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INTERVENTIONAL RADIOLOGY

ORIGINAL ARTICLE

Non-routine thrombectomy in pediatric arterial ischemic stroke

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PURPOSE

Unlike in adults, the indications and techniques for mechanical thrombectomy for arterial ischemic stroke (AIS) in children are not clearly established. The medical and interventional management of children with acute large vessel occlusion may entail the modification of the standardized management of this condition in adults. We present six cases of children who underwent non-routine thrombectomy for AIS.

METHODS

We retrospectively reviewed the records of children diagnosed with AIS between 2015 and 2023 and evaluated patient characteristics, procedural technical data, and final clinical outcomes. Procedures deviating from the current definition and indications for AIS treatment in adults as well as previously reported pediatric thrombectomy cases were defined as non-routine thrombectomy.

RESULTS

Seven non-routine thrombectomy procedures in six children were included in the study. The National Institutes of Health Stroke Scale scores on admission ranged from 4 to 35; no procedure-related mortality or major neurologic morbidity occurred. One child died of causes related to the initial severe heart failure and stroke; otherwise, all the children had a modified Rankin scale score of 0 to 1 at follow-up. Unique clinical and procedural features in our case series included presentation with acute stent occlusion (two children), bilateral simultaneous internal carotid artery occlusions associated with a unilateral tandem middle cerebral artery (MCA) occlusion (one child), MCA occlusion caused by thromboembolism of the atrial myxoma (one child), and very distal (one child) or delayed thrombectomy (two children).

CONCLUSION

Modifications to the standard medical and interventional algorithms may be required for mechanical thrombectomy in children.

CLINICAL SIGNIFICANCE

Referral centers specialized in pediatric neurology, pediatric anesthesia, and pediatric intervention are optimal for treating children using mechanical thrombectomy and for modifying the treatment, if required.

KEYWORDS

Stroke, children, thrombectomy, thrombolysis, stent, aspiration

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Arterial ischemic stroke (AIS) is a primary cause of long-term neurologic deficit and mortality in children despite its rarity (1.3–13:100.000).[1] Its etiology and pathophysiology in children differ from those in the adult population because adults and children differ in terms of arterial morphology and their particular response to ischemia.[2] The diagnosis of AIS is often challenging in children because of its low incidence, variability in clinical presentation, and wide spectrum of underlying risk factors.[3]

Evidence-based data and guidelines on revascularization treatments such as intravenous tissue plasminogen activator and mechanical thrombectomy have not yet been established

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for children.[4] However, following the worldwide acceptance of mechanical thrombectomy in adults with AIS, a growing number of cases have been reported in children. Recently, a multicenter study[5] and a meta-analysis[6] reported favorable neurologic outcomes, indicating that this procedure is safe and efficacious in children.

We reviewed the cases of six children treated with non-routine mechanical thrombectomy at a single pediatric tertiary referral center and evaluated these patients with regard to any unique, distinguishing characteristics that have not previously been reported in the relevant literature.

Methods

Our study was approved by the Hacettepe University Institutional Review Board (approval number: SBA 23/426 2023/09-06). The endovascular procedures were performed under emergency conditions with written informed consent signed by the parents, and the evaluations were conducted retrospectively; therefore, no additional consent to participate was required. The cases of patients with AIS admitted to our children's hospital for endovascular treatment between 2015 and 2023 were reviewed retrospectively to determine whether the procedures were performed according to the guidelines for adults. For cases with clinical suspicion of acute stroke, initial neuroimaging work-up included non-enhanced head computed tomography (CT) to exclude hemorrhagic stroke, followed by neck and head CT angiography (CTA), cranial time-of-flight magnetic resonance (MR) angiography, or diffusion-weighted imaging to evaluate cerebral vessels and the viability of the affected cerebral territory. Those diagnosed with acute intracranial large vessel occlusion were urgently evaluated by specialists in interventional neuroradiology, pediatric emergency medicine, and pediatric neurology to determine if the patient would benefit from mechanical thrombectomy.

Between 2015 and 2023, 22 children presented with acute stroke caused by large vessel occlusion. Of these, seven with large core infarcts upon presentation identified through cross-sectional imaging and eight presenting more than 24 hours after the onset of stroke symptoms were excluded from the study. Among the remaining seven children, one underwent a straightforward endovascular mechanical thrombectomy, with the indications and techniques mirroring those for adult patients. After excluding the child receiving "routine" thrombectomy, six children aged between 6 and 17 years underwent "non-routine" mechanical thrombectomy (Figure 1).

The neurological status of the patients was evaluated using the National Institutes of Health Stroke Scale (NIHSS) on admission. Briefly, the NIHSS score (between 0 and 42) is determined as follows: 0: no stroke symptoms, 1–4: minor stroke, 5–15: moderate stroke, 16–20: moderate to severe stroke, 21–42: severe stroke. Revascularization at the end of the procedure was evaluated in accordance with the modified Thrombolysis in Cerebral Infarction (mTICI) score, and mTICI scores of 2B, 2C, or 3 were considered "successful revascularization." At follow-up, the modified Rankin scale (mRS), with scores ranging from 0 to 6, was used to determine the final neurologic status of the patients.[7,8]

Informed consent was obtained from all families before the procedure. Endovascular procedures were performed under general anesthesia through transfemoral access. Throughout the procedure, systemic anticoagulation was achieved by using intravenous heparin targeting an activated clotting time of between 200 and 250 s. Mechanical thrombectomy was performed through direct aspiration or with only stent retrievers or by a combination of the two. Systemic anticoagulation was continued for 24–36 hours after the procedure in the intensive care unit, except for case 2, in which anticoagulation was reversed with protamine at the end of the procedure because of the self-limited contrast extravasation on the post-procedural flat panel detector CT images. The five surviving children received long-term prophylactic anticoagulation or antiplatelet therapy after the procedures to address underlying risk factors (follow-up duration: 4 days to 31 months).

Results

Relevant clinical data from children treated with non-routine mechanical thrombectomy are presented in Table 1. All patients except the patient in case 5 presented with unilateral hemiparesis; one also had focal seizures and altered consciousness. The arterial occlusion was in the anterior circulation in five children (right sided in three, left sided in one, and bilateral in one) and in the posterior circulation in one. None received intravenous thrombolysis before mechanical thrombectomy, but the patient in case 4 had received enoxoparin sodium in hour 2 of the symptoms prior to the emergent transfer to our center. The mean NIHSS score was 13.3 (4–35), which is consistent with minor to moderate stroke, in five children. The patient in case 2 had an NIHSS score of 35 on neurologic examination upon admission, which

Main points

- Pediatric stroke differs from adult stroke in terms of etiology and underlying pathologies.
- The major technical aspects of mechanical thrombectomy for acute ischemic stroke with large vessel occlusion and the devices used for endovascular treatment are similar in both pediatric and adult patients.
- Endovascular treatment criteria and guidelines should be improved because neural tolerance to ischemia and collateral circulation dynamics are different in the pediatric population.

