of cortical venous drainage as a result of this pertains to the defined, preferably side by side in the same projection to determine sigmoid region, both supratentorial and infratentorial drainage and the direction of drainage. For carefully assessed from each injection to determine their presence phase examination. The veins in the region of the drainage remained anterograde into the sinus.

Angiography remains the gold standard in assessing venous drainage pattern. This requires a complete six-vessel angiogram (including external carotid artery injections) with delayed venous phase examination. The veins in the region of the fistula must be carefully assessed from each injection to determine their presence and the direction of drainage. For fistulas in the transverse-sigmoid region, both supratentorial and infratentorial drainage must be evaluated. Each of the injections must be carefully examined, preferably side by side in the same projection to determine where there is normal venous drainage. One nuance relating to this pertains to the difficulty which can potentially arise in determining the direction of cortical venous drainage as a result of arterial changes during power injection. If there is a very high flow fistula, the slight increase in arterial pressure from the power injection with diagnostic angiography can transmit contrast through the fistula and retrograde into the venous system at the site of the fistula. We have found two methods to address this issue. First, the direction of cortical drainage is evaluated only after the power injection is complete, and occasionally a reversal of the initial flow in the venous structures is noted. The second potential technique is with the use of quantitative magnetic resonance angiography (Q-MRA) (NOVA; VasSol, River Forest, Illinois, USA). This technique allows for quantitative measurement of flow in the venous structures as well as the directionality. Although we have only begun to apply this technology to decision-making in dAVF, it may have a role in the future for detailed evaluation of venous function.

Technical nuances

Once the functional and non-functional segment has been identified, a strategy must be developed to completely occlude the non-functional segment while preserving the functional segment including all its cortical draining veins. This may not always be the most direct vascular route to the fistula since a margin is usually needed within the vein for the first few coils to find purchase. Transarterial sinus sacrifice with Onyx can be accomplished, but must be done with the same care that transvenous sacrificed is performed—that is, sinus occlusion should be performed deliberately in these patients rather than as an unplanned part of the procedure. Entry of Onyx into the sinus and the region of functional sinus must be carefully monitored. The Onyx within the sinus will have less control and no ability to reposition. This strategy is best suited to situations where there is a long non-functional segment. A balloon may be used in the venous sinus to preserve the lumen or protect the normal venous drainage. Either way, the position of the most proximal normal draining vein should be carefully understood and one might even consider positioning a second arterial catheter in the vessel that defines the functional segment to ensure that the vein is not being encroached upon. For example, if the nearest anterograde draining vein is seen on a vertebral injection, control angiograms through the vertebral may determine the relation of the Onyx to the vein and therefore the boundary of acceptable Onyx reflux into the sinus.

Venous sacrifice is typically performed with transvenous coil embolization owing to the much higher degree of control. Both groins should be punctured. We typically position a 6 F shuttle sheath in the internal jugular with the tip positioned at the jugular bulb. The shuttle sheath is used to provide support and avoid guide buckling. Through this a guiding catheter (Neuron 0.070 inch or 0.053 inch, 105 cm or 115 cm; Penumbra) or distal access catheter 0.057 inch or 0.070 inch (Concentric, Mountain View, California, USA) is advanced into the sinus to provide support for the coiling microcatheter. This is especially important when the torcular needs to be crossed with the microcatheter. The guide catheter beyond the torcular region will provide the support and avoid microcatheter herniation into the superior sagittal sinus. The microcatheter is then advanced well beyond the fistula, preferably into the cortical refluxing vein at the far (distal) end of the non-functional segment. The placement of the catheter distal to the fistula allows for a small segment where the coils will need to gain purchase before tight packing can be accomplished. If coiling is started in the sinus at the distal end of the non-functional segment, complete occlusion of the most distal refluxing vein must be ensured, which can be difficult as the starting segment may not be as tightly packed due to lack of distal bolstering. This is why we prefer to begin the coiling in the most distal refluxing vein. The point where the coiling is started is critical since, once the sinus is occluded, there will probably not be a venous access point if there is residual fistula after the treatment. The coiling is then continued until the previously identified first vein which drains into the sinus is reached (the functional segment). If incomplete occlusion of the sinus persists, one may consider supplementing the coil mass with Onyx or n-BCA, taking care to not allow any reflux into the functional segment.

A diagnostic arterial catheter is left in the vessel that best defines the non-functional and functional segment of the sinus. This allows for periodic control angiography to assess the adequacy of sinus occlusion, disconnection of the fistula as well as to confirm patency of the anterograde draining veins. In addition, we have found that there are some cases where, due to the high flow into a fistula, transvenous road maps or angiography may not identify a portion of the fistula/sinus connection due to the high pressure and arterial road mapping is required.

Special access situations may arise owing to the complex nature of dAVF and the putative pathogenic mechanism involving venous sinus occlusion. If the segment cannot be reached directly, a contralateral approach via the torcular may be considered (see patient 2). In some patients a transarterial approach into the venous system may be considered if the fistulas are large enough. This is distinguished from transarterial feeder occlusion of the sinus as described above by the fact that the microcatheter is positioned through the fistula and into the venous sinus for coiling (as in patient 1). When access to a segment of the sinus which is completely isolated (no anterograde or retrograde access can be achieved) is required, surgical access may be considered (see patient 3). A Burr hole or small craniotomy is made over the sinus and an armored sheath is placed into the sinus and secured. In this situation, planning is especially critical to ensure that the
sheath is placed in such a way that it will allow for complete embolization of the isolated segment. The craniotomy should be performed in the operating room with image guidance and intraoperative angiographic confirmation of the position of the sheath. Hemostasis around the sheath can be achieved with fibrin glue or temporary packing with hemostatic agents. When the sheath is secure and the wound closed, the patient is brought to the angiography suite for coiling to allow the use of biplanar angiography and control arterial injections. Coiling is then completed using the same techniques described above. These cases are ideally suited for combined surgical/angiography suites. Houdart et al. described the use of direct surgical access to an isolated sinus segment in 10 patients. The fistulous segment was then occluded with coils, glue or a combination and the fistula was cured in all cases. Five patients had long-term angiographic follow-up with stable results.

CONCLUSIONS
Sinus occlusion is the definitive treatment for dAVF involving the sinus with cortical reflux. The direction of the cortical veins defines the fistulous segment and any anterograde cortical drainage must be preserved regardless of the direction of flow in the sinus. The sinus occlusion should be planned for and the fistulous segment clearly defined prior to any intervention (transarterial or transvenous). The sinus occlusion should be performed deliberately, completely and precisely to avoid any residual flow in the segment or any occlusion of normal drainage. Multiple approaches including transarterial, transvenous or direct surgical as well as many embolic materials including detachable coils, Onyx and n-BCA may all be required for treatment. Using these principles, a high cure rate with low morbidity can be achieved.

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Contributors
APC: acquisition of data, analysis, drafting and revising the manuscript, final approval. AA: conception and design, revising the article, final approval. SA-H: interpretation of data, revising the article, final approval. FTC: conception, revising the article, final approval. VA: analysis and interpretation of data, revising the article, final approval.

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