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Mechanical thrombectomy via direct carotid artery approach for the treatment of acute anterior circulation large vessel occlusion

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A R T I C L E I N F O

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A B S T R A C T

Background: Mechanical thrombectomy (MT) has become an important treatment method for acute anterior circulation large vessel occlusion. The carotid artery approach is a fast and effective alternative when the transfemoral approach is difficult due to vascular variation. The present study reports on seven cases of acute anterior circulation stroke where direct carotid approach was used to obtain vascular access.

Methods and materials: Patients with acute anterior circulation large vessel occlusion treated via carotid artery access between January 2018 and January 2020 were retrospectively analyzed. Brain computed tomography (CT) and angiographic imaging results, indications for carotid artery approach and technical aspects of the method, modified thrombolysis in cerebral infarction (mTICI), procedure-related complications, and patient outcomes were evaluated.

Results: Seven patients were treated using a direct carotid artery approach. Among the seven cases, four patients were treated using percutaneous carotid artery puncture, and two patients were treated with emergency carotid artery incision and thrombectomy. The remaining case involved carotid artery puncture for MCA thrombectomy, followed by carotid artery incision for carotid artery thrombectomy. The carotid artery puncture point was exposed via surgical incision and sutured after MT. Modified Rankin Scale (MRS) scores 90 days after surgery showed good prognosis in three patients, poor prognosis in four patients.

Conclusion: This case series highlights the advantage of using a transcarotid approach to bypass anatomical barriers to achieve faster reperfusion when the femoral approach is not possible. The carotid artery puncture point was surgically exposed and sutured to reduce the incidence of postoperative complications.

1. Background

Acute anterior circulation large vessel occlusion leads to rapid destruction of brain tissue, resulting in cerebral infarction in the blood supply area. It has high disability and mortality rates. Five prospective randomized trials published in 2015 [1–5] have shown that mechanical thrombectomy (MT) is superior to standard medical treatment in patients with acute ischemic stroke caused by anterior circulation large vessel occlusion. The DAWN and DEFUSE3 studies [6,7] have demonstrated that the time window for MT in acute anterior circulation large vessel occlusion can be extended to 6–24 h based on the patient's blood flow compensation condition.

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Randomized controlled trials have shown that the time from the onset of stroke symptoms to recanalization is a key factor in improving functional outcomes [8]. Therefore, shortening the operation time will have a positive impact on MT in patients with acute large vessel occlusion [9].

Currently, the transfemoral artery approach remains the standard technique for establishing surgical access in neurovascular interventions. Transfemoral arterial approach is the best route due to its location in compressible tissue, large diameter, smooth direction, and more familiarity by neurointerventionists. Anatomical variations present in the patient's vessels, such as severe curvature of the aortic arch, kinking, and coiling of the internal carotid artery (ICA), introduce technical challenges to MT, resulting in delayed vascular recanalization or even failure [10]. In these cases, the transcarotid artery approach is a viable alternative. It bypasses anatomically disadvantaged areas and significantly reduces the time from establishment of access to successful revascularization.

The present study describes seven cases of acute anterior circulation ischemic stroke treated via the transcarotid artery approach in order to provide some experience for clinical colleagues.

2. Methods and materials

2.1. Patient selection and evaluation

A database of all patients with acute ischemic stroke who had undergone an MT in our hospital between January 2018 and January 2020 was retrospectively analyzed. Cases of thrombectomy were screened out via direct carotid artery approach due to acute anterior circulation large vessel occlusion. All cohort patients underwent a computed tomography angiography (CTA) of the head and neck, were confirmed to have anterior circulation large vessel occlusion, and satisfied the indications for endovascular treatment of acute ischemic stroke [11]. The patients met the criteria for a complicated surgical path for thrombectomy, with indications for choosing a transcarotid artery approach. The study was approved by the institutional review board of our hospital, and all patients or relatives signed the informed consent for treatment.

2.2. Inclusion and exclusion criteria

Inclusion criteria were as follows: anterior circulation stroke up to 24 h since symptom onset; anterior circulation large vessel occlusion with favorable collaterals; age >18 years; National Institutes of Health Stroke Scale (NIHSS) score >6; Alberta Stroke Program Early CT score (ASPECTS) ≥ 5; and CT excluding intracranial hemorrhage or large-area cerebral infarction.

