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Case Report

Dual-Balloon–Assisted Coil–Onyx Embolization with Intraprocedural Management of Onyx Reflux for a High-Flow Direct Carotid–Cavernous Fistula: A Technical Case Report

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Introduction: High-flow direct carotid–cavernous fistulas (CCFs) are most commonly caused by traumatic injury to the cavernous segment of the internal carotid artery (ICA). During balloon-assisted coil–Onyx embolization, reflux of Onyx into the ICA remains a persistent technical challenge, as it carries a risk of intracranial arterial occlusion and potentially severe neurological sequelae. **Case:** A 58-year-old man came with progressive right-sided proptosis, chemosis, orbital bruit, and diplopia following head trauma. Digital subtraction angiography (DSA) confirmed a high-flow traumatic direct CCF (Barrow Type A). Dual-Balloon flow control was performed using a distal ICA protective balloon positioned across the fistulous orifice and a proximal balloon guide catheter (BGC) placed in the cervical ICA. Coil framing was performed, followed by controlled injection of Onyx-18. Minor Onyx reflux into the ICA was managed by BGC inflation to arrest antegrade flow, thereby preventing intracranial embolization, and aspirating the refluxed Onyx via an intermediate catheter. Final angiography demonstrated complete fistula occlusion with preserved ICA flow, and symptoms improved significantly within 48 hours. **Conclusion:** Dual-balloon-assisted coil–Onyx embolization represents an effective reconstructive strategy for high-flow direct CCFs, particularly in mitigating the risk of Onyx reflux. The proximal BGC serves as a critical "safety net": in the event of reflux, its inflation prevents embolic migration into the intracranial circulation and allows targeted aspiration of refluxed Onyx. To our knowledge, this represents the first reported use of this dual–balloon–assisted coil–Onyx embolization technique for high-flow direct CCF at our center.

Keywords: Balloon guide Catheter, Carotid-cavernous fistula, Coil-Onyx embolization, Dual-balloon technique

Highlights
- Proximal BGC inflation enables superselective angiography to localize the fistula.
- Distal ICA balloon blocks antegrade flow, reducing the risk of Onyx reflux.
- Proximal BGC arrests Onyx reflux and enables aspiration to preserve ICA patency.

Introduction

Direct carotid–cavernous fistulas (CCFs) are high-flow arteriovenous shunts that form between the cavernous segment of the internal carotid artery (ICA) and the cavernous sinus, most commonly caused by traumatic disruption of the ICA.[1] The hallmark clinical manifestations, including proptosis, chemosis, orbital bruit, and cranial neuropathies, arise from venous hypertension within the cavernous sinus, leading to impaired orbital venous drainage and compression of cranial nerves traversing this region, particularly the oculomotor (III), trochlear (IV), trigeminal ophthalmic (V1), trigeminal maxillary (V2), and abducens (VI) nerves.2,3 Endovascular therapy has become the first-line treatment for direct CCFs, with reconstructive strategies aimed at preserving ICA patency.[3]Traditional approaches, including detachable balloons and standalone coil embolization, are limited by issues including balloon instability, coil migration, and incomplete occlusion in high-flow lesions.[4,5] The combined use of coils and Onyx has emerged as a standard reconstructive technique, in which coil freaming reduces shunt flow and facilitates Onyx infiltration for durable occlusion.[6,7,8]

However, even with transarterial balloon protection, Onyx reflux into the ICA remains a major limitation, as it may result in ICA or distal intracranial artery occlusion with fatal neurological consequences.[9,10] To address this limitation, we present a case of a high-flow traumatic direct CCF treated using a dual-balloon-assisted coil-Onyx embolization technique, which combines distal ICA protection across the fistulous orifice with proximal flow control using a balloon guide catheter (BGC), emphasizing its role in emergent reflux management and in preventing intracranial embolic migration.

