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Post-Traumatic Carotid-Cavernous Fistula in a Child: An Unusual Complication of Craniofacial Injury

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Abstract | **Case Report**

Carotid-cavernous fistulas (CCFs) are rare vascular abnormalities in children, especially when occurring as a delayed consequence of trauma. They are defined as arteriovenous shunts caused by an abnormal communication between the intracavernous portion of the internal carotid artery and the cavernous sinus, usually resulting from a tear in the arterial wall. We report the case of a 4-year-old boy who presented with acute unilateral proptosis evolving over 8 days. The clinical history revealed a blunt orbital trauma that had occurred three months earlier following a fall during play. A contrast-enhanced orbital CT scan confirmed the diagnosis of a post-traumatic carotid-cavernous fistula. The patient was successfully treated by endovascular embolization. This case highlights the importance of considering delayed vascular complications in pediatric craniofacial trauma and emphasizes the key role of imaging and interventional radiology in the diagnosis and management of CCFs.

Keywords: Carotid – Cavernous – Fistula – Traumatic – Imaging – CT.

INTRODUCTION

Craniofacial trauma involves a complex transitional zone that serves as an anatomical crossroads, containing numerous structures of vital, functional, and aesthetic significance. This complexity explains the potential severity of such injuries and underscores the need for an initial multidisciplinary approach to management [1].

Among the possible complications, carotid-cavernous fistulas (CCFs) are rare but serious vascular entities, especially in children. Although most commonly encountered in adults following high-velocity trauma, post-traumatic CCFs in the pediatric population are exceptional and may present with delayed symptoms, often leading to diagnostic challenges [2,3].

We report a rare case of a traumatic carotid-cavernous fistula in a 4-year-old child, illustrating the importance of clinical suspicion, timely imaging, and the role of endovascular therapy in pediatric neurovascular emergencies.

OBSERVATION

A 4-year-old boy was referred to our institution for evaluation of progressive right eye proptosis evolving over eight days. The medical history revealed a blunt craniofacial trauma sustained three months earlier during a fall while playing. The initial trauma was not followed by immediate complications and had not required imaging or hospitalization.

Ophthalmologic examination revealed a reducible, non-inflammatory axial exophthalmos of the right eye. A marked dilatation of the episcleral veins, producing a characteristic "caput medusae" appearance, was observed *(Figure 1)*. The cornea and anterior chamber were clear, with a normal iris and lens. Fundus examination showed a normal optic disc, associated with vascular tortuosity, a normal macula, and a flat retina, with no signs of hemorrhage or retinal detachment. The controlateral eye was unremarkable.

A contrast-enhanced orbital CT scan was performed, which demonstrated dilatation of the right superior and inferior ophthalmic veins, as well as the sphenoparietal sinus and the right cavernous sinus, all of which showed early contrast enhancement consistent

with high-flow arteriovenous shunting. A grade 1 right-sided exophthalmos was confirmed. No associated abnormalities were detected in the cerebral parenchyma or intracranial arterial circulation.

The imaging findings were highly suggestive of a right post-traumatic carotid-cavernous fistula *(Figure 2)*. The patient was subsequently referred to an interventional radiology center for outpatient management, where he underwent successful endovascular embolization.

Figure 1: Dilated episcleral veins with 'medusa head' appearance, indicative of orbital venous congestion

