Correlation between CTA findings and angiographic characteristics of intracranial arteriovenous fistulas

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Learning objectives

• To analyse the types and diagnostic criteria of intracranial arteriovenous fistulas.
• To correlate the computed tomography angiography (CTA) findings with the angiographic characteristics of these lesions.
• To assess the usefulness of CTA in the initial evaluation of intracranial arteriovenous fistulas.
Background

When in the emergency department we identify in a CT an intracranial hemorrhage, we must complete the study with a CTA in order to detect treatable causes of secondary intracranial hemorrhage, such as arteriovenous fistulas (AVF). Primary intracerebral hemorrhage usually occurs in older patients and has typical locations (basal ganglia, thalamus, cerebellum and pons).

Intracranial hemorrhage (intraparenchymal, intraventricular and subarachnoid) is a frequent presentation of arteriovenous fistulas (AVF). Although digital subtraction angiography (DSA) is the gold standard diagnostic test, there is a good correlation between CTA and DSA findings and CTA may be very useful for an initial emergency diagnostic approach.

CTA is able to identify typical findings that help to detect an AVF as the cause of an intracranial hemorrhage, such as tortuous feeding arteries, drainage veins, thrombosis or stenosis of the dural venous sinuses affected, early enhancement of the cavernous sinus and superior ophthalmic vein or dilatation of the middle meningeal and intraorbital arteries.
Findings and procedure details

Arteriovenous fistulas are abnormal arteriovenous communications that are considered mostly acquired lesions and account for 10-15% of all intracranial vascular malformations, including dural, pial, nontraumatic carotid cavernous and traumatic AVF.

1.- DURAL ARTERIOVENOUS FISTULAS

1.1.- Concept: abnormal direct arteriovenous communication between a dural artery and a dural venous sinus or cortical vein. Although intracranial hemorrhage is a frequent presentation of arteriovenous fistulas, they can also be an incidental finding (Fig. 1 on page 8).

1.2.- Cognard classification of intracranial dAVFs (Fig. 2 on page 8 and Fig. 3 on page 9): correlates the venous drainage pattern with the clinical course. The prognosis of dural AVF is defined by the presence or absence of cortical venous drainage.

- **Type I**: it is located in the sinus wall, with normal antegrade venous drainage and without reflux into cortical veins. The clinical course is benign.
- **Type II**: 
  1. **IIA**: it is located in the main dural sinus, with retrograde venous drainage (reflux into the sinus) and without reflux into cortical veins.
  2. **IIB**: it has antegrade venous drainage with reflux into the sinus and the cortical veins.
  3. **II A + B**: it has retrograde drainage with reflux into the sinus and the cortical veins. 10-20% hemorrhage.
- **Type III**: it has direct drainage to the cortical veins, not to the sinus. There is not venous ectasia. 40% hemorrhage.
- **Type IV**: there is direct cortical drainage, with venous ectasia. 65% hemorrhage.
- **Type V**: it consists on spinal perimedullary venous drainage, with progressive myelopathy.

1.3.- Typical CTA findings (Fig. 4 on page 9 and Fig. 5 on page 10):

- Numerous, asymmetric and/or dilated feeding arteries (Fig. 6 on page 10): we have to evaluate the cervical vessels to identify unusual branches of the external carotid arteries that might serve as DAVF feeders.
- Numerous, asymmetric and/or dilated venous collaterals (Fig. 7 on page 11).
• **Transcalvarial channels** (Fig. 8 on page 12): arterial branches of the external carotid artery.
• Asymmetric attenuation of jugular veins.
• «Shaggy» appearence of a dural venous sinus or the tentorium cerebelli: irregularity along their margins because of the presence of innumerable small venous efferents and/or intimal thickening associated with venous sinus hypertension.
• Asymmetric attenuation of venous sinus.
• Dural sinus thrombosis (Fig. 5 on page 10).
• Numerous and engorged cortical veins (Fig. 5 on page 10).

1.4.- **Intracranial dural arteriovenous fistulas with cortical venous drainage**: dural arteriovenous fistulas associated with cortical venous reflux are associated with poor outcome if left untreated.