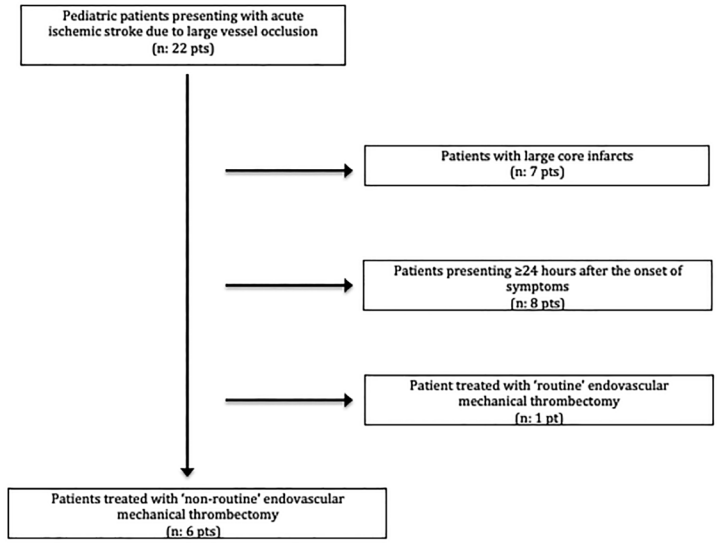

Figure 1. Patient selection flowchart.

was performed before emergent intubation. The mean symptom onset to recanalization time was 5.7 hours (3–9 hours). The technical data related to the procedures are summarized in Table 2, and the specific features of children with non-routine mechanical thrombectomy are explained below.

Case 1

This 6-year-old girl was born to consanguineous parents following an uneventful pregnancy and delivery. She was diagnosed with multiple intracranial aneurysms (Supplementary Figure 1a), one of which was a large (3.8 × 3.7 cm) dissecting cavernous internal carotid artery (ICA) aneurysm compressing the right optic nerve (Supplementary Figure 1b, c). She had proptosis, lateral gaze palsy, loss of vision in the right eye, and right optic nerve atrophy. After the diagnosis, the posterior circulation aneurysm was embolized. In a subsequent session, a flow diverter stent was inserted for the treatment of the carotid aneurysm. Antiplatelet therapy with a daily dose of 2.5 mg of oral prasugrel was started prior to the embolization of the posterior circulation aneurysm after a VerifyNow assay identified the child as hyporesponsive to clopidogrel. Three days after the second treatment of the cavernous ICA aneurysm, the patient was admitted with confusion, left hemiparesis, mild facial paralysis, and dysarthria. At hour 2 of symptoms, her NIHSS score was 10, and CTA and digital subtraction angiography (DSA) identified total occlusion of the stents in the right ICA (Supplementary Figure 1d). Mechanical thrombectomy was performed immediately using a Solitaire device (Medtronic, Irvine, CA, USA) (Supplementary Figure 1e, f), and revascularization was achieved 3 hours after the onset of symptoms (Supplementary Figure 1g, h). At her subsequent follow-up, the right ICA eventually became occluded, and the right anterior circulation territory was reconstructed via the contralateral carotid and ipsilateral posterior circulations through the partially (and proximally) occluded flow diverter. The patient returned to her baseline neurologic state, remaining asymptomatic, and her mRS scores at discharge and at 31-month follow-up were both 0.

Case 2

This 10-year-old boy had no notable medical history other than mild learning difficulties. He presented with fatigue, vomiting, and diarrhea, which had continued for several days, and was diagnosed with gastroenteritis and administered antibiotics. After 10 days, he developed acute right hemiparesis, dysarthria, right focal seizures, and altered consciousness. Upon admission, he had hypotension and supraventricular arrhythmia. The Glascow Coma scale score was 4. Emergent transthoracic echocardiography revealed dilatation of the right and left atria and systolic dysfunction. Cardiac thromboembolism was strongly suspected although no thrombus was detected on echocardiography. The patient underwent a coronary and head and neck CTA, which identified thrombus in the left atrial appendage (Supplementary Figure 2a), severe dilatation of all cardiac chambers, tandem occlusions of the right ICA at its origin and right MCA at the distal M1 segment (Supplementary Figure 2b), as well as occlusion of the left ICA terminus (Supplementary Figure 2c). The patient was

Table 1. Clinical and procedural summary of the patients

Procedure #	Age (y)/ gender	Presenting time/symptom	NIHSS	Clot location	Risk factors/etiology	Follow-up after procedure (months)	Outcome (mRS)
1 (case 1)	6/F	2 hours/hemiparesis	10	Right ICA, inside the stent	Stent placement	31	0
2 (case 2)	10/M	3 hours/hemiparesis, seizure	>30	Right cervical ICA and MCA distal M1 segment	Dilated CMP	4 days	6
3 (case 2)	10/M	3 hours/hemiparesis, seizure	>30	Left ICA bifurcation	Dilated CMP	4 days	6
4 (case 3)	16/F	4 hours/hemiparesis	13	Right ICA bifurcation	Hypertrophic CMP → dilated CMP	24	0
5 (case 4)	16/M	7 hours/hemiparesis	4	Right MCA M1	Factor V Leiden, prothrombin, and heterozygous *MTHFR* mutation	12	1
6 (case 5)	11/M	More than 3 days/ataxia, vertigo, oculomotor nerve deficits	5	Basilar artery	Stent placement	5	0
7 (case 6)	17/F	3 hours/hemiparesis, aphasia	13	Left MCA M1	Atrial myxoma	3	1

NIHSS, National Institutes of Health Stroke Scale; mRS, modified Rankin scale (0: no deficit, 6: death); F, female; M, male; ICA, internal carotid artery; MCA, middle cerebral artery; CMP, cardiomyopathy.

