Saudi Journal of Medicine and Public Health

https://saudijmph.com/index.php/pub

https://doi.org/10.64483/202522476

Superior Ophthalmic Vein Cannulation in the Management of Carotid-Cavernous Fistula: Nursing Considerations

Nouf Belal Albloushy (1) , Hanan Mohammed Muslim alhwity (2) , Meshal Dughaylib Obead Alharbi (3) , Shouq Yahia Mohammed Solan (4) , Esraa Mohammed Alradady (5) , Taghreed khleef Alenezy (6) , Rajha Hussain Masfer Alshahrani (7) , Awatif Hamoud Alharbi (8) , Hana Otish Al Rowily (9) , Tahani Ahmad AlDrea (10) , Khlood Mousa Hassan Mjamami (4) , Deema Battah Alanazi (11)

(1) Imam Abdulrahman Alfaisal hospital,Ministry of Health, Saudi Arabia,
(2) Tabuk Health Cluster, Emergency and Medical Coordination,Ministry of Health, Saudi Arabia,
(3) Al-Mohammadiyah Health Center,Ministry of Health, Saudi Arabia,
(4) Prince Mohammed Bin Nasser Hospital,Ministry of Health, Saudi Arabia,
(5) Uhud hospital in Madinah,Ministry of Health, Saudi Arabia,
(6) King Hospital returns to Unaizah,Ministry of Health, Saudi Arabia,
(7) Asir health cluster bisha directorate ,Ministry of Health, Saudi Arabia,
(8) Maternity and Children's Hospital ,Ministry of Health, Saudi Arabia,
(9) T.G.h,Ministry of Health, Saudi Arabia,
(10) East primary health care center,Ministry of Health, Saudi Arabia,
(11) Turaif General Hospital,Ministry of Health, Saudi Arabia

Abstract

Background: Carotid–cavernous fistulas (CCFs) are abnormal arteriovenous communications between the carotid arterial system and the cavernous sinus, often resulting in orbital venous congestion, proptosis, chemosis, diplopia, and potential vision loss. While transvenous embolization via the inferior petrosal sinus (IPS) is the standard treatment, anatomical or pathological barriers may render this approach infeasible, necessitating alternative access routes such as superior ophthalmic vein (SOV) cannulation.

Aim: This article aims to describe the role of SOV cannulation in the management of CCFs, with particular emphasis on nursing considerations, procedural indications, technical challenges, multidisciplinary coordination, and patient safety.

Methods: A narrative, practice-focused review was conducted, synthesizing current clinical knowledge on SOV anatomy, indications, contraindications, equipment, procedural techniques, and nursing interventions involved in SOV cannulation for CCFs. Emphasis was placed on peri-procedural nursing care and interprofessional collaboration.

Results: SOV cannulation was identified as a highly effective alternative when standard venous access fails, particularly in indirect dural CCFs with predominant ophthalmic venous drainage. Successful outcomes depend on meticulous anatomical knowledge, advanced imaging guidance, skilled catheterization, and vigilant nursing monitoring to prevent complications such as orbital hemorrhage, infection, or visual deterioration.

Conclusion: SOV cannulation remains a critical, though technically demanding, intervention in selected CCF cases. Nursing expertise and coordinated interprofessional care are vital in optimizing procedural success, minimizing complications, and promoting positive patient outcomes.

Keywords: Superior ophthalmic vein; carotid-cavernous fistula; endovascular embolization; nursing care; interprofessional collaboration

Introduction

The superior ophthalmic vein (SOV) approach for the embolization of carotid-cavernous fistulas (CCFs) has been utilized for over 25 years as a specialized technique in neurovascular intervention. CCFs are abnormal communications between the carotid artery and the cavernous sinus, leading to elevated venous pressure and a spectrum of orbital and ocular symptoms, including proptosis, chemosis, and potential vision loss. CCFs are classified into direct (Barrow type A) and indirect (Barrow types B, C, or D) lesions. Direct lesions result from an endothelial tear in the carotid artery, while indirect lesions involve smaller branches of the internal or external carotid systems. While a subset of CCFs—particularly low-flow indirect lesions—may resolve spontaneously or respond to conservative management such as carotid compression therapy, many lesions progress and require interventional treatment [1][2]. Endovascular approaches have

