Perfusion-CT in stroke: false ischemic penumbra.

Poster No.: C-2097
Congress: ECR 2015
Type: Educational Exhibit
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Keywords: Embolism / Thrombosis, Contrast agent-intravenous, CT-High Resolution, CT-Angiography, CT, Emergency, Neuroradiology brain, Acute, Ischemia / Infarction

DOI: 10.1594/ecr2015/C-2097

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Learning objectives

Familiarize radiologists and residents begin with image patterns and causes of false ischemic penumbra in emergency CT perfusion.

Background

The multimodal brain CT plays an essential role in the diagnosis of acute ischemia and treatment decision. The evaluation of suspected includes ischemic stroke, cerebral perfusion images made with CT to allow differentiation of the ischemic areas at risk of myocardial infarction areas established. Time Delay Peak with a normal, slightly decreased or even increased Cerebral Blood Volume (vasodilation, collaterals) suggests cerebral ischemic penumbra. Acute stroke in the presence of an ischemic penumbra is an indication that the thrombolytic therapy may be beneficial. The exact interpretation of CT Perfusion is hindered by the presence of cerebrovascular anatomical variations, changes of chronic ischemia and physiological conditions (limitation of cerebral blood flow, vascular dysregulation) that produce benign oligohemia and false appearance of gloom; has also been found that the angle of the head of the patient during acquisition of the study is a frequent cause of false ischemic penumbra. Since 2011, our center has been set in place stroke code protocol with involvement of Emergency Radiology, Neuroradiology Interventional Radiology and Neurology. We present through the review of 209 studies Urgency of our hospital from 2012-2014, patterns of normal and pathological perfusion and ischemic penumbra false.

Findings and procedure details

REVISION OF THE ISSUE

The multimodal brain CT plays an essential role in the diagnosis of acute ischemia and treatment decision.

The evaluation of suspected ischemic stroke includes images of cerebral perfusion CT performed to allow differentiation of ischemic areas that are at risk of stroke (ischemic penumbra) of areas of infarction established.
CT perfusion (CTP) has been established as a clinically useful tool for multimodal images ischemic stroke and has the advantages of being widely available and easily provides quantitative perfusion parameters. (Radiology Vol. 274 Issue 1. 2015).

Brain tissue with delayed time to peak (TTP) and a cerebral blood volume (CBV) normal or even increased slightly decreased (vasodilation, collaterals) suggests the cerebral ischemic penumbra.

However, not all anomalies in the CTP are specifically related to ischemic stroke, there are many neurological diseases that cause symptoms that mimic ischemic stroke; also, the presence of cerebrovascular anatomical variations, changes and chronic ischemia physiological conditions (cerebral blood flow limitation) can cause altered cerebral perfusion and therefore may lead to alterations in the CTP.

Also keep in mind certain technical factors such as post-processing software used (maximum slope or deconvolution) input function selection arterial, venous ouput function selection, delay in arrival of bolus that can cause changes to the maps resulting from CTP.

Since 2011, our center has been set in place Stroke Code protocol with involvement of Emergency Radiology, Neuroradiology Interventional Radiology and Neurology.

We present through the review of 209 studies Urgency of our hospital from 2012-2014, patterns of normal and pathological perfusion and false ischemic penumbra.

**PERFUSION PATTERN NORMAL. INTERPRETATION**

In perfusion imaging a series of CT images of the territories of the middle cerebral artery (MCA) after administration of intravenous contrast and changes in brain parenchyma attenuation obtained are measured over time.

CTP parameters such as time to peak (TTP), mean transit time (MTT), cerebral blood volume (CBV) and cerebral blood flow (CBF) are calculated and displayed in color-coded maps.
Peak Time is the interval of time after administration of intravenous contrast to peak maximum lift at each pixel of the image, measured in seconds.
Middle Transit Time is the average time required for blood to pass through a given brain volume is measured in seconds.
Cerebral Blood Volume is the volume of blood per unit of brain volume is measured in milliliters of blood per 100 g brain.
Cerebral Blood Flow is the volume of blood passing through a volume of tissue at a specific time and is measured in milliliters of blood per 100 g of brain tissue per minute. Relate to each other by the central volume principle to the equation: \( \text{CBF} = \frac{\text{CBV}}{\text{MTT}} \).

In our center the maps are evaluated by qualitative visual inspection, which is faster and easier, however, in cases that pose difficulty in interpreting, a quantitative assessment is performed.

**Fig. 1**: 75 years old male with left hemiparesis and low progressive consciousness. The NCCT (a) and CTA (b) showed no abnormalities. The CTP (c) is normal parameters. It was a coma.

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The primary goal of perfusion imaging is to diagnose infarction and possibly to quantify the size of the core and penumbra that is, to identify the mismatch between infarct core (irreversible brain tissue) and ischemic penumbra (potentially viable tissue if reperfused).

