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Multi-slice computed tomography angiography in patients suspected of brain death

In most cases there are no controversies and major problems for a medical board to diagnose of brain death (death of the brainstem) according to the guidelines of the decree issued by the Minister of the Healthcare and Social Welfare on 29 October 1996 (10). The diagnosis of brainstem death is based on the confirmation of irreversible loss of brainstem function in patients with confirmed structural and irreversible brain injury, those deeply comatose due to known cause, and artificially ventilated. The following exclusions should also be made: 1) intoxication of a different type and influence of some pharmacologic agents; 2) hypothermia of external cause; 3) metabolic and endocrine disturbances; 4) the presence of seizures and decerebrate spasms. The next step is to demonstrate the loss of all brainstem reflexes (absent corneal ("Blink Reflex") and pupillary light responses; no spontaneous movements of the eye, absent caloric responses to iced water after visual examination of the tympanic membranes ("Cold Calorics"), no motor response to pain stimuli in the territory of cranial nerves; absent cough and)or pharyngeal reflexes, no oculocephalic reflexes) and to confirm non-reactivity of the respiratory centre by apnea test.

The Polish guidelines do not require any imaging examinations to confirm the brain death. However, there are some situations when the diagnosing of brain death by the medical board based only on clinical testing is not feasible because of craniofacial or)and spinal cord injuries, pulmonary disturbances, or prolonged increased levels of some drugs. There are some additional laboratory tests which could be helpful in such circumstances. They are not required by Polish law, but on the other hand, they are not forbidden. These tests can be divided into two groups: the first group consists of neuroimaging examinations that show lack of flow in the intracranial vessels, the second one includes the examinations confirming no bioelectrical activity of the brain. The consensus exists that "lack of cerebral flow for a dozen or so minutes suggests the brain stem death" (8).

The examinations that can be used to show this include: transcranial Doppler ultrasonography, isotope angiography, isotope perfusion imaging, selective four-vessel angiography (angiography of carotid and vertebral arteries) and digital subtraction angiography (DSA). The methods used to confirm the loss of bioelectical activity of the brain include electroencephalography and somatosensory and brainstem auditory evoked potentials. Recently, due to development of low-invasive, advanced radiological techniques, the computed tomography angiography (CTA), magnetic resonance angiography and perfusion computed tomography have become increasingly important in the diagnosis of pathology of the brain and its vessels (5). These techniques more and more frequently substitute four-vessel angiography and DSA, especially, when intravascular therapeutic procedures

are not required. The first description of the helical computed tomography used to show the loss of cerebral blood flow was published by Arnold et al. (3), but it is just the last decade, when the spread of multi-row computed tomography devices resulted in an increasing number of publications on the usefulness of this method in the diagnosis of brain death (1, 4, 12).

Our study presents the results of brain imaging with the use of multi-slice computed tomography with angiography option in patients suspected of brain death.

MATERIAL AND METHODS

The study group consisting of 10 patients (9 men and one woman aged 19 to 56 years) were admitted to the First Department of General Surgery and Transplantology from January 2004 to March 2006, with posttraumatic or vascular brain injuries, who were suspected of brainstem death by clinical examination. The computed tomography imaging was performed in all patients (8-row tomography in 3 patients and 64-row in 7 patients) using LightSpeed Ultra or VCT device and diagnostic console Advantage 4.2 (GE Medical System). The examinations were performed in native scanning and after intravenous bolus 80–100 ml of nonionic contrast agent 370 mg I/ml with the rate of 4 ml/s in angio option (collimation 1.2 or 0.6 mm, delay time with bolus tracking technique). The examination included the assessment of brain structure and focal lesions in native scanning and additionally evaluation of vessels in angiographic phase, acquired in multiplanar reconstructions (MPR) and maximum intensity projections (MIP), and in 3D volume rendering projections. All the patients underwent examinations in the presence of the medical board for brain death diagnosis, based on procedures required by Polish law.

RESULTS

In all the patients the analysis of computed tomography images showed the following lesions: severe oedema of the brain with loss of sulcus outlines, compression of the brain ventricles, no delineation between white and gray matter – homogeneity and hypodensity of the brain tissue (Fig. 1). The lack of flow was found in angioimaging with the preservation of circulation in branches of the external carotid artery in all patients (Fig. 2–4).

