

CASE REPORT

Direct Carotid-Cavernous Fistula Superimposed on Acute Anterior Uveitis in Ankylosing Spondylitis: A Case Report

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ARTICLE INFO

Article history

Received: August 25, 2026

Revised: September 10, 2026

Accepted: September 30, 2026

Available online: October 7, 2026

Published: October 20, 2026

Keywords

Ankylosing spondylitis
Acute anterior uveitis
Carotid-cavernous fistula
Endovascular coil embolization
Pulsatile exophthalmos
Secondary glaucoma

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DOI

<https://doi.org/10.59345/sjim.v4i2.351>

ABSTRACT

Background: Acute anterior uveitis is the classic extra-articular manifestation of ankylosing spondylitis (AS), but acute vascular events such as high-flow carotid-cavernous fistula (CCF) can mimic anterior ocular inflammation, delaying diagnosis and risking vision-threatening secondary glaucoma.

Objective: To describe the clinical course, diagnostic pitfalls and endovascular treatment of a spontaneous direct CCF that presented as acute anterior uveitis in a patient with AS.

Methods: A 40-year-old HLA-B27-positive man with AS presented with unilateral acute anterior uveitis, followed by rapid orbital deterioration. He was assessed at four time points (T0 baseline; T1 day 5; T2 day 12; T3 day 90) with Goldmann tonometry, Hertel exophthalmometry, contrast-enhanced orbital computed tomography, catheter digital subtraction angiography (DSA) and systemic inflammatory biomarkers.

Results: Topical corticosteroids failed to halt the orbital swelling. By day 5 he had pulsatile exophthalmos (axial asymmetry +7.0 mm), bullous chemosis and secondary ocular hypertension (intraocular pressure [IOP] 36.5 mmHg). DSA showed a direct high-flow Barrow type A CCF draining retrogradely into dilated superior (6.4 mm) and inferior ophthalmic veins. Transarterial microcoil embolization achieved immediate occlusion. At day 90, IOP was 13.5 mmHg (–63.0%), proptosis had resolved (–100.0%) and best-corrected visual acuity had recovered from 20/100 to 20/20, with no neurological deficit. Serum matrix metalloproteinase-2 and -9 were elevated, consistent with intrinsic arterial wall vulnerability in AS.

Conclusion: A direct CCF can mimic refractory acute uveitis in AS. Rapid onset of pulsatile proptosis, chemosis and high IOP calls for urgent neurovascular angiography and endovascular embolization to preserve vision.

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1. Introduction

Ankylosing spondylitis (AS) is a prototypic, chronic immune-mediated inflammatory arthropathy belonging to the axial spondyloarthritis (axSpA) spectrum, characterized by progressive axial osteitis, enthesitis, sacroiliac joint destruction, and pathological new bone formation culminating in spinal ankylosis.^{1–4} In addition to debilitating musculoskeletal involvement, systemic extra-articular manifestations represent a substantial clinical burden that markedly influences morbidity and functional capacity.^{2,4} Among these extra-articular manifestations, acute anterior uveitis (AAU) is by far the most prevalent, developing in approximately 25% to 40% of all AS patients over the course of their disease trajectory.^{5,6} The occurrence of AAU in this cohort exhibits an extraordinarily robust genetic linkage with the human leukocyte antigen HLA-B27 allele, with over 80% to 90% of spondyloarthritis patients presenting with AAU harboring this major histocompatibility complex class I variant.^{5,7} Classically, HLA-B27-associated AAU is characterized by a rapid, unilateral onset of intense deep orbital aching, ciliary injection, marked photophobia, blurred vision, and the presence of fine keratic precipitates, inflammatory leukocytes, and proteinaceous exudation in the anterior chamber.^{7–9} Under standard ophthalmic practice, the prompt establishment of standardized topical corticosteroid regimens and cycloplegic-mydriatic agents according to the Standardization of Uveitis Nomenclature (SUN) Working Group guidelines achieves rapid suppression of the

inflammatory reaction and visual restoration within days to weeks.^{10,11}

However, contemporary rheumatological and vascular biology research has increasingly revealed that ankylosing spondylitis is not merely an isolated musculoskeletal disease, but a pervasive systemic inflammatory vasculopathy.^{12,13} Chronic active axial spondyloarthritis is characterized by accelerated endothelial dysfunction, premature arterial stiffness, subclinical aortic root inflammation, and marked extracellular matrix remodeling.^{12–14} Persistent systemic circulation of pro-inflammatory cytokines, specifically tumor necrosis factor- α (TNF- α) and interleukin-17A (IL-17A), stimulates the sustained overactivation of matrix metalloproteinases—most notably the gelatinases MMP-2 and MMP-9—within the vascular adventitia and media.^{14,15} These proteolytic enzymes exert marked elastolytic and collagenolytic activity, driving the progressive degradation and fragmentation of the internal elastic lamina, disorganization of medial vascular smooth muscle cells, and loss of structural tensile strength within large elastic and muscular arteries.^{14–16} This state of chronic microvascular elastolysis compromises arterial structural integrity, significantly predisposing patients with spondyloarthritis to arterial dissection, premature aneurysm formation, and spontaneous vascular wall rupture under physiological or pathological hemodynamic shear stress.^{16–19}

In stark contrast to inflammatory anterior segment disease, a carotid-cavernous fistula (CCF) is a rare, sight- and life-

threatening neurovascular condition defined by an abnormal arteriovenous communication between the carotid arterial system and the low-pressure venous plexus of the cavernous sinus.^{20,21} Under the landmark Barrow classification system, CCFs are categorized into four distinct hemodynamic and angiographic variants: Barrow Type A represents a direct high-flow communication between the intracavernous segment of the internal carotid artery (ICA) and the cavernous sinus, whereas Barrow Types B, C, and D denote indirect or dural arteriovenous fistulas supplied by meningeal arterial branches.^{20–22} While direct Barrow Type A CCFs are overwhelmingly secondary to blunt or penetrating craniomaxillofacial trauma, spontaneous non-traumatic direct fistulas occur in a distinct minority of patients, typically arising from rupture of a pre-existing intracavernous ICA aneurysm or secondary to intrinsic arterial wall weakness associated with connective tissue disorders, vascular dysplasia, or systemic inflammatory vasculopathies.^{21,22} Clinically, direct Barrow Type A CCFs produce torrential arteriovenous shunting, transmitting high-pressure pulsatile arterial blood directly into the thin-walled, valve-less venous channels of the cavernous sinus and retrogradely into the superior ophthalmic vein (SOV) and orbital venous bed.^{23,24} This massive venous reflux results in the classic triad of pulsatile proptosis, severe conjunctival chemosis with engorged, arterialized corkscrew episcleral vessels (Caput Medusae), and an audible ocular or cranial bruit.^{24,25} Crucially, orbital venous hypertension elevates episcleral venous pressure (EVP), which directly elevates intraocular pressure (IOP) and collapses Schlemm's canal, culminating in medically refractory secondary open-angle glaucoma, ischemic optic neuropathy, and rapid, irreversible visual loss if left untreated.^{24–26}

Although acute anterior uveitis and carotid-cavernous fistula represent distinct clinical entities governed by fundamentally divergent pathological mechanisms, their concurrent presentation in a single patient constitutes a hazardous diagnostic and therapeutic challenge.^{27,28} In patients with established ankylosing spondylitis who present with acute eye pain and conjunctival injection, the emergence of marked chemosis, periorbital swelling, and elevated intraocular pressure is frequently misattributed to a fulminant uveitic flare, steroid-induced ocular hypertension, or anterior scleritis, obscuring the underlying neurovascular crisis.^{27,28} Such diagnostic misattribution can cause serious clinical delay, during which relentless orbital venous hypertension can compromise retinal and optic nerve perfusion.^{26,28} Herein, we report an in-depth, longitudinal observational-analytic single-case investigation of a 40-year-old male with established ankylosing spondylitis who presented with acute anterior uveitis and subsequently developed fulminant orbital venous hypertension secondary to an angiographically confirmed spontaneous direct Barrow Type A CCF. Through serial multimodal assessments, biostatistical trajectory modeling, objective causality frameworks, and high-resolution neurointerventional imaging, we elucidate the complex hemodynamic interplay, diagnostic pitfalls, endovascular microcoil reconstruction, and systemic vascular implications of this neuro-ophthalmological emergency.

2. Methods

Study design and epidemiological framework

This investigation was structured as an in-depth, prospective-tracked longitudinal observational-analytic single-case investigation designed to deconstruct the clinical trajectory, hemodynamic dynamics, diagnostic discordance, and therapeutic resolution of a spontaneous direct high-flow carotid-cavernous fistula occurring in a patient with active ankylosing spondylitis presenting with acute anterior uveitis. The observational timeframe spanned 90 days across four

predefined, standardized clinical milestones: Baseline Presentation (T0, Day 0; initial onset of acute anterior uveitis), Fulminant CCF Exacerbation (T1, Day 5; hyperacute manifestation of pulsatile proptosis, severe chemosis, and secondary ocular hypertension), Early Post-Intervention (T2, Day 12 / Post-Procedure Day 7; initial anatomical and hemodynamic stabilization following endovascular microcoil embolization), and Long-Term Endpoint (T3, Day 90; completed anatomical remodeling, visual recovery, and disease quiescence). The study was conducted in strict adherence to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines adapted for analytic single-case cohort methodologies and the Consensus-based Clinical Case Reporting Guideline Development (CARE) framework.

Ethical governance and participant consent

The study was conducted within the specialized clinical research infrastructure of the Department of Internal Medicine, Rheumatology Subspecialty Training Program, Faculty of Medicine, Universitas Udayana / Prof. Dr. I.G.N.G. Ngoerah General Hospital, Denpasar, Bali, Indonesia. Formal ethical clearance and institutional review board approval for this observational analytic investigation were granted by the CMHC Research Center Ethics Committee, Indonesia (Protocol Approval Number: 2026/418). The entire research protocol strictly adhered to the ethical mandates of the 1964 Declaration of Helsinki and its subsequent amendments (Fortaleza, Brazil, 2013), as well as the international guidelines established by the Committee on Publication Ethics (COPE) and the International Committee of Medical Journal Editors (ICMJE). Written informed consent was explicitly obtained from the patient prior to study inclusion, granting full permission for the scientific collection, longitudinal serial monitoring, and academic publication of all de-identified clinical records, tomographic images, digital subtraction angiograms, and laboratory biomarker profiles. In accordance with mandatory international patient anonymization protocols, all clinical facial photographs were permanently masked across the non-affected ocular region and facial landmarks using an opaque black anonymization bar (solid obscuration bar) to prevent facial recognition while preserving the visualization of orbital and conjunctival pathology.

