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Radionuclide Cerebral Angiography: A Confirmatory Test for the Diagnosis of Brain Death

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＝국문 초록＝

동위원소 뇌혈관 촬영술을 이용한 뇌사의 판정

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최 재 걸 · 이 민 재

뇌와 뇌간의 모든 기능이 정지되어 인공적으로 심폐 기능은 유지되고 있더라도 뇌의 혈액순환은 중지되고 전체 뇌에 경색이 있어 회복이 불가능한 상태를 뇌사라 한다. 이렇게 뇌와 뇌간의 모든 기능이 정지된 이후에는 곧 심장 정지가 뒤따른다. 심장과 폐의 기능 정지에 의해 죽음을 정의하는 것은 심폐 소생 장치 및 생명유지 장치의 효과적인 발달로 이제는 뇌자체의 기능을 평가하는 것으로 대치되게 되었다. 최근 장기 이식술의 발달로 혈액순환을 비롯한 식물적인 기능은 인공적으로 유지되는 상태에서 가능한한 빠른 시간내에 적용할 수 있는 뇌사 판정 방법의 필요성이 대두되었다. 그래서 이러한 판정을 하는데 소요되는 시간을 줄이기 위한 뇌사를 확진할 수 있는 여러가지 진단 방법에 대한 관심이 고조되었다. 동위원소 뇌혈관촬영술도 이런 진단방법중 하나로 뇌혈액순환의 정지를 보여줌으로써 임상적으로 뇌사를 진단하는 데 보조적인 방법으로 사용될 수 있다.

INTRODUCTION

The definition of brain death is total and irreversible cessation of all brain function. Brain death is a diagnosis based on the clinical findings of coma, absence of cephalic reflexes, absence of spontaneous respiration, and flat electroencephalograms (EEG)[1~5]. Thus patients with brain death will inevitably die within a relatively short period of time (days or weeks), despite intensive modern medical intervention. Reliance on evaluation of heart and lung function was displaced by the advent of effective cardiopulmonary support systems, and attention instead focused on evaluation of brain function. More recently, the technical feasibility of organ transplantation has amplified the need for a definition of brain death that can be applied in the shortest possible time in the presence of artificial maintenance of vegetative functions, including circulation[5]. The emphasis on minimizing the time involved in making this determination has renewed interest in the efficacy of a variety of diagnostic procedures capable of "confirming" brain death[6].

Radionuclide cerebral angiography (RCA) is one of a group of diagnostic procedures that can be employed to confirm the clinical diangnosis of brain death through demonstration of absence of cerebral blood flow[6~11].

We recently expericenced 2 cases of brain death showing the confirmatory evidence of brain death with radionuclide cerebral angiography (RCA). The

clinical courses of cases, findings of RCA and brief discussion are presented.

PRESENTATION OF CASES

1. Case 1

A 69 year-old man was admitted to the hospital because of semicomatose mentality. There was a history of hypertension and intermittent medication. Several hours before the admission, he complained of severe headache and vomiting. So he entered another hospital, at there he developed respiratory arrest while taking a brain CT scan. Immediate intubation and cardiopulmonary resuscitation was performed and he tranferred to this hospital in semicomatose state.

The physical examination revealed weak response to painful stimuli and positive Babinski's reflex on the both feet. The pupils are dilated and fixed. The CT scan taken at the former hospital revealed massive intraventricular hemorrhages. Assisted ventilation was initiated and life supportive measures started. Ventriculostomy and drainage was performed for the evacuation of intraventricular blood and decompression, but the condition of the patient is progressively deteriorated.

The RCA performed on the 3rd day of admission revealed that there is no evidence of cerebral arterial and parenchymal radioactivity, nonvisualization of dural sinuses, and "hot nose" sign (Fig. 1). The patient died on the 6th day of admission despite of all intensive life supportive cares.

2. Case 2

A 33 year-old man was brought to the hospital because of comatose mentality. He suffered from hypertension, but had have no specific treatment. A few hours before admission, he developed severe headache and subsequent loss of consciousness while driving his car. At the emergency room, the patient

