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Intravenous Digital Subtraction Angiography in the Diagnosis of Brain Death

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The diagnosis of brain death requires: (1) the performance of all appropriate and therapeutic procedures; (2) the presence of cerebral unresponsivity, apnea, dilated pupils, absent cephalic reflexes, and electrocerebral silence; and (3) if one of these criteria cannot be tested or is met imprecisely, the performance of a confirmatory test to demonstrate the absence of cerebral blood flow. Selective cerebral arteriography has been the most widely used method of assessing cerebral blood flow. Digital intravenous angiography was used as a means of evaluating cerebral blood flow, and it was found to be a useful confirmatory test in the diagnosis of brain death.

Based on the results of a collaborative study, the National Institute of Neurological and Communicative Disorders and Stroke proposed criteria for the diagnosis of cerebral death. The requirements for this diagnosis are: (1) that all appropriate and therapeutic procedures have been performed; (2) that cerebral unresponsivity, apnea, dilated pupils, absence of cephalic reflexes, and electrocerebral silence be present for 30 min, at least 6 hr after the ictus, and (3) that if one of these standards is met imprecisely or cannot be tested, a confirmatory test be made to demonstrate the absence of cerebral blood flow [1].

The demonstration of the cessation of intracerebral blood flow is the most reliable confirmatory criterion of cerebral death. Cessation of flow has been demonstrated by selective arteriography and radionuclide cerebral arteriography [2, 3]. However, selective arteriography is time-consuming and radionuclide angiography can present difficulties in differentiating extracerebral from intracerebral vessels. The availability of digital intravenous angiography suggested the use of this relatively noninvasive method to evaluate cerebral blood flow. We report its use in the confirmation of brain death in three patients.

Subjects and Methods

Digital subtraction angiography was performed using a commercially available digital vascular imaging unit (Phillips Medical Systems, Inc., Shelton, CT). Anterioposterior (AP) and oblique cerebral digital intravenous angiograms were obtained via a superior vena cava injection of 40 ml of Renografin-76. This procedure was then followed immediately by standard percutaneous selective femoral cerebral angiography in the first two cases. Extended filming sequences were used in all procedures.

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Case Reports

Case 1

A 30-year-old male auto accident victim was admitted in shock with irregular respirations. He was noted to be moving all four extremities, had right nystagmus, anisocoria, and a left Babinski. Blood was noted in both external auditory canals and skull films revealed basilar skull fractures. Admission computed tomographic (CT) scan revealed a right posterior

temporal contusion and hematoma with mild left displacement. He was treated with Decadron, Dilantin, and antibiotics. Repeat CT over the ensuing days showed enlargement of the contusion, further hemorrhage, and left shift. Despite treatment, intracranial pressure progressively increased, and, on the sixth day after admission, both pupils were found to be fixed and dilated. Surgical evacuation of the contused cortex was performed by a right parietotemporal craniotomy. Pentobarbital infusion was initiated, but intracerebral hypertension persisted and the patient deteriorated neurologically. The pupils remained fixed and dilated, corneal reflexes were lost bilaterally, and deep tendon reflexes disappeared. The pentobarbital level was 19 mg%. Intravenous digital subtraction angiography revealed filling of the external carotid arteries bilaterally. The flow through the internal carotid artery halted at the level of the skull base and there was no filling of the intracranial vessels by 12 sec. Selective arteriography of the right and left common carotid arteries was then performed and confirmed these findings. Two electroencephalograms (EEGs) were administered 24 hr apart, and both showed electrocerebral silence.