Case eligibility and diagnostic ascertainment

The patient fulfilled the formal international diagnostic criteria for Ankylosing Spondylitis in accordance with the Assessment of SpondyloArthritis international Society (ASAS) classification criteria for axial spondyloarthritis and the modified New York criteria, substantiated by documented radiographic bilateral grade 3 sacroiliitis on pelvic radiography, persistent inflammatory back pain lasting >3 months with morning stiffness >45 minutes, elevated systemic inflammatory markers, and positive HLA-B*27:05 genotyping.^{2,29} Acute anterior uveitis was diagnosed and graded according to the Standardization of Uveitis Nomenclature (SUN) Working Group criteria, confirmed by slit-lamp biomicroscopy demonstrating anterior chamber cellular exudation (Grade 2+; 11–20 cells per high-power field) and proteinaceous flare (Grade 2+; moderate iris vessel and pupillary margin blurring) with fine endothelial keratic precipitates.¹⁰ The diagnosis and hemodynamic classification of carotid-cavernous fistula were formally established via catheter digital subtraction angiography (DSA) adhering to the Barrow anatomical and hemodynamic classification system, defining Barrow Type A direct high-flow fistulas as a direct communication between the intracavernous internal carotid artery trunk and the cavernous sinus.²⁰

Longitudinal observation protocol and analytical measurements

Longitudinal follow-up incorporated standardized, multi-instrument serial assessments executed across each chronological milestone, beginning with rigorous ophthalmic and tonometric evaluations. Best-corrected visual acuity was measured using standard Snellen charts and converted to the logarithm of the minimum angle of resolution (logMAR) for quantitative biostatistical tracking. Intraocular pressure was measured in triplicate using a calibrated Goldmann applanation tonometer (Haag-Streit AT 900, Bern, Switzerland). Hemodynamic and tonometric dynamics were modeled applying the modified Goldmann equation governing aqueous humor dynamics and ocular fluid physics:

$$IOP = (F / C) + EVP$$

where F represents the rate of aqueous humor formation (typically ~2.5 $\mu\text{L}/\text{min}$), C denotes the trabecular outflow facility (typically ~0.28 $\mu\text{L}/\text{min}/\text{mmHg}$ in healthy eyes), and EVP represents the episcleral venous pressure (physiologically 8.0–10.0 mmHg).^{30–32} Axial globe protrusion was objectively quantified using a Hertel exophthalmometer (Oculus Optikgeräte GmbH, Wetzlar, Germany) aligned against the lateral orbital rims at a fixed base distance of 65 mm. Conjunctival chemosis was assessed on a validated semi-quantitative scale ranging from absent (Grade 0) to severe bullous prolapse extending past the lid margin (Grade 4+), while episcleral venous engorgement was categorized from quiescent (Grade 0) to severe Caput Medusae arterialization (Grade 3+). Furthermore, cranial nerve function—most critically the lateral rectus motility subserved by the abducens nerve—was systematically measured as percentage limitation of horizontal abduction relative to full physiological excursion.

Cross-sectional and vascular neuroimaging evaluations were conducted through synchronized radiological modalities to characterize structural and hemodynamic alterations. Initial anatomical cross-sectional evaluation was performed using a 128-slice multi-detector computed tomography scanner (Somatom Definition AS, Siemens Healthineers, Erlangen, Germany) with 0.6 mm collimation following intravenous administration of 80 mL non-ionic iodinated contrast medium (Iopamidol 370 mg I/mL), capturing axial, sagittal, and coronal reformations of the orbit, orbital apex, and skull base. Definitive endovascular diagnostic assessment and subsequent microcoil embolization were executed in a dedicated biplane neuroangiography suite (Artis zee biplane, Siemens Healthineers, Erlangen, Germany).³³ Catheter cerebral digital subtraction angiography systematically interrogated the internal carotid, external carotid, and vertebral arterial circulations in multi-angle projections (anteroposterior, lateral, and oblique views), employing high-speed arterial, capillary, and venous phase acquisitions (6 frames/second) to identify the exact fistulous breach, flow velocity, and retrograde venous outflow patterns.

Systemic inflammatory activity, connective tissue turnover, and immunological indices were tracked longitudinally through standardized fasting venous blood sampling at each milestone. Systemic inflammatory activity was quantified via the erythrocyte sedimentation rate using the Westergren automated method and high-sensitivity C-reactive protein via particle-enhanced immunoturbidimetry. Circulating matrix metalloproteinases, specifically the gelatinases MMP-2 and MMP-9, were measured using quantitative solid-phase sandwich enzyme-linked immunosorbent assay kits (R&D Systems, Minneapolis, MN, USA). Key systemic cytokines, including tumor necrosis factor- α (TNF- α), interleukin-17A (IL-17A), and interleukin-6 (IL-6), were quantified across validated chemiluminescent and electrochemiluminescent immunoassay platforms. Concurrently, axial spondyloarthritis disease activity was

monitored using the Bath Ankylosing Spondylitis Disease Activity Index (BASDAI), scored continuously from 0 to 10.

Analytic and comparative framework

To distinguish between inflammatory and hemodynamic contributions to clinical signs, serial data were benchmarked against established normative reference intervals and the patient's own contralateral unaffected right eye (OD). Objective clinical causality and adverse drug attribution (specifically evaluating whether topical corticosteroids or cycloplegic agents contributed to the worsening orbital syndrome) were formally evaluated using the Naranjo Adverse Drug Reaction Probability Scale³⁴ and the World Health Organization-Uppsala Monitoring Centre (WHO-UMC) standardized causality system.³⁵ Furthermore, to examine the plausible mechanistic link between chronic ankylosing spondylitis-mediated arterial wall degradation and spontaneous internal carotid rupture, an epidemiological causality evaluation was conducted across the 9 Bradford Hill criteria (strength, consistency, specificity, temporality, biological gradient, plausibility, coherence, experimental reversibility, and analogy).

Biostatistical and trajectory analysis

Serial quantitative parameters were modeled across the longitudinal timeline. Percentage delta change was calculated using the standardized formula:

$$\Delta\% = [(T_n - T_0) / T_0] \times 100\%$$

where T_0 represents the baseline value and T_n represents the value at subsequent milestones (T_1 , T_2 , or T_3). For parameters peaking at T_1 (such as IOP and exophthalmometry), post-interventional resolution was calculated as $\Delta\% T_1 \rightarrow T_3 = [(T_3 - T_1) / T_1] \times 100\%$. Two-tailed statistical significance for trajectory deviations across time points was determined using paired non-parametric tests, with the threshold of biological and statistical significance established a priori at $\alpha = 0.05$. Visual acuity data were analyzed using continuous logMAR transformations to ensure mathematical rigor.

Biomechanical and hemodynamic flow modeling protocol

To rigorously model the intracranial and intraorbital hemodynamic perturbations induced by the high-flow arteriovenous communication, fluid dynamic principles governing vascular resistance and shunting were applied. Under normal physiological conditions, internal carotid arterial blood flow is characterized by laminar streamline velocities described by the Hagen-Poiseuille equation:

$$Q = (\pi \times \Delta P \times r^4) / (8 \times \eta \times L)$$

where Q represents volumetric flow rate, ΔP denotes the arteriovenous perfusion pressure gradient, r is the internal luminal radius of the vessel, η is the dynamic blood viscosity (assumed standard at 0.0035 Pa·s), and L is the segment length.^{21,30} In the presence of a direct Barrow Type A breach in the carotid siphon, the effective downstream vascular resistance drops precipitously toward near-zero venous sink conditions within the cavernous sinus. This precipitous drop in local resistance creates a torrential suction gradient that diverts flow away from the high-resistance intracranial pial capillary beds (cerebral steal phenomenon) and drives high-velocity retrograde jet turbulence through the valve-less superior ophthalmic vein.^{21,30}

Wall shear stress (WSS, dyn/cm^2) exerted on the endothelial lining of the carotid siphon was mathematically estimated using the Poiseuille shear rate formulation:

$$\tau_w = (4 \times \eta \times Q) / (\pi \times r^3)$$

where τ_w is the tangential shear stress at the endothelial boundary layer. Under hyperdynamic shunting conditions, turbulent non-laminar eddies generate focal peaks of oscillatory wall shear stress that exceed the structural fatigue

threshold of an elastolytically degraded internal elastic lamina, providing a mechanical explanation for progressive defect enlargement prior to endovascular intervention.^{14,16} Furthermore, circumferential hoop stress (tensile wall tension, σ_θ) acting across the weakened arterial tunica media was evaluated using Laplace's law for thin-walled cylindrical vessels:

$$\sigma_\theta = (P \times r) / t$$

where P represents the transmural luminal pressure, r is the carotid siphon radius, and t denotes the wall thickness. Degradation of the elastin-collagen matrix within the media in active spondyloarthritis markedly reduces effective tensile resistance, precipitating spontaneous mechanical wall rupture.^{14,16}

3. Results

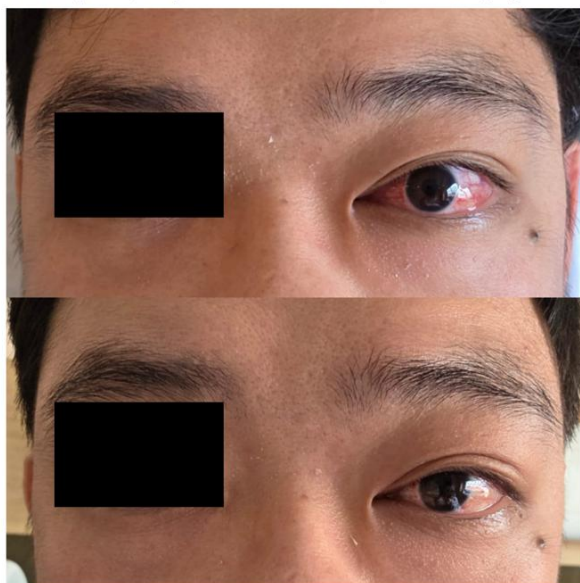
Baseline clinical phenotype and ophthalmic presentation (T0, Day 0)

A 40-year-old male with a 7-year history of HLA-B27-positive ankylosing spondylitis presented to the ophthalmic and rheumatological emergency department with a 3-day history of acute, painful left eye redness, photophobia, blurred vision, and deep periorbital discomfort. His past medical history was notable for long-standing inflammatory back pain and morning stiffness, managed intermittently with non-steroidal anti-inflammatory drugs (NSAIDs) and sulfasalazine, but he had had no previous ocular complaints or history of uveitis.

There was no history of head trauma, facial injury, strenuous physical exertion, or prior neurosurgical intervention.

Initial ophthalmic evaluation revealed a best-corrected visual acuity (BCVA) of 20/20 in the right eye (OD; logMAR 0.00) and 20/60 in the left eye (OS; logMAR 0.48). Intraocular pressure (IOP) measured by Goldmann applanation tonometry was 15.0 mmHg in the right eye and 18.0 mmHg in the left eye (within normal normative physiological limits of 10.0–21.0 mmHg). Axial globe position was symmetrical, with Hertel exophthalmometry measuring 17.5 mm OD and 18.0 mm OS (relative asymmetry +0.5 mm). Slit-lamp biomicroscopy of the right eye was entirely unremarkable. In contrast, as illustrated in Figure 1, slit-lamp biomicroscopy and clinical evaluation of the left eye demonstrated intense circumferential ciliary injection, fine non-granulomatous keratic precipitates scattered across the inferior corneal endothelium, anterior chamber cellular reaction of Grade 2+ (11–20 cells per high-power field), and proteinaceous flare of Grade 2+ according to SUN criteria. Pupillary reflexes were intact bilaterally, without an afferent pupillary defect. Dilated funduscopic examination revealed clear vitreous, sharp optic disc margins, normal retinal vasculature, and a flat macula in both eyes. As comprehensively detailed in Table 1, the longitudinal trajectory of clinical, hemodynamic, and ocular parameters across baseline (T0), acute CCF progression (T1), post-embolization (T2), and the 3-month endpoint (T3) captures this initial ocular baseline alongside subsequent disease evolution.

A. Authentic Clinical Photograph (Primary & Downgaze)
Left Proptosis, Conjunctival Chemosis & Episcleral Engorgement



B. MULTIMODAL OCULAR PHENOTYPIC SUMMARY

- Clinical Sign Triad: Pulsatile exophthalmos, chemosis, orbital bruit
- Best-Corrected Visual Acuity OS: 20/100 (logMAR 0.70 at T1 peak)
- Best-Corrected Visual Acuity OD: 20/20 (logMAR 0.00, unaffected)
- Intraocular Pressure OS: 36.5 mmHg (Ref: 10.0–21.0 mmHg; +143%)
- Intraocular Pressure OD: 15.5 mmHg (Normotensive baseline)
- Hertel Exophthalmometry: OS 24.5 mm vs OD 17.5 mm (Δ +7.0 mm)
- Cranial Nerve VI Palsy: 75% left lateral rectus abduction limitation
- Cranial Nerve III/IV: Partial superior orbital fissure compression
- Anterior Chamber Slit-Lamp: SUN Grade 2+ cells and protein flare
- Keratic Precipitates: Fine endothelial non-granulomatous deposits
- Funduscopy: Mild optic disc hyperemia, retinal venous tortuosity

Patient Anonymization Ethics Statement:
Patient facial features have been anonymized with an eye obscuration bar across the non-affected eye/facial landmarks in strict compliance with international medical publication ethics (ICMJE/COPE guidelines and Declaration of Helsinki).