**Fig. 2:** 60 years old male with right hemiparesis. NCCT (a): loss of gray / white differentiation in the left insular region. CTP (c): decreased CBV in insular region, M2, M4 and M5. TTP delay in the whole amount of the left MCA territory are respected only the basal ganglia. CTA (b): filling defect in distal M1 in relation to intraluminal thrombus. **References:** Radiodiagnóstico, Hospital Universitario de La Princesa, Hospital Universitario de La Princesa - Madrid/ES

**CAUSES OF FALSE PENUMBRA**

**ALTERATIONS OF PERFUSION WITHOUT DEFINITE ACUTE ISCHEMIA**
Variation in cerebrovascular anatomy

Some common variations in cerebrovascular anatomy are known to lead to alterations in tissue perfusion between the anterior and posterior circulations may be unilateral or bilateral. The reason is a difference of flow rate between the anterior and posterior cerebral circulation. Variants of the circle of Willis, such as hypoplasia posterior communicating artery may result in increased time in the ipsilateral occipital lobe. Similarly atresia or hypoplasia of both segments P1 be isolated cerebellar flow anterior circulation producing a time delay in the cerebellar parenchyma. In atresia or severe hypoplasia of A1 and atresia or hypoplasia segment of the posterior communicating, internal carotid artery is isolated and smaller, which may result in impaired perfusion delay time.

**Fig. 3:** Male 77 years with dizziness and dysarthria. (a) The NCCT shows no signs of acute ischaemia. The CTA is observed stenosis 50% in the middle third of the basilar artery and irregularity of P1 segment of the right to adequate distal ACP filler through the right ACoP. In the CTP (b) maps of CBF and CBV not show alterations. TTP with
slight asymmetry observed a delay in the territory of the ACP left, probably secondary to vascular supply of the territory by the dominant right posterior communicating artery.

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ICA stenosis

Often results from atherosclerosis at the carotid bifurcation. The hemodynamically significant stenosis of the internal carotid artery is associated with decreased CBF and increased TTP; however this mismatch will be less noticeable when there is significant collateral blood supply through the ACoA or ACoP. When the flow is limited because of arteriosclerosis of carotid bulb perfusion maps can show increased blood volume in a distribution in the other hemisphere. This serves as a reminder that in interpreting parametric maps of CTP, you should always review the images of the Angio-CT (CTA) for possible arterial stenoses or occlusions that can cause cerebral flow limitation.
Fig. 4: - 85 year old male with symptoms of right hemiplegia. The basal TC (a) shows no abnormalities. On maps of perfusion (b) maps show time to peak twilight zone right
across convexity, not observing changes in the volume and flow maps. In the study of CT angiography of supra-aortic trunks (b and c) we see a chronic occlusion of the right internal carotid artery, extending from the carotid bifurcation until the beginning of the right ophthalmic artery.

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Vasospasm
CTP may be abnormal in case there vasospasm, expressed as areas of hypoperfusion. In interpreting the CTP should consider the findings displayed in the NCCT, such as subarachnoid hemorrhage. Significant alterations in perfusion territories vasospasm be considered at similar risk to what is seen in the ischemic penumbra. CTP has also been used to evaluate the therapeutic effect of intra-arterial and vasodilators intravascular stent placement.
Fig. 5: 65 year old patient with subarachnoid hemorrhage (a) due to embolised ACA aneurysm. On maps of TCP decreased CBF and CBV observed in right MCA territory, secondary to vasoconstriction of the right MCA and its branches (b).

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**Chronic ischemia**

The presence of a chronic infarcted area can mimic acute ischemic perfusion imaging, correspondence with hypodense in the NCCT allows identification.
Fig. 6: 73 year old male with a history of prior stroke MCA left, with current clinic of dysarthria and paresis of MSD. NCCT(a): hypodense relative to malácica area secondary to chronic infarction in the territory of the MCA left. Perfusion CT (b): a decrease in the volume and delayed time to peak seen in the area corresponding to the hypodense in the NCCT.

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Phase vasospasm in migraine / pseudomigraine (The syndrome of transient headache and neurologic deficits with cerebrospinal fluid lymphocytosis (HaNDL).

In a migrainous state, vasospasm phase may have areas of hypoperfusion, generally displayed on the parietoocipitales regions.
Fig. 7: 35 year old female patient with headache and dysarthria. The NCCT (a) shows no signs of acute ischemia. The CTA (b) shows no abnormalities. In CTP maps (c) a decrease in CBF and CBV. The TTP delay in the left parieto occipital region is observed. The clinical picture sent within hours, the final diagnosis was HaNDL.

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Fig. 8: 25 year old male patient with headache and aphasia. The NCCT (a) shows no signs of acute ischemia. On maps of CTP (b) identifies a slight decrease of CBV and CBF most obviously in the left parietal region that primarily affects the cortical region, viewing maps TTP delay in the arrival of the contrast in these locations. The clinical picture was self-limiting and the final diagnosis was HaNDL.

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**Vasospasm due to posterior reversible encephalopathy syndrome (PRES)**

CTP can show areas of hypoperfusion in patients with PRES. Delay MTT mild to moderate decrease in CBF may occur secondary to arteriolar vasoconstriction, findings that are more frequent in the posterior circulation, which may progress to ischemic stroke.
Fig. 9: 77 year old female patient with left hemiparesis and dysarthria. The CTA and NCCT (a)(b) show no alterations. En maps TTP (c) delayed is observed throughout both the right hemisphere and occipital regions not correspond to arterial territories. Clinical improvement within 24 hours of admission, final diagnosis of PRES in context of high pressure values or hypertensive encephalopathy.

