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CT perfusion imaging in the early diagnosis of acute stroke

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ABSTRACT
Early diagnosis of acute cerebral infarction is critical due to the time limit of thrombolytic treatment. Cerebral computed tomography (CT) perfusion imaging is a new technique, which appears to provide early diagnosis of major vessel occlusions in the brain. CT perfusion imaging also provides valuable information about the hemodynamic status of ischemic brain tissue. In this report, we present the CT perfusion findings in comparison to the non-contrast CT and diffusion-weighted (DW) magnetic resonance (MR) imaging findings in two cases of acute cerebral infarction. Non-contrast CT findings were non-specific in the first case and there was minimal hypoattenuation in the superior aspect of the lentiform nucleus in the second case. CT perfusion imaging demonstrated significant perfusion defects in the middle cerebral artery territory in both cases. DW-MR imaging confirmed acute infarctions, which were smaller than the perfusion defect areas in the CT perfusion imaging in both cases.

Key words: ● *cerebral infarction* ● *tomography, X-ray computed* ● *perfusion* ● *diffusion magnetic resonance imaging*

Stroke is the third most frequent cause of deaths after cardiovascular diseases and cancers (1, 2). However, prognosis can be good if thrombolytic therapy is administered to patients within the first three hours (3, 4). Computed tomography (CT) is generally performed before starting the therapy in order to exclude the presence of bleeding and tumors. With cerebral perfusion imaging, it is possible to diagnose ischemia early, as well as gather information about the extension and severity of the ischemia. In this article, we will discuss the perfusion brain CT findings in two cases of acute ischemic stroke in which non-contrast brain CT findings were not specific in the early period.

Case reports

Case 1

A 71-year-old female presented to the emergency service of our hospital with complaints of loss of strength in the right side of her body and inability to speak, which had started 3.5 hours earlier. Right hemiparesis was found in neurological examination. In the non-contrast brain CT performed with the pre-diagnosis of cerebrovascular incident, no marked pathology was observed except for diffuse cerebral and cerebellar atrophy (Figure 1a). Following the non-contrast brain CT, a perfusion brain CT examination was performed. Brain perfusion examination was performed using a CT device (Somatom Sensation 16, Siemens Medical Systems, Erlangen, Germany) with 16 detectors and an automatic injector, giving a total of 40 ml of non-ionic iodinated contrast material with a speed of 8 ml/sec. Sections 10 mm thick from two neighbouring sections (60 sections from basal ganglia level and 60 sections from corona radiata level) were obtained. The source images were then sent to a separate computer system for postprocessing (Leonardo, Siemens Medical Systems, Erlangen, Germany). Relative cerebral blood flow, relative cerebral blood volume, and perfusion images of time to peak were obtained with a semi-automatic procedure. Wide perfusion defects were found in the feeding region of the left middle cerebral artery (Figure 1b-d). In the diffusion-weighted magnetic resonance (MR) examination performed about 24 hours later, using echo-planar imaging technique with b=0 s/mm^2 and b=1000 s/mm^2 (TR/TE, 10,000/135 msec), a restricted diffusion image consistent with acute infarction was observed in the corona radiata localization on the left (Figure 1e and f).

Case 2

A 30-year-old female presented to the emergency room of our hospital with complaints of weakness at left upper and lower extremities that started 6 hours earlier. Left hemiparesis was found in neurological examination. In the non-contrast brain CT performed with the pre-diagnosis of cerebrovascular incident, minimal edematous appearance was

