Surgical procedures including carotid-carotid crossover bypass and ring-stripping hybrid operation for Rile's type 1A common carotid artery occlusion: an experience of 6 cases

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Background: At present, there is no consensus on the treatment of common carotid artery occlusion (CCAO). We explored the surgical indications and observed the therapeutic effects of carotid-carotid crossover bypass and ring-stripping hybrid operation for treatment of Rile's type 1A CCAO.

Methods: The imaging data, clinical manifestations, surgical complications and postoperative ischemic events were retrospectively collected from the 6 cases with Rile's type 1A CCAO that underwent surgery in our department from 2011 to 2018. Of the 6 cases, 4 received carotid-carotid crossover bypass and 2 ring-stripping hybrid operation.

Results: Of the 6 cases, 4 were male and 2 females, with a mean age of 62.7 years. All cases had the left CCAO combined with decreased computed tomography perfusion (CTP) in the left internal carotid artery blood supply area. In the 4 cases receiving carotid-carotid crossover bypass, the mean operation time was 186±13 min, the mean hospital stay was 17±1 d, postoperative CTP improved, one case had swallowing foreign body sensation, synthetic vascular grafts were patent and no ischemic events occurred during the mean follow-up of 62.3±26.3 months. In the 2 cases receiving ring-stripping hybrid operation, the mean operation time was 118±11 min, the mean hospital stay was 5.5±0.7 d, postoperative CTP improved, and the opened common carotid arteries (CCA) were patent and no ischemic events occurred during the mean follow-up of 17.5±3.5 months.

Conclusions: Rile's type 1A CCAO with related symptoms and decreased CTP should be treated by revascularization. The carotid-carotid crossover bypass is a good choice in bypass schemes because of its easy operation and good long-term patency. The ring-stripping hybrid operation may be an ideal surgical scheme for Rile's type 1A CCAO.

Keywords: Common carotid artery occlusion (CCAO); Rile's typing; crossover bypass; hybrid operation

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Introduction

In carotid artery occlusion, internal carotid artery occlusion has attracted a great deal of attention, while common carotid artery occlusion (CCAO) is often ignored. Since external carotid artery occlusion generally does not cause patients' symptoms, so the CCAO is usually confused with the internal carotid artery occlusion. In fact, CCAO and internal carotid artery occlusion are completely different in

incidence, clinical manifestation and therapeutic method. The incidence of chronic internal carotid artery occlusion is about 6/100,000 (1). In the internal carotid artery occlusion, if collateral circulation compensation is good, the patients may have no symptoms; if the collateral circulation compensation is poor, the patients may suffer from transient ischemic attack, or mild or severe ischemic stroke. Although the carotid occlusion surgery study (COSS) randomized trial has indicated that the therapeutic effect of external carotis-internal carotis bypass is not better than that of drug therapy for the internal carotid artery occlusion (1), some studies have shown that bypass can effectively reduce the incidence of stroke in the patients with internal carotid artery occlusion who are consistent with rigorous inclusion criteria (2,3). Besides the bypass, intravascular intervention has also been used in the treatment of internal carotid artery occlusion, but it may bring a certain risk (4,5). The CCAO incidence is low, accounting for about 0.5% of the patients with ischemic stroke found by Doppler ultrasound (6), and only 2–4% of the patients with symptomatic cerebral blood supply deficiency confirmed by angiography (7). Most patients with CCAO (94.5%) have symptoms mainly including hemispheric blood supply deficiency, hemispheric stroke, amaurosis, etc. (8).

In 2011, American Stroke Association (ASA) Guide recommended revascularization for patients with symptomatic ischemia involving the anterior cerebral circulation caused by common carotid or brachiocephalic artery occlusive disease, but it did not describe specific surgical scheme (9). So far 285 patients with CCAO have received surgical treatments including open surgery and intravascular intervention (10-18). There is no consensus on CCAO treatment, and the points in controversy are whether the asymptomatic patients require surgical treatment, and which surgical scheme is the best. It has been reported that Rile's type 1A CCAO is the most likely to benefit from surgical treatment (8,10).

