Title: Urgent Open Embolectomy for Cardioembolic Cervical Internal Carotid Artery Occlusion

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Abstract

Acute ischemic stroke attributable to cervical internal carotid artery (ICA) occlusion is frequently associated with severe disability or death, and is usually caused by atherosclerosis. By contrast, the cardioembolic cervical ICA occlusion is rare, and feasibility of urgent recanalization remains unclear. We present the first study in the literature that focuses on urgent open embolectomy for treatment of cardioembolic cervical ICA occlusion. A retrospective review of the charts for patients undergoing open embolectomy was performed. Between April 2006 and September 2007, 640 consecutive patients with acute ischemic stroke were treated. Of them, 3 patients (0.47%) with the acute complete cardioembolic cervical ICA occlusion underwent urgent open embolectomy. All patients presented with profound neurological deficits and atrial fibrillation. The urgent open embolectomy achieved complete recanalization in all patients without any complications. All emboli in 3 patients were very large and fibrinous in histological findings. Two of 3 patients showed rapid improvement in neurological functions after surgical treatments. The cardioembolic occlusion of the cervical ICA is rare, but its possibility should be considered in patients with the acute ischemic stroke suffering profound neurological deficits and atrial fibrillation. Urgent open embolectomy may be a treatment option to obtain successful recanalization for cardioembolic cervical ICA occlusion and is recommended because it is technically easier and similar to the carotid endarterectomy.

Keywords: open embolectomy, cerebral ischemia, cardioembolism, cervical internal carotid artery occlusion

Introduction

Patients with acute internal carotid artery (ICA) occlusion suffer significant initial neurologic deficits and are often refractory to intravenous tissue plasminogen activator (tPA) therapy, and their outcome is usually poor [1, 2]. A review of the natural history of the acute ICA occlusion suggest that 16 to 55% of patients with serious neurologic deficits will die as a result of their infarct, 40 to 60% will suffer severe neurologic disability, and only 2 to 12% will make a good recovery depending on the follow-up period [13]. The cervical ICA occlusion is usually caused by atherosclerosis, where preexisting high grade stenotic lesions of the carotid sinus generate local thrombosis following rupture of an unstable atherosclerotic plaque [9]. By contrast, the cervical ICA occlusion is rarely caused by cardioembolism.

Because of the poor prognosis, various procedural approaches to acute recanalization for atherothrombotic occlusion have been reported including emergency carotid endarterectomy (CEA) or carotid thromboendarterectomy (CTEA) [8, 12, 13, 18], and emergent endovascular interventions [7, 16]. These treatments may be effective in selected patients [7, 8, 12, 13, 16, 18]. There are, however, no reports regarding open embolectomy for cardioembolic occlusion.
In this article we describe a series of three patients who underwent urgent open embolectomy for the acute cardioembolic cervical ICA occlusion.

Patients and Methods

Patients

Clinical and radiographic data were retrospectively reviewed through medical charts. During the 18-month period between April 1, 2006 and September 30, 2007, 640 consecutive patients with acute ischemic stroke were treated at our institution. Of these patients, 3 patients (0.47%) with the acute complete cardioembolic cervical ICA occlusion were admitted. All 3 patients fulfilled our inclusion criteria and underwent urgent open embolectomy.

Inclusion Criteria for Open Embolectomy

Patients, who received intravenous tPA therapy, or who were not eligible for angiography because of a medical contraindication, or who could not provide family's informed consent for diagnostic angiography or open embolectomy, were excluded. Inclusion criteria for emergency revascularization at our institution have been reported in details [6, 14]. In short, indications for open embolectomy were as follows: 1) a patient was independent in his/her daily life before ictus; 2) a patient showed profound neurological deficits; 3) initial computed tomography (CT) scans with or without diffusion magnetic resonance (MR) images demonstrated neither cerebral hemorrhage nor early ischemic changes; 4) cerebral angiography revealed complete occlusion of the cervical ICA, but did not disclose occlusion or severe stenosis in main arteries of other anterior and posterior circulations; 5) CT scans obtained immediate after angiography revealed no early ischemic signs.

