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CT Angiography for Brain Death Diagnosis

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BACKGROUND AND PURPOSE: Lack of cerebral circulation is an important confirmatory test for brain death (BD). Conventional angiography remains the standard imaging method, but CT angiography (CTA) is emerging as an alternative. France accepts BD diagnoses relying on a score based on lack of opacification of 7 intracerebral vessels in CTA images. The purpose of this study was to validate the efficiency of this score and to evaluate the sensitivity of a novel 4-point CTA score in confirming BD.

MATERIALS AND METHODS: A prospective multicentric study was conducted during 12 months with 105 patients referred for CTA to confirm a clinical diagnosis of BD. Clinical data were recorded. CTA images were interpreted first by local radiologists at the referent center, resulting in a 7-point score based on lack of opacification of the pericallosal and cortical segments of the middle cerebral arteries (MCAs), internal cerebral veins (ICVs), and 1 great cerebral vein per patient and, second, by a consensus panel of 3 expert radiologists, blinded to the initial scores, resulting in novel 4-point scores based on the lack of opacification of the cortical segments of the MCAs and ICVs.

RESULTS: Injection of contrast medium did not alter renal function. With the initial 7-point score, sensitivity was 62.8%. With the simplified 4-point score, sensitivity was 85.7% and specificity was 100%. Opacification of ICVs was absent in 98.1% of patients.

CONCLUSIONS: Lack of opacification in the cortical segments of the MCAs and internal veins in CTA is efficient and reliable for confirming BD.
(120 mL; concentration >300 mg/mL) was injected through an ante-
cubital vein at a rate of 3 mL/s by using a power injector and an
18-gauge catheter. The second and third scans were then acquired,
starting 20 and 60 seconds after the contrast medium injection
commenced. The same geometric parameters were used to allow fur-
ther subtractions. Images were acquired with a section thickness of
1 mm (pitch, 0.5–1); scanning parameters were 120 kV, 300 mAs,
200-mm FOV, and 512×512 matrix. Contiguous axial images
(5 mm) were then reconstructed. Subtractions of the precontrast and
postcontrast series and sagittal reformations were performed as
needed.

**Vessel Opacification and CTA Scores**

CTA images were first interpreted by local radiologists at the 6 referent
centers, to confirm clinical BD; then all examinations were reviewed by 3
expert radiologists blinded to the results of the first interpretation to
assess lack of opacification and resolve discrepant initial interpretations.

Opacification of superficial temporal arteries was assessed on the second
phase at 20 seconds to confirm the correct injection of contrast medium.
The third phase, at 60 seconds, was used to evaluate opacification of the
following vessels: pericallosal arteries, cortical segments of the MCAs,
right and left ICVs, and GCV (Fig 1). Following Dupas et al,5 a point was
given for each vessel without opacification, resulting in “lack of opacifi-
cation” scores of between 0 and 7. Opacification of the basilar artery (BA)
was also recorded for all patients. The same dataset was then used to
construct a novel 4-point CTA score based on the lack of opacification of
cortical segments of the MCAs and the 2 ICVs.

**Confirming CTA Score BD Diagnosis**

The 7-point CTA scores were used for diagnosing BD, scores of 7 indi-
cating BD (Fig 2). Patients with scores <7 were given a complementary
examination to assess BD: delayed CTA (n = 10 patients), conventional
angiography (n = 10), or 2 EEGs (n = 12). Data were missing for 7
patients.
Table 1: Impact of residual opacified vessels on initial 7-point CTA score for patients with scores <7 (N = 39)

| Vessel | No. of Patients (%) |
|--------|---------------------|
| 2 CA   | 22 (56.4)           |
| 1 CA   | 16 (41.0)           |
| 2 C-MCA| 7 (17.9)            |
| 1 C-MCA| 8 (20.5)            |
| 1 ICV  | 2 (5.1)             |
| GCV    | 2 (5.1)             |
| BA     | 6 (15.4)            |

Note:—CA indicates pericallosal artery; ICV, internal cerebral vein; GCV, great cerebral vein; BA, basilar artery; CTA, CT angiography.

| Table 2: New simplified 4-point CTA score for BD (N = 105 patients) |
|---------------------------------------------------------------|
| Score/4* | No. of Patients | Opacified ICV No.† |
|----------|-----------------|---------------------|
| 4        | 90              | 0                   |
| 3        | 8               | 0                   |
| 2        | 5               | 0                   |
| 1        | 2               | 2                   |

Note:—BD indicates brain death.
* Score based on 4 new points: 1 point was noted for each of the following nonopacified vessels 60 seconds after contrast medium injection: right and left cortical segment of the MCA and right and left ICV. Sensitivity of this new score is 85.7%.
† Number of patients with 1 opacified ICV is then noted.

