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Four-dimensional Flow Magentic Resonance Imaging Assessment of Hemodynamics in Patients after Extracranial-Intracranial Bypass Surgery

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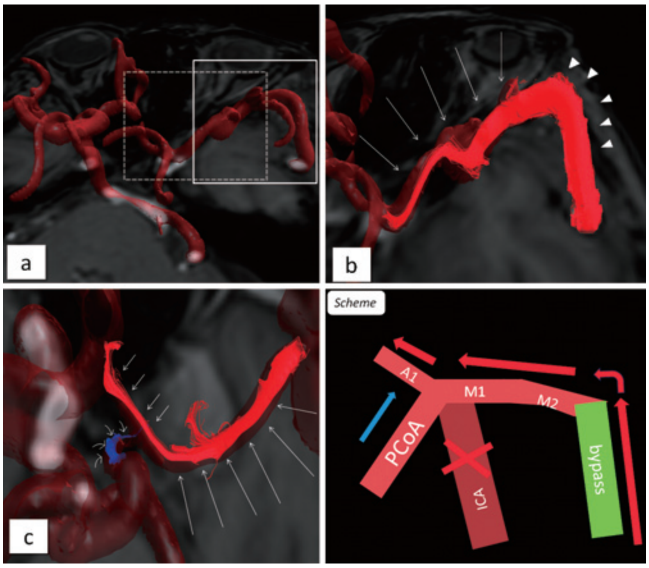

Fig. 1

Extracranial-intracranial (EC-IC) bypass surgery is performed for patients with 2 types of cerebrovascular disease: 1) internal carotid artery (ICA) occlusion and 2) cerebral aneurysm requiring ligation of the ICA[1,2]. Flow patterns of the cerebral arteries may vary after EC-IC bypass, because the flow from the bypass and the collateral flow through the circle of Willis compensate for the decrease in flow from the occluded ICA. Conventional X-ray angiography has been the standard method of assessing hemodynamics after EC-IC bypass surgery but is invasive and requires irradiation and an iodinated contrast agent. Thus, X-ray angiography is not suitable for the long-term follow-up of patients after EC-IC bypass surgery.

We use time-resolved 3-dimensional phase-contrast (4-dimensional [4D] Flow) magnetic resonance imaging (MRI) for flow analysis before and after EC-IC bypass surgery. Unlike X-ray angiography, 4D Flow MRI is noninvasive and does not require injection of a contrast agent[3]. We have used 4D Flow MRI to assess intracranial hemodynamics in 19 patients who underwent EC-IC bypass surgery. With 4D Flow MRI, the patency of EC-bypass arteries was identified in all patients. Retrograde flow at the M1 segment of the middle cerebral artery (MCA) from the EC bypass was observed in 10 patients, whereas anterograde flow was identified in 9. We were able to comprehensively assess the flow crossing from the circle of Willis to the bypass, and visualized the complicated flow at the bifurcation of the MCA. Our results indicate that 4D Flow MRI is feasible for following up patients after EC-IC bypass surgery.

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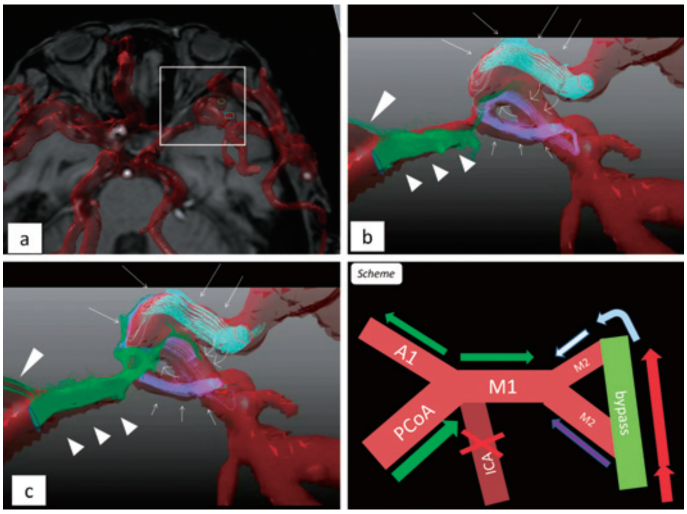

Fig. 2

Fig. 1 A 72-year-old woman with a left ICA aneurysm after ligation of the ICA and EC-IC bypass. (a): Volume rendering of the cerebral arteries. (b): Enlarged view of line square. 4D Flow MRI with streamlines visualizes the flow of blood from the patent EC-IC bypass **(arrowheads)**. The bloodstream from the bypass subsequently flows into the M1 in a retrograde direction **(long arrows)**. (c): Enlarged view of dashed square. The M1 segment of the MCA has retrograde flow **(long arrows)**, and the A1 segment of the anterior cerebral artery subsequently maintains inherent anterograde flow **(short arrows)**. The posterior communicating artery (PCoA) shows retrograde flow **(curved arrows)**.

Fig. 2 A 73-year-old man after EC-IC bypass to the left ICA occlusion. (a): Volume rendering of the cerebral arteries. (b, c): Enlarged view of line square. Time course of bloodstreams around the M1–M2 bifurcation. The posterior communicating artery (PCoA) has retrograde flow, the M1 segment of the MCA **(short arrow heads)** maintains inherent anterograde flow, and the A1 segment of the anterior cerebral artery **(long arrow heads)** shows anterograde flow (green streamlines). The two branches of the M2 segement show retrograde flow from the EC bypass (light blue and purple streamlines; **long and short arrows**). The anterograde M1 bloodstream (green stereamlines) and two retrograde M2 bloodstreams (light blue and purple streamlines) flow together into the other M2 branch **(curved arrows)**. The sum of the purple streamlines flowing into the M2 branch **(curved arrows)** is larger at the time point of diastole (b) than of systole (c). On the other hand, the sum of green streamlines flowing into the M2 branch **(curved arrows)** is smaller at the time point of diastole (b) than of systole (c). The hemodynamics varies through the time course of the heart phase.

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