Table 2. Technical data of the procedures

Procedure	mTICI scores	Thrombectomy technique	Thrombectomy devices	Time to recanalization
1 (case 1)	3	Stent retriever	Solitaire	3 hours
2 (case 2)	2B	Aspiration & stent retriever	Catchview Maxi	4.5 hours*
3 (case 2)	0	Aspiration & stent retriever	Solitaire, Catchview Mini & Trevo Mini	-
4 (case 3)	2C	Aspiration & stent retriever	Catchview Maxi & Mini	7 hours
5 (case 4)	2C	Aspiration alone	Sofia 5F	9 hours
6 (case 5)	3	Stent retriever	Catchview	Not applicable
7 (case 6)	2C	Stent retriever	Solitaire	5 hours

*Revascularization of right internal carotid artery (ICA) and middle cerebral artery; left ICA could not be recanalized; mTICI, modified Thrombolysis in Cerebral Infarction.

immediately transferred to the angiography suite for mechanical thrombectomy. After documentation of the right cervical ICA and right MCA occlusions on the initial angiograms (Supplementary Figure 2d, e), the clot in the right cervical ICA was removed and the right MCA territory was recanalized with an mTICI score of 2B (Supplementary Figure 2f-h); however, the left ICA terminus could not be recanalized (Supplementary Figure 2i-n). A self-limiting extravasation occurred during the recanalization attempt of the left ICA, and a flat panel detector CT revealed focal subarachnoid hemorrhage and a hematoma with a maximal size of 8 mm at the left basal ganglia. At the follow-up imaging, the hematoma had not increased in size. The follow-up MR imaging (MRI) revealed signs of increased intracranial pressure. The patient died 4 days later as a result of cardiac dysfunction and cerebral hypoperfusion, which was most likely dilated cardiomyopathy.

Case 3

This 16-year-old girl had previously been diagnosed with hypertrophic cardiomyopathy and presented within the first 6 hours of symptom onset. A head and neck CTA and DSA revealed acute right ICA occlusion (Figure 2a, b). After angiography, the right ICA terminus was recanalized through thromboaspiration (Figure 2c, d). Subsequently, the M1 segment of the MCA and A2 segment of the anterior cerebral artery were recanalized after performing a stent retriever thrombectomy using a Catchview Maxi device (Balt, Montmorency, France) (Figure 2e, f). Finally, a "very distal" thrombectomy was performed using a Catchview Mini device (Balt) for the residual thrombus located at a parietal branch (M3/M4 segment) (Figure 2g, h), achieving a final mTICI score of 2C (Figure 2i, j). The follow-up MRI revealed focal acute infarction at the right basal ganglia (Figure 2k-n). At the 24-month follow-up, her follow-up mRS score was 0.

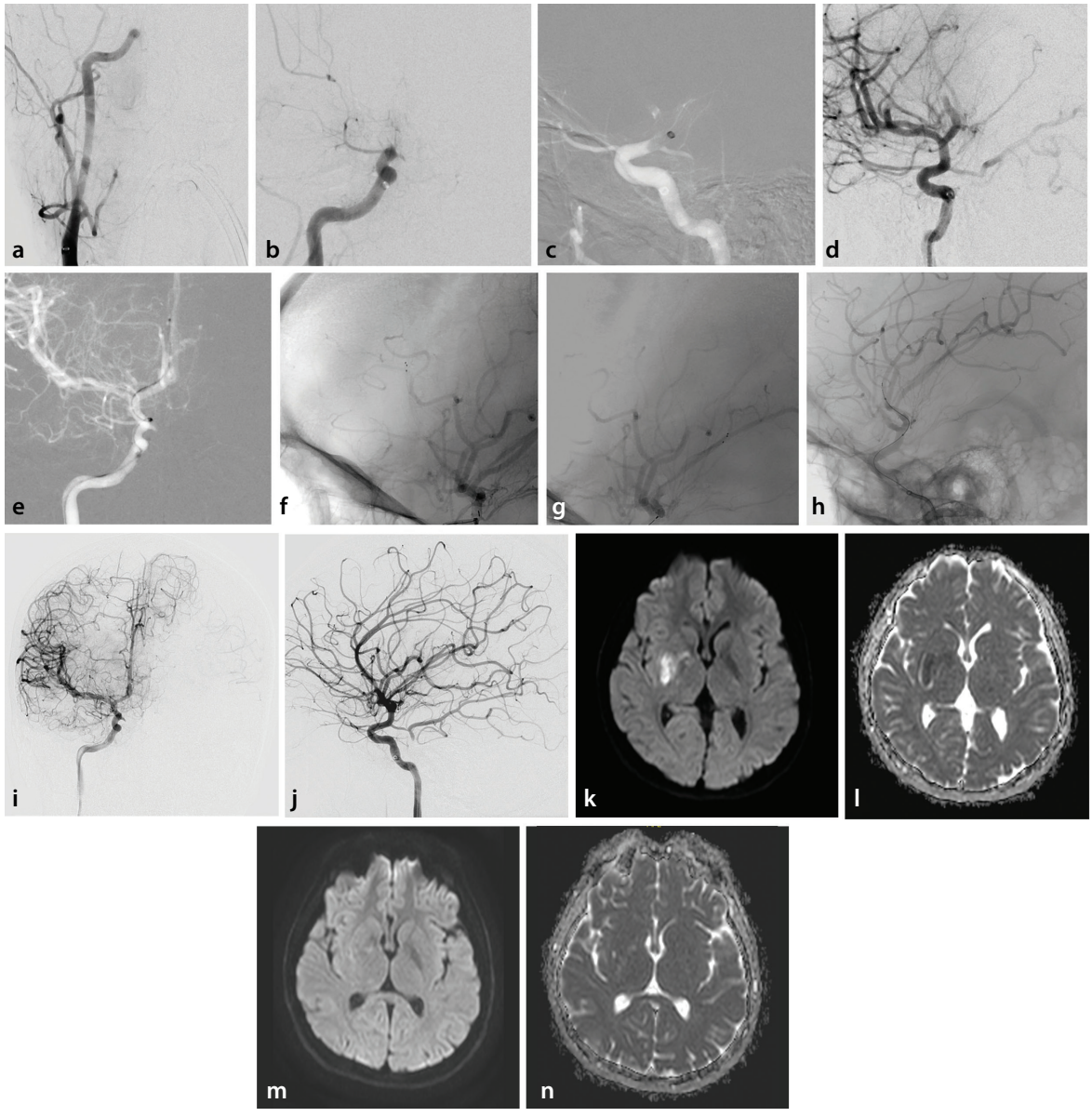

Figure 2. Preprocedural right carotid angiograms in anterior–posterior (AP) projection **(a, b)** reveal total occlusion of the right internal carotid artery (ICA) terminus. After recanalization of the supraclinoid ICA with aspiration thrombectomy **(c)**, residual distal middle cerebral artery (MCA) and anterior cerebral artery (ACA) occlusions persist on the carotid angiogram **(d)**. Both distal ACA **(e, f)** and distal MCA **(g, h)** occlusions were recanalized through stent retriever thrombectomy. Final AP **(i)** and lateral **(j)** carotid injections demonstrate the successful recanalization of the whole carotid artery territory. Diffusion-weighted image **(k)** and corresponding apparent diffusion coefficient (ADC) map **(l)** demonstrate acute infarction at the right basal ganglia. Follow-up magnetic resonance imaging **(m, n)** indicates regression of the diffusion restriction and consequent ADC pseudonormalization.

