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TECHNICAL NOTE - NEUROSURGICAL TECHNIQUES

Multiple reimplantation technique for treatment of complex giant aneurysms of the middle cerebral artery: technical note

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Abstract
Background Giant middle cerebral artery (MCA) aneurysms are among the most challenging neurovascular lesions, especially when the M2 and M3 branches are incorporated into the aneurysm. Here we report on two cases with complex MCA aneurysms, in which double and triple arterial reimplantation of the efferent vessels into a saphenous vein graft (SVG) was applied to reconstruct the MCA tree, allowing final trapping of the aneurysm.
Methods In the first case, a 41-year-old woman presented with a partially thrombosed giant MCA aneurysm including three efferent branches. Two superior trunks were disconnected and reimplanted onto an SVG fed by the external carotid artery (ECA). Following anastomosis between the SVG and the inferior trunk, the aneurysm was trapped. The second case is a 67-year-old man with recurrent giant MCA aneurysm incorporating two efferent M2 branches. First, the superior trunk was reimplanted onto an SVG, then the SVG was anastomosed to the inferior trunk. Finally the afferent M1 was clipped. Intraoperative indocyanine green (ICG) videoangiography (FLOW 800) was used for studying bypass patency.
Results In both cases, successful bypass patency was demonstrated by ICG videoangiography. Postoperative digital subtraction angiography (DSA) confirmed bypass patency. The first case was discharged without any neurological deficit. The second case suffered from bleeding due to refilling of the aneurysm via the inferior M2. An additional clip was placed on the inferior M2 in a second step. The patient was discharged with weakness of the left arm.
Conclusion Reconstructing an MCA bifurcation or trifurcation combining multiple arterial reimplantation is effective for treatment of selective cases of complex MCA aneurysms.

Keywords Giant aneurysm · Extra-intracranial bypass · Middle cerebral artery · Saphenous vein graft · FLOW 800 · ICG videoangiography

Introduction

Intracranial giant aneurysms are among the most challenging neurovascular lesions. Due to the high incidence of rupture, mortality and morbidity rates are high [4, 15, 17]. Giant aneurysms are most frequently found at the MCA bifurcation [3]. Microsurgical clipping or endovascular techniques may be impossible in particular when parent artery or adjacent arterial branches are incorporated into the aneurysm's base or dome [3, 14, 16]. Alternative surgical approaches using revascularization are

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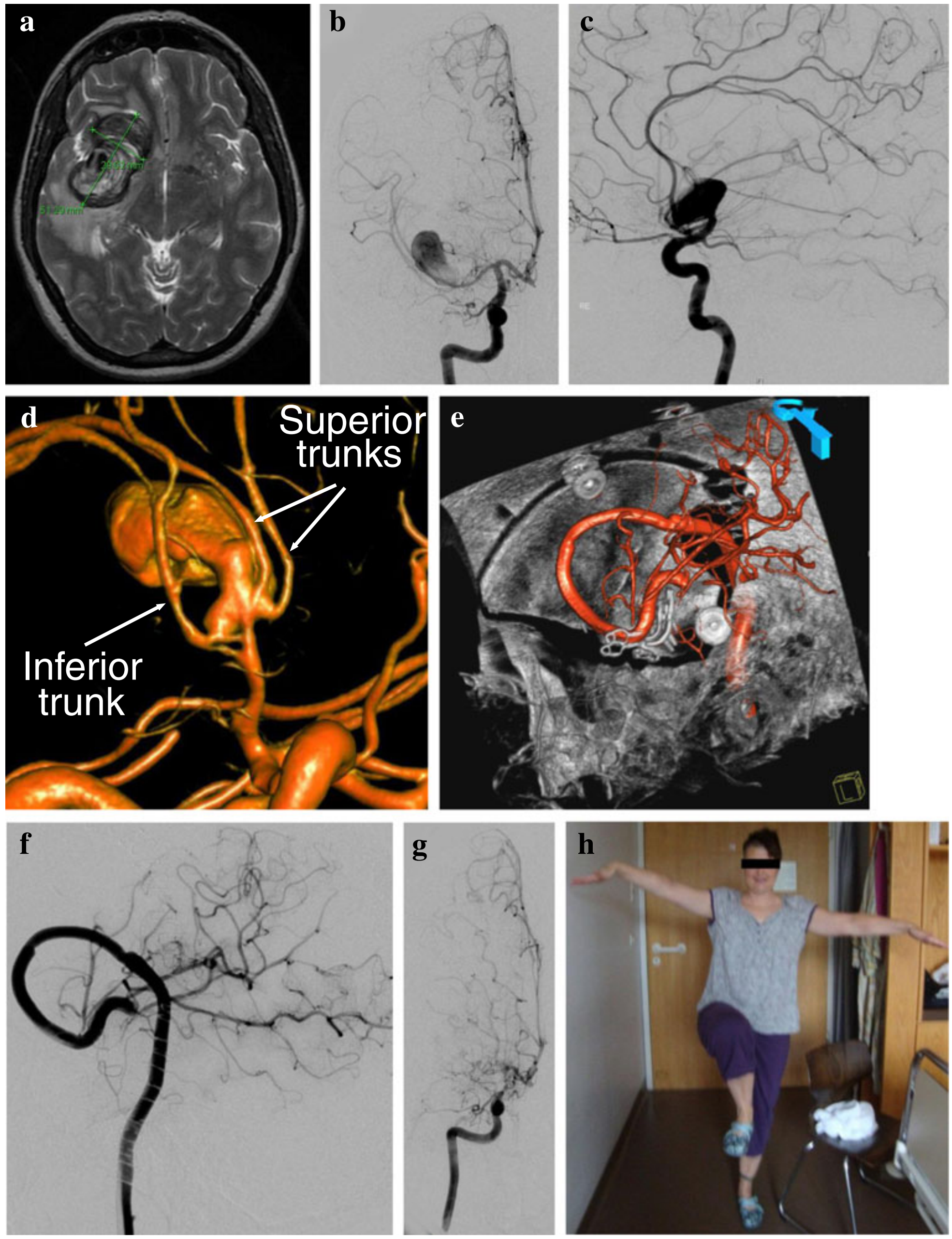