In this study, we retrospectively analyzed the surgical therapeutic effects of 6 patients with symptomatic Rile's type 1A CCAO including 4 cases receiving carotid-carotid crossover bypass from 2011 to 2016 and 2 cases receiving ring-stripping hybrid operation from 2017 to 2018, providing a beneficial experience for the treatment of Rile's type 1A CCAO.

Methods

Statement of ethics approval

The study was approved by Ethics Committee of the Third Affiliated Hospital, Sun Yat-Sen University (NO.: [2019]02-259-01) and informed consent was taken from all the patients.

Subjects

The patients with CCAO that received surgical treatment in our hospital between 2011 and 2018 were retrospectively collected in this study. The inclusion criteria were: (I) CCAO confirmed by Doppler ultrasound, CT and digital subtraction angiography (DSA) as well as caused by atherosclerosis; (II) having symptoms of ischemic stroke or cerebral insufficiency caused by ipsilateral CCAO; and (III) decreased computed tomography perfusion (CTP) in the CCAO blood supply area. The exclusion criteria included: (I) infectious arterial lesion; (II) acute arterial occlusion; (III) a history of radiotherapy; (IV) ipsilateral anterior circulation aneurysm; or (V) Rile's type 1B or 2 CCAO.

Preoperative imaging examination and medication

After admission, all patients underwent cervical and head computed tomography angiography (CTA) to show the condition of vascular patency, head CTP to indicate the condition of cerebral perfusion on CCAO side, and DSA to know CCAO length and the compensatory status of cerebral blood flow on CCAO side.

Fasting blood glucose was controlled under 11.1 mmol/L, blood pressure under 140/90 mmHg and low-density lipoprotein under 2.6 mmol/L in all patients. The patients receiving carotid-carotid crossover bypass took aspirin (100 mg) qd and atorvastatin (40 mg) qn within preoperative 5 days, while the patients receiving ring-stripping hybrid operation also took clopidogrel (75 mg) qd besides aspirin (100 mg) qd and atorvastatin (40 mg) qn.

Surgical procedures

All patients underwent operation in supine position under general anesthesia in hybrid operating rooms.

Carotid-carotid crossover bypass

After exposing the distal end and bifurcation of the affected common carotid artery (CCA) and the middle part of the contralateral CCA, retropharyngeal space was separated by fingers, and then a synthetic vascular graft (IRS46045L; W. L. Gore & Associates, Newark, Delaware, USA) passed through it. After systemic heparinization (100 U/kg), the

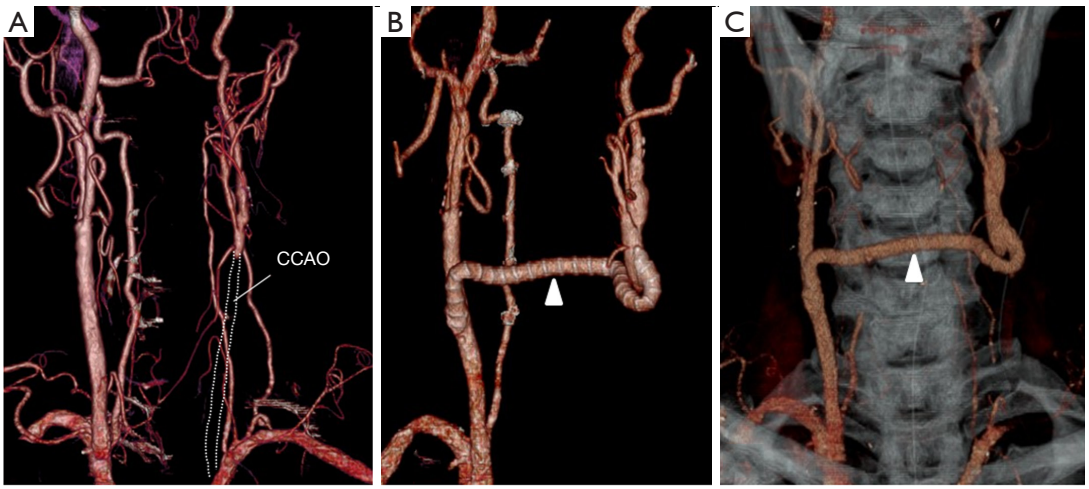

Figure 1 Rile's type 1A left common carotid artery occlusion in a 67-year-old man. (A) The dashed lines indicate an occlusive common carotid artery; (B,C) The arrows indicate the patent synthetic vascular graft after carotid-carotid crossover bypass.