Case 4

This 16-year-old boy, who had a family history of thrombophilia (his mother and sister) as well as a father with myocardial infarction at the age of 40, was referred with left hemiparesis at hour 7 of the symptoms. He had received enoxaparin sodium 2 hours after symptom onset at another hospital before arriving at our center. His neurologic examination slightly improved during transfer, and his NIHSS score had decreased to 4 by the time of admission to the angiography suite. On the initial brain MRI, diffusion-weighted images and apparent diffusion coefficient maps revealed an acute infarction extending from the posterior right putamen to the corona radiata caused by a right proximal MCA occlusion. The groin was punctured at hour 8, and recanalization of an acute right M1 total occlusion was achieved 9 hours after the onset of symptoms (Supplementary Figure 3a-d). His mRS score was 1 (mild weakness in his left leg without disability) at the 12-month follow-up.

Case 5

This 11-year-old boy was treated at another hospital for a large, almost totally thrombosed, vertebrobasilar aneurysm (Supplementary Figure 4a) through the placement of telescopic flow diverters. The child was started on clopidogrel before the procedure, and this treatment was continued after the procedure. He was neurologically intact immediately after the endovascular procedure but developed oculomotor nerve deficits, ataxia, and vertigo during the postoperative period before discharge from the hospital. As a result of fluctuating neurologic symptoms, at the request of his family, the child was referred to our hospital after the onset of symptoms. He underwent mechanical thrombectomy within 24 hours of the last deterioration of his neurologic status. His NIHSS score was 5 on admission to the hospital and 4 at the angiography suite. A cerebral angiogram was obtained, which revealed near occlusion of the mid basilar artery secondary to a thrombus just distal to the flow diverter construct (Supplementary Figure 4b, c). Under a roadmap, a Rebar 18 microcatheter (Medtronic) was advanced through a 5F intermediate catheter, and the basilar artery was recanalized using a single pass of a Catchview device (Balt) (Supplementary Figure 4d). The child was switched from clopidogrel to prasugrel after the procedure. At the follow-up MRI, the mass effect of the partially thrombosed aneurysm on the neighboring brain stem structures and focal ischemic foci at the pons and cerebellar hemispheres were evident (Supplementary Figure 4e-i). At his follow-up DSA at 5 months (Supplementary Figure 4j), both the flow diverter stent and basilar artery were patent and his mRS score was 0.

Case 6

This 17-year-old girl without a notable medical history presented with acute right hemiparesis, facial paralysis, and global aphasia. A mass-like lesion at the left atrium was visualized through echocardiography, indicating cardiac thromboembolism. A head and neck CTA demonstrated left MCA distal M1 segment occlusion. Partial occlusion at the distal M1 and proximal M2 segments of the MCA with significant slow antegrade flow was identified through angiography (Supplementary Figure 5a, b). After selective "distal" catheterization of the superior and inferior trunks and the temporal branch (Supplementary Figure 5c-e), successful recanalization was achieved through stent retriever thrombectomy using a Solitaire device (Medtronic) (Supplementary Figure 5f, g). Postoperative cardiac CT revealed a hypodense soft tissue mass at the left atrium suggestive of atrial myxoma (Supplementary Figure 5h). Her cardiac mass was operated on after mechanical thrombectomy on the same day, and the pathological evaluation results of both the cardiac mass and cerebral thrombus were consistent with myxoma. At the 3-month clinical follow-up, her mRS score was 1 and she had minimal aphasia, allowing almost complete communication and mild weakness in the right leg.

Discussion

Following extensive studies comparing endovascular treatment with medical management within 6 hours of stroke onset, mechanical thrombectomy has been accepted as the standard of care for adult patients with AIS secondary to intracranial large vessel occlusion.[9-11] Although the efficacy and safety of this treatment have not been clearly established in children, the number of pediatric case reports and series are increasing.[12-14] Dicpinigaitis et al.[15] extracted the data on patients with pediatric stroke from the National Inpatient Sample, identifying 190 children treated with mechanical thrombectomy with a favorable clinical outcome of 55.3%. Bhatia et al.[16] compared 26 children with AIS who had undergone mechanical thrombectomy with 26 children with AIS who had received medical management, reporting improved clinical outcomes among the mechanical thrombectomy group with an odds ratio of 3.76. A recent meta-analysis on pediatric mechanical thrombectomy revealed a successful recanalization rate of over 90% among 184 children, a positive clinical outcome (mRS ≤2) rate of 83.3% among 183 children, and a mortality rate of 3.2% among 184 children.[17] These multicenter studies and case series with relatively high patient numbers suggest that pediatric thrombectomy may be a safe and effective treatment option for pediatric patients with AIS.

In general, thrombectomy for children has mirrored that for adults with respect to indications, technique, and to some extent, clinical evaluation scales. In the retrospective evaluation of the pediatric patients with stroke in this study, we noted that the patients had several unique and instructive characteristics, as all strayed from the usual indications, timing, and technique of routine mechanical thrombectomy. Cases 1 and 5 are examples of thrombectomy procedures performed for acute stent occlusions, which, to our knowledge, has not been reported before in the pediatric population. We are also unaware of an acute bilateral presentation or endovascular treatment in children, as in case 2. Moreover, in cases 3 and 6, distal and very distal (M3/4 segment of the MCA) thrombectomy was performed, which, in the adult population, is a controversial procedure[18] and has not been reported in children. The literature contains few case reports of children treated with mechanical thrombectomy for intracranial large vessel occlusion caused by atrial myxoma.[19] Finally, large vessel occlusion in case 4 was recanalized successfully beyond the first 8 hours of symptom onset. In the standard adult therapy, this would be possible only for patients meeting strict imaging-based indications.[20,21]