Fig. 1 *Case 1*. a Preoperative T2-weighted MRI showing an intracranial mass with perifocal edema in the right Sylvian fissure. b, c, d Conventional DSA and 3D reconstruction demonstrating partially thrombosed fusiform giant aneurysm at bifurcation of right MCA. e, f Postoperative DSA and 3D reconstruction showing bypass patency and perfusion of the MCA territory fed by SVG. g The aneurysm was not detected in internal carotid arteriography. h Photograph of the 1st case at 13 days after the operation. She did not display remarkable neurological deficits

needed in these cases [3, 14, 16]. The majority of such complex cerebrovascular lesions have been excluded from the International Subarachnoid Aneurysm Trials, thus evidence for adequate treatment is lacking [10]. In 2006, Lawton et. al. described a double reimplantation technique to reconstruct the MCA bifurcation for achieving complete trapping of the giant aneurysm [6, 9]. Here, we report on two cases with complex MCA aneurysms, in which double and even triple arterial reimplantation into an SVG was applied for reconstructing the MCA vascular tree and allowing consecutive trapping of the aneurysms.

Case presentation

Case 1

A 41-year-old woman presented with severe headache and seizures. Initial computed tomography (CT) showed no signs of subarachnoid hemorrhage. However, magnetic resonance imaging (MRI) demonstrated a partially thrombosed aneurysm of the right MCA measuring approximately 29×51 mm with perifocal edema in the right Sylvian fissure (Fig. 1a). Conventional angiography revealed a fusiform giant aneurysm at the MCA bifurcation (Fig. 1b, c). At least three efferent branches originating from the aneurysm were suspected (Fig. 1d). Neurological exam revealed no remarkable deficits.

The patient underwent a standard frontotemporal craniotomy while intraoperative motor evoked potentials (MEP) were monitored continuously. After semicircular incision of the dura, the Sylvian fissure was gently opened to approach the aneurysm. The arachnoid membrane and trabecula around the aneurysm were carefully dissected. The frontal lobe and temporal pole were retracted following aspiration of cerebrospinal fluid. Three efferent branches originating from the aneurysm were exposed on the lateral surface of the aneurysm. Two superior trunks and one inferior trunk were evolving from the wall of the aneurysm (Fig. 2a). As the aneurysm was therefore not clippable, we decided to reconstruct the MCA bifurcation via multiple bypasses allowing for trapping of the aneurysm. The SVG was harvested from the right leg. At first the SVG was anastomosed in end-to-side technique to the ECA, and then passed upwards beneath the skin. The SVG was placed in a "*J*" shape on the brain surface. Next, the superior trunk was disconnected from the aneurysm and reimplanted onto the SVG with an end-to-side anastomosis (Fig. 2b). Then the second superior trunk was reimplanted onto the SVG via the same technique (Fig. 2c). Following this maneuver, we anastomosed the SVG to the branch of the inferior trunk (end-to-side) (Fig. 2d). For these anastomoses of efferent branches, we advanced the temporary clip on the SVG distally, step by step. This strategy allows for constant inflow of each anastomosed vessels while performing the next anastomosis. After the 4th anastomosis, the inferior trunk was clipped close to the aneurysm. A permanent clip was placed on the afferent M1 segment. Finally the wall of the aneurysm was opened, and