Exclusion criteria were as follows: contrast agent allergy; asthma and/or renal insufficiency; platelet count $<50 \times 10^9$/L; pregnancy or life expectancy <3 months; difficulty with follow-up completion; and patients or their families refused to sign the informed consent.

Complicated surgical path for thrombectomy required the following: the aortic arch is of type III or is bovine, the angle between the left common carotid artery and the horizontal line of the apex of the aortic arch is $< 60^\circ$ with or without abdominal aortic tortuosity; and the coaxial technique could not deliver the guide catheter to the target carotid artery within 30 min [12].

2.3. Evaluation content

The angiographic images were reviewed for each case. Clinical details and outcome data were obtained from our hospital thrombectomy database. Baseline and clinical data for all patients were collected, including gender, age, cardiovascular disease risk factors, NIHSS score upon admission, intravenous thrombolysis, time from onset to puncture, time from puncture to recanalization, modified thrombolysis in cerebral infarction (mTICI), postoperative complications, and postoperative NIHSS and 90-day mRS scores, to evaluate the efficacy and safety of the direct carotid artery approach.

The time from puncture to recanalization was defined as the time from carotid puncture to the time when the vessel reached mTICI level 2b or above. The total ASPECTS score consisted of 10 points that were selected from the basal ganglia area and the central semiovale area. The early cerebral infarction with low density at each point reduced the score by one point. The lower the score, the larger the infarct area [13].

2.4. Operative procedure

After admission, the patient immediately completed a preoperative examination. A head CT determined whether there was intracranial hemorrhage or a large-area cerebral infarction. CTA examination of the head and neck was used to ascertain the presence of a large vessel occlusion. Patients without contraindications for intravenous thrombolysis within the time window of thrombolysis were administered intravenous thrombolysis before surgery. Patients with anterior circulation large vessel occlusion with anatomical variation could choose to be treated via a transcarotid artery approach.

After a successful general anesthesia administration, the patient was placed in the supine position. First, the femoral artery approach was attempted, and an 8 F short guide sheath was placed in the femoral artery to see if the coaxial system consisting of a 125-cm diagnostic catheter (ev3-Covidien) and a 260-cm 0.035-inch guide wire could be advanced to the target carotid artery. If difficulties or failure were encountered after repeated attempts during the operation, the transcarotid artery approach was immediately utilized. The neck was exposed on the proper side of the operation and disinfected. The area about 3 cm above the clavicle was selected as the puncture point. The common carotid artery was punctured at a 45° angle with an 18-gauge micropuncture needle. A 0.035-inch soft tip guidewire was advanced into the ICA using X-ray fluoroscopy. The puncture needle was then withdrawn and a 6F sheath was placed

Table 1
Patient and procedural details.

Patient	sex	age	hypertension	diabetes	atrialfibrillation	previouscerebralischemia	NIHSS	ASPECT	Occlusion	IVtPA	carotid puncture	carotidincision	Intervalfemoraltocarotid puncture(min)	TotalProcedure(min)	mTICI	Carotidaccess Complications	mRS
1	male	79	Yes	No	Yes	Yes	20	9	Rt M1	Yes	Yes	No	32	45	2b	SAH	2
2	male	70	No	No	Yes	No	23	9	Lt M1 & ICA	Yes	No	Yes	43	60	3	Nil	1
3	female	81	Yes	No	No	Yes	35	8	Lt M2	Yes	Yes	No	50	73	2b	Nil	5
4	female	87	No	Yes	Yes	Yes	23	7	Lt M1	Yes	Yes	No	40	66	3	Nil	2
5	male	75	No	No	Yes	No	28	6	Lt M1 & ICA	No	Yes	No	40	116	2b	Nil	6
6	male	73	Yes	Yes	No	Yes	15	6	Rt M1 & ICA	Yes	No	Yes	35	105	3	ICH	6
7	male	62	No	No	Yes	Yes	18	8	Lt ICA	No	No	Yes	Nil	56	3	Nil	3

ASPECTS=Alberta stroke program early CT score, ICA = internal carotid artery, MCA = middle cerebral artery, M1: M1 segment of middle cerebral artery, Rt: right, Lt: left; NIHSS=National Institutes of Health Stroke Scale, rt-PA = recombinant tissue plasminogen activator.
ICH = intracranial hemorrhage, mRS = modified Rankin scale, mTICI = the modified thrombolysis in cerebral infarction, SAH=Subarachnoid hemorrhage.

into the ICA through the 0.035-inch guidewire and then secured to the neck skin with sutures. Carotid angiography was then performed to confirm the site of the intracranial occlusion. Distal aspiration thrombectomy was carried out first. If the method failed to achieve complete recanalization, stent retrieval technique was used. Balloon angioplasty was applied in cases of severe residual stenosis and a stent was deployed if necessary. After a successful vascular recanalization, a surgical incision was performed to expose the puncture point of the ICA. The puncture sheath was then pulled out and the puncture point was sutured. After the operation, the patient was transferred to the intensive care unit (ICU) after becoming awake.