Although the current endovascular armamentarium, which is adult oriented, was sufficient for the pediatric cases in this study,[22] we faced various other technical challenges during treatment. One challenge, which affected two children with intracranial stent thrombosis, was the potential risk of flow diverter displacement, device intussusception, and arterial dissection or vasospasm during catheterization and thrombus retrieval. A similar salvage procedure was recently reported for acute in-stent occlusion in two adults.[23] However, mechanical thrombectomy for in-stent thrombosis has not been previously reported in children. The other challenge in our case series was related to bilateral acute ICA occlusion, associated

with a tandem occlusion on one side. These primary multivessel occlusions are rare, accounting for only 0.35% of adult thrombectomies, and they are frequently mortal.[24] We found just one report of thrombectomy for a primary multivessel occlusion in a child.[25] Nevertheless, multivessel occlusions associated with a tandem occlusion are extremely rare in adults,[24] and to our knowledge, they have not been reported in children. The compensation of bilateral ICA occlusion relies on collateral circulation through the vertebrobasilar system, an external carotid/ophthalmic anastomosis, or a combination of the two. In case 2 of our study, a 10-year-old patient with no notable history was diagnosed with dilated cardiomyopathy when he presented with acute stroke. Increased intracranial pressure indications were present, and the increased pressure possibly aggravated the ischemic insult.[26] Supraventricular tachycardia may also have contributed to the ischemia,[27] and tandem occlusions of the ICA and MCA on one side may have further hampered the collateral circulation. Routine isolated tandem occlusions, however, occur in up to 20% of patients with AIS in the adult population.[28] Acute tandem occlusion in pediatric patients is rare. In the literature, we were able to find a single report of a 13-year-old girl who underwent mechanical thrombectomy and had favorable clinical and radiological outcomes.[29] Recent studies in adults investigating prognoses of the subtypes of acute anterior circulation large vessel occlusions noted that, compared with unilateral MCA, patients with AIS with tandem ICA/MCA and bilateral occlusions or those with contralateral stenosis had less favorable outcomes.[30,31] The most likely cause is the diminished collateral flow to the affected tissue. With a tandem occlusion as well as a contralateral acute ICA occlusion, our patient had an unfavorable prognosis on presentation.

Notably, some adult outcome measures (such as the 90-day outcome) may not be directly transferable to the pediatric population. Children with AIS have a much longer remaining life span than older adults with AIS. The extent of recovery resulting from brain plasticity and adaptation to stroke may be optimal in children, and a more aggressive approach may be warranted in pediatrics. It is postulated that neural injury at the early phases of brain development may be compensated more effectively because the pediatric brain is a dynamic environment with greater neuroplasticity.[32,33] The pediatric brain responds to acute ischemia through extensive neural network development and synaptogenesis, recruiting not only ipsilateral connections but also contralateral ones. Synaptogenesis is itself a dynamic process that includes synaptic pruning, eliminating weak synapses while enhancing stronger connections, a process that is most active before early adulthood.[34]

In recent years, the critical time window for thrombectomy has been extended by up to 16–24 hours in a subpopulation of adult patients with rescuable penumbra.[20,21] Moreover, pediatric cases with a time-window extension and favorable outcomes have been reported.[35] Accordingly, in the cohort in this study, case 4 was transferred to the angiography suite after the usual time window had passed, and in case 3, the groin puncture was at the upper limit of the time window when a very distal thrombectomy was performed.

As their underlying etiology, four patients had cardioembolic thrombus, one had thrombophilia, and two had intracranial aneurysms treated through flow diverter stent placement. With the exception of the latter etiology, these are known to be the most common risk factors for childhood AIS.[36,37] With regard to the clinical results, we achieved functional independence with an mRS score ≤1 in five of our patients (83.3%) despite the drawbacks stated above. Given this more favorable outcome for stroke in children[38] and the similar patient outcomes in previous reports,[6] we suggest that claims regarding the high risks of endovascular treatment for AIS in children (up to approximately 20 times of medical treatment as reported by Malik et al.[37]) be reappraised, with treatment preferably provided by centers with sufficient pediatric experience.[38]

Our study has limitations inherent to its retrospective nature as well as its small and heterogenous patient cohort.

In conclusion, children that are likely to benefit from mechanical thrombectomy should be transferred urgently to centers with experience in pediatric neurology, anesthesia, and interventional neuroradiology for a case-by-case evaluation or modification of indications and methods for endovascular treatment.

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Conflict of interest disclosure

The authors declared no conflicts of interest.

