Internal Carotid Artery Bifurcation Aneurysm: Symptomatic Internal Carotid Artery Bifurcation Aneurysm in a Pediatric Patient Treated with Flow Diversion

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Abstract

Intracranial aneurysms are uncommon in pediatric patients and present different characteristics and underlying etiopathogenesis from those in adults. The available literature on pediatric aneurysms is surprisingly scarce, but it seems clear that from the therapeutic point of view, there has been a significant shift from microsurgical treatment toward endovascular management due to the better outcomes and lower rates of procedural complications. The use of flow diverter stents, initially reserved for adult patients, is also becoming an accepted practice in selected pediatric cases. We present the case of an 11-year-old boy with an unremarkable medical history who experienced an episode of sudden-onset severe headaches. Over-the-counter analgesics, administered at home, provided partial relief. A day after this, his headaches intensified. The boy vomited repeatedly and experienced general malaise. He was transferred to a primary care hospital.

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H. Henkes et al. (eds.), *The Aneurysm Casebook*,
https://doi.org/10.1007/978-3-319-70267-4_121-1

Cranial CT and CTA revealed an irregularly shaped bifurcation aneurysm on the left internal carotid artery (ICA). Its fundus was associated with a spontaneously hyperdense spot, a sign of pseudoaneurysm and contained hemorrhage. No subarachnoid hemorrhage was detected. The anterior communicating artery (AcomA) complex showed a typical configuration. Lumbar puncture yielded pinkish cerebrospinal fluid (CSF), confirming the minor hemorrhagic leak. The patient was then medicated with stronger analgesics and urgently transferred to our center for treatment. The child could not remain still, and the diagnostic angiogram was performed under general anesthesia. It confirmed an irregularly shaped saccular aneurysm on the left ICA bifurcation and pseudoaneurysmatic bleb associated with the fundus. After failed attempts to selectively catheterize the aneurysm with a microcatheter, we administered a loading dose of aspirin and prasugrel via nasogastric tube (NGT). Once it was seen that dual antiplatelet medication had taken effect, a single flow diverter stent was implanted across the aneurysm neck (M1-ICA). The procedure was uneventful and the patient was discharged home after 7 days. Platelet inhibition was evaluated every 12 h for the first 3 days after the intervention, and the antiplatelet dose was adapted as necessary. A follow-up angiogram at 6 months confirmed complete occlusion of the treated aneurysm. The feasibility, safety, and effectiveness of

flow diverter stents in pediatric patients, and in the management of bifurcation aneurysms, are the main topics of this chapter.

Keywords
Internal carotid artery bifurcation · Pediatric aneurysm · Flow diverter stent · Bifurcation aneurysm

Patient

An 11-year-old boy with severe sudden-onset headaches, vomiting, and malaise, with an otherwise unremarkable medical history. Upon lumbar puncture the slightly hemorrhagic CSF confirmed the suspected subarachnoid hemorrhage (SAH).

Diagnostic Imaging

Preoperative cranial CT revealed a spontaneously hyperdense round lesion on the left internal carotid artery (ICA) bifurcation. CTA showed a left ICA bifurcation aneurysm with an unusual necklace pattern, suggesting aneurysm dissection or pseudoaneurysm formation. Diagnostic cerebral angiogram of the left ICA followed by rotational angiography with tridimensional reconstruction confirmed the presence of an irregularly shaped small aneurysm on the bifurcation to the left ICA with a pseudoaneurysm at the fundus. The spontaneously hyperdense spot seen on non-contrast CT corresponds to this pseudoaneurysm. Angiography of the right ICA confirmed that the anterior communicating artery (AcomA) complex showed a typical configuration (Fig. 1).

Treatment Strategy

The primary goal of treatment was to occlude the left ICA bifurcation aneurysm in order to prevent a second SAH. We initially intended to treat the aneurysm by balloon-assisted coiling; however, we were unable to safely catheterize the aneurysm sac. The longitudinal axis of the distal ICA was directed laterally while the axis of the aneurysm sac pointed in the opposite direction, medially. We thus decided to treat the aneurysm by implanting a flow diverter. The AcomA was present with a diameter considered sufficient to supply the left ACA via the right ICA. This is an important consideration, which theoretically increases the likelihood that this strategy be successful, as will be discussed in more detail below.

Then, under general endotracheal anesthesia using a coaxial system and under full heparinization, the left ICA was catheterized past the aneurysm with a Marksman catheter (Medtronic) which was placed in the M1 segment. A single flow diverter stent (PED Shield, Medtronic) was implanted from M1, across the aneurysm neck, ending at the distal ICA.

