Multiphase CTA: collateral circulation evaluation on acute stroke

Poster No.: C-1275
Congress: ECR 2015
Type: Educational Exhibit
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Keywords: Neuroradiology brain, CT-Angiography, Diagnostic procedure, Image verification
DOI: 10.1594/ecr2015/C-1275

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Learning objectives

- Review the classification and importance of collateral circulation on acute ischemic stroke, especially in patients suitable to receive reperfusion therapy.
- Display the collateral circulation protocol used in our hospital.
**Background**

Progression to complete infarction after occlusion of a cerebral artery is highly variable. In some cases, infarction is complete in less than an hour, but other patients might show evidence of viable tissue for days. In patients whose tissue survives for a long period despite proximal arterial occlusion, retrograde filling of pial arteries (a surrogate indicator of leptomeningeal collateral vessels) is often evident in imaging studies.

Leptomeningeal collaterals are anastomotic vessels providing alternative routes for blood flow, especially in times of acute vascular occlusion. They are small arteriolar connections that allow retrograde perfusion of adjacent territories, so blood can flow in both directions as a function of the haemodynamic and metabolic needs of the two territories that they connect. In thrombotic and embolic stroke, intravascular pressure distal to the occlusion falls immediately. Concurrently, pressure within the pial vessels is relatively well preserved, resulting in a gradient that can promote flow through anastomoses.

There is much variation in collateral vessel density and diameter, and in their capacity to enlarge during ischaemia.

Their quality is reported to be an independent predictor of outcome after acute ischemic stroke, so better collateral circulation is associated with less infarct growth and better response to thrombolytic therapy, while poor collateralization is associated with hemorrhage after reperfusion therapy. Good collateral flow is assumed to be associated with favorable outcome as a consequence of maintaining the ischemic penumbra for longer until reperfusion occurs.

It is unclear whether the collateral grade represents an inherent characteristic of individual subjects or a potential therapeutic target in the treatment of acute stroke. Several interventions that might augment collateral blood flow are being investigated.
Findings and procedure details

Which is the best technique to evaluate collateral circulation is controversial.

Digital subtraction angiography provides excellent temporal and spatial resolution of collateral vessels and has been the gold standard because is the method that can best measure collateral extent and number. However, because of its invasive approach is not routinely used, especially in the acute setting. It also requires bilateral carotid and vertebral injection to determine the complete collateral circulation, which is unethical because it would delay the endovascular reperfusion treatment. Therefore, only justifies its use in context of a endovascular reperfusion procedure.

Single-phase CTA is widely used, but the low temporal resolution can result in overestimation of collateral flow.

Multiphase CTA is a non-invasive technique that allows assessment of the global collateral circulation with a single injection of contrast. It is a quick technique because post processing is not necessary and its rapid availability for patients with acute stroke makes it ideal for study of collateral status. In addition it has demonstrated good interobserver reliability and correlation with clinical outcome.

There is no standardization for the evaluation of collateral circulation, and there is great variability among different scanners and realization of CTA techniques.

Given the importance of collateral circulation in acute ischemic stroke, particularly in patients receiving reperfusion therapy, our hospital has established a protocol study of collateral circulation.

We have included patients with acute ischemic stroke of carotid territory (less than 8 hours from the onset of symptoms), stroke on awakening or indeterminate beginning, to be evaluated for reperfusion procedures.

Depends on the stroke features we perform one or another imagin technique. In patients within 4.5 and 8h from the onset of symptoms we use perfusion TC. CTA is performed in patients with less than 4.5h from the onset of symptoms, following the simple cranial CT to rule out a brain hemorrhage or extensive early signs that desestimate reperfusion procedures.

The collateral circulation rating scale most used today has 4 degrees depending on vascular filling (no vascular filling, <50% filler, > 50% and <100%, and a similar vascular filling or greater than the healthy contralateral hemisphere). However, has the disadvantage that depending on the time when the imaging is performed can vary the vascular filling and therefore the gradation. If it is done too soon, there is not enough
time to fill the arteries, and if it is done too late, little relevant arteries appear and venous appearance difficult the evaluation.

