Emergency neuroradiologic management (CTA, MRA, DSA) in traumatic head and neck vascular injury: Indications, diagnostic findings and treatment

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Authors: G. Sanfilippo, A. M. Simoncelli, E. Lafe, F. Zappoli Thyrrion; Pavia/IT
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Learning objectives

Emergency selection Criteria of traumatized Patient at risk of neurovascular injury (arterial dissection, venous thrombosis and AV fistulae)

Role of CTA-MRA and DSA in the diagnosis (sensitivity and specificity of different techniques) and management of the lesions (follow up and therapy)

Neuroradiological semiotics of vascular damage in different techniques (direct and indirect signs)

Diagnostic and therapeutic role of Digital Subtraction Angiography (DSA)
Background

Traumatic neurovascular injuries are rare (0.1%-2% of severe trauma), and are associated with high rates of morbidity (32%-67%) and mortality (17%-38%), especially if not recognized and promptly treated.

Post traumatic dissections are the main cause of stroke in young people.

A good screening protocol can reduce injury-related strokes in patients without primary focal neurologic deficits. (13)

PATHOPHYSIOLOGY

The central nervous system has a high sensitivity to the trauma, and to neurovascular injuries, that result in a diagnostic and therapeutic challenge.

Various parameters modification can break brain homeostasis inside the skull and lead to a permanent nervous tissue's injury if not recognized.

Once a vascular injury is localized and identified, the appropriate treatment may be initiated. Treatment options depend on the need to strike a balance between the risks and the benefits, upon the evaluation of the injury and the collateral circulation of the brain. The crucial variable is the neurologic status of the patient. It's important to remember that many times there are concomitant post traumatic lesions, sometime to be managed first.

Tab 1: Morbidity and mortality rate.

<table>
<thead>
<tr>
<th>Blunt vascular injuries</th>
<th>Morbidity</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICA</td>
<td>32-67%</td>
<td>17-38%</td>
</tr>
<tr>
<td>VA</td>
<td>14-24%</td>
<td>8-18%</td>
</tr>
</tbody>
</table>

Morbidity and mortality are therefore related to the extent of the trauma (Tab 1); for this reason, selection criteria have been identified for applying patients to angiographic study. (5)
Beyond the dynamics of the trauma, it is important to consider the patients' clinical condition (Glasgow coma scale GCS).

According to Wintermark, traumatic neurovascular injuries should be suspected in patients with a high-velocity trauma, low GCS, high injury severity score, and besides mandible fracture, complex skull fractures, (including carotid canal fractures), scalp degloving, any type of cervical spine injury, and/or TBI with thoracic injuries, and/or thoracic vascular imaging, as well as in patients with penetrating neck injury (class I recommendation).

The absence of manifest clinical signs or symptoms of a clinically significant vascular injury does not mean that the injury is not present. Based on Fogelman and Steenburg studies, the frequencies of missed vascular injuries ranging from 23% to 43%.

Sometimes patient's neurological condition can be silent in the first hours. Postraumatic neurovascular lesions are dynamic, and especially the less severe (grade I-II of Denver) can evolve. A follow up is needed, so CTA/MRA are usually performed after 7-10 days. MRI allows also to evaluate cerebral parenchyma.

**CATEGORIES OF VASCULAR LESIONS**

The types of endovascular lesions are two, and are classified as "blunt" and "penetrating". They can affect both the carotid and the vertebral arteries (18%-32% multivessel involvement), with different incidence. Vascular damage also affects the venous siystem, and this occurs more frequently in penetrating traumas.

Crissey and Bernstein have identified four different mechanisms of blunt carotid injury, related to the dynamic of the trauma.

<table>
<thead>
<tr>
<th>Type</th>
<th>Mecanism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type I</td>
<td>Direct blow to the neck</td>
</tr>
<tr>
<td>Type II</td>
<td>Hyperextension-contralateral rotation of the head and neck (most common)</td>
</tr>
<tr>
<td>Type III</td>
<td>Intraoral trauma</td>
</tr>
<tr>
<td>----------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Type IV</td>
<td>Skull base fractures (sphenoid or petrous bones)</td>
</tr>
</tbody>
</table>

Regardless of the type of injury, the mechanism is intimal destruction, which exposes the thrombogenic subendothelial collagen surface, resulting in platelet aggregation and distal embolization, partial or complete thrombosis.

About vertebral artery injuries, motion at the atlantoaxial joint, cervical fractures, and dislocations with bony impingements can lead to intimal and medial injuries.

The vascular lesions, and resulting radiologic signs, of penetrating traumas are generally similar, but with a higher prevalence of arterial occlusion and transection because of the penetrating nature of the injury.

