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Computed Tomographic Angiography in the evaluation of brain death

Marcin Sawicki[1], Anna Walecka[1], Janusz Kordowski[1], Wojciech Poncyljusz[1], Ewa Gabrysz-Trybek[1], Magdalena Mączka[2], Romuald Bohatyrewicz[2]

[1] Department of Diagnostic Imaging and Interventional Radiology, Pomeranian Medical University, Szczecin, Poland
[2] Department of Anaesthesiology and IntensiveTherapy, Pomeranian Medical University, Szczecin, Poland

Author's address: Marcin Sawicki, Dept. of Diagnostic Imaging and Interventional Radiology, Pomeranian Medical University, Clinical Hospital No1, Unii Lubelskiej 1, Szczecin, Poland, e-mail: msaw@sci.pam.szczecin.pl

Summary

According to Polish criteria two neurophysiological methods are used to demonstrate the cessation of brain function: electroencephalography (EEG) and brain stem auditory evoked potentials. Among the techniques measuring cerebral blood flow, conventional angiography of the four cerebral arterial axes is the reference standard for imaging brain death. Thus, it is an invasive examination which needs an experienced neuroradiologist and the availability of an angiography suite. The use of a computed tomographic (CT) scan to diagnose BD was proposed as early as 1978. This exam developed widely these last years thanks to a new generation of multirow CT which allows visualization of opacified cerebral vessels. The aim of the present study was to determine the accuracy of CT-a for the confirmation of BD.

We examined four patients with suspicion of BD according to clinical criteria defined by law. CT scan was performed without and with injection of contrast material, followed by cerebral angiography. In our material CT-angiography showed opacification of A2-ACA in two patients (patient 1 and 2). In all our patients the results of CT-angiography fulfill the criteria proposed by the French Society of Neuroradiology in 2007 – absence of perfusion of M4 middle cerebral artery segments (M4-MCA) and deep cerebral veins. In conventional angiography one patient (patient 2) showed, at the level of the anterior and middle cerebral artery, a phenomenon already described as "stasis filling".

CT angiography seemes to be a promising radiological exam in the diagnosis of BD. When confirmatory examinations are required among brain-dead patients for whom the clinical diagnosis remains essential, it may be an interesting alternative to conventional cerebral angiography, which is more invasive and constraining, and to EEG when it is unavailable or inadequate.

Key words: **brain death • conventional angiography • CT-angiography**

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Background

Brain Death (BD) is the consequence of cerebral blood flow arrest leading to total and irreversible loss of hemispheric and brain stem functions. The diagnosis of brain death must respect all the guarantees required by law and be determined as early as possible to avoid unnecessary treatment and to allow organ harvesting for transplantation. Clinical criteria for brain death include deep unresponsive coma, no brain stem function (no pupillary light or corneal, oculocephalic, oculovestibular, oropharyngeal, or tracheal reflexes) and no spontaneous ventilation. Sometimes clinical criteria cannot be applied reliably, e.g., when the cranial nerves cannot be adequately examined, when neuromuscular paralysis or heavy sedation is present, or in some patients for whom the apnea test is precluded (respiratory instability or high cervical spine injury) or not valid (high carbon dioxide retainers). In these situations ancillary tests are necessary.

According to Polish criteria two neurophysiological methods are used to demonstrate the cessation of brain function: electroencephalography (EEG) and brain stem audito-

Table 1. Patients characteristics.

Patient No.	Age (years)	Sex	Pathology
1	56	M	ICH
2	71	M	SAH
3	47	F	BT
4	58	F	CS

ICH – intracranial hemorrhage; SAH – subarachnoid hemorrhage; BT – brain tumor; CS – cerebral stroke.

ry evoked potentials [1]. Among the techniques measuring cerebral blood flow, conventional angiography of the four cerebral arterial axes is the reference standard for imaging brain death. Thus, it is an invasive examination which needs an experienced neuroradiologist and the availability of an angiography suite. The use of a computed tomographic (CT) scan to diagnose BD was proposed as early as 1978 [2]. This exam developed widely these last years thanks to a new generation of multirow CT which allows visualization of opacified cerebral vessels. Some criteria for validity have been proposed [3]. The advantages of CT-a include its availability in most hospitals where patients are admitted for organ harvesting and its rapid feasibility, low-invasiveness, and ability to assess BD in the presence of neurodepressant agents. To date only a limited number of prospective studies and a few case reports have evaluated CT-a for the diagnosis of BD [3–6]. The aim of the present study was to determine the accuracy of CT-a for the confirmation of BD.

