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Brain Death: Use of Dynamic CT and Intravenous Digital Subtraction Angiography

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Brain death results when irreversible intracranial circulatory arrest, involving both the internal carotid and intracranial vertebral basilar systems, occurs despite preservation of extracranial circulation. To document the absence of intracranial blood flow and establish the irreversibility of the condition, intraarterial cerebral angiography and radionuclide cerebral angiography have become the accepted imaging means of confirming a clinical diagnosis of brain death. After encountering cases in which the radionuclide angiogram was equivocal and cerebral arteriography was therefore required for confirmation, we undertook to study the ability of intravenous digital subtraction angiography (DSA) and dynamic CT to diagnose brain death.

Materials and Methods

Five patients for whom it was necessary to confirm a clinical diagnosis of brain death had radionuclide cerebral angiography, intravenous cerebral DSA, and dynamic cerebral CT. Final diagnoses in the five patients, respectively, were intracranial hemorrhage due to coarctation of the aorta (age of patient, 22 years), hypertensive intracranial hemorrhage (two patients, ages 62 and 35 years), traumatic intracranial hemorrhage (age of patient, 4 years), and ruptured posterior communicating artery aneurysm (age of patient, 63 years). Each patient's clinical diagnosis of brain death was based on cerebral unresponsivity, absent brainstem (cephalic) reflexes, and electroencephalographic cerebral silence (four patients) and/or positive apnea test (four patients).

Intravenous cerebral DSA was performed with a 6.3 F catheter positioned in the right atrium via the femoral vein. Contrast material (meglumine diatrizoate 60%) was injected at 30 ml/sec for 1 sec and anteroposterior images of the head were obtained at one frame/sec for 30 sec. Rapid sequence (dynamic) CT studies were performed with a GE 8800 CT/T scanner, using a scan time of 4.8 sec and an interscan delay of 1.2 sec. Injection of meglumine diatrizoate 60% contrast material at a rate of 8 ml/sec for 4 sec was made through the indwelling right atrial catheter. Scanning began simultaneously with contrast injection so that an initial baseline image would be acquired before arrival of the contrast bolus. Six sequential images were made over 36 sec at a single level of the brain selected to include the frontal, parietal, and occipital lobes at the level of the lateral ventricles. A second dynamic sequence was then made at the level of the fourth ventricle, to include the posterior fossa. Time-density graphs plotting the change in CT numbers in specified regions of interest (ROI) in the cerebral and cerebellar hemispheres were then made using scanner computer software. Large areas of interest including most of each cerebral or cerebellar hemisphere were used (Figs. 1 and 2A). Absence of any intracranial bolus effect was then confirmed by multiple smaller ROI covering all included portions of the brain. Confirmation of technically adequate bolus with preserved external carotid flow was done with small ROI in the scalp and/or neck tissues (Fig. 2B).

Results

In all five cases, both IVDSA and dynamic CT demonstrated an absence of intracranial blood flow. Radionuclide cerebral angiography also indicated absent intracranial circulation in all patients. These findings, added to the clinical test findings of electroencephalographic cerebral silence and/or positive apnea test, resulted in a final diagnosis of brain death in all patients.

Discussion

A collaborative study sponsored by the National Institute of Neurological Disease and Stroke formulated a set of criteria to establish cerebral death, one of which is that if one of the clinical standards is met imprecisely or cannot be tested, a confirmatory test should be made to demonstrate the absence of cerebral blood flow [1].

Arteriography was the first imaging technique capable of proving absent intracranial flow. This was illustrated in 1964 by Heiskanen using selective carotid or vertebral angiograms in 25 patients [2], and later by Bergquist and Bergstrom [3]. Although technical advances in selective carotid and vertebral angiography since that time have made complications and technical errors rare, cerebral arteriography remains cumbersome and potentially hazardous to the brain.

In 1975, Korein et al. [4] and Kricheff et al. [5] reported good correlation of radioisotope cerebral blood flow studies with standard cerebral arteriography in demonstrating the absence of cerebral flow in the evaluation of cerebral death.

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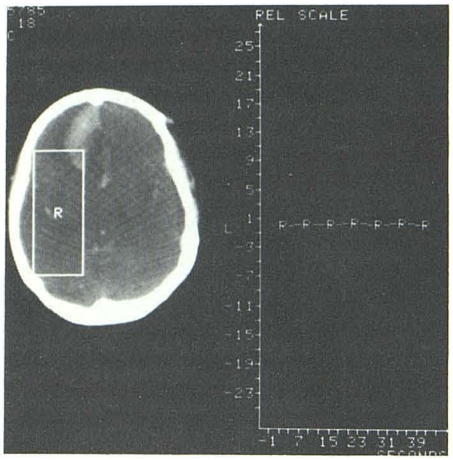

Fig. 1.—Hypertensive intracerebral and intraventricular hemorrhage. No change in CT numbers indicating absent blood flow.