Case 2

A 29-year-old woman with stage I squamous cell cervical carcinoma was admitted after radiation therapy for a simple hysterectomy. She had a previous history of mild respiratory complaints, chronic bronchitis, and an 80 pack-year history of smoking. At surgery, shortly after tracheal intubation and opening of the abdomen, she began coughing and was reintubated. Although breath sounds were heard bilaterally, she again began coughing and wheezing. A smooth muscle relaxant was administered, but high pressures were still required for adequate ventilation. She became hypotensive and a persistent air leak was noted around the endotracheal tube despite maximal cuff inflation. She then developed a profound bradycardia with complete heart block. Atropine was administered. Breath sounds were noted to be decreased on the left; a left pneumothorax was diagnosed and a chest tube inserted. The endotracheal tube was then rechecked, found to be out, and was repositioned. The abdomen was closed.

In the recovery room the patient remained on the ventilator in deep coma, unresponsive to verbal or cutaneous stimuli. Corneal reflexes were absent, pupils were fixed and dilated, oculocephalic and oculovestibular reflexes were absent, and sustained clonus was present in all extremities. Her condition did not improve. Serial EEGs showed progressive deterioration, and, 4 days after surgery, showed no definable electrocerebral rhythm. This was verified again 48 hr later. At that time, an intravenous digital subtraction angiogram showed no evidence of intracranial blood flow (fig. 1). Selective right and left common carotid artery injections confirmed these findings and the diagnosis of brain death (figs. 1C and 1D). Later that day, her blood pressure fell to 70/50 mm Hg on maximal doses of dobutamine, and supportive measures were discontinued.

Case 3

A 10-year-old boy with a history of asthma developed status asthmaticus while playing basketball. He progressed to severe respiratory distress and had a grand mal seizure followed by cardiorespiratory arrest. Paramedics found him apneic, in ventricular fibrillation with fixed dilated pupils. Cardiopulmonary resuscitation was instituted. At hospital admission, he was unconscious, unresponsive to pain, and showed decerebrate posturing. His pupils were 3 mm and reactive. Corneal and gag responses were absent. There was no response to oculocephalic or caloric maneuvers. Wheezes were heard over both lungs and there was marked retraction of the chest wall. Cardiac rhythm was irregularly irregular. Blood gases revealed hypoxemia with pH of 6.88.

Treatment with bicarbonate, mechanical ventilation, bronchodilators, steroids, and vasopressors was instituted. Seizure activity developed and was treated with pentobarbital. A right frontal subarachnoid bolt was placed 24 hr after admission to monitor intracranial pressure. Over the next 3 days, intracranial pressure rose despite treatment with pentobarbital, mannitol, and urea. Brain stem and auditory-evoked responses were abnormal bilaterally, consistent with cortical and brain stem dysfunction. On the fifth day of hospitalization his intracranial pressure was equal to the mean arterial blood pressure. He remained comatose on the ventilator, unresponsive to deep pain. Bilateral papilledema was present; his pupils became fixed and dilated. Corneal, oculocephalic, and oculovestibular reflexes were absent. On the sixth day an intravenous digital subtraction angiogram revealed no intracranial blood flow (fig. 2). Life support measures were discontinued.

Discussion

Severe insults to the brain often result in cerebral edema. When the development of cerebral edema is of such severity that intracranial pressure exceeds systolic blood pressure, blood flow to both higher and lower centers of the brain ceases. Studies have documented this total interruption of blood flow to the brain in all cases of brain death [3].

The concept of cerebral death implies destruction of the brain to the degree that all volitional and reflex responsivity is absent. This is in contrast to the condition of a "persistent vegetative state" [4] where brain damage is primarily to the cerebral hemispheres, which are more susceptible to temporary deprivation of blood flow. Patients in a persistent vegetative state will demonstrate intracranial circulation of blood even in the face of clinical evidence of overwhelming destruction to the higher centers [3]. Brain stem function is often relatively preserved in these patients [5]. Such patients manifest a wide range of clinical signs ranging from absent motor responses to noxious stimuli to localizing movements toward such stimuli and from absent spontaneous eye movements to apparent orienting movements. The common denominator is the appearance of wakefulness without any external evidence of communication, complex behavior, or awareness [4, 5]. Other terms used by neurologists to denote this state of severe brain damage in which the patient demonstrates no behavioral response even though he appears to be awake include the "apallic syndrome" [6] and "neocortical death" [7].

