Placement of Endovascular Stent for Reperfusion of Cerebral Infarct After Pediatric Traumatic Internal Carotid Artery Dissection

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ABSTRACT

Background: Traumatic intracranial ICA dissections are not commonly seen in children. Dissection resulting in perfusion deficit warrants intervention. Here we encountered a patient who experienced traumatic ICA dissection, treated by endovascular stenting.

Methods: A 10-year-old female presented with aphasia and right sided weakness following trauma. Imaging showed deficit in the left MCA territory without core. Further imaging showed dissection of the left supraclinoid ICA, confirmed by digital subtraction angiography.

Results: A Neuroform Atlas stent was placed without complication. All dysarthria and weakness had resolved on follow-up 5 months post-stenting.

Conclusions: Acute stroke symptoms in children can result in lasting deficits if not treated quickly. Medical management is regarded to be first line, depending on presentation. Endovascular stenting may provide a promising means to treat pediatric ICA dissections involving perfusion deficits and mitigate permanent ischemic changes.

CASE REPORT

CASE REPORT

A 10-year-old girl had fallen from the bleachers at school and encountered dizziness, nausea, and vomiting immediately, resolving after 2 hours, but otherwise no neurological symptoms. It is possible these symptoms can be attributed to concussion rather than arterial dissection. A few days later, this patient performed a somersault on the trampoline at approximately 4 pm. The patient acutely developed progressively worsening aphasia, right nasolabial flattening, right extremity weakness, and dysarthria and was taken to an outside hospital emergency department. The Pediatric National Institutes of Health Stroke Score (NIHSS) at time of presentation was 20. CT head and neck were done at the outside hospital, and the patient was then transferred to our institution, arriving around midnight.

CT head and neck were unremarkable, and she was started on heparin therapy upon admission to the pediatric intensive care unit (PICU), prior to neurosurgery and neurology consults. She had no documented predisposing stroke factors at the time of presentation. CT perfusion scan showed a large perfusion abnormality in the left middle cerebral artery (MCA) distribution, with no significant core infarct (Figure 1). CTA demonstrated left supraclinoid internal carotid artery occlusion (Figure 2A). High FLAIR signal around petrous and cavernous ICA is consistent with blood products and indicative of arterial dissection (Figure 2B). MRA suggest a left supraclinoid internal carotid artery dissection with proximal flow restriction compared to the contralateral and DWI hyperintensity revealed infarcted tissue (Figure 2C, 2D).

The neuro-interventional radiology team decided stent placement was indicated due to presentation of right sided hemiplegia and preoperative CT perfusion demonstrating a large penumbra in the right MCA territory, representing a large volume of salvageable brain tissue. Cerebral angiography confirmed a flow limiting dissection flap in the left supraclinoid segment of the ICA (Figure 3A-3C). In this situation, reperfusion of the brain tissue in the left MCA territory was only feasible with the deployment of an intracranial stent. A 3 x 24 mm Neuroform Atlas Stent (Stryker Neurovascular, Fremont, California, USA) was chosen due to its flexible, low-profile, and self-expandable characteristics. This was a flow limiting non-atherosclerotic dissection extending from the supraclinoid ICA into the proximal M1, with no meaningful contributions coming from the false lumen. Extensive narrowing of the left

ICA was noted at skull base and throughout the petrous and cavernous portions of the left ICA with ultimate occlusion in the supraclinoid segment.

A Neuroform Atlas is the best device in our inventory that could be navigated easily through an 018 microcatheter to the site of the lesion. It possesses enhanced conformability, wall apposition, high deployment accuracy, and excellent radial force in non-atherosclerotic dissection to restore perfusion. The left supraclinoid ICA from the M1 segment to the ophthalmic segment was stented. After the stent was deployed, significant improvement was demonstrated in final angiography (Figure 3D,3E). There was some residual narrowing of the ICA lumen was appreciated at the end of the procedure, however, it would be expected to improve with stent expansion (Figure 3D,3E).