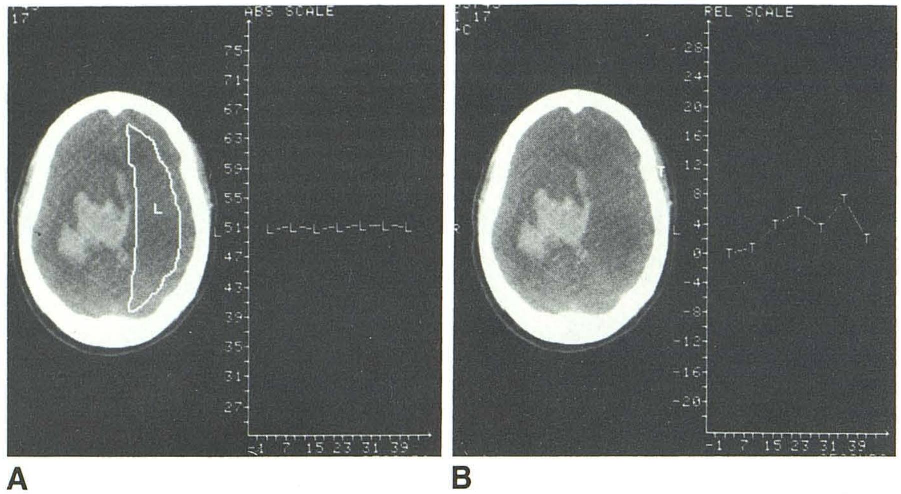

Fig. 2.—Hypertensive intracranial hemorrhage.

A, Flat density-time graph indicates absence of blood flow in cerebral region of interest. Large hemorrhage on right.

B, Bolus enhancement preserved in scalp tissue.

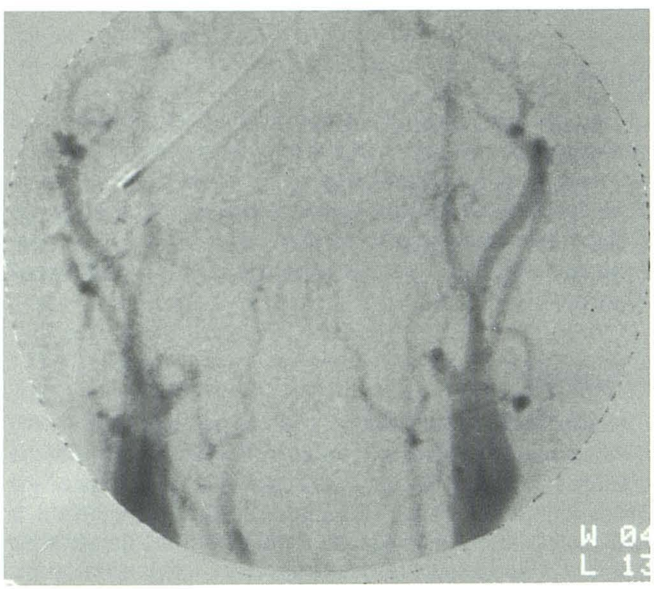

Fig. 3.—Intracranial hemorrhage with coarctation of the aorta. Digital subtraction angiography of neck (anteroposterior view). No internal carotid blood flow. External carotid flow preserved.

Brain death is diagnosed when no intracranial tracer activity is present despite good perfusion of the extracranial tissues. Because this technique is safe, simple, and can be performed at the bedside, it has become the imaging method of choice in the diagnosis of brain death. However, it is difficult to examine the circulation in the vertebrobasilar system because of poor resolution.

With the superior resolution of intravenous DSA, arrest of the intracranial circulation involving both the supratentorial and posterior fossa regions can be rapidly and accurately studied, as was reported by Gomes and Hallinan [6]. The criteria for brain death with DSA are fundamentally the same as for radionuclide angiography and conventional arteriography: nonvisualization of intracranial blood flow in the presence of normal extracranial flow (Fig. 3).

Functional information from dynamic CT can be obtained at the same time CT is used to evaluate intracranial hemorrhage, brain swelling, trauma, other suspected lesions, or worsening neurologic status. With dynamic CT, the intracranial circulatory arrest associated with brain death causes all intracranial time-density graphs to be flat bilaterally, whereas normal circulation graphs are obtained from areas in the scalp supplied by the external carotid arteries (Fig. 2). If the scalp tissues are too thin to permit accurate measurements, dynamic scanning is done through the carotid vessels in the neck. The presence of normal, well-defined circulation peaks in the extracranial tissues is an absolute requirement for the diagnosis so that technical problems are excluded as the cause of unmeasurable circulation of contrast agent in the brain.

On the basis of the experience described here, we feel that intravenous DSA and dynamic CT are potentially accurate methods for the diagnosis of intracranial circulatory arrest in brain death. Theoretically, both methods are more accurate than radionuclide angiography owing to greatly superior resolution. CT has the additional advantage, especially when compared with radionuclide studies, of a complete lack of superimposition of the extracranial and intracranial vascular territories. Practically, both DSA and CT are simpler than conventional arteriography.

Because of its simplicity, portability, and low cost, radionuclide angiography remains the imaging procedure of first choice when brain death is suspected. Intravenous DSA or dynamic CT, or both, can be used as supplementary tests whenever the diagnosis of brain death remains uncertain because of equivocal radionuclide or clinical test results.

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