Clinical criteria used to diagnose cerebral death are deep coma with cerebral unresponsivity, apnea, dilated pupils, absence of cephalic reflexes, and electrocerebral silence on EEG. Clinical examination in these patients reveals deep coma with no arousal or voluntary motor movements on intense stimulation. Some spinal cord reflexes or movements may be present, as spinal cord circulation is unaffected by increased intracranial pressure. All brain stem functions are absent. The pupils do not respond to light and eye movements at the brain stem level are absent (oculocephalic and oculovestibular reflexes are absent). Spontaneous respirations cease due ot permanent destruction of the respiratory centers in the lower brain. The patient is dependent on mechanical respiratory support [3].

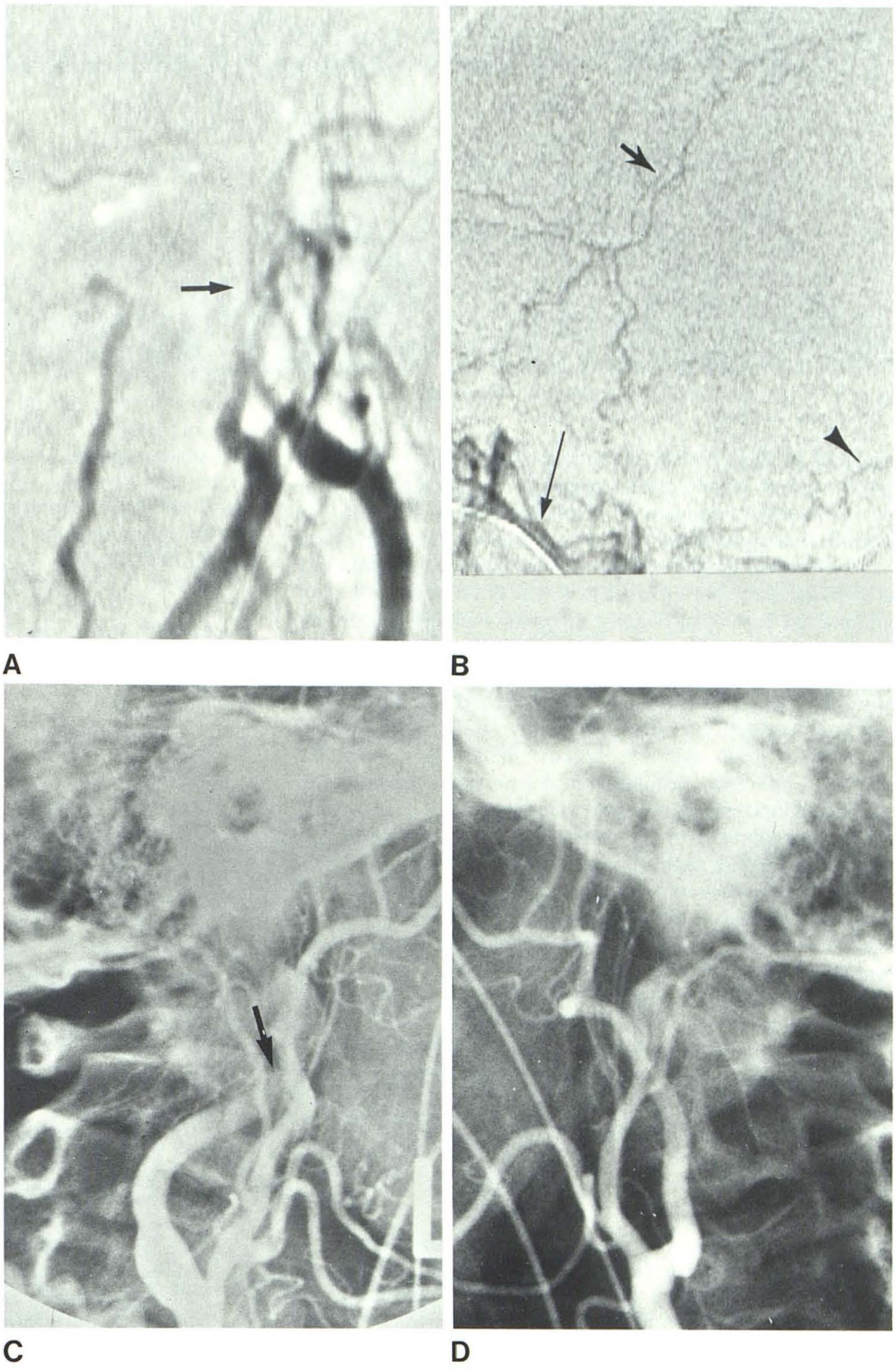
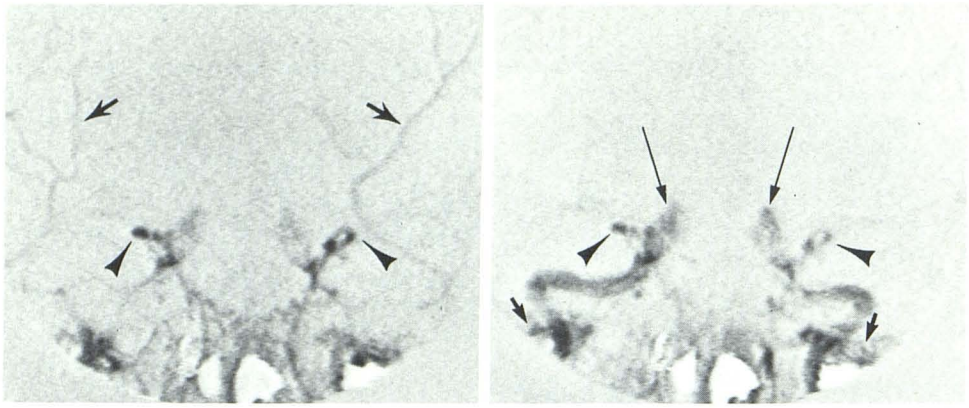