The patient was loaded with 75 mg of Plavix and 325 mg of aspirin intra-operatively through a nasogastric tube to reduce the risk of in-stent thrombosis. After 24 hours, the patient began taking 37.5 mg of Plavix and 81 mg of aspirin daily for 6 months. Patient is now on 81 mg of aspirin daily indefinitely. All dosages are determined by institutional guidelines based weight/age assessment. P2Y12 assay was obtained on post-operative days 3 and 7 which showed platelet reactivity units (PRU) values within therapeutic range. Use of antiplatelet agents in this pediatric patient is consistent with the literature [9,11-14].

During rehabilitation in the coming weeks, the patient was ambulatory, but she required some prompting for attention on the right side. Her main motor deficit involved proximal right upper extremity (RUE) strength 1/5 and distal RUE strength 2/5 as documented immediately post-stent placement. However, 3 months post-stent placement, patient was noted to be moving anti-gravity in all four extremities. 5 months post-stent placement, patient had complete resolution of dysarthria and extremity weakness; patient was using RUE to eat and write with full strength in all muscle groups. CTA displayed proper stent placement and patency of distal vessels (Figure 4). Only some mild right hemineglect has persisted. At 1-year post-stent placement, patient had no motor deficits and mild cognitive issues. MRA at 1-year displayed marked improvement in patency and distal perfusion compared to MRA immediately post-operatively (Figure 5).

DISCUSSION

ETIOLOGY & DEMOGRAPHICS

Internal carotid artery (ICA) dissections are most commonly secondary to trauma, and most of these dissections originate in the extracranial portion of the ICA [1,2]. Pediatric management guidelines have largely come about through modifying standard guidelines of adults [3,4]. Perfusion deficits left untreated may lead to long-term neurological dysfunction [5]. Recently, more pediatric patients are undergoing endovascular treatment [6,7].

The proposed mechanism in traumatic ICA dissection involves hyperextension, rotation, or direct forces disrupting the physiologic layers of the vessel, leading to a sub-intimal or sub-adventitial tear that can introduce blood between planes as well as platelet activation and ultimately the formation of a thrombus over the encasing internal elastic lamina [6,8]. It is thought that in pediatric populations, the dissection is prone to stay in the subadventitial layer which may explain observed delayed presentation [1]. Thus, pediatric patients have presented with different timelines after a traumatic event [2,8].

Some patients may present with acute ischemic stroke (AIS) in conjunction with the ICA dissection. AIS in pediatric patients has been estimated at 2.5-8 per 100,000 per year, with up to 20% of childhood acute ischemic stroke etiology being craniocervical arterial dissection [2,9]. Common symptoms include headache, neck pain, hemiparesis, and aphasia. It is worth noting that clinically silent cases have been reported [4,10].

Oftentimes, spontaneous resolution is observed with anticoagulation or antiplatelet agents, though, persistence of the dissection flap has been observed as well [3,4]. Should conservative measures fail, and patients experience recurrence or worsening neurologic decline, other interventions may be indicated for treatment including thrombectomy or stenting depending on the clinical picture. A recent case series of pipeline placement in 6 pediatric pseudoaneurysmal patients displays growth of pediatric endovascular management and encourages exploration of new treatment modalities for this population [7].

CLINICAL & IMAGING FINDINGS

Traumatic ICA dissections, particularly in pediatric patients, can have a delayed presentation, however, most typically present with headache, hemiparesis, and aphasia if symptomatic. Consequential ischemic events can occur within minutes or up to a month after initial insult [2-4,6,9,10]. If there is clinical suspicion of dissection, MRA is considered the best noninvasive standard to identify this pathology, with high sensitivity and specificity [2,6]. CTA may also detect ICA dissection, though usually with lower sensitivity and specificity, and can be normal within the first 12 hours [2,3,9,10]. Cerebral catheter angiography remains the gold standard in diagnosis, and access could be used to guide endovascular treatment if warranted [2,3,10].

It has been previously noted that in the use of magnetic resonance imaging, T1 fat-saturated imaging or contrast-enhanced images are advantageous in detection of ICA dissection. Identification of ICA dissection should involve some of the following features; irregular dilatation at a non-branching site or involving an intramural hematoma, intimal flap, presence of a false lumen, or sudden change in appearance; irregular stenotic segments or “string sign” with an intramural hematoma, intimal flap, presence of a false lumen, or sudden change in appearance; or occlusion of the vessel lumen that distally recanalizes with irregular dilatation [4,6]. The dissection may display contrast enhancement, potentially due to a slowing of blood flow within a false lumen or due to the presence of inflammation [6,10]. Dissections may present with a classic "crescent" sign indicative of a false lumen [6].

