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Dynamic Computed Tomography Angiography in Suspected Brain Death: A Noninvasive Biomarker

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Abstract

Purpose: Neurologic determination of death or brain death is primarily a clinical diagnosis. This must respect all guarantees required by law and should be determined early to avoid unnecessary treatment and allow organ harvesting for transplantation. Ancillary testing is used in situations in which clinical assessment is impossible or confounded by other factors. Our purpose is to determine the utility of dynamic computed tomographic angiography (dCTA) as an ancillary test for diagnosis of brain death.

Materials and Methods: We retrospectively reviewed 13 consecutive patients with suspected brain death in the intensive care unit who had dCTA. Contrast appearance timings recorded from the dCTA data were compared to findings from 15 controls selected from patients who presented with symptoms of acute stroke but showed no stroke in follow-up imaging.

Results: The dCTA allows us to reliably assess cerebral blood flow and to record time of individual cerebral vessels opacification. It also helps us to assess the intracranial flow qualitatively against the flow in extracranial vessels as a reference. We compared the time difference between enhancement of the external and internal carotid arteries and branches. In all patients who were brain dead, internal carotid artery enhancement was delayed, which occurred after external carotid artery branches were opacified.

Conclusion: In patients with suspected brain death, dCTA reliably demonstrated the lack of cerebral blood flow, with extracranial circulation as an internal reference. Our initial results suggest that inversion of time of contrast appearance between internal carotid artery and external carotid artery branches at the skull base could predict a lack of distal intracranial flow.

Résumé

Objectif : La détermination du diagnostic de décès neurologique ou de mort cérébrale est d'abord fondée sur un diagnostic clinique. Le processus doit satisfaire à toutes les exigences de la loi et être effectué rapidement pour éviter les traitements inutiles et assurer le prélèvement d'organes à des fins de transplantation. Dans les cas où une évaluation clinique n'est pas possible, notamment en raison de facteurs confondants, on réalise alors des tests auxiliaires. Notre objectif consiste à évaluer si l'angiographie par tomodensitométrie dynamique (ATDM dynamique) constitue un test auxiliaire efficace pour établir un diagnostic de décès neurologique.

Matériel et méthodes : De façon rétrospective, nous avons examiné le dossier de 13 patients consécutifs qui ont semblé présenter une mort cérébrale à l'unité de soins intensifs et chez lesquels une ATDM dynamique a été réalisée. Les occurrences d'opacification relevées dans les données de l'ATDM dynamique ont été comparées à celles observées chez 15 patients de référence, sélectionnés en raison des symptômes d'AVC aigu qu'ils présentaient, mais dont les résultats aux examens d'imagerie de suivi n'ont révélé aucun AVC.

Résultats : L'ATDM dynamique permet d'étudier la circulation sanguine cérébrale en toute fiabilité et d'enregistrer l'occurrence d'opacification de chaque vaisseau cérébral examiné. Elle permet également les comparaisons qualitatives entre la circulation intracrânienne et celle des vaisseaux extra-crâniens. Nous avons donc comparé l'occurrence d'opacification des branches de l'artère carotide externe à celle des branches de l'artère carotide interne. Dans tous les cas de mort cérébrale, l'opacification de l'artère carotide interne a accusé un retard par rapport à l'opacification des branches de l'artère carotide externe.

Conclusion : L'ATDM dynamique peut démontrer en toute fiabilité l'absence de circulation cérébrale chez les patients chez lesquels on soupçonne une mort cérébrale lorsqu'on utilise la circulation extra-crânienne en guise de référence interne. Les résultats initiaux révèlent

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qu'une inversion dans la séquence d'opacification des branches de l'artère carotide interne et des branches de l'artère carotide externe situées à la base du crâne permettrait de prédire l'absence de circulation dans les vaisseaux intracrâniens distaux.

Key Words: Computed tomography; Brain death; Angiogram; Ancillary test; Dynamic computed tomography angiogram

Neurologic determination of death, or brain death (BD), is a clinical diagnosis. The diagnosis of BD must respect all guarantees required by law and should be determined as early as possible to avoid unnecessary treatment and to allow organ harvesting for transplantation [1−3]. Ancillary testing is used when clinical assessment is impossible or confounded by other factors [3,4]. Demonstration of the global absence of cerebral blood flow is the standard finding for confirmation of neurologic determination of death by ancillary testing [5]. In this article, we present the findings of 13 consecutive patients with clinically indeterminate BD who have had a dynamic computed tomographic angiogram (dCTA) to confirm and/or support the clinical diagnosis and to describe a dCTA sign referred to as the "inversion sign," which is seen in these patients.