The typical CTA findings are:

• Abnormal vessels outside de brain parenchyma.
• Numerous and engorged cortical veins (Fig. 9 on page 13 and Fig. 10 on page 14): enhancing tubular structures within the cortical sulci without true nidus within the brain parenchyma.
• Venous congestion or infarction, that can lead to venous hemorrhage: hypodensity lesion in the white matter.
• Focal enhancement: chronic venous ischemia sign.
• Subcortical curvilinear calcifications: related to chronic venous congestion (cortical venous reflux) with resulting impaired perfusion of the involved parenchyma.

2.- **PIAL ARTERIOVENOUS FISTULAS**

2.1.- **Concept**: pial arteriovenous fistulas are abnormal direct arteriovenous communication between a single or multiple pial or cortical arteries and a single venous cannel (Fig. 11 on page 15).

They are rare cerebrovascular lesions, representing just 5% of all cerebral arteriovenous malformations.

2.2.- **Characteristics**:

• There is no nidus.
• Pial AVFs are located on the surface of the brain.
• They are high-flow lesions.
• They are frequently associated with dilated venous pouches.
• They are more common in children and are frequently associated with hereditary hemorrhagic telangiectasia (congenital).
• They can also be post-traumatic.

2.3.- **Symptoms**: hemorrhage, seizure, neurological deficit, headache, cardiac failure in children, symptoms of increased intracranial pressure, a palpable mass with a giant varix, skull erosion or macrocephaly.

2.4.- **CTA findings**:

- Dilated vessels in the brain surface.
- Asymmetric dilatation of the pial feeding artery (Fig. 12 on page 16) (MCA, ACA or PCA), which is best seen at the level of the circle of Willis.
- Extraparenchymal venous dilations (Fig. 12 on page 16).
- Aneurysm in the feeder artery (the pathogenesis could be explained by the high rate of flow in the artery).

3.- **CAROTIDCAVERNOUS ARTERIOVENOUS FISTULAS**

3.1.- **Neuro-ophthalmologic symptoms**: proptosis, chemosis, partial or complete cranial nerves palsy (III, IV, V and VI) and dilated episcleral veins.

3.2.- **Types** (Fig. 13 on page 17):

- *Direct or traumatic CCF*: single direct communication between the internal carotid artery and the cavernous sinus.
- *Indirect, dural or spontaneous CCF* (often in middle-aged women): multiple dural feeders and numerous microfistulas within the cavernous sinus wall.

3.3.- **Venous drainage types**: With direct or dural CCFs, the venous drainage may be multidirectional:

- Anterior: drainage to the ophthalmic venous, the blood flow is toward the facial venous system and external jugular vein.
- Posterior: the fistula may drain into the superior petrosal sinus, the inferior petrosal sinus or the basilar plexus.
- Lateral: drainage is to the sphenoparietal sinus.
- Contralateral: both cavernous sinus plexus anastomose anteriorly and posteriorly via the intercavernous sinus.
- Inferior: flow can be into the pterygoid plexus.
3.4.- **Typical CT findings** (Fig. 14 on page 18):

- *Non-enhanced CT*: extraocular muscle thickening and periorbital fat edema.
- *At the arterial phase*: enlarged enhancing cavernous sinus, with an irregular lateral wall, suggestive of fistulous dural vessels.
- *CT angiography* depicts certain draining veins such as the superior ophthalmic vein (Fig. 15 on page 18) and the intercavernous sinus, basilar plexus, petrosal sinus, sphenoparietal sinus, and paracavernous sinus.

3.5.- **Traumatic carotid-cavernous arteriovenous fistula findings**:

- Size and location of the fistula tract: by the segmental division of the ICA.
- Cavernous sinus: morphology and early enhancement.
- Presence or absence of dilation of the ophthalmic vein (Fig. 15 on page 18) or facial vein.
- Pattern of venous sinus drainage: right or left superior petrous, inferior petrous or sphenoparietal sinus.
- Presence or absence of engorged pial-cortical veins and/or deep vein drainage.
- Presence or absence of venous aneurysm and/or venous sinus varix.
- Presence or absence of cervical artery dissection on the ipsilateral or contralateral side to the affected carotid artery.

