Introduction

Carotid-cavernous fistulas (CCFs) are an uncommon pathology in the pediatric population with an incidence of 4.6% per 100,000,\(^1\) and are a vascular malformation resulting in abnormal connection between the internal (ICA) and or external (ECA) carotid artery and the cavernous plexus. Barrow et al\(^2\) classified CCFs into four types, type A being the most common. The primary etiology of type A fistulas is head trauma, representing approximately 70% of all CCF, the majority occurring in young adults.\(^3\) Type B and C result from dural branches of the ICA and ECA, respectively. Type D results from both dural branches from ICA and ECA.\(^4\)

Traumatic carotid-cavernous fistula (TCCF) is a very rare occurrence in the pediatric population, with a frequency of 0.2 to 0.3% after craniofacial trauma, and increasing up to 4% following skull base fractures.\(^5,6\) Despite its rare occurrence, TCCF reported in children can be accompanied by drastic consequences such as intracerebral hemorrhage, de novo aneurysm formation, and irreversible vision loss or ophthalmoplegia.\(^6,7\) Due to the high vulnerability of pediatric patients, the TCCF's neurological sequelae are associated with...
higher burden of visual disability and potential mortality in this population.

We report a rare case of a traumatic cavernous carotid fistula in a 2-year-old child treated with endovascular surgery at the National Institute of Child Health—San Borja in Lima, Peru. The local institutional ethics committee approved the report. A literature review in PubMed and Google scholar databases was performed, in which eight cases of TCCF were identified in children under 10 (Table 1).

Illustrative Case

A 2-year-old child with no significant prenatal history sustained a fall of approximately 5 meters 1 hour prior to admission. On admission, the patient had a poor general condition, with multiple abrasions of the skull and mild right ocular edema. Due to severe intracranial hypertension, effacement of the basal cisterns, and fracture of the skull base, the patient underwent emergent decompressive craniectomy. Two hours following surgery, patient had neurological worsening and new brain tomography without contrast was obtained, which demonstrate diffuse cerebral edema and hydrocephalus (Fig. 1A). She, therefore, underwent a second surgery for placement of an external ventricular drain. The patient was transferred to the intensive care unit, where exophthalmos, ocular edema, chemosis, and venous engorgement of the right eye became more evident (Fig. 1B). Postoperative brain computed tomography (CT) scan at 6 hours showed hyperdensity at the right parasellar level (Fig. 1C) Due to suspicion of a posttraumatic cavernous carotid fistula, cerebral CT angiography was performed, demonstrating a direct communication with the right ICA, with increased flow in the superior ophthalmic, the angular, and the facial vein (Fig. 1D).

Based on the cerebral CT angiography results, we decided to perform endovascular procedure to close the CCF while preserving the parent artery. The approach was performed under the Seldinger technique, using a 4 Fr femoral introducer and a 4 Fr guide catheter. The initial angiography showed a high-flow CCF, Barrow classification type A, and dilatation of the superior ophthalmic vein (Fig. 1E). The injection of the contrast substance through the left vertebral artery showed adequate flow to the right carotid territory through the right posterior communicating artery. Selective angiography using a 1.3 Fr microcatheter approached the fistula (Fig. 1F) to release eight coils. The control injection demonstrated persistent flow from the ICA into the cavernous sinus (Fig. 1G–H) so we decided to deploy the embolizing agent Onyx (Medtronic, Minneapolis, Minnesota, United States) to aid in plug formation at the CCF point, to obtain controlled embolization, and prevent distal Onyx migration. For this purpose, the microcatheter was flushed with 3 mL of sodium chloride, then 0.25 mL of dimethyl sulfoxide was flushed slowly over 40 seconds, and finally Onyx-18 was slowly injected under roadmap guidance (two-dimensional image). However, a control injection obtained after this procedure demonstrated persistent CCF inflow. We, therefore, decided to trap the right internal artery at the cavernous segment to permanently close the CCF; a total of 4.5 mL of Onyx was injected. Trapping of the parent artery was performed due to the persistent CCF inflow despite placement of coils and Onyx, and after demonstration of adequate collaterals to maintain right carotid circulation. The final result was closure of the fistula with adequate collateral flow maintained in carotid circulation on the right side from the right posterior communicating artery (Fig. 1I).

After a satisfactory recovery, patient was discharged to home. At 2 months follow-up, ocular symptoms were markedly improved with preservation of vision in the right eye (Fig. 1J). At 1-year, the patient has remained asymptomatic; however, no long-term imaging follow-up is available due to a change in the patient’s health insurance coverage.

Discussion

Observations

Traumatic and spontaneous fistulas can occur in pediatric patients. Spontaneous fistulas are infrequent and often occur in the setting of other pathologies, such as Ehlers-Danlos syndrome. Traumatic fistulas, such as type A (direct) fistula, are most often due to head trauma associated with craniofacial trauma and skull base fracture.

Our patient, a 2-year-old girl, was younger than all previously reported cases (Table 1). She presented with chemosis, proptosis caused by venous engorgement and palsy of the third cranial nerve, and orbital murmur caused by the arterial flow in the superior ophthalmic vein. Her traumatic high flow fistula resulted from a direct carotid lesion over the cavernous sinus following a basilar skull fracture.