end to side anastomosis between the synthetic vascular graft and the distal end of the affected CCA was first performed. If the CCA stump was short or the internal carotid was stenotic, carotid endarterectomy (CEA) was carried out to enlarge the outflow tract. After the blood pressure was increased to 120% of basic blood pressure followed by blocking CCA, the end to side anastomosis between the synthetic vascular graft and the middle part of the contralateral CCA was performed. After that, the blood pressure was decreased to normal, the blocked CCA was released, heparin was neutralized, and femoral artery puncture angiography was performed to show the patent condition of the synthetic vascular graft (*Figure 1*).

Ring-stripping hybrid operation

Aortic arch angiography was performed by femoral artery puncture to determine the initial part of the occlusive CCA, and then an 8F guide catheter was placed near the initial part. The affected CCA was exposed from its stump to middle part followed by systemic heparin (100 U/kg). After blocking CCA stumps but retaining internal carotid artery blood flow, two 1–2 cm cuts were made at the distal end and middle part of the affected CCA, respectively, along vascular long axis. The plaque in the distal end was separated and retrogradely pushed to the middle cut using ring stripper followed by removal of the plaque. After the cut in the distal end was sutured, under the guidance of fluoroscopy and roadmap, the ring stripper was placed into the middle cut and was retrogradely pushed to the proximal end of the affected CCA until arterial blood was ejected. After releasing the blocked CCA, CCA angiography was performed to know the patent condition. If the residual stenosis in the CCA and internal carotid artery was more than 50%, a stent was placed. Finally, the incision was closed (*Figure 2*).

Postoperative treatment and follow-up

All patients took aspirin (10 mg/d) for lifetime and atorvastatin (20 mg/d) for 3 months. The patients receiving stent took clopidogrel (75 mg/d) for 3 months besides aspirin (10 mg/d) and atorvastatin (20 mg/d). Head CTA and CTP were performed on the first day after operation. Doppler ultrasound was performed 6 and 12 months after operation, and then every year it was performed to show the patent condition of blood vessels. Postoperative complications, clinical manifestations and ischemic events were recorded.

Results

Patients' general data

From 2011 to 2018, 6 cases with Rile's type 1A CCAO received surgery in our department. Of the 6 cases, 4 were male and 2 females, with a mean age of 62.7 years. Their symptoms included amaurosis, somnolence, transient ischemic attack (TIA) and limb weakness. In the 6 cases, 4 had hypertension, 3 diabetes mellitus, one coronary heart disease and 4 a history of smoking. All the 6 cases had