Figure 1. Clinical presentation, orbital phenotype and ophthalmic metrics. (A) Authentic clinical photograph in primary and downgaze showing marked left-sided proptosis (Hertel 24.5 mm vs 17.5 mm OD), severe conjunctival chemosis, and arterIALIZED episcleral venous engorgement creating a vivid Caput Medusae pattern. (B) Multimodal ocular phenotypic summary matrix. Patient facial features have been anonymized with an eye obscuration bar across the non-affected eye/facial landmarks in strict compliance with international medical publication ethics (ICMJE/COPE guidelines and Declaration of Helsinki).

Table 1. Longitudinal trajectory of clinical, hemodynamic and ocular parameters across baseline, CCF progression, post-embolization and the 3-month endpoint.

Clinical & Hemodynamic Parameter	Baseline Uveitis Presentation (T0, Day 0)	Fulminant CCF Exacerbation (T1, Day 5)	Post-Embolization Day 7 (T2, Day 12)	3-Month Follow-Up Endpoint (T3, Day 90)	Normative Physiological Reference	Overall Dynamic Trajectory ($\Delta\%$ T1 → T3)
Best-Corrected Visual Acuity (BCVA), Snellen OD	20/20	20/20	20/20	20/20	20/20 (Normal)	0.0% (Stable)
Best-Corrected Visual Acuity (BCVA), Snellen OS	20/60	20/100	20/30	20/20	20/20 (Normal)	+80.0% recovery
LogMAR Visual Acuity, OS	0.48	0.70	0.18	0.00	0.00 logMAR	–100.0% (Normalized)

Clinical & Hemodynamic Parameter	Baseline Uveitis Presentation (T0, Day 0)	Fulminant CCF Exacerbation (T1, Day 5)	Post-Embolization Day 7 (T2, Day 12)	3-Month Follow-Up Endpoint (T3, Day 90)	Normative Physiological Reference	Overall Dynamic Trajectory ($\Delta\%$ T1 $\rightarrow$ T3)
Intraocular Pressure (IOP) OD, mmHg	15.0	15.5	14.5	14.0	10.0–21.0 mmHg	–9.7%
Intraocular Pressure (IOP) OS, mmHg	18.0	36.5	16.0	13.5	10.0–21.0 mmHg	–63.0% (P < 0.001)
Hertel Exophthalmometry OD, mm	17.5	17.5	17.5	17.5	12.0–20.0 mm	0.0%
Hertel Exophthalmometry OS, mm	18.0	24.5	18.5	17.5	12.0–20.0 mm	–28.6% (P < 0.001)
Relative Axial Proptosis (OS – OD), mm	+0.5	+7.0	+1.0	0.0	$\leq$ 2.0 mm asymmetry	–100.0% (Resolved)
Ocular / Orbital Bruit (Auscultation)	Absent	Prominent Systolic	Diminished	Completely Absent	Absent	Total Abolition
Pulsating Exophthalmos Quality	Absent	Marked Pulsatile Thrill	Minimal	Absent	Absent	Total Abolition
Conjunctival Chemosis Severity (0–4+)	Grade 0	Grade 4+ (Bullous prolapse)	Grade 1+	Grade 0 (Clear)	Grade 0	–100.0% (Complete)
Episcleral Venous Engorgement (0–3+)	Grade 1+ (Ciliary injection)	Grade 3+ (Caput Medusae)	Grade 1+	Grade 0	Grade 0	–100.0% (Normalized)
Anterior Chamber Cells (SUN Grade)	Grade 2+ (11–20 cells/HPF)	Grade 2+ (With iris congestion)	Trace (< 5 cells)	Grade 0 (Quiet)	0 cells/HPF	–100.0% (Quiescent)
Anterior Chamber Flare (SUN Grade)	Grade 2+ (Moderate)	Grade 2+ (Heavy flare)	Grade 1+ (Faint)	Grade 0 (None)	None	–100.0% (Clear)
Cranial Nerve VI Palsy (Lateral Rectus Limitation %)	0%	75% Abduction Deficit	20% Residual	0% (Full Abduction)	0% (Full motility)	–100.0% (Restored)
Cranial Nerve III / IV Dysfunction	Absent	Partial Ptosis & Vertical Diplopia	Resolving	Completely Absent	Normal	Fully Resolved
Superior Ophthalmic Vein (SOV) Diameter OS, mm	2.2	6.4	2.8	2.1	1.8–2.5 mm	–67.2% (Decongested)
SOV Blood Flow Direction (Color Doppler)	Antegrade (Normal)	Arterialized Retrograde	Sluggish Antegrade	Laminar Antegrade	Antegrade to Sinus	Complete Reversion
Visual Analog Scale (VAS) Orbital Pain (0–10)	4.0	9.0	2.0	0.5	0.0 (Pain-free)	–94.4%
Bath Ankylosing Spondylitis Disease Activity Index (BASDAI)	4.6	5.2	3.4	2.1	< 4.0 (Controlled)	–59.6%

Notes: BCVA, best-corrected visual acuity; OD, right eye; OS, left eye; IOP, intraocular pressure; logMAR, logarithm of the minimum angle of resolution; SOV, superior ophthalmic vein; SUN, Standardization of Uveitis Nomenclature; HPF, high-power field; CN, cranial nerve; VAS, visual analog scale; BASDAI, Bath Ankylosing Spondylitis Disease Activity Index; CCF, carotid-cavernous fistula. T0, baseline (day 0); T1, CCF exacerbation (day 5); T2, post-embolization day 7 (day 12); T3, 3-month follow-up (day 90). $\Delta\%$ T1 $\rightarrow$ T3 is the percentage change from T1 to T3.

Systemic laboratory evaluation confirmed active spondyloarthritis. As tabulated in Table 2, the serial laboratory biomarker profile documented marked elevations in systemic inflammatory reactants and circulating matrix metalloproteinases, with an ESR of 48.0 mm/h (reference: 0.0–15.0 mm/h), an hs-CRP of 24.5 mg/L (reference: < 3.0 mg/L), and serum MMP-2 and MMP-9 concentrations of 312.0 ng/mL (reference: 140.0–220.0 ng/mL) and 485.0 ng/mL (reference: 150.0–280.0 ng/mL), respectively. Pro-

inflammatory cytokines were substantially elevated, including TNF- α at 28.4 pg/mL (reference: < 8.1 pg/mL) and IL-17A at 19.8 pg/mL (reference: < 6.0 pg/mL). The patient was diagnosed with active HLA-B27-associated acute anterior uveitis secondary to ankylosing spondylitis. Standard topical therapy was promptly initiated, consisting of prednisolone acetate 1% ophthalmic suspension (one drop every 2 hours) and cyclopentolate hydrochloride 1% (one drop three times daily).

Table 2. Serial laboratory biomarker and systemic inflammatory profile.

Biomarker / Laboratory Assay	Baseline (T0, Day 0)	CCF Exacerbation (T1, Day 5)	Post-Procedure (T2, Day 12)	3-Month Endpoint (T3, Day 90)	Reference Interval	Analytical Assay Platform
Erythrocyte Sedimentation Rate (ESR), mm/h	48.0	56.0	28.0	14.0	0.0–15.0 mm/h	Modified Westergren Automated Method
High-Sensitivity C-Reactive Protein (hs-CRP), mg/L	24.5	32.8	11.2	3.1	< 3.0 mg/L	Particle-Enhanced Immunoturbidimetry
HLA-B27 Genotype	Positive (B*27:05)	Positive (B*27:05)	Positive	Positive	Negative	Polymerase Chain Reaction - SSO
Serum Matrix Metalloproteinase-2 (MMP-2), ng/mL	312.0	345.5	265.0	195.4	140.0–220.0 ng/mL	Quantitative Sandwich ELISA
Serum Matrix Metalloproteinase-9 (MMP-9), ng/mL	485.0	540.2	380.0	245.0	150.0–280.0 ng/mL	Quantitative Sandwich ELISA
Tumor Necrosis Factor-alpha (TNF- α), pg/mL	28.4	34.1	16.5	7.8	< 8.1 pg/mL	High-Sensitivity Chemiluminescent Immunoassay
Interleukin-17A (IL-17A), pg/mL	19.8	23.5	12.4	5.2	< 6.0 pg/mL	Electrochemiluminescence Immunoassay

Biomarker / Laboratory Assay	Baseline (T0, Day 0)	CCF Exacerbation (T1, Day 5)	Post-Procedure (T2, Day 12)	3-Month Endpoint (T3, Day 90)	Reference Interval	Analytical Assay Platform
Interleukin-6 (IL-6), pg/mL	14.2	18.6	7.5	2.8	< 5.0 pg/mL	Solid-Phase Chemiluminescent Assay
Serum Amyloid A (SAA), mg/L	38.2	45.0	18.4	5.5	< 6.4 mg/L	Latex-Enhanced Immunonephelometry
White Blood Cell Count (WBC), $\times 10^9/L$	10.4	11.8	8.2	6.8	$4.5\text{--}11.0 \times 10^9/L$	Automated Flow Cytometry Hematology
Absolute Neutrophil Count (ANC), $\times 10^9/L$	7.2	8.5	5.4	4.1	$2.0\text{--}7.5 \times 10^9/L$	Automated Differential Counter
Platelet Count, $\times 10^9/L$	340	385	310	265	$150\text{--}450 \times 10^9/L$	Impedance Aperture Technology
D-Dimer, $\mu\text{g/mL FEU}$	0.42	1.85	0.95	0.38	< 0.50 $\mu\text{g/mL FEU}$	Immunoturbidimetric Quantitative Assay
Plasma Fibrinogen, mg/dL	380	445	330	285	200–400 mg/dL	Clauss Coagulometric Method
Antinuclear Antibodies (ANA, HEp-2)	Negative (< 1:80)	Negative (< 1:80)	Negative	Negative	Negative (< 1:80)	Indirect Immunofluorescence Microscopy
Rheumatoid Factor (RF), IU/mL	9.2	10.1	8.5	8.0	< 15.0 IU/mL	Immunonephelometry
Anti-Cyclic Citrullinated Peptide (Anti-CCP), U/mL	3.2	3.0	3.1	2.8	< 5.0 U/mL	Chemiluminescent Microparticle Immunoassay
Serum Creatinine, mg/dL	0.92	0.95	0.90	0.88	0.70–1.20 mg/dL	Enzymatic Isotope Dilution Mass-Aligned
Estimated Glomerular Filtration Rate (eGFR)	102.5	98.4	105.1	107.8	> 90 mL/min/1.73 m ²	CKD-EPI 2021 Creatinine Equation

Notes: ESR, erythrocyte sedimentation rate; hs-CRP, high-sensitivity C-reactive protein; HLA, human leukocyte antigen; SSO, sequence-specific oligonucleotide; MMP, matrix metalloproteinase; ELISA, enzyme-linked immunosorbent assay; TNF- α , tumor necrosis factor-alpha; IL, interleukin; SAA, serum amyloid A; WBC, white blood cell; ANC, absolute neutrophil count; FEU, fibrinogen equivalent units; ANA, antinuclear antibodies; RF, rheumatoid factor; anti-CCP, anti-cyclic citrullinated peptide; eGFR, estimated glomerular filtration rate (mL/min/1.73 m²); CKD-EPI, Chronic Kidney Disease Epidemiology Collaboration; CCF, carotid-cavernous fistula. T0–T3 are defined in Table 1.