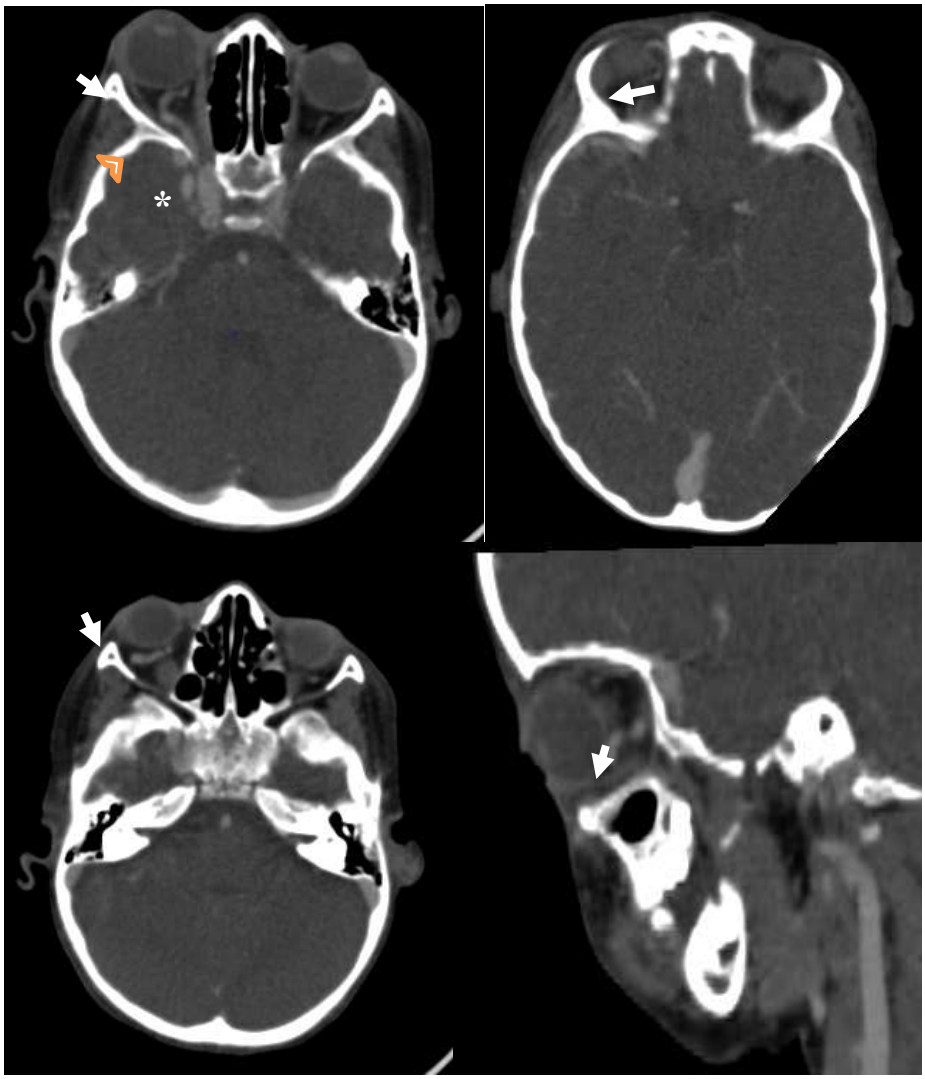

Figure 2: Axial and sagittal post-contrast CT scan showing a dilation of the right superior and inferior ophthalmic veins (arrows), the sphenoparietal sinus (arrow head), and the right cavernous sinus (asterix), with early contrast enhancement consistent with high-flow arteriovenous shunting

DISCUSSION

Carotid-cavernous fistulas are classified into direct and indirect types based on the pattern of communication between the internal carotid artery and the cavernous sinus. Direct carotid-cavernous fistulas (type A according to Barrow's classification [4], typically present with overt clinical signs due to high-flow arteriovenous shunting, often leading to orbital congestion and readily apparent symptoms. In contrast, indirect carotid-cavernous fistulas (types B, C, or D) are low-flow and frequently pauci-symptomatic, resulting in delayed diagnosis that may compromise both visual and vital prognosis [5]. Barrow type B fistulas are characterized by shunting through meningeal branches of the internal carotid artery, while type C fistulas involve branches of the external carotid artery. Type D fistulas represent a combination, with contributions from both internal and external carotid arteries meningeal branches. Spontaneous dural carotid-cavernous fistulas most commonly fall under type D [4].

