64-slice CT angiography (MDCTA) for the determination of brain death (BD) in potential organ donors: our preliminary results.

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Aims and objectives

Brain death (BD) is a biological event which can occur as a result of various pathologies and is defined as the irreversible cessation of neuronal activity of brain and brainstem [1].

The diagnosis of this condition is considered significant, since it allows organ donation for transplantation or withdrawal of life support and it is based on clinical criteria according to the legal standard and/or practice guidelines currently held in Greece and in most countries. In particular, clinical criteria defining brain death include comatose state (GCS = 3), absence of brain stem reflexes on neurologic examination, with normal core body temperature (above 36°C /~ 97°F) and apnea (no spontaneous respirations with normal PaCO2) [2].

While clinical examination remains the key in determining brain death there are certain situations when it may be inadequate or incomplete and ancillary tests are required [1]. Several medical conditions (such as facial trauma) or interventions (sedatives with prolonged half life) may confound or delay the clinical testing. Finally, these may increase the diagnostic confidence and accuracy before taking the final crucial decision of withdrawing patient's life support and discuss with relatives the issue of organ donation [3].

There are two types of confirmatory tests [4]: Radiological, including cerebral angiogram, CT angiography and perfusion, MR angiogram and transcranial Doppler and Neurophysiological examinations, which involve EEG (±) bispectral index [5] and Somatosensory- evoke potentials [6]. Conventional angiography is considered the gold standard among imaging tests, demonstrating lack of cerebral circulation after a four- vessel cerebral angiography. However CT angiography (CTA) [7] is an emerging alternative imaging modality, showing several advantages over conventional angiography. Particularly, it has shorter time of performance, lower invasiveness, it is readily available and does not require the presence of a specialty trained physician.

Dupas et al in 1998 [8] first demonstrated the efficacy of CTA in diagnosing BD, based on a 7 point score. In a recent study by Frampas et al in 2009 [9], BD diagnosis relied on a novel 4 point score based on lack of opacification of the cortical segments of the middle cerebral artery (M4- MCAs) and internal cerebral vein (ICVs).This study reported a sensitivity of 85.7% and specificity of 100% with the four-point score, in comparison with the seven-point score in the same group of patients, showing a sensitivity of 62.8%. Nevertheless, both false-positive and false-negative results from CTA may primary affect the accuracy of BD diagnosis and secondary the duration of intensive care treatment. Most commonly are related to alteration in perfusion or intracranial pressure (ICP) due to cranial defects, skull fractures or CSF drainage [7, 10].
The aim of this 20-month retrospective study is to assess the efficacy of CTA as an adjunct in the diagnosis of brain death.

**Methods and materials**

In a 20 month period (Jan 2012 to Sept 2013) a 64-slice CTA was performed in 7 patients (3 males and 4 females) - potential organ donors, in order to confirm BD. Median age was 45 years (28-70).

All patients were admitted to the Intensive Care Unit and neurological testing was carried out, showing no evidence of brain function, including the brainstem. Clinical tests were performed according to international recommendations.

All patients (but one with facial trauma) fulfilled clinical criteria of brain death and CTA was performed to reinforce the diagnosis and facilitate discussion about organ donation.

Brain death has occurred as a result of various pathologies, which included:

- Subarachnoid and intraventricular hemorrhage, secondary to rupture of main cerebral arteries aneurysm - 2.
- Subdural hematomas and infratentorial herniation, secondary to epidural anesthesia - 1.
- Hodgkin's lymphoma with invasive CNS candidiasis - 1.
- Brain tumor - 1.
- Traumatic brain injury after a road traffic accident - 1.
- Septic shock - 1.

The CT protocol consisted of a 64- detector CT scan of the head and neck, (1) before intravenous injection of contrast material, (2) an angiogram 20 seconds and (3) a late scan 60 seconds after the injection.

All studies were assessed by two experienced radiologists according to the 4 point criteria proposed by Frampas et al.[9], based on the absence of opacification of M4 middle cerebral artery segments (M4-MCA) and of internal cerebral veins (ICVs). The correct contrast medium administration was documented by the presence of contrast medium in the external carotid arteries and their branches, in particular the superficial temporal arteries.