TREATMENT & PROGNOSIS

ICA dissections are rare, and in the pediatric population, have yet to have a specific evidence-based treatment protocol. Many cases are treated with anticoagulation or antiplatelet agents and monitored closely with imaging [6]. Prognosis of cerebral ischemia in the pediatric population tend to have a good prognosis up to 75% regaining full functionality within 12 weeks of infarct [10]. Outcome is thought to be more favorable in pediatric patients than adults, possibly due to increased brain plasticity, however, long term studies have noted a majority of pediatric ischemic stroke patients go on to develop long-term physical and cognitive disabilities more frequently than the general population [2]. Several trials and retrospective studies found no difference between anti platelets and anticoagulants in prevention of stroke in patients with ICA dissections, however, to date no studies have compared endovascular stenting to antiplatelet or anticoagulant agents in the setting of pediatric ICA dissection with perfusion deficit [5]. Open surgery, endovascular stenting, thrombolysis, or thrombectomy have also been proposed in cases that demonstrate ischemic symptoms and risk loss of perfusion to salvageable tissue, and in patients that demonstrate ICA dissection there is no contraindication to endovascular recanalization [3,6]. There is a low adverse event rate and excellent future patency with endovascular stenting of ICA dissection in adults, though a more complete analysis of the pediatric population is currently lacking due to rarity of the disease pathology, and rarity of endovascular intervention [4,6,10]. It has previously been suggested that a pediatric NIH Stroke Scale score ≥ 6, radiographically confirmed large artery dissection, and multi-departmental treatment decision are all valid indications for endovascular intervention in presentations such as that which we have described above [10]. Small sample studies have suggested approximately 62% of pediatric patients with blunt trauma-related ICA dissection had incomplete neurological recovery when treated strictly medically [4-10].

DIFFERENTIAL DIAGNOSES

Traumatic intracranial internal carotid artery dissection, spontaneous dissection, while possible, is unlikely due to traumatic history.

DISCUSSION

There is paucity in the literature of instances of pediatric ICA dissection, and documentation of the management thereof. This case is unique in exhibiting hypo perfusion of the MCA territory without an embolic source in the setting of intracranial ICA dissection. While intracranial ICA dissection is commonly related to traumatic events in pediatric patients, it can often occur spontaneously and has been associated with predisposing factors such as inherited arteriopathies [1,3]. Similar to our patient, several cases of intracranial ICA dissection have been reported due to minor trauma rather than direct trauma to the head or neck. It is possible that rather than damage through direct impact to the vessel, the cavernous and supraclinoid ICA are particularly mobile in pediatric patients, such that displacement of vascular structures in trauma may cause dissension of the vessel [8,15-17]. The dissection may have stayed in the subadventitial layer and might have led to delayed presentation. It is unclear if our patient experienced a dissection upon falling from the bleachers with a delayed presentation days later, or if the dissection occurred following the somersault with a more acute presentation [6]. It may be that the fall from the bleachers resulted in concussion and was unrelated to the dissection. The somersault on the trampoline leading to dissection and symptom onset has a time course that is more consistent with the literature for traumatic ICA dissection [10,15,16,18]. Given the 8hour delay between the onset of symptoms and arrival to our hospital, it was not complete occlusion, however, prolonged hypoperfusion that may have turned into an ischemic event had the perfusion deficit been left untreated. Prolonged hypoperfusion would explain the slow resolution of symptoms despite restoring blood flow.

Treatment for carotid artery dissections has historically been anticoagulant or antiplatelet therapy and observation [1-3]. Endovascular intracranial ICA techniques have been performed with balloon angioplasty and stent placement dating back to the 1990s. Both angioplasty and thrombolytic techniques pose a problem in that they do not address the potential for re-occlusion of the vessel. Stenting would provide a physical barrier to this potential re-occlusion. Though, it should be mentioned that patient compliance with post-operative antiplatelet agents has previously been noted to be a crucial consideration when electing to stent a pediatric patient [15].