Although balloon–assisted coil–Onyx embolization aims to reduce the risk of reflux, current techniques primarily provide passive flow modulation and offer limited alternatives once reflux occurs. In high–flow direct CCFs, even minor Onyx reflux can rapidly propagate into the intracranial circulation with potentially catastrophic consequences. This report highlights a dual-balloon strategy with complementary roles: a distal protective balloon positioned across the fistulous orifice to reduce baseline reflux risk, and a proximal balloon guide catheter (BGC) serving as an active intraprocedural safeguard. Inflation of the proximal BGC allows immediate arrest of antegrade arterial flow upon detection of Onyx reflux, thereby preventing intracranial embolic migration and creating a protected environment for targeted aspiration of refluxed Onyx. By expanding the role of the BGC beyond passive flow control, this approach enhances procedural safety while preserving patency of the internal carotid artery in complex high–flow traumatic direct CCFs.

Case

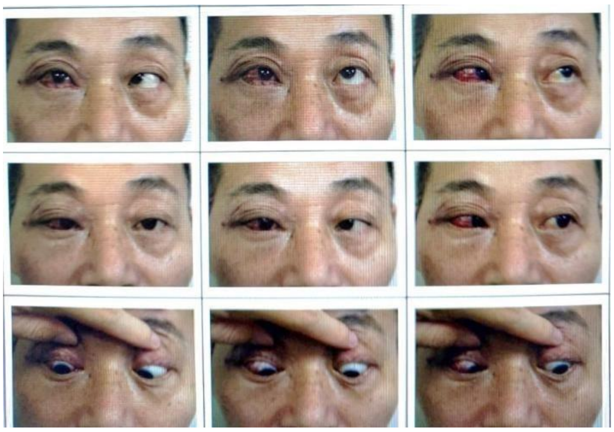

Figure 1. Pre-treatment clinical photograph. Right eye proptosis and conjunctival chemosis, with limited right eye abduction consistent with right sixth nerve (abducens nerve) palsy

A 58-year-old man was admitted with progressively worsening right eye redness, swelling, proptosis, chemosis, diplopia, and an audible orbital bruit, persisting for three weeks. These symptoms developed two months after a traumatic fall from an electric scooter, during which he had lost consciousness and sustained craniofacial abrasions along with bilateral periorbital ecchymosis. An initial non-contrast head CT conducted post-trauma revealed skull base fractures affecting the lateral wall of the right cavernous sinus, accompanied by a small subdural hematoma, traumatic subarachnoid hemorrhage (SAH) in the basal cisterns, and right periorbital swelling. Early contrast-enhanced CT angiography (CTA) demonstrated premature opacification of the cavernous sinus and right superior ophthalmic vein (SOV), raising suspicion for a direct CCF.

On admission, neurological examination revealed a right sixth cranial nerve palsy, characterized by limited eye abduction (Figure 1). Ophthalmologic evaluation showed right-sided proptosis (20.5 mm vs.19 mm on the left), conjunctival chemosis, dilated episcleral vessels, and an audible orbital bruit.

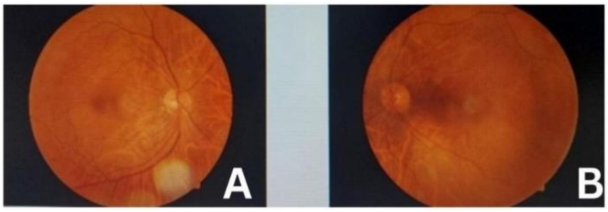

Figure 2. (A) Fundus photograph of the right eye showing venous congestion and mild optic disc edema; (B) Fundus photograph of the left eye.

Funduscopic examination revealed venous congestion and mild optic disc edema in the right eye (Figure 2). No other focal neurological deficits were identified.

Imaging findings

Non-contrast head CT post-trauma demonstrated a skull base fracture involving the lateral wall of the right cavernous sinus (Figure 3A), with an additional fracture line adjacent to the cavernous ICA on bone window reconstruction (Figure 3B). A hyperdense focus within the right cavernous sinus was consistent with post-traumatic hematoma or venous engorgement (Figure 3C), and thin traumatic SAH was present in the basal cisterns (Figure 3D), findings consistent with traumatic injury to the cavernous ICA.

