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Technical note

320-Multidetector row whole-head dynamic subtracted CT angiography and whole-brain CT perfusion before and after carotid artery stenting: Technical note

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ABSTRACT

Introduction: Multidetector CT (MDCT) is increasingly used for the investigation of neurovascular disorders, but restricted *z*-axis coverage (3.2 cm for 64-MDCT) currently limits perfusion to a small portion of the brain close to the circle of Willis, and precludes dynamic angiographic appreciation of the entire brain circulation. We illustrate the clinical potential of recently developed 320-MDCT extending the *z*-axis coverage to 16 cm in a patient with symptomatic carotid artery stenosis.
Methods: In a 74-year-old patient presenting with critical symptomatic stenosis of the left CCA, pre- and post-carotid artery stenting whole-head subtracted dynamic MDCT angiography and perfusion were obtained in addition to CT angiography of the supra-aortic trunks. Both whole-head subtracted MDCT angiography and perfusion demonstrated delayed left ICA circulation, which normalized after carotid stenting.
Discussion: 320-MDCT offers unprecedented *z*-axis coverage allowing for whole-brain perfusion and subtracted dynamic angiography of the entire intracranial circulation. These innovations can consolidate the role of MDCT as a first intention imaging technique for cerebrovascular disorders, in particular for the acute management of stroke.

1. Introduction

Multidetector CT (MDCT) is increasingly used for the investigation of neurovascular disorders. However, restricted *z*-axis coverage (3.2 cm for 64-MDCT) currently limits MDCT perfusion to a small portion of the brain close to the circle of Willis, and precludes dynamic angiographic appreciation of the entire brain circulation. Recently developed 320-MDCT machines extend the *z*-axis coverage to 16 cm. This increased longitudinal coverage offers the possibility of acquiring whole-brain perfusion (WBCTP) and whole-head subtracted dynamic angiography (WHSDCTA) of the intracranial circulation. We illustrate the clinical potential of this novel equipment in a patient with symptomatic carotid artery stenosis, who was evaluated with 320-MDCT before and after carotid stenting.

2. Technical note

The patient is a 74-year-old man treated in 1978 for laryngeal carcinoma by total laryngectomy and radical neck dissection complemented by irradiation and chemotherapy. Three weeks prior to admission, the patient presented multiple episodes of left-sided amaurosis and left facial and right hand numbness that resolved completely over 30 s. He was referred for further investigation and management after carotid Doppler sonography revealed a 90% stenosis of his left common carotid artery (CCA). Initial MRI showed no evidence of stroke, but disclosed multiple white matter lesions consistent with small vessel disease. 320-MDCT (Aquilion One, Toshiba Medical Systems, Japan) was performed to evaluate the cervicocranial vasculature and the brain perfusion, after informed consent was obtained from the patient. Non-enhanced head CT and CT angiography (CTA) of the supra-aortic trunks were obtained following standard protocols similar to conventional 64-MDCT. WHSDCTA/WBCTP was performed before the CTA of the supra-aortic trunks using low dose parameters (80 kV, 100 mAs) [1]. Twenty-one whole-head volumes were acquired at 2-s intervals (15 volumes) and 3-s intervals (6 volumes), starting 5 s after bolus injection of 50 ml of iodinated contrast agent (Isovue 370, Bracco Diagnostics Inc., USA) at a rate of 6 ml/s. Perfusion analysis was performed on a dedicated