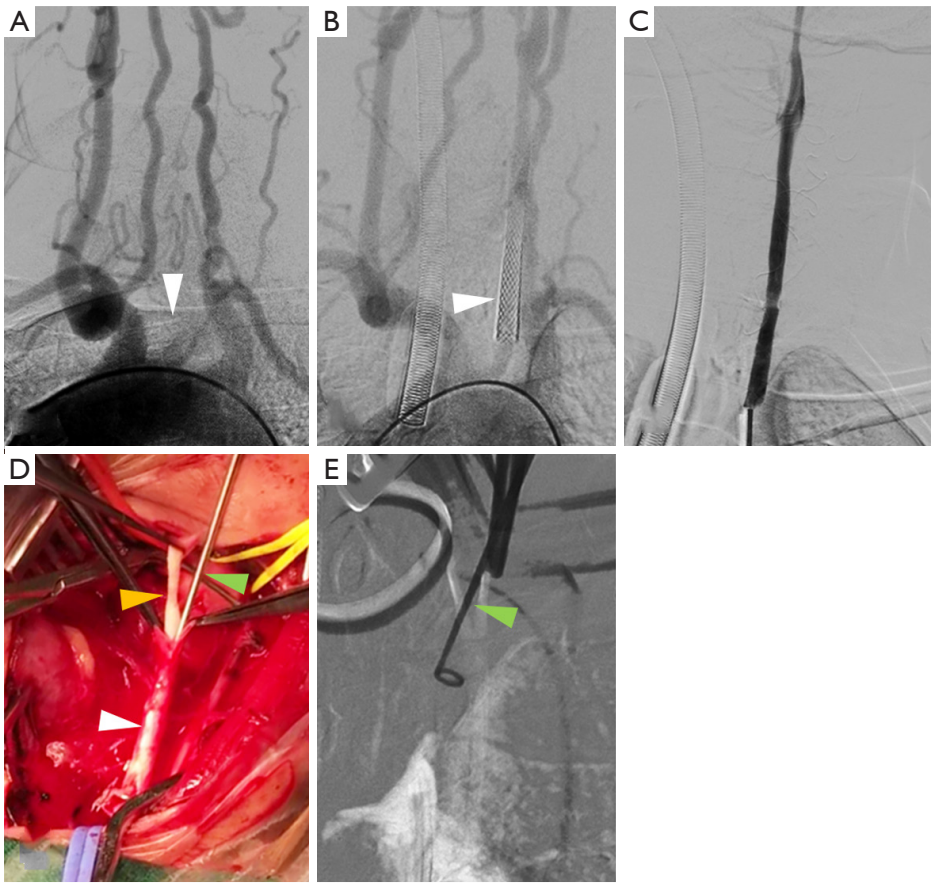

Figure 2 Rile's type 1A left common carotid artery occlusion in a 54-year-old woman. (A) The arrow indicates the left common carotid artery stump; (B) the arrow indicates the patent common carotid artery after ring-stripping hybrid operation; (C) postoperative arteriography shows patent common carotid artery and stent; (D,E) retrogradely opening under direct vision and fluoroscopy, respectively. The white arrow indicates the common carotid artery, the yellow arrow the separated plaque, and the green arrow a ring stripper.

the left CCAO combined with decreased CTP in the left internal carotid artery blood supply area (*Table 1*).

Surgical outcomes and follow-up

Of the 6 cases, 4 received carotid-carotid crossover bypass and 2 ring-stripping hybrid operation. In the 4 cases receiving carotid-carotid crossover bypass, the mean operation time was 186±13 min, the mean time of blocking the contralateral CCA was 19±4 min, the mean hospital stay was 17±1 d, postoperative CTP improved (*Figures 3*,*4*), one case had swallowing foreign body sensation, and synthetic vascular grafts were patent and no ischemic events occurred during the mean follow-up of 62.3±26.3 months. In the 2 cases receiving ring-stripping hybrid operation, the mean operation time was 118±11 min, the contralateral CCA did not need to be blocked, the mean hospital stay was 5.5±0.7 d, postoperative CTP improved, and the opened CCA was patent and no ischemic events occurred during the mean follow-up of 17.5±3.5 months (*Table 2*).

Discussion

Why did we select the patients with Rile's type 1A CCAO for surgery? and what are the surgical indications for treatment of Rile's type 1A CCAO?

CCAO incidence is low and there are a few reports about CCAO. There are no guidelines and consistent opinions on its treatment. Its natural history, surgical indications and best surgical scheme are not clear. We explored the surgical treatment for CCAO based on reviewing some studies.

Table 1 Patients' general data

Case	Age	Sex	Symptom	Hypertension	Diabetes	Coronary heart disease	Smoking	Side	CTP
1	69	F	Amaurosis	Yes	No	No	No	Left	Reduction
2	49	M	Limb weakness	Yes	Yes	No	Yes	Left	Reduction
3	68	M	Somnolence, TIA	Yes	No	Yes	Yes	Left	Reduction
4	67	M	TIA	No	Yes	No	Yes	Left	Reduction
5	54	F	Dizziness	No	No	No	No	Left	Reduction
6	69	M	Dizziness, TIA	Yes	Yes	No	Yes	Left	Reduction

F, female; M, male; CTP, computed tomography perfusion; TIA, transient ischemic attack.