Saudi Journal of Medicine and Public Health (SJMPH) ISSN 2961-4368
*Corresponding author e-mail: Nfnf1992@gmail.com (Nouf Belal Albloushy).
Receive Date: 04 December 2025, Revise Date: 27 December 2025, Accept Date: 31 December 2025

revolutionized CCF management. Direct lesions are generally amenable to endoarterial treatment, whereas indirect lesions are optimally treated via transvenous embolization, typically accessed through the ipsilateral inferior petrosal sinus (IPS). When conventional venous routes fail due to stenosis, hypoplasia, or tortuosity, SOV cannulation provides an alternative pathway. The SOV connects the facial venous system to the cavernous sinus and serves as a critical drainage route, making it a valuable access point for embolization in anatomically challenging cases. Access to the SOV can be achieved through the facial-angular venous system or, when necessary, via direct surgical cutdown. Though less frequently required today due to advancements in endovascular techniques, direct SOV cannulation remains an essential tool in the neurointerventional arsenal [3][4].

SOV cannulation is indicated particularly in patients with indirect dural CCFs demonstrating predominant ophthalmic venous drainage, or in those with venous thrombosis or anatomical anomalies precluding transfemoral or transjugular access. Urgent intervention via the SOV may also be necessary for patients with severe proptosis and orbital venous congestion to prevent permanent visual impairment. Procedural success relies on detailed knowledge of orbital venous anatomy, as the SOV originates near the medial canthus from the angular vein and courses posteriorly toward the superior orbital fissure. The vein's small caliber, tortuosity, and proximity to critical structures, such as the optic nerve and extraocular muscles, demand precise catheterization guided by advanced imaging modalities, including real-time ultrasound, fluoroscopy, and angiography [5]. The SOV cannulation procedure begins with careful preoperative preparation, which includes sterile field creation, anesthesia administration, and imaging guidance to identify and access the vein. A micropuncture needle is introduced via a medial canthal approach, and a guidewire is advanced into the SOV. Subsequently, a microcatheter is threaded through the SOV into the cavernous sinus under fluoroscopic guidance. Embolization is then performed using coils, liquid embolic agents such as Onyx, or detachable balloons to occlude the fistulous connection. Postprocedural imaging confirms successful closure, and meticulous hemostasis is maintained to prevent venous leakage [6].

Despite its utility, SOV cannulation presents numerous technical challenges. The vein's small diameter, tortuosity, or partial thrombosis can complicate catheter placement. The SOV's fragility increases the risk of rupture, orbital hemorrhage, or inadvertent injury to adjacent structures, including the optic nerve or arterial branches. Incomplete embolization can result in persistent symptoms and may necessitate repeat interventions. Additionally, infection and thrombophlebitis are potential postoperative complications, highlighting the importance of diligent patient monitoring and follow-up [7]. Advances in imaging and catheter technology continue to enhance the safety and efficacy of SOV cannulation. Endoscopic-assisted visualization improves anatomical accuracy, while robotic-assisted navigation offers precision in microcatheter placement. Bioabsorbable embolic agents may reduce long-term complications, and artificial intelligence-assisted imaging analysis enhances procedural planning, particularly in complex anatomical cases. Collectively, these innovations aim to optimize procedural outcomes, minimize complications, and improve patient safety and long-term visual prognosis [8][9][10]. In conclusion, SOV cannulation represents a specialized but critical intervention for managing CCFs when conventional venous access is not feasible. Success relies on comprehensive anatomical knowledge, advanced imaging guidance, precise catheterization, and careful postoperative monitoring. Continued technological innovation promises to refine this technique further, enhancing both safety and efficacy, and solidifying its role in contemporary neurovascular practice.

Anatomy and Physiology

The superior ophthalmic vein (SOV) is a critical component of orbital venous drainage and serves as a key access route in the endovascular management of carotid-cavernous fistulas (CCFs). A thorough understanding of its complex anatomy and physiology is essential for successful cannulation and embolization procedures. The SOV is intimately connected with the cavernous sinus, the orbital venous system, and numerous critical neurovascular structures, making precise localization and catheterization technically demanding [11]. Anatomically, the SOV originates from the angular vein near the medial canthus of the eye and courses posteriorly through the orbit. It functions as the primary venous drainage pathway of the orbit, collecting blood from both anterior and posterior orbital veins before draining into the cavernous sinus via the superior orbital fissure. Key tributaries include the angular vein, central retinal vein, vorticose veins draining the choroid, and the lacrimal and muscular veins, which drain the extraocular muscles and lacrimal gland [12]. The vein's proximity to the optic nerve (CN II), oculomotor nerve (CN III), and branches of the ophthalmic division of the trigeminal nerve (CN V1) increases the risk of iatrogenic injury during surgical or interventional procedures. Its valveless structure permits bidirectional blood flow, which is central to the pathophysiology of CCF, as retrograde flow into the orbit results in venous congestion, proptosis, and chemosis in high-flow fistulas [13].