**NEURORADIOLOGICAL CLASSIFICATION**

The spectrum of imaging findings is wide.

Digital subtraction angiography (DSA) is the gold standard in the detection of neurovascular lesion, but it is not available in all hospitals and it is an invasive procedure. It can be performed, when the patient is medically stable, to establish a diagnosis and proceed with endovascular treatment, if indicated. Thanks to the DSA it is possible to evaluate at the same time the location of the injury and the collateral circulation of the brain, to plan the best endovascular approach.

Retrospective studies and meta-analyses showed that multidetector CT angiography is a rapid, noninvasive and accurate diagnostic technique for vascular injuries investigation. CTA of the epiaortic vessels extended to include the circle of Willis has a sensitivity and specificity of almost 90%-100% for diagnosing vascular trauma in blunt vascular injury within the neck (evidence level II). (12)

The Denver grading scale is a grading scheme, composed of five entities, graded according to angiographic appearance:

- Grade I: intimal irregularity <25% narrowing
- Grade II: dissection with intramural hematoma and 25% narrowing
- Grade III: pseudoaneurysm
- Grade IV: occlusion
- Grade V: transection with extravasation, arteriovenous fistula (5)

The natural history and evolution of this lesions are different. A prognostic correlation was determined between the grade of injury and the risk of postinjury stroke (12). As showed in Tab 3, the lack of linear increase of stroke risk with vertebral artery injuries may be due the presence of collateral vessels (protective factor).

Tab 3. Grading scheme for blunt vascular injuries

<table>
<thead>
<tr>
<th>Denver grading scale</th>
<th>DSA/CTA aspect</th>
<th>Risk of stroke ICA</th>
<th>Risk of stroke VA</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>intimal irregularity with &lt; 25% narrowing</td>
<td>8%</td>
<td>/</td>
</tr>
<tr>
<td>II</td>
<td>dissection with intramural hematoma and &gt;25% narrowing</td>
<td>14%</td>
<td>38%</td>
</tr>
<tr>
<td>III</td>
<td>pseudoaneurysm</td>
<td>26%</td>
<td>27%</td>
</tr>
<tr>
<td>IV</td>
<td>occlusion</td>
<td>50%</td>
<td>28%</td>
</tr>
<tr>
<td>V</td>
<td>transection with extravasation, arterio-venous fistulas</td>
<td>Letal Refractory to therapy</td>
<td>100%</td>
</tr>
</tbody>
</table>

MRA is a reliable alternative to CTA in vascular mapping, (10) especially after injector-based contrast administration. (1)

During a MRI-MRA exam are also performed axial fat-suppressed T1 weighted sequences, that reveal intramural hematoma as hyperintensity around the vessel. MRA identifies dissections in up to 99%. (8)
Fig. 1: NECT image of a 47 yo man with ICA dissection after distortive trauma of the cervical spine; CT demonstrates absence of acute ischemic or hemorrhagic brain injury but shows an increase in caliber of the distal cervical tract of the right ICA, and eccentric focal hyperdensity (intramural hematoma).

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**Fig. 2:** Axial CTA in the arterial phase shows asymmetry of the distal cervical segment of right ICA, markedly thin.

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Fig. 3: MIP reconstruction. Coronal image shows caudo-cranial extension of the right ICA stenosis, in distal cervical segment; its lumen is filiform.

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**Fig. 4:** CTA (arterial phase). Axial cut shows reduced density of intracranial segments of right ICA (intrapetrous segment).

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Fig. 5: MIP CTA reconstruction of Willis poligonum shows reduction of density in right middle cerebral artery and of its terminal branches; note the absence of anterior and right posterior communicating arteries (reduction of blood flow in right ICA in plausible sub-occlusive stenosis).

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**Fig. 6:** The patient is subjected to medical therapy by venous thrombolysis but followed neurological clinical deterioration; after a CT negative for hemorrhagic events, it is decided to endovascular intervention. The figure shows AP projection, with injection into the right ICA which confirms dissection at intra-extracranial passage, residual flow is filiform and flow of the ipsilateral hemisphere is slow.

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Fig. 7: AP projection acquired after stent placement in the right ICA presenting enlargement of the caliber and greater blood flow velocity of the intracranial arteries.

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Fig. 8: Axial MRI-DIFFUSION (b1000) image shows early subacute lesion on the right hemisphere, after 7 days from trauma.

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Fig. 9: Axial FLAIR image, shows early subacute lesion on the right hemisphere, after 7 days from trauma.