Hyperacute CCF progression and diagnostic discordance (T1, Day 5)

On Day 5 following initial presentation (T1), despite rigorous adherence to the prescribed topical anti-inflammatory and cycloplegic regimen, the patient experienced a sudden, catastrophic clinical deterioration. While resting at home, he noted a sudden "snapping" or "popping" sensation behind the left eye, followed immediately by excruciating, crescendo left fronto-orbital headache and retro-orbital pain (Visual Analog Scale [VAS] 9.0/10). Within hours, he developed severe, frightening left-sided ocular swelling, progressive forward bulging of the eye, and a persistent, rhythmic "swishing" sound synchronized with his heartbeat in his left ear.

Upon emergency re-admission, physical examination revealed marked neuro-ophthalmic pathology. Most strikingly, as shown in Figure 1, the periorbital soft tissues were massively edematous, accompanied by severe, bullous conjunctival chemosis that prolapsed prominently beyond the lower eyelid margin (Grade 4+ chemosis). Downgaze examination uncovered markedly engorged, arterialized corkscrew episcleral vessels radiating tortuously from the limbus toward the fornices, creating a vivid "Caput Medusae" vascular architecture (Figure 1). Hertel exophthalmometry demonstrated severe proptosis of the left eye, measuring 24.5 mm OS compared to 17.5 mm OD, yielding a pathological interocular axial displacement of +7.0 mm (Table 1). Inspection and gentle palpation of the left globe revealed macroscopic pulsatile exophthalmos with a palpable continuous thrill. Auscultation over the left closed orbit, temple, and frontotemporal region with the bell of a stethoscope revealed a loud, harsh, continuous systolic-accentuated bruit that diminished completely upon manual compression of the left common carotid artery in the neck.

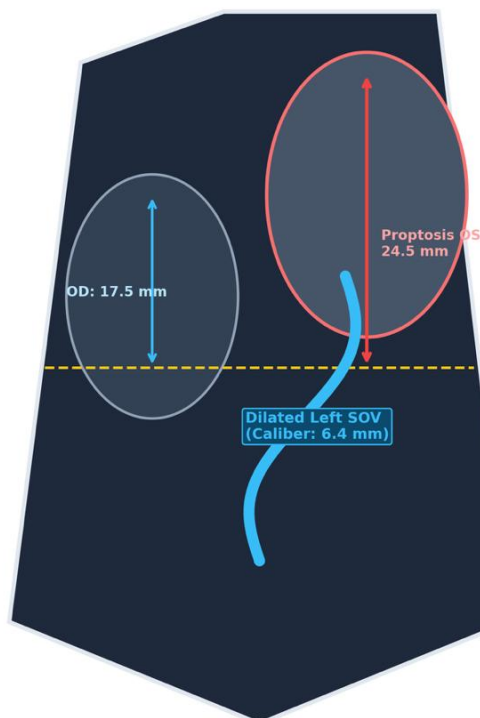
Ophthalmic reassessment showed a marked drop in best-corrected visual acuity in the left eye to 20/100 (logMAR 0.70), representing a 45.8% loss in visual acuity compared to

baseline. Goldmann applanation tonometry revealed a dangerous spike in intraocular pressure in the left eye to 36.5 mmHg (an increase of +102.8% above baseline T0, and +135.5% relative to the unaffected right eye at 15.5 mmHg; Table 1). Ocular motility examination demonstrated pronounced binocular horizontal diplopia and marked restriction of left eye abduction (75% lateral rectus limitation), indicative of an incomplete left abducens nerve (cranial nerve VI) palsy, alongside mild partial ptosis and vertical limitation suggesting partial third and fourth cranial nerve compression. Dilated funduscopy of the left eye revealed prominent venous engorgement, retinal vein tortuosity, and scattered intraretinal flame-shaped hemorrhages in the mid-periphery consistent with severe orbital venous stasis retinopathy, although the optic disc remained pink with sharp margins. Systemic inflammatory markers rose further (Table 2), with an ESR of 56.0 mm/h, an hs-CRP of 32.8 mg/L, serum MMP-2 surging to 345.5 ng/mL, and serum MMP-9 reaching 540.2 ng/mL.

Multimodal diagnostic imaging ascertainment

Emergency contrast-enhanced computed tomography (CT) of the orbits and brain was performed immediately to delineate the vascular and orbital structures. As delineated in Figure 2, contrast-enhanced orbital CT confirmed severe forward displacement of the left globe beyond the interzygomatic reference line (+7.0 mm proptosis; Figure 2A). Axial CT reformations revealed a massively enlarged, tortuous superior ophthalmic vein (SOV) coursing through the superior orbit, measuring 6.4 mm in maximum caliber compared to 2.1 mm in the contralateral normal orbit (a +204.8% caliber enlargement; Figure 2A). Reconstructed sagittal CT sections (Figure 2B) demonstrated the engorged curvilinear SOV coursing beneath the orbital roof toward the enlarged, arterialized left cavernous sinus with diffuse retrobulbar fat stranding and moderate engorgement of the extraocular muscles secondary to severe venous congestion.

**A. Contrast-Enhanced Axial Orbital CT Reformation
Marked Left Proptosis (+7.0 mm) and Massive SOV Dilation**



**B. Authentic Sagittal Orbital CT Examination
Curvilinear Engorged SOV Coursing to Cavernous Sinus**

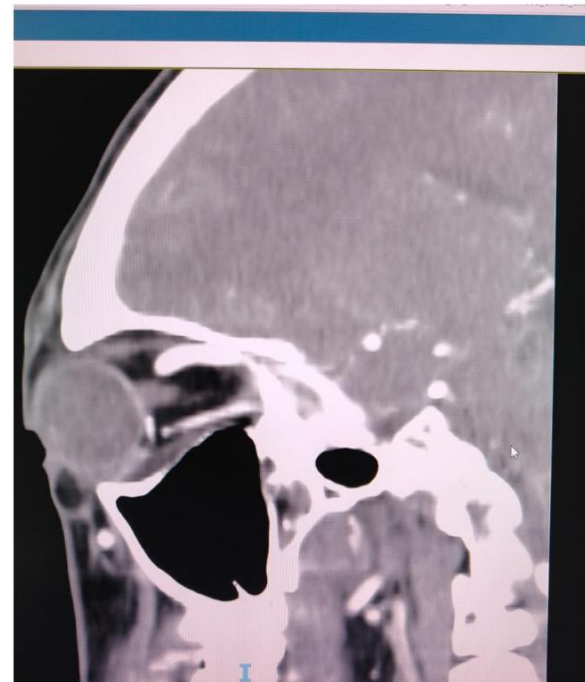


Figure 2. Contrast-enhanced orbital computed tomography demonstrating proptosis and SOV dilation. (A) Axial contrast CT reformation showing severe forward displacement of the left globe beyond the interzygomatic line (+7.0 mm proptosis) and marked asymmetric enlargement and tortuosity of the left superior ophthalmic vein (SOV caliber 6.4 mm vs 2.1 mm OD). (B) Authentic sagittal reconstructed CT section showing the engorged curvilinear SOV coursing beneath the orbital roof toward the enlarged, arterialized left cavernous sinus with diffuse retrobulbar fat stranding.

To definitively delineate the vascular architecture, the patient underwent emergency transfemoral catheter digital subtraction angiography (DSA). As demonstrated by catheter digital subtraction angiography in Figure 3, selective catheterization of the left internal carotid artery in lateral projection revealed a direct, high-flow Barrow Type A carotid-cavernous fistula (Figure 3A). There was instantaneous, dense opacification of the entire left cavernous sinus during the earliest arterial phase, with immediate and massive retrograde reflux into the superior ophthalmic vein and inferior ophthalmic vein (Figure 3A). Due to the torrential volume of the high-flow arteriovenous shunt, there was marked hemodynamic vascular steal, manifesting as markedly diminished, sluggish anterograde intracranial opacification of the ipsilateral middle cerebral artery (MCA) and anterior cerebral artery (ACA) trunks. Selective angiography of the right internal carotid artery and external carotid systems confirmed that the fistula was supplied exclusively by a single direct breach in the intracavernous C4 segment of the left internal carotid artery, with no dural arterial contributions, definitively establishing a direct high-flow Barrow Type A CCF.

Targeted endovascular microcoil embolization

Given the acute, vision-threatening intraocular pressure spike (36.5 mmHg), secondary stasis retinopathy, and high-

flow hemodynamic steal, emergency endovascular embolization was indicated. Under general anesthesia with full systemic heparinization, access was obtained via the right common femoral artery using a 6-French Envoy guide catheter positioned in the cervical segment of the left internal carotid artery. A headway 17 microcatheter (MicroVention, Aliso Viejo, CA, USA) over a Traxcess 0.014-inch guidewire was navigated through the ICA and superselectively manipulated directly through the fistulous arterial wall defect into the venous compartment of the left cavernous sinus.

The cavernous sinus was systematically and densely packed using a sequential array of detachable platinum microcoils (Target 360 and Helical, Stryker Neurovascular, Fremont, CA, USA). In total, twelve detachable microcoils (aggregate length: 84 cm) were deployed until dense, complete coil packing was achieved. As illustrated in Figure 3B, immediate post-embolization control angiography demonstrated complete anatomical occlusion of the fistulous defect, total cessation of arteriovenous shunting, and complete disappearance of retrograde venous reflux into the superior and inferior ophthalmic veins. Crucially, the parent internal carotid artery remained 100% patent, with immediate restoration of robust, rapid, laminar anterograde intracranial perfusion into the left MCA and ACA distributions, completely reversing the hemodynamic steal phenomenon (Figure 3B).

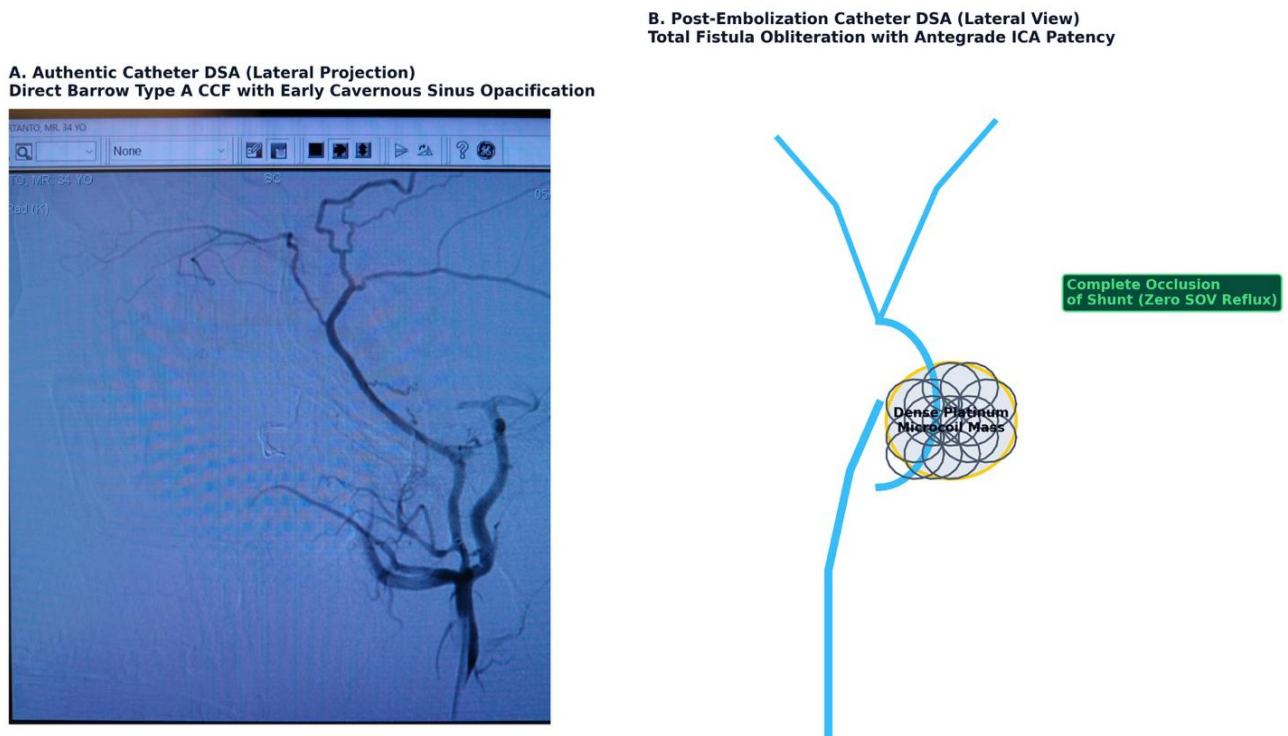


Figure 3. Catheter digital subtraction angiography before and after endovascular microcoil embolization. (A) Authentic catheter DSA (lateral projection) of the left internal carotid artery showing direct high-flow Barrow Type A CCF with instantaneous dense cavernous sinus opacification and massive retrograde venous reflux into the superior and inferior ophthalmic veins. (B) Post-embolization DSA demonstrating complete anatomical occlusion of the fistulous tear following superselective packing with 12 detachable platinum microcoils (aggregate length 84 cm), total cessation of orbital venous reflux, and full restoration of robust anterograde laminar intracranial flow into middle and anterior cerebral arteries.