Material and Methods

We examined four patients with suspicion of BD according to clinical criteria defined by law. CT scan was performed without and with injection of contrast material, followed by cerebral angiography. During these exams, mean arterial blood pressure was maintained above 80 mm Hg. The characteristics of our patients are presented in Table 1.

CT angiography

Concerning CT scan (Siemens Sensation 64), there were 3 spiral CT scan phases: 20, 30 and 50 seconds after the start of contrast medium injection. Images were acquired at a collimation of 64×0.6 mm with a pitch of 1.2. The scanning parameters were as follows: 120 kV, 130 mAs, range C1-C2 level to the vertex, FOV 220mm and matrix 520×520. Images were reconstructed with 3mm MPRs and 10mm MIPs. Injection was performed with 80 mL of iomeprol 400 at a flow rate of 5.0 mL/s using a power injector and an 18-gauge catheter. Multimodality Workplace with "syngo 2008" software (Siemens, Erlangen, Germany) was used for post processing.

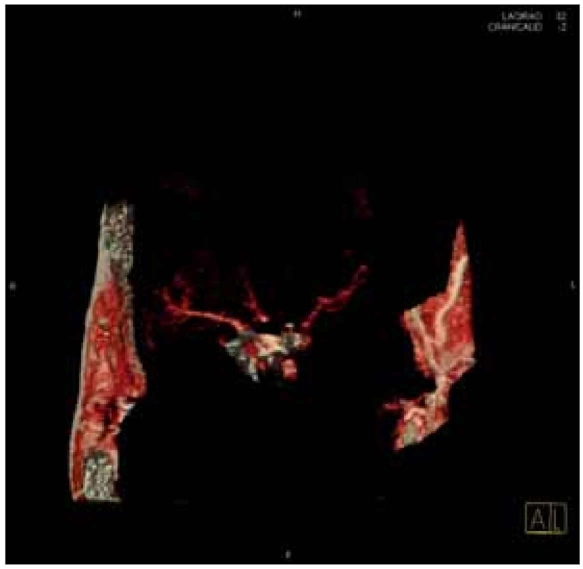

Figure 1. CT angiography revealed weak opacification of the middle cerebral arteries (M2 segment) and the anterior cerebral arteries (A2 segment) in early and late phase. External carotid arteries were opacified, indicating that contrast medium had been injected correctly.

Digital subtraction angiography

Immediately after spiral CT scanning, arterial digital subtraction angiography (DSA) was carried out in all patients to demonstrate intracerebral circulatory arrest. Arteriography was performed by the Seldinger femoral approach using a 5F pigtail catheter and injection into the ascending aorta. The injection was performed with nonionic contrast material (30 mL of iodixanol 320) at a rate of 15 mL/s using a power injector with two images per second during 30 seconds. Imaging was performed in the a-p projection. The acquisition delay of images was 0.5 second.

Table 2. Angiographic and CT-a findings.

Patient no.	Conventional angiography		Arrest level		CT angiography		Arrest level	
	ICA		VA		ICA		VA	
	R	L	R	L	R	L	R	L
1	C4	C5	C	C	A2	A2	M2	M2
2	A2-M2	C2	C	C	A2	A2	M2	M2
3	C4	C4	C	C	C	C	C	C
4	C5	C5	FM	FM	C	M1	C	C

C – indicates segments of internal carotid artery; A1,M1,M2 – subarachnoid arterial segments; FM – foramen magnum.