Treatment

Procedure, 10.10.2017: diagnostic cerebral angiography, followed by the implantation of a flow diverter stent from the left proximal M1 segment to the left distal ICA

Anesthesia: general anesthesia; 2,500 U unfractionated heparin IV, bolus dose 80 IU/kg; target activated coagulation time (ACT) 250–320 sec

Premedication: 3× 100 mg ASA (Cartia) and 3× 10 mg prasugrel (Effient) were administered 47 min before stent implantation via a nasogastric tube; VerifyNow (Accriva) was used to test the platelet function 40 min after prasugrel administration and confirmed a P2Y12 receptor inhibition effect, corresponding to 80% platelet function inhibition; the ASA effect was also in the therapeutic range (ARU 470)

Access: right femoral artery, 6F introducer sheath (Terumo); *guide catheter:* 6F Envoy (Cordis); *microcatheters:* Excelsior SL10 (Stryker) for attempted coil occlusion, Marksman 27 (Medtronic) for the flow diverter implantation; *microguidewire:* Synchro2 0.014″ 200 cm (Stryker)

Implant: Pipeline (PED) Shield 3.75/16 (Medtronic)

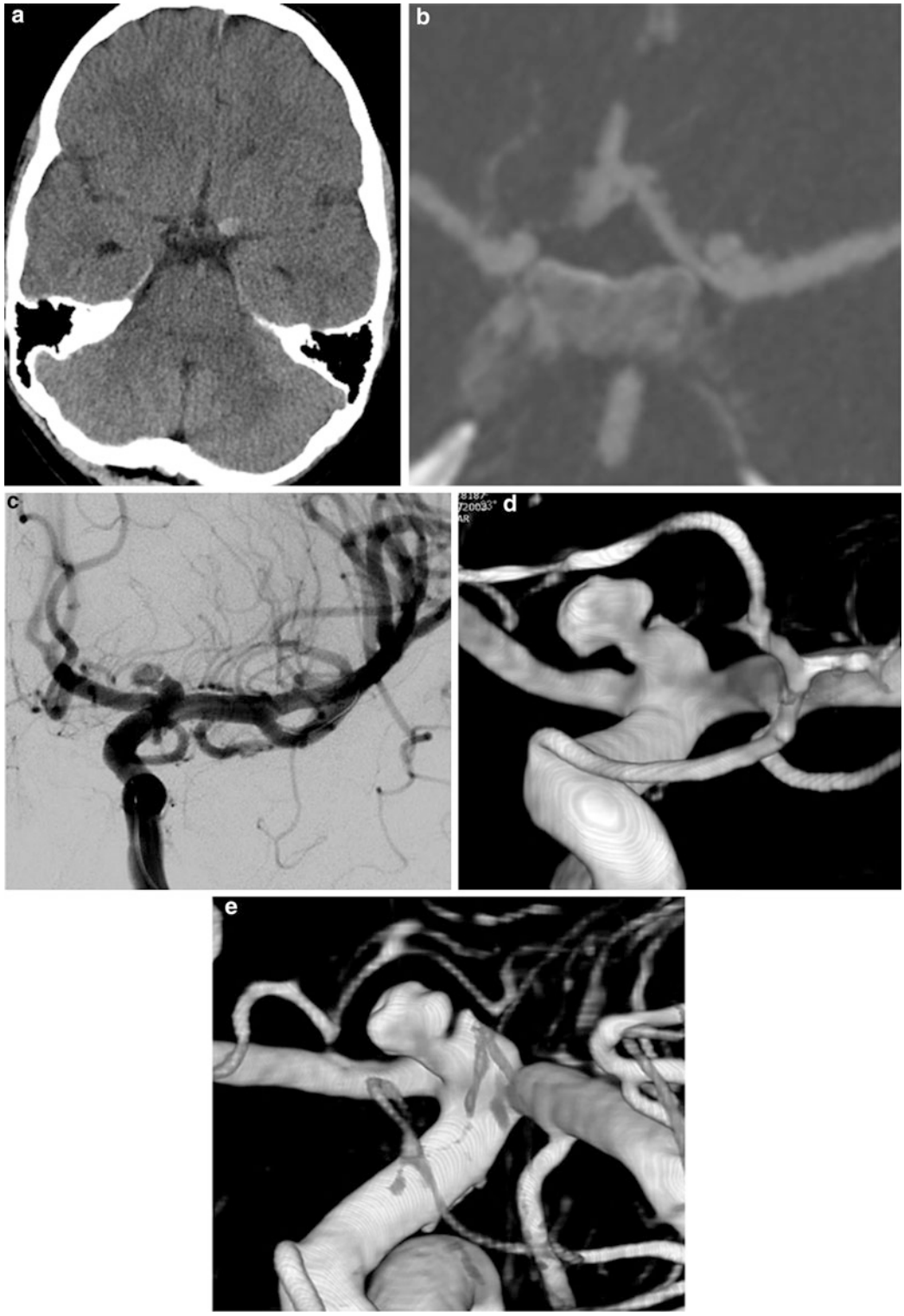

Fig. 1 Diagnostic imaging in an 11-year-old boy with suspected SAH. A cranial non-contrast CT (NCCT) examination revealed a hyperdense round lesion at the left ICA bifurcation (**a**). CTA depicted a left ICA bifurcation aneurysm with an unusual "necklace sign," suggesting a dissection of the aneurysm wall or

Course of treatment: An Envoy guide catheter was placed in the left cervical ICA after catheter exchange in the left external carotid artery. The attempted catheterization of the aneurysm with an Excelsior SL10 microcatheter for intended coil occlusion with balloon remodeling had failed. The Excelsior SL10 microcatheter was removed and a Marksman 27 microcatheter was navigated along the distal half of the left M1 segment. The PED Shield flow diverter was then deployed from the proximal M1 segment, covering the aneurysm orifice and finally landing at the distal supraclinoid segment of the left ICA (Fig. 2).

Duration of treatment: 1st–14th DSA run: 148 min; fluoroscopy time: 31 min

Complications: none

Postmedication: 1× 100 mg ASA PO daily was continued for 1 year, 1× 5 mg prasugrel or 1× 10 mg prasugrel PO daily on alternating days for 9 months; prasugrel was then discontinued

Clinical Outcome