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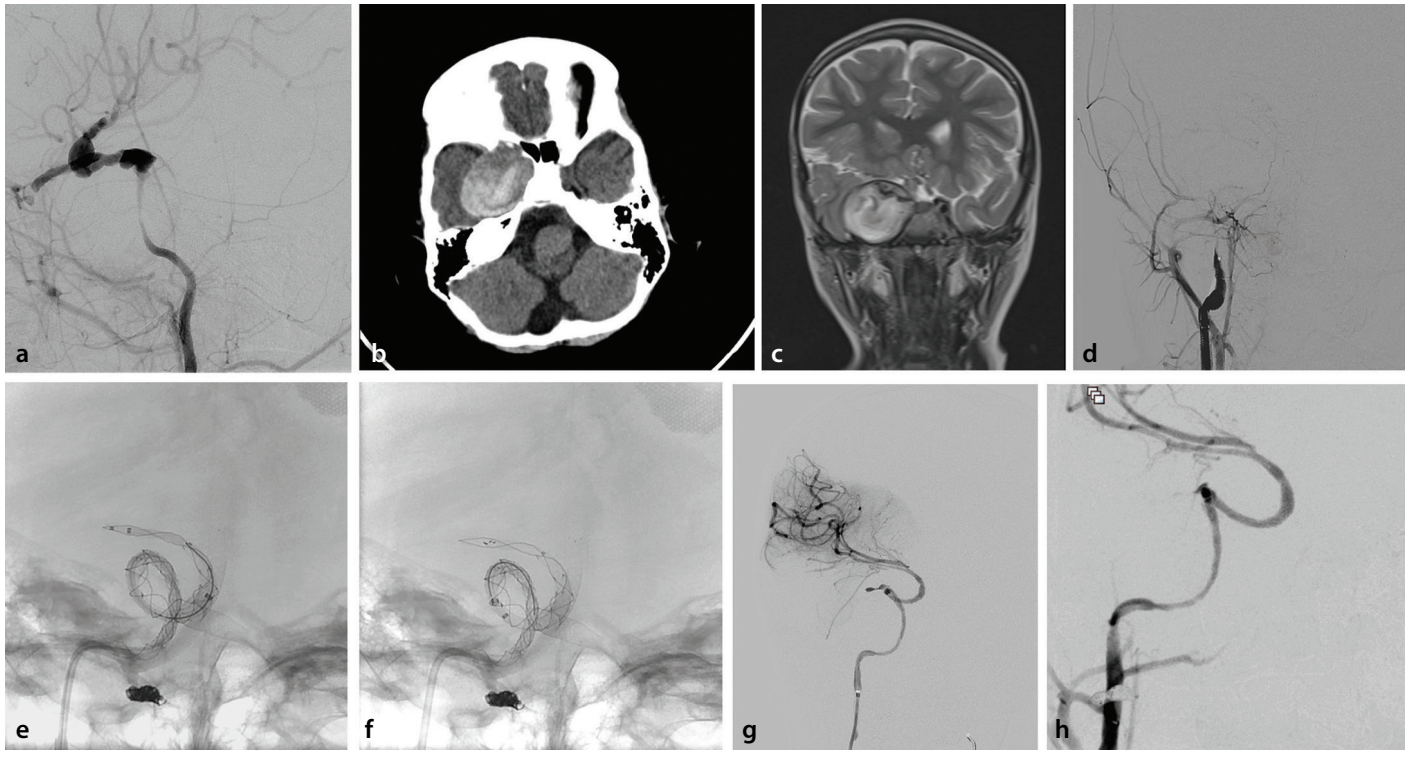
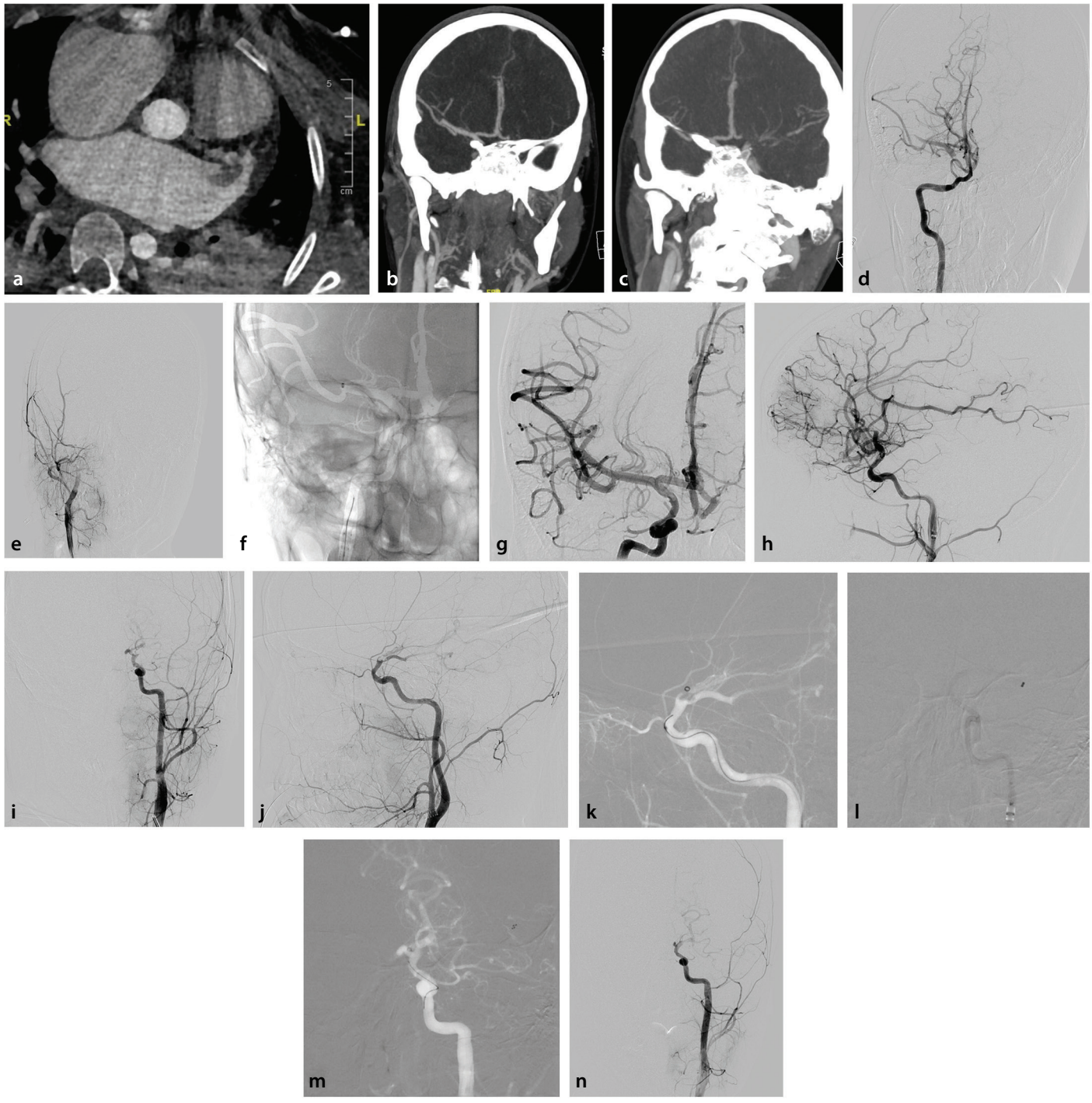
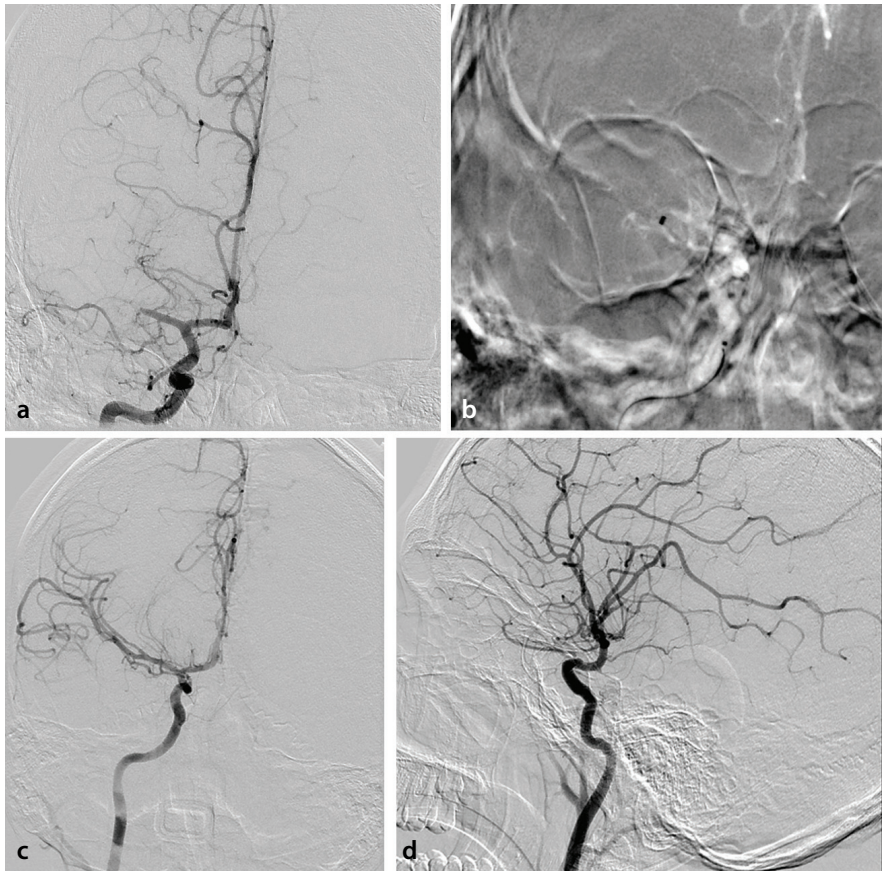