The diagnosis was made based on the clinical picture and neuroimaging findings within 12 hours of admission. Given the acute of symptoms after presentation, the endovascular treatment was performed before major ophthalmological complications developed. The initial approach attempted to preserve the patent right ICA; however, as there was incomplete closure of the fistula and imaging demonstrated collateral flow, the right ICA was occluded; unlike other reported cases, we used embolic substance that had not been reported previously for treatment of TCCF in this age group (Table 1).

Lessons

After embolization management with coiling and injection of embolizing substance, the patient’s vision was preserved, and her symptoms improved. Endovascular management of an acute TCCF is a challenge due to the high morbidity and mortality during the acute phase and can be complicated when other traumatic injuries are present. Maintaining the parent artery is important; however, when this is not possible, trapping the parent artery may provide an alternate option when appropriate collaterals exist.
<table>
<thead>
<tr>
<th>Autor/year</th>
<th>Number cases</th>
<th>Sex</th>
<th>Age</th>
<th>Side</th>
<th>Time to diagnosis</th>
<th>Treatment</th>
<th>ICA preservation</th>
<th>Evolution</th>
<th>Complete occlusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Debrun et al, 1981</td>
<td>1</td>
<td>F</td>
<td>5 y</td>
<td>ND</td>
<td>ND</td>
<td>Arterial access, removable balloons</td>
<td>No</td>
<td>ND</td>
<td>Yes</td>
</tr>
<tr>
<td>Barrow et al, 1982</td>
<td>1</td>
<td>F</td>
<td>10 y</td>
<td>R</td>
<td>&lt; 24 hours</td>
<td>Endovascular: 3 balloons</td>
<td>Yes</td>
<td>Yes, Recurrence of right oculomotor compromise after treatment, which remitted with high-dose steroids at 6-month follow-up</td>
<td>Yes</td>
</tr>
<tr>
<td>Paiva et al, 2013</td>
<td>1</td>
<td>M</td>
<td>10 y</td>
<td>R</td>
<td>47 days</td>
<td>Venous approach, coils</td>
<td>Yes</td>
<td>Clinical improvement with amaurosis of the right eye</td>
<td>Yes</td>
</tr>
<tr>
<td>Pawar et al, 2013</td>
<td>1</td>
<td>F</td>
<td>6 y</td>
<td>ND</td>
<td>10 days</td>
<td>Arterial and venous approach, coils</td>
<td>No</td>
<td>Complete resolution of symptoms at 2 months</td>
<td>Yes</td>
</tr>
<tr>
<td>Yang et al, 2015</td>
<td>1</td>
<td>M</td>
<td>6 y</td>
<td>L</td>
<td>2 months</td>
<td>Venous coils</td>
<td>Yes</td>
<td>Mild proptosis of the left eye at 2 months</td>
<td>Yes</td>
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<tr>
<td>Wajima et al, 2017</td>
<td>1</td>
<td>M</td>
<td>6 y</td>
<td>L</td>
<td>2 years</td>
<td>Arterial coils</td>
<td>No</td>
<td>Complete resolution of symptoms</td>
<td>Yes</td>
</tr>
<tr>
<td>Morais et al, 2018</td>
<td>1</td>
<td>M</td>
<td>8 y</td>
<td>L</td>
<td>7 days</td>
<td>Removable balloons</td>
<td>Yes</td>
<td>Slight improvement in ocular motility after 2 days of treatment</td>
<td>Yes</td>
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<tr>
<td>Tsuda et al, 2022</td>
<td>1</td>
<td>M</td>
<td>10 y</td>
<td>R</td>
<td>28 days</td>
<td>1st intention: venous access, coils 2nd intention (21 days posttreatment 1): arterial access, flow diverter 3rd intention (2 weeks posttreatment 2): venous access, coils</td>
<td>Yes</td>
<td>Palsy of the cranial nerve on the third postoperative day. Decreased visual acuity and temporal hemianopsia</td>
<td>Yes</td>
</tr>
<tr>
<td>Our case</td>
<td>1</td>
<td>F</td>
<td>2 y</td>
<td>R</td>
<td>&lt;12 hours</td>
<td>Arterial access coils and embolizing substance</td>
<td>No</td>
<td>Improvement of symptoms at 2 months of follow-up</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Abbreviations: ICA, internal carotid artery; ND, not described; y, years old; L, left; R, right; TCCF, traumatic carotid-cavernous fistula.
F.S., L.M., and M.T. were involved in data collection, conceptualization, and manuscript drafting. R.G. helped in data review and translation. R.E. contributed to data review, image preparation, technical and manuscript drafting.

Conflict of Interest
None declared.

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References
7 Pawar N, Ramakrishnan R, Maheshwari D, Ravindran M. Acute abducens nerve palsy as a presenting feature in carotid-cavernous fistula in a 6-year-old girl. GMS Ophthalmol Cases 2013;3:Doc03
Challenging Management of an Acute TCCF in a 2-Year-Old Child

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