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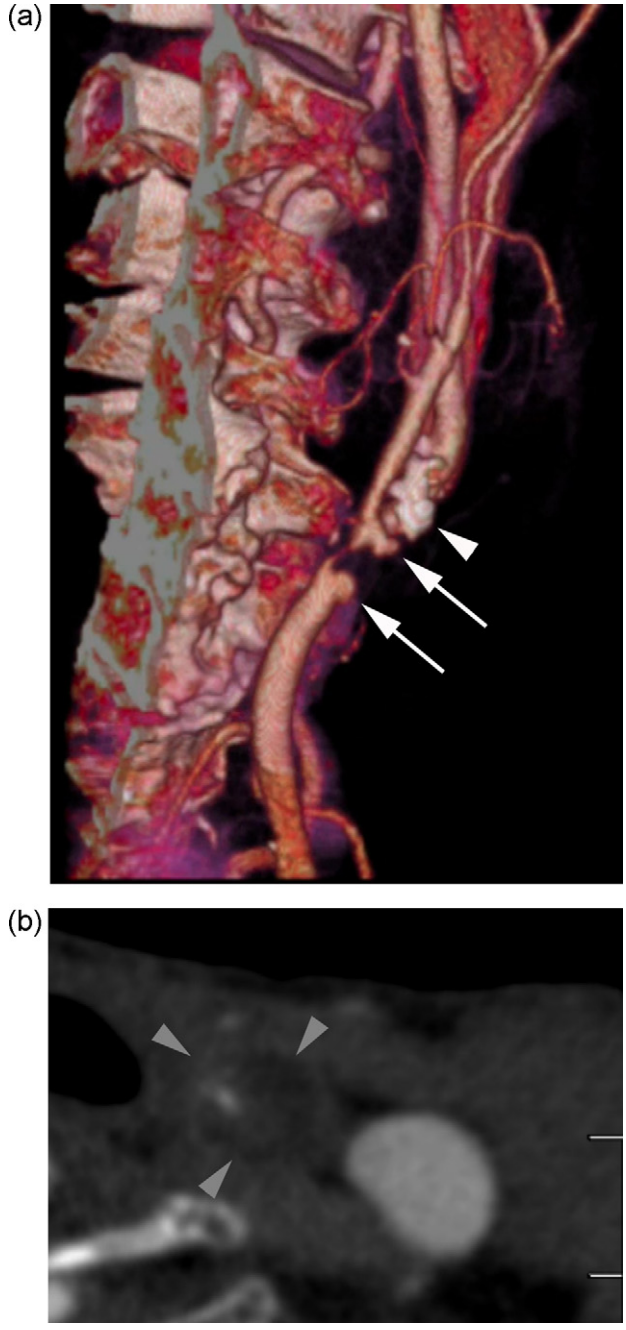

Fig. 1. CTA of the supra-aortic trunks. (a) Volume-rendered 3D reconstruction showing a 83% stenosis of the distal CCA, with ulcerated plaque (arrows). There is also a calcified plaque of the proximal left ICA (arrowhead). (b) Axial source images showing soft atheromatous plaque (arrowheads).

workstation (Vitrea fX, Vital Images, USA). Digital subtraction of the whole-head volumes were performed on a display workstation (Toshiba Medical Systems, Japan) allowing for subtracted 3D reconstructions and WHSDCTA images with arterial, mixed arterial and venous, and venous phases. The total radiation exposure was of 11.2 mSiV, including 3.9 mSiV for the SDCTA/WBCTP protocol.

CTA of the supra-aortic trunks confirmed a focal stenosis of the distal left CCA measured at 83% stenosis (NASCET criteria) (Fig. 1a and b). WHSDCTA demonstrated a 2-s filling delay of the left internal carotid artery (ICA) compared to the right ICA (Fig. 2a), consistent with a 2-s delay in the time-to-peak (TTP) on WBCTP. The mean transit time (MTT),[2] cerebral blood volume (CBV), and cerebral blood flow (CBF) were normal in the left MCA territory (the left ACA territory was supplied by the right ICA through the anterior communicating artery) (Fig. 2b). Given the history of radical neck dissection, radiation therapy, and tracheostomy stoma, carotid stenting was favored over endarterectomy [2]. The patient was premedicated with clopidogrel and acetylsalicylic acid and informed consent for the procedure was obtained. A self-expandable stent (6–8 mm × 30 mm, Acculink, Guidant, USA) was delivered under general anesthesia using a distal protection device (Accunet, Guidant, USA), with excellent angiographic result and absence of immediate or delayed (4 months follow-up) neurological complications. 320-MDCT performed after stenting and after informed consent was obtained from the patient, confirmed the absence of residual stenosis (Fig. 3a) and normalization of the circulatory delay both on WHSDCTA (Fig. 3b) and WBCTP (Fig. 3c–e).