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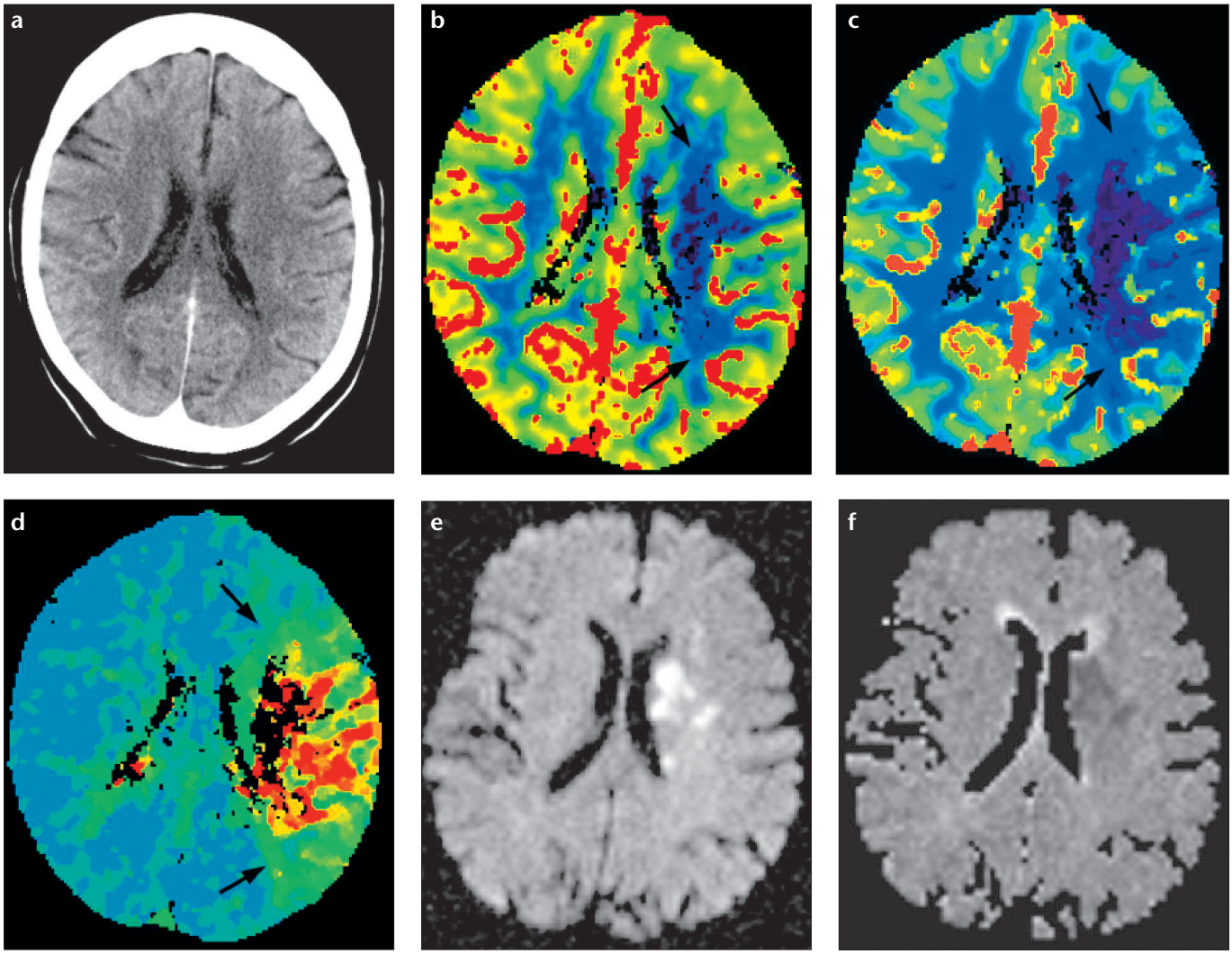

Figure 1. **a-f.** A 71 year-old female with right hemiparesis. No marked edema appearance consistent with acute infarct can be noted in the non-contrast axial brain CT image **(a)** through the lateral ventricles 3.5 hours after the onset of acute symptoms. Relative cerebral blood volume **(b)**, relative cerebral blood flow **(c)** and time to peak **(d)** CT perfusion maps show large perfusion defect observed in the feeding area of the middle cerebral artery *(arrows)*. Despite the wide perfusion defect observed on CT images, it was noted that tissue progressing to infarct has been arrested in the left corona radiata on a diffusion weighted MR image **(e)**, and the corresponding apparent diffusion coefficient (ADC) map **(f)**.

noted in the right lentiform nucleus (Figure 2a). Following the non-contrast brain CT, brain perfusion CT was performed with a protocol similar to that of the first case previously described. Source images were then sent to a separate computer system for postprocessing (Vitrea 2 Workstation, Vital Images Inc., Plymouth, MN, USA). Relative cerebral blood flow, relative cerebral blood volume, and mean transit time images were obtained with a semi-automatic procedure. Wide perfusion defects were found in the left middle cerebral artery territory (Figure 2b-d). On DW images performed about 16 hours after the onset of the patient's symptoms, using a similar technique with that of the first case, a restricted diffusion consistent with acute infarction was observed in the corona radiata (Figure 2e and f). Contrast-enhanced MR carotid angiograms taken in the same session showed the embolism that caused infarct in the patient, originating from a dissection, was observed in the distal part of the common carotid artery.