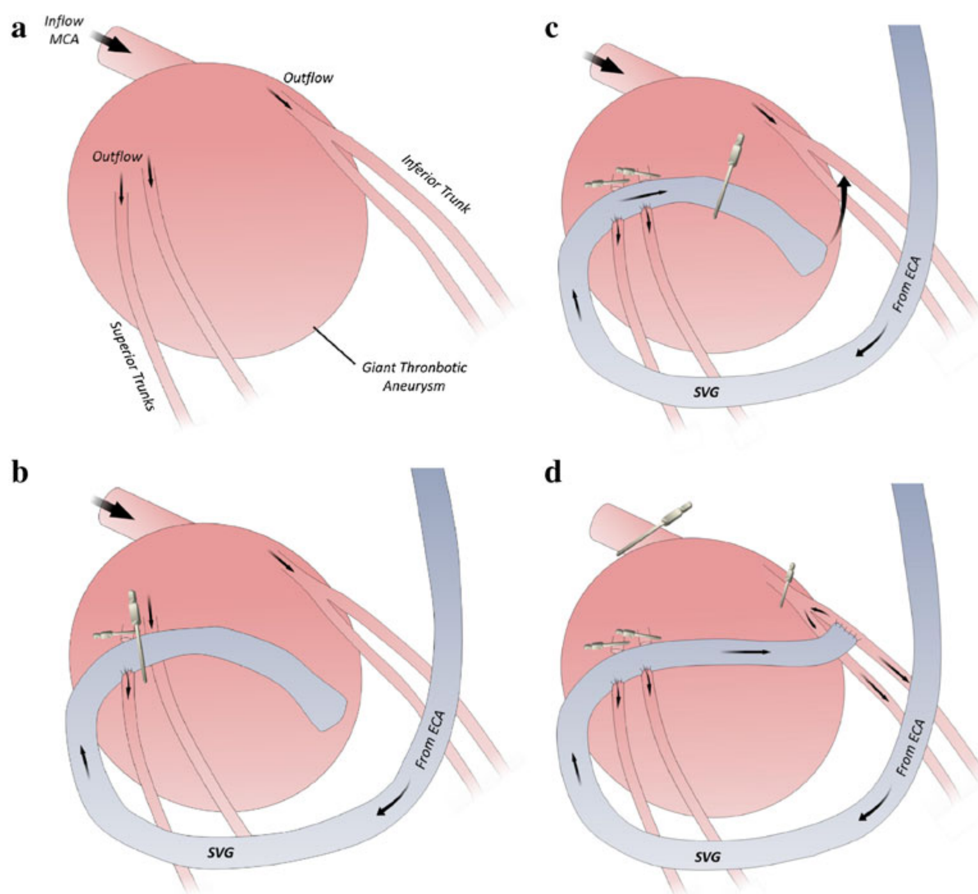

Fig. 2 *Illustration of the triple reimplantation technique*. The structure of the giant aneurysm in case 1 showing three efferent branches originating from the aneurysm (**a**). First superior trunk was reimplanted onto the SVG fed by the ECA (**b**). Second superior was also reimplanted with the same technique and the temporary clip on the SVG was advanced distally (**c**). The aneurysm was trapped after anastomosis between the SVG and the inferior trunk (**d**)