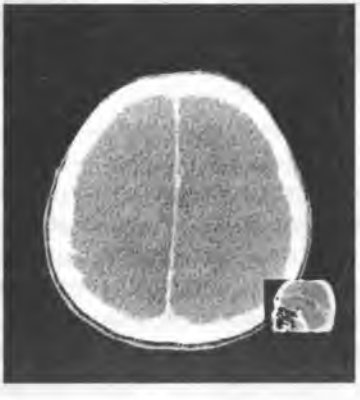

Fig. 1. CT coronal view in native scanning.
The homogeneous structure of cerebral tissue in patient with post-traumatic haematoma

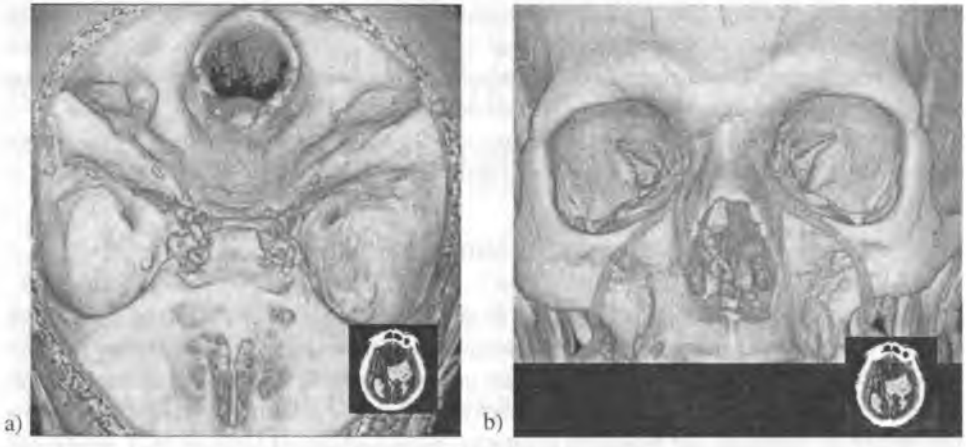

Fig. 2. CTA – 3D volume rendering view. The cerebral arteries are not visible (a), whereas the extracranial arteries are opacified (b)

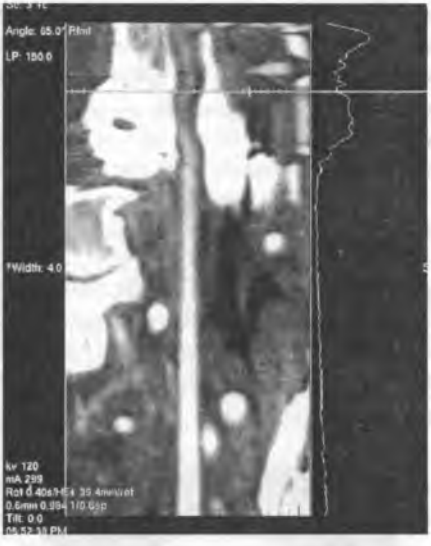

Fig. 3. CTA – lumen view in advanced vessel analysis. Flow arrest in the petrous portion of the right internal carotid artery

In all the patients neither intracranial, meningeal portions of both bilateral internal carotid and vertebral arteries could have been demonstrated, nor filling of their branches or collaterals could have been seen. The exact level of circulatory arrest in both internal carotid and vertebral arteries was established with the use of multiplanar reconstructions (the results are shown in Table 1).

Among 10 patients with the suspicion of brain death and CTA confirmed cerebral circulatory arrest in 9 cases the diagnosis was confirmed in the presence of the medical board by clinical testing; one patient died due to systemic circulatory arrest before all confirmatory tests.

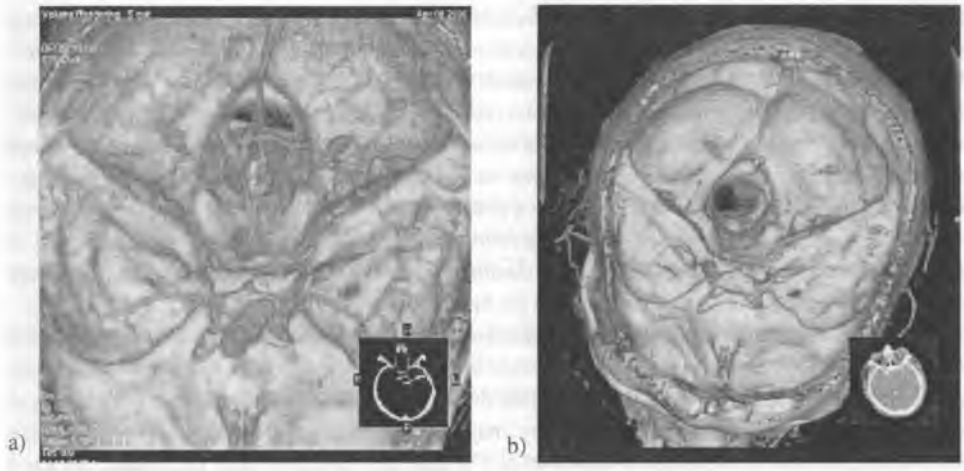

Fig. 4. CTA – 3D volume rendering projections. The patient with anterior communicating artery aneurysm. All arteries are opacified (a). After three days: the examination of the same patient suspected of brain death. No enhancement of the intracranial vessels (b)