Surgical Technique and Perioperative Management

The patients were administered with intravenous heparin, steroid and phenytoin after the diagnoses were made. Under general anesthesia with stringent control of perioperative hypertension, standard positioning and operative technique for CEA were used. Embolus was extracted under direct vision using forceps through a longitudinal arteriotomy made on the occluded common carotid artery (CCA) or proximal ICA. The backflow expelled with embolus was confirmed and enough blood was disposed to prevent distal embolus while the clamp forceps of ICA was loosened. If backflow was not achieved or seemed to be inadequate, then a FURUI's Double-Balloon Internal Shunt device for CEA (No.340-22; INTER MEDICAL CO., LTD, Japan) was inserted into the distal ICA (Fig. 1A and 1B). A distal embolus was pulled by a 10-ml syringe after inflation of balloon under clamped shunt tube of unilateral side, and was removed with the inserted shunt tube after deflation of the balloon. An adequate backflow was thus obtained. An additional CEA was performed under re-circulated ICA using the internal shunt device if thickened intima was observed. An arteriotomy was approximated primarily with 6-0 monofilament nylon without patch angioplasty. Anterograde blood flow of the ICA and distal emboli were immediately confirmed by cerebral angiography. If urgent recanalization was not achieved, superficial temporal artery-middle cerebral artery (MCA) bypass was carried out continuously. Postoperatively, the patients were administered with warfarin, an oral anticoagulant.

Results

All 3 patients presented with severe neurological deficits and an atrial fibrillation on the electrocardiograms. Urgent open embolectomy resulted in complete recanalization in all patients without any complications. The extracted emboli in 3 patients were fibrinous in histological findings. A mean of onset-to-recanalization time was approximately 7 hours, and two of 3 patients achieved favorable outcome.

Case 1

A 73-year-old woman suddenly developed right hemiplegia and global aphasia at family doctor's clinic. She was referred and hospitalized 45 minutes after onset, and no early ischemic signs were shown on initial CT scans (Fig. 2A). A National Institutes of Health Stroke Scale (NIHSS) score was 25 points. The intravenous tPA therapy was not applied because it was not available in our institution yet. Diffusion MR images demonstrated no abnormal findings (Fig. 2B) and MR angiograms disclosed a left cervical ICA occlusion. Cerebral angiography demonstrated complete occlusion of the left CCA (Fig. 2C) and a collateral flow through the anterior communicating artery (ACoA) (Fig. 2D). Urgent open embolectomy was carried out because subsequent CT scans after

angiography showed no early ischemic changes. A giant embolus was lodged in the left common carotid bifurcation and proximal ICA, which was removed 5 hours after onset (Fig. 2E). CEA was additionally performed for moderate stenosis of the proximal ICA using an internal shunt device. The size of extracted emboli was 65 mm (length) by 8 mm (width) (Fig. 2F). Angiography was immediately carried out, which revealed full recanalization of the left CCA and no distal embolic occlusions (Fig. 3A and 3B). Histological findings of the emboli and the thickened intima were fibrinous thrombi and atheroma with calcification. Postoperatively, her right hemiplegia resolved and aphasia improved. Follow-up CT scans only showed a watershed infarction in the left frontal lobe (Fig. 3C). The patient was discharged with mild motor dysphasia on postoperative day 11, and modified Rankin Scale (mRS) after 6 months was 1.

Case 2

A 42-year-old man was transferred to our institution with progressive left hemiplegia 4 hours after onset. Neurological examinations showed 17 points of NIHSS score and admission CT scans demonstrated no abnormal lesions (Fig. 4A). Subsequent angiography disclosed a complete occlusion of the right cervical ICA (Fig. 4B) and some collateral flow through the ACoA and retrograde filling of the ophthalmic artery (Fig. 4C). Since subsequently taken CT scans revealed no low-density area, open embolectomy was carried out. Giant embolus filled the right cervical ICA and extracted, and the onset-to-recanalization time was 10 hours 50 minutes. The removed emboli were 84 mm (length) by 9 mm (width) in size (Fig. 4D). A thickened intima was not found in the internal lumen of the right cervical ICA. Although complete recanalization of the right ICA was confirmed and no distal embolic occlusion was observed on the immediate postoperative angiograms (Fig. 4E, 4F), follow-up CT scans revealed new infarctions suggested hemodynamic cause without hemorrhagic change in the right frontal lobe and right basal ganglia distributed by perforators originating from the anterior and middle cerebral arteries (Fig. 4G). Postoperatively, left severe hemiparesis remained and he was transferred for rehabilitation on postoperative day 30. He became ambulant with a short leg brace and cane, and mRS at 6 months after the onset was 3.