For patients with ICA occlusion and/or tandem MCA occlusion, an emergency carotid artery incision and thrombectomy were performed. The head was turned to the non-operated side and an incision was made at the anterior edge of the sternocleidomastoid muscle. The incision was made layer by layer to expose and open the carotid arterial sheath and expose the carotid artery and its bifurcation, ICA, external carotid artery, and other important branches. Then, the external carotid, superior thyroid, and common carotid arteries were sequentially blocked. Carotid endarterectomy (CEA) was used to excise the plaque, followed by incision and removal of the thrombectomy. The carotid artery in situ stenosis was relieved, the blood vessels were sutured, and the blood flow of the external carotid artery, superior thyroid artery, common carotid artery, and ICA was sequentially restored. After the operation, the patient was transferred to the ICU after becoming awake.

2.5. Postoperative management and follow-up

Postoperative systolic blood pressure was maintained at 120–140 mmHg. Brain CT was reviewed immediately after the operation and 24 h after surgery.

In the absence of symptomatic intracranial bleeding, intravenous tirofiban was administered for 24 h, followed by oral aspirin and clopidogrel 24 h later. After stent implantation, intravenous tirofiban was administered for 24 h. At the same time, aspirin (100 mg/day) and clopidogrel (75 mg/day) were taken orally every night. Intravenous antiplatelet aggregator tirofiban and oral antiplatelet aggregator in combination with tirofiban were discontinued 6 h later. The rest of the treatment was in accordance with the Chinese Stroke Association guidelines for clinical management of cerebrovascular disorders [11]. Brain CT results were re-examined 24 h after the operation, the NIHSS score was evaluated, and postoperative intracranial hemorrhage, symptomatic intracranial hemorrhage, and death were recorded. Outpatient and telephone follow-up of the patients for 90 days of mRS scores. A good clinical prognosis was defined as mRS score of 0–2, and a poor prognosis was defined as an mRS score of 3–6, where 6 represents death [14].

3. Results

3.1. Patients and characteristics

A total of 367 patients underwent an emergency MT during a two-year period. Seven patients (1.9%) chose the transcarotid artery approach because of the difficulty of the transfemoral artery approach. Patient and procedural details are outlined in Table 1. There were five males and two females, and the median age was 75 years (range 62–78 years). The median NIHSS score at presentation was 23, ranging from 15 to 35. Median ASPECTS was 8 (range 6–9). There were three patients with hypertension, two with diabetes, five with atrial fibrillation, and five with history of cerebral ischemia. Three cases had MCA occlusion, one case had ICA occlusion, and three cases had tandem lesion of ICA and MCA. Five patients received intravenous thrombolysis within the thrombolysis time window.

3.2. Choice of thrombectomy access

Among the seven cases, six patients were first treated via a transfemoral approach, with a median time of 40 min. When the transfemoral approach encountered difficulties and in order to shorten the operation time, the transcarotid artery approach was immediately utilized. The seventh patient was preoperatively confirmed to have a type III arch and ankylosing spondylitis. Femoral artery puncture was not attempted and a direct carotid incision was chosen instead. Among the seven cases, four patients were treated with percutaneous carotid artery puncture, and two cases were treated with select carotid artery incision thrombectomy. For a patient with acute tandem lesions, the first carotid artery puncture was performed for MCA thrombectomy, followed by carotid artery incision for carotid artery thrombectomy.

3.3. Recanalization time and mTICI grade

The time from carotid access to recanalization was 55–135 min, while the median recanalization time was 73 min. Postoperative mTICI grading showed that three patients achieved grade 2b blood flow recanalization, and four patients achieved grade 3 blood flow recanalization.