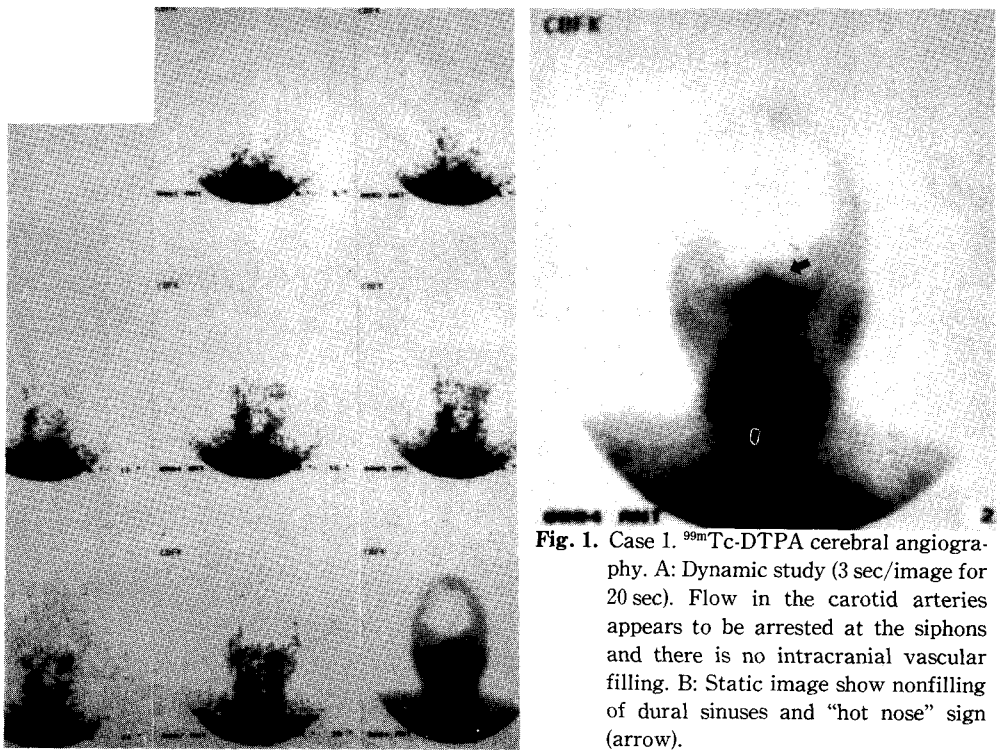

Fig. 1. Case 1. ^{99m}Tc-DTPA cerebral angiography. A: Dynamic study (3 sec/image for 20 sec). Flow in the carotid arteries appears to be arrested at the siphons and there is no intracranial vascular filling. B: Static image show nonfilling of dural sinuses and "hot nose" sign (arrow).

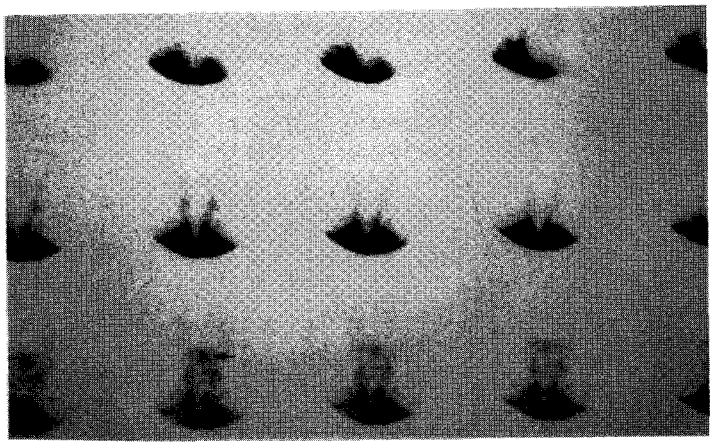

Fig. 2. Case 2. ^{99m}Tc-DTPA cerebral angiography. The dynamic study (3 sec/image for 60 sec; from the top right to the left bottom) shows good ascent of tracer bolus through the common carotid arteries, but no evidence of intracranial vascular and parenchymal blush. Note the "hot nose" seen in the late image (arrow).

has no definite external wounds suggesting trauma. The blood pressure was 150/80 mmHg; pulse rate, 110/min; and there is no voluntary respiration. The pupils are dilated and fixed. He did not responed to any noxious stimuli. The CT scan disclosed brain stem hematoma. Immediate intubation was performed and artificial respiration was initiated.

The RCA was done 5 days after admission. The perfusion phase image revealed good ascent of tracers in the common carotid artetries, but no evidence of brain parenchymal blush. The delayed image showed activity in the calvarial rim with no activity in the brain parenchyme, nonvisualization of superior sagittal sinus and "hot nose" sign (Fig. 2). The patients' cardiac functions are progressively compromised despite of all supportive measures. The patient died the day following the RCA.