Case 3

A 72-year-old healthy man presented with sudden-onset right hemiplegia and aphasia and was hospitalized approximately 3 hours after onset. There were 22 points of NIHSS score on his neurological findings and no abnormal findings on baseline CT studies. Cerebral angiography demonstrated complete occlusion of the left cervical ICA (Fig. 5A) and some collateral flow through the ACoA, posterior communicating artery and retrogradely filled ophthalmic artery. CT scans obtained after angiography revealed no early ischemic signs, and urgent open embolectomy was performed. An embolus was not identified in the left bifurcation of CCA and backflow was not achieved in the declamped ICA. Long stretched emboli in the distal ICA were pulled and removed using an internal shunt device, vigorous backflow then expelled. The size of extracted emboli was 114 mm (length) by 5.5 mm (width) (Fig. 5B) and the time to recanalization from onset was 5 hours 30 minutes. Immediate angiography demonstrated complete recanalization of the left ICA and no distal embolic occlusion (Fig. 5C and 5D). The patient fully recovered and follow-up CT scans showed no abnormal findings. The patient was discharged without any neurological deficits on postoperative day 11 and mRS was 0 at 6 months after the onset.

Discussion

This present study shows that urgent open embolectomy is technically feasible in patients with acute cardioembolic cervical ICA occlusion; in addition, it may lead to improvement of profound neurological symptoms and favorable prognosis. Atherothrombosis is the major cause of cervical ICA occlusions, whereas cardioembolism is relatively rare. Acute atherothrombotic cervical ICA occlusion with hemodynamic impairment portends a particularly worse prognosis being associated with early clinical deterioration and late stroke recurrence risk [3]. Several authors have reported successful emergency recanalization for atherothrombotic cervical ICA occlusion [7, 8, 12, 13, 16, 18]. However, such treatments remain controversial. Neither surgical nor endovascular intervention is currently the standard procedure, because of the risks involved, including injury of the intima, distal embolism and hemorrhagic infarction. These emergency revascularizations may only be indicated in

selected patients with clinical fluctuations or deterioration from presumed hemodynamic instability. In contrast, detailed reports on emergency revascularization for acute cardioembolic cervical ICA occlusion are absent in literature.

Embolism of cardiac origin accounts for over one quarter of all ischemic strokes [4]. Atrial fibrillation remains the most common cause of cardioembolic stroke and is the commonest sustained cardiac arrhythmia. In our cases, all had atrial fibrillation and all emboli were very large and fibrinous in histological findings. In elder patients with atrial fibrillation, left atrial enlargement and other co-morbidities may increase the propensity for the formation of larger thrombus in the left atrium [11]. Small emboli are destined to lodge in the cerebral circulation as a result of hydrodynamic, anatomic, and physical factors [10, 11]. Large emboli are likely to bypass the cerebral arteries merely as a function of size and cause ischemic occlusion of larger-diameter arteries, such as in the lower extremities.

In the acute cardioembolic occlusion involving the carotid axis, the most common site of embolism may be at the bifurcation of the MCA, at branches of the MCA, or at the carotid terminus [19]. In analysis of thrombi retrieved from cerebral arteries of patients with acute ischemic stroke, no thrombus more than 3-mm width was removed from the MCA, and no thrombus more than 5-mm width was extracted from the intracranial ICA [10]. The size of embolus determines ultimate destination, those more than 5-mm width are likely to bypass the cerebral vessels entirely. Therefore, cardioembolic occlusion of cervical ICA may be rare. In our cases, all emboli were large and retrieved in some fragments. The mean size of extracted embolus was 87.5 mm (length) by 7.5 mm (width) and all emboli were over 5 mm wide. Although the cervical ICA occlusions are usually caused by atherothrombosis, cardioembolism should be also considered in patients presented with atrial fibrillation, because large embolus might be lodged into the cervical ICA as in our patients.