3. Discussion

The limited *z*-axis (longitudinal) coverage of current MDCTs results in several shortcomings for the evaluation of patients with acute stroke. First, the small volume of brain studied during CT perfusion, which is limited to 32 mm above the circle of Willis with 64-MDCT, confines the perfusion study to proximal arterial territories, with perfusion abnormalities in distal arterial territories escaping detection. Insufficient volume sampling may result in underestimation of the extension of the perfusion abnormalities and potential infarct size, and adversely affect decision-making for intravenous or intra-arterial recanalization procedures. Second, table displacement is necessary during conventional CTA in order to cover the entire brain. This precludes performing fast iterative data acquisition of the whole-head necessary to a dynamic analysis of the arterial, mixed, and venous phases that can clearly objectivate circulatory delay and leptomeningeal anastomoses.

This case report demonstrates that, with its 16-cm *z*-axis coverage, 320-MDCT can overcome these limitations. In our patient with a critical symptomatic stenosis of the left CCA, WHSDCTA and WBCTP were obtained in addition to CTA of the supra-aortic trunks. WHSDCTA showed sequential filling of the entire intracranial arterial and provvenous circulations, and demonstrated a circulatory delay in the left ICA distribution when compared to the right side. Optimal subtraction of bone and intracranial calcifications demonstrated the absence of additional stenosis in arterial segments such as the petrous and cavernous portions of the ICA and the V4 segment of the vertebral arteries, which are typically difficult to evaluate using non-subtracted CTA due their intra-osseous location and the frequent occurrence of calcified atheromatous plaque. The absence of table displacement during each volume acquisition and the short scanning time (1 s) offers perfect subtraction provided that the patient remains perfectly still during the 60 s necessary for simultaneous MDCT angiography and perfusion.

WBCTP provides perfusion analysis of the entire brain by sequentially scanning entire whole-brain volumes during the intracranial passage of contrast material bolus. The whole-brain qualitative and quantitative perfusion analysis was concordant with the circulatory delay observed during WHSDCTA. There was a 2-

[2] MTT is obtained via a delay invariant deconvolution method (SVD+), which corrects for time shift between hemispheres, thus the MTT appears normal despite a delayed TTP.