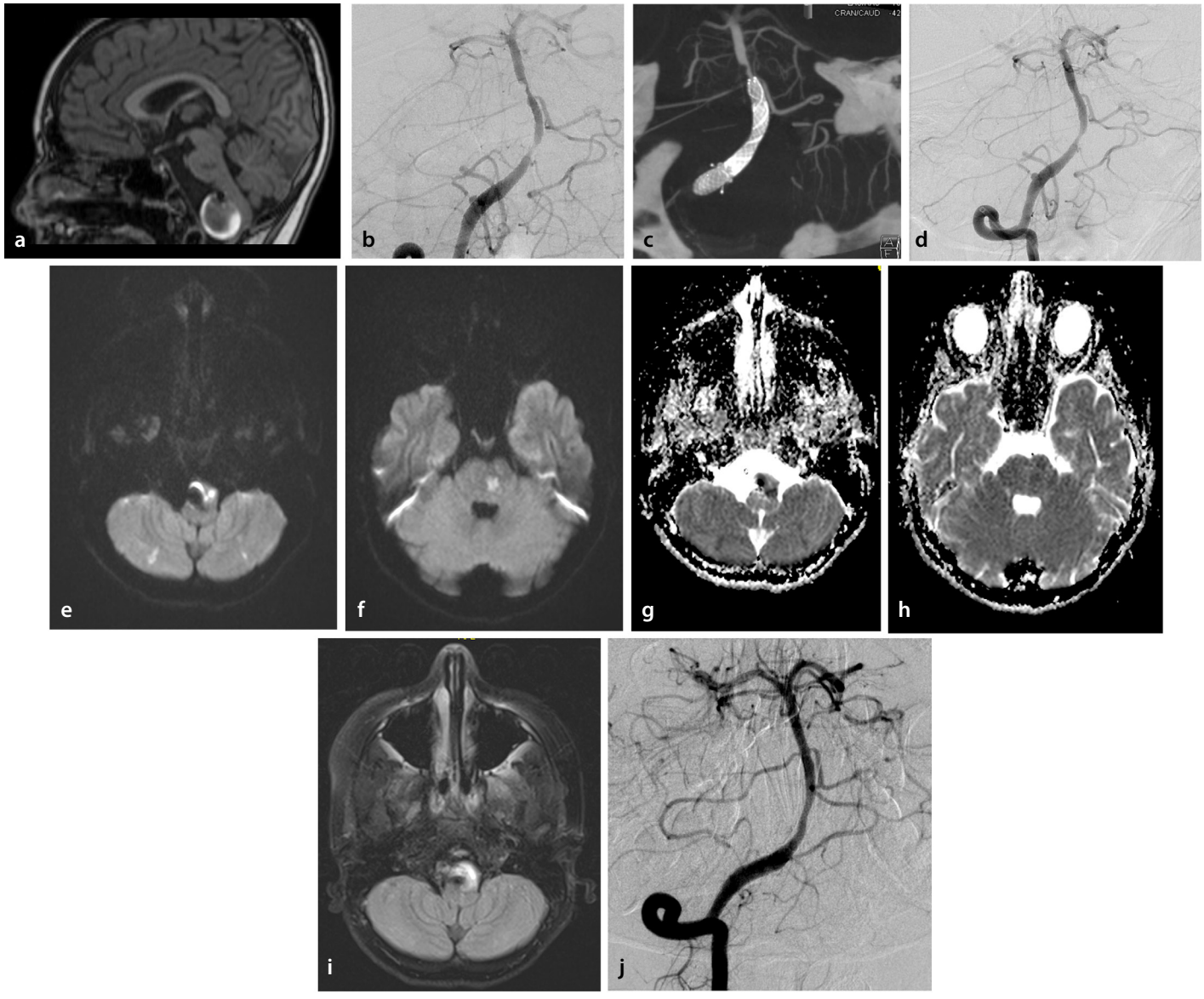
Supplementary Figure 1. Preoperative right carotid angiogram **(a)**, axial CT **(b)** and coronal T2-weighted MR images **(c)** show a partially thrombosed giant cavernous ICA aneurysm distal to a preocclusive stenosis. Right carotid angiogram performed 72 hours after the endovascular treatment of the aneurysm with a flow diverter and stent **(d)** reveals acute stent occlusion with arterial occlusion at the distal cervical ICA. After passing the occlusion with a coaxial system of catheters **(e)**, a stent retriever device was deployed **(f)** for thrombectomy. Control angiograms **(g, h)** demonstrate successful recanalization of the MCA, the ipsilateral ACA was supplied via the anterior communicating artery. CT, computed tomography; MR, magnetic resonance; ICA, internal carotid artery; MCA, middle cerebral artery.