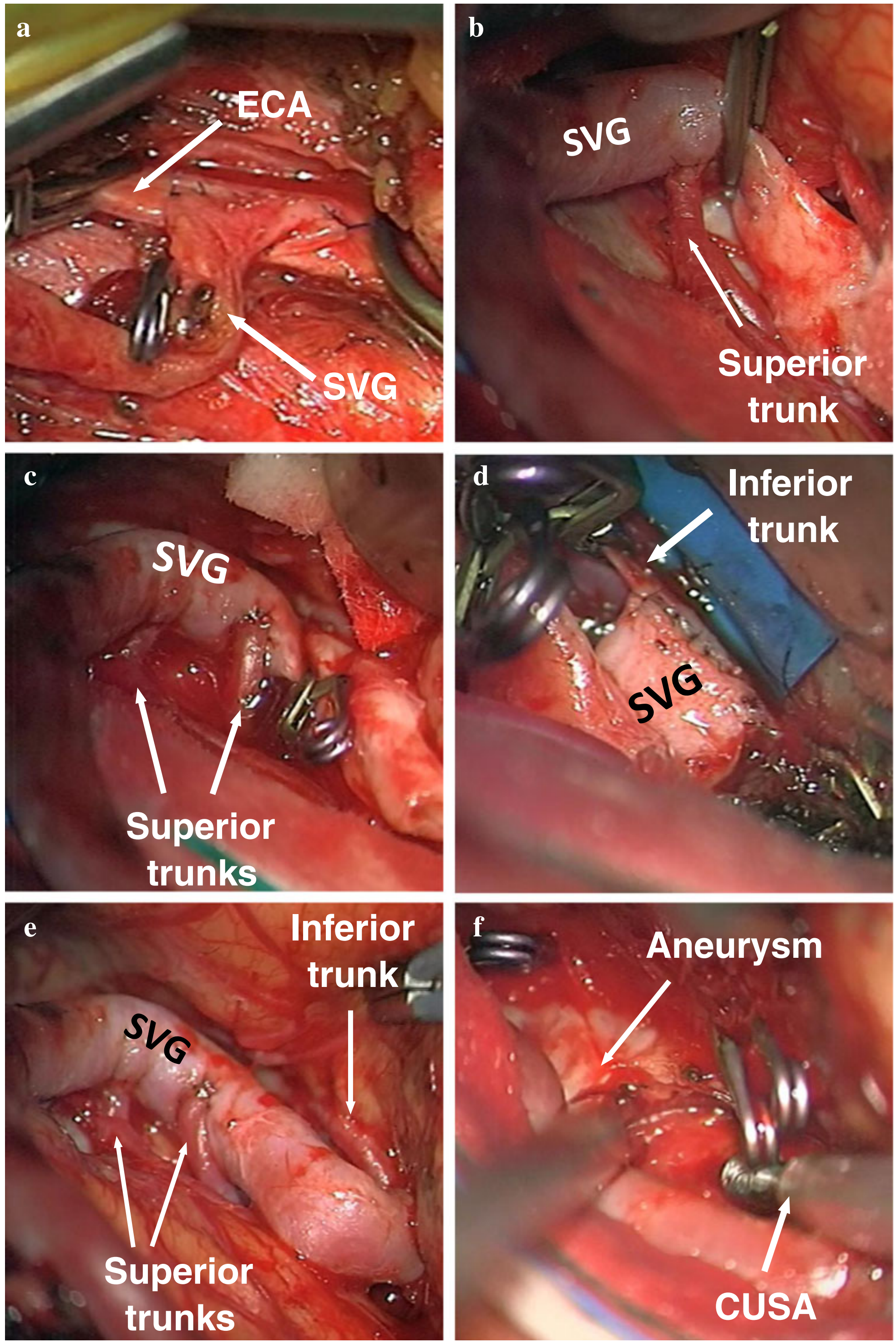

Fig. 3 *Photographs of each surgical step in case 1*. **a** first anastomosis of proximal SVG to the ECA. **b** one of superior trunks was anastomosed to SVG end-to-side. **d** a second superior trunk of was reimplanted to the SVG with end-to-side. d SVG was anastomosed to the inferior trunk with end-to-side anastomosis. **e** total reconstruction after reimplantation of all three efferent M2 branches. f after trapping of aneurysm, the intraluminal thrombus was evacuated with CUSA

decompressive thrombectomy was performed using the cavitron ultrasonic surgical aspirator (CUSA) (Fig. 3). MEP monitoring indicated no change of amplitude and latency during surgery.

Although the patient showed a transient left-sided hemiparesis after surgery, the patient's symptoms normalized within a few days. Postoperative angiography revealed adequate patency of the three vessels fed by the SVG (Fig. 1e, f and g). The patient was discharged 15 days after surgery without any significant neurological deficits (modified Rankin Scale (mRS) 0) (Fig. 1h).

Case 2

A 67-year-old man with a refractory MCA giant aneurysm consulted our department for additional therapeutic options. His aneurysm had been found incidentally and clipped 6 years prior at another hospital. Complete occlusion of the aneurysm was confirmed by DSA soon after the first operation. However a follow-up CT indicated recurrence of the MCA aneurysm. Preoperative neurological findings were normal. DSA revealed a giant aneurysm with at least two efferent M2 branches (Fig. 4a, b). The size of the aneurysm was 32×37 mm.