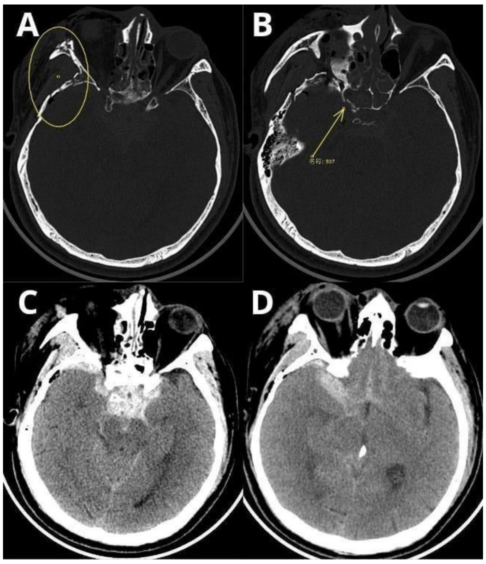

Figure 3. Initial non-contrast head CT following trauma.(A) Skull base fracture involving the lateral wall of the right cavernous sinus. (B) Bone window image showing a fracture line adjacent to the cavernous ICA. (C) Hyperdensity in the right cavernous sinus region, compatible with post-traumatic hematoma or venous congestion. (D) Traumatic subarachnoid hemorrhage in the basal cisterns.

Early post-trauma CTA showed prominent opacification of the cavernous sinus and enhancement of the right SOV, suggesting altered venous hemodynamics and an evolving direct CCF.[2,11,12] DSA confirmed a high-flow direct CCF (Barrow type A), with rapid filling of the cavernous sinus and venous drainage into the SOV, intercavernous sinus, inferior petrosal sinus, and contralateral cavernous sinus (Figure 4A), findings typical of traumatic direct CCF.[1,2,3] No pseudoaneurysm or ICA stenosis was identified, supporting the feasibility of a reconstructive embolization approach.

Procedure description

Access and system preparation

An 8F femoral arterial sheath was inserted. An 8F balloon guide catheter (BGC) (EverBridge Medical (HK) Limited, Shanghai, China) was positioned in the cervical segment of the ICA to achieve proximal flow arrest. A compliant distal protective balloon (Eclipse 2L, Balt, IL, USA) was then navigated across the fistulous orifice into the distal cavernous segment of the ICA, providing direct protection during embolization.

Flow control and embolization

Superselective angiography was performed with partial inflation of the proximal BGC to reduce shunt flow, thereby allowing clear delineation of the fistulous point and venous outflow channels (Figure 4B). A microcatheter was then advanced into the cavernous sinus through the fistula. Embolization was initiated using detachable coils (6×18 mm, 5×22 mm, and 4×10 mm; Taijieweiye Technology Co., Ltd., Beijing, China) to establish a stable framework within the cavernous sinus (Figure 4C), resulting in a reduction of shunt flow.

Under dual-balloon protection (distal balloon fully inflated across the fistula and proximal BGC partially inflated), controlled injection of Onyx-18 was performed. A total of 2 mL of Onyx-18 was injected following coil framing of the cavernous sinus. The distal balloon prevented reflux from the fistula into the ICA, while the proximal BGC created a low-flow environment that facilitated controlled Onyx deposition (Figure 4D). Progressive Onyx filling resulting in gradual occlusion of the cavernous sinus and SOV (Figure 4E).

Management of Onyx reflux

Minor reflux into the ICA was observed on fluoroscopic imaging during Onyx injection. The proximal BGC was immediately fully inflated to arrest antegrade arterial flow, thereby preventing migration of refluxed Onyx into the intracranial circulation. In this case, no intermediate catheter was in place at the beginning of the procedure. Therefore, the distal protective balloon and microcatheter were withdrawn from the system first. An intermediate catheter (6F Extraflex, Heart Care) was then inserted through the BGC, and the refluxed Onyx embolus was successfully aspirated with balloon protection (Figure 4F).