Immediately after the endovascular procedure, the patient was transferred to the neurosurgical intensive care unit. The introducer sheath was removed 1 h later after ACT re-evaluation. The patient was then extubated and returned to baseline status without feeling pain or discomfort. Cranial NCCT performed 24 h later was unremarkable. The patient was discharged home 7 days after the intervention.

Follow-up Examinations

The 9-month follow-up DSA confirmed a complete occlusion of the treated aneurysm and the obliteration of the covered left A1 origin. The left ACA was supplied by the right ICA via the AcomA. The implanted flow diverter was patent, without signs of in-stent stenosis (Fig. 3). Prasugrel was then discontinued.

Discussion

Intracranial aneurysms are unusual in childhood and differ in many ways from those seen in adults (Proust et al. 2001) with male predominance, high incidence of aneurysms in the posterior circulation, and high incidence of giant and fusiform aneurysms. Children often have underlying diseases but generally have not been exposed to the environmental factors seen in adults (Takemoto et al. 2014). With regard to the treatment of pediatric intracranial aneurysms, there has been a significant shift from microsurgical treatment toward endovascular management due to the better outcomes and lower rates of procedural complications (Takemoto et al. 2014).

The use of flow diverter stents was originally reserved for adult patients harboring carotid wide-necked aneurysms and gradually expanded to other populations and other aneurysm types and locations (D'Urso et al. 2011; Navarro et al. 2015; Pistocchi et al. 2012). There is very limited data concerning the use of flow diverters in children. Burrows et al. (2013) reported the successful treatment of a recurrent pediatric fusiform MCA aneurysm with a PED. Zarzecka et al. (2014) reported the implantation of two flow diverters in a child with a giant, fusiform vertebral artery aneurysm. Ikeda et al. (2015) reported the successful endovascular reconstruction of a recurrent giant MCA aneurysm with multiple telescoping flow diverters in a pediatric patient.

There are, of course, concerns related to the placement of flow diverters in pediatric patients, as long-term device patency in this age group is unknown. Clinical experience in adults suggests

Fig. 1 (continued) pseudoaneurysm formation (**b**). Diagnostic cerebral angiography of the left ICA (posterior-anterior view) (**c**) and rotational angiogram with tridimensional reconstruction (left oblique views) (**d**, **e**), confirmed the presence of an irregularly shaped small bifurcation aneurysm on the left ICA with a fundus pseudoaneurysm