Material and Methods

Patient Selection

Our study was approved by the hospital research ethics board. We retrospectively reviewed the charts and radiologic studies of 13 patients in the intensive care unit (age range, 18-81 years; mean age, 46 years; 11 men and 2 women) with severe brain damage and a working diagnosis of BD. In all these cases, a computed tomography angiogram (CTA) was requested by the intensive care unit staff or treating physicians as an ancillary tool for the diagnosis of BD. The decision to switch conventional single-phase CTA to dCTA was made by consensus, based on our experience in using dCTA in stroke imaging and our knowledge of its utility to provide dynamic blood flow information. Patient demographics, presentation, protocol used, and known confounding factors are listed in Table 1. The final declaration of death was made by repeated clinical testing at a later time point. No catheter cerebral angiogram or nuclear medicine testing was performed in this clinical cohort. Contrast appearance timings recorded from the dCTA data were recorded and compared with findings from 15 control patients (age range, 46-91 years; mean age, 65 years; 7 men and 8 women). The control group consisted of patients who presented with acute stroke and were scanned as per stroke protocol but during follow-up imaging demonstrated no stroke. They were all free from significant carotid artery disease by the North American Symptomatic Carotid Endarterectomy Trial (NASCET) criteria.

dCTA protocol

By using a 320-row volume CT scanner (Aquilion ONE; Toshiba, Otawara, Japan), dCTA of the whole brain was performed. This system uses 320 ultra-high−resolution detector rows (0.5 mm in width) to image the entire brain in a single gantry rotation. By using this CT scanner, we are able to get whole-brain CT perfusion data. From the same data set, dCTA images are reconstructed [6], which enables us to analyse the blood flow in the entire cranial circulation in a noninvasive way with high spatial and temporal resolution. Compared with older-generation CT scanners that are able to generate a CTA image of the brain in a predetermined time point (snapshot views, standard CTA), dCTA can monitor the contrast flow of the intra- and extracranial circulation during the total scanning time (80 seconds in the BD protocol). The predetermined time point used in an older CT scanner is often unreliable in these patients due to the abnormal and/or delayed flow. A dCTA eliminates the presumption of optimal timing used in conventional CTA because it monitors the flow of contrast in the cerebral vasculature during the whole scanning period (Figure 1). A dCTA permits us to acquire a time series of bone subtracted or nonsubtracted CTA images of the whole head in a noninvasive way, which provides excellent temporal flow information.

In our BD imaging protocol, whole-brain imaging is performed in 23 volume sets. It begins at 7 seconds from the start of injection of contrast (the first volume is used as a mask for subtraction), then a single volume set is acquired every 2 seconds from 10-35 seconds (total 13 volumes), followed by every 5 seconds from 40-80 seconds (9 volumes) after the initial contrast bolus (Figure 1). Only 40 mL of intravenous contrast is used. The radiation dose for this scan is 5.3 mSv, equivalent to 2 years of background radiation. The stroke protocol is performed with similar time intervals to the BD protocol but has fewer volume sets (19 volume sets), and the total scanning period is only 60 seconds. The generation of CT perfusion maps are dependent on significant intracranial flow and a detectable arterial input function. In our BD cases, the processing software was unable to generate perfusion maps.

Data Analysis

Time-resolved dCTA images were generated by using a Vitrea workstation (Toshiba, Canada). The imaging studies of both groups, patients with BD and control patients, were reviewed by a single observer (S.C.) and the timings of contrast arrival in the intra- and extracranial vessels were recorded from each case. We recorded time of contrast arrival in the distal cervical (at skull base) and supraclinoid segments of both internal carotid arteries (ICA) and the superficial temporal branch of external carotid arteries (ECA) at the skull base and vertex. In addition, bilateral anterior cerebral arteries (A1 and A3 segments), middle cerebral arteries (M1 and cortical segments), and posterior cerebral arteries (P2 segments) also were