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Diagnosis of Brain Death. Transcranial Doppler Sonography as an Additional Method

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Summary

Ever since transplant surgery became a common procedure, the early diagnosis of irreversible cessation of cerebral function has become an important need.

We made a comparative study of EEG, angiography and transcranial Doppler imaging in patients who fulfilled the clinical criteria for brain death. The imaging was performed with a 2 MHz pulsed Doppler system with a unique transcranial probe (EME, type TC 2-64 B).

Intracranial reverberating flow patterns with counterbalancing forward and backward components of the blood column indicate flow arrest.

Transcranial Doppler Sonography was found to be a practical, non invasive, early and reliable method for the diagnosis of arrest of the cerebral circulation.

Keywords: Brain death; transcranial Doppler (TCD).

Introduction

Since the increasing need for organ transplantation, early diagnosis of brain death is certainly mandatory in order to save suitable organs. When we speak about brain death, we speak about the "ceasing to live" of the organ of the brain. An organ can die without the total ending of human life; but since the brain is responsible for the totality of human functions, we can state that human life stops when the brain irreversibly ceases to function.

Originally brain death presupposed that the entire central nervous system had to be dead: cortex, brain stem and spinal cord[11, 3].

It soon became evident however, that the crucial element of brain death was permanent cessation of function in the brain stem, because once this has occurred the heart always stops functioning in a matter of one or two weeks even when the ventilatory and other support is maintained. (Spinal reflex activity in the limbs can persist long after cessation of brain stem function; electrical activity sometimes persists in parts of the cortex for some time after brain stem death.)[7]

One has to take into account however, that the clinical diagnosis of brain death cannot be considered until the course of brain damage is known to be irreversible. This implies that reversible causes of brain stem depression have to be excluded: hypothermia, gross metabolic or endocrine imbalance, drug intoxication (alcohol, relaxant drugs)[7, 12].

Brain stem death should not be considered in the presence of these conditions, whether they are the primary causes of the coma or possible contributory factors.

It takes only a few minutes to carry out the tests necessary to show that the brain stem is not functioning[13]. Five brain stem reflexes have to be tested systematically: pupillary response to light, corneal reflexes, vestibulo-ocular reflexes, motor response to adequate stimulation, gag reflex or coughing by bronchial stimulation. The ultimate test of brain stem function is the test for apnoea. (Apnoea is established when no respiratory movements occur during disconnection from the ventilator with a sufficiently high pCO_2.)

In some centers and countries, the clinical criteria are considered insufficient and an objective document is needed to confirm the irreversible state of brain death. It is our personal opinion that these confirmatory tests are not scientifically necessary and are required more for public relations and forensic reasons. Tests that study the electrical activity of the brain and/or the cerebral circulation are usually recommended. However within a year of the publication of the Harvard criteria[3] it was already stated by several that an iso-electrical EEG was not necessary for diagnosis, since it assesses function in the cortex and does not alter the prognosis after clinical brain stem death[4, 10].

It was also accepted that angiography is the most reliable method to show arrest of the cerebral bloodflow, but it is not only impractical but also unnecessary and even possibly compromises the renal function.

Because of the technical difficulties, the danger and the unreliability of previous methods, Doppler sonography was used to show the characteristic changes in the flow-wave forms[5, 9, 15]. We did a study of transcranial Doppler imaging in patients who fulfilled the clinical criteria for brain death.

Material and Methods

29 patients admitted to the intensive care unit of our department of neurosurgery from March 1987 to January 1988 and candidates for organ prelevation were examined with the transcranial Doppler (TCD).

There were 9 females and 20 males with an age distribution of 2 to 75 years. The main aetiology was head injury (23 cases). The others were intracerebral haematoma (4 cases), subarachnoid haemorrhage (1 case) and abscess (1 case).

The imaging was performed with a 2 MHz pulsed Doppler device (TC 2-64, EME) which was developed by Aaslid in 1981[1,2], and with which Doppler shift signals could be recorded through the skull. The TC 2-64 is compact and light in construction and contains a built-in loudspeaker, making it ideal for bedside examination.

The built-in computer calculates and displays the systolic and diastolic ratio and mean-time velocity, either in cm/sec or Doppler shift in Hz. The maximum transmitted sound energy is given as $100\,mW/cm^2$. A complete transcranial examination incorporates three approaches to investigation of the intracranial arteries: transtemporal (circle of Willis), transorbital (carotidsiphon), suboccipital (basilar artery). Only in a minority (6%) can no usable Doppler signals be registered through the skull[6].

During the search procedure for a signal, the investigator visualizes the approximate location of the artery and directs the probe accordingly. The identification of the artery is made by the following information: the depth where the signal is procured and the angle of the probe, the direction of flow (towards or away from the probe), the response of the signal to compression of the extracranial arteries. In normal cases a specific flow pattern is obtained for every artery.