3.4. Postoperative complications and 90-day prognosis

Postoperative subarachnoid hemorrhage and postoperative cerebral hemorrhage each occurred in one case. No obvious complications were present in the remaining patients. Carotid artery dissection and cervical subcutaneous hematoma were not found in the seven patients. The 90-day mRS score showed that three patients had a good prognosis, four patients had a poor prognosis, and two patients died (one case due to postoperative massive cerebral infarction and the other case due to postoperative cerebral hemorrhage).

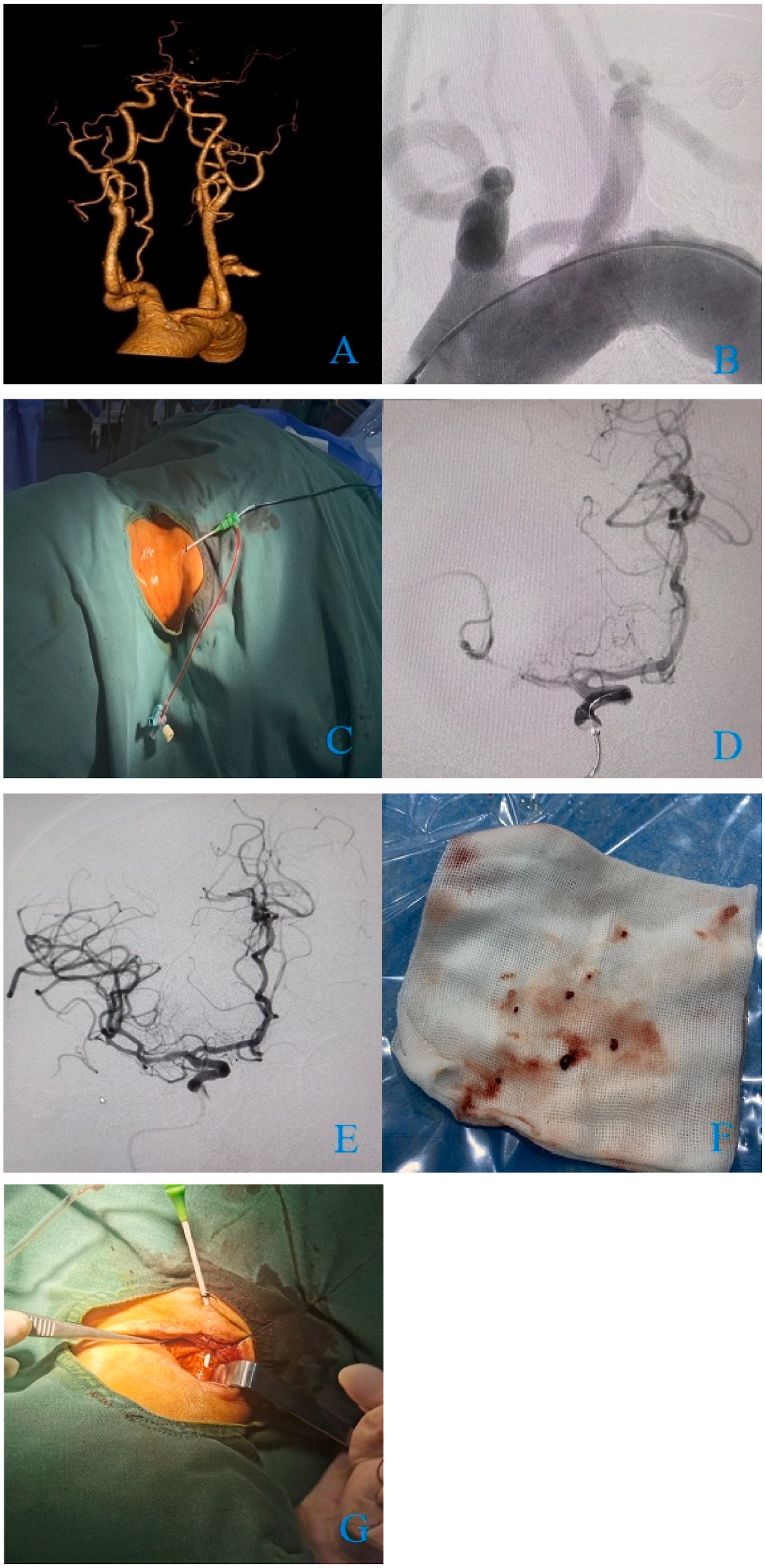

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Fig. 1. **A** Head and neck CTA showed acute right middle cerebral artery occlusion, the aortic arch was a bovine arch, and the right common carotid artery was obviously tortuous. **B** We had attempts to establish thrombectomy access via femoral artery puncture were unsuccessful. **C** The right common carotid artery was punctured, and the thrombectomy access was successfully established. **D and E** After successful carotid artery puncture, the right middle cerebral artery thrombectomy was performed to achieve recanalization of the middle cerebral artery (mTICI 2b). **F** Thrombus removed during operation. **G** The neck skin was incised, the puncture point of the common carotid artery was exposed, and the puncture point was sutured to stop the bleeding.