Final Angiography

Postprocedural DSA confirmed complete occlusion of the direct CCF, with preserved antegrade flow in the right ICA (Figure 4F, Figure 4G). No residual shunting or intracranial embolic complications were identified.

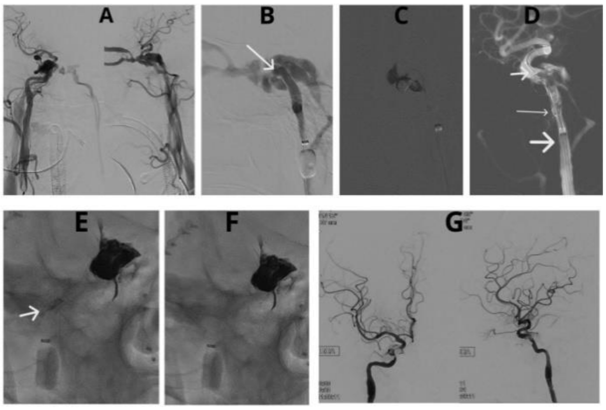

Figure 4. Angiographic overview of diagnosis, treatment, and final outcome using dual-balloon–assisted coil–onyx embolization.
(A) Pre-treatment DSA (AP and lateral views) demonstrating a high-flow direct CCF supplied by the right ICA. **(B)** Right ICA angiogram (lateral view) showing precise localization of the fistula with partial inflation of the proximal BGC to reduce shunt flow (white arrow). **(C)** Coil framing using 6×18 mm, 5×22 mm, and 4×10 mm coils to construct a stable metal cage, followed by Onyx injection. **(D)** Dual-balloon protection shown in the roadmap imaging (distal balloon markers: thick and thin white arrows; proximal BGC: thick white arrow). **(E)** Onyx refluxed into the ICA under fluoroscopy (white arrow). **(F)** Aspiration of refluxed Onyx through an intermediate catheter under balloon protection, with the BGC inflated to arrest the gradient flow. **(G)** Post-treatment DSAdemonstrating complete occlusion of the fistula with preservation of internal carotid artery (ICA) flow.

Outcome

The patient had rapid clinical improvement. Within 48 hours, right-sided proptosis and chemosis significantly reduced (Figure 5), the orbital bruit resolved, and diplopia improved. The function of the right sixth cranial nerve showed gradual recovery. No new neurological deficits were observed, and the patient was discharged in good condition. Short-term clinical and angiographic follow-up confirmed stable fistula occlusion and preserved ICA patency, without recurrent symptoms.

Figure 5. Post-treatment clinical photograph (day 2) showing marked improvement of right-sided proptosis and chemosis.

Discussion

Traumatic direct CCFs (Barrow type A) are characterized by high-flow, high-pressure arteriovenous shunting between the cavernous segment of the ICA and the cavernous sinus, posing significant technical challenges for endovascular treatment.[1,3] The principal objectives of therapy are to eliminate the arteriovenous shunt, preserve ICA patency, and resolve clinical symptoms while minimizing the risk of severe complications, including intracranial embolism or ICA occlusion.[3,13]

In this context, recovery of cranial nerve dysfunction is an important clinical outcome. Although deficits may gradually improve following successful fistula closure, recovery, particularly of cranial nerves III, IV, and VI, often requires prolonged follow-up and evaluation. Furthermore, Onyx-related mass effect or local toxicity may contribute to temporary or, rarely, permanent cranial nerve dysfunction, underscoring the need for continued long-term evaluation.