The primary goal in treating a patient with the acute ischemic stroke is to restore the cerebral blood flow as rapidly and safely as possible. Currently, the acute ischemic stroke represents a major therapeutic challenge. Intravenous tPA therapy needs to meet the strict inclusion criteria, in which only accounts for 5% of patients with acute ischemic stroke, and achieves early recanalization in only 30%-50% of patients treated with tPA, even with lower recanalization rates in the intracranial large vessel occlusions (MCA, carotid terminus, and basilar artery) [17]. The resistance of large clots to tPA has been suggested by experimental studies [21]. A large and long embolus occluding the cervical ICA may also respond poorly. Thus, an alternative intervention is needed to achieve early recanalization in larger artery occlusions.

In thromboembolic intracranial large vessel occlusion, a number of endovascular approaches designed for revascularization, such as intraarterial fibrinolysis [5] and mechanical thrombectomy [15], have been reported with relatively high-recanalization rate for patients who neither included in the criteria for intravenous fibrinolytic therapy nor obtained recanalization by the intravenous fibrinolytic therapy. In addition, alternative surgical procedure such as emergency open embolectomy has been reported to obtain complete recanalization in patients with insufficient recanalization of acute MCA occlusion following intraarterial fibrinolysis [6].

In cardioembolic cervical ICA occlusion, however, feasibility of urgent recanalization by endovascular procedures remains unclear. Intraarterial fibrinolitic therapy for occluded larger artery may be less effective than that for MCA [15]. At present, endovascular retrieval devices are approved only for intracranial thrombectomy such as Merci retriever device in the limited countries [15]. We have no experience with the retrieval device and no information on whether large embolus lodged into the cervical ICA is able to be removed using the device only for intracranial thrombectomy. Instead of the endovascular approach, we performed open embolectomy. It is technically easier and similar to the CEA, which becomes a standard surgical procedure and is attempted in worldwide. Complete recanalization was achieved in our cases without any complications. However, the potential benefit of emergency recanalization has to be balanced against procedure-related complications including injury of intima, distal embolism, or hemorrhagic infarction. After embolus was directly removed via arteriotomy, if no backflow was observed, remaining embolus in the distal ICA was pulled using a FURUI's Double-Balloon Internal Shunt device, and vigorous backflow was achieved. A balloon embolectomy catheter such as Fogarty catheter for extraction of clots in the distal ICA was used in the previous reports describing emergency CEA or CTEA for atherothrombotic occlusion [8, 12, 13, 18]. The maneuver of retrieving embolus

in the distal ICA probably avoids risks of injury of intima and distal embolism more with using shunt device rather than using Fogarty catheter because the catheter has to pass through the embolus and has to extract the embolus after inflation of the balloon.

There are various factors affecting the prognosis in the cardioembolic cervical ICA occlusion cases: how much collateral circulation has developed, whether the lesion site is left or right, and the onset-to-recanalization time. We consider that the most important indications for urgent open embolectomy is no ischemic signs on CT scan obtained both initially and immediately after angiography, and the presence of collateral blood flow to the affected ICA territory on angiography. These findings in the ischemic area mean the possibility of maintained collateral blood flow and therefore indicate the possibility of saving this area with open embolectomy. However, successful recanalization does not always result in favorable outcome. Although the patient's blood pressure was stringently managed perioperatively, large infarctions on follow-up CT scan were shown in one patient (Case 2). It is very difficult to assess whether there is sufficient residual blood flow and how long ischemic penumbra can be tolerated. The development of collateral circulation varies among individual patients. Cerebral blood flow study was not performed in our cases in order to start treatment as early as possible. However, it will be necessary to reduce a risk of hemorrhagic infarction. MR images involving perfusion-weighted (PWI) and diffusion-weighted images (DWI) may be helpful to indicate patients for urgent recanalization. Patients without large hyperintensity lesion on DWI and with a PWI/DWI mismatch are probably ideal candidates. The cerebral blood flow study will be added as our treatment protocol in the near future.