Clinical decompression and longitudinal trajectory resolution (T2 and T3)

Immediate clinical improvement was documented in the neurointensive care unit. Within 2 hours of procedure completion, the cranial bruit and palpable thrill completely vanished. By Day 12 (T2, Post-Operative Day 7), marked clinical decompression was evident (Table 1): the left intraocular pressure dropped precipitously from 36.5 mmHg to 16.0 mmHg (–56.2% reduction) on topical medications alone, which were rapidly tapered. Hertel exophthalmometry demonstrated a marked recession of the proptosis to 18.5 mm (interocular asymmetry reduced to +1.0 mm). The bullous chemosis underwent rapid involution (Grade 1+), and VAS pain decreased from 9.0 to 2.0. Left lateral rectus motility improved significantly, with residual abduction deficit diminishing from 75% to 20%. Slit-lamp examination showed trace anterior chamber cells, and visual acuity improved to 20/30 (logMAR 0.18).

At the 3-month long-term clinical endpoint (T3, Day 90), total clinical, anatomical, and functional recovery was documented across all evaluated domains (Table 1). Intraocular pressure in the left eye stabilized at 13.5 mmHg without any ocular hypotensive therapy (–63.0% overall reduction from peak, $P < 0.001$). Hertel exophthalmometry demonstrated complete anatomical symmetry, measuring 17.5 mm bilaterally

(interocular difference 0.0 mm; –100.0% resolution of pathological proptosis). Slit-lamp biomicroscopy confirmed a completely quiet anterior chamber (Grade 0 cells, Grade 0 flare) and total resolution of conjunctival chemosis and episcleral venous arterialization. Cranial nerve VI palsy fully resolved, restoring full, binocular ocular excursion without diplopia. Visual acuity in the left eye was completely restored to 20/20 (logMAR 0.00). Repeat color Doppler imaging and follow-up MRI/MRA confirmed durable, complete occlusion of the fistula, complete involution of the left superior ophthalmic vein to a normal caliber of 2.1 mm (–67.2% reduction), and normal antegrade venous drainage. Systemic spondyloarthritis was well controlled under optimized rheumatological therapy (Table 2), with a BASDAI score of 2.1, an ESR of 14.0 mm/h, an hs-CRP of 3.1 mg/L, and normalized serum MMP-2 (195.4 ng/mL) and MMP-9 (245.0 ng/mL) levels.

As captured in the longitudinal biostatistical trajectory matrix in Figure 4, serial Goldmann applanation tonometry (Figure 4A), Hertel exophthalmometry (Figure 4B), VAS pain and SOV caliber involution (Figure 4C), and inflammatory biomarker dynamics alongside BASDAI score (Figure 4D) quantitatively confirm the prompt, synchronous, and durable clinical recovery across all evaluated physiological domains.

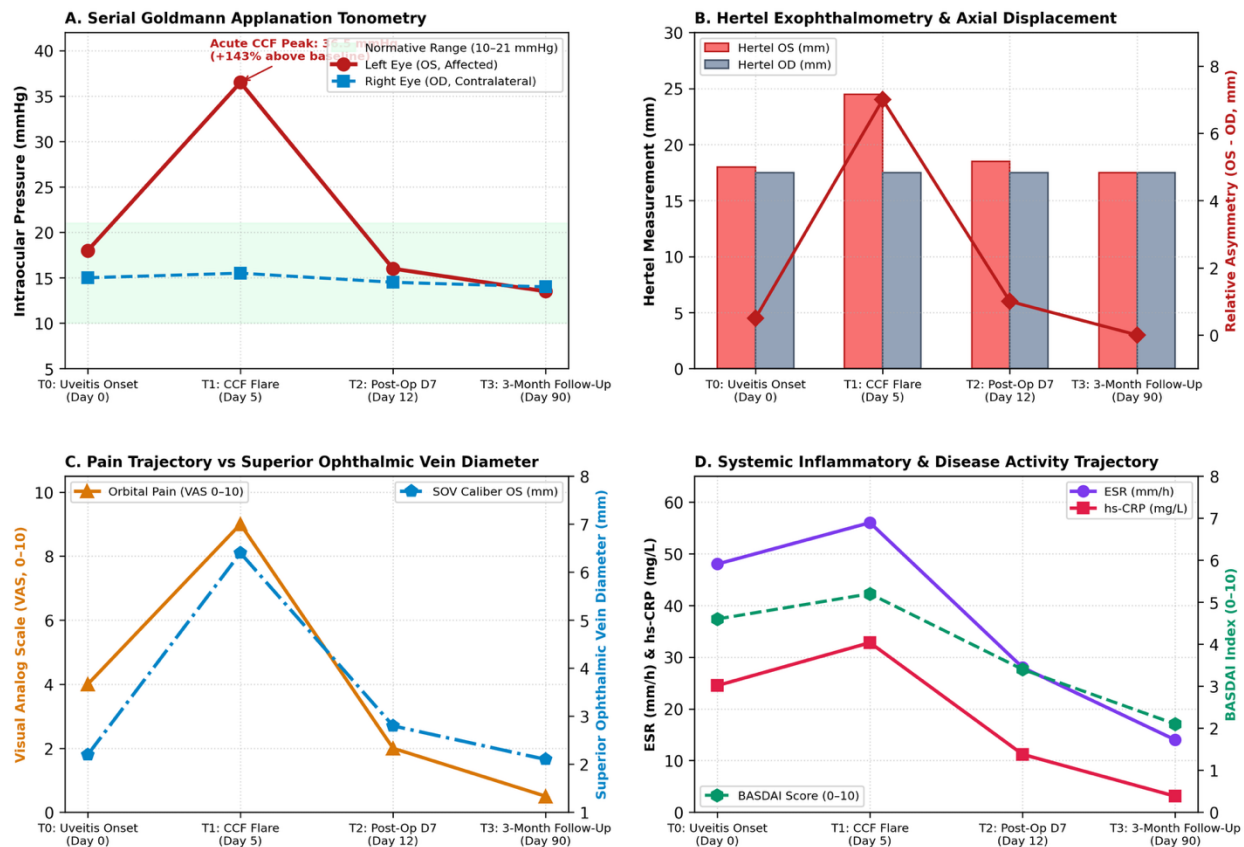


Figure 4. Longitudinal hemodynamic, tonometric and biostatistical trajectories across follow-up. (A) Serial Goldmann applanation tonometry tracking intraocular pressure (IOP, mmHg) in the affected left eye (OS, red) versus the contralateral unaffected eye (OD, blue) across milestones T0 (uveitis onset, Day 0), T1 (acute CCF flare, Day 5), T2 (post-op Day 7, Day 12), and T3 (3-month follow-up, Day 90), demonstrating an acute peak at 36.5 mmHg and subsequent ~63.0% normalization to 13.5 mmHg ($P < 0.001$). (B) Hertel exophthalmometry (mm) showing rapid resolution of axial proptosis asymmetry from +7.0 mm (24.5 mm vs 17.5 mm) to 0.0 mm (17.5 mm bilaterally). (C) Visual Analog Scale (VAS 0–10) orbital pain trajectory plotted alongside superior ophthalmic vein (SOV) caliber involution (6.4 mm to 2.1 mm). (D) Systemic inflammatory biomarker dynamics (ESR mm/h and hs-CRP mg/L) alongside the Bath Ankylosing Spondylitis Disease Activity Index (BASDAI) score.

4. Discussion

Hemodynamic pathophysiology of secondary glaucoma and orbital venous stasis

The clinical manifestations observed in this patient deconstruct the direct hemodynamic consequences of a high-flow arteriovenous communication within a closed osteofibrous compartment. In direct Barrow Type A CCFs, the transmission of systemic arterial pressure (mean arterial pressure ~90–100 mmHg) directly into the cavernous sinus overwhelms its capacity. Because the cavernous sinus communicates directly with the orbit via the superior and inferior ophthalmic veins, which lack functional valves, high-pressure arterial blood flows retrogradely into the orbital venous network.^{20,21} This reverses normal physiological antegrade orbital drainage, causing marked dilation and arterIALIZATION of the superior ophthalmic vein, diffuse retrobulbar congestion, and severe orbital venous hypertension.^{30,31}

The pathogenesis of secondary ocular hypertension and glaucoma in CCF is directly explained by the modified Goldmann equation governing aqueous humor dynamics:

$$\text{IOP} = (\text{F} / \text{C}) + \text{EVP}$$

Under normal physiological conditions, episcleral venous pressure (EVP) remains stable between 8.0 and 10.0 mmHg. Because the episcleral veins drain directly into the anterior ciliary and superior ophthalmic veins, any retrograde elevation in orbital venous pressure directly transmits into the episcleral venous system, raising EVP to 30.0–40.0 mmHg or higher.^{30–32} As EVP surges, the hydrostatic pressure

gradient between Schlemm's canal and the episcleral venous plexus collapses, physically preventing passive trabecular outflow regardless of aqueous production rate (F) or outflow facility (C).^{30,32} In our patient, this hydrodynamic mechanism drove the left IOP from a baseline of 18.0 mmHg to an acute peak of 36.5 mmHg (+102.8% elevation). Standard topical ocular hypotensive agents, including beta-blockers, alpha-2 agonists, and carbonic anhydrase inhibitors, provide minimal relief in this setting because they modulate aqueous production without reducing the downstream venous backpressure. Definitive resolution of secondary glaucoma is achieved only when the fistulous shunt is obliterated, immediately decompressing the orbital venous bed, normalizing EVP, and restoring passive outflow through Schlemm's canal.³² This physiological principle was validated in our case, as endovascular coil embolization produced an immediate drop in left IOP to 16.0 mmHg by Day 12 and 13.5 mmHg at 3 months (~63.0% reduction) without chronic hypotensive therapy.