Fig. 1.—Case 2, 29-year-old woman with brain death after general anesthesia. **A,** Intravenous digital subtraction angiogram, left posterior oblique position. No filling of right and left internal carotid arteries above cervical parts (*arrow*). **B,** Lateral view. Filling of only external carotid artery branches, internal maxillary artery (*long arrow*), occipital artery (*arrowhead*), and superficial temporal arteries (*short arrow*). No filling of intracerebral branches identified. **C,** Selective left common carotid artery injection confirms nonfilling of intracerebral branches of internal carotid artery. Flow terminates in high cervical part (*arrow*). Filling of left external carotid artery branches is present. **D,** Similar findings with selective right common carotid artery injection. Flow in right internal carotid artery terminates in high cervical region.

It must be ascertained that the cessation of function is irreversible and not transient due to a reversible cause such as drug intoxication [8, 9], hypothermia [10], encephalitis [10], metabolic disease, or other remediable process [1, 11]. The EEG primarily evaluates cerebral cortical function and two isoelectric EEGs 24 hr apart is a commonly used indicator of brain death [8]. However, drug intoxication can result in a falsely positive silent EEG [8, 9], and other limitations of the EEG include movement, electrical and respirator artifacts, as well as individual interpretation [12].

Short latency auditory-evoked potentials arising in the auditory nerve and in brain stem structures have been studied in fulfilling clinical criteria for brain death, and, in some of these patients, only the first potential that arises in the auditory nerve has been recorded [13].