References: Radiodiagnóstico, Hospital Universitario de La Princesa, Hospital Universitario de La Princesa - Madrid/ES

**Venous thrombosis**

Cerebral venous thrombosis is a rare but serious neurological disorder that can have an ictal presentation. The perfusion abnormalities described in patients with venous thrombosis is increased TTP with a brain volume retained in a venous vascular territory. Note that venous thrombosis may occur without infarct perfusion disorder or associated with venous infarction.
Fig. 10: 81 year old male patient with motor aphasia and hemiparesis of the right arm. (a) in the NCCT hypodensity seen in the lumen of the posterior sagittal sinus. (b) filling defects CTA in the sagittal sinus thrombosis regarding. (c) delayed TCP maps TTP on both occipital lobes, most marked on the right side. As CBV maps established foci of ischemia in the left occipital lobe are appreciated.

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HYPERPERFUSION PHENOMENON THAT CAUSE FALSE ISCHEMIC PENUMBRA
Not only is important to correctly diagnose the cause of hyperperfusion, we must also take care that they should not be wrongly identified as areas of contralateral hypoperfusion and / or acute infarction since these entities produce hyperemia and apparent delays in perfusion can result from the comparison with the hyperemic side.

Phenomenon of reperfusion in acute ischemia areas and subacute

This phenomenon has been called luxury perfusion, and may occur in treated and untreated stroke. Early revascularization through leptomeningeal vessels can also cause hyperperfusion in the acute phase of cerebral ischemia early tends to last a shorter time and has been associated with better prognosis.
Moreover, persisting postischemic hyperperfusion in the subacute stages of ischemia can indicate a poor prognosis and is associated with increased edema and hemorrhage.

**Fig. 11:** A 47 years woman with ischemic stroke with 6 hours, the NCCT shows an established ischemic area in the right MCA territory. In the CTP the CBV and CBF maps are symmetrical, it is only seen a delayed right hemisphere in the TTP map. The CTA demonstrated an M1 occlusion. This phenomena may be explained as very low grade of colateral circulation during the first hours after de stroke onset, at the moment of the CTP de CBV map (6 hours later) is normal, probably because de leptomenigeal colateral circulation has been develop during these hours. Also the changes in the blood pressure during these hours may contribute to mantain the penumbra areas.

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**Ictal phase of epilepsy**
In the area of ictal activity there initially hyper perfusion and hypo perfusion later on. The ictal hypoperfusion can be confused with acute stroke.

Fig. 12: 57 year old female patient with left hemiparesis and seizure. NCCT and CTA showed no abnormalities. CTA with increased TTP and CBV decreased in the right occipital temporal territory.

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Complicated migraine/ late stage of stroke

The clinical characteristics and perfusion abnormalities evolve over time in the case of hemiplegic migraine with increased cerebral perfusion in the late phase. Perfusion image in this type of scenario should always be interpreted in relation to the history and NCCT and CTA findings.
Fig. 13: Patient 35 year old woman with a history of headache and dysarthria 24 hours without clinical at present (it is the same patient as in Fig 7) (a) MRI performed at 24 hours shows no signs of acute ischemia in the diffusion or other sequences. However, MRI perfusion now shows increased CBF and CBV in the left parieto occipital region. 

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Post carotid stenting hyperperfusion

Cerebral hyperperfusion syndrome is a rare and serious complication of carotid revascularization, either after carotid endarterectomy or carotid stent placement. Chronic cerebral hypoperfusion may cause alterations in local vascular homeostasis. When the normal pressure and flow is restored, there may be transient cerebral vascular hyperemia causing dysregulation.

Hyperperfusion after stent placement shunt flow from ACI to M1

Cerebral hyperperfusion syndrome is a rare complication in the use of flow diverter, likely due to excessive flow from the distal ICA to M1 conditioned by placing the flow diverter to cover the ACA in origin. In this case we observed a marked delay TTP no perceptible change in flow or volume maps, clinical and radiological picture was reversible within 24 hours without showing areas of established ischemia in the MRI performed the next day.
Fig. 14: Male patient, 34 years spoke this morning with a stent flow diverter from ACI right to MCA right. After hours after awakening the general anesthesia begins gradually with decreasing level of consciousness and the left-sided hemiparesis. The CTP shows a delay in TTP in all the right hemisphere, with normals CBF and CBV. Self disorder likely flow conditioned by placement of the device. Clinical recover completely within 48 hours after and non ischemic lesions are demonstrated in the study of diffusion MRI. The right hemisphere probably readjust to the new hemodynamic condition.

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Images for this section:

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Conclusion

CT perfusion is a fundamental tool in Emergency Radiology for the correct diagnosis of acute cerebral ischemia. It is important that the radiologist is familiar with image patterns and causes of false shadows since the early helps them reduce the frequency of unnecessary administration of thrombolytic agents and therefore patient morbidity recognition.

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References


