Confirming the brain death diagnosis using brain CT angiography: experience in Tokat State Hospital

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Abstract: Objective: Fourteen brain death cases diagnosed in March 2012-May 2013 period in Tokat State Hospital were studied retrospectively. CT angiography experience about those cases was shared, and use of CT angiography in confirmation of brain death was discussed. Material and Methods: All 14 cases were patients on mechanical ventilator, who did not respond to medical and surgical treatments at intensive care unit and were diagnosed clinically with brain death. All of these patients had CT angiography as a confirmatory test using a 4-slice CT scanner in Radiology department in Tokat State Hospital. Findings: Six of the patients were female and eight were male. All of them were referred from intensive care unit and had clinical brain death diagnosis before CT angiography. In the evaluation of CTA, four-point scoring involving opacification loss in both ICVs and cortical segments of MCA was used. CTA examinations confirmed brain death diagnoses in all patients who had clinical brain death diagnoses, and no confliction between CTA findings and clinical diagnoses was observed. Conclusion: Demonstrating the lack of cerebral circulation is a necessity for confirmation of brain death diagnosis. While conventional angiography remains the standard method, CTA emerged as an alternative method. In parallel to increase in prevalence of organ implants, CTA, a fast and efficient method, has been increasingly used in confirmation of brain death diagnoses.

Keywords: Brain death, CT angiography, confirmatory tests

Introduction

Brain death is defined as irreversible cessation of all brain and brain stem functions. Principal diagnosis of brain death is overwhelmingly clinical, which needs effective ruling out of reversible symptoms and toxicities which clinically resembles and can mimic the brain death. Absence of cerebral blood flow due to an elevated intracranial pressure is generally considered a sure indication of brain death [1, 2]. Brain death can be diagnosed based on clinical criteria, but some confirmative tests may be necessary. Confirmative tests that can be conducted radiologically are intracranial blood flow examinations, which include CTA, MR angiography, cerebral angiography and venography, ophthalmic artery flow examinations and transcranial Doppler ultrasound examinations [2, 4].

In the present study, brain CTAs of 14 patients were evaluated who had brain death diagnoses due to serious brain edemas of different origins, who did not respond to appropriate medication and mechanic ventilation and continued to be in deep coma. Validity of the findings for the verification of brain death diagnosis was discussed based on the information in the literature. Brain death diagnoses of all 14 patients in the study were confirmed using CTA and six of them became organ donors.

Material and methods

In the present study, a total of 14 patients, six women and eight men, who had clinical brain death diagnoses in Tokat State Hospital during the period from March 2012 to May 2013 were retrospectively studied using CTA as a confirmative test for brain death. CTA examinations were carried out by Toshiba Asteion S4 4-slice multi-detector CT machine (Toshiba, Japan). In CTA examinations, after the lateral topogram was removed, the area from the first and second cervical vertebrae level to cerebral convexity...
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was scanned. First, contrast-free images and then contrasted CTA images were taken 60 seconds after the injection of a non-ionic contrast medium (120 ml solution of ≥ 300 mg/ml) administered by an automatic injector at a rate of 3 ml/second) with an 18G needle into ante-cubital vein. Slice thickness was 1 mm across all series, and machine settings were 120 kV, 300 mAs, FOV 200 mm and 512 × 512 matrix. CTA images obtained were evaluated by three radiology experts, one local and two from other health institutions. Presence of contrast medium in superficial temporal arteries (STA) was considered as an indication of appropriate administration of contrast medium. In images taken 60 seconds after the contrast medium injection, opacifications in pericallosal arteries, cortical branches of MCA (middle cerebral artery), both internal cerebral veins (ICV) were evaluated. Four-point scoring method in which opacification loss in cortical segments of MCA and two ICVs are studied developed by Frampas et al [3] was used for evaluation. A score of 4 was assigned when all vascular structures studied had opacification loss, and 1 was assigned when only one of them had opacifica-