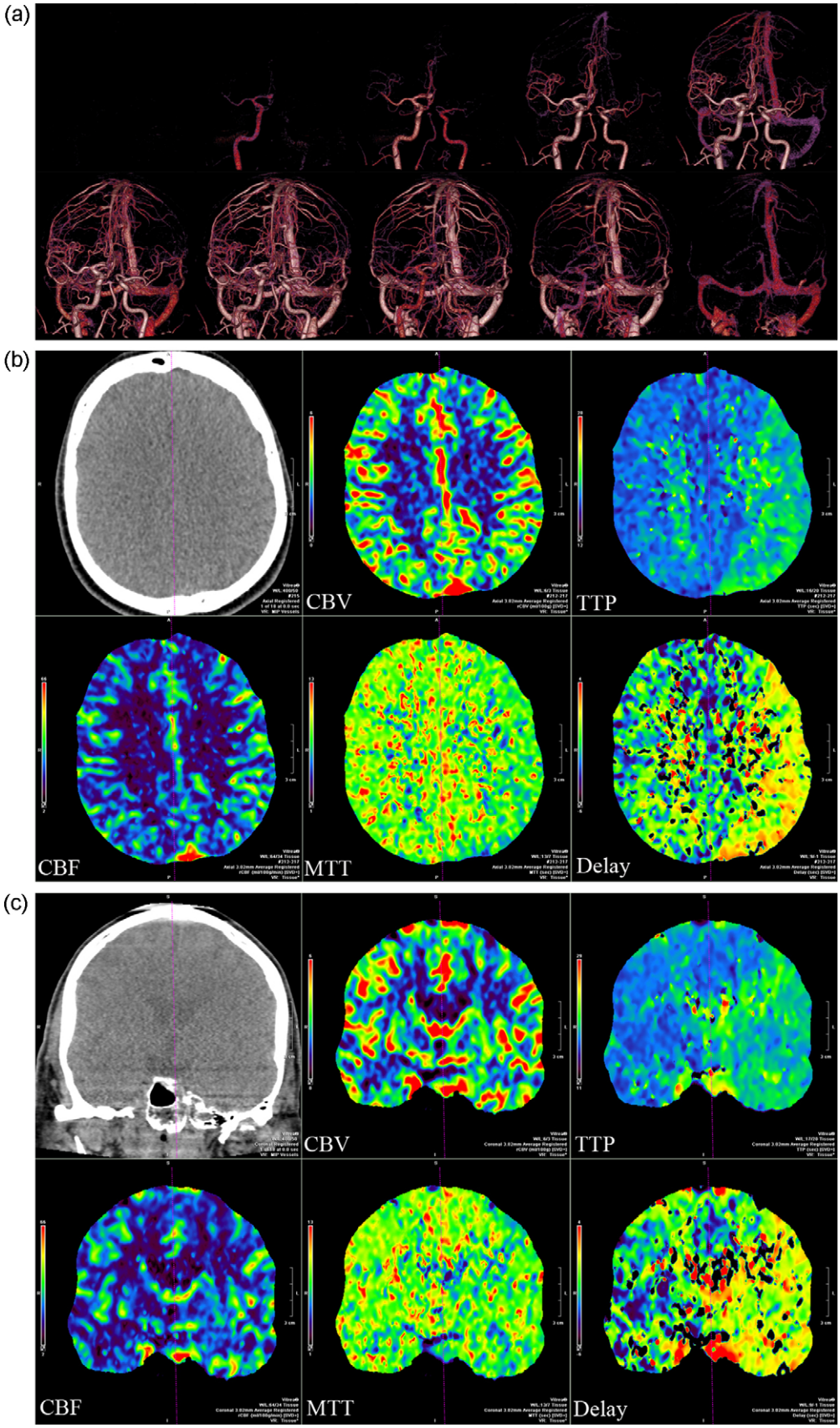

Fig. 2. Pre-stenting WHSDCTA and WHCTP: (a) WHSDCTA showing delayed filling of the left ICA and MCA compared to the right (reads left to right and top to bottom). There is a hypoplastic A1 segment of the left anterior cerebral artery and a right anterior communicating artery aneurysm; (b and c) axial and coronal perfusion maps showing a delayed left hemispheric TTP. A quantitative analysis demonstrated the absence of significant changes in CBV/CBF/MTT. The bottom right map corresponds to the correction for delay of arrival of contrast material in the left ICA. Delay time demonstrates the relative time of contrast arrival for tissue voxels, and is calculated from the residue (transfer) function; (d and e) left and right lateral projections of surface rendered 3D reconstructions of the perfusion maps showing the delayed TTP and normal CBV/CBF/MTT.