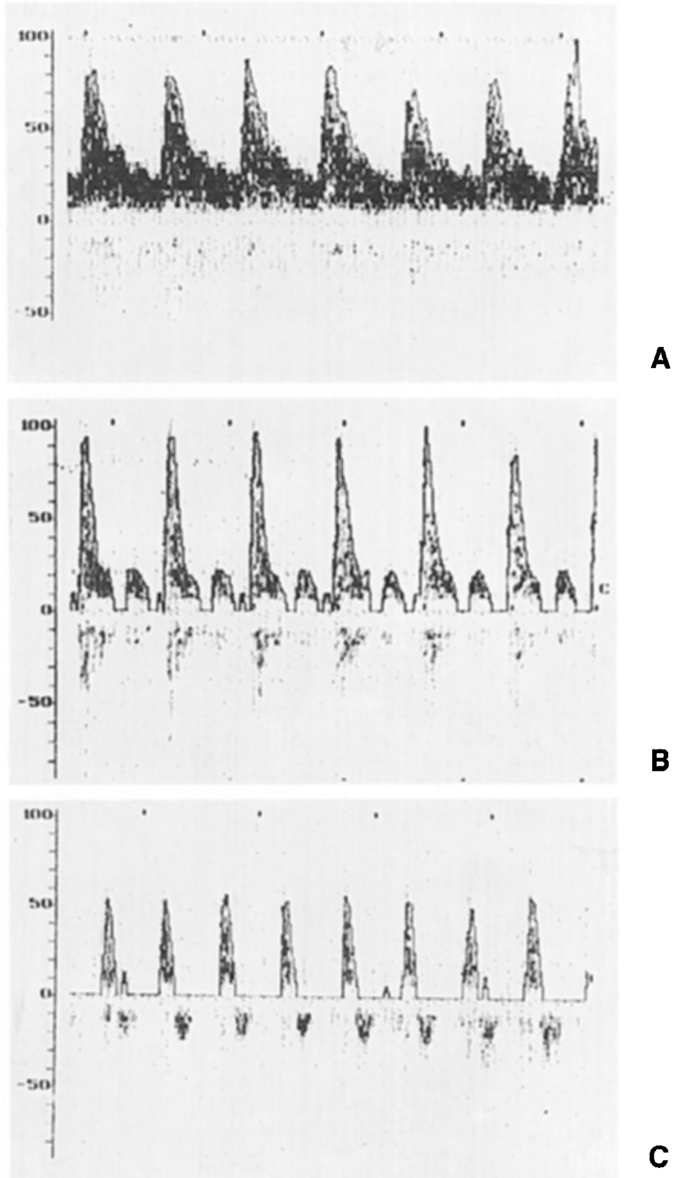

Fig. 1. Evolution towards cerebral death. Recordings of the MCA with time elapses of several hours: (A) Normal velocity curve. (B) Dissociation of the systolic and diastolic component. (C) Reverberating flow pattern with reflux phenomenon in the early diastolic phase

Results

1. Description of the TCD-Findings

The characteristic and diagnostic phenomenon of intracranial circulatory arrest is an oscillating movement of the blood column within the arteries[6, 14], which causes brain death because of a complete and irreversible cessation of cerebral perfusion; this occurs when the arterial pressure is the same as the intracranial pressure. A reduction of the systolic orthograde flow takes place and there is an early retrograde phase. This reverberating flow pattern with counterbalancing forward and backward components of the blood column indicates flow arrest[5, 9, 15].

We found this flow pattern in 26 patients who fulfilled the clinical criteria of brain death: a systolic forward flow and an early diastolic reflux phenomenon, which indicates the zero net flow and which is essential for the diagnosis of brain death (Figs. 1 and 3).

2. Correlation Between Clinical Diagnosis and TCD-Examination

A complete TCD examination was performed in all 29 cases; 20 patients were clinically brain stem dead on admission; for 3 of them no Doppler signals could be recorded.

9 patients were not cerebrally dead at the moment of first examination. Those registrations still showed a differentiation of the different intracranial arteries. In the hours following admission those patients proceeded to clinical brain death; at the same time a change of the TCD recordings occurred (Fig. 1).

Finally 26 cases (all clinically brain dead) showed the typical pattern of circulatory arrest on TCD, described in the previous paragraph and Fig. 1.

3. Correlation Between Angiography and TCD-Examination

A 4-vessel angiography, done in 9 cases at the moment of clinical brain death, showed a total stop of brain circulation. The TCD registrations demonstrated the same circulatory arrest.