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Findings and procedure details

Our CT study protocol includes basal spiral acquisition of brain and neck (also with bone HR) and MPR reconstructions of the cervical tract. The examination is completed with TCA study of the apiaortic and intracranial vessels with biphasic technique (venous after 40 sec for the study of collateral circulation) and MPR and MIP reconstructions. The MRI study protocol includes FLAIR-weighted mutiplanar standard T1W-T2W sequences, GE and DWI for the study of the brain that can be completed with MRA sequences for the study of arterial and venous vessels. Arterial MRA sequences: without contrast medium (cm) for the study of arterial intracranial vessels (TOF), and with cm for the study of epiaortic vessels and Willis circulation, with CE Care bolus technique and 3D MIP reconstructions. In case of study of venous sinuses, it is preferred to use a technique with cm (CE MR venography) to the less invasive ones without cm like 2D TOF or 3D Phase Contrast.

Regarding the arterial lesions, and remaining faithful to the aforementioned radiological classification (tab 3), we can make a first distinction between ischemic and hemorrhagic lesions.

Ischemic

Laceration of the intimal layer of vessel wall, with dissection flap and formation of an intramural hematoma, that can evolve in the stenosis of the lumen itself until its complete occlusion. However, there is a further radiological presentation for different evolution of the lesion, that is the formation of a pseudoaneurysm. See table 4 and 5.

Tab 4. Direct findings-arterial injuries

<table>
<thead>
<tr>
<th>NECT</th>
<th>CTA</th>
<th>MRI-MRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Vessel wall haematoma in the involved portion of the ICA: spontaneous crescent-shaped hyperattenuating focus</td>
<td>• Narrowed eccentric lumen surrounded by a crescent-shaped mural thrombus and thin annular enhancement (vasa vasorum of the adventitia)</td>
<td>• Absent flow-void in ICA and VA segments (vs the healthy side)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Hyperintense crescent sign (sickle-shaped hyperintensity) within the vessel wall (Fat</td>
</tr>
</tbody>
</table>
• Intimal flap and "double lumen" appearance
• Pseudoaneurysm
• Abnormal vessel contour on MRA (stenosis, pseudoaneurysm, occlusion)

As for vertebral artery (VA), dissections are mostly located in the segment V2 (~35%) and V3 (~34%). An important feature is to assess if the dissection involves the intradural portion V4, and thus the origin of the posterior inferior cerebellar artery.

As for the ICA, the most exposed to traumatic injuries are C1-C2 segments. This depends on the greater motility of these segments respect to the "fixed" tracts in the context of bone structures (high vulnerability to torsional forces).

The ICA, like the VA, have different distribution of elastic fibres compared to similar sized vessels elsewhere. Although the tunica media and tunica adventitia are present they are only a third as thick as their extracranial counterparts, with the vast majority of elastic fibres located in a subendothelial elastic lamina. This fundamental difference accounts for the markedly different natural history of intracranial arterial dissections compared to the extracranial ones. When a tear breaches the aforementioned subendothelial elastic layer, then there is little tissue preventing extension into the subarachnoid space, thus accounting for the very high rate of subarachnoid haemorrhage.

Tab 5. Indirect findings-arterial injuries

<table>
<thead>
<tr>
<th>NECT</th>
<th>CTA</th>
<th>MRI-MRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Early ischaemic brain changes in anterior/posterior circulation’s territories on CT an MRI images</td>
<td>-</td>
<td>• cerebral ischemia (hyperintense DWI-FLAIR)</td>
</tr>
<tr>
<td>• Complex skull fractures, skull base fractures</td>
<td></td>
<td>• Hemorrhagic foci (hypointense GE)</td>
</tr>
</tbody>
</table>
Hemorrhagic

Complete tearing of the vessel wall, accompanied by intraparenchymal (brain) or perivascular hematoma in the soft tissue contest (neck). After administration of contrast medium, the blush correspond to the presence of an active bleeding. Based on the affected compartment, we recognize: epidural, subdural, intraparenchymal hematomas, subarachnoid haemorrhage, laterocervical hematomas. Carotid cavernous fistulae are also included among hemorrhagic lesions.

*Carotid cavernous fistulas* (CCF) are a subtype of artero-venous fistula, characterized by abnormal communications between arteries and veins located in the cavernous sinus (CS). They are usually caused by severe head injuries or surgical traumas (2).

In penetrating trauma the laceration track crosses through the CS and cavernous segment of ICA.

In blunt trauma the CCF is the result of the transmission of shear stresses to the connective tissue fibers that connect cavernous segment of ICA to CS walls (for example central skull base fractures extended to CS region). Patients who suffered severe facial traumas require a long follow-up because of direct CCF may be clinically and radiologically evident even several days after the trauma.