It is very difficult to distinguish cardioembolic occlusion from atherothrombotic occlusion of the cervical ICA because both clinical features and neuroimages are similar. In 2 (Case 1, 2) of 3 patients, cerebral angiography revealed no deferential findings to atherothrombotic complete occlusion. Although the site of occlusion was not visible in all patients on ultrasonography, differential findings between plaque and embolus may be clarified. In addition, carotid plaque MR imaging allows visualization of diseased vessel wall and characterization of the morphology of the atherosclerotic carotid plaque [20]. It may be possible to distinguish embolus from carotid plaque in the acute complete occlusion of ICA using plaque imaging. An atherothrombotic occlusion is frequently associated with an intracranial tandem occlusion, and the absence of a tandem lesion may be predictive of a favorable outcome in patients who undergo emergent stenting [7]. A cardioembolic occlusion may be less associated with a tandem occlusion because of no presence in our patients, and urgent recanalization may achieve a favorable outcome.

The singular weakness of our study is its small sample size, which renders discussion speculative. However, the one of the value in this work is that it alerts readers to an existence of cardioembolism in the cervical ICA occlusion. Therefore, possibility of cardioembolism should be considered in patients with the acute ischemic stroke caused by occluded cervical ICA with profound neurological deficits and atrial fibrillation. Moreover, urgent open embolectomy may be an advisable surgical option for this entity.

Conclusion

This present study describes urgent open embolectomy for treatment of cardioembolic occlusion of the cervical ICA, which results in successful recanalization in all patients without any complications. The cardioembolic occlusion of the cervical ICA is rare, but its possibility should be considered in patients with the acute ischemic stroke suffering profound neurological deficits and atrial fibrillation. Urgent open embolectomy may represent an advisable surgical option even if it is difficult to differentiate the cardioembolic occlusion from the atherothrombotic occlusion. This procedure is recommended because it is technically easier and similar to the CEA.

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Figure Legends:

Fig. 1 The maneuver of retrieving embolus illustrating using a FURUI's Double-Balloon Internal Shunt device

A: Shunt device with clamping tube of unilateral side is inserted into the left proximal internal carotid artery (ICA), and an embolus is pulled by a 10-ml syringe after inflation of balloon (black arrowhead). The white arrow showing pressure of pulling syringe. The black arrow showing backflow to the ICA from a collateral flow. B: Shunt device is removed with embolus after deflation of balloon.

Fig. 2 Case 1. A 73-year-old woman. A: Initial CT scan showing no early ischemic signs. B: Diffusion MR image demonstrating no abnormal findings. C: Left common carotid artery (CCA) angiogram, lateral view, disclosing the left CCA occlusion. D: Right carotid artery angiogram, anteroposterior view, revealing a collateral flow to ICA territory via the anterior communicating artery. E: Intraoperative photograph showing a removed giant embolus in the left CCA. F: Postoperative photograph showing some retrieved emboli.

Fig. 3 Case 1. A 73-year-old woman. A and B: Immediate postoperative angiograms, lateral view of left CCA injection, demonstrating CCA recanalization and no distal embolic occlusions. C: Follow-up CT scan revealing the left frontal infarction.

Fig. 4 Case 2. A 42-year-old man. A: Admission CT scan showing no early ischemic signs. B and C: Right CCA angiograms, lateral view, disclosing the right cervical ICA occlusion and a collateral flow to the right distal ICA via retrograde filling of the right ophthalmic artery. D: Postoperative photograph showing extracted emboli. E and F: Immediate postoperative angiogram, lateral view of right CCA injection, demonstrating complete ICA recanalization and no distal embolic occlusion in the right ICA territory. G: Follow-up CT scan revealing a large low-density area at the right frontal lobe and basal ganglia.