CCAO is divided into four types including Rile's type 1A CCAO, Rile's type 1B CCAO, Rile's type 1C CCAO and Rile's type 2 CCAO (*Figure 5*). Type 1C is generally a purely theoretical variant. Type 1A is the most common type, accounting for 61.5% of CCAO. Type 1B and type 2 account for 26.6% and 11.9%, respectively (10). Only 4 cases with Rile's type 2 CCAO underwent revascularization (2 cases receiving vertebral artery-middle cerebral artery and 2 cases subclavian artery-external carotid artery) (19,20). Riles *et al.* (8) considered that surgical treatment was ineffective for Rile's type 2 CCAO. For the surgical treatment of Rile's type 1B CCAO, there were two main surgical schemes including subclavian artery-external carotid artery and axillary artery-external carotid artery, which provided intracranial blood supply by increasing the blood flow of the external carotid artery, but the surgical therapeutic effects on Rile's type 1B CCAO were not ideal. In Rile's type 1A CCAO, cerebral ischemia symptoms such as TIA, limb weakness and somnolence, often occur because intracranial blood supply only from the anastomosis branches of vertebral artery—external carotid artery and thyrocervical trunk-external carotid artery is insufficient, but Rile's type 1A CCAO is most likely to benefit from revascularization because it has normal outflow tract (internal carotid artery). Therefore, the patients that had Rile's type 1A CCAO and cerebral ischemia symptoms were selected to receive surgical treatment in this study. Most of the patients with Rile's type 1A CCAO have cerebral ischemia symptoms such as TIA, limb weakness, somnolence and cognition disorders; and some patients with Rile's type 1A CCAO have posterior circulation ischemia symptoms such as amaurosis and dizziness which are associated with vertebral artery steal blood. The purpose of surgical treatment for Rile's type 1A CCAO is to prevent possible ischemic stroke and to improve cerebral blood supply. In the past, the choice of surgical treatment for Rile's type 1A CCAO mainly depended on whether patients had cerebral ischemia symptoms without considering the condition of brain tissue perfusion (11). In fact, brain tissue perfusion is strongly associated with cerebral apoplexy. In the 6 cases of this study, the preoperative CTP all decreased and postoperative CTP all improved. Therefore, we believe that the surgical indications for CCAO are: (I) Rile's type 1A CCAO confirmed by vascular imaging; (II) CCAO-related symptoms; and (III) decreased CTP in the occlusion-side internal carotid artery blood supply area.

For the treatment of Rile's type 1A CCAO, there are many surgical schemes which may be classed into bypass and opening *in situ* (8,10-15,21).

Why choose cardioid-carotids crossover bypass in many Bypass schemes?

In the bypass schemes for treatment of Rile's type 1A CCAO, the ipsilateral subclavian artery is mostly used as a blood supply vessel, followed by the axillary artery. Klonaris *et al.* (10) reviewed 21 articles contained 58 cases receiving bypass surgery for treatment of Rile's type 1A CCAO. Of the 58 cases, the subclavian artery was used as a blood supply vessel in 28 cases (48.3%, 28/58) with a postoperative patency rate of 85.7% (24/28), and the axillary artery as a blood supply vessel in 26 cases (44.8%, 26/58) with a postoperative patency rate of 88.5% (23/26). The subclavian artery is deep in the supraclavicular fossa and is surrounded by the brachial plexus, jugular vein, lymphatic vessel and apex pulmonis, so it is difficult to expose it and the operation space is limited. The exposure and operation space for the axillary artery are superior to that for the subclavian artery, but the bridge vessel pathway is longer. The postoperative patency rate of carotid-carotid crossover