Craniofacial trauma is by far the most common cause of carotid-cavernous fistulas, particularly when associated with skull base fractures. In approximately 75% of cases, symptoms develop within 15 days following the trauma [6]. However, CCFs have also been reported in the context of ballistic injuries [6], following surgical procedures involving the cranial region, or even spontaneously in patients with underlying vascular fragility [7].

In terms of imaging in a traumatic context, as in our case, ultrasonography is a valuable tool for assessing the globe and intraorbital structures; however, it is contraindicated in cases where globe rupture is suspected. Magnetic resonance imaging (MRI), while informative, is often impractical in emergency settings and should be avoided if there is any suspicion of a metallic intraorbital foreign body. Computed tomography (CT) remains the imaging modality of choice in the evaluation of orbital trauma. The optimal approach involves acquiring thin-slice axial scans followed by multiplanar reconstructions [3]. Angiography remains essential, not only for confirming the diagnosis but also for guiding the therapeutic approach, as the treatment of choice is venous embolization [6].

Orbital ultrasound often shows a dilated superior ophthalmic vein (SOV) and signs of orbital congestion such as enlarged extraocular muscles. It can also help rule out other conditions mimicking carotid-cavernous fistulas (CCF), like orbital tumors or inflammation [8]. Color Doppler ultrasound assesses blood flow direction and velocity, with flow reversal in the SOV being suggestive of CCF [9].

Patients suspected of having a CCF should undergo neuroimaging, usually with computed tomographic angiography (CTA) or magnetic resonance angiography (MRA). Both have high sensitivity for detecting direct and dural CCFs that cause visual symptoms. A study by Chen *et al*. [10] showed that CTA's sensitivity (87%) was close to digital subtraction angiography (DSA) (94.4%), while MRA had lower sensitivity (80%). The accuracy depends on the fistula's location along the internal carotid artery (ICA).

Enlargement of the SOV seen on standard CT or MRI is also suggestive of CCF, along with orbital congestion signs such as enlarged extraocular muscles and changes in the cavernous sinus wall [11,12]. However, these findings are not specific, so DSA remains the gold standard for diagnosis and classification of CCF and can also serve as a treatment guide.

Angiographically, high-flow fistulas show rapid filling of the cavernous sinus with little intracranial vessel filling, while low-flow fistulas show slower venous filling with preserved intracranial artery filling. DSA also reveals the fistula's drainage pattern—anteriorly via the SOV, posteriorly via the inferior petrosal sinus, or both—and detects any reflux into cortical veins [13].

The treatment of choice for carotid-cavernous fistulas, especially direct high-flow types, is endovascular embolization, which provides a minimally invasive and effective method to close the abnormal arteriovenous connection and alleviate symptoms [10, 11]. The treatment landscape has evolved significantly; previously, invasive surgical options such as carotid ligation posed high risks of cerebral ischemia [14]. Today, endovascular embolization is the preferred approach, allowing preservation of the internal carotid artery and offering a minimally invasive, safer alternative [15]. Techniques typically involve trans arterial catheterization with embolic agents like coils or liquid embolics to occlude the fistula. Transvenous approaches may be used when arterial access is limited [16,17]. Endovascular therapy achieves high cure rates (90–100%) with low morbidity and mortality. Treatment choice depends on fistula anatomy, flow dynamics, and cerebral collateral circulation, emphasizing the need for individualized multidisciplinary management to optimize functional outcomes [15]. A multidisciplinary approach involving neuroradiologists, ophthalmologists, and neurosurgeons is crucial for optimal management [13].

CONCLUSION

In conclusion, post-traumatic carotid-cavernous fistulas in pediatric patients, although rare, require a high index of suspicion due to their potentially delayed presentation and risk of serious ocular and neurological complications. Diagnosis relies on multimodal imaging, with digital subtraction angiography remaining the gold standard. Endovascular embolization remains the gold

standard treatment, offering effective symptom resolution with minimal invasiveness. Multidisciplinary management is crucial to optimize outcomes and preserve both vision and neurological function.

Conflicts of interest: Authors declare no conflict of interest.

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