Discussion

Thromboembolic stroke can be seen at any age; however, morbidity and mortality rates are high in middle aged and elderly patients (6). Diagnosis is made only with neurological examination. However, while the symptoms are sensitive in cerebral ischemia, they are not specific (7). Therefore, imaging methods are used for the purpose of supporting the clinical diagnosis. Non-contrast brain CT examination is frequently used since it is a method that can be employed in emergency conditions and is available in almost every hospital. Brain CT examination is used for detecting tumors, vascular malformations, or subdural hematomas that can clinically imitate stroke and also for excluding bleeding that is a contraindication for thrombolytic treatment (8). CT is typically positive 6-18 hours after ischemia. However, sometimes the early findings of ischemia can be observed on CT images in the first 6 hours. Hyperdense middle cerebral artery sign, hypoattenuation in lentiform nucleus, edema in insular cortex (insular ribbon sign), disappear-

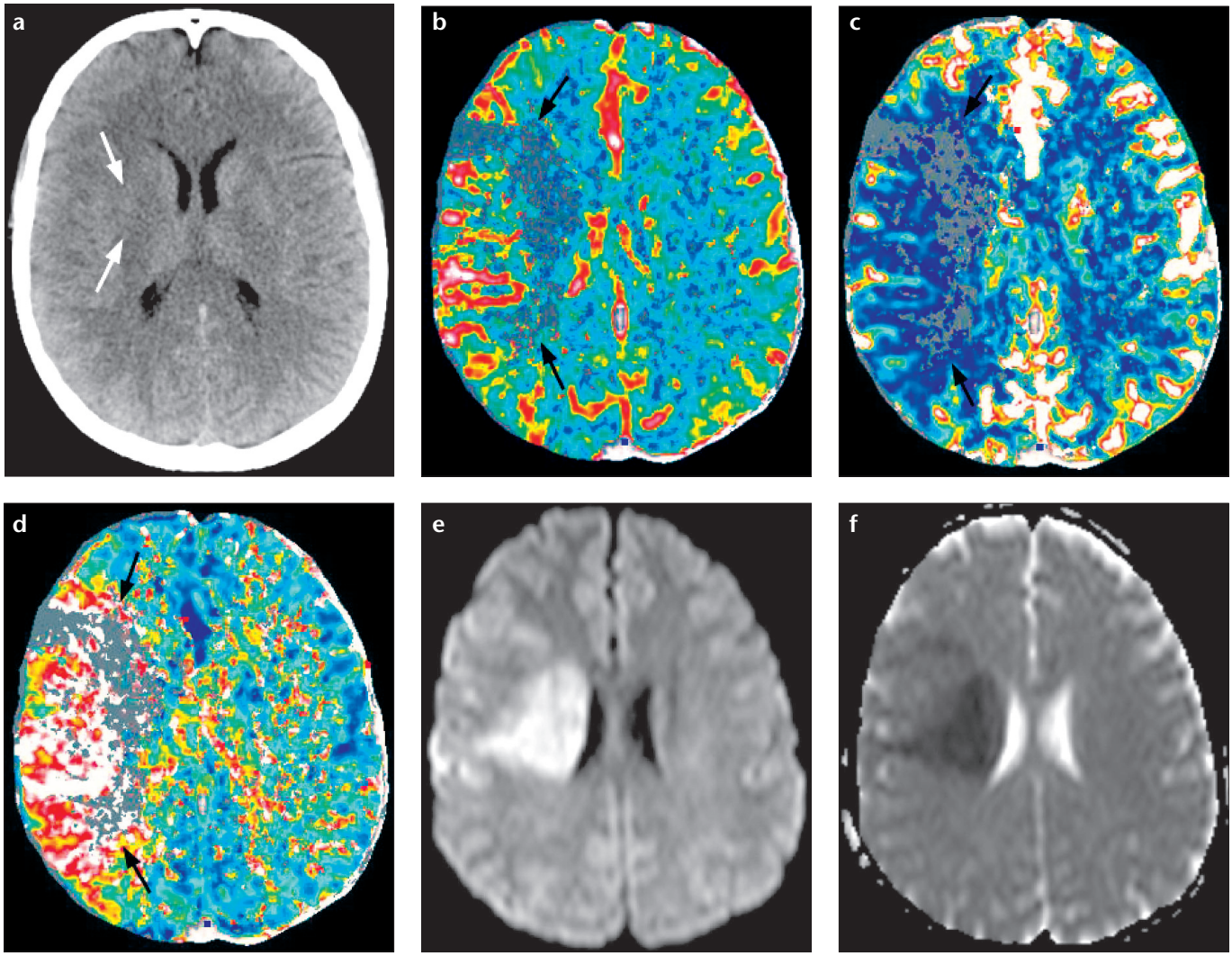

Figure 2. a-e. A 30-year-old female with left hemiparesis. Minimal hypoattenuation is observed on non-contrast axial brain CT image at the level of the right lentiform superior nucleus **(a)** *(arrows)* 6 hours after the onset of acute symptoms. Relative cerebral blood volume **(b)**, relative cerebral blood flow **(c)** and mean transit time **(d)** CT perfusion maps show large perfusion defect observed in the feeding area of the right middle cerebral artery *(arrows)*. Despite the wide perfusion defect observed on CT images, it was noted that tissue progressing to infarct has been arrested in the right corona radiata on diffusion weighted MR image **(e)**, and apparent diffusion coefficient (ADC) map **(f)**.

ance of gray-white matter discrimination, obliteration of sulci, and shifting due to edema can be observed (9, 10). In Case 1, while the CT findings of the early period could not be observed, minimal hypoattenuation at the lentiform nucleus was seen.

Perfusion and diffusion-weighted MR examinations are more sensitive imaging methods in the diagnosis of acute ischemia as compared to routine brain CT. Ischemic areas can be determined within minutes or hours. Both imaging methods can provide rather useful information for determining the tissue under risk that is progressing to infarct, particularly when used together (11). Ischemia with perfusion defect in perfusion MR, which does not progress to infarct in diffusion MR imaging (ischemic penumbra, diffusion-perfusion mismatch), can be reversible with efficient early treatment. However, diffusion and perfusion examination with MR, although one of the most efficient imaging methods in acute stroke, are not used as the first-step imaging method, especially during the initial hours following the onset of symptoms. Other methods used for determining the perfusion deficit are positron emission tomography, xenon CT, and single photon emission computed tomography (12-14). Use of these methods has been restricted since they are not available in every hospital and are difficult to employ under emergency conditions.