### Table 1. Demographic features of patients and causes of coma

<table>
<thead>
<tr>
<th>Case No:</th>
<th>Date of brain death</th>
<th>Sex</th>
<th>Age</th>
<th>Organ donor status</th>
<th>Cause of onset of coma</th>
<th>Calvarial bone structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>06.02.2012</td>
<td>M</td>
<td>78</td>
<td>Ventriculated opened parenchymal hemorrhage, SAH, brain edema</td>
<td>Post-operative changes</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>02.03.2012</td>
<td>M</td>
<td>67</td>
<td>Brain edema</td>
<td>Intact</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>20.03.2012</td>
<td>F</td>
<td>78</td>
<td>Acute infarct in left MCA on DWI MR, dense MCA lesion in CT</td>
<td>Intact</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>20.03.2012</td>
<td>F</td>
<td>32</td>
<td>Operation due to brain tumor, parenchymal hemorrhage and edema, contrasting in MCA M1 and ACA A1 branches</td>
<td>Post-operative changes</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>07.07.2012</td>
<td>F</td>
<td>68</td>
<td>Extended calcified atheroma plaques in CCA bulb localizations and cavernous portions of ICA. On the right, infarct in MCA cistern area, dense MCA lesion on the right, Ventriculated opened parenchymal hemorrhage</td>
<td>Intact</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>09.07.2012</td>
<td>M</td>
<td>76</td>
<td>Ventriculated opened parenchymal hemorrhage</td>
<td>Intact</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>23.08.2012</td>
<td>F</td>
<td>49</td>
<td>Ventriculated opened parenchymal hemorrhage, SDH</td>
<td>Post-operative changes</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>07.09.2012</td>
<td>F</td>
<td>76</td>
<td>Ventriculated opened parenchymal hemorrhage</td>
<td>Intact</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>17.09.2012</td>
<td>M</td>
<td>59</td>
<td>Total infarct in left cerebral hemisphere</td>
<td>Intact</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>02.11.2012</td>
<td>M</td>
<td>67</td>
<td>SAH</td>
<td>Post-operative changes</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>06.12.2012</td>
<td>F</td>
<td>65</td>
<td>Ventriculated opened parenchymal hemorrhage</td>
<td>Intact</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>09.12.2012</td>
<td>M</td>
<td>67</td>
<td>Traumatic SAH, intraventricular hemorrhage</td>
<td>Intact</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>05.01.2013</td>
<td>M</td>
<td>39</td>
<td>SAH</td>
<td>Fracture</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>03.05.2013</td>
<td>M</td>
<td>57</td>
<td>Intraventricular hemorrhage, SAH</td>
<td>Intact</td>
<td></td>
</tr>
</tbody>
</table>


Figure 1. Thirty-two year old woman who developed parenchymal hemorrhage after glial tumor operation, developed coma and subsequently had brain death (case 4). Contrast medium opacification could be seen in CTA examination in bilateral MCA M1 and ACA A1 segments. No intravascular contrasting was observed in more distal segments of MCA and ACA (CTA score = 4). In addition, contrast matter was not observed in intracranial venous system structures.
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Figure 2. CTA examination of a 27 years old male patient monitored in ICU who developed coma after lightning strike who had clinical and brain CT findings comparable to the patient in Figure 1 but did not have clinical brain death diagnosis. Contrast medium was observed in cortical and sub-cortical segments of MCA, ACA and PCA, but brain death diagnosis was excluded since flow was evident in internal cerebral veins and transverse and sigmoid sinuses (CTA score = 0). (This figure was used to compare with Figure 1).

Results

All of the patients were referred from intensive care unit. Age of the patients varied from 32 to 78 (average 62.7). The cause of onset of the coma was cerebral hemorrhage in 10 patients, cerebral stroke in 2 patients and head trauma in 2 patients (Table 1).

Clinical diagnosis criteria were present in all patients before CTA. None of the patients was hypotensive before CTA. None of the patients had disturbances such as drug intoxication and hypothermia that could mimic clinical brain death. CTA score was 4 in all patients (Figures 1, 2).

Bilateral STAs and nasal arteries were studied in VR images. Sudden endings were present at cavernous sinus level in ICAs, but other vascular intracerebral circulation structures were not studied (Figure 3).

In all patients who had clinical brain death diagnoses, CTA examinations confirmed brain death and CTA and clinical diagnoses were consistent. For two of the patients (cases 3 and 5), diffusion weighed MR images taken before CTA were available, and diffusion limited areas compatible with acute infarction were observed in both cases. None of the patients had recent Doppler ultrasonography examination of carotid vertebral artery. Despite the verified brain deaths based on CTA findings in cases 7 and 12, clinicians monitored the cases one more day and repeated CTA examinations, but no difference was reported in CTA findings of both cases.

Discussion

Brain death is defined as irreversible ceasing of brain and brain stem [1, 2]. Among the causes of brain death are intense head traumas, aneurismal subarachnoid hemorrhages, intracerebral hemorrhages, brain edema, herniation, prolonged cardiac resuscitation and asphyxia [2-4]. Basic diagnosis of brain death is mainly clinical, which requires a clear ruling out of reversible syndromes and toxicities which clinically resemble and mimic brain death [1, 3].