The patient underwent a standard frontotemporal craniotomy with MEP monitoring. The aneurysm and the M1 segment were exposed as described above. Two efferent M2 branches were identified on the aneurysmal dome (Fig. 5). An SVG was harvested from the patient's right leg. After end-to-side anastomosis between the ECA and the SVG (Fig.6a), the superior trunk was disconnected from the dome of the aneurysm and reimplanted onto the SVG via end-to-side anastomosis (Fig.6b). Additionally, the distal end of the SVG was anastomosed to the branch of the inferior trunk (Fig.6c, d). Finally, a permanent clip was placed on the M1 segment of the MCA close to the aneurysm. Since MEP monitoring indicated lower amplitude during temporary occlusion of the inferior trunk, we didn't occlude the base of the inferior trunk. After all reconstruction, the flow volume of the bypass graft measured 120 ml/min by Doppler ultrasonography. Postoperative DSA confirmed bypass patency (Fig. 4c).

After surgery the patient showed a left-sided hemiparesis which gradually improved. However 14 days later, the left hemiparesis progressed suddenly. CT revealed an intracerebral hemorrhage (ICH) around the aneurysm (Fig. 4d). A refilling of the aneurysm via the inferior trunk fed by the SVG was found by DSA (Fig. 4e). Therefore an additional clip was placed on the base of the inferior trunk and the intraluminal

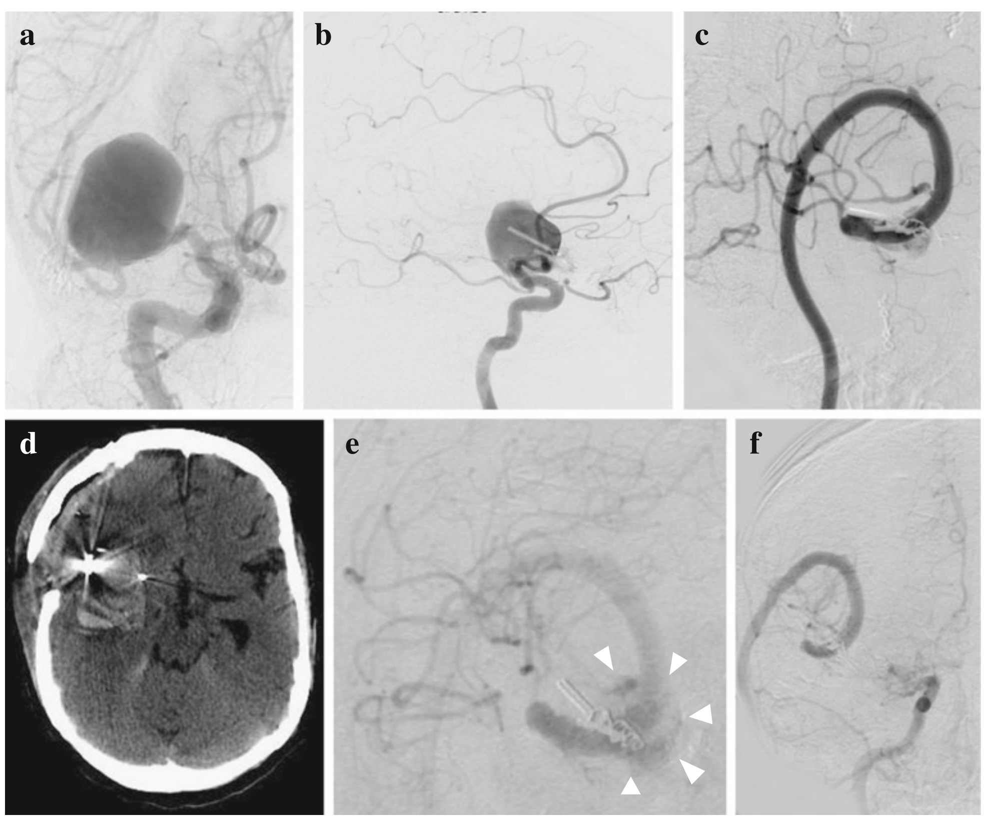

Fig. 4 *Case 2*. a, b Preoperative DSA showing giant MCA aneurysm of the right M1-M2 bifurcation. c Good bypass patency was confirmed by postoperative DSA. d CT scan carried out 14 days after 1st operation indicating ICH near the aneurysm. e Repeated DSA shows refilling of the aneurysm (*arrow heads*) via bypass graft. f DSA after 2nd operation confirmed complete disappearance of aneurysm