3.5. Case presentation

A 79-year-old male patient with a 10-year history of atrial fibrillation was admitted to the hospital due to sudden left limb movement failure with speech inability for half an hour. Physical examination revealed left limb hemiplegia (NIHSS score: 23). The CTA revealed acute right MCA occlusion (Fig. 1A) and a type III aortic arch (Fig. 1B). Initially, the transfemoral artery route approach was attempted, but failed after 32 min. Then, the carotid artery was punctured to establish a thrombectomy access (Fig. 1C). The common carotid artery was punctured under fluoroscopy, and the thrombectomy stent was delivered into the MCA (Fig. 1D). Complete recanalization of the MCA region was achieved after two passes of the stent retrieval thrombectomy (Fig. 1E and F). Surgical incision of the neck skin, exposure of the common carotid artery puncture point, and sutures for hemostasis (Fig. 1G).

The muscle strength of the left limb was grade 3 24 h after the operation, and a small amount of subarachnoid hemorrhage was present on a brain CT 24 h after the operation. The patient underwent three months of rehabilitation and medical observation for AF with good recovery. The mRS score was 2 without recurrence over the 90-day follow-up period.

4. Discussion

The transfemoral approach remains the standard technique for establishing access in neuroendovascular interventions, including intra-arterial stroke interventions, due to its relative simplicity and low incidence of adverse events, making it suitable for most patients [15]. However, anatomical variations present in the vascular access, such as unfavorable aortic arch anatomy, arterial tortuosity, and severe peripheral vascular disease, can present potential barriers to the *trans*-femoral approach, resulting in prolonged procedure times and potentially prevent recanalization [14]. Moreover, prolonged and repeated attempts to access the carotid artery via the transfemoral artery approach is dangerous, as it increases the risks of vessel dissection and potential embolic complications [16]. Therefore, when the transfemoral approach is difficult, other approaches need to be attempted to shorten the operation time and reduce surgical complications. Alternative vascular access routes include radial or brachial access and transcervical carotid artery access. Transradial or transbrachial approaches provide a favorable method for rapid recanalization of occluded vessels in type II or III aortic arches. However, the transradial or transbrachial approach also presents some drawbacks. First, the transradial and transbrachial artery routes do not overcome tortuous supra-aortic trunk anatomy and only provide meaningful advantages for the right carotid and vertebral arteries. Second, the small caliber of the radial artery increases the risk of arterial injury and postoperative arterial occlusion [17]. Third，Almallouhi et al. [18] study has shown that the failure rate of transradial artery thrombectomy (18%) was higher than that of transfemoral artery thrombectomy (6.9%). The fastest recanalization can improve the prognosis of patients with acute thrombectomy.

To avoid delayed recanalization time due to failed attempts to transradial arteries, this access was not attempted. The transcarotid approach can bypass unfavorable vascular anatomy, shorten the time for establishing thrombectomy access, and achieve faster reperfusion [19]. Compared to the transfemoral approach, the catheter guide wire travels a shorter distance *in vivo* and is more controllable during the carotid approach. The transcarotid access allows for the use of a short and soft guide wire, which results in a faster and safer catheter exchange [20]. Cerebral angiography through the carotid artery approach is not a new technique. Cases of intracranial aneurysms, vascular malformations, and intracranial angioplasty/stent implantation have been reportedly treated using the transcarotid approach [15,21,22]. Therefore, when the thrombectomy through the femoral artery approach is difficult, the carotid artery approach is also feasible. In summary, when the femoral artery approach presents difficulties with entering the carotid artery, similar challenges may be present with the radial or brachial artery. Neurointerventionalists should then opt for a direct transcarotid approach as soon as possible, rather than spend too much time on multiple attempts with different catheter and wire combinations.