Perfusion brain CT, on the other hand, is a new imaging method capable of providing information about the extension and hemodynamic status of ischemic brain tissue, which can be used in emergency conditions (15, 16). In this examination, the quantity of contrast material passing through the brain tissue is measured, and asymmetrical changes in cerebral perfusion are determined. Perfusion examination of the entire brain is not possible yet. Since only a few neighbouring sections can be imaged, the anatomical region that is clinically involved can be examined with the cooperation of the clinician; otherwise, the basal ganglia level can be selected, including the feeding areas of the anterior, middle, and pos-

terior cerebral arteries. A total of 40 ml of non-ionic iodine contrast material is given using an automatic injector with a delay of 6 seconds and a speed of 8 ml/sec, and then images are taken from two neighbouring sections (16). Parameters such as relative cerebral blood flow, relative cerebral blood volume, and time elapsed for reaching the peak are determined after a semi-automatic procedure to differentiate reversible and irreversible ischemic tissue (15). This differentiation is important particularly in planning the therapy. In both our cases, it was noted that while there were wide perfusion defects in perfusion CT examinations, the brain tissue with progressing infarct was limited to the central region of the perfusion defect. The most important factor here is the efficient planning of therapy in the early period.

Tomandl et al. divided the perfusion of brain tissue in perfusion brain CT examinations into 5 groups according to the values of cerebral blood flow, relative cerebral blood volume, and time elapsed for reaching the peak (16). Brain tissue has been classified as normal, compensating arterial stenosis or occlusion, possibly restorable oligemic tissue, risky tissue, and irreversibly damaged tissue, and a protocol of treatment according to this classification was created (16). In both of our cases, early diagnosis was possible during the time when the brain tissue suffering from acute infarct was in oligemic or risky tissue, and treatment was started in the early phase. When early treatment begins in patients with a diagnosis of acute infarct, the more risky tissue can be spared. In our cases, it was possible to cure the more risky tissues with the help of early diagnosis with perfusion brain CT examination.

The most significant drawbacks of perfusion brain CT examination are the limitations of multi-detector CT technology presently available and the inability of obtaining sufficient information about the perfusion of the entire brain, since it is possible to take images of only a few sections of the brain. It is recommended that the examination be performed on the basal ganglia level in order to minimize this restriction. It is thus possible to get information about the feeding areas of the anterior, middle, and posterior cerebral arteries.

In conclusion, we believe that using diffusion MR imaging and perfusion CT together provide rather useful information for diagnosing ischemia in the early phase, showing the extension of ischemia, and planning the appropriate therapy.

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