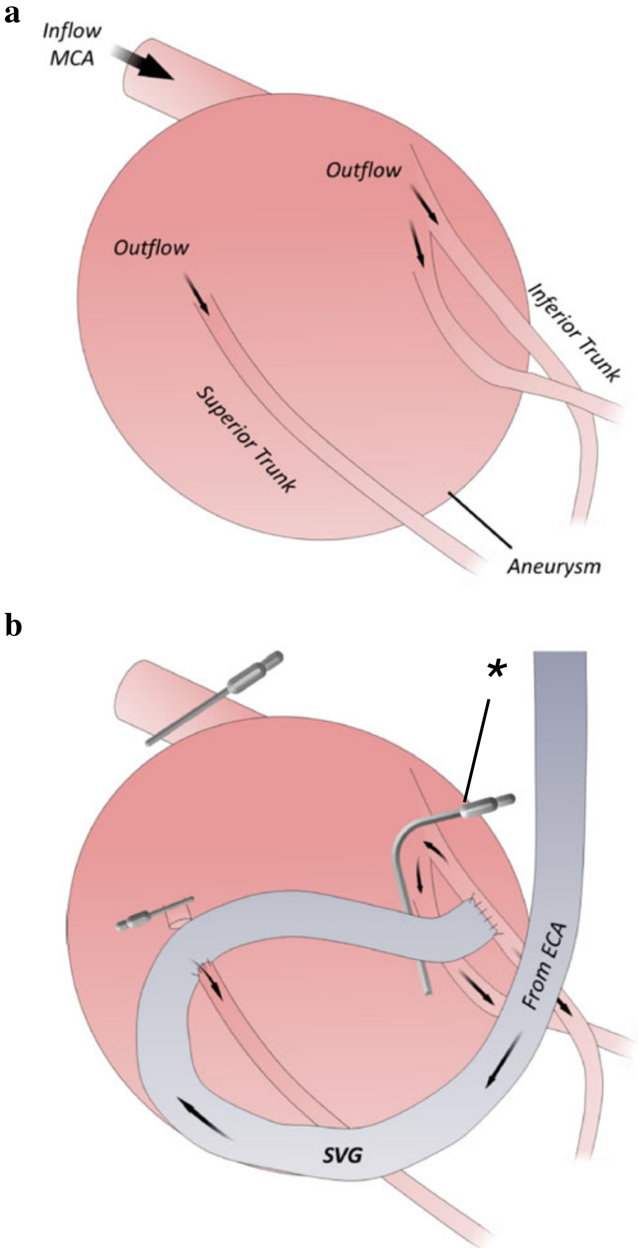

Fig. 5 *Schema of double reimplantation technique*. a The structure of giant aneurysm in case 2 before reimplantation. b Efferent branches were anastomosed onto the SVG in the same manner as in case 1. * = placed in 2nd operation

thrombus was evacuated via CUSA. After the 2nd surgery, complete trapping of the aneurysm was confirmed by DSA (Fig. 4f). The patient was discharged 37 days after the initial operation with a moderate weakness of the left arm (mRS 0).

Using intraoperative ICG angiography, successful reconstructions of the efferent branches were clearly confirmed in each patient. In addition, analysis of the ICG intensity curves underlined good patency with color mapping (Fig. 7).

Discussion

In recent decades, the strategies for treating complex giant aneurysms have become more versatile due to the progress of bypass techniques [8, 13, 14]. Thrombosed giant aneurysms are among the most complex vascular lesions. Most frequently they are located at the MCA. The incidence was reported to be 4 to 6 % [3]. One third of all patients with giant aneurysms will suffer from bleeding if not treated adequately, and 5-year mortality rates are as high as 50 % [4, 15, 17]. For these challenging aneurysms, occlusion or flow alterations with various bypass techniques were performed occasionally [3, 14, 16]. If efferent branches are incorporated into the aneurysm dome, the definitive treatment requires a remodeling of the vascular tree with multiple bypass techniques [1, 3, 12, 14, 16].

Lawton et al. classified complex aneurysms with intraluminal thrombus into six types and recommended an algorithm of surgical strategies [7]. In this context, the concept of the double reimplantation technique for complex giant aneurysms was introduced [6]. The basic concept of this technique is that instead of hooking the bypass vessels on the efferent branches before their disconnection from the aneurysm, the efferent branches are implanted at multiple sites into the large caliber bypass graft [9]. This technique allows for definite trapping or flow reversal of the aneurysm following reconstruction of the vascular tree.

In the present study, we have described our experience with this reimplantation technique. In contrast to previous reports, these aneurysms are characterized by an even higher complexity level with more than two M2 branches originating from the aneurysm. Thus, multiple or triple reimplantations had to be considered, reflecting the versatility and flexibility of this technique.