Fig. 5 Case 3. A 72-year-old man. A: Left CCA angiogram, lateral view, disclosing the left proximal ICA occlusion and a collateral flow to the left distal ICA through retrograde filling of the left ophthalmic artery. B: Postoperative photograph showing retrieving emboli. C and D: Immediate postoperative angiograms, lateral view of left CCA injection, demonstrating the ICA recanalized and no distal embolic occlusions.

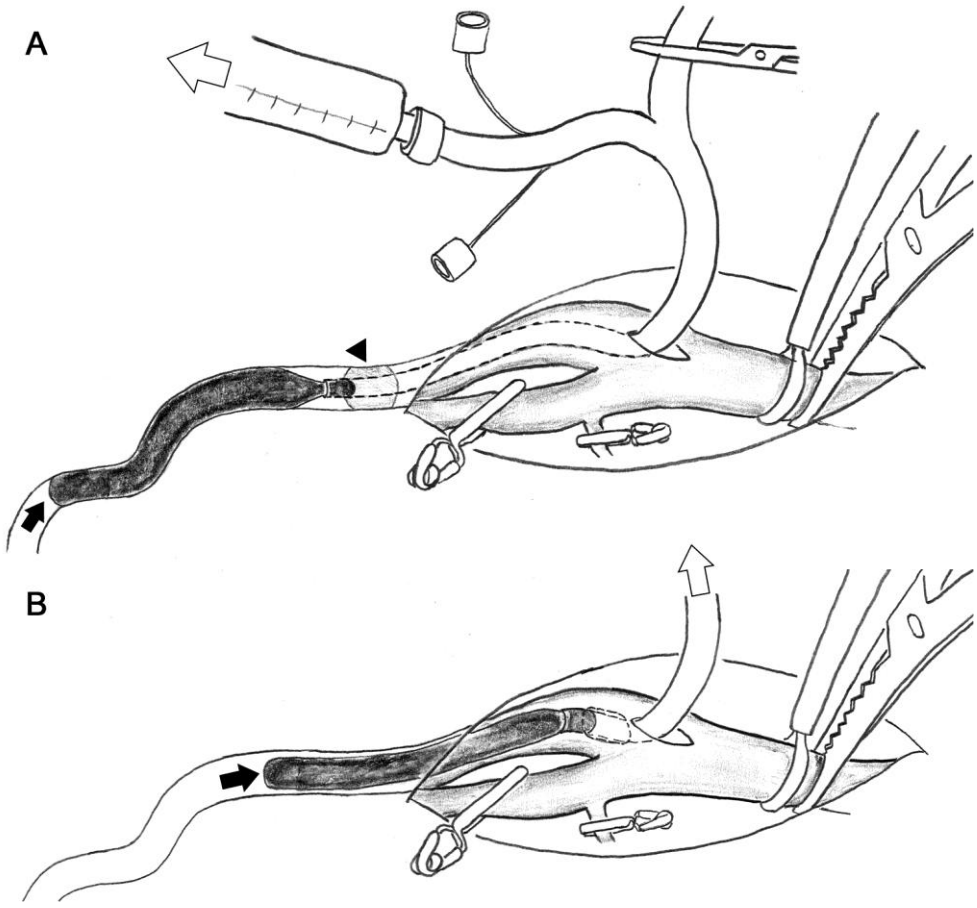
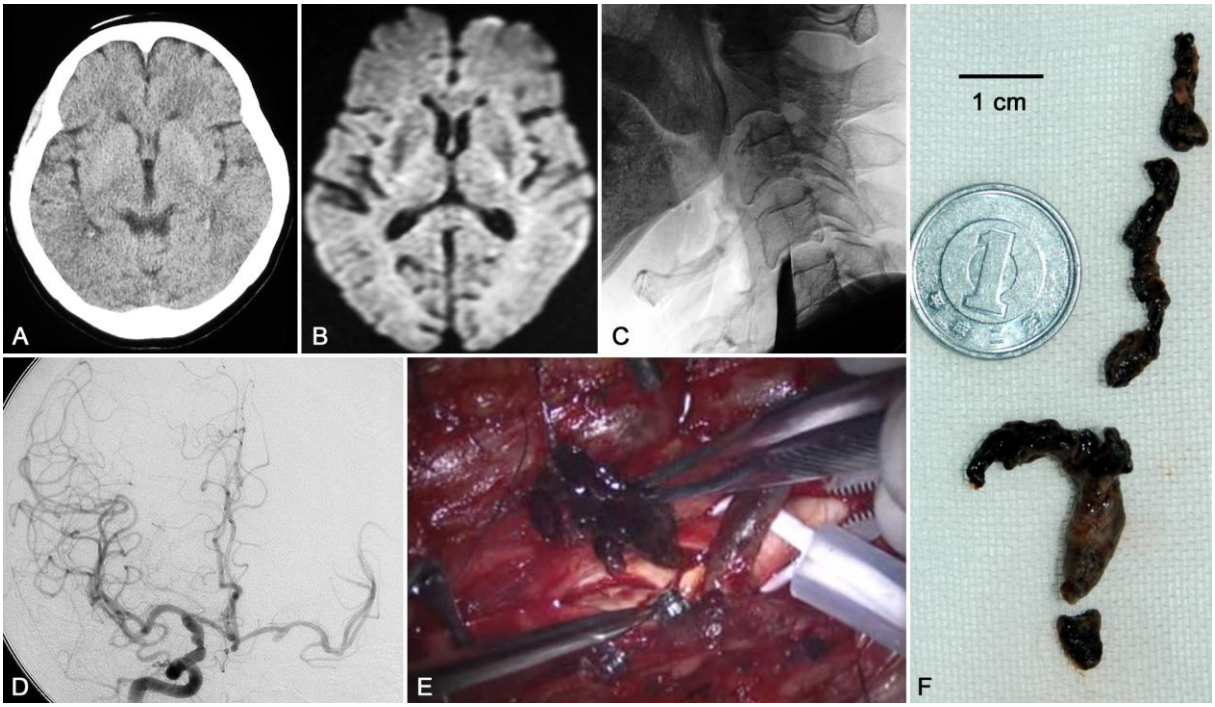


