CT perfusion: rationale in acute stroke patients

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In recent years, there has been growing interest in the treatment of acute ischaemic stroke and now we have a number of therapeutic options for this kind of situation, ranging from i.v. thrombolysis, to sonothrombolysis, local intra-arterial infusion of thrombolytic drugs, mechanical removal of the thrombus, and mixed mechanical/pharmacological strategies.
The primary aim in all cases is to remove an obstruction in an artery in an attempt to restore flow in the affected territory. Since all further molecular and biochemical alterations contributing to the cascade of ischaemic damage are initiated by the disturbance in flow, the priority, in the treatment of acute ischemic stroke, must be the restoration of sufficient perfusion.
The outcome of reperfusion of an arterial district is strictly dependent on its timing: as time passes, the probability of recovery reduces and the risk of a haemorragic transformation increases. Therefore, the therapeutic window during which we can operate is a limiting factor.
Besides the timing, other elements to be taken into account when planning a treatment are the site of the occlusion, the nature of the occluding agent, and the pathophysiological state and functional area of the brain parenchyma involved in the ischaemic damage.
The neuroradiologist is faced with a series of questions:
– Is there any ischaemic damage?
– What is the extent of that damage?
– Which artery/ies are involved (Where is the obstruction located)?
– Is the damage already irreversible or is it mild and potentially salvageable, if reperfused?
– Is there a risk of bleeding if that portion of parenchyma is reperfused?
Obviously, all these questions must be answered rapidly, since the ischaemic situation has to be resolved in the shortest time possible.
CT perfusion (CTP) associated with a CT angiography (CTA) study provide answers to most of these questions.
The equipment required, irrespective of the number of detectors, is basically only a spiral CT scanner. The recent development of high-performance CT scanners (i.e. 64 slices or even more) has generated fresh interest in this kind of application, since we now have the potential to cover a greater area of brain parenchyma with high temporal resolution.
The technique is based on the injection of a contrast bolus into an antecubital vein and a frequent concern is that of the possible risks connected with the use of contrast material during hyperacute ischaemic stroke, sometimes in patients whose possible medical contraindications to such drugs are not known. In this regard, it must be remembered that the total dose of contrast with the modern technology is very low, approximately 50 cc, around half the dose we use in a routine contrast-enhanced brain CT. There is no adverse effect when iodinated contrast material is used in an acute ischaemic brain given that, at this moment in time, the blood-brain barrier is still intact.
A good and complete approach, in our experience, is to collect a basal brain CT followed by the perfusion study, and later on a CTA study from arch to vertex.
With this kind of approach, adding a few minutes (approximately 10) to the acquisition of the basic standard brain CT, we can obtain precious data about the site and extent of the arterial occlusion, the state of the collateral pathways, the presence and extent of the ischaemia, and the viability of the affected tissues. Indeed, the CTP technique, can identify not only the extent of the ischaemic territory in a very short time (in the order of minutes, whereas standard CT takes some hours to show the first indirect signs of ischaemic damage), but also its pathophysiolocial state, identifying the tissue already irreversibly damaged and the extent of tissue at risk if not reperfused (i.e., potentially salvageable tissue). The results of numerous studies in the international literature and our own data confirm the high predictive value of this kind of information.

The great challenge to the neuroradiologist and stroke specialist is to establish the proportion of dead/salvageable tissue (so-called core/penumbra mismatch) so as to be able to make rational treatment decisions. There is great debate on this topic as different parameters have been used to quantify the mismatch proportion that should guide the decision to treat. Some authors consider a volume ratio between core and penumbra, others a ratio based on the respective areas; another strategy is to apply the ASPECTS criteria (widely used in the interpretation and quantification of acute stroke on standard non-contrast-enhanced brain CT) to perfusion maps. We believe that all these approaches have a sound basis, but that a "functional" reasoning should be proposed: indeed, perhaps we should consider not only the respective spatial dimensions of the core/penumbra, but also the "nobility" of the salvageable brain tissue. In other words, we should weigh up, when planning a treatment, whether the effective (or presumed) functional value of the area we are going to re-perfuse is worth the risk we are taking.

Another outstanding advantage of CTP in acute stroke is the possibility it offers of overcoming the timing limitation. Indeed, it can help us to decide to treat a given patient even after the usual time window has passed, or if we have no information about the time of onset (as in the case of so-called awakening stroke, for example); on the other hand, if the CTP tells us that all the involved tissue is already irreversibly damaged, it can lead us to make the decision not to treat a patient, even if only a short time has elapsed since the onset of symptoms.

Using the new generation of CT scanners, we can obtain CTP and CTA acquisitions in a very short time, which is ideal for patients who, in the majority of cases, are not or are only partially cooperative. This peculiarity gives CT perfusion a major advantage over MRI.

An alternative to the study with CT, CTP and CTA is, indeed, the use of functional diffusion and perfusion MR imaging. This kind of approach is widely applied in many institutions and is supported by an extensive body of literature. It has high sensitivity and specificity, but also some drawbacks:

– longer acquisition times (almost 3-4 times longer than CT);
– concerns about patient compliance (it must be remembered that the patients we encounter are frequently confused, aphasic, disoriented, vomiting…) and inadequate images as a result of motion artefacts;
– safety concerns if the patient cannot give information about pacemakers, prosthetic heart valves or any other device not compatible with the magnet.

The new generation of CT scanners, moreover, overcomes the problem of the limited spatial coverage which characterised the old versions, and makes it possible to explore a large thickness of brain parenchyma in a very short time. In particular situations, when a more extensive coverage is needed, it is possible to acquire two different data sets on two different slabs, waiting 5 minutes between the first and the second contrast infusion; in this way we can explore nearly 10 cm of brain parenchyma, which means all the supratentorial region.

The risks for the patients and adverse effects are really low: as stated before, the total amount of contrast media infused for both CTP and CTA is similar to that used for a standard contrast-enhanced brain CT; the X-ray exposure is kept well within the limits recommended for clinical use.

In conclusion, we can consider the association of standard CT, CTA and CTP an effective strategy for the emergency study of a patient with acute ischaemic stroke. The time required for acquisition of the data set is very suitable for a poorly cooperative patient; the short time required for post-processing is also suitable, given the need for a quick answer. The risks to the patient are acceptable as the iodinated contrast material injected and the X-ray exposure are both within safe limits.