Carotid artery approach can be divided into two types: carotid artery puncture and carotid artery incision. The ideal puncture site for percutaneous carotid artery puncture is 2–3 cm above the clavicle, which is approximately at the C5–C6 level [19]. If the location of the puncture point is too low, the arterial sheath and the carotid artery will run close to a right angle, resulting in the breaking of the sheath tube and obstruction of the puncture needle by the clavicle during the operation [19,23]. If the puncture site is too high (too close to the carotid bifurcation), the needle may damage the carotid sinus during puncture. In order to improve the safety of percutaneous carotid artery puncture, we chose to perform carotid artery puncture under fluoroscopic monitoring. Carotid artery incision and CEA are also commonly used surgical methods for thrombectomy [24,25,26]. Acute ICA occlusion is the underlying reason in 4–15% patients with ischemic stroke [27]. For ICA occlusion caused by internal carotid atherosclerotic plaque, balloon dilation and stent implantation are currently used to achieve ICA recanalization [28]. However, this technique has limitations. First, acute ICA occlusion may present various difficulties in stent retrieval or thrombectomy. It has been reported that plaque in the initial segment of the ICA is hard, and the guidewire fails to pass the ICA occlusion site. In a case report published by our medical team, the ICA thrombosis was tough and bulky, and recanalization could not be achieved by an aspiration catheter. In order to avoid distal escape of the thrombus, a direct incision of the carotid artery was performed to remove the thrombus [24]. Second, it has been reported that one year after ICA thrombectomy and stent implantation, 15% of the subjects developed carotid artery restenosis with a cervical artery stent and required reintervention [29]. Carotid artery incision and CEA is one of the surgical methods to achieve recanalization of the ICA occlusion. Recanalization of the occluded ICA within the time window may achieve favorable outcomes [25]. Emergency carotid artery incision would increase the risk of bleeding in patients treated with intravenous rtPA for thrombolysis. However, Frenkel et al. [25] believe that surgery after rtPA injection is still a viable option because rtPA has a short half-life (<5 min) and does not increase the chance of intracerebral hemorrhage and subcutaneous hematoma. Therefore, carotid artery incision and thrombectomy can be chosen for patients with ICA occlusion when an effective access approach cannot be established through the femoral artery approach. For acute ICA occlusion caused by carotid atherosclerotic plaque, CEA can be selected to reduce the chance of postoperative cerebral infarction recurrence.

Common complications in MT using the carotid artery approach include cerebral infarction and cerebral hemorrhage, in addition to complications caused by carotid artery puncture. Transcarotid artery puncture has a higher chance of complications than transfemoral approach [19]. The complications include subcutaneous hematoma, carotid artery dissection, carotid sheath kink, and carotid artery peripheral nerve injury. Subcutaneous hematoma is the most common complication after carotid artery puncture. A percutaneous hemostatic device can reduce the possibility of a subcutaneous hematoma. However, this device is inconvenient to operate with and can induce potential complications, such as subcutaneous hematoma, thrombosis, pseudoaneurysm, infection, and arteriovenous fistula [17]. Previous case reports have shown that subcutaneous hematoma formation cannot be completely avoided even with a percutaneous hemostatic device. Roche et al. [14] have reported that incision of the carotid artery and the use of purse-string suture to treat the puncture point can reduce the incidence of postoperative subcutaneous hematoma. In order to prevent the formation of postoperative subcutaneous hematoma, the present study also adopted this method. After recanalization of the occluded vessel, a surgical incision was performed to expose the carotid artery puncture point, which was closed with silk suture for hemostasis. Past reports also confirm that incision and suturing of the carotid artery can minimize the possibility of subcutaneous hematoma in patients who are on preoperative antiplatelet and anticoagulant drugs. Surgical suture is currently the most effective method to prevent a subcutaneous hematoma [30]. Suture of the carotid puncture point can reduce the incidence of postoperative subcutaneous hematoma without prolonging the time required for vascular recanalization.

Although the transcarotid approach is an effective surgical method, it has some limitations. First, there is currently no device designed specifically for carotid access, which requires shorter length sheaths, catheters, and wires [14]. Second, there are many nerves, blood vessels, and lymphatic tissues around the carotid artery. The risk of injury to these tissues is higher when puncturing the carotid artery. Third, neurointerventional physicians lack experience in puncturing the carotid artery, which prolongs the operation time, reduces the probability of recanalization, and increases the incidence of postoperative complications.