FCC rarely heal spontaneously, and a delay in diagnosis and treatment increase the chance of irreversible neurologic ocular damage. Instead, early endovascular treatment can improve clinical outcome.

The pathological communication between arterial and venous system implicates a modification of the normal flow (speed and volume especially in venous compartment of cavernous sinus and tributary veins), and for this reason clinical manifestation are chemosis, conjunctival bleeding, diplopia, eyelid swelling, intense proptosis and vision loss, for oftalmic venous system cranial and nerve palsis (III, IV, Vc ,VI inside the CS) involvement.
Radiological findings of CCF are presented in the Tab 6.

Tab 6.CCF

CT/CTA

- proptosis
- orbital oedema
- enlargement of extraocular muscles (MR or LR greater than 4mm)
- SAH/ICH (rupture of cortical vein)
- fracture lines (CT)
- enlarged superior ophtalmic veins (>4mm)
- full-thickness defect within CS (abnormal arterialization of the flow)
- lateral bulging of CS, asymmetrical and early enhancement vs contralateral one
- enlargement and asymmetrical enhancement in sphenoparietal sinus, inferior petrosal sinus and superior petrosal sinus

MRI/MRA

- high flow shunt from cavernous ICA to CS
- retrograde flow from CS, most commonly into the ophtalmic veins
- enlargement of draining veins

Venous injury may occur both after a penetrating or a blunt trauma. Generally the involvement of the venous system is more common in penetrating injuries.

In penetrating trauma, the wound results in a venous sinus mural distruption and epidural hematomas, because of it crossing the site of dural sinus attachment. The same extra axial hemorrhagic lesion may occur in case of a skull fracture crossing the dural attachment of the sinus itself. In blunt injury the mechanism of the trauma lead to a venous thrombosis (whether the sinus is crossed by a fracture or not). About 7% of patients with venous thrombosis may experience venous infarction. (9)
For this reason in patients with fractures of the skullbase in a NCE-CT after a trauma, a slight hyper-density near the course of the venous sinuses must make suspect a focal post-traumatic thrombosis, and eventually a second diagnostic step with a CTA.

A delayed acquisition after the first arterial phase of CTA may show a focal full-thickness defect within the dural sinus involved, maybe neighbouring a fracture.

**DSA findings and treatment possibilities**

Angiography is still considered the gold standard for imaging cerebrovascular anatomy. Modern technology and further technical refinements (rotational angiography, 3D angiography) made this technique able to perform more efficiently imaging. DSA provides spatial and temporal resolution to evaluate dynamic and functional anatomy of cerebral circulation.

Biplane angiography (flat panel detectors) allows for orthogonal images to be simultaneously obtained, with a single contrast injection, limiting the time, contrast, radiations.

Angiographic images are acquired through low osmolality, nonionic cm (less allergenic) selective injection.

DSA is an invasive technique. Its risks include stroke, renal issues, access site hematomas, and others. Complication are about the 1%. (3)

High-grade dissection with suspicion of inadequate collaterals based on CT or MR techniques, or in inconclusive CTA cases, may be an indication to DSA, to complete the study of the lesion, and plan the best endovascular approach. (3)

In his review, Sianou suggests the following criteria for stenting: (3)

- patients with recurrent symptoms despite medical therapy,
- patients with hemodynamic hypoperfusion (involvement of multiple vessels or poor collateral vessels), patients with expanding or symptomatic pseudoaneurysm and contraindication to anticoagulation because of intracranial or systemic hemorrhage. (11)

Stenting procedures need appropriate pre- and postprocedural antiplatelet therapy, to guarantee patency of the stent and the target vessel itself.

When the patient presents other concomitant injuries with a high risk for severe bleeding, the approach must be evaluated by a interdisciplinary team to identify optimal type and time of treatment. (3)
Embolization therapy doesn't need pharmacological premedication. It is the first choice in patient, with active bleeding. Other purpose of this minimally invasive technique is to secure a impaired vessel, also if not actively bleeding. The neurointerventionalist has many arrows in his quiver. The approach depends on case by case evaluation, and basically on two different aims, the first referred to the "kind" of occlusion to achieve, and second the dimensions of the target vessel. See the table 7.