In this case, although the inferior petrosal sinus (IPS) is typically the preferred access route and transvenous embolization is the first-line treatment for cavernous sinus dural arteriovenous fistulas (CSDAVFs), direct CCFs differ due to their high-flow shunt and large fistulous orifice located directly on the ICA wall. In this context, ICA balloon protection is crucial for reducing shunt flow and preventing Onyx reflux into the parent artery.

Technically, the transvenous approach may limit stable microcatheter positioning for Onyx injection after coil embolization, even with dual microcatheters (one for coiling and one for Onyx injection). Consequently, a larger volume of Onyx may be required, and non-target portions of the cavernous sinus may be embolized to achieve complete occlusion due to suboptimal microcatheter positioning. In contrast, the transarterial approach allows more stable and precise positioning of the microcatheter tip adjacent to the fistulous point, allowing more targeted embolization with a smaller volume of Onyx. This is advantageous from both technical and economic perspectives. Moreover, limiting the extent of embolization may reduce the risk of cranial nerve injury within the cavernous sinus.

The persistent challenge of Onyx reflux in direct CCF embolization

Hybrid coil–Onyx embolization has become a cornerstone of reconstructive therapy for high-flow direct CCFs, as coils reduce shunt velocity and provide a mechanical scaffold for Onyx deposition, while Onyx enables penetration of the fistulous tract and durable occlusion.[6,7,8] However, even with balloon protection, Onyx reflux into the ICA remains a major technical concern, as it can cause distal ICA or intracranial artery occlusion, leading to stroke, hemiparesis, or visual loss.

The pathophysiology of Onyx reflux is rooted in the hemodynamics of high-flow direct CCFs.As Onyx accumulates within the cavernous sinus, pressure equilibrates with the ICA, disrupting the directional stability of the Onyx column.[6,9,10] Even with balloon protection, subtle gaps between the balloon and vessel wall (due to tortuous anatomy or irregular vessel caliber) can allow retrograde migration of Onyx into the ICA.[14,15] Once reflux occurs, conventional single-balloon techniques do not provide a reliable mechanism to prevent intracranial migration or retrieve the embolus, often necessitating a choice of incomplete embolization and accepting the risk of ICA sacrifice.[3,10]

The Dual-Balloon paradigm: Addressing reflux with a "Two-Tiered Safety System"

The dual-balloon technique described herein addresses this limitation by integrating two complementary protective mechanisms, creating a two-tiered safety system for embolization of high-flow direct CCFs.First, a distal protective balloon (Eclipse 2L, Balt), positioned across the fistulous orifice, directly blocks antegrade Onyx reflux into the distal ICA. Its compliant design allows adaptation to irregular vessel anatomy, thereby minimizing gaps that could facilitate reflux, representing an advantage over stiffer balloon systems in the complex anatomy of the cavernous sinus segment.[14,15]

In the present case, the distal balloon reduced baseline reflux risk during coil framing and initial Onyx injection, enabling controlled embolic deposition. Second, a proximal BGC serves as a critical failsafe for emergent reflux management. Unlike single-balloon approaches, in which reflux into the cervical ICA can rapidly progress to intracranial embolization, inflation of the BGC immediately arrests antegrade flow, effectively confining refluxed Onyx within the ICA. This not only prevents the risk of catastrophic intracranial occlusion but also provides a protected environment for aspiration thrombectomy. The large lumen of the BGC permits advancement of an intermediate catheter, enabling efficient retrieval of refluxed Onyx.[10,16] In this case, even minor Onyx reflux was successfully managed using the dual-balloon system, without neurological sequelae or compromise of ICA patency.

Comparative advantages over existing techniques

Several treatment strategies have been described for direct CCFs.Parent artery occlusion, although effective in selected cases with robust collateral circulation, results in loss of ICA patency and is generally undesirable, particularly in younger patients with preserved ICA function.[3,10] Combined coil-Onyx embolization with balloon protection is widely used; while distal balloons may reduce reflux risk, they do not provide a reliable mechanism for managing reflux once it occurs.[14,15] Flow diverter stents have also been reported, but their role in traumatic high-flow lesions due to persistent shunt flow, the risk of stent thrombosis requiring dual antiplatelet therapy, and their inability to address acute Onyx reflux.[3,17]

Although the dual-balloon technique requires multiple devices, including a BGC, distal protection balloon, detachable coils, and Onyx, which may increase procedural cost, it offers important safety advantages in selected high-flow cases. Enhanced control of embolic reflux and preservation of ICA patency may reduce the risk of severe complications, such as intracranial embolization or the need for parent artery sacrifice.[3,10,13] Therefore, in complex lesions where procedural safety is a major concern, these benefits may justify the additional device-related cost.

Technical considerations and limitations

The dual-balloon approach enhances procedural safety, but it demands precise technical execution. Precise balloon positioning is essential; the distal balloon must be precisely positioned across the fistulous orifice to avoid blocking normal ICA flow or missing the reflux pathway. Superselective angiography performed under proximal BGC inflation facilitates accurate localization, as demonstrated in our case.

The timing of balloon inflation is equally important. Immediate inflation of the proximal BGC upon detection of reflux is essential to prevent intracranial migration. Furthermore, aspiration of Onyx should be performed using a large-bore intermediate catheter and gentle suction to avoid vessel injury.

This report is limited by its single-patient design and short-term follow-up. Larger case series are needed to validate the efficacy and long-term safety of the dual-balloon, particularly in comparison withsingle-balloon or flow-diverter approaches. Additionally, the technique may be less feasible in patients with severe cervical ICA tortuosity or calcification, which may complicate BGC positioning.

A dual-balloon-assisted coil–Onyx embolization represents a refined reconstructive strategy for the treatment of high-flow traumatic direct CCFs, directly addressing the persistent challenge of Onyx reflux. The combined use of a distal protective balloon, which reduces baseline reflux risk, and a proximal BGC, which enables providing emergent reflux management through flow arrest and aspiration, provides a reliable safety mechanism that preserves ICA patency and minimizes neurological risk. Accordingly, this technique expands the utility of coil–Onyx embolization in complex high-flow lesions, and offers a viable alternative to more invasive or limited treatment strategies. As demonstrated in this case, the dual-balloon technique enhances procedural control and safety, making it a valuable addition to the endovascular management of high-flow direct CCFs.

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To our knowledge, this is the first time our institution has used a dual–balloon–assisted coil–Onyx embolization strategy to treat a high-flow direct CCF. While individual components of this technique, such as balloon-assisted coil embolization and Onyx injection, have been previously reported, the deliberate combination of distal ICA protection and proximal BGC-mediated flow arrest for emergent reflux management has not been routinely described in prior institutional practice.

Conclusion

This case illustrates that dual-balloon–assisted coil–Onyx embolization is a feasible and effective reconstructive strategy for the treatment of high-flow traumatic direct CCF. The combination of distal ICA balloon protection and proximal BGC flow arrest provides enhanced control of Onyx reflux, allowing safe embolization while preserving ICA patency. This technique may improve procedural safety in complex high-flow lesions and represents a valuable adjunct to existing endovascular treatment strategies.

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Conflict of interest

The authors declared no conflict of interest related to this case report.

Patient consent for publication

The author has consulted with the patient, who has granted consent for this case to be published.

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Author contribution

All authors contributed to all aspects of this research. **Yahya Assegaff:** Conceptualization, Investigation, Writing – Original Draft, Writing – Review & Editing. **Erwin Hardiansyah:** Investigation, Writing – Review & Editing. **Rani Kerinciani:** Investigation, Data Interpretation, Writing – Review & Editing. **Zhongwei Xu**: Investigation, Supervision, Writing – Review & Editing. **Kai Qiu**: Supervision, Writing – Review & Editing. **Linbo Zhao**: Investigation, Supervision, Writing – Review & Editing. **Sheng Liu:** Supervision, Writing – Review & Editing. All authors approved the final version of the manuscript.

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