The present study has several limitations. First, the data in this report are from a single center. Second, there were few cases of the carotid artery approach included in the experiments. Third, the lack of a control group resulted in inability to demonstrate the advantages and disadvantages of carotid artery puncture in normal vascular anatomy. Therefore, transcarotid artery approach safety and efficacy need to be further confirmed by multi-center, large sample size, and randomized controlled studies.

5. Conclusion

Transcarotid access is an effective alternative when MT cannot be performed via transfemoral access due to anatomical abnormalities. It can bypass anatomical obstacles, shorten the operation time, achieve effective recanalization of occluded blood vessels, and promote nerve function recovery. For patients with severe carotid artery stenosis, emergency CEA surgery can be performed to prevent postoperative restenosis. The carotid artery puncture point in the present study was exposed via surgical incision and sutured after an MT. This method can reduce the incidence of postoperative complications, such as subcutaneous hematoma and carotid dissection.

Statement of ethics

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Author contribution statement

All authors listed have significantly contributed to the investigation, development and writing of this article.

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Additional information

No additional information is available for this paper.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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References

[1] M. Goyal, A.M. Demchuk, B.K. Menon, M. Eesa, J.L. Rempel, J. Thornton, et al., Randomized assessment of rapid endovascular treatment of ischemic stroke, N. Engl. J. Med. 372 (11) (2015) 1019–1030.
[2] T.G. Jovin, A. Chamorro, E. Cobo, M.A. de Miquel, C.A. Molina, A. Rovira, et al., Thrombectomy within 8 hours after symptom onset in ischemic stroke, N. Engl. J. Med. 372 (24) (2015) 2296–2306.
[3] J.L. Saver, M. Goyal, A. Bonafe, H.C. Diener, E.I. Levy, V.M. Pereira, et al., Stent-retriever thrombectomy after intravenous t-PA vs. t-PA alone in stroke, N. Engl. J. Med. 372 (24) (2015) 2285–2295.
[4] O.A. Berkhemer, P.S. Fransen, D. Beumer, et al., A randomized trial of intraarterial treatment for acute ischemic stroke, N. Engl. J. Med. 372 (1) (2015) 11–20.
[5] B.C. Campbell, P.J. Mitchell, T.J. Kleinig, et al., Endovascular therapy for ischemic stroke with perfusion-imaging selection, N. Engl. J. Med. 372 (11) (2015) 1009–1018.
[6] T.G. Jovin, J.L. Saver, M. Ribo, et al., Diffusion-weighted imaging or computerized tomography perfusion assessment with clinical mismatch in the triage of wake up and late presenting strokes undergoing neurointervention with Trevo (DAWN) trial methods, Int. J. Stroke 12 (6) (2017) 641–652.
[7] G.W. Albers, M.G. Lansberg, S. Kemp, et al., A multicenter randomized controlled trial of endovascular therapy following imaging evaluation for ischemic stroke (DEFUSE 3), Int. J. Stroke (2017), 174749301770114.
[8] W.J. Powers, A.A. Rabinstein, T. Ackerson, et al., American heart association stroke council. 2018 guidelines for the early management of patients with acute ischemic stroke: a guideline for healthcare professionals from the American heart association/American stroke association, Stroke 49 (3) (2018) e46–e110.
[9] Z. Yuan, J. Li, M. Zhou, et al., Common carotid artery puncture in anterior circulation thrombectomy in patients with unfavorable vascular anatomy: a case-control study, Medicine (Baltim.) 98 (40) (2019), e17477.
[10] B.M. Snelling, S. Sur, S.S. Shah, et al., Unfavorable vascular anatomy is associated with increased revascularization time and worse outcome in anterior circulation thrombectomy, World Neurosurg. 120 (2018) e976–e983.
[11] L. Liu, W. Chen, H. Zhou, et al., Chinese Stroke Association Stroke Council Guideline Writing Committee. Chinese Stroke Association guidelines for clinical management of cerebrovascular disorders: executive summary and 2019 update of clinical management of ischaemic cerebrovascular diseases, Stroke Vasc. Neurol. 5 (2) (2020) 159–176.