Our cases underwent trapping and flow alteration after reconstruction of the vascular tree. We achieved triple and double reimplantation of efferent MCA branches with multistep replacement of the temporary clip on the SVG. With this method, blood flow of each efferent branch was maintained via the SVG while we

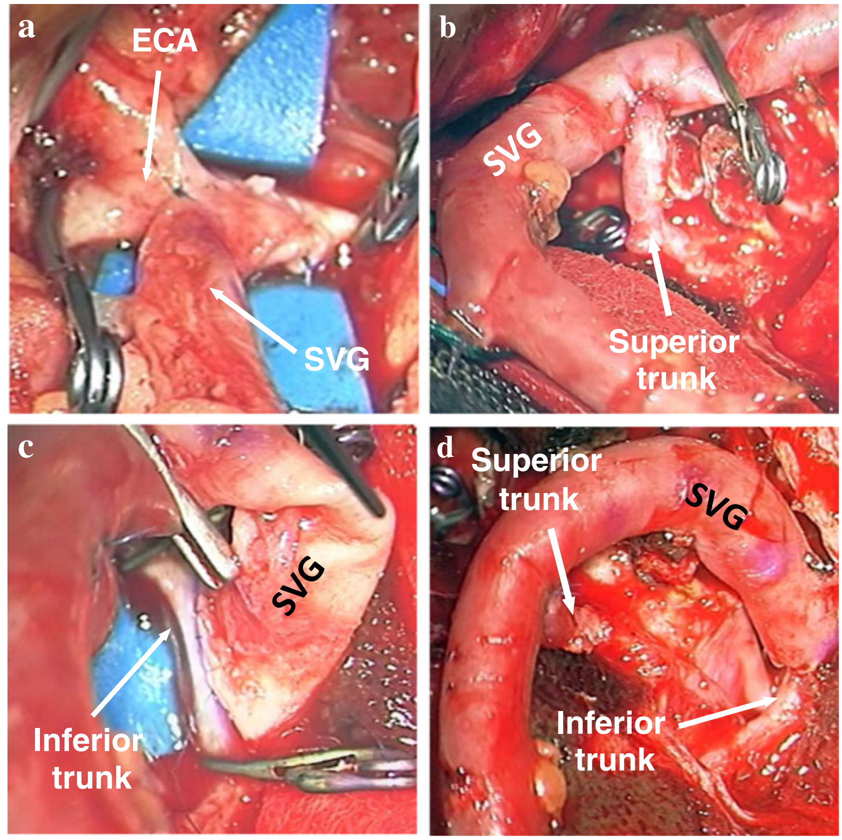

Fig. 6 *Photographs of each surgical step in case 2*. **a** first anastomosis of the SVG to the ECA. **b** superior trunk was anastomosed to the SVG with end-to-side. c the SVG was anastomosed to the branch of the inferior trunk with end-to-side. d reconstruction after double reimplantation of two efferent M2 branches

performed the neighboring anastomosis. Consequently, temporary occlusion times of individual M2 branches did not exceed 20 min.

In the 2nd case, we performed proximal occlusion of the aneurysm only after the double reimplantation of efferent M2 branches since retrograde flow through a third branch had to be maintained. In fusiform unruptured aneurysms, flow reversal is usually sufficient to obtain occlusion and healing of the aneurysms via secondary thrombosis and remodeling [5, 16]. However, in the present case, residual flow from the SVG via the revascularized efferent M2 branch maintained aneurysm perfusion which unexpectedly resulted in aneurysm rupture. Based on this experience, we now strive even more aggressively to achieve complete revascularization of the vascular tree in order to facilitate aneurysm trapping as the sole definite way of excluding the aneurysm.

The multiple reimplantation technique requires the use of a long bypass graft. Although radial artery graft (RAG) has an adequate diameter which fits the MCA recipient vessels, we chose the SVG as an ideal graft supplying enough length (40 cm) and higher blood flow compared to an RAG. Usage of a standard STA-MCA bypass can be considered alternatively for the reconstruction of the MCA tree as well. However, it seemed difficult to revascularize all three efferent M2 branches in the 1st case. Indeed, the Doppler ultrasonography indicated over 100 ml/min on the bypass graft of the 2nd case. Besides, harvesting STA branches was also difficult due to the old wound which was operated on initially in another hospital. Therefore, reconstruction using a large caliber free graft was supposed to be much more reliable for our present cases. On the other hand, long-term patency of a long SVG may be lower than with an RAG, necessitating careful long-term follow-ups with repetitive angiographic studies [6, 14].