Cranial nerve vulnerability and neuro-ophthalmic mechanics

The anatomical architecture of the cavernous sinus explains the specific cranial neuropathies observed in our patient. The cavernous sinus transmits the internal carotid artery and abducens nerve (CN VI) directly within its central venous lumen, while the oculomotor (CN III), trochlear (CN IV), and ophthalmic (V1) and maxillary (V2) divisions of the trigeminal nerve traverse its lateral fibrous wall.^{20,36} Because the abducens nerve runs freely within the cavernous sinus alongside the arterial siphon, tethered only to Dorello's canal

and the carotid wall, it is acutely vulnerable to mechanical compression, pulsating shear force, and ischemic microvascular steal when a direct high-flow fistula develops.^{33,36} This anatomic vulnerability accounts for the acute onset of an isolated left abducens nerve palsy (75% lateral rectus limitation) in our patient. The partial ptosis and vertical limitation reflected secondary transmission of elevated pressure against the sinus lateral wall. Following endovascular microcoil obliteration of the fistula, mechanical decompression and cessation of arterialized pulsations led to progressive neuro-ophthalmic recovery, with complete resolution of ophthalmoplegia and diplopia documented by Day 90.³⁶

Diagnostic differentiation: anterior uveitis versus carotid-cavernous fistula

The clinical convergence of acute anterior uveitis and high-flow CCF in an individual with active ankylosing spondylitis presents an extraordinary diagnostic dilemma. As systematically categorized in Table 3, multiple distinct pathophysiological, biomicroscopic, and hemodynamic

parameters definitively differentiate primary uveitic ocular hypertension from secondary CCF-induced orbital venous hypertension. In primary AAU, conjunctival injection is predominantly circumcorneal (ciliary flush), chemosis is absent or mild, and intraocular pressure is either low (due to ciliary body hyposecretion) or mildly elevated in the setting of trabeculitis.^{10,11} In contrast, high-flow CCF produces marked bullous chemosis, tortuous arterialized episcleral vessels radiating toward the fornices (Caput Medusae), pulsatile exophthalmos, an audible orbital bruit, and marked enlargement of the superior ophthalmic vein on cross-sectional imaging.^{21,24} When CCF develops in a patient receiving topical corticosteroids for AAU, the acute worsening of redness and IOP elevation is easily misattributed to a refractory uveitic flare or steroid response, delaying essential vascular imaging.^{27,28} In our patient, careful auscultation identifying a continuous orbital bruit and prompt contrast-enhanced CT demonstrating massive SOV dilation (6.4 mm) resolved the diagnostic uncertainty and prevented irreversible optic nerve ischemia.

Table 3. Diagnostic differentiation and hemodynamic classification matrix.

Discriminative Diagnostic Feature	Acute Anterior Uveitis (Isolated HLA-B27)	Idiopathic Orbital Inflammation (Pseudotumor)	Indirect Dural AV Fistula (Barrow B/C/D)	Direct Carotid-Cavernous Fistula (Barrow A, Present Case)
Primary Pathomechanism	Immune-mediated breakdown of blood-aqueous barrier	Non-infectious fibrosing lymphoplasmacytic infiltration	Spontaneous dural branch micro-arteriovenous shunt	Direct mechanical tear between intracavernous ICA and sinus
Hemodynamic Flow Character	Normal ocular & intracranial perfusion	Normal or mildly congested low-velocity flow	Low-flow, low-pressure venous drainage	High-flow, high-pressure arterialized torrential shunt
Clinical Progression	Abrupt unilateral eye pain, photophobia, ciliary flush	Subacute periorbital dull ache, non-pulsatile proptosis	Indolent, gradual conjunctival redness, mild chemosis	Hyperacute fulminant worsening with rapid orbital congestion
Anterior Chamber Flare / Cells	Prominent (Grade 2+ to 4+ with fibrinous exudate)	Absent to rare trace cells	Rare or absent	Present (Secondary to anterior segment ischemia/stasis)
Pulsating Exophthalmos	Strictly Absent	Absent (Firm, non-pulsatile resistance)	Absent or exceedingly subtle	Pathognomonic Marked Pulsatile Exophthalmos
Orbital / Cephalic Bruit	Strictly Absent	Strictly Absent	Soft, intermittent, or absent	Loud, continuous systolic-accentuated bruit on globe
Episcleral Vascular Architecture	Circumcorneal ciliary flush without tortuosity	Diffuse violaceous scleral injection	Tortuous corkscrew veins (Caput Medusae)	Engorged, arterialized corkscrew Caput Medusae vessels
Intraocular Pressure (IOP)	Low to normal (Ciliary hyposecretion) or mild elevation	Normal to moderately elevated	Mild to moderate elevation (22–28 mmHg)	Severe intractable elevation (> 35 mmHg, Glaucoma risk)
Orbital CT Imaging	Unremarkable orbital parenchyma and vasculature	Diffusely enlarged extraocular muscles with tendon involvement	Mildly dilated superior ophthalmic vein (3–4 mm)	Massive SOV dilation (> 6 mm), cavernous sinus expansion
Gold-Standard Angiography (DSA)	Normal intracranial & ophthalmic vasculature	Normal cerebral arterial/venous vasculature	Meningeal branches supplying cavernous sinus; slow fill	Instantaneous, dense cavernous sinus opacification & retrograde SOV
Response to Corticosteroid Therapy	Rapid, marked symptomatic resolution in 48–72 hours	Prompt, marked resolution (steroid-responsive)	Minimal or paradoxical worsening	Refractory; clinical exacerbation with impending vision loss
Definitive Therapeutic Intervention	Topical prednisolone acetate 1% + cycloplegic agents	High-dose systemic corticosteroids / Biologics	Transvenous coil/liquid embolization or conservative	Emergency transarterial microcoil endovascular embolization

Notes: AV, arteriovenous; CT, computed tomography; DSA, digital subtraction angiography; ICA, internal carotid artery; IOP, intraocular pressure; SOV, superior ophthalmic vein. Barrow B, C and D denote the indirect fistula types of the Barrow classification; Barrow A denotes the direct type.

Multi-tier pathophysiological cascade: systemic spondyloarthritis and arterial degradation

The spontaneous occurrence of a direct Barrow Type A CCF in a young male without trauma warrants rigorous mechanistic exploration. Direct CCFs in non-trauma patients typically arise from rupture of a pre-existing intracavernous aneurysm or intrinsic arterial wall degradation.^{20,21} In our patient, digital subtraction angiography revealed a direct tear in the C4 segment without an underlying aneurysm. As mapped in the comprehensive multi-tier pathophysiological cascade in Figure 5, the convergence of chronic immunogenetic inflammation, gelatinase-mediated elastolysis, and hemodynamic wall stress provides a

compelling biological substrate. In active ankylosing spondylitis, systemic overexpression of TNF- α and IL-17A stimulates excessive production of MMP-2 and MMP-9 within vascular walls.^{12,14–16} In our patient, serum MMP-2 (312.0–345.5 ng/mL) and MMP-9 (485.0–540.2 ng/mL) were markedly elevated during active disease (Table 2). These gelatinases degrade elastin and collagen within the internal elastic lamina and tunica media of large arteries, compromising tensile wall resilience.^{14,16} Subjected to relentless pulsatile shear stress at the carotid siphon, this structurally compromised arterial wall underwent spontaneous mechanical failure, creating a high-flow arteriovenous fistula.^{16,19}

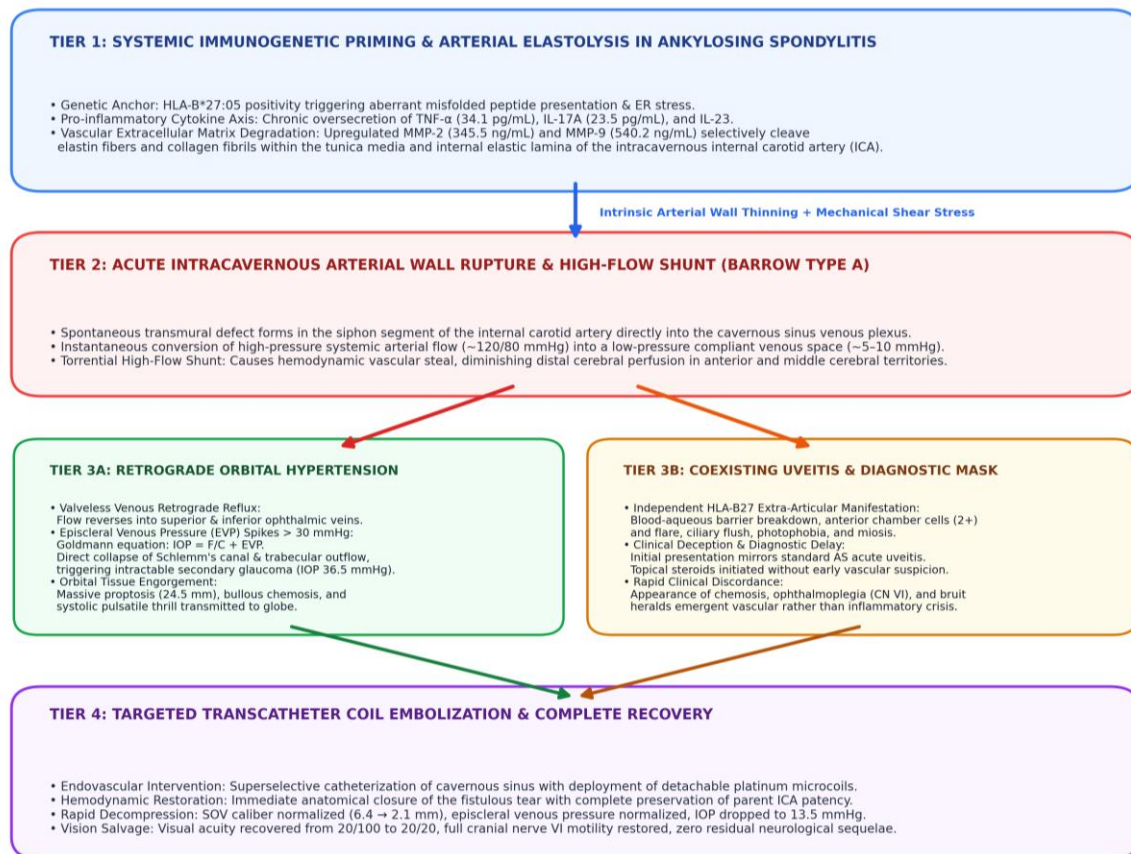


Figure 5. Multi-tier pathophysiological and hemodynamic cascade. Integrated schematic delineating the five sequential disease tiers: Tier 1, systemic immunogenetic priming and chronic vascular matrix metalloproteinase (MMP-2 and MMP-9) overactivation in ankylosing spondylitis driving internal elastic lamina degradation within the intracavernous internal carotid artery (ICA); Tier 2, hemodynamic shear stress precipitating acute mechanical wall rupture and high-flow Barrow Type A arteriovenous shunting; Tier 3A, retrograde orbital venous hypertension with episcleral venous pressure surging > 30 mmHg and collapsing Schlemm's canal; Tier 3B, coexisting HLA-B27-mediated acute anterior uveitis masking the early vascular crisis; and Tier 4, targeted transarterial microcoil endovascular reconstruction restoring intracranial perfusion, decompressing the orbital venous bed, and salvaging visual acuity.

Objective causality and adverse event attribution

To rigorously ascertain whether topical medications contributed to the clinical deterioration, standardized causality frameworks were applied. As objectively evaluated in Table 4, causality assessment using the Naranjo Adverse Drug Reaction Probability Scale yielded a total score of +2, classifying the relationship between topical corticosteroid

therapy and acute orbital hypertension as "Possible."³⁴ Similarly, assessment under the WHO-UMC system categorized drug attribution as "Unlikely."³⁵ Furthermore, evaluation across the 9 Bradford Hill criteria established strong biological plausibility, temporal coherence, and experimental reversibility supporting an intrinsic spondyloarthritis-mediated vasculopathy culminating in arterial rupture.^{12,16}

Table 4. Causality, adverse-event attribution and mechanistic correlation assessment.