[12] B.M. Snelling, S. Sur, S.S. Shah, et al., Unfavorable vascular anatomy is associated with increased revascularization time and worse outcome in anterior circulation thrombectomy, World Neurosurg. 120 (2018) e976–e983.
[13] V. Puetz, I. Dzialowski, M.D. Hill, et al., The alberta stroke program early ct score in clinical practice: what have we learned? Int. J. Stroke 4 (5) (2010) 354–364.
[14] A. Roche, E. Griffin, S. Looby, et al., Direct carotid puncture for endovascular thrombectomy in acute ischemic stroke, J. Neurointerventional Surg. 11 (7) (2019) 647–652.
[15] E.A. Samaniego, G. Dabus, R. Raju, et al., Intracranial angioplasty and stenting through direct carotid puncture, J. Neuroimaging 23 (2013) 207–210.
[16] C. Dorfer, H. Standhardt, A. Gruber, et al., Direct percutaneous puncture approach versus surgical cutdown technique for intracranial neuroendovascular procedures: technical aspects, World Neurosurg. 77 (2012) 192–200.
[17] R. Larrazabal, P. Klurfan, D. Sarma, T. Gunnarsson, Surgical exposure of the carotid artery for endovascular interventional procedures, Acta Neurochir. 152 (3) (2010) 537–544.
[18] E. Almallouhi, S. Al Kasab, M.G. Sattur, et al., Incorporation of transradial approach in neuroendovascular procedures: defining benchmarks for rates of complications and conversion to femoral access, J. Neurointerventional Surg. 12 (11) (2020) 1122–1126.
[19] E. Colombo, L. Rinaldo, G. Lanzino, Direct carotid puncture in acute ischaemic stroke intervention, Stroke Vasc. Neurol. 5 (1) (2020) 71–79.
[20] Pipinos II, M. Bruzoni, J.M. Johanning, G. Matthew Longo, T.G. Lynch, Transcervical carotid stenting with flow reversal for neuroprotection: technique, results, advantages, and limitations, Vascular 14 (2006) 245–255.
[21] R. Blanc, M. Piotin, C. Mounayer, et al., Direct cervical arterial access for intracranial endovascular treatment, Neuroradiology 48 (2006) 925–929.
[22] K. Nii, K. Kazekawa, M. Onizuka, H. Aikawa, M. Tsutsumi, M. Tomokiyo, M. Iko, T. Kodama, S. Matsubara, Y. Go, A. Tanaka, Direct carotid puncture for the endovascular treatment of anterior circulation aneurysms, AJNR Am. J. Neuroradiol. 27 (7) (2006 Aug) 1502–1504.
[23] C.J. Kwolek, M.R. Jaff, J.I. Leal, L.N. Hopkins, R.M. Shah, T.M. Hanover, S. Macdonald, R.P. Cambria, Results of the ROADSTER multicenter trial of transcarotid stenting with dynamic flow reversal, J. Vasc. Surg. 62 (5) (2015 Nov) 1227–1234.
[24] M. Zhang, J.H. Hao, K. Lin, Q.K. Cui, L.Y. Zhang, Combined surgical and interventional treatment of tandem carotid artery and middle cerebral artery embolus: a case report, World J. Clin. Cases 8 (3) (2020 Feb 6) 630–637.
[25] M.B. Frenkel, J.J. Renfrow, J. Singh, N. Garg, S.Q. Wolfe, Combined interventional and surgical treatment of tandem middle cerebral artery embolus and internal carotid artery occlusion: case report, J. Neurosurg. 129 (2018) 718–722.
[26] M.B. Frenkel, J.J. Renfrow, J. Singh, N. Garg, S.Q. Wolfe, Combined interventional and surgical treatment of tandem middle cerebral artery embolus and internal carotid artery occlusion: case report, J. Neurosurg. 129 (3) (2018) 718–722.
[27] M. Rubiera, M. Ribo, R. Delgado-Mederos, et al., Tandem internal carotid artery/middle cerebral artery occlusion: an independent predictor of poor outcome after systemic thrombolysis, Stroke 37 (2006) 2301–2305.
[28] F. Al-Mufti, K. Amuluru, N.W. Manning, et al., Emergent carotid stenting and intra-arterial abciximab in acute ischemic stroke due to tandem occlusion, Br. J. Neurosurg. 31 (2017) 573–579.
[29] M. Paciaroni, C. Balucani, G. Agnelli, et al., Systemic thrombolysis in patients with acute ischemic stroke and Internal Carotid ARtery Occlusion: the ICARO study, Stroke 43 (2012) 125–130.
[30] Pipinos II, M. Bruzoni, J.M. Johanning, G. Matthew Longo, T.G. Lynch, Transcervical carotid stenting with flow reversal for neuroprotection: technique, results, advantages, and limitations, Vascular 14 (2006) 245–255.