Fig. 1



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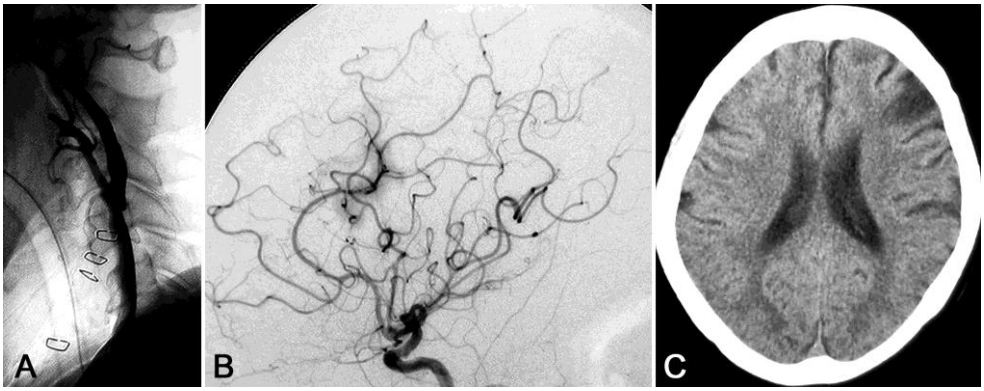