Despite some early instances, endovascular intervention and stenting for ICA occlusion has not typically been recommended, unless complicating factors such as hemodynamic changes with hypertension or acute neurological symptoms are observed [12]. The literature supports stenting, however, in a case such as ours, with a concurrent acute hypoperfusion observed in the MCA distribution without an embolic source [3,4]. Endovascular intervention should further be considered if backfilling from the ipsilateral posterior communicating artery is inadequate to compensate in perfusing the territory, which was demonstrated in our hypoperfused patient. As the child grows, some concern for the integrity of the stent has previously been expressed in the literature, however, it has been suggested to use a flexible, low-profile, and self-expandable stent, such as the Neuroform Atlas, to avoid complications from natural vessel enlargement [19].

Some authors have argued for the efficacy of superficial temporal artery (STA) to middle cerebral artery bypass in cases of ICA dissection with MCA ischemia [13]. Pediatric patients pose a more challenging surgical procedure; if the donor blood vessel is not of adequate diameter, and therefore flow caliber, the anastomosis will likely not prove feasible [20].

There is no definite guideline for followup of pediatric patients undergoing placement of an endovascular stent to date. Review of literature has shown that the median follow-up is 4 months, with some studies following up as early as 1 month, and some in 6 months. Whether a patient is followed up with CTA, MRA, or DSA is provider dependent, though it appears that MRA and DSA are more commonly utilized [7,8,17]. In our management, we have obtained CTA at 4 months after initial presentation, followed by MRA at 1 year after initial presentation [7,17]. We intend to follow up with MRA at 2 years after initial presentation, and gradually space follow-up should stability of the device and vasculature permit. We plan on repeating DSA in 5 years. Followup with MRA decreases the amount of radiation the patient receives while still providing high quality imaging of the vasculature.

Stenting prevents re-occlusion in ICA dissection patients, and it provides a less-invasive means of intervention than the STA-MCA bypass. Stenting has been used in pediatric patients with progressively symptomatic dissection. In instances where a false lumen offers no meaningful contributions and stenting would increase distal perfusion, stenting may be an effective treatment in the management of ICA dissection with distal cerebral infarct in the pediatric population [17].

TEACHING POINT

Traumatic ICA dissection with associated perfusion deficit in children may be treated with endovascular stenting. Our patient presented here had excellent outcomes with no lasting motor deficit, and only minor cognitive deficit at one year.

AUTHOR CONTRIBUTIONS

Author Contributions: Conceptualization, A.R., W.C., A.A., T.T.; methodology, T.T., A.A; software, W.C., T.T., A.A.; validation, T.T., A.A., M.K.; formal analysis, A.R., W.C., A.A, M.K., T.T.; investigation, A.R., D.B., W.C., A.A., T.T.; resources, A.A., M.K., T.T.; data curation, A.R., W.C., A.A., M.K., T.T.; writing—original draft preparation, A.R., W.C.; writing—review and editing, A.R., W.C., T.T., A.A., M.K.; visualization, A.R., W.C., T.T., A.A., M.K.; supervision, T.T., M.K., A.A.; project administration, T.T.; funding acquisition not applicable. All authors have read and agreed to the published version of the manuscript.

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Consent: Consent has been obtained from patient's legal guardian to publish this case report.