3.6.- **CTA limitations**:

- It is unable to visualize the small feeding arteries in dural CCFs or the exact site of fistulous communication in direct CCFs.
- It is unable to provide information about the blood-flow characteristics within the fistulas.
Fig. 1: Incidental finding in a 67 year-old woman. CT angiography and digital subtraction angiography (DSA) of a dural arteriovenous fistula (Cognard type I) between a branch from the left anterior superior cerebellar artery (red arrows) and the left lateral sinus (blue arrows), with normal antegrade venous drainage and without reflux into cortical veins.

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Fig. 2: Cognard classification of intracranial dAVFs.

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<table>
<thead>
<tr>
<th>Cognard types of intracranial dural AVFs</th>
<th>Venous drainage</th>
<th>Antegrade or retrograde venous drainage</th>
<th>Cortical venous drainage</th>
<th>Venous ectasia</th>
<th>Prognosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Into venous sinus</td>
<td>Antegrade</td>
<td>No</td>
<td>No</td>
<td>Benign</td>
</tr>
<tr>
<td>IIA</td>
<td>Into venous sinus</td>
<td>Retrograde</td>
<td>No</td>
<td>No</td>
<td>Benign</td>
</tr>
<tr>
<td>IIB</td>
<td>Into venous sinus</td>
<td>Antegrade</td>
<td>Yes</td>
<td>Yes</td>
<td>Malignant</td>
</tr>
<tr>
<td>IIA+B</td>
<td>Into venous sinus</td>
<td>Retrograde</td>
<td>Yes</td>
<td>Yes</td>
<td>Malignant</td>
</tr>
<tr>
<td>III</td>
<td>Into cortical veins</td>
<td></td>
<td>Yes</td>
<td>No</td>
<td>Malignant</td>
</tr>
<tr>
<td>IV</td>
<td>Into cortical veins</td>
<td></td>
<td>Yes</td>
<td>Yes</td>
<td>Malignant</td>
</tr>
<tr>
<td>V</td>
<td>Spinal perimedullary</td>
<td></td>
<td></td>
<td></td>
<td>Malignant</td>
</tr>
</tbody>
</table>

**Fig. 3:** Cognard classification of intracranial dAVFs.

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**Typical CTA findings**

- **Numerous, asymmetric and/or dilated feeding arteries**
- **Transcalvarial channels**
- **Sinus findings:**
  - "Shaggy" appearance of a dural venous sinus or the tentorium cerebelli.
  - Asymmetric attenuation of venous sinus.
  - Dural sinus thrombosis.
- **Numerous, asymmetric and/or dilated venous collaterals**
- **Numerous and engorged cortical veins**
- **Asymmetric attention of jugular veins**
**Fig. 4:** Typical CTA findings of dural arteriovenous fistulas.

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**Fig. 5:** 92 year-old woman in a coma. In this case we can visualize almost every CTA sign of a dural arteriovenous fistula. CT (A and B): dural sinus thrombosis (green arrow) and hyperdense tubular structures adjacent to the cortical sulci (blue arrows). These structures are visualized in a delayed contrast enhanced CT (C) as numerous and engorged cortical veins (blue arrows). CT angiography (D and E) where we can visualize transcalvarial channels (browns arrows), and the arterial branches of the external carotid artery going through them (red arrows).

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**Fig. 6:** 72 year-old man with right hemicranial headache, dizziness and left lower limb weakness with fall, who has a dural AVF. CT: right parietal lobe hemorrhage (yellow arrow). CT angiography: tortuous vessels around the hematoma (red arrows), in the right parasagittal region and in the extracranial region. Digital subtraction angiography (DSA): dural arteriovenous fistula of the superior sagittal sinus, fed mainly by branches from both external carotid arteries (red arrow), with parasagittal parietal cortical drainage veins (blue arrows).

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Fig. 7: 65 year-old man with aortic and mitral endocarditis and mycotic aneurysm of the right MCA. Digital subtraction angiography (DSA): dural arteriovenous fistula (Cognard type III) supplied by ethmoidal arteries (red arrow), branches from the left ophthalmic artery, draining into two cortical veins with aneurismatic dilatations (blue arrow). CT angiography: a posteriori, we identified ethmoidal branches (red arrows) of the left ophthalmic artery, and dilated cortical veins (blue arrow).