In addition, our study has again proven the major advantage of intraoperative ICG videoangiography, which has become indispensable for us during clipping procedures [11]. The new software of ICG videoangiography (FLOW 800) is currently under investigation in our institute. In the present cases, FLOW 800 provided an excellent intraoperative illustration of flow

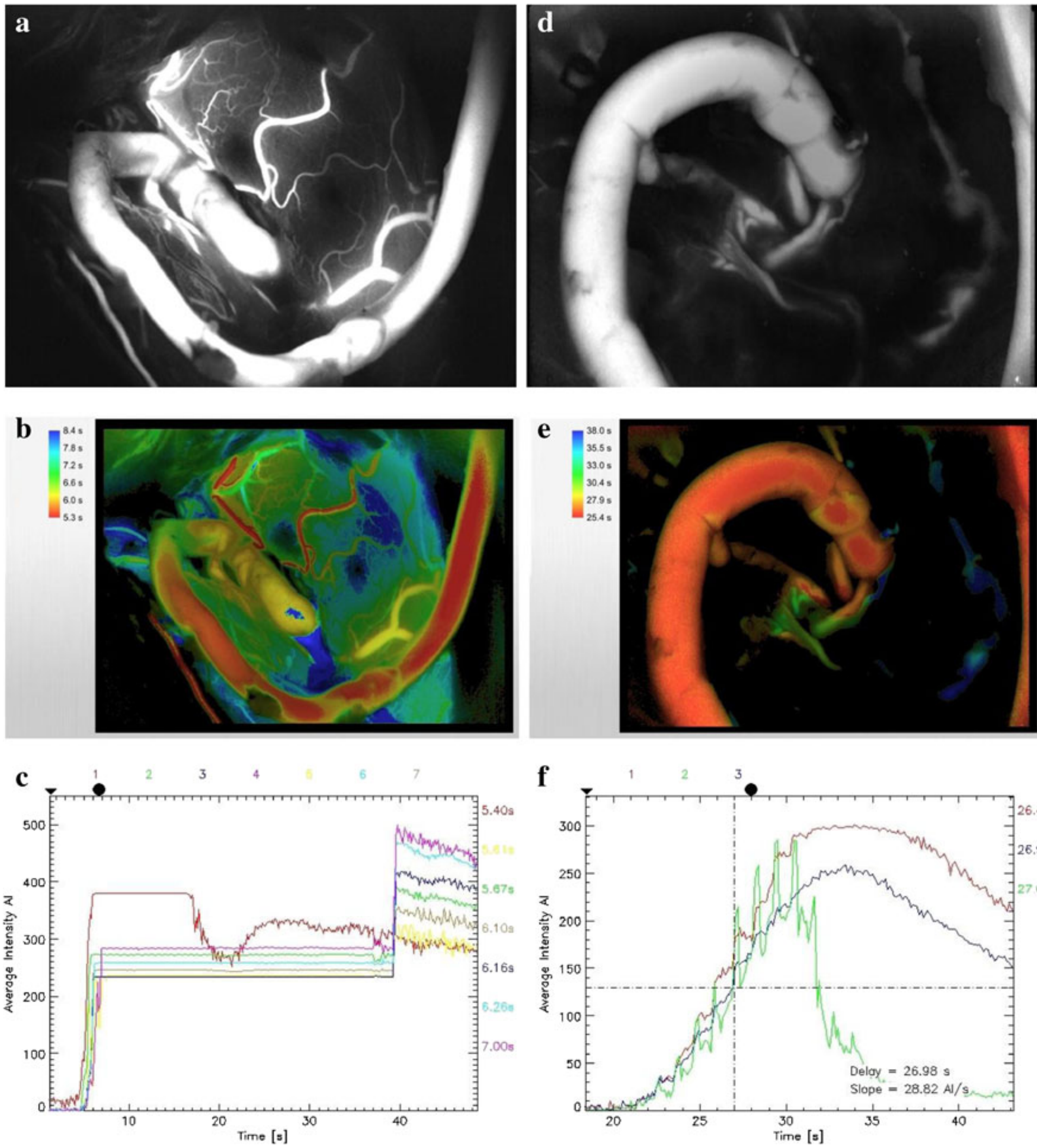

Fig. 7 *Intraoperative ICG videoangiography and delay map with diagram in each patient (case 1; a, b, c, case 2; d, e, f).* Intraoperative ICG videoangiography revealed successful patency of each anastomosis (**a**, **d**). Delay map indicating excellent perfusion of each anastomosed vessels and graft (**b, e**). Intensity time curve diagram showing prompt arising of ICG intensity in targeted vessels (**c, f**). ROI was plotted respectively

dynamics. The delay map showed false-colored images indicating time interval between appearance and half peak of the ICG intensity in vessels. The early inflow of ICG would be colored with red or yellow and late inflow will be colored blue in the concerned vessel [2]. All this information supported the intraoperative assessment of bypass function and successful reconstruction of the MCA vascular tree.

Conflict of interest None

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