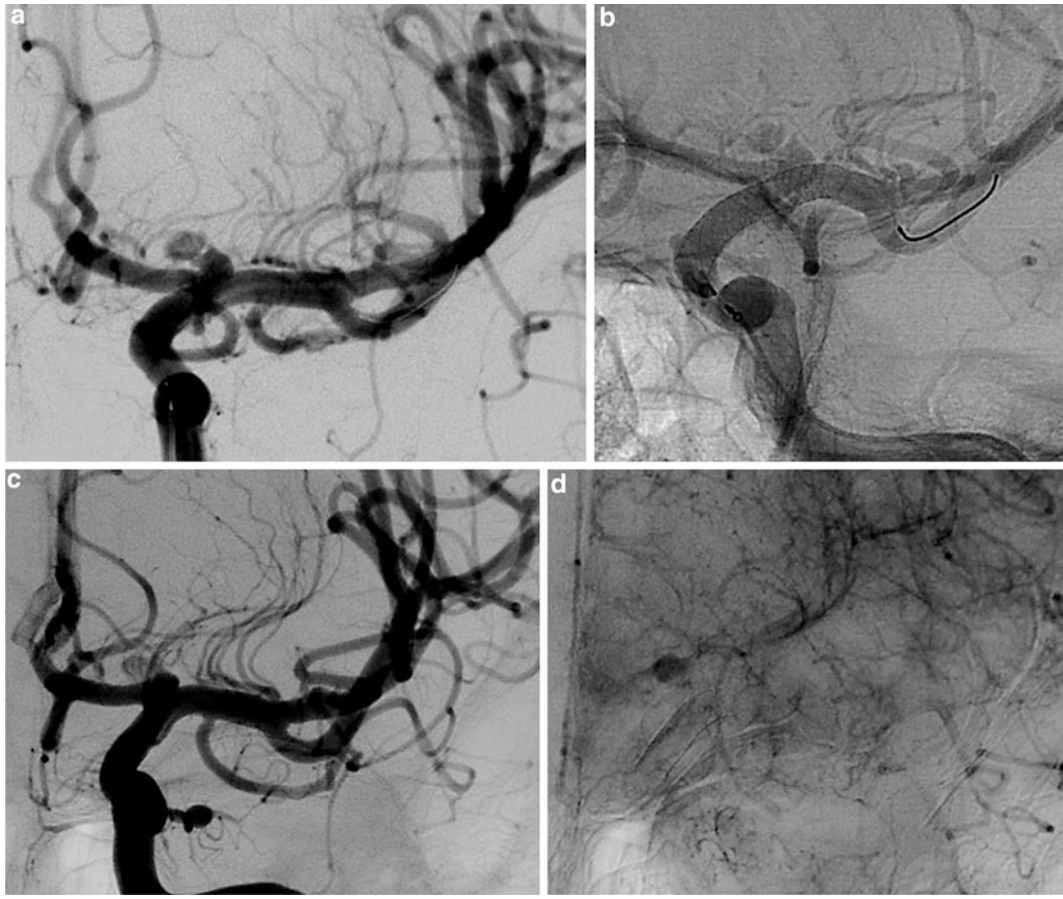

Fig. 2 Endovascular treatment of a left ICA bifurcation aneurysm by flow diversion after clinical signs of a minor leak and formation of a pseudoaneurysm distal to the aneurysm fundus. DSA of the left ICA (left anterior oblique view (**a**)) was chosen for guidewire navigation through the inferior branch of the middle cerebral artery (MCA). Unsubtracted angiogram of the left ICA shows the flow diverter implanted across the aneurysm orifice from the proximal MCA/M1 segment to the distal ICA. For safety reasons and in order to avoid any unjustified risk of compromising the lenticulostriate arteries originating from the left M1 segment, the distal end of the PED was placed just distal to the aneurysm orifice. Most of the flow diverter was implanted into the distal ICA (**b**). Immediately after the flow diverter implantation, DSA showed an only faint opacification of the distal portion of the treated aneurysm and contrast stagnation inside the aneurysm sac (early (**c**) and late (**d**) arterial angiographic phases)

that patency rates are very high in the ICA at late follow-up, although cases of delayed occlusion of flow diverters have been reported. Barburoglu and Arat (2017) presented the largest series of pediatric aneurysms treated by means of flow diverter stents to date. They concluded that flow diverter placement appears to be safe and effective on midterm follow-up in children but stressed that longer follow-up is critical. The authors also concluded, based on angiographic morphometry of internal carotid artery circulation in children, that the current sizes of flow diverter devices and delivery systems available cover the pediatric size range, obviating the need to develop dedicated pediatric flow diverters (Arat et al. 2015; Barburoglu and Arat 2017).

