Computed Tomography Angiography (CTA) as an Ancillary Tool in the Diagnosis of Brain Death - The Bern Experience

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Purpose

The determination of brain death in potential organ donors is a highly sensitive procedure that involves ethical, medical, and legal aspects.

In Switzerland, federal legislation on the transplantation of organs, tissues, and cells defines that a patient is dead "if the functions of his or her brain, including the brainstem, have ceased irreversibly" [1].

The Swiss Academy of Medical Sciences issues guidelines that deal with the practical implementations of this law, i.e., which procedures have to be performed when and by whom in order to make this diagnosis.

Please note:

When we performed the studies that were used for a publication on this topic and during the preparation of the manuscript [2], these guidelines were still effective in the 2005 version. On September 1, 2011, a modified version of these guidelines came into force [3].

There are notable differences between these two versions, but as these guidelines are irrelevant for readers in other countries, we will not discuss them here. The indications for the use of MD-CT in the diagnosis of brain death in Switzerland have changed, but the topic of this poster, how to perform and interpret the CT study, have remained unchanged.

In certain clinical settings, the clinical diagnosis of brain death alone may not be sufficient. In these cases, ancillary tests are required. The above mentioned guidelines allow transcranial Doppler ultrasonography, CT angiography (CTA), intra-arterial DSA, or magnetic resonance imaging and angiography (MRI/MRA).

As an operator-independent method that can be performed in an intubated patient with an acceptable amount of time and effort, CTA is the method of choice. (We still perform DSA in patients where evaluation of the coronary arteries is required; after angiographic determination of brain death by the neuroradiologist, the cardiologist performs cardiac angiography via the same femoral arterial access.)

It is evident that a contrast-enhanced study with high spatial resolution is required for detailed evaluation of the intracranial vasculature, but the core problem is: **When can we safely diagnose brain death?**
Two key publications that found their way into the Swiss and French [4] guidelines for the determination of brain death defined criteria for CTA to determine intracranial circulatory arrest:

- In 1998, Dupas et al. [5] presented an evaluation scheme that considered opacification of the A3-segments of the anterior cerebral artery, the M4-segments of the middle cerebral artery, the vein of Galen or the internal cerebral veins as signs of persistent brain perfusion (a 7-point-scale).
- In 2009, Frampas et al. [6] suggested a modified protocol that only considered opacification of M4-segments of the middle cerebral artery or the internal cerebral veins as signs of a still perfused brain (i.e., a 4-point-scale).

In a retrospective analysis that was approved by the institutional review board, we applied both criteria lists to the studies that were performed at our institution and compared the results to the clinical determination of brain death as standard of reference [2].

**Methods and Materials**

Between October 2007 and April 2010, 29 CT studies were performed at our institution for the diagnosis of brain death with a standardized protocol (15 men, 14 women, mean age 49.2 years).

The protocol consists of

- a thin-section (1.5 mm slice thickness) unenhanced study,
- a CTA from the aortic arch to the vertex, and
- a late enhanced study with identical parameters and positions as the unenhanced study.

These two thin-section studies were used for the evaluation of vessel enhancement.

Timing was standardized, the late enhanced study planned to start one minute after contrast injection for the CTA began (actual timing: 1:04 +/- 22 seconds).

Opacification of the superficial temporal arteries serves as an indicator for a technically sufficient study in the contrast-enhanced series (fig. 1).

All images were read by two experienced board-certified neuroradiologists in consensus reading.
Fig. 1: Thin-section (1.5 mm) studies. Left: unenhanced, right: contrast-enhanced. Opacification of the superficial temporal arteries (open arrow) indicates technically sufficient study.
Results

Seven of the 29 patients included in this study could not be declared as brain-dead due to opacification of arterial and/or venous vessels (fig. 2-4).

There were no differences between the 4-point- and the 7-point-scale (fig. 5).

In these seven patients, another clinical exam within six to twelve hours after the CT study definitely confirmed brain death.

Using the clinical exam as standard of reference, the CT studies had a sensitivity of 75.9 %.

Images for this section:

**Fig. 2:** Brain death? Yes. The opacification that is visible in the contrast-enhanced series (right) corresponds to a M3-segment of the middle cerebral artery.
Fig. 3: Brain death? No. Here, there is slight opacification of a distal branch (M4) of the middle cerebral artery.
**Fig. 4:** Brain death? No. Although the complete posterior circulation territory including pons and brainstem is infarcted in this patient with a basilar artery thrombosis, the formal criteria for brain death are not fulfilled as there is still normal opacification of the anterior and middle cerebral arteries.

<table>
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<th>Age</th>
<th>MCA M4 right</th>
<th>MCA M4 left</th>
<th>ACA A3 right</th>
<th>ACA A3 left</th>
<th>Internal cerebral vein right</th>
<th>Internal cerebral vein left</th>
<th>Vena cerebri magna</th>
<th>Brain death (7-point-scale)</th>
<th>Brain death (4-point-scale)</th>
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**Fig. 5:** Tabular overview of the findings in the seven patients that could not be declared as brain dead in the CT study. Note that the results are identical in both the 7-point- and the 4-point-scale.
Conclusion

The CT protocol presented here is a fast and easily performed method for the determination of brain death. As the 4-point-scale yielded the same results as the older 7-point-scale, evaluation of the late enhanced thin-slice study can be reduced to only four parameters. It should, however, be performed by an experienced neuroradiologist as subtle enhancement of M4-segments may be difficult to discern, especially in patients with subarachnoid hemorrhage.

The sensitivity of 76 % that we found in our study is in accordance with the literature; published results range from 52.4 % (CTA compared to EEG [7]) to 86 % (CTA compared to nuclear medicine perfusion studies [8]).

In summary, CT is a robust and clinically usable tool in the diagnosis of brain death. It should be used as the first method whenever clinically ambiguous findings recommend the use of an ancillary test.

References

1. Federal Act of 8 October 2004 on the Transplantation of Organs, Tissues and Cells (SR 810.21)

Personal Information