Etiology of the primary disease, in other words, what the disease or the reason causing the brain damage is, should be ascertained, and no improvement in clinical indications should be observed after all surgical and medical treatments. Clinical diagnosis require three main criteria; i.e. coma, brain stem areflexia and apnea. Lack of cerebral blood flow due to elevated intracranial pressure is considered the decisive indication of brain death [2, 4].

Although diagnosis of brain death can be obtained using clinical criteria, some confirmative tests may be necessary. The reasons for verification tests are the lack of all necessary clinical indications in brain death, shortening
the examination time in order to maintain the viability of transplantable organs and excluding drug intoxication or hypothermia clinically mimicking brain death in children younger than 5 years old pediatric brains are more resistant to damage and show improvement in crucial functions even after non-responding neurological events [1, 2, 4].

Confirmative tests for brain death diagnosis are neuronal function evaluations (EEG, BAEP), intracranial blood flow examinations (CTA, MR Angiography, PET, radionuclide brain scintigraphy, radionuclide cerebral angiography, cerebral angiography and venography, ophthalmic artery flow examination, transcranial Doppler) and intracranial pressure examinations [1, 3, 4].

Until 1990s, conventional angiography was considered the golden standard in the diagnosis of brain death. Conventional angiography has been limited because of false negative evaluations due to the reasons such as artifacts that can arise from dependent position of head during angiography or when contrast matter is injected in high pressures as well as due to the injury potential of contrast matter on transplantable organs [1, 5, 6].

MR indications of brain death are transtentorial and foramen magnum herniation, loss of flow-based signaling in intracranial veins, loss of differentiation between gray and white matters, lack of intracranial contrast matter enhancement, observation of intravascular contrast matter especially in carotid arteries and clear contrasting in nose and scalp (hot nose sign). Lack of cerebral flow in MR angiography has been reported to be a specific indication of brain death [7, 8].

Recently developed four-point scoring method described by Frampas et al [3] based on cortical segments of bilateral MCA and non-opacification of ICVs is quite specific in confirmation of brain death diagnosis. Loss of opacification in ICVs is the most sensitive and fast indication of the new method. The four-point CTA scoring is more sensitive and requires the opacification evaluation of only four veins. Although cortical branches of MCA are easier to evaluate, cere-
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Cerebral veins are subject to suppression and localization changes due to their deep localizations in the presence of clinical entities such as mass, edema and hemorrhage. In these situations, multiplanar evaluations take precedence. Compared to other adjunct tests used in confirmation of brain death diagnosis, CTA provides a non-invasive, reliable, easily accessed, fast, standardized and practitioner-independent examination method [3, 4]. Loss of vein opacification secondary to operation in patients with craniotomy cannot be evaluated in conventional angiography, but can easily be evaluated in CTA. Especially in patients with subarachnoid hemorrhage, contrasting patterns of intracranial vascular structures can easily be evaluated in subtracted images when non-contrast brain CT examination was performed before brain CTA examination. During the examination, evaluation of ICA continuity and branching through magnifying the cavernous sinus level imaging and adjusting window settings is useful especially in patients with SAH. Presence of contrast matter in STAs shows that contrast matter was administered in examination and also that the contrast matter was excessive. We observed that lack or insufficient use of contrast matter due to technical limitations led to misdiagnoses in CTA examinations. In addition to checking the contrasting in STA, absence of contrasting in intracranial vascular structures, especially in cortical branches of MCA, ICVs and Galen vein, is important in confirmation of brain death diagnosis. For a simultaneous evaluation of transplantable organs during CTA, abdominal CT can easily be performed. Currently, evaluation of patients with brain death diagnosis as organ transplantation donors has been made through bedside ultrasonographic examination [2-4].

Recently, we found that organ donation frequency increased in our patient series whose brain death diagnoses were verified by CTA, which may be due to increased experience of organ donation team in our hospital as well as increased awareness of patients’ relatives.

In conclusion, verification of the absence of cerebral circulation is crucial in confirmation of brain death diagnosis. Although conventional angiography remains the standard method, CTA has emerged as an alternative for this purpose. In parallel to increasing organ replacement therapy, use of CTA, a fast and efficient examination method in confirmation of brain death diagnosis, is becoming widespread. In conclusion, determination of brain death should be carried out in a fast and error-proof way.

Disclosure of conflict of interest

None.

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References