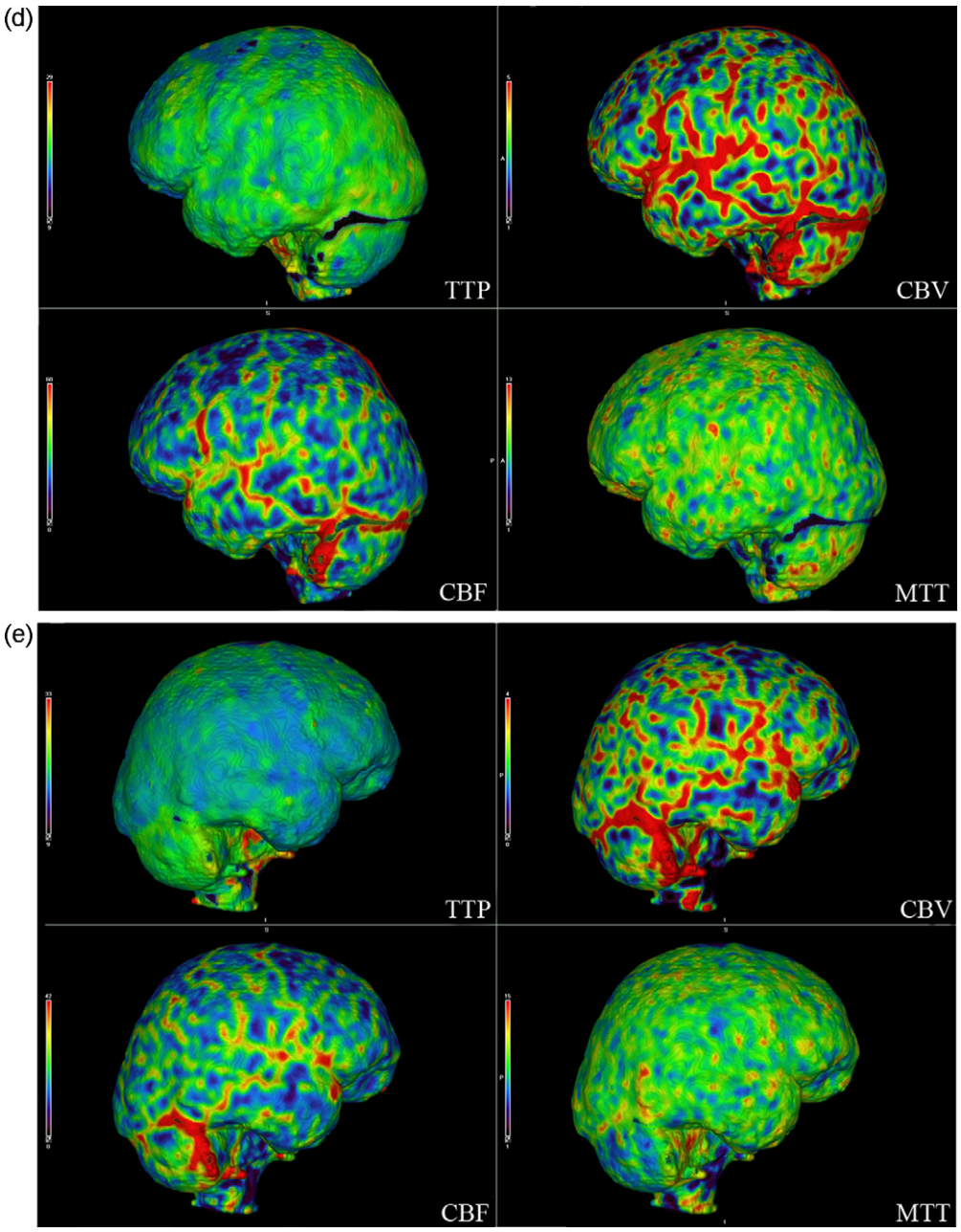

Fig. 2. (*Continued*).

s delay on TTP maps, but time-invariant MTT, CBV, and CBF were not significantly altered in the left ICA territory when compared to the right side. CBV is an important parameter in the pre-treatment evaluation of extracranial steno-occlusive disease, as it may predict susceptibility for developing hyperperfusion syndrome after correction of the stenosis [3]. In our case, normal pre-stenting CBV correlated well with the absence of hyperperfusion on the post-stenting 320-MDCT study, in which both the circulatory delay of the ICA on WHSDCTA and the prolonged TTP on WBCTP had normalized.

The introduction of 320-MDCT raises the question of potential increase in radiation exposure secondary to dynamic sequential scanning. The current protocol uses low-dose parameters for WHS-DCTA and WBCTP, with an exposure dose of 3.9 mSv, or a total dose of 11.2 mSv if non- and post-contrast head CT and supra-aortic trunk CTA are added. Sequential acquisition of whole-brain volumes with 1- and 2-s time intervals instead of continuous dynamic scanning contributes to dose reduction, while offering accurate perfusion time intensity curves [4] and sufficient temporal resolution for pure arterial and venous phases.