Table 1. Computed tomography angiography circulation arrest level

Patient	Right internal carotid artery	Left internal carotid artery	Right vertebral artery	Left vertebral artery
1	*Pars petroneus*	C1	C1	C1
2	C2	C2	C1	C2
3	*Pars petroneus*	C2	C1	C2
4	Siphon	C1	C1	C1
5	C1	C2	C2	C2
6	C2	C3	C1	C2
7	*Pars petroneus*	C1	C1	C2
8	C1	C1	C1	C2
9	C2	C2	C1	C2
10	*Pars petroneus*	C1	C1	C2

Note. C (1, 2, 3) indicates cervical arrest level

DISCUSSION

Radiological confirmation of the brain death is based on demonstrating the arrest of cerebral circulation. This is due to the "non-filling phenomenon", also called "no reflow phenomenon", first described 50 years ago (2, 13). Posttraumatic or anoxic-ischemic brain injury results in the brain swelling and increased intracranial pressure that after exceeding the level of 40 mmHg leads to loss of venous outflow and to further increase in the intracranial pressure and reduction of blood supply to the brain. When intracranial pressure exceeds systemic diastolic pressure, the disturbances in cerebral flow can be observed, described as oscillatory flow in transcranial Doppler (9). As intracranial pressure exceeds systolic pressure, the cerebral circulation arrests and this can be seen as lack of filling of cerebral vessels in DSA, the image of an empty skull in perfusion scintigraphy or small systolic peaks in transcranial Doppler. The cerebral circulatory arrest for more than 15 min results in brain death due to high brain susceptibility to anoxia. Further reduction in the intracranial pressure

does not restore cerebral circulation. The increased resistance of the vessels, leading to the cerebral circulatory arrest is caused by perivascular oedema of the glial cells and formation of subintimal blebs that result in collapse of the wall of the small vessels (2). The lack of filling of cerebral vessels in angiography in patients with high intracranial pressure was described by Pribam (11) in 1961, who considered it a result of spasm of the muscular layer in arteries. Until today it has not been explained why the circulatory arrest occurs on one and not on the other level. Four-vessel cerebral angiography has been the first method used and it remains a gold standard to show the cerebral circulatory arrest and to compare the other methods. In many countries it is obligatory to perform angiography or other laboratory tests to confirm the cerebral circulatory arrest, but in some other countries it is only optional during the procedure of diagnosis of the brain death.

Most patients suspected of brain death undergo CT imaging to confirm or exclude irreversibility of intracranial structural lesions. The angio option can be easily added to this examination with minimal risk for the patients to confirm or exclude the arrest of the cerebral circulation. The blurring of the outlines of cerebral structures, hypodensity, major compression of cerebal ventricles and midline shift were described by Dominguez-Roldan et al. (7), but they considered only the midline shift and compression of some subarachnoid cisterns (ambiens cistern) to be indicative of the suspicion of brain death in CT native scanning.

In our experience the homogeneity of the brain is an equally characteristic feature in the CT brain imaging. The picture of the cerebral circulatory arrest in angio CT imaging triggers no controversies. Dupas et al. (8) compared the images of intracranial circulation in patients suspected of having their brains dead by four vessel angiography with the images by CTA and they obtained identical results in both methods. However, they noticed better feasibility and lesser invasiveness of computed tomography compared to the other technique.

In all our patients with brain death no cerebral circulation was observed. Other authors confirm such findings. However Braun et al. (6) described preserved circulation in the posterior cerebral fossa in 6% of examined patients from 140 patients with the diagnosis of brain death in whom DSA was performed. This circulation is likely to result from connections of the intra- and extracranial cerebral circulations with the venous system and from arterio-venous direct connections. Toffol et al. (14) by contrast, presented the case of a 3-year-old child, in whom CT showed preserved cerebral circulation on CTA, despite the clinically identifiable brain death and unquestionable loss of activity on EEG. This emphasizes the difficulties in the diagnosis of brain death in children. Alvarez et al. (1) described a patient with diagnosed brain death in whom the brain vessels on one side were contrasted on DSA and extravasation of the contrast agent occurred. This resulted from diffused skull damage causing reduced intracranial pressure on the side of injury. In one of our patients after extensive craniectomy no cerebral circulation was seen, despite large postoperative bone defect.

In general, computed tomography with angioimaging seems to be a fast, easily to interpret and to perform examination confirming the cerebral circulatory arrest which is characterized by a relatively low risk of side-effects.