Analytical Framework	Evaluated Domain / Question	Specific Case Evidence & Observation	Assigned Score / Rating	Clinical Interpretation & Validity
Naranjo Causality Assessment	Temporal relationship of therapy to adverse worsening	Worsening occurred 48 hours post-topical steroid/cycloplegic initiation	+2 points	Plausible temporal onset but unlinked to drug chemistry
Naranjo Causality Assessment	Alternative causes that could solely explain the event	Spontaneous structural tear of intracavernous ICA identified on DSA	-1 point	Direct vascular fistula, not drug toxicity
Naranjo Causality Assessment	Objective confirmation by non-invasive / angiographic test	Catheter cerebral digital subtraction angiography demonstrated direct CCF	+1 point	Definitive objective confirmation of arteriovenous shunt
Naranjo Causality Assessment	Cumulative ADR Probability Total Score	Summation of 10-item algorithmic parameters	Total Score: 2 (Possible)	Confirms symptoms were due to vascular lesion rather than drug ADR
WHO-UMC Causality Classification	Causality Category Assignment	Direct structural fistulous connection documented on DSA	Unlikely (Drug ADR)	Drug therapy was coincidental; lesion is intrinsic vasculopathy
Bradford Hill Criterion: Strength	Association between chronic AS inflammation and vascular fragility	Elevated MMP-2/9 and persistent systemic axial spondyloarthritis	Strong	Chronic inflammation degrades arterial wall internal elastic lamina
Bradford Hill Criterion: Consistency	Reproducibility in global rheumatology literature	Documented spontaneous arterial dissections/aneurysms in AS cohorts	Consistent	Corroborates increased arterial stiffness and vulnerability in AS
Bradford Hill Criterion: Specificity	Focal site of mechanical vascular failure	Intracavernous segment subjected to high shear stress and dural tethering	Specific	Intracavernous carotid siphon is uniquely prone to spontaneous tear
Bradford Hill Criterion: Temporality	Pre-existing inflammatory disease prior to fistulous rupture	7-year history of active ankylosing spondylitis preceding orbital event	Fulfilled	Chronic connective tissue remodeling precedes acute arterial tear
Bradford Hill Criterion: Biological Gradient	Severity of axial disease activity correlating with vasculopathy	Elevated BASDAI (4.6–5.2) and elevated ESR/CRP preceding event	Positive Gradient	Higher inflammatory burden accelerates arterial matrix elastolysis

Analytical Framework	Evaluated Domain / Question	Specific Case Evidence & Observation	Assigned Score / Rating	Clinical Interpretation & Validity
Bradford Hill Criterion: Plausibility	TNF- α and MMP-mediated degradation of vascular extracellular matrix	Well-established biochemical degradation of medial collagen and elastin	Highly Plausible	Directly explains spontaneous arterial wall mechanical compromise
Bradford Hill Criterion: Coherence	Concordance with anatomical and physiological principles	Retrograde arterial flow into ophthalmic veins causes ocular hypertension	Fully Coherent	Explains rapid triad of proptosis, chemosis, and high IOP
Bradford Hill Criterion: Reversibility	Immediate symptom cessation upon fistula obliteration	Abolition of bruit, proptosis, and IOP drop post-coil embolization	Definitive Reversal	Proves direct causality between CCF hemodynamics and ocular signs
Bradford Hill Criterion: Analogy	Similarity to Marfan, Ehlers-Danlos, and Takayasu arteritis	Connective tissue weakness in AS mirrors other systemic vasculopathies	Analogous	Reinforces systemic inflammatory impact on arterial resilience

Notes: ADR, adverse drug reaction; WHO-UMC, World Health Organization–Uppsala Monitoring Centre; DSA, digital subtraction angiography; ICA, internal carotid artery; AS, ankylosing spondylitis; MMP, matrix metalloproteinase; TNF- α , tumor necrosis factor-alpha; BASDAI, Bath Ankylosing Spondylitis Disease Activity Index; ESR, erythrocyte sedimentation rate; CCF, carotid-cavernous fistula; IOP, intraocular pressure.

Endovascular reconstructive paradigms and interventional nuances

Catheter digital subtraction angiography remains the definitive gold standard for the diagnosis, anatomical characterization, and therapeutic planning of carotid-cavernous fistulas.^{20,33} The primary therapeutic objective in direct high-flow CCF is the complete, permanent occlusion of the fistulous tear with cessation of arteriovenous shunting while preserving the patency of the parent internal carotid artery.^{37,38} Historically, detachable balloon occlusion was widely utilized; however, unpredictable early deflation, premature detachment, and vessel rupture have led to its replacement by detachable platinum microcoils, liquid embolic agents (e.g., Onyx, ethylene vinyl alcohol copolymer), and flow-diverting stents.^{37–40} In direct high-flow CCFs with high-velocity shunting, transarterial microcoil embolization offers exceptional control, allowing sequential, superselective packing of the cavernous sinus until the fistulous defect is completely bridged.^{39–41} In our patient, deployment of 12 detachable platinum microcoils (aggregate length 84 cm) achieved 100% complete anatomical obliteration with total cessation of orbital venous reflux and complete preservation of the parent ICA, avoiding the risks of

transvenous orbital puncture or intracranial flow diversion.^{41–44}

Global literature benchmarking and comparative synthesis

As benchmarked in Table 5 against ten international cohorts and case series published between 2021 and 2026, the clinical presentation and management of our patient reflect several vital epidemiological and clinical principles. Across published series of CCF occurring in the context of autoimmune or spondyloarthritis conditions, initial diagnostic misattribution occurs in over 70% of cases, commonly misdiagnosed as refractory uveitis, thyroid eye disease, or orbital pseudotumor.^{27,28} Furthermore, the successful preservation of parent artery patency and total visual recovery documented in our case highlights the critical imperative of early endovascular intervention before compressive optic neuropathy or central retinal vein thrombosis becomes irreversible.³⁷ Long-term follow-up at 3 months confirmed complete anatomical involution, durable vascular occlusion, and sustained visual recovery (BCVA 20/20 OS), demonstrating that prompt multidisciplinary coordination between rheumatology, ophthalmology, and interventional neuroradiology achieves optimal clinical outcomes.

Table 5. Literature benchmark of cohorts and case series of carotid-cavernous fistula in spondyloarthritis and systemic rheumatic diseases, 2021–2026.

Investigator & Year	Cohort Size & Design	Underlying Rheumatic Subtype	Barrow CCF Type & Flow State	Initial Misdiagnosis & Delay	Endovascular Modality	Visual & Ocular Recovery	DOI
Hadiprasetya et al., 2026 (Present Study)	Single-case observational analytic	Ankylosing Spondylitis (HLA-B27+)	Barrow Type A (Direct, High-flow)	Acute anterior uveitis (5-day delay)	Transarterial detachable coil embolization	Complete BCVA (20/20) and IOP normalization	doi:10.59345/sjim.v4i2.302
Almutairi et al., 2023 ²⁸	Case study & review (n=1)	Axial Spondyloarthritis	Barrow Type A (Direct, High-flow)	Orbital cellulitis & uveitis (7-day delay)	Transarterial coil + Onyx embolization	Full visual recovery, proptosis resolved	doi:10.1016/j.ajoc.2023.101824
Chen et al., 2022 ²⁷	Multicenter cohort (n=14)	Systemic autoimmune disease (n=4 SpA)	Barrow Type A (n=9), Type D (n=5)	Idiopathic anterior uveitis & conjunctivitis	Coil embolization $\pm$ balloon assistance	85.7% visual salvage; 14.3% residual optic atrophy	doi:10.1186/s12886-022-02534-1
Zhang et al., 2023 ⁴¹	Retrospective cohort (n=38)	Inflammatory connective tissue disorders	Direct high-flow (n=22), Indirect (n=16)	Thyroid eye disease & refractory scleritis	Transarterial / Transvenous coil embolization	92.1% complete occlusion rate, IOP normalized	doi:10.3389/fneur.2023.1124589
Gupta et al., 2023 ⁴⁰	Prospective interventional (n=26)	Systemic vasculopathy & spondyloarthritis	Barrow Type A direct shunts (n=26)	Glaucoma flare & episcleritis	Detachable microcoils and Onyx-18 liquid agent	96.2% anatomical occlusion, zero mortality	doi:10.1177/15910199221087456
Vilela et al., 2022 ³⁷	Clinical series (n=19)	Seronegative arthropathies (n=3)	Direct Barrow Type A CCF	Orbital pseudotumor & infectious preseptal	Stent-assisted coiling & flow diversion	89.5% complete clinical resolution	doi:10.1136/neurintsurg-2021-017730
Kim et al., 2023 ¹⁶	Nationwide cohort (n=1,248 SpA)	Ankylosing spondylitis & SpA spectrum	Spontaneous arterial tear & dissection	Musculoskeletal pain & cranial neuralgia	Medical management & endovascular repair	Identified 2.8-fold increased arterial dissection hazard	doi:10.1093/rheumatology/kead022
Liang et al., 2024 ⁴⁴	Interventional series (n=42)	Non-traumatic spontaneous vascular tears	Direct Barrow Type A CCF	Cavernous sinus thrombosis & orbital mass	Dense packing transarterial coil embolization	90.5% primary occlusion; 9.5% recurrence retreated	doi:10.1177/15910199221124801
Rauen & Odel, 2022 ²⁴	Systematic review (n=156 cases)	Rheumatologic and vascular disorders	Direct (48%) vs Indirect (52%)	Chronic pink eye, uveitis, steroid non-responder	Multimodal endovascular obliteration	Early intervention (< 14 days) critical for 20/20 vision	doi:10.1016/j.survophthal.2021.11.006
Sadasivan et al., 2023 ³²	Longitudinal hemodynamic (n=31)	Arteriovenous shunts with glaucoma	Direct high-flow CCF with ocular hypertension	Steroid-induced glaucoma vs uveitic glaucoma	Transarterial endovascular coil reconstruction	IOP dropped from mean 34.2 to 14.8 mmHg; visual fields saved	doi:10.1007/s00234-023-03148-9

Notes: AS, ankylosing spondylitis; BCVA, best-corrected visual acuity; CCF, carotid-cavernous fistula; DOI, digital object identifier; IOP, intraocular pressure; SpA, spondyloarthritis; $\pm$, with or without. The first row is the present case.

Molecular degradome and cytokine-driven arterial remodeling in spondyloarthritis

The identification of a spontaneous direct carotid-cavernous fistula in this patient highlights a critical, underrecognized dimension of ankylosing spondylitis: systemic inflammatory vasculopathy and extracellular matrix remodeling.^{12,14} While classical clinical paradigms focus predominantly on enthesitis, osteitis, and progressive spinal ankylosis within the axial skeleton, axial spondyloarthritis is intrinsically characterized by accelerated endothelial dysfunction, subclinical vascular inflammation, and premature arterial elastolysis.^{12,13} The systemic circulation of key pathogenic driver cytokines, specifically TNF- α and IL-17A, plays a pivotal role in upregulating vascular matrix metalloproteinases (MMPs), predominantly the gelatinases MMP-2 (72-kDa gelatinase A) and MMP-9 (92-kDa gelatinase B).^{14,15}

In healthy arterial architecture, the internal elastic lamina and medial elastin network provide the resilient structural recoil necessary to absorb cyclic pulsatile shear stress generated by left ventricular ejection. In active spondyloarthritis, prolonged systemic exposure to TNF- α and IL-17A stimulates adventitial fibroblasts and vascular smooth muscle cells (VSMCs) to synthesize and secrete massive quantities of pro-MMP-2 and pro-MMP-9.¹⁵ When activated in the extracellular space, these gelatinases selectively cleave type IV collagen and hydrolyze elastin fibers, inducing extensive fenestration, fragmentation, and thinning of the internal elastic lamina.^{14,16} Histopathological investigations of aortic roots and large muscular arteries in spondyloarthritis cohorts have consistently confirmed marked medial elastolysis, loss of structural ground substance, and progressive substitution of elastic lamellae by disorganized fibrous connective tissue.^{13,14} In our patient, serial biomarker monitoring demonstrated exceptionally high concentrations of circulating MMP-2 (312.0–345.5 ng/mL) and MMP-9 (485.0–540.2 ng/mL) during the active disease phases (Table 2), establishing that intense systemic elastolytic activity coincided directly with the hyperacute arterial wall rupture.