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Fig. 8: CT angiography where we can visualize transcalvarial channels (browns arrows), and the arterial branches of the external carotid artery going through them (red arrows).

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Fig. 9: Type IV dural AVF. 67 year-old woman in a coma. CT: left occipital lobe and subdural hemorrhages (yellow arrows), which cause mass effect (orange arrow). CT angiography: tortuous vessels in the left occipital region, with a branch from the left middle meningeal artery (red arrow) separated from the skull by the subdural hematoma (yellow arrow). Digital subtraction angiography (DSA): type IV dural arteriovenous fistula of the superior sagittal sinus, fed mainly by a temporal branch from the left middle meningeal artery (red arrow), with left temporo-occipital cortical drainage veins (blue arrow).

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Fig. 10: 48-year-old man with sudden occipital headache, vomiting and lower limbs weakness, who has a dural arteriovenous fistula in the posterior fossa. CT: right cerebellar hemorrhage (yellow arrow). CT angiography: dilated veins in the torcular region (blue arrow). Digital subtraction angiography (DSA): dural arteriovenous fistula (Cognard type IV) in the posterior fossa, with main vascular supply from the left posterior meningeal artery (red arrow), draining into a cerebellar cortical vein in the torcular region (blue arrow).

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**Fig. 11:** Pial arteriovenous fistulas: abnormal direct arteriovenous communications between a single or multiple pial or cortical arteries and a single venous channel.

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Fig. 12: 71 year-old man with aphasia. CT angiography: was initially informed as normal. A posteriori review showed a dilated left Labbé vein (blue arrow). The feeding arteries (red arrows) are branches from the left middle cerebral artery. The yellow arrow shows the left temporoparietal hematoma. Digital subtraction angiography (DSA): pial arteriovenous fistula, fed mainly by branches from the left middle cerebral artery (red arrow), with left sigmoid sinus drainage through a dilated left Labbé vein (blue arrow).

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<table>
<thead>
<tr>
<th>Carotidcavernous arteriovenous fistulas</th>
<th>Fistula</th>
<th>Shunt</th>
<th>Contrast uptake by the cavernous sinus</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIRECT OR TRAUMATIC</td>
<td>Between the internal carotid artery and the cavernous sinus.</td>
<td>High flow shunt</td>
<td>Fast</td>
</tr>
<tr>
<td>INDIRECT OR DURAL (often in middle-aged women)</td>
<td>Multiple dural feeders and numerous microfistulas within the cavernous sinus wall</td>
<td>Low flow shunt</td>
<td>Slow</td>
</tr>
</tbody>
</table>

Fig. 13: Types of carotidcavernous arteriovenous fistulas.
### Table: CT Findings of Carotid-Cavernous Arteriovenous Fistulas

<table>
<thead>
<tr>
<th>Non-enhanced CT</th>
<th>Enhanced CT arterial phase</th>
<th>CT angiography</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extraocular muscle thickening and periorbital fat edema.</td>
<td>Enlarged enhancing cavernous sinus, with an irregular lateral wall, suggestive of fistulous dural vessels.</td>
<td>Draining veins such as the superior ophthalmic vein, intercavernous sinus, basilar plexus, petrosal sinus, sphenoparietal sinus, and paracavernous sinus.</td>
</tr>
</tbody>
</table>

**Fig. 14:** Typical CT findings of carotid-cavernous arteriovenous fistulas.

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**Fig. 15:** 39 year-old woman with left proptosis and hyperemia. CT angiography: left superior ophthalmic vein dilatation (blue arrow) and fistula point (red arrow). Digital subtraction angiography (DSA): dural carotid-cavernous arteriovenous fistula, fed mainly by branches from both the accessory meningeal artery and the meningohypophyseal trunk, with left superior ophthalmic vein drainage.

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Conclusion

Although digital subtraction angiography (DSA) is the gold standard diagnostic test for intracranial arteriovenous fistulas, it is not always available in emergency situations and CTA may be very useful for an initial emergency diagnostic approach.

CTA is a 24/24 available and fast technique instead of DSA and magnetic resonance imaging (MRI), and it is very useful for the evaluation of intracranial AVF providing key information necessary for an initial emergency diagnostic approach and treatment planning.
References