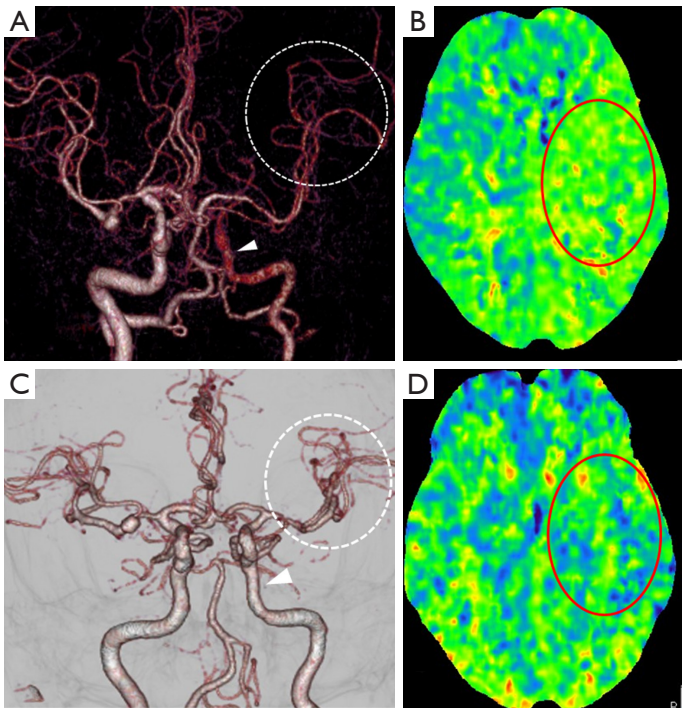

Figure 3 Rile's type 1A left common carotid artery occlusion in a 67-year-old man. (A) In the preoperative head CTA, the arrow indicates the left internal carotid artery and the circle indicates its branches; (B) in the preoperative CTP, the oval indicates the extended MTT; (C) after carotid-carotid crossover bypass, the arrow indicates the left internal carotid artery and the circle indicates its branches in CTA; (D) in the postoperative CTP, the oval indicates the improved MTT. CTA, computed tomography angiography; CTP, computed tomography perfusion; MTT, mean transit time.

bypass is high. Ozsvath *et al.* (12) reported the long-term patency rate was 94% in 24 cases receiving carotid-carotid crossover bypass. In this study, the bridge vessel was patency during 34- to 93-month follow-up in the 4 cases receiving carotid-carotid crossover bypass. The advantages of carotid-carotid crossover bypass are that (I) its technology is simple, so the doctor who has a good grasp of CEA can perform it; (II) contralateral CEA may be performed simultaneously if there is atherosclerotic stenosis in the contralateral CCA; and (III) its complications are lower than that of subclavian artery blood supply because Law *et al.* (22) have reported that the incidences of complications and nerve injury are 35% and 8.7%, respectively, in subclavian artery-CCA bypass.

At present, most of the bridge blood vessels are veins, followed by synthetic vascular grafts. In this study, the 4 cases all used polytetrafluoroethylene (PTFE) synthetic vascular grafts as bridge vessels, obtaining better therapeutic effects. PTFE synthetic vascular grafts have support rings similar to tracheal rings, which overcomes the shortcomings of easy distortion and compression of venous vessels; and synthetic vascular grafts do not require heparin or other anticoagulant drugs after bypass. Therefore, we think that synthetic vascular grafts should be used as the first choice for bridge vessels, which is consistent with the viewpoint of Ziomek *et al.* (23).

Advantages of ring-stripping hybrid operation

Apparently, opening occlusive CCA *in situ* is the best for restoring normal physiological channel. However, it is difficult and dangerous only to use catheter and guide wire to open occlusive CCA, because catheter and guide wire cannot easily pass through large calcified plaques, and exfoliated plaques are likely to cause far-end infarction. Hybrid operation overcomes the above shortcomings, greatly increasing the probability of opening occlusive CCA and reducing the incidence of far-end infarction. The advantages of ring-stripping are as follows: (I) only blocking CCA stump and retaining internal carotid artery blood flow without reduction of intracranial blood supply during

