Whole brain perfusion CT imaging and CT angiography with a 64-channel CT system

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Due to the development of new computed tomography (CT) techniques over the last 30 years, there are a vast amount of new diagnostic options available today. When Sir G.N. Hounsfield invented CT [1] (based on the preliminary works of A. MacLeod Cormack), the acquisition of a single slice took more time than CT-angiography of the complete supraaortic circulation today. And, of course, the image quality was not at all comparable to the high standard we are used to today.

Scanning speed rose significantly when multidetector CT was established in the 1990s. In many elective cases, short examination times are convenient and allow the introduction of new diagnostic possibilities. Especially when it comes to acute stroke management, short examination times are mandatory.

**Stroke management**

Since neuroimaging techniques have the potential to improve acute stroke treatment by selecting the appropriate patients for thrombolytic therapy, CT brain perfusion (PCT) and CT angiography (CTA) have become important, widely used diagnostic tools for the early detection and classification of strokes [2-8].

The neuroradiologist’s principal task in stroke management is to quickly gather as much valid and precise information as is necessary to come to a decision. The 64-channel multidetector CT system is the perfect tool for this purpose, because it makes it possible to shorten the time of acquisition, improve image quality, and scan a larger total anatomical volume. The growing speed of post-processing tools and the wide variety of different features are equally important for modern CT examinations.

For CTA, another major advantage is the possibility of shortening the bolus of contrast medium (though higher concentrations are preferred) and still having a fully contrasted arteriogram from the aortic arch up to the M2 branches within a few seconds. For the first time, it is now possible to differentiate the arterial from the venous phase in a single dual-phase examination.

In a retrospective evaluation of diagnostic imaging of 113 patients with supposed acute stroke, Tan et al. [9] found that PCT in combination with CTA is the most helpful diagnostic tool for predicting the final infarct volume in the case of reduced cerebral blood volume (CBV) and identifying the tissue at risk in the case of elevated mean transit time (MTT), while CTA shows the site of occlusion and the degree of collateralization.

Murphy et al. used an animal model to show that the cerebral blood flow (CBF) and CBV values obtained from CT perfusion imaging could be used to distinguish between oligemic and infarct regions [10].
technique for everyday clinical use is still PCT. Extensive studies have analyzed the validity of different information from PCT studies, such as CBF and CBV, for assessing the penumbra and core of infarcts. The quality of the PCT was found to be dependent upon several factors, such as concentration of the contrast agent [11] and injection rate [4]. With a fixed setup for the examination and the post-processing technique, the outcome of the interpretation was not influenced by the experience of the observer [12]. Nevertheless, there was still a significant problem. The maximum coverage of the scan volume in these studies was 4 cm. Thus, it was not possible to study more than approximately one-third of the supratentorial parenchyma in one study.

With the new 64-channel CT systems and a special technique, the coverage (4 slices at 1 cm) can be doubled to 8 cm. In most cases this is nearly a whole brain perfusion measurement. This is achieved by the “Jog Mode” scan technique (Philips Healthcare, Cleveland, OH, USA), in which the in- and outflow of the contrast agent in the different slices is measured with an alternating table movement during the examination, so that each slice is scanned in a specific order every 2.5 seconds. The spatial resolution is the same as with the conventional technique, but the time-based resolution decreases by approximately 50%.

In the Jog Mode scan technique, the post-processing of the perfusion data is done with the same setting as in conventional PCT settings. The new technique opens up the questions of the validity and the reproducibility of the acquired data. Research on this issue is still ongoing in our institute. For routine use, we found in several cases of acute ischemic stroke and cases of hypoperfusion induced by spasms after subarachnoid hemorrhage that the data produced with the Jog Mode technique gave valid results when compared with digital subtraction angiography (DSA) findings, follow-up CT, or magnetic resonance (MR) imaging – including MR perfusion techniques.

The use of absolute values of CBF, CBV or MTT seems to be much less important than creating ratios of these values by comparing them to the values of the same anatomical region of the clinically unaffected hemisphere.

Schaefer et al. [13] took a comparable approach in their workup of 14 cases of PCT in pre-interventional therapy. In their paper, the initial quantitative CBV and CBF values were visually segmented and normalized with the

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Figure 1b-c. CCT with no signs of infarction, hyperdense vessels or ICH.