Direct demonstration of cerebral blood flow is recom-



A B

Fig. 2.—Case, 3 intravenous digital subtraction angiogram in 10 year-old-boy with brain death following cardiorespiratory arrest. **A,** AP intracranial view early during injection. Retrograde filling of ophthalmic arteries (*arrowheads*) and filling of superficial temporal artery branches of external carotid artery (*arrows*). **B,** Later phase. Static column of contrast in right and left internal carotid arteries (*long arrows*). Absence of any supraclinoid flow in internal carotid arteries. Internal maxillary (*small arrows*) and ophthalmic arteries (*arrowheads*) opacify.

mended as the ancillary confirmatory procedure of choice when clinical criteria have not been unequivocally met or when an early diagnosis of cerebral death is required [1]. This is especially important in cases where an early diagnosis of cerebral death is needed for organ transplantation or in situations where the exclusion of brain death will alter treatment. Four vessel angiography has been the procedure of choice, but there may be reluctance to subject critically ill patients to this invasive procedure [1]. Radionuclide cerebral angiography, which can be performed at the bedside, has been used in the diagnosis of brain death [14]. Failure to obtain a good systemic bolus injection is a potential source of difficulty, circulation in the posterior fossa is not measured, and use of the test is limited to adults [2, 14].

The development of intravenous digital subtraction angiography permits rapid assessment of the status of intracerebral blood flow and accurate distinction of intracranial from extracranial vessels. Although it requires transfer of the patient to the radiology department, the status of cerebral blood flow can be rapidly ascertained using a venous approach. As with direct arteriography, filming should be carried out to at least 12 sec to permit accurate assessment of the absence of cerebral circulation. Our experience, in three patients indicates intravenous digital subtraction angiography is a useful alternative to four vessel arteriography in the confirmation of brain death.

REFERENCES

1. Walker AE, Bickford R, Aung M, et al. An appraisal of the criteria of cerebral death. A summary statement. A collaborative study. *JAMA* **1977**;237:982–986
2. Korein J, Braunstein P, Kricheff I, Lieberman A, Chase N. Radioisotopic bolus technique as a test to detect circulatory deficit associated with cerebral death. *Circulation* **1975**; 51:924–939
3. Cranford RE, Smith HL. Some critical distinctions between brain death and the persistent vegetative state. *Soc Sci Med [F]* **1979**;6:199–209
4. Jennett B, Plum F. Persistent vegetative state after brain damage. Lancet **1972**;1:734–737
5. Levy DE, Knill-Jones RP, Plum F. The vegetative state and its prognosis following nontraumatic coma. *Ann NY Acad Sci* **1978**;315:293–306
6. Ingvar DH, Brun A, Johansson L, Samuelsson SM. Survival after severe cerebral anoxia with destruction of the cerebral cortex: the apallic syndrome. *Ann NY Acad Sci* **1978**; 313:184–214
7. Brierley JB, Adams JH, Graham DI, Simpson JA. Neocortical death after cardiac arrest. *Lancet* **1971**;2:560–565
8. Silverman D, Saunders MG, Schwab RS, et al. Cerebral death and the electroencephalogram. Report of the ad hoc committee of the American Electroencephalographic Society on EEG criteria for determination of cerebral death. *JAMA* **1969**; 209:1505–1510
9. Powner D. Drug-associated isoelectric EEG's—a hazard in brain death certification (commentary). *JAMA* **1976**;236:1123
10. Tentler RL, Sadove M, Becka DR, et al. Electroencephalographic evidence of cortical 'death' followed by full recovery: protective action of hypothermia. *JAMA* **1957**;164:1667–1670
11. Fischgold H, Mathis P. Onubliations comas, et stupers. *Electroencephalogr Clin Neurophysiol [Suppl]* **1959**;16:51–52
12. Walker AE. Cerebral death. In: Tower DB ed. *The clinical neurosciences*, Vol 2. New York: Raven, **1975**:75–87
13. Starr A. Auditory brain-stem responses in brain death. *Brain* **1976**;99:543–544
14. Korein J, Braunstein P, George A, et al. Brain death: I. Angiography correlation with the radioisotopic bolus technique for evaluation of critical deficit of cerebral blood flow. *Ann Neurol* **1977**;2:195–205