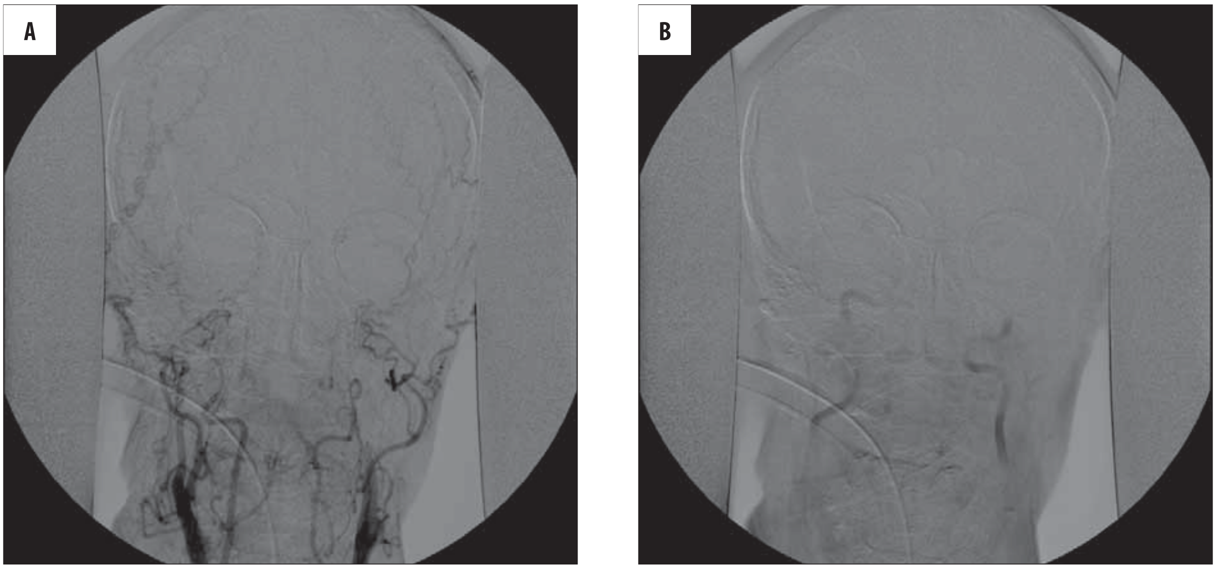

Figure 2. Arteriography: the branches of the external carotid arteries were opacified and washed out quickly (**A**). Decreased circulation in the internal carotid associated with stagnation and arrest of contrast medium at C4 and C5 level and no evidence of venous drainage by the great cerebral vein and straight sinus 30 seconds after injection (**B**).

Figure 3. CT angiography showed weak opacification of the middle cerebral arteries (M2 segment) and the anterior cerebral arteries (A2 segment) in early and late phase. External carotid arteries were opacified, indicating that contrast medium had been injected correctly.