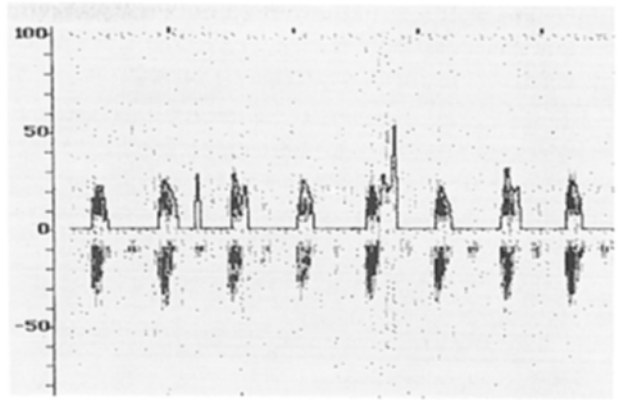

Fig. 3. Case report. TCD recordings at the moment of clinical brain death: the forward and backward flow components indicating the zero net flow

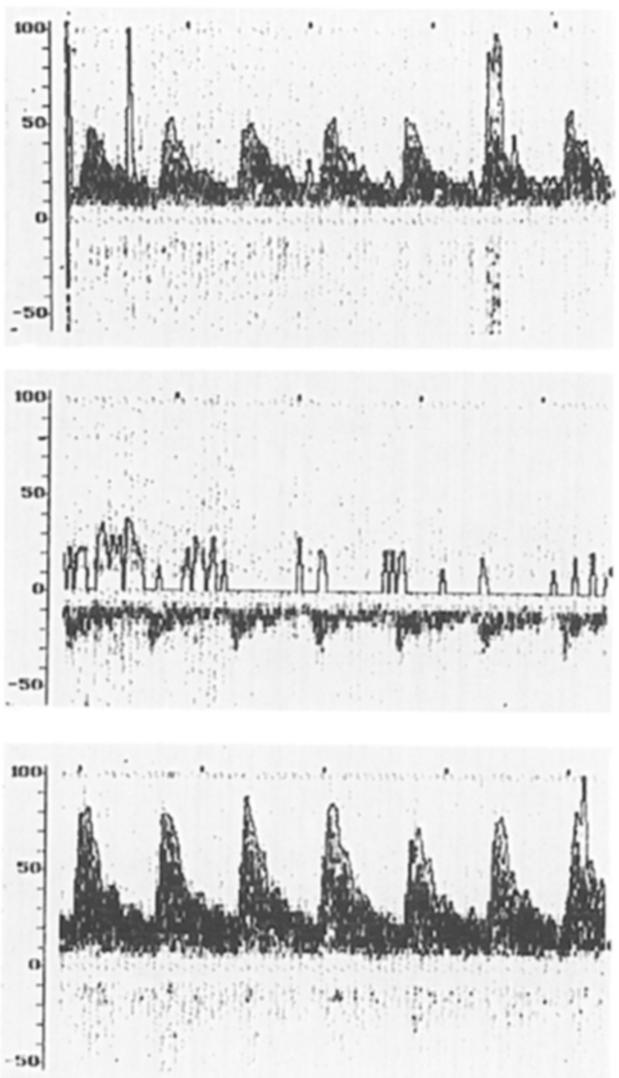

Fig. 2. Case report. Registration before clinical brain death of the patient: there is reduction of the velocities, but still differentiation of the different intracranial arteries is possible

4. Correlation Between EEG and TCD

An EEG was performed in 8 of the 29 cases. Those 8 patients, clinically brain dead, had the typical circulation arrest pattern on TCD, while only 7 of them had an iso-electric EEG. One patient's EEG only became iso-electric several hours later. (This example of EEG-unreliability is stressed in the following case history.)

Case report: A 34-year-old man, admitted after a traffic accident, was in apnoeic coma, bilateral mydriasis with no pupillary response to light. There was still some pain reaction. Since the patient was not brain dead at that moment, differentiation of the different intracranial arteries was still found on TCD (Fig. 2).

Some hours later – when the patient fulfilled all the clinical criteria of brain stem death – the TCD recordings showed the typical pattern of circulatory arrest (Fig. 3), which was confirmed on angiography, while the EEG was not yet iso-electric!

Conclusion

In our opinion the clinical diagnosis (when all the preconditions are fulfilled) is sufficient to declare a patient cerebrally dead. For those who need an additional documentation, TCD was found to be a practical and fast method. The reverberating flow patterns in the intracranial arteries are a reliable indication of arrest of circulatory cerebral flow. The method shows a close correspondance with angiography and has the advantage of not being invasive. The superiority to EEG is that it can be practiced at the bedside in the intensive care unit and possibly gives the diagnosis earlier, since the cortical function is not taken into account. Only in rare cases of hyperostosis are the Doppler signals found too weak for documentation.

In conclusion, out of our comparative study, we can say that this new method of cerebrovascular monitoring is reliable in the early diagnosis of brain death.

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