“infarct core”:
- Region 1 “infarct core” (reduced CBV and CBF, infarction on follow-up)
- Region 2 “penumbra that infarcts” (normal CBV, reduced CBF, infarction on follow-up)
- Region 3 “penumbra that recovers” (normal CBV, reduced CBF, normal on follow-up)

In this group, areas with a CBF ratio < 0.32, CBV ratio < 0.68, CBF < 12.7 ml/100 g/min, or CBV < 2.2 ml/100 g turned to infarct, and no area with CBF ratio > 0.44 suffered from infarction.
PCT is an important tool in our clinic today for screening patients with subarachnoid hemorrhage (SAH, mostly caused by aneurysm) with clinical symptoms of vasospasms and/or acceleration of CBF in transcranial Doppler ultrasound (TCD). In cases of prolonged MTT and/or low CBF and CBV, intra-arterial DSA is performed. Depending on the result and correlation with perfusion deficits, this will be followed by immediate therapy with angioplasty.

For PCT in the detection of vasospasms after SAH, Kanazawa et al. found, in a group of 19 patients, that an MTT value 20% higher than the average indicated progression. Patients with vasospasm-related infarcts exhibited an MTT that was 47% higher than the mean value [5].

Wintermark et al. stated in a retrospective analysis of 27 patients that had undergone CTA and PCT, DSA, and TCD after acute SAH that the combination of CTA and PCT represents an accurate screening test for the detection of vasospasms [14].

**Clinical application**

In our department, PCT scans are performed using a Philips Brilliance CT 64-channel configuration. The scan parameters are as follows:

- 80 kV
- 150 mAs
- Collimation 32 x 1.25
- Standard resolution
- Rotation Time 0.4 s
- FOV 250 mm
- Brain standard filter (UB)
- 512 x 512 matrix.
The scan is started with a 1 second post-injection delay following administration of 45 ml Imeron $350^\text{a}$ at a flow of 5 ml/s.

The following two cases serve as representative examples.

**Case 1**

A 68-year-old woman presented with left-sided hemiparesis, with sudden onset of symptoms 1.5 hours before arrival of the ambulance. The initial CCT showed no trace of infarction. An intracerebral hematoma was excluded (Figure 1a-c). The transverse slices of the CTA showed a reduction of contrasted M2 branches on the right side (Figure 2). The 3D rendered image (Figure 3) provided an easily interpreted presentation for discussion with the neurologist.

After a short delay, PCT was performed. In a Wintermark Index map [15] (Summary Map, Advanced Brain Perfusion, Philips Healthcare, Cleveland, OH), the already infarcted core (red) and the tissue at risk (green) could be easily differentiated (Figure 4). An instantly induced systemic thrombolysis was not able to reperfuse the occluded vessels. The CT scan performed the next morning shows the infarcted area perfectly matching the tissue shown to be at risk in the Wintermark map (Figure 5).

**Case 2**

A 50-year-old woman presented with TCD accelerations after severe SAH caused by a ruptured aneurysm six days earlier. The PCT slice of the basal ganglia region showed a somewhat reduced perfusion of the areas supplied by the M1 segmental artery, but obviously reduced perfusion of the areas supplied by M2 and A2. A more dedicated analysis of the mirrored ROI of the basal ganglia showed normal and equal perfusion curves (Figure 6). A slice

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Figure 6. PCT slice of basal ganglia. M2 and A2 related reduced perfusion. Non-suspicious perfusion of basal ganglia. Normal perfusion curves.

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Figure 7. PCT of a slice close to the vertex with extensive hypoperfusion of areas supplied by A2 and M2.

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Figure 8. DSA of the right ACI with spasms of distal M1 ▼ and whole A1 segments.

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Figure 9. DSA of the left ACI with spasms of M2 and ▼ whole A1 segments.
DSA performed immediately after the PCT showed distal M1 spasms on the right side, M2 spasms on the left side, and A1 spasms on both sides (Figures 8 and 9). Administration of a calcium antagonist and balloon dilatation of the right distal M1 resulted in complete reperfusion (Figure 10).

Conclusion

CTA and whole brain PCT performed with 64-channel multidetector CT are most helpful for quickly gathering all the information needed for classification and therapy in acute stroke and vasospasm, representing important new tools in the neuroradiological work-up of patients with cerebrovascular disease. Although the absolute values of the different brain perfusion parameters acquired with the Jog Mode scan technique are not yet validated, correlation with clinical findings and patient outcomes show this CT technique to be comparable to established MR techniques.

References