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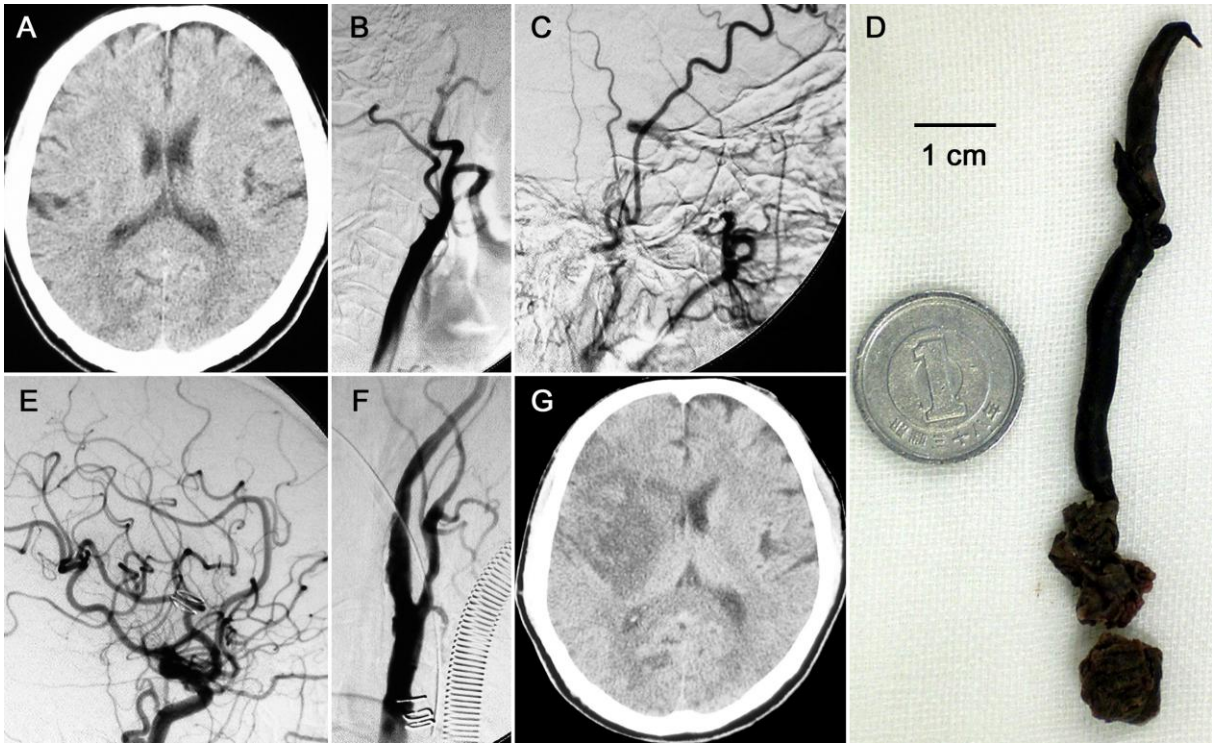

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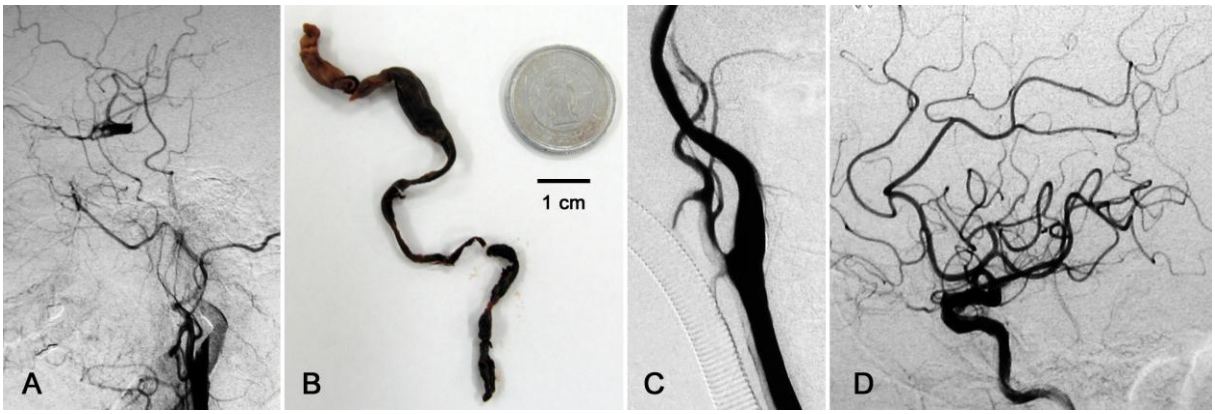

Fig. 5