Discussion

The novel 4-point CTA score based on the lack of opacification of 4, instead of 7, cerebral vessels appears more sensitive in confirming BD than the accepted 7-point CTA score. A demonstration of lack of cerebral circulation may be required for BD confirmation. Ideally, the technique for such a demonstration would be noninvasive, easily accessible, operator-independent, highly specific, and highly sensitive. Conventional angiography is highly sensitive, but it is invasive and time-consuming and requires an experienced neuroradiologist, leading to delayed examinations. CTA is emerging as a viable alternative and was accepted by the French Agency of Biomedicine for BD confirmation in 1998 after its utility was demonstrated by Dupas et al in a study of 25 subjects (14 BD patients and 11 controls). Dupas et al developed a 7-point CTA score based on lack of opacification of 7 cerebral vessels, with scores of 7 indicating BD. However, larger prospective studies were needed to validate CTA for BD diagnoses, and only a few reports are available in the literature.

Since this first study, follow-up studies by others investigated the efficacy of the 7-point CTA score and demonstrated residual arterial opacification on CTA in clinically BD patients, particularly for the pericallosal and horizontal portions of the MCAs. This phenomenon is called “stasis filling” and necessitates repetitive CTAs, increasing the waiting period between clinical brain death and radiologic confirmation to >71 hours.

A study of 43 patients by Combet et al found that the 7-point score had a sensitivity of 69.7% compared with conventional angiography; 76.9% of divergent cases were due to opacification of the anterior cerebral arteries (38.5% of the patients, they were the only opacified vessels). There was no opacification of BAs. With the novel 4-point CTA score, which does not include those vessels, the sensitivity would have been 81.4%.

In the present study, 37.1% of patients had opacified residual vessels. A single persistent pericallosal artery opacification was present in 16 of the 17 patients with a CTA score of 6; both arteries were opacified in all 7 patients with a score of 5. With the new 4-point CTA score, sensitivity was 85.7%, obviating new examinations. Nine of 11 patients who had a second CTA (mean interval, 99 hours) had a score of 7. Pericallosal arteries were still opacified for 2 patients. One had an opacified cortical artery, but no venous return was noted. Leclerc et al found similar results; and on the basis of their data, the sensitivity of the 4-point CTA score would have been 93.3%. Together with the present findings, this suggests that the absence of ICVs and bilateral cortical branches of the MCAs constitutes the best criterion of BD diagnosis by using CTA. The absence of the
ICV also appears to be the most sensitive and earliest sign. Both internal veins were absent in 98.1% of the patients. Quesnel et al13 found similar results; 85.7% of their patients lacked deep venous return.

In the present study, 2 patients had 1 residual opacified ICV, but the score was low (≤2). One patient had opacification of only the GCV, leading to a score of 6, but the BA was opacified at 20 and 60 seconds. This was previously described by Braun et al14 in intravenous angiography with residual flow in the vertebrobasilar system, despite clinical BD. These findings suggest that it was judicial to exclude the GCV for the 4-point score.

The novel 4-point CTA score appears more sensitive (85.7%) and requires analysis of only 4 vessels. Whereas the cortical segments of the MCAs were assessable in all previous studies,11,12 the excluded cerebral veins were deemed difficult to assess because of cerebral hemorrhage or edema. Strict comparison of unenhanced and enhanced images, additional sagittal and axial subtractions, is helpful for confirming lack of opacification. CTA remains a 100% specific method as shown by the 10 conventional angiographies and 12 EEGs performed when the CTA score was <7.

An increase in intracranial pressure (ICP), leading to cerebral circulation arrest, is a major consideration. CTA, given its independent, and 5%–10% of patients cannot be examined because of the absence of bone window or initial flow19,20; moreover, posterior circulation can be difficult to analyze. TCD could be useful to determine the most appropriate interval for CTA, to avoid repetitive examinations. Other efficient methods, such as radionuclide brain perfusion, can shorten time to BD confirmation and improve organ harvest rates. However, they remain costly, and sensitivity was 62% in a study of 58 patients by Newberg et al.21

Ancillary confirmatory testing practices vary worldwide. In the United States, for example, EEG is performed in 84% of main neurologic hospitals; conventional angiography, in 74%; and CTA, in only 6%.22 The main advantages of CTA are that it is a highly sensitive imaging examination with an operator-independent standard protocol, has a simplified score, and has greater accessibility. Moreover, CT is not limited to brain: The whole body can be examined simultaneously. Indeed, chest, abdominal, and pelvic examinations are now routinely integrated in our CT protocol for assessing BD. This additional information provides further insights into organ vasculature and abnormalities before harvesting.

Conclusions

The novel 4-point CTA score based on nonopacification of the cortical segments of the MCAs and the ICVs appears highly sensitive for confirming brain death, maintaining a specificity of 100%. Absence of opacification of ICVs is the most sensitive sign. Compared with other ancillary tests for BD, CTA is reliable, standardized, and widely accessible and can examine the whole body, making it particularly useful in cases in which there is a potential for organ harvesting.

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