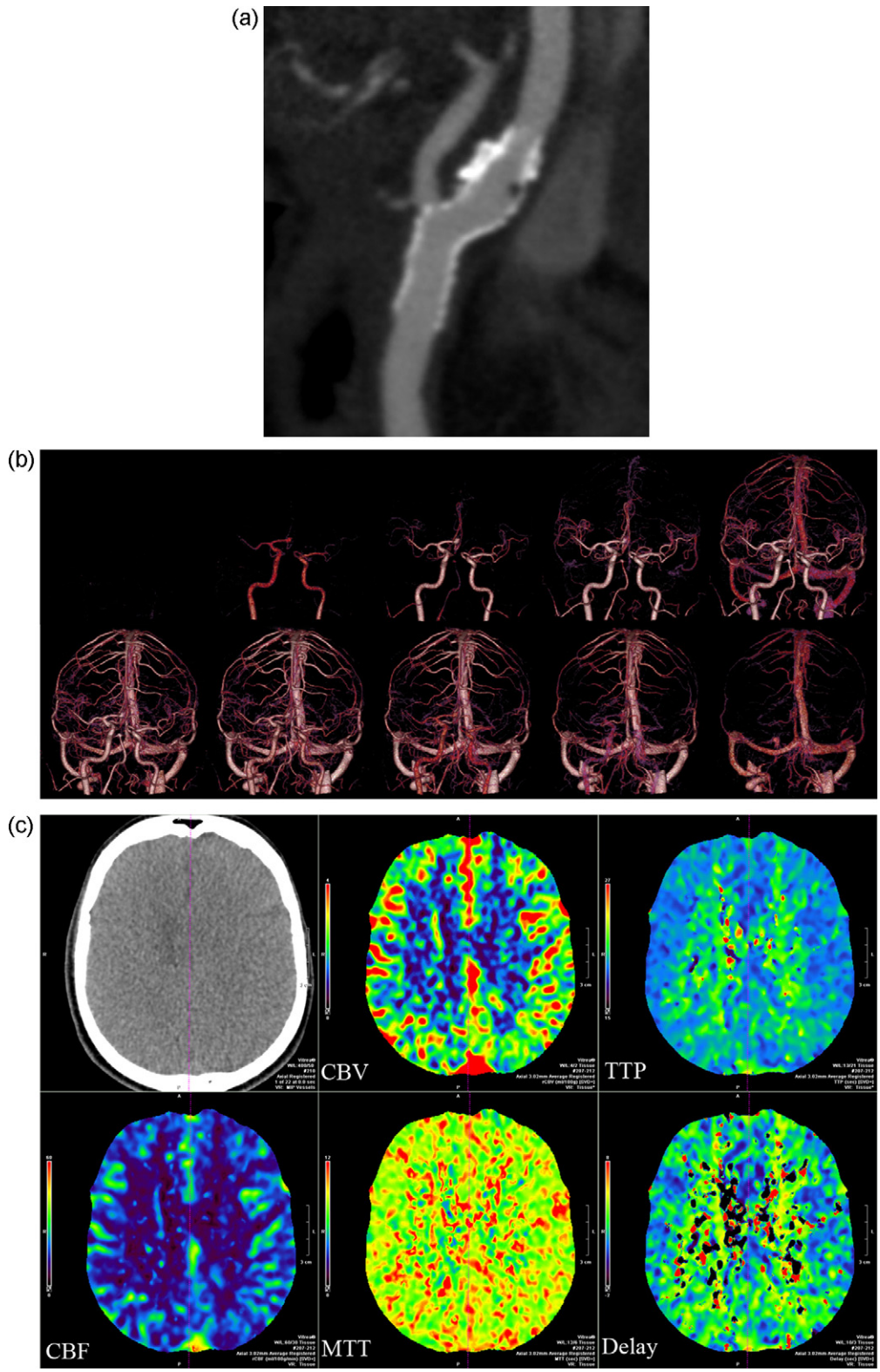

Fig. 3. Supra-aortic trunks CTA, WHSDCTA and WBCTP after stenting: (a) sagittal reconstructions showing the stent across the distal CCA and proximal ICA with no residual stenosis; (b) WHSDCTA showing simultaneous filling of the left and right anterior circulations after stent placements; (c and d) axial and coronal perfusion maps showing normalization of the TTP; (e) left lateral projections of surface rendered 3D reconstructions of the perfusion maps showing normalization of the TTP.