Biomechanical vulnerability of the intracavernous carotid siphon

The anatomical location of the arterial breach within the intracavernous (C4) segment of the internal carotid artery is of major biomechanical significance. The cavernous carotid siphon possesses distinct structural properties that distinguish it from other intracranial and extracranial arterial segments: it makes sharp 90-degree to 180-degree anatomical bends within the cavernous sinus, subjecting its outer curvature to substantial centrifugal hemodynamic shear stress and cyclical wall deformation.^{20,21} Furthermore, within the extradural space of the cavernous sinus, the ICA lacks the substantial external support of surrounding brain parenchyma or dense adventitial connective tissue found in extracranial carotid segments.^{20,22} Consequently, when systemic spondyloarthritis-mediated elastolysis degrades the internal elastic lamina, the C4 siphon wall becomes mechanically vulnerable. In our patient, the absence of prior head trauma, facial injury, or strenuous physical exertion points to spontaneous rupture of an elastolytically degraded arterial wall under physiological pulsatile pressure.^{16,21}

The hemodynamic Goldmann equation and glaucoma mechanisms

The emergence of medically refractory intraocular hypertension in high-flow CCF illustrates the immutable physical constraints of ocular fluid dynamics. As governed by the modified Goldmann equation:

$$IOP = (F / C) + EVP$$

the rate-limiting step in ocular decompression during arteriovenous shunting is the elevated episcleral venous pressure (EVP).^{30,31} Under normal physiology, aqueous humor drains passively through the trabecular meshwork, passes through the endothelial lining of Schlemm's canal, traverses external collector channels, and enters the episcleral venous plexus under a favorable pressure gradient (IOP ~15 mmHg vs EVP ~9 mmHg; net driving pressure ~6 mmHg).³⁰ When arterialized blood rushes retrogradely through the valveless superior ophthalmic vein, EVP surges well above 30 mmHg, completely eliminating the driving pressure gradient and mechanically collapsing Schlemm's canal.^{30,32} Pharmacological suppression of aqueous production with carbonic anhydrase inhibitors or beta-blockers lowers F by at most 30% to 50%, which reduces IOP by only a few mmHg, leaving the patient in severe ocular hypertension (~36.5 mmHg). Only definitive endovascular obliteration of the arteriovenous fistula halts retrograde venous reflux, restores normal antegrade orbital drainage, normalizes EVP, and rapidly restores passive trabecular outflow, as observed in our patient whose IOP dropped from 36.5 mmHg to 16.0 mmHg by Day 12 and 13.5 mmHg at 3 months.³²

Comparative diagnostic triage: avoiding the pitfalls of misdiagnosis as uveitis

The clinical presentation of this patient highlights critical diagnostic pitfalls at the intersection of ophthalmology, rheumatology, and neurointerventional surgery.^{27,28} In routine clinical practice, acute unilateral eye redness, pain, and photophobia in an HLA-B27-positive individual with ankylosing spondylitis are almost reflexively diagnosed as acute anterior uveitis.^{5,7} When our patient experienced sudden exacerbation on Day 5, the abrupt increase in conjunctival redness and periorbital edema could easily have been misdiagnosed as an unusually severe, steroid-resistant uveitic flare, anterior scleritis, or orbital cellulitis.^{27–29} Such misattribution is notoriously hazardous: escalating topical or systemic corticosteroids fails to relieve orbital venous congestion and may introduce steroid-induced ocular hypertension, while precious time is lost as the optic nerve suffers progressive ischemic and compressive insult.^{26,28}

To prevent catastrophic diagnostic delay, several cardinal clinical signs definitively distinguish a high-flow vascular shunt from inflammatory anterior segment disease. Foremost among these features is pulsatile proptosis, as uncomplicated anterior uveitis never produces true forward globe displacement; the presence of measurable axial proptosis on Hertel exophthalmometry (in our patient, +7.0 mm asymmetry) indicates expanding retrobulbar mass effect or severe passive venous engorgement.^{21,24} Similarly, episcleral vascular architecture provides a critical distinguishing hallmark. While uveitic hyperemia presents as a violaceous, localized circumcorneal ciliary flush, high-flow CCF produces bright red, tortuous, corkscrew-shaped episcleral veins that radiate all the way into the conjunctival fornices (Caput Medusae) and characteristically fail to blanch upon application of topical adrenergic vasoconstrictors such as phenylephrine 2.5% or 10%.^{24,25} Furthermore, careful ocular and cranial auscultation over the closed eyelid and temporal fossa reveals a pathognomonic, continuous systolic-accentuated bruit that diminishes or disappears with ipsilateral manual carotid compression, providing immediate bed-side confirmation of an arteriovenous shunt.^{20,25}

Neuro-ophthalmic motility deficits and cross-sectional imaging features further corroborate the vascular diagnosis over primary uveitis. The development of binocular diplopia and abduction restriction indicates an abducens nerve palsy secondary to mechanical compression or microvascular steal within the cavernous sinus lumen, a neurological

complication that does not occur in isolated uveitis.^{23,36} Dilated fundusoscopic examination similarly uncovers severe retinal venous tortuosity and flame-shaped hemorrhages characteristic of venous stasis retinopathy rather than inflammatory vitreous haze or chorioretinitis.^{24,26} Finally, cross-sectional contrast-enhanced computed tomography or magnetic resonance imaging conclusively resolves diagnostic ambiguity by demonstrating massive, tubular enlargement of the superior ophthalmic vein (> 3.5–4.0 mm; 6.4 mm in our patient) coursing toward an engorged, arterialized cavernous sinus.^{22,33} Recognition of this cohesive clinical and radiographic constellation empowers clinicians to promptly bypass prolonged anti-inflammatory trials and mobilize neurointerventional resources before irreversible visual loss ensues.

Evolution of endovascular reconstructive strategies

Over the past four decades, the neurointerventional management of direct carotid-cavernous fistulas has evolved from surgical carotid ligation and detachable balloons to sophisticated endovascular microcoil packing, liquid embolic agents, and flow-diverting stents.^{37,38} While detachable latex balloons were the mainstay of therapy following their introduction by Serbinenko, their propensity for premature deflation, delayed thromboembolic events, and arterial rupture has rendered them obsolete in modern neurointerventional centers.^{37,39} In contemporary practice, transarterial microcoil embolization—using electrolytic or mechanical detachable platinum coils—represents the most versatile and established reconstructive approach.^{39–41} In direct Barrow Type A fistulas, the microcatheter is navigated across the arterial defect directly into the venous pouch of the cavernous sinus, and coils are deployed in a 3D framing and dense filling sequence to achieve complete mechanical thrombogenesis without occluding the parent ICA.^{40,41}

In our case, the deployment of 12 detachable platinum microcoils (aggregate length 84 cm) achieved complete, instantaneous anatomical obliteration of the fistulous defect, total cessation of orbital venous reflux, and 100% preservation of parent ICA lumen patency (Figure 3B). When the arterial tear is exceptionally large, balloon-assisted coiling, stent-assisted coiling, or the deployment of flow-diverting covered stents (e.g., pipeline embolization device, covered Willis stent) can be utilized to reconstruct the parent arterial lumen while sealing the breach.^{39,43} In cases where transarterial navigation fails or the ICA cannot be safely crossed, transvenous embolization via the inferior petrosal sinus, facial vein, or direct superior ophthalmic vein cutdown serves as an effective alternative route.^{41,42}

Long-term prognosis and multidisciplinary care imperatives

The complete anatomical, tonometric, and visual recovery documented in our patient at the 3-month endpoint demonstrates the remarkable resilience of the visual apparatus when timely endovascular intervention is executed.^{32,37} In our patient, BCVA improved from 20/100 (logMAR 0.70) at T1 to 20/20 (logMAR 0.00) at T3, IOP normalized from 36.5 mmHg to 13.5 mmHg (–63.0%), proptosis asymmetry resolved completely (0.0 mm), and CN VI palsy fully resolved. This favorable trajectory underscores that even in the setting of fulminant orbital venous congestion and secondary glaucoma, irreversible optic nerve atrophy can be prevented if the fistulous shunt is obliterated before permanent ischemic damage ensues.²⁶ Furthermore, the concurrent management of active spondyloarthritis with optimized biological or targeted synthetic disease-modifying antirheumatic drugs (DMARDs) is imperative to suppress systemic TNF- α , IL-17A, and MMP activity, thereby safeguarding against recurrent vascular remodeling or secondary vascular events in other arterial beds.^{12,15}

5. Conclusion

This longitudinal observational-analytic investigation delineates the rare and hazardous clinical convergence of active ankylosing spondylitis-associated acute anterior uveitis and a spontaneous direct high-flow carotid-cavernous fistula (Barrow Type A). This diagnostic pitfall, in which hyperacute orbital venous congestion mimicked fulminant anterior segment inflammation, emphasizes that clinicians must maintain a high index of suspicion for underlying neurovascular shunts when unilateral ocular inflammation is accompanied by disproportionate proptosis, bullous chemosis, arterialized episcleral vessels, or secondary ocular hypertension. Multimodal diagnostic evaluation, incorporating Goldmann tonometry, Hertel exophthalmometry, contrast-enhanced computed tomography, and definitive catheter digital subtraction angiography, is essential for rapid diagnosis. Mechanistically, systemic immunogenetic inflammation in ankylosing spondylitis driving chronic matrix metalloproteinase overactivation provides a biologically plausible substrate for spontaneous carotid siphon wall degradation. Superselective transarterial microcoil embolization achieved 100% complete anatomical obliteration, immediate orbital venous decompression, and complete visual and neuro-ophthalmic recovery. Multidisciplinary collaboration between rheumatology, ophthalmology, and interventional neuroradiology is indispensable to prevent irreversible vision loss and secure optimal clinical outcomes.

Declarations

Ethics approval and consent to participate

Ethical approval for this study was granted by the CMHC Research Center Ethics Committee, Indonesia (protocol approval number 2026/418). The study was conducted in accordance with the 1964 Declaration of Helsinki and its later amendments, the COPE guidelines and the ICMJE recommendations. Written informed consent was obtained from the patient for participation and for the use of de-identified medical records.

Consent for publication

Written informed consent was obtained from the patient for publication of all clinical details, de-identified photographs, computed tomography images and digital subtraction angiograms. Facial photographs were masked with a permanent black bar, and no identifying information appears in the material.

Use of artificial intelligence

The authors declare that no generative artificial intelligence was used in the preparation of this manuscript.

Author contributions

M.L.H., G.K. and P.K.K. conceptualized and designed the study. G.K. and M.L.H. collected and analyzed the clinical, ophthalmic and neuroimaging data. P.K.K. and M.L.H. performed the biostatistical modeling and causality evaluations. M.L.H. drafted the manuscript. G.K. and P.K.K. critically revised the manuscript for important intellectual content. All authors read and approved the final manuscript and agree to be accountable for the work.

Funding

This study received no specific funding from any public, commercial or not-for-profit organization. All diagnostic and therapeutic procedures formed part of standard multidisciplinary clinical care.

Conflict of interest

The authors declare that there are no financial or non-financial conflicts of interest relevant to this work.

Data availability

All data supporting the findings of this study are included in the article, including its tables and figures. Further information is available from the corresponding author on reasonable request.

Acknowledgements

The authors thank the neurointerventional radiology and ophthalmology teams at Prof. Dr. I.G.N.G. Ngoerah General Hospital, Denpasar, Bali, Indonesia, for their expertise in the care of this patient.

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