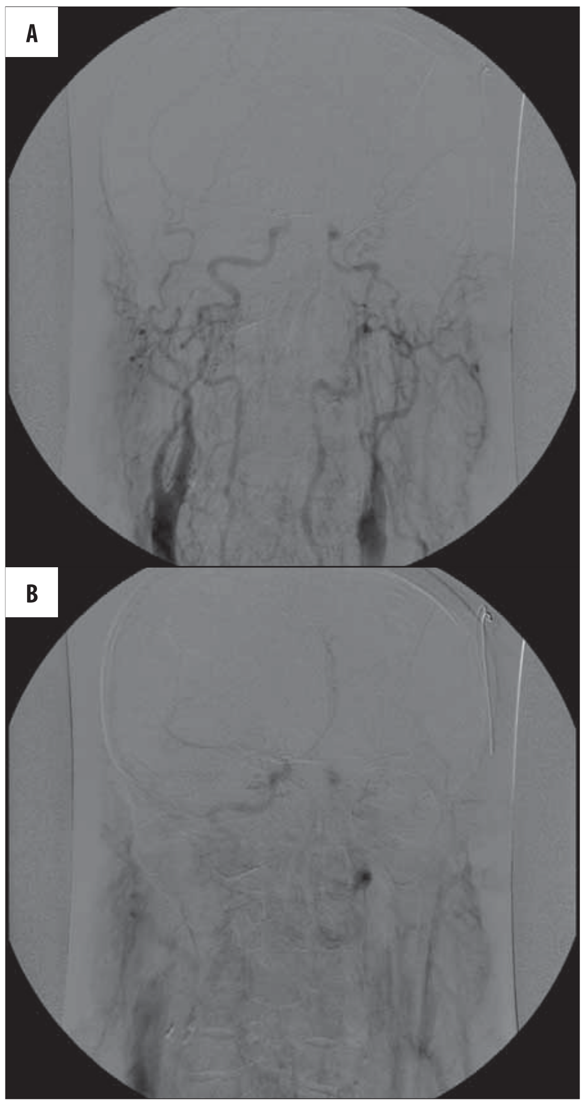

Figure 4. Arteriography: in early phase (**A**) the branches of the external carotid arteries were opacified and washed out quickly. In late phase (**B**) delayed opacification in proximal segment M2 and A2 on the right side. These segments were thin, thus differing from the normal pattern. This phenomenon has been already described as "stasis filling." This is due to stagnation of contrast material at the level of the first horizontal segments of the anterior, middle, and posterior cerebral arteries; it does not mean effective vascularization.

Figure 5. CT angiography didn't reveal opacification of any cerebral artery in early and late phase. External carotid arteries were opacified, indicating that contrast medium had been injected correctly.

Results

Our findings are presented in Table 2.

Case 1

Fifty-six years old man with the history of arterial hypertension was admitted to the ICU with severe intracerebral bleeding and developing hydrocephalus. Despite intensive treatment the patient was unreactive and circulatory unstable.

CT angiography revealed weak opacification of the middle cerebral arteries (M2 segment) and the anterior cerebral arteries (A2 segment) in all three phases. External carotid arteries and superficial temporal arteries were opacified, indicating that contrast medium had been injected correctly (Figure 1).

Arteriography performed 52 minutes later demonstrated intracerebral circulatory arrest - decreased circulation in the internal carotid and vertebral arteries associated with stagnation and arrest of contrast medium at C4 and C5 level in internal carotid arteries, at cervical level in vertebral arteries and no evidence of venous drainage by the great cerebral vein and straight sinus 30 seconds after injection. The branches of the external carotid arteries were opacified and washed out quickly, whereas contrast medium remained in the internal carotid and vertebral arteries (Figure 2).

Case 2

Seventy-one years old man with a massive subarachnoid bleeding from the ruptured aneurysm of the anterior communicating artery (Hunt and Hess scale IV) was admitted to the Neurosurgery Department for the clipping of the aneurysm. The follow-up CT revealed severe ischemic stroke with massive brain edema. Decompressive bilateral craniectomy was performed and the patient was admitted to the ICU.

Figure 6. Arteriography: the branches of the external carotid arteries were opacified and washed out quickly, whereas contrast medium remained in the internal carotid and vertebral arteries (**A**). Decreased circulation in the internal carotid and vertebral arteries associated with stagnation and arrest of contrast medium at C3 level of internal carotid arteries, at cervical level in vertebral arteries and no evidence of venous drainage by the great cerebral vein and straight sinus 30 seconds after injection (**B**).

CT angiography showed weak opacification of the middle cerebral arteries (M2 segment) and the anterior cerebral arteries (A2 segment) in all three phases (Figure 3).

Arteriography performed 45 minutes later revealed delayed opacification in proximal segment M2 and A2 on the right side. These segments were thin, thus differing from the normal pattern (Figure 4).

Case 3

Forty-seven years old woman with the meningioma of the base of the right anterior and middle cranial fossa was

Figure 7. CT angiography revealed weak opacification of the left middle cerebral artery (M1 segment) in early and late phase. External carotid arteries were opacified, indicating that contrast medium had been injected correctly.

admitted to the Neurosurgery Department. During the postoperative period a severe right sided ischemic stroke with brain edema occurred. The patient was unreactive with respiratory insufficiency on the day of addmition into the ICU.