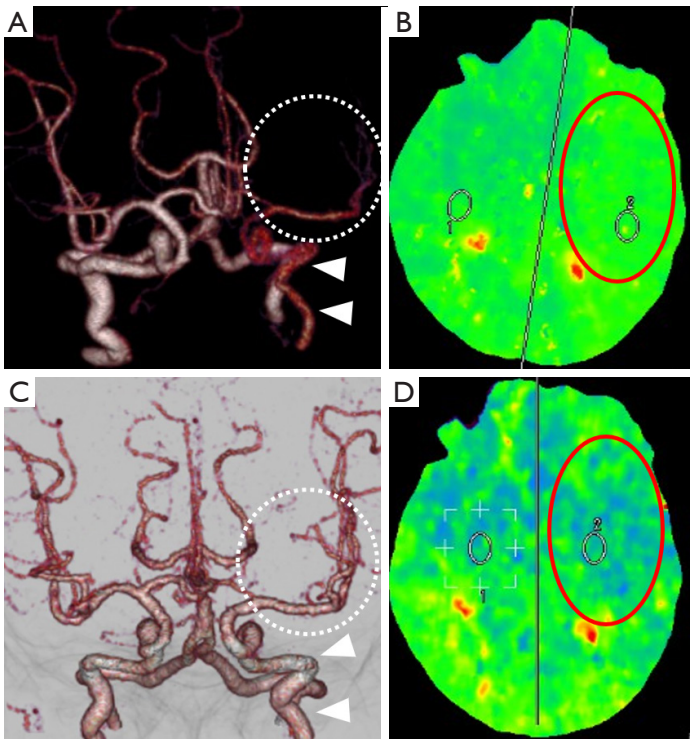

Figure 4 Rile's type 1A left common carotid artery occlusion in a 54-year-old woman. (A) In the preoperative head CTA, the arrows indicate the left internal carotid artery and the circle indicates its branches; (B) in the preoperative CTP, the oval indicates the extended MTT; (C) after ring-stripping hybrid operation, the arrows indicate the left internal carotid artery and the circle indicates its branches in CTA; (D) in the postoperative CTP, the oval indicates the improved MTT. CTA, computed tomography angiography; CTP, computed tomography perfusion; MTT, mean transit time.

Table 2 Operative outcomes and follow-up

Case	Surgical manner	Operation time (min)	Blocking CCA time (min)	Hospital stay (d)	Complication	Follow-up (m)	Patency	Ischemic events	CTP
1	Crossover bypass	185	18	19	No	95	Yes	No	Improved
2	Crossover bypass	175	17	17	No	71	Yes	No	Improved
3	Crossover bypass	205	24	16	No	47	Yes	No	Improved
4	Crossover bypass	180	16	16	Foreign body sensation	36	Yes	No	Improved
5	Hybrid operation (ring stripping)	125	0	6	No	20	Yes	No	Improved
6	Hybrid operation (ring stripping)	110	0	5	No	15	Yes	No	Improved

CCA, common carotid artery; CTP, computed tomography perfusion.

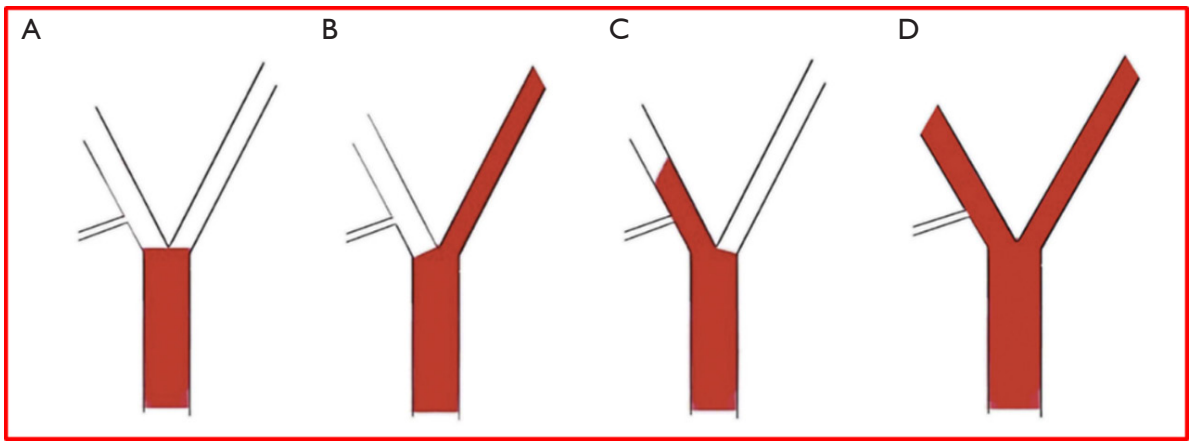

Figure 5 Riles classification of CCAO. (A) CCA occlusion with preserved circulation in the ICA and ECA; (B) CCA and ICA occlusions with preserved circulation in the ECA; (C) CCA and ECA occlusions with preserved circulation in the ICA; (D) CCA and ICA occlusions with extension to the proximal ECA. CCAO, common carotid artery occlusion; CCA, common carotid artery; ECA, external carotid artery; ICA, internal carotid artery.