Tab7. Endovascular approaches

<table>
<thead>
<tr>
<th>Vascular lesions (DSA/CTA aspect)</th>
<th>Endovascular approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intimal irregularity with &lt;25% narrowing</td>
<td>Medical approach is preferred</td>
</tr>
<tr>
<td>Dissection with intramural hematoma and &gt;25% narrowing (if not responding to medical therapy, or in patient symptomatic)</td>
<td>Stenting</td>
</tr>
<tr>
<td>Pseudoaneurysm (if expanding or symptomatic)</td>
<td>Stenting with vessel wall reparation (ICA)</td>
</tr>
<tr>
<td></td>
<td>Embolization with vessel occlusion (ECA)</td>
</tr>
<tr>
<td>Symptomatic occlusion (acute)</td>
<td>Recanalization +/- stenting</td>
</tr>
<tr>
<td>Arterio-venous fistula</td>
<td>Embolization (coils)</td>
</tr>
<tr>
<td>Transection with extravasation</td>
<td>Embolization (coils or plug for large vessels, other embolic agents for small vessels)</td>
</tr>
</tbody>
</table>
**Fig. 10:** Axial CTA image of a 50 yo man after moto-cycle trauma, shows double lumen in distal cervical segment of the right ICA (basal CT negative for brain lesions).

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Fig. 11: MR Axial T1-weighted image shows eccentric vascular hyperintensity at the distal portion of the right ICA.

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Fig. 12: CTA MIP reconstruction; the sagittal image shows distal portion of the right ICA markedly irregular.

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Fig. 13: MRA MIP reconstruction shows distal portion of the right ICA markedly irregular.

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**Fig. 14:** Axial bone HRCT image, of a tetraplegic 45 yo man, shows unstable vertebral fracture, involving right transverse process of C5, with C5-C6 disc rupture. The patient was tetraplegic after a fall from 2 meters.

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Fig. 15: CTA axial image shows the absence of flow in the right VA.

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Fig. 16: T2-w Coronal image of the cervical spine shows the absence of regular signal void in the context of the right VA.

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Fig. 17: The MRA study confirms the occlusive stenosis of the right VA, from the cervical to the intracranial tract.

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Fig. 18: Lateral DSA projection with selective catheterization of the left internal masecellar artery that shows dural AVF of the left cavernous sinus’ region. Exclusive discharge into the ipsilateral superior orbital vein and angular vein. The patient is a 20 yo man, one year after a car accident.

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**Fig. 19:** Lateral DSA projection with selective injection in the left common carotid artery that confirms closure of the DAVF after endovascular treatment by coils.

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**Fig. 20:** Axial bone HRCT of a 45 yo man, after a work accident, shows a fracture line in the occipital bone on the left side.

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**Fig. 21:** Axial CTA in the venous phase shows parzial defect of opacization in the left transverse sinus (focal thrombosis).

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Conclusion

Imaging findings of acute severe trauma is performed to detect treatable lesions, involving neurovascular structures of head and neck, before secondary neurologic damage occurs. Usually CT and CTA imaging are the best and faster technique to study this patients, in wich parenchimal, bones and vascular damages may occur.

Detecting the vascular lesions allow a prompt treatment. Sometime the best approach is the endovascular one, after a multidisciplinary case discussion.
**Fig. 6:** The patient is subjected to medical therapy by venous thrombolysis but followed neurological clinical deterioration; after a CT negative for hemorrhagic events, it is decided to endovascular intervention. The figure shows AP projection, with injection into the right ICA which confirms dissection at intra-extracranial passage, residual flow is filiform and flow of the ipsilateral hemisphere is solw.

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**Fig. 9:** Axial FLAIR image, shows early subacute lesion on the right hemisphere, after 7 days from trauma.

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**Personal information**

Dr Giuseppina Sanfilippo

Resident in training. Neuroradiology Section. Department of Radiology and Neuroradiology diagnostic and interventional, IRCCS Policlinico San Matteo, piazzale Golgi 19, 27100 Pavia, Italy

Email: giuseppina.sanfilippo86@gmail.com

Dr Anna Maria Simoncelli

Neuroradiology Section. Department of Radiology and Neuroradiology diagnostic and interventional, IRCCS Policlinico San Matteo, piazzale Golgi 19, 27100 Pavia, Italy

Email: a.simoncelli@smatteo.pv.it

Dr Elvis Lafe

Neuroradiology Section. Department of Radiology and Neuroradiology diagnostic and interventional, IRCCS Policlinico San Matteo, piazzale Golgi 19, 27100 Pavia, Italy

Email: e.lafe@smatteo.pv.it

Dr Federico Zappoli Thiryon

Neuroradiology Section. Department of Radiology and Neuroradiology diagnostic and interventional, IRCCS Policlinico San Matteo, piazzale Golgi 19, 27100 Pavia, Italy

Email: f.zappoli@smatteo.pv.it
References