In general, flow diversion devices are currently favored for the management of side wall aneurysms rather than for bifurcation aneurysms. Some bifurcation aneurysms, however, have been treated successfully by flow diversion. In an experimental canine model, flow diversion of

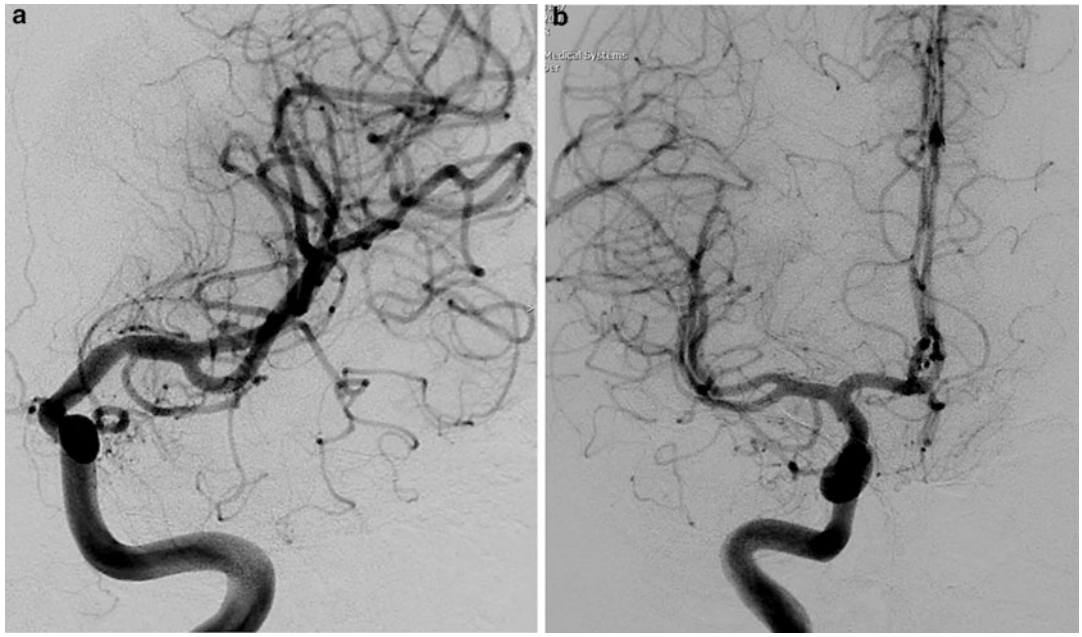

Fig. 3 DSA of the left ICA (posterior-anterior view (**a**)) at 9-month follow-up demonstrates complete exclusion of the left ICA bifurcation aneurysm. Note occlusion of the covered left A1 origin. The left ACA is supplied by the right ICA via the AcomA (right ICA injection, posterior-anterior projection, (**b**))

bifurcation aneurysms was more effective when the covered branch was occluded (Fahed et al. 2017). From this experimental study, it can be concluded that a branch emanating from the aneurysm may hinder intra-aneurysmal blood stasis, which seems to be necessary for fast thrombosis and subsequent cure (Gawlitza et al. 2016). An extrapolation of this finding may explain the successful exclusion of the aneurysm presented here, where there was concomitant occlusion of the covered left ICA-A1 junction. Conversely, occlusion of bifurcation ICA aneurysms with flow diverters will probably be less likely or more gradual in patients with contralateral A1 aplasia or in the case of a missing AcomA. This assumption has to be evaluated in future studies.

There is no standard antiplatelet/anticoagulant therapy for children undergoing intracranial placement of vascular scaffolds (Barburoglu and Arat 2017). In general, antiplatelet dosage for children over 45 kg is similar to the adult regimen. Lighter children usually receive appropriately reduced doses. Routine testing of platelet function has been recommended for management of antiplatelets in children with cardiac disease (Hanke et al. 2012), and it may help to prevent excessive platelet inhibition in pediatric cerebrovascular diseases as well. In the pediatric population, ASA should be used cautiously because of its association with Reye syndrome. The American Heart Association recommends that ASA use should be withheld in children suffering from influenza and chicken pox infections (Giglia et al. 2013).

Despite placing the PED at the ICA-MCA junction, no ischemic changes related to anterior choroidal or lenticulostriate artery occlusions were observed on follow-up imaging. Infarcts in the lenticulostriate territory are not infrequent after flow diverter stent implant at the ICA bifurcation, but are usually asymptomatic or well tolerated (Gawlitza et al. 2016).

We present the successful treatment of an acutely symptomatic ICA bifurcation aneurysm in a child treated by flow diverter stent implantation. This single case suggests that flow diverters may play a definite and growing role in the

management of ruptured and bifurcation aneurysms in children.

Cross-References

- ▶ Balloon Assisted Coiling
- ▶ Microsurgical Clipping
- ▶ Straight Coiling
- ▶ WEB

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