CONCLUSIONS

1. Computed tomography with angioimaging is a useful method for confirmation of the cerebral circulatory arrest.

2. Further studies are needed to assess the sensitivity and specificity of CTA in the diagnosis of the cerebral circulatory arrest.

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SUMMARY

According to current Polish law, diagnosis of brain death consists in demonstrating lack of brainstem function using clinical tests. Lack of cerebral circulation revealed by radiological examinations is one of the factors confirming brain death. Cerebral angiography is thought to be "the golden standard" in the diagnosis of cerebral circulation arrest; however less invasive diagnostic methods of cerebral diseases are becoming increasingly important. The aim of the study was to describe the changes in the brain and its vascularization detected by multi-slice computed tomography angiography in patients suspected of brain death. CT scans of 10 patients with features of post--traumatic or stroke-induced brain damage (8- or 64-slice LightSpeed tomograph with diagnostic console Advantage 4.2 (GE Medical Systems) were evaluated. The examinations were conducted using native axial scanning following the intravenous contrast medium bolus (collimation 1.2 or

0.6; 80 or 100 ml of contrast medium with concentration 370 mgI/ml. The study evaluated cerebral structure changes on native scanning and cerebral vessel scans in multiplanar reconstructions with maximum intensity option and 3D volume rendering projections. The analysis of CT scans showed the following changes observed in all the patients: severe brain oedema without visible sulci, compression of the brain ventricles, and no delineation between white and gray matter", homogeneity and hypodensity of the brain tissue. In all the patients, MSCT angiography revealed the arrest of circulation in internal carotid and vertebral arteries enabling the diagnosis of lack cerebral circulation with preserved circulation in the branches of external carotid artery. In nine patients the brain death diagnosis was confirmed using binding clinical examinations; one patient died due to systemic circulatory arrest. Multislice computed tomography angiography may be a useful diagnostic tool confirming the cerebral circulation arrest. Further studies are needed to determine its sensitivity and specificity.

Wielorzędowa tomografia komputerowa z opcją angiograficzną u chorych z podejrzeniem śmierci mózgowej

Rozpoznawanie śmierci mózgowej na podstawie obowiązującego w Polsce prawa polega na wykazaniu testami klinicznymi braku czynności pnia mózgu. Brak krążenia mózgowego wykazany badaniami radiologicznymi jest jednym z wyznaczników potwierdzających śmierć mózgu. Angiografia naczyń mózgowych uznawana jest za „złoty środek" w rozpoznaniu zatrzymania krążenia mózgowego, lecz w diagnostyce schorzeń mózgu coraz większe znaczenie zdobywają mniej inwazyjne metody diagnostyczne. Celem pracy było opisanie zmian w mózgowiu i jego unaczynieniu, wykazanych przy użyciu wielorzędowej tomografii komputerowej z opcją angiograficzną u chorych z podejrzeniem śmierci mózgowej. Ocenie poddano obraz badań KT wykonanych u 10 chorych z cechami pourazowego lub naczyniopochodnego uszkodzenia mózgu (tomograf 8- lub 64–rzędowy z konsolą diagnostyczną Advantage 4.2 GE). Badania przeprowadzono metodą skaningu przeglądowego oraz po dożylnym podaniu bolusa środka cieniującego w opcji angiograficznej (kolimacja 1.2 lub 0,6 mm, 80–100 ml środka cieniującego o stężeniu 370 mgJ/ml). Ocenie poddano zmiany w strukturze mózgu w skaningu przeglądowym oraz obraz naczyń mózgowych uzyskany w rekonstrukcjach multiplanarnych (MIP i MPR) oraz w projekcji 3D. Analiza obrazów tomografii komputerowej wykazała u wszystkich chorych następujące zmiany: duży obrzęk mózgu ze zniesieniem bruzd, zaciśnięcie zbiorników podstawy, brak zróżnicowania istoty białej i szarej, homogenność i hipodensję mózgu. U wszystkich chorych w opcji angiograficznej stwierdzono zatrzymanie krążenia w tętnicach szyjnych wewnętrznych i kręgowych przy zachowanym krążeniu w naczyniach będących gałęziami tętnicy szyjnej zewnętrznej, pozwalające na rozpoznanie braku krążenia mózgowego. U dziewięciu chorych potwierdzono rozpoznanie śmierci mózgowej stosując obowiązujące badania kliniczne, a jeden chory zmarł w mechanizmie zatrzymanie krążenia. Wielorzędowa tomografia komputerowa z opcją naczyniową może być użytecznym narzędziem diagnostycznym potwierdzającym zatrzymanie krążenia mózgowego. Niezbędne są dalsze badania, by określić czułość oraz swoistość metody.