CT angiography didn't reveal opacification of any cerebral artery in all three phases. External carotid arteries and superficial temporal arteries were opacified, indicating that contrast medium had been injected correctly (Figure 5).

Arteriography performed 50 minutes later demonstrated decreased circulation in the internal carotid and vertebral arteries associated with stagnation and arrest of contrast medium at C3 level of internal carotid arteries, at cervical level in vertebral arteries and no evidence of venous drainage by the great cerebral vein and straight sinus 30 seconds after injection. The branches of the external carotid arteries were opacified and washed out quickly, whereas contrast medium remained in the internal carotid and vertebral arteries (Figure 6).

Case 4

Fifty-eight years old woman with a history of arterial hypertension and atrial fibrillation was addmited to the ICU with the brainstem ischemic stroke. The patient was unconscious, unreactive with bradycardia and hypertension.

CT angiography revealed weak opacification of the left middle cerebral artery (M1 segment) in all three phases. External carotid arteries and superficial temporal arteries were opacified, indicating that contrast medium had been injected correctly (Figure 7).

Arteriography performed 43 minutes later showed decreased circulation in the internal carotid and vertebral arteries associated with stagnation and arrest of contrast medium at C5 level of internal carotid arteries, at the level of foramen magnum in vertebral arteries and no evidence of venous drainage by the great cerebral vein and straight sinus 30 seconds after injection. The branches of the external carotid arteries were opacified and washed out quickly, whereas contrast medium remained in the internal carotid and vertebral arteries (Figure 8).

Figure 8. Arteriography: the branches of the external carotid arteries were opacified and washed out quickly, whereas contrast medium remained in the internal carotid and vertebral arteries (**A**). Decreased circulation in the internal carotid associated with stagnation and arrest of contrast medium at C5 level and no evidence of venous drainage by the great cerebral vein and straight sinus 30 seconds after injection (**B**).

Discussion

Conventional arteriography is currently considered to be the gold standard for demonstrating brain death. If three-phase spiral CT is to replace conventional arteriography for this purpose, it must be capable of satisfying all criteria indicative of absence of intracerebral blood flow.

In 1998 Dupas et al. proposed the criteria for confirming BD in CT-a [3]. According to that paper, the CT scan had to show the absence of perfusion of A2 anterior cerebral artery segments (A2-ACA), M4 middle cerebral artery segments (M4-MCA), P2 posterior cerebral artery segments (P2-PCA), basilar artery, internal cerebral veins, and finally the great cerebral vein.

In our material CT-angiography showed opacification of A2-ACA in two patients (patient 1 and 2). The same finding was observed by Combes et al. in 76.9% of 43 patients [4]. They explained, that this finding is probably linked to the arterial distance, which is longer for M4-MCA than for A2-ACA. Thus, they proposed 2 possibilities: either opacification of A2-ACA is not searched or their vascular opacification is observed at the level of cortical A3-ACA segments, which is technically difficult for interpretation.

In all our patients the results of CT-angiography fulfill the criteria proposed by the French Society of Neuroradiology in 2007 – absence of perfusion of M4 middle cerebral artery segments (M4-MCA) and deep cerebral veins [7].

In conventional angiography one patient (patient 2) showed, at the level of the anterior and middle cerebral artery, a phenomenon already described as "stasis filling." This is due to stagnation of contrast material at the level of the first horizontal segments of the anterior, middle, and posterior cerebral arteries; it does not mean effective vascularization [2,3].

Conclusions

Concluding, CT angiography seemes to be a promising radiological exam in the diagnosis of BD. When confirmatory examinations are required among brain-dead patients for whom the clinical diagnosis remains essential, it may be an interesting alternative to conventional cerebral angiography, which is more invasive and constraining, and to EEG when it is unavailable or inadequate.

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