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FIGURES

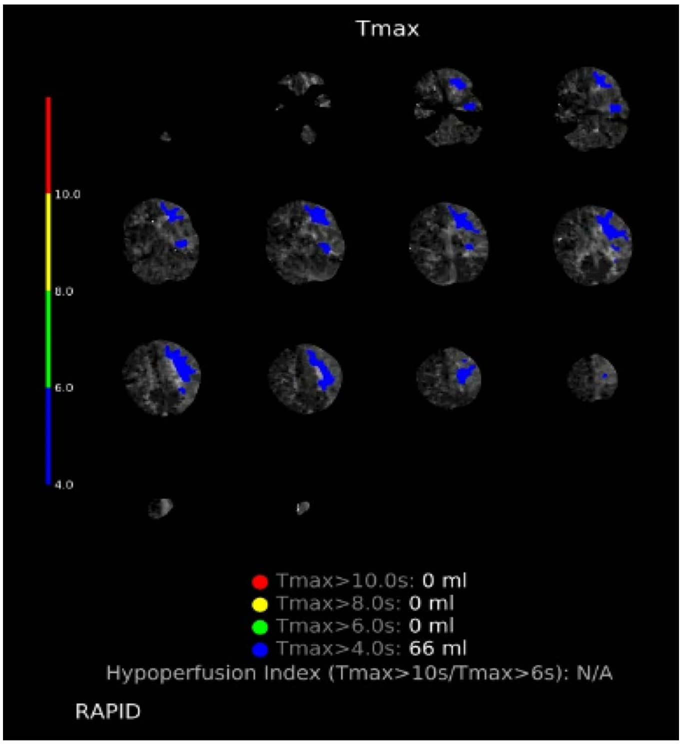

Figure 1: 10 year old female
CT perfusion study axial cuts showing increased Tmax as compared to the contralateral hemisphere in the left MCA territory, suggesting perfusion deficit. CBF was measured and unremarkable at presentation, suggesting lack of core.

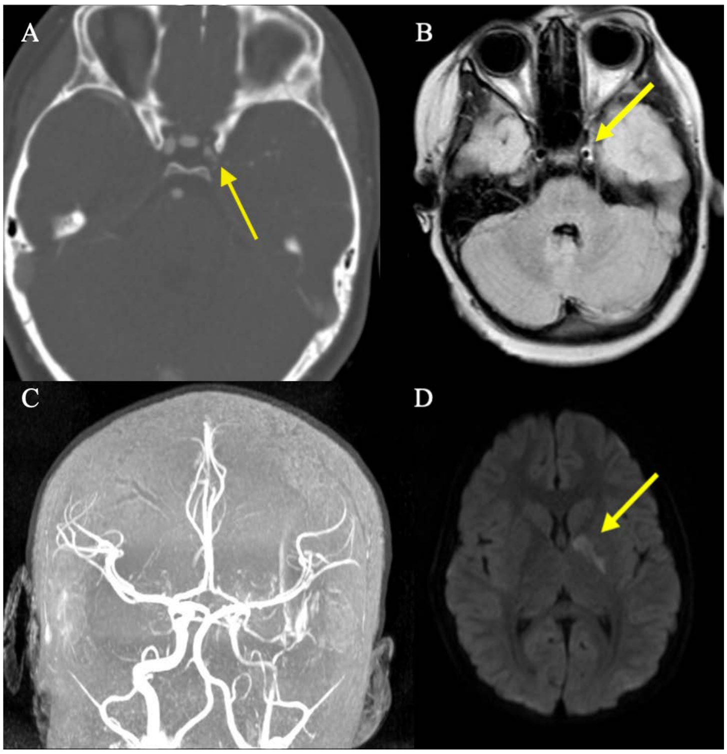

Figure 2: 10 year old female
A: Initial axial CTA contrasted study in arterial phase showing left supraclinoidal ICA intraluminal irregularity with part of posterior communicating artery directly below. B: FLAIR sequence non-contrasted MRI axial cuts with arrow indicating circumferential hyperintensity consistent with blood products and suggestive of dissection C: Initial contrast enhanced MRA vessel reconstruction coronal plane indicating left ICA occlusion/ stenosis. D: MRI DWI B1000 axial cuts, bright area indicated by arrow showing area of acute infarcted tissue.