DISCUSSION

It is generally accepted that cessation of intracranial blood flow is incompatible with viability of neuronal tissue, i.e., is consistent with brain death[6~10,12]. The common pathophysiologic pathway for this event is generally considered to be a progressive increase in intracranial pressure that results in progressive compromise of intracranial circulation, beginning in the supraclinoid region, where the internal carotid artery is first subjected to resultant compressive forces. When this pressure reaches diastolic levels, intermittent interruption of cerebral perfusion occurs during cardiac diastole, a phenomenon refferred to by Mitchell as "hemodynamic ischemia"[12]. Venous return is impeded, resulting in diminished flow, stagnation, ischemic infarction, and progressive increases in intracranial pressure. Intracerebral circulaton ceases when intracranial pressure reaches systolic pressure; howevere, irreversible damage may occur before this terminal event[6].

Today there are more than 30 different criteria worldwide for the diagnosis of brain death. The most influential and well known criteria is the criteria established by the U.S. Collaboratory Study Group (USCSG) in 1981 titled "Uniform Deternimation of Death Act": i.e.,

An individual who has sustained either (1) irreversible cessation of circulatory and respiratory functions or (2) irreversible cessation of all functions of the entire brain, including the brain stem, is dead[2,6,13].

The Havard criteria rely on clinical examination and EEG results to indicate absence of brain function. In practice these indicators may be difficult to perform and time consuming (requirement of 24 hours), and be too conservative and detrimental to the subsequent utility of organs that might become available for transplantation[3,4].

Thus the USCSG criteria include other confirmatory tests to evaluate blood flow of the brain in determining brain death, as the brain cannot remain viable or function without blood supply[7,8,12]. The ability to predict "imminent" death is a major component of the criteria. All patients fulfilling the Havard criteria were dead within 14 days. The USCSG criteria were more liberal, extending the viable period to 3 months[1~5].

Complete cessation of circulation to the normothermic adult brain for more than 10 minutes is incompatible with survival of brain tissue. Documentation of this circulatory failure is therfore evidence of death of entire brain. A number of technical approaches have been used to demonstrate impairment or cessaion of intracerebral blood flow. The "gold standard" remains four-vessel contrast inrtracerebral angiography, which is accepted as legal proof of brain death in a number of countries, particularly the Scandinavian countries and Germany[6].

Four-vessel intracranial angiography is definitive for diagnosing cessation of circulation to the entire brain (both cerebrum and posterior fossa), but entails substantial practical difficulties and risks. Other confimatory tests for diagnosing cessation of cerebral blood flow are digital subtraction angiography (DSA), contrast enhanced CT, cranial color doppler study, and radionuclide cerebral angiography (RCA). The role of confirmatory tests in the diagnosis of brain death is principally to augment clinical assessment in the presence of complicating circumstances such as drug intoxication, hypothermia and to reduce to the minimum time practical the interval between the occurance of brain death and its diagnosis[6].

Radionuclide cerebral angiography has emerged as an alternative method for evaluating cerebral blood flow that offers the significant advantage of easy and safe technique, short examination time, and portability. Although the anatomic detail provided by this procedure is admittedly inferior to that with contrast cerebral angiography, it is sufficient for the purpose of diagnosing cessation of intracerebral blood flow. A number of authors have demonstrate a high degree of correlation with contrast angiography, and some have even suggested greater sensitivity for the radionuclide procedure[6~11].

The perfusion phase of the RCA in brain death classically demonstrates ascent of the tracer bolus through the carotid arteries to the base of the skull, with subsequent filling of the external carotid circulation, but no filling of the internal carotid circulation. The resultant images demonstrate relatively intense activity in the face, particularly in the vascular plexuses in the region of the nose (the "hot nose" sign), with a rim of scalp and calvarial activity enclosing the brain parenchyme devoid of cerebral arterial tracer blush. The static phase of the RCA in brain death typically fails to demonstrate any activity in the superior sagittal sinus or transverse sinuses[6,8~11,14].

The "hot nose" sign is an abnormal increase of activity (more intense than that in the adjacent carotid arteries) in the nasal region or in the midline below the region of circle of Willis. It is described as scintigraphic evidence of internal carotid artery obstruction among fully conscious patients[10,14]. The presence of the "hot nose" sign in the radionuclide cerebral angiography (RCA) is due to increase in

collateral blood flow from the exteranl carotid artery through the facial and ophthalmic arteries[10,13]. Among brain death patients, cessation of internal carotid artery flow at the siphon is due to increase in intracranial pressure, and not to intraluminal obstruction (brain tamponade)[7,10,12]. However, the hemodynamic effects are similar in patients with true intraluminal obstruction of the internal carotid arteries[15]. Although the presence of the hot nose sign by itself is nonspecific and may not indicate brain death, when it is present together with no cerebral arterial blood flow, it may represent a secondary scintigraphic sign to further support the diagnosis of brain death[13].

We feel that radionuclide cerebral angiography is a easy, safe, rapid, and specific diagnostic test for confirming brain death by demonstrating the lack of critical cerebral perfusion.

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