The SOV is consistently located approximately 6 mm above the superior eyelid sulcus on the nasal side. It can also be identified by tracing the supraorbital vein, which passes through the supraorbital notch when present. The vein courses posteriorly and laterally alongside the ophthalmic artery, which is positioned posterior and lateral to the superior oblique muscle. Along its path, the SOV receives drainage from the ethmoid veins, central retinal vein, muscular veins, and superior vortex veins. It crosses the anterior optic nerve and runs beneath the superior rectus muscle in the superomedial periorbital cone, which can serve as a landmark when the vein is not hypertrophied [2]. Anastomoses with the inferior ophthalmic vein are variable, further adding to anatomical complexity. Physiologically, the SOV maintains orbital venous outflow by linking the anterior facial venous system with the posterior cavernous sinus. Under normal conditions, blood flows from the orbit to the cavernous sinus; however, CCFs produce arteriovenous shunting that reverses this flow. The resulting increased venous pressure manifests as pulsatile proptosis, conjunctival chemosis, and elevated intraocular pressure. Chronic congestion may lead to optic nerve compression, ischemic retinopathy, and secondary glaucoma if untreated [13].

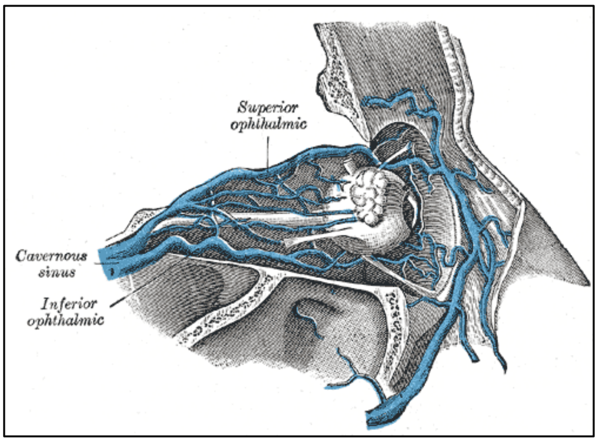

Fig. 1: Superior Ophthalmic Vein, Inferior Ophthalmic Vein, and Cavernous Sinus.

SOV cannulation is indicated when conventional transvenous approaches, such as via the inferior petrosal sinus or transfemoral access, are inaccessible due to thrombosis, stenosis, or anatomical anomalies. Indirect dural CCFs with predominant ophthalmic venous drainage also warrant SOV access. The procedure involves percutaneous medial canthal access guided by ultrasound and fluoroscopy. A micropuncture needle is used to puncture the vein, followed by guidewire and microcatheter insertion, with navigation through the superior orbital fissure into the cavernous sinus for embolization [14]. Challenges in SOV cannulation include small vein diameter, tortuosity, anatomical variability, and fragility. Risks involve venous rupture with orbital hemorrhage, catheter misplacement leading to optic nerve injury or inadvertent arterial puncture, incomplete embolization resulting in residual shunting, and postoperative thrombophlebitis or infection [15]. In conclusion, understanding the detailed anatomy and physiology of the SOV is critical for safe and effective cannulation in the management of CCF. The SOV's role as the primary orbital venous drainage channel and its valveless structure contribute directly to CCF pathophysiology. When conventional venous routes are unavailable, SOV cannulation provides a viable alternative for embolization. Meticulous anatomical knowledge, advanced imaging guidance, and careful procedural technique are essential to minimize complications and ensure procedural success.

Indications

Direct cannulation of the superior ophthalmic vein (SOV) represents a critical option in the endovascular management of indirect carotid-cavernous fistulas (CCFs), particularly when conventional venous access routes are either unavailable or have failed. Indirect CCFs, typically low-flow lesions arising from dural branches of the internal or external carotid arteries, often present with a constellation of orbital and ocular symptoms that indicate the need for intervention. Common clinical manifestations include pulsatile visual disturbances, headache, ocular and orbital pain, diplopia, conjunctival chemosis, proptosis, and the presence of orbital bruits. These signs frequently correlate with congestion of the inferior petrosal sinus (IPS) and retrograde arterialization of the ophthalmic and orbital venous system, highlighting the underlying hemodynamic disturbance caused by the arteriovenous communication [16]. The preferred endovascular approach to indirect CCFs is transvenous access via the IPS. However, anatomical variations or pathological alterations, such as tortuosity, hypoplasia, stenosis, or discontinuity of the IPS with the proximal jugular venous system, may preclude safe catheