

A Non-Traditional Approach to the Management of Carotid Cavernous Fistula: A Case Report

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ABSTRACT:

Introduction:

Carotid-cavernous fistula (CCF) is an aberrant flow from the carotid artery and its branches into the cavernous sinus, which can be either direct or indirect. Acute ocular congestion, cranial nerve dysfunction, and orbital bruits are common symptoms of direct CCFs, which are primarily traumatic but can also occur spontaneously. This article details two direct CCF cases in which transvenous coil embolization was successfully performed after failure of transarterial access.

Case Presentation:

We report two patients, a man aged 53 and a woman aged 69, each presenting with acute unilateral ocular signs, including exophthalmos, conjunctival chemosis, and an audible orbital bruit. Cranial nerve involvement was observed in both patients, with no characteristic vision loss. Digital subtraction angiography revealed direct high-flow CCFs that drained mostly into orbital venous channels and originated from the intracavernous internal carotid artery. Due to poor architecture and high-flow dynamics, trans-arterial catheterization of the fistulous site was not possible in either patient. Consequently, a transvenous technique was used to repair each fistula, passing into the inferior petrosal sinus and filling the cavernous sinus with coils until total occlusion was attained. Imaging following embolization verified complete shunt closure while maintaining ICA patency. Both patients experienced immediate relief of ocular congestion, elimination of bruits, and progressive normalization of cranial nerve function.

Discussion:

These two cases demonstrate the difficulties in diagnosing direct CCFs, which might have both spontaneous and traumatic-anatomical causes. Transvenous coil embolization provides a safe and efficient alternative when arterial access is limited by anatomical constraints or high-flow dynamics. Relief in neurological and ocular conditions of both patients highlighted the effectiveness of the said method.

Conclusion:

For direct CCFs, transvenous coil embolization is a useful treatment option, especially if transarterial access is speculative. Excellent clinical outcomes and complete symptom relief may result from early detection and tailored endovascular care.

Keywords: Carotid–cavernous fistula, Direct CCF, Transvenous embolization, Coil embolization, Cavernous sinus

INTRODUCTION:

Carotid-cavernous fistula (CCF) is an abnormal flow from the carotid artery and its branches into the cavernous sinus that can be direct or indirect(1,2). Despite being uncommon, it is a serious vascular condition that, if left untreated, can have detrimental effects on the eyes and brain. Most of the direct, high-flow cases of CCFs are caused by traumatic fistulas, while they can also develop spontaneously or as a result of trauma(3). Lower flow and a more subtle beginning are typical characteristics of spontaneous or indirect variants, which are frequently linked to diseases such as atherosclerosis, hypertension, or connective tissue diseases(3–5).

CCFs are categorized using a variety of methods, including etiology (spontaneous or traumatic), hemodynamics (high flow vs. low flow), and angiographic features (direct vs. indirect)(6).

The Barrow classification is the most commonly used of the several classification schemes that have been proposed to help identify and treat these lesions. Based on hemodynamic characteristics and arterial angioarchitecture of the lesion, this method categorizes CCFs into four types(1,2,6). The most frequent cause of type A fistulas, which are direct contacts between the cavernous sinus and the intracavernous section of the internal carotid artery (ICA), is trauma or rupture of an intracavernous aneurysm, Ehlers–Danlos syndrome type IV, or iatrogenic interventions, including transarterial endovascular intervention, internal carotid endarterectomy, percutaneous treatment of trigeminal neuralgia, trans-sphenoidal resection of a pituitary tumor etc (5,7). Types B, C, and D are indirect (dural) shunts. Meningeal branches of the ICA are involved in Type B, external carotid artery (ECA) meningeal branches are involved in Type C, and mixed shunts including both ICA and ECA branches are involved in Type D(5,7). In addition to helping with diagnosis, this classification assists in prognostication and therapy planning.

The pattern of venous drainage and the rate and direction of shunt flow both affect the clinical signs and symptoms of CCF. Pulsatile exophthalmos, chemosis, conjunctival arterialization, diplopia, orbital bruit, ophthalmic monoplegia, ptosis, loss of sensation in the distribution area of the trigeminal nerve, facial pain, chemosis, blood in Schlemm's canal on gonioscopy, Horner's syndrome, and headache are typical symptoms (1,4,5,8). However, indirect or low-flow fistulas can appear more subtly, perhaps resembling thyroid eye illness, idiopathic orbital inflammation, or orbital cellulitis, which could cause a delay in diagnosis(5). A strong index of suspicion is necessary due to the overlapping presentations, especially in individuals who experience orbital pain, cranial nerve palsies, or unexplained ocular congestion.

Diagnostic accuracy has increased dramatically as a result of imaging advancements in technology. Digital subtraction angiography (DSA) is still the gold standard for confirming and defining the fistula; however, non-invasive techniques like CT and MR angiography can show aberrant cavernous sinus enhancement or dilated superior ophthalmic veins (1,4,5,9). To avoid irreversible vision loss and neurological impairments, early detection and endovascular intervention, usually through transarterial or transvenous embolization, are essential.

Case Presentation:

Case 1:

A 53-year-old male presented with a 3-day history of progressive unilateral ocular congestion, characterized by exophthalmos, conjunctival chemosis, and a continuous orbital bruit. Neurological examination revealed mild limitation of extraocular movements, consistent with early involvement of cranial nerves within the cavernous sinus, while visual acuity and pupillary reflexes remained intact.

Imaging Findings: Digital subtraction angiography (DSA) demonstrated a direct high-flow carotid–cavernous fistula originating from an anomaly in the intracavernous portion of the internal carotid artery (ICA). The shunt mostly drained into the superior ophthalmic vein, which was in line with the patient's orbital symptoms. Catheterization via the arterial side of the ICA was unsuccessful due to the geometry and high-flow nature of the defect.

Intervention: A transvenous endovascular approach was employed, accessing the cavernous sinus through the inferior petrosal sinus. The cavernous sinus compartment was filled to the brim with platinum coils, which completely occluded the fistula. Post-embolization angiography confirmed cessation of shunt flow with full restoration of ICA openness.

Outcome: Ocular congestion and bruit regressed immediately following embolization. At 1-month follow-up, the patient demonstrated full neurological and ophthalmological recovery with complete resolution of cranial nerve symptoms and no complications.

Case 2:

A 69-year-old woman presented with swelling in one eye and conjunctival chemosis, along with tinnitus. Symptoms emerged spontaneously, devoid of prior trauma. A neurological exam showed mild sixth nerve paresis, but there was no loss of sensation in the ophthalmic (V1) or maxillary (V2) divisions.

Imaging Results: DSA showed a direct spontaneous CCF that was only fed by the intracavernous ICA and drained through a very wide suborbital venous channel. As in the

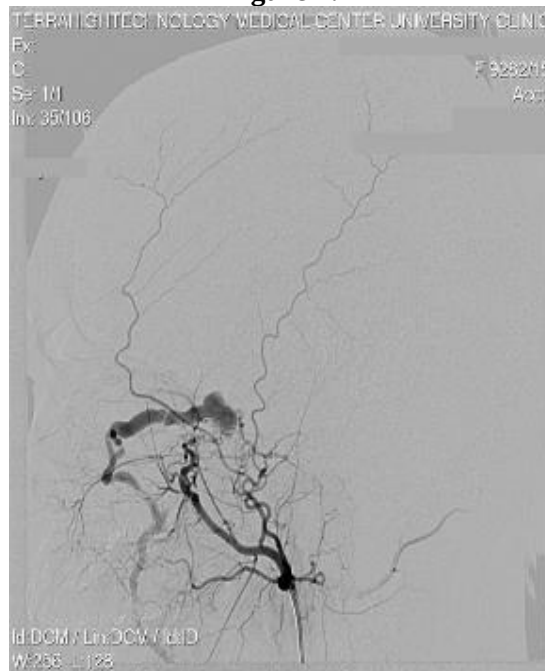
first case, it was not possible to do trans-arterial catheterization of the fistulous point.

Intervention: Transvenous embolization was performed with microcatheters that were guided into the cavernous sinus through a vein, and the fistula was successfully blocked with coils that were not visible on X-rays. Final

angiography showed that the shunt was completely blocked while the ICA flow remained similar.

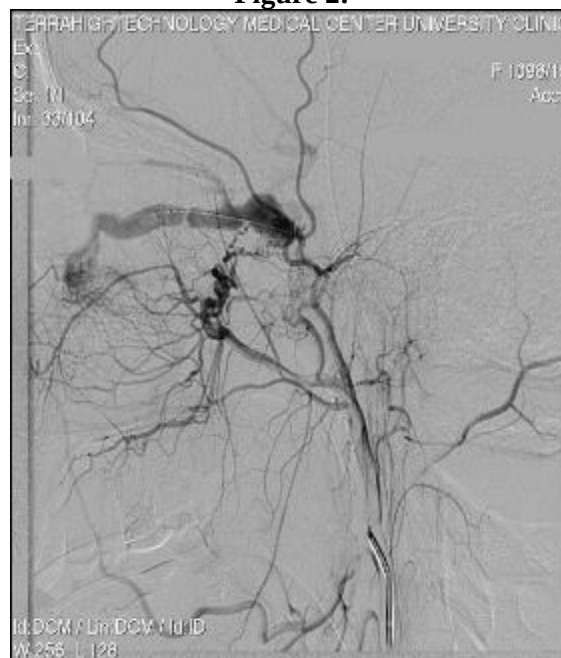
Outcome: The patient's ocular signs improved right away after the procedure. At the one-month follow-up, she continued to be asymptomatic, with extraocular movements returning to normal and no signs of recurrent arteriovenous shunting.

Figure 1:



Early dense opacification of the cavernous sinus with rapid drainage into a dilated superior ophthalmic vein, consistent with a high-flow carotid–cavernous fistula.

Figure 2:



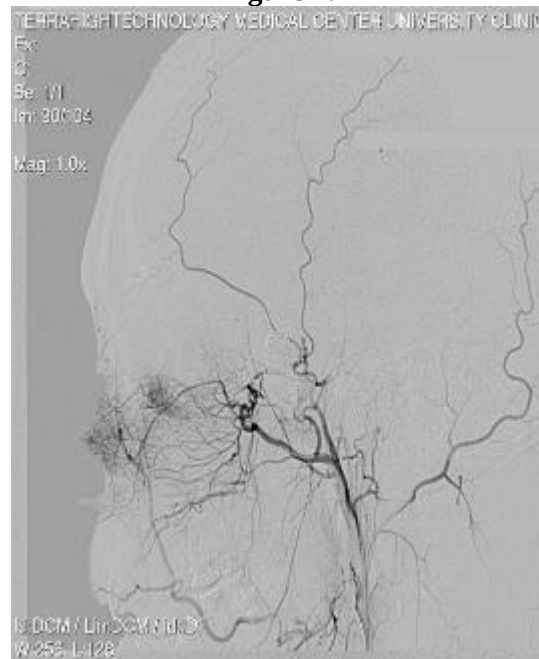
Marked dilation of the superior ophthalmic vein with immediate venous filling from the cavernous sinus.

Figure 3:



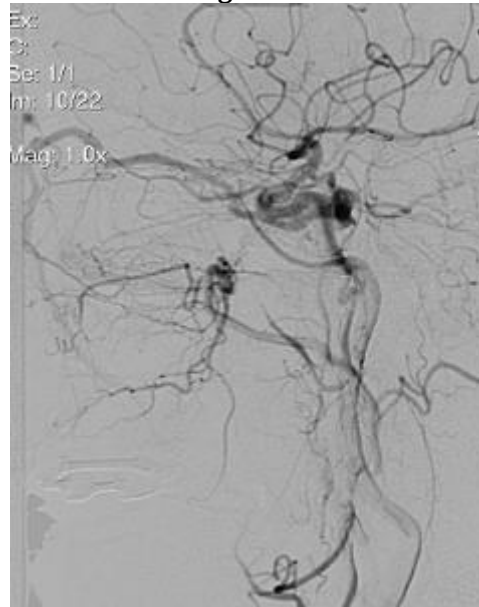
Dense coil mass occupying the cavernous sinus with preserved antegrade flow in the internal carotid artery.

Figure 4:



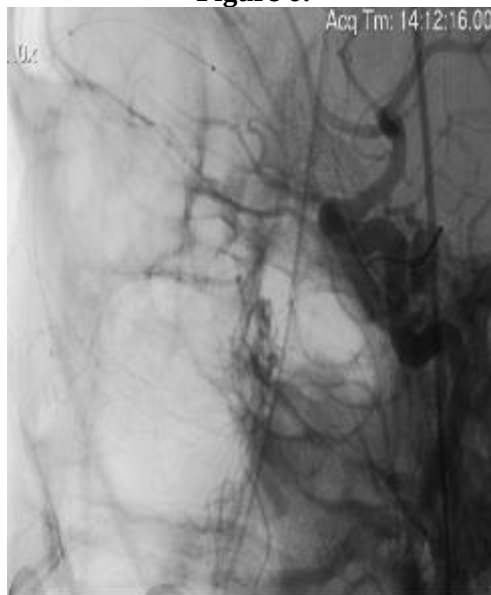
Selective external carotid artery injection demonstrating contribution from extracranial meningeal branches to the fistulous network.

Figure 5:



Direct shunting of contrast from the intracavernous internal carotid artery into the cavernous sinus with rapid venous outflow.

Figure 6:



Microcatheter navigated through the inferior petrosal sinus into the cavernous sinus prior to coil deployment.

Figure 7:



Compact, well-packed coil construct within the cavernous sinus with complete angiographic occlusion of the fistula and preserved ICA patency.

DISCUSSION:

CCFs represent an uncommon yet clinically significant vascular anomaly characterized by abnormal shunting between the carotid arterial system and the cavernous sinus(10). CCFs can be classified into two main types: direct CCFs, also known as traumatic carotid–cavernous fistulas (TCCFs), which are high-flow lesions that usually result from trauma or basal bones, and indirect CCFs, also called cavernous sinus dural arteriovenous fistulas (CS-DAVFs), which are low-flow lesions that may develop as a result of cerebral venous sinus thrombosis, venous hypertension, inflammation, minor trauma, or endocrine disorders(11).

A significant portion of Direct CCF cases are caused by the rupture of a preexisting aneurysm in the cavernous segment of the internal carotid artery (ICA)(10). For prompt identification and treatment, it is crucial to understand their hemodynamic mechanisms and clinical spectrum, given their varied presentations and potential for visual morbidity. The most prevalent clinical manifestations are orbital and neuro-ophthalmological symptoms and indicators.

While CS-DAVF can present with rare intracranial bruits, hyperemia, and edema of the bulbar conjunctiva and eyelid, it can also lead to intracranial hemorrhage and be easily misdiagnosed as conjunctivitis. In contrast, symptoms of TCCF include cerebral bruit, exophthalmos, intraorbital pressure rise, ocular mobility restriction, and, occasionally, intracranial haemorrhage (11). The size and configuration of the fistula, the direction of venous drainage, and any underlying diseases can all significantly impact the neuro-ophthalmic symptoms of CCFs. These symptoms, which can be rather severe, frequently provide important diagnostic clues. Ocular redness, decreased

visual acuity, and pulsatile exophthalmos are among the distinctive symptoms that can result from elevated venous pressure caused by abnormal venous drainage (3). Since the types of shunts, flow rate, and venous drainage pressure affect the severity of symptoms and signs, as was previously mentioned, the significantly elevated venous pressure from direct arteriovenous shunts causes higher back pressure to the ocular and adnexal tissues, which leads to more chemosis, proptosis, bruit, and dilated retinal vessels(8).

The pre-treatment injection of the External Carotid Artery (ECA) system confirms that smaller arterial branches (extracarotid supply) are contributing to the fistula. The latter stage of the ECA run backs up the idea that the extracranial arteries helped the CCF before treatment

Clinical Notes:

- The preoperative assessment comprised CBC, coagulation profile, and serum creatinine, in alignment with neurointerventional protocols necessitating contrast administration.
- Both patients were in good health and did not have any long-term systemic diseases.
- There were no complications after surgery, and no further treatments were needed.
- Both cases showed great recovery in the nervous system and eyes, which supports transvenous coil embolization as a good option when arterial access isn't possible.

Based on their pathologic mechanism, CS-DAVF that present with ocular signs can be divided into four types: intraorbital fistula with drainage into the superior ophthalmic vein, intracranial hypertension caused by massive venous engorgement of the cerebrum, compression of an oculomotor nerve by venous dilatation, or local venous reflux into the superior ophthalmic vein(12).

Diagnostic Framework Discussion:

Classification:

Barrow's angiographic taxonomy remains the pragmatic anchor for cavernous carotid fistulas (CCFs) because it divides pathophysiology into four arterial inflow patterns that predict venous drainage risk and procedural strategy(13). Type A lesions make a direct link between the cavernous internal carotid artery (ICA) and the sinus. Types B–D, on the other hand, are indirect dural fistulas

that get their blood flow from several different places. Type B gets its blood from ICA dural branches, type C gets its blood from external carotid artery (ECA) dural pedicles, and type D gets its blood from both ICA and ECA dural inflow. Selective angiography in our patients revealed convergent supply from the meningohypophyseal trunk (ICA) and the accessory meningeal artery (ECA), categorising the lesion as Barrow type D and elucidating the mixed-flow clinical presentation that necessitated venous-route protection to prevent cortical reflux(13,14).

Table 1. Barrow's classification of cavernous carotid fistulas

Type	Arterial supply	Hemodynamic profile	Characteristic presentation
A	Direct ICA–cavernous sinus	High-flow	Pulsatile exophthalmos, bruit
B	Dural ICA branches → cavernous sinus	Low–moderate	Cranial neuropathies, chemosis
C	Dural ECA branches → cavernous sinus	Low–moderate	Orbital pain, mild chemosis
D	Dural ICA + ECA branches → cavernous sinus	Variable	Hybrid B/C features cortical venous risk

Comparison of Imaging Modalities:

A multimodality pathway was necessary, as each technique contributed enhanced sensitivity and anatomical resolution. MRI with time-of-flight MRA is a radiation-free way to screen for venous engorgement and changes in the soft tissue around the eyes. However, it relies on flow-related signals, which may lead it to miss sluggish dural feeders or misrepresent venous varices(13). CTA quickly showed the three-dimensional structure of the superior ophthalmic vein and cavernous sinus, but it is challenging to distinguish between small ICA dural branches because of beam-hardening around the skull base and limited arterial phase timing. Bibliometric analyses of dural AVF imaging have recognized this concern(14). DSA remained definitive: selective ICA and ECA runs elucidated the dual-sourced arterial lattice, validated the absence of cortical venous reflux, and enabled dynamic assessment of venous drainage pathways all critical elements for establishing a secure transvenous embolisation(13,15).

Table 2: Diagnostic Imaging Characteristics and Findings.

Modality	Strengths	Limitations	Role in our case
MRI/MRA	Excellent soft-tissue contrast; depicts SOV dilation and cavernous sinus expansion; no radiation	Flow artifacts; may miss low-flow dural feeders; limited arterial phase detail	Initial screening for orbital congestion and cavernous asymmetry

CTA	Fast and widely available; good depiction of venous morphology and bony landmarks	Skull-base streak artifact; small dural branches less conspicuous; iodinated contrast	Confirmed venous hypertension, but could not map the precise arterial supply
DSA	Dynamic, high-resolution visualization of arterial feeders and venous drainage; therapeutic gateway	Invasive; requires contrast and radiation	Confirmed Barrow type D pattern and guided transvenous coil strategy

Diagnostic Approach:

The planned implementation of these modalities decreased blind spots. MRI/MRA showed orbital venous congestion but didn't adequately depict the complex arterial anatomy. CTA improved venous anatomy, but didn't adequately address feeder ambiguity. DSA cleared up both of these issues and made treatment possible in the same session. Diagnostic pitfalls consequently converge on excessive dependence on non-invasive imaging: MRI/MRA may incorrectly classify type D lesions as type C when ICA dural feeders opacify slowly. On the other hand, CTA may incorrectly interpret benign venous ectasia as early arterialized drainage (13,15). Our stepwise algorithm screen, characterise, confirm embodies the core logic that connects Barrow's theoretical taxonomy to real-life decision-making. It also reflects the general idea that careful imaging workflows lead to long-lasting results in managing dural arteriovenous shunts(14,15).

Management, Outcomes, and Takeaways:

The kind, flow pattern, and intensity of symptoms determine carotid cavernous fistulas (CCFs) management (16). While indirect (low-flow) dural CCFs may occasionally resolve spontaneously or be treated conservatively, direct (high-flow) traumatic CCFs usually require immediate endovascular intervention(17).

Treatment Alternatives:

Conservative management entails manual carotid compression and vigilant observation in certain low-flow instances(17). Spontaneous closure occurs in 20–30% of indirect CCFs with mild symptoms, especially when venous drainage is restricted and cortical reflux is absent. Conversely, spontaneous closure of direct (traumatic) fistulas is uncommon, and conservative treatment is suitable only when ocular pressure and vision are stable(16). Endovascular treatment is the benchmark for the majority of symptomatic CCFs(17). The process is dependent upon angioarchitecture and access pathways(18).

Transarterial embolization is favored for direct high-flow shunts to occlude the fistula while preserving internal carotid artery (ICA) patency(19). Detachable coils, Onyx (ethylene-vinyl alcohol copolymer), and flow-diverting stents are the predominant materials utilized(18,19). Transvenous embolization usually via the inferior petrosal sinus or superior ophthalmic vein is the preferred treatment for indirect dural CCFs, enabling controlled packing of the cavernous sinus with coils while reducing ischemia risk(19). Surgical and radiosurgical methods are designated for instances where endovascular access is inadequate or recanalization has occurred. Microsurgical fistula closure or stereotactic radiosurgery offers lasting obliteration in refractory lesions but entails an increased risk of cranial-nerve damage and protracted symptom relief(20).

Complications and Prognosis:

Complications include cranial-nerve palsies (notably abducens nerve), visual impairment due to venous congestion or ischemia, cerebral bleeding, and recurrence(18). Endovascular treatments typically exhibit modest morbidity; nonetheless, cranial-nerve palsy may occur due to coil mass effect or Onyx reflux(18,19). The prognosis is positive when angiographic closure is attained promptly; visual recovery is observed in 70–90% of patients when treatment occurs before irreparable optic injury(19). Persistent treatment delays or continuing cerebral venous reflux indicate inferior outcomes(20).

Comparison to the Presented Case:

In these cases, management deviated from conventional reporting due to the inability to achieve transarterial catheterization of the fistulous site, secondary to high-flow dynamics and unfavorable vascular geometry. Unlike typical direct Barrow Type A lesions that are treated via transarterial occlusion, both patients required a transvenous approach through the inferior petrosal sinus. This allowed controlled coil deployment within the cavernous sinus while preserving internal carotid artery patency, resulting in complete angiographic occlusion

and rapid clinical recovery(17,19). This alteration likely facilitated rapid visual enhancement and reduced cranial-nerve complications, highlighting the need for a tailored approach grounded in real-time angiographic data (18,20).

Educational Insights:

Diagnostic vigilance is essential, with the emergence of new orbital congestion, bruit, or diplopia necessitating rapid CTA/MRA and digital subtraction angiography (DSA) to avert delayed diagnosis(16,18). Timely multidisciplinary intervention involving neuro-interventional, neurosurgical, and ophthalmologic teams enhances visual and neurological results(17). Customized endovascular methods informed by venous anatomy, hemodynamics, and embolic selection (coils, Onyx, flow-diverters) provide the optimal safety-efficacy equilibrium(18,19).

CONCLUSION:

Carotid-cavernous fistulas maintain their status as a complex vascular pathology, despite various innovations in diagnosis and treatment. Due to their vast symptomatology and its potential for dire complications, rapid diagnosis along with personalized management becomes necessary. These two cases of CCFs, which we presented, demonstrate the complex nature of clinical progression and how an alternative method of transvenous coil embolization is an effective and safe method in direct high-flow CCFs when the traditional transarterial access isn't feasible. In these cases, complete fistula occlusion and complete clinical recovery were achieved through early intervention, careful angiographic assessment, and preservation of ICA patency. Customized endovascular strategies based on the individual's angioarchitecture, hemodynamics, and classification of CCF are essential for improving prognosis.

Abbreviations:

CBC – Complete Blood Count
CCF – Carotid–Cavernous Fistula
CS-DAVF – Cavernous Sinus Dural Arteriovenous Fistula
CTA – Computed Tomography Angiography
CT – Computed Tomography
DAVF – Dural Arteriovenous Fistula
DSA – Digital Subtraction Angiography
ECA – External Carotid Artery
ICA – Internal Carotid Artery
MRA – Magnetic Resonance Angiography
MRI – Magnetic Resonance Imaging
TCCF – Traumatic Carotid–Cavernous Fistula

Declaration:

Author Contribution:

KMSA: Data curation, Investigation, Writing – original draft, Writing – review & editing, Resources. RHAR: Conceptualization, Methodology, Project administration, Writing – original draft, Writing – review & editing. DN: Writing – original draft, Data curation, Resources. DRT: Supervision, Formal analysis. SSA: Writing – review & editing, Validation, Visualization. IA: Writing – original draft (Conclusion), Writing – review & editing. A: Resources, Writing – review & editing.

Conflicts of interest:

The authors declare that they have no conflicts of interest.

Ethical Approval:

Formal ethical approval was not required for this case report, as confirmed by our supervising physician, because the institution does not mandate ethics committee review for single-patient case reports. Permission to use the anonymised clinical information was obtained from the treating consultant.

Patient Public Involvement:

Patient and Public Involvement (PPI): No patients or members of the public were involved in the design, conduct, reporting, or dissemination plans of this research.

Consent to publication:

Informed consent to publication was obtained from the participant.

Availability of data and materials:

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