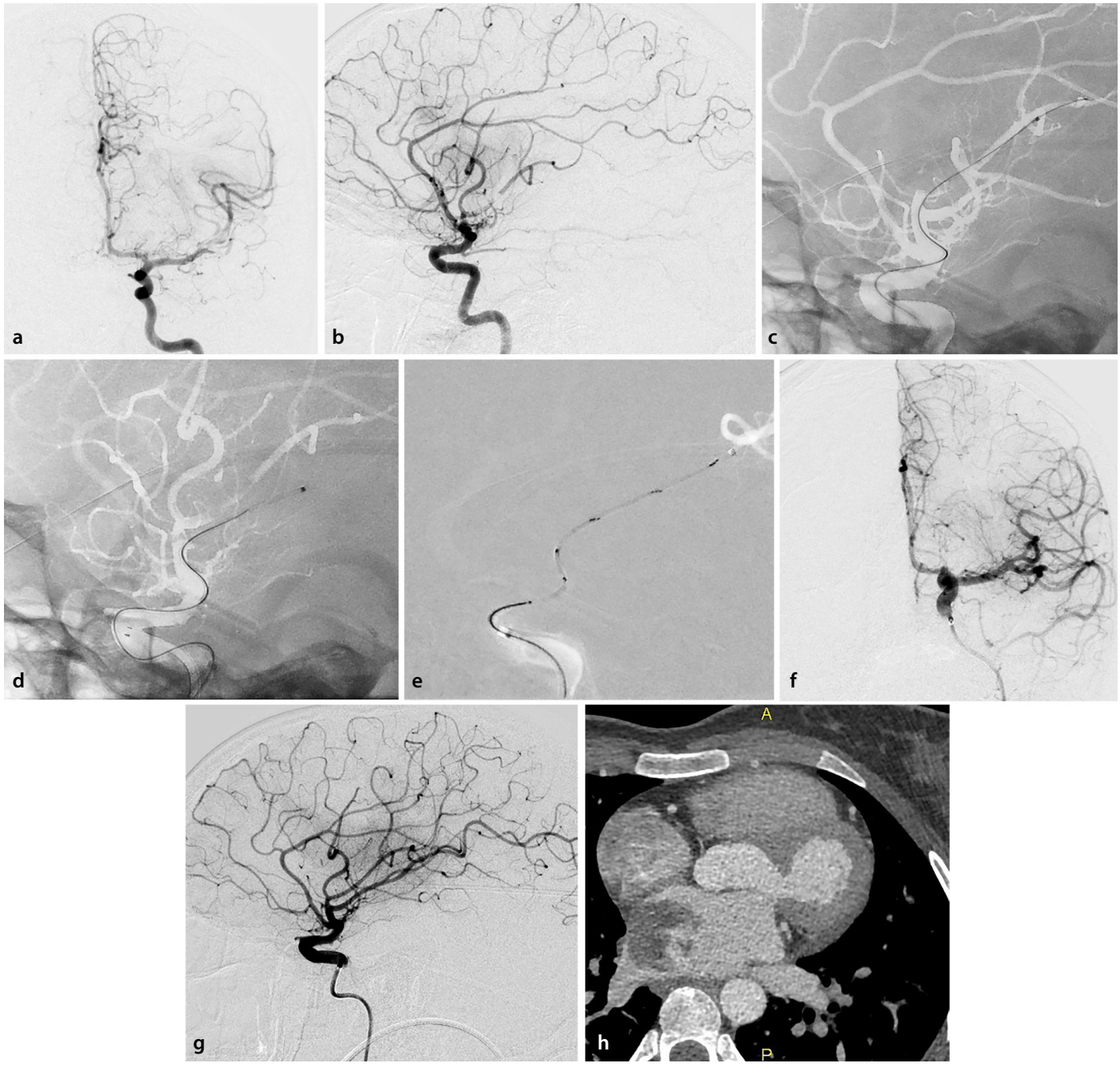
Supplementary Figure 2. A hypodense filling defect consistent with thrombus in the left atrial appendage **(a)**, a right cervical ICA/MCA tandem occlusion **(b)** as well as a left ICA terminus occlusion **(c)** are seen on head and neck CT angiography. Vertebral angiogram **(d)** shows reconstruction of the right intracranial anterior circulation via the posterior communicating artery and the right MCA occlusion distal to the cervical occlusion is revealed. Right cervical ICA arteriogram **(e)** demonstrates the cervical occlusion. After cervical ICA recanalization, aspiration thrombectomy was undertaken **(f)** and resulted in recanalization of the right MCA territory as evident on AP and lateral projections of carotid angiograms **(g, h)**. Then, following left ICA angiogram **(i, j)**, aspiration **(k, l)** and stent retriever **(m)** thrombectomies were performed. Yet, as noted on the final left ICA angiograms **(n)** the attempts were futile. ICA, internal carotid artery; MCA, middle cerebral artery; CT, computed tomography.



Supplementary Figure 3. Right MCA occlusion is seen on the initial right carotid artery injection **(a)**. After aspiration thrombectomy **(b)**, final angiograms show recanalized MCA territory **(c, d)**. MCA, middle cerebral artery.



Supplementary Figure 4. Sagittal pre-contrast T1-weighted MR image **(a)** demonstrates a large distal V4 segment vertebral artery aneurysm which was previously treated with flow diversion. Right vertebral injection **(b)** shows a pre-occlusive filling defect in the basilar artery distal to the flow diverter stent consistent with acute thrombosis. Maximum intensity projection reformatted image of 3D rotational angiogram **(c)** confirms the acute thrombus in the basilar artery. Postprocedural right vertebral angiogram **(d)** illustrates complete removal of the thrombus. Diffusion-weighted images **(e, f)** and corresponding ADC maps **(g, h)** reveal acute ischemic lesions at the brain stem and bilateral cerebellar hemispheres. Partially thrombosed aneurysm and compression of adjacent structures are appreciated on axial FLAIR image **(i)**. Follow-up DSA at 5 months **(j)** shows an intact flow diverter and a patent basilar artery. MR, magnetic resonance; ADC, apparent diffusion coefficient; FLAIR, fluid-attenuated inversion recovery; DSA, digital subtraction angiography.



Supplementary Figure 5. Preprocedural AP **(a)** and lateral **(b)** projection carotid angiograms show partially occluded MCA. After superselective microcatheterization of both MCA trunks **(c, d)** and subsequent stent retriever thrombectomy **(e)**, recanalization of the left MCA territory can be seen on AP **(f)** and lateral **(g)** projection angiograms. Axial contrast enhanced cardiac CT **(h)** of the patient reveals a hypodense filling defect in the left atrium. AP, anterior–posterior; MCA, middle cerebral artery.