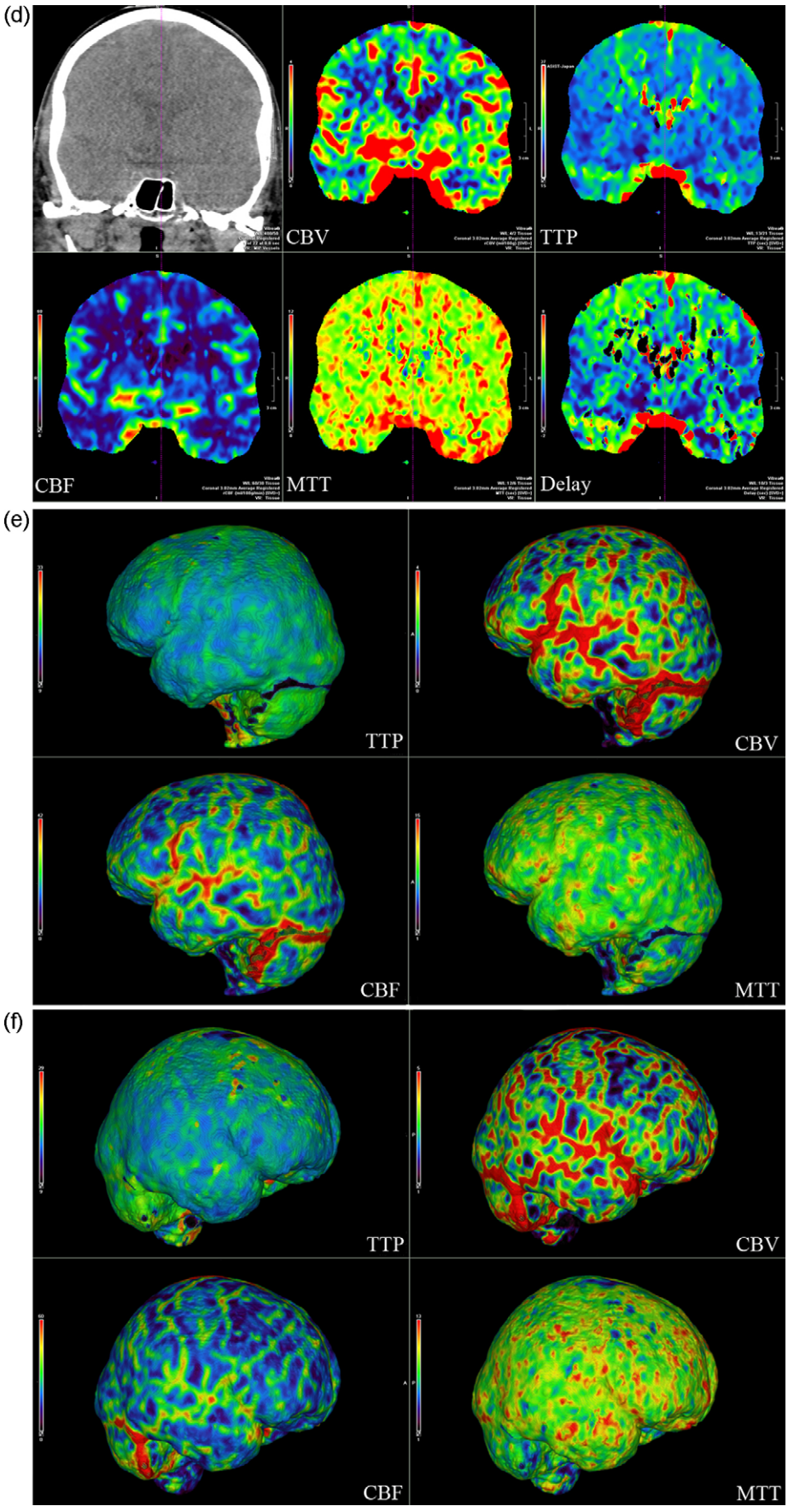

Fig. 3. (*Continued*).

4. Conclusion

320-MDCT offers unprecedented *z*-axis coverage allowing for whole-brain perfusion and subtracted dynamic angiography of the entire intracranial circulation. These innovations can consolidate the role of MDCT as a first intention imaging technique for cerebrovascular disorders, in particular for the acute management of stroke.

Conflict of interest

Philippe Gailloud declares no conflict of interest.

Diego San Millán Ruíz and Kieran Murphy declare having received honoraria for conferences and courses from Toshiba Medical Systems, not exceeding 1000$.

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