To solve this problem we perform cranial CTA in 3 phases (arterial, venous and delayed phase), which would allow assessment in 3 different vascular filling times and therefore provides more information regarding the hemodynamic status of the collateral circulation.

The first phase starts from the aortic arch, and the next two only in the brain. A 18G needle is used to inject 80 cc of contrast, at least 320 of concentration. The "bolus timing" is performed from the descending aorta and the imagin acquisition starts 7-9 seconds after the arrival of contrast to descending aorta (including this delay the machine itself). The second and third phase have 8 seconds delay in each phase without new injection of contrast.

Collaterals are measured by comparing backfilling arteries beyond the blocked artery to similar arteries in the opposite unaffected hemisphere. Vascular enhancement distal to occlusion is scored in anterior and posterior MCA territories. They are classified according to the University of Calgary classification.

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<th>Category</th>
<th>Score</th>
<th>Findings</th>
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| **Poor** | 0     | Compared to asymptomatic contralateral hemisphere:  
• There are no vessels visible in any phase within the occluded vascular territory. |
|          | 1     | Compared to asymptomatic contralateral hemisphere:  
• There are just a few vessels visible in any phase within the occluded vascular territory. |
| **Intermediate** | 2     | Compared to asymptomatic contralateral hemisphere there is:  
• A delay of two phases in filling in of peripheral vessels and decreased prominence (thinner vessels) and extent,  
  or  
• A one-phase delay and some regions with no vessels in some part of the territory occluded. |
|          | 3     | Compared to asymptomatic contralateral hemisphere there is:  
• A delay of two phases in filling in of peripheral vessels but prominence and extent is the same.  
  or  
• A one phase delay and decreased prominence and reduced number of vessels in some part of the territory occluded. |
| **Good** | 4     | Compared to asymptomatic contralateral hemisphere:  
• There is a delay of one phase in filling in of peripheral vessels but prominence and extent are the same. |
|          | 5     | Compared to asymptomatic contralateral hemisphere, there is:  
• No delay, normal or increased prominence and normal extent of peripheral vessels. |
In some patients the presence of "clinical-vascular mismatch" (less clinical severity than expected by the location of arterial occlusion) could be considered as a clinical marker of good collateral circulation. However, in many cases, if recanalization is not achieved finally the patient has a neurological impairment that is attributed to CC failure.
**Fig. 1:** Collateral grade 0

86 years old woman with a left M1 MCA occlusion (arrow) and poor collaterals (grade 0) on multi-phase CTA. There are no vessels visible distal to the occlusion point. Absence of collaterals in any phase within the occluded vascular territory.

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Fig. 2: Collateral grade 1

68 years old woman with a right supraclinoid segment occlusion of internal carotid artery (arrow) and poor collaterals (grade 1) on multi-phase CTA. There are just a few vessels visible with a delay of two phases in filling in of peripheral vessels and decreased prominence.
Fig. 3: Collateral grade 2

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77 years old man with a left M1 MCA occlusion (arrow) and intermediate collaterals (grade 2) on multi-phase CTA.

There is a delay of two phases in filling in of peripheral vessels and decreased prominence and extent.
Fig. 4: Collateral grade 3

75 years old woman with a left petrous segment occlusion of internal carotid artery (arrow) and intermediate collaterals (grade 3) on multi-phase CTA.

There is a delay of two phases in filling in of peripheral vessels but prominence and extent is the same.

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64 years old man with a right M1 MCA occlusion (arrow) and good collaterals (grade 4) on multi-phase CTA. There is a slight delay of first phase filling in of peripheral vessels but later in phases 2 and 3 are matched with left territory. Prominence and extent is the same.

**Fig. 5:** Collateral grade 4

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Fig. 6: Collateral grade 5

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74 years old man with a left M1 MCA occlusion (arrow) and good collaterals (grade 5) on multi-phase CTA.

There is enhancement of vessels distal to the occlusion. Absence of delay, increased prominence and normal extent of peripheral vessels within the occluded arteries territory.
Conclusion

The dynamic information of ischemia progression probably depends, in great measure, on the collateral circulation and a good technique to evaluate it in patients with less than 4.5h from the onset of symptoms is the multi-phase CTA.
References