operation; (II) removing most of the plaques by ring-striper, and reducing the chance of restenosis; (III) reducing the chance of far-end infarction due to retrogradely opening occlusive CCA and blocking CCA stump; (IV) opening most of the occlusive segments under direct vision, only small segments (3–4 cm) under fluoroscopy; and (V) after retrogradely opening, stent placement to resolve residual stenosis if necessary. In this study, the mean operation time and mean hospital stay were markedly shorter in the 2 cases receiving ring-stripping hybrid operation (118±11 min, 5.5±0.7 d) than in the 4 cases receiving carotid-carotid crossover bypass (186±13 min, 17±1 d), but clinical outcomes were similar between both; so ring-stripping hybrid operation seemed to be superior to carotid-carotid crossover bypass. However, the mean follow-up was markedly longer in the 4 cases receiving carotid-carotid crossover bypass (62.3±26.3 months) than in the 2 cases receiving ring-stripping hybrid operation (17.5±3.5 months), so which surgical scheme is superior remains to be further confirmed by large-sample studies.

Vessel rupture is a severe complication of ring-stripping hybrid operation, especially for the infectious inflammatory vessel and post-radiation vessel, which are not suitable for ring-stripping hybrid operation because these vessels have been damaged with high possibility of vessel rupture (14,24). Other complications of ring-stripping hybrid operation include arterial dissection, restenosis, etc. Therefore, the surgical techniques such as endovascular stenting and open vascular repair, are essential for these emergencies.

Advantages and disadvantages of the two surgical schemes

The reports on the above two surgical schemes are small, so we compared the advantages and disadvantages of the two surgical schemes and showed them in *Table 3*.

From *Table 3*, we can see that compared with the carotid-carotid crossover bypass, ring-stripping hybrid operation has advantages in operative incision, mean operation time, hospital stay, foreign bodies in the body and technical difficulty, more importantly, in hemodynamics. Firstly, carotid-carotid crossover bypass needs to block the normal CCA during operation, which brings the risk of ischemic stroke; while the ring-stripping hybrid operation does not need to block blood flow. Secondly, in the aspect of postoperative internal carotid artery blood flow, bilateral internal carotid artery blood flow is supplied by the contralateral normal CCA after the carotid-carotid crossover bypass; while after the ring-stripping hybrid operation, the internal carotid artery blood flow is supplied by own CCA. This is the greatest advantage of ring-stripping hybrid operation. However, the ring-stripping hybrid operation requires a complex hybrid operating room, but the carotid-carotid crossover bypass does not depend on hybrid operating room.

The limitations of this study were as follows: (I) small sample-size; (II) short follow-up period; and (III) retrospective study.

Table 3 Advantages and disadvantages of the two operation plans

Items	Crossover bypass	Hybrid operation (ring stripping)
Operative incision	Bilateral	Unilateral
Blocking blood flow	Yes	No
Technical difficulty	Relatively difficult	Relatively easy
Hybrid operating room	No	Yes
Mean operation time and hospital stay	longer	Shorter
Foreign bodies in the body	Yes (synthetic vascular graft)	Sometimes, if application of stent
Source of postoperative internal carotid artery blood flow	Bilateral internal carotid artery blood flow supplied by contralateral normal common carotid artery	Restoring normal physiological channels and the internal carotid artery blood flow supplied by own common carotid artery

Conclusions

In this study, 6 cases with Rile's type 1A CCAO including 4 receiving carotid-carotid crossover bypass and 2 receiving ring-stripping hybrid operation, all obtained better therapeutic effects. We believe that (I) CCAO surgical indications include Rile's type 1A, CCAO-related symptoms and decreased CTP; (II) carotid-carotid crossover bypass is a good choice in bypass schemes because of easy operation and good long-term patency; and (III) ring-stripping hybrid operation may be an ideal surgical scheme for Rile's type 1A CCAO.

Apparently, it is necessary to carry out a large-scale prospective study about CCAO surgical treatment.

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Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/atm.2020.03.177). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was approved by Ethics Committee of the Third Affiliated Hospital, Sun Yat-Sen University (NO.: [2019]02-259-01) and informed consent was taken from all the patients. Written informed consent was obtained from the patient for publication of this study and any accompanying images.

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