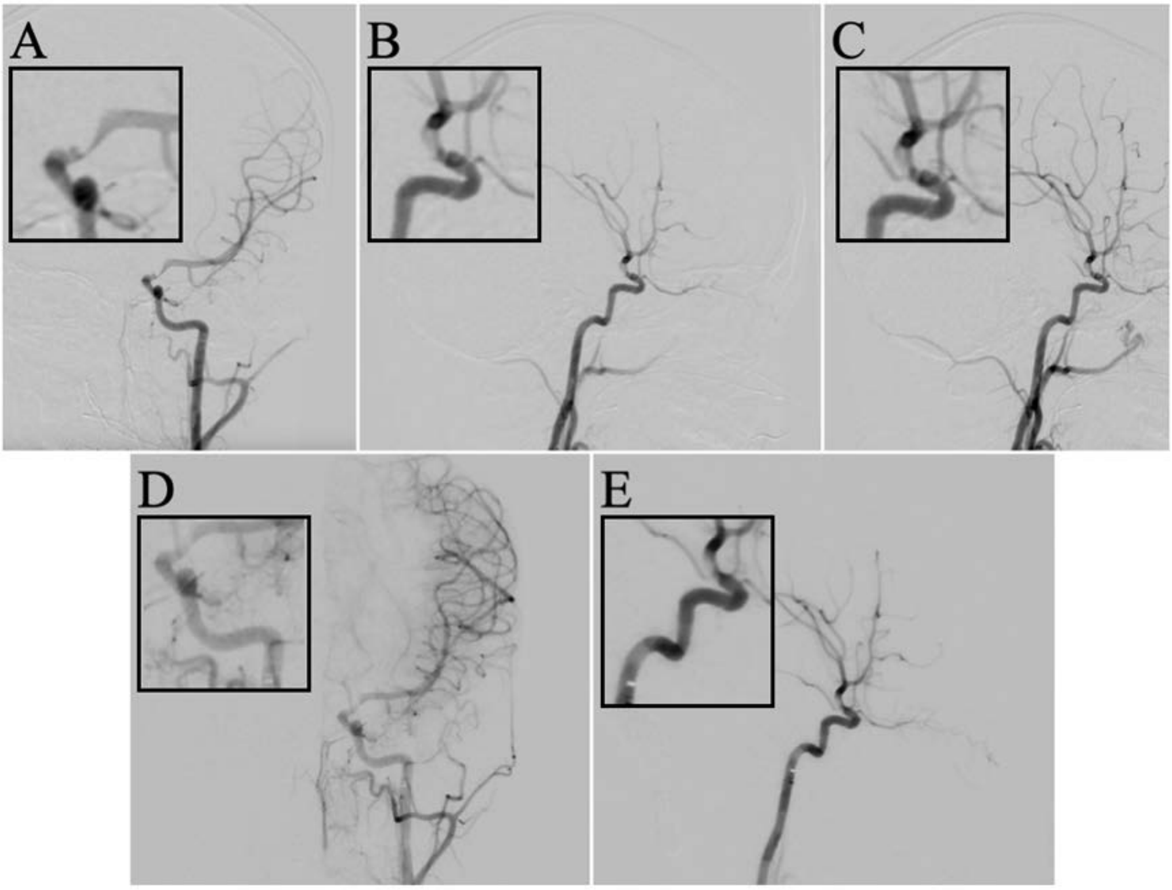

Figure 3: 10 year old female
Intraoperative digitial subtraction angiography. A: Pre-stent contrasted digital subtraction angiography AP view of left ICA demonstrating affected territory, lack of recanalization, square showing area of interest. B: Pre-stent contrasted digital subtraction angiography lateral view of left ICA demonstrating affected territory, square showing area of interest. C: Pre-stent contrasted digital subtraction angiography oblique view of left ICA demonstrating posterior communicating artery branching prior to dissection flap, square showing area of interest. D: Post-stent contrasted digital subtraction angiography AP view, final intraoperative angiography demonstrating increased flow across affected territory, square showing area of interest. E: Post-stent lateral view, final intraoperative angiography demonstrating increased flow across affected territory, square showing area of interest. Flow expected to increase with stent expansion.

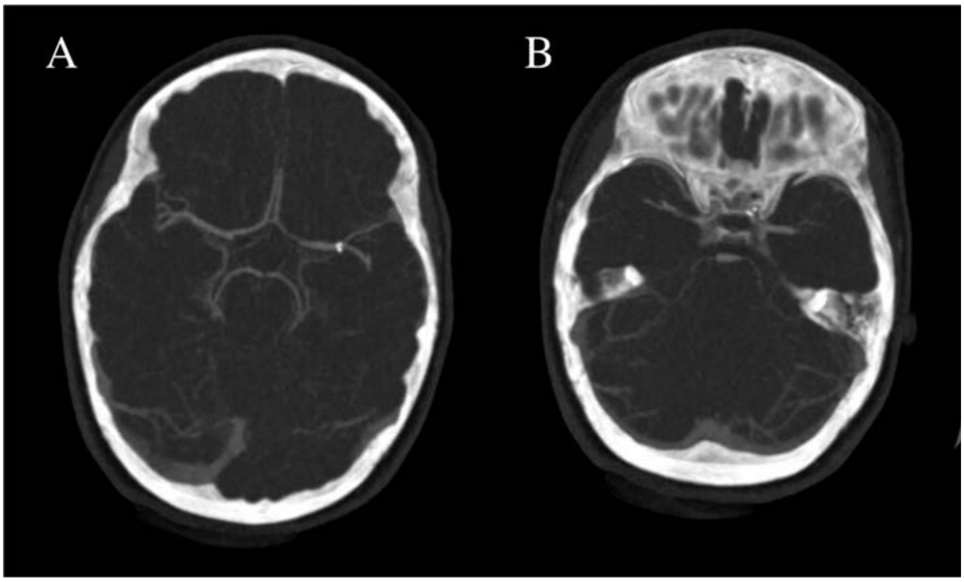

Figure 4: 10 year old female
4-month post-operative contrasted CTA scan axial cuts. A: Demonstrating patent distal M2 branches. B: Demonstrating proximal end of stent and patent supraclinoid ICA and M1.

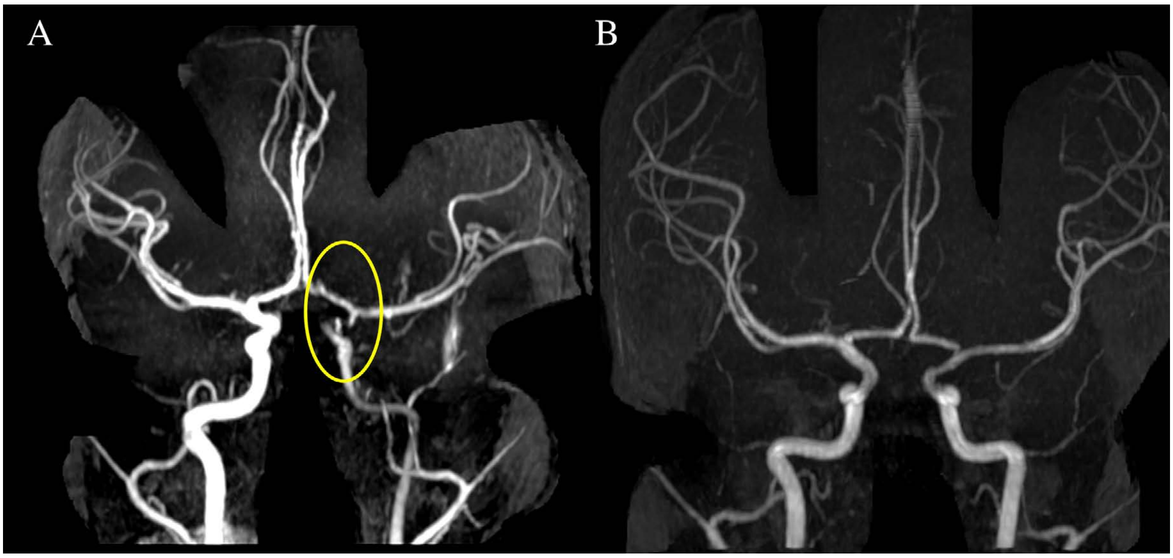

Figure 5: 10 year old female
A: MRA contrasted coronal cuts performed immediately post-operatively showing supraclinoid ICA dissection and reduction in patency as compared to contralateral hemisphere. B: MRA performed at 1-year follow-up displaying patent ICA and preserved distal perfusion.

SUMMARY TABLE

Etiology	Trauma
Incidence	2-8 per 100,000 children per year
Gender Ratio	68% male
Age Predilection	8.6 years
Risk Factors	Trauma, connective tissue disease
Treatment	Medical vs endovascular treatment
Prognosis	Variable
Findings on imaging	Occlusion, tapering stenosis, flame sign, string sign, crescent sign, double lumen, filling defect

KEYWORDS

Pediatric; Endovascular; Stent; Dissection; Ischemia; Perfusion

ABBREVIATIONS

AIS: Acute Ischemic Stroke; CTA: Computed Tomography Angiography; ICA: Internal Carotid Artery; MCA: Middle Cerebral Artery; MRA: Magnetic Resonance Angiography; NIHSS: National Institutes Of Health Stroke Score; RUE: Right Upper Extremity; STA: Superficial Temporal Artery

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