All patients underwent clinical testing within 12 hours after CTA.
Results

In six patients CTA revealed cessation of cerebral circulation with absence of opacification of M4 of middle cerebral artery (MCA) and internal cerebral veins (ICVs). One patient who had a head injury after a road traffic accident demonstrated residual contrast enhancement of M4-MCA.

Additionally, severe cerebral edema and absence of opacification of basilar artery (BA) was noted in all patients. 3 patients also had weak opacification of ICA, A1/A2 segments of the anterior cerebral artery and M2/M3 branches of MCA.

All patients were transported to CT suite without any complications or adverse events.

Clinical re-evaluation confirmed the diagnosis of BD in all patients and they were declared dead within 48 hours after CT.

Our preliminary investigation showed one false negative result and a sensitivity and specificity of 85.7% and 100%, respectively. No false positive results were reported.
Table 1: * (+) opacified , (-) non opacified vessels. CNS= central nervous system. M1-4 and A1-2= medial cerebral artery segment 1-4 and anterior cerebral artery segment 1-2. ICVs= internal cerebral veins. BA= basilar artery. ICA= internal carotid artery. RMCA= right medial cerebral artery. SAH= subarachnoid hemorrhage. VH= ventricular hemorrhage. SD= subdural. CLN= cortical laminar necrosis.

References: 2nd Department of Radiology, University Hospital of Athens/ Greece 2013

Images for this section:

<table>
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<th>Patients</th>
<th>M4*</th>
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<th>Opacified Arteries</th>
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<td>M1 (b)</td>
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<td>BA – ICA + M1, M2 +</td>
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<td>Sepsis- CLN</td>
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Table 1: * (+) opacified , (-) non opacified vessels. CNS= central nervous system. M1-4 and A1-2= medial cerebral artery segment 1-4 and anterior cerebral artery segment 1-2. ICVs= internal cerebral veins. BA= basilar artery. ICA= internal carotid artery. RMCA= right medial cerebral artery. SAH= subarachnoid hemorrhage. VH= ventricular hemorrhage. SD= subdural. CLN= cortical laminar necrosis.
**Fig. 1:** Patient with sepsis. Axial CTA images before (A), 20sec (B) and 60sec (C) after IV contrast medium injection. Diffuse cerebral edema and peripheral cortical hyperdensities (red arrow) due to diffuse hypoxic brain ischemia. Absence of opacification of MCA- M4 cortical segments (B) and ICVs (C). Superficial temporal arteries are well opacified (white arrow). MRI of the brain revealed cortical laminar necrosis and diffuse hypoxic ischemic encephalopathy.

**Fig. 2:** Patient with decompressive craniectomy after head injury and diffuse brain edema. Axial CT images before (A), 20sec - arterial (B) and 60sec delayed (C) after IV contrast medium injection. MCA- M4 cortical segments are well opacified in arterial and delayed phase due to hyperperfusion and "stasis filling" (arrows). ICVs are not opacified.
**Fig. 3:** Patient in figure 2. Axial (A) and coronal (B) images with MIP reconstruction on arterial phase (20sec) demonstrate: opacification of MCA- M2 (yellow arrow) and M4 (red arrows) segments and also ACA- A2 (white arrow) segments. Superficial temporal arteries are also visible.

**Fig. 4:** CT in BD before (A), 20sec (B) and 60 seconds(C) after contrast medium injection. Absence of filling of ICVs and MCA cortical segments. Temporal arteries and veins are visible. Superficial temporal arteries are opacified, indicating that contrast medium has been correctly injected.
**Fig. 5:** Diagnosis of brain death in a patient with rapture of right MCA aneurysm. Axial CT images before (A), 20sec - arterial (B) and 60sec delayed (C) after IV contrast medium injection. In the delayed phase (C): the middle cerebral arteries (M2-M3 segment) shows prolonged opacification (red arrow) corresponding to "stasis filling". The distal branches of the external carotid arteries (superficial temporal arteries) are still opacified (red arrowheads), already visible during the arterial phase, as the external carotid network is normally opacified during brain death.
Conclusion

Although clinical criteria remain the gold standard for the diagnosis of BD, there are several conditions in which ancillary tests may be necessary. CTA confers a number of advantages and facilitating timely and reliable diagnosis can be a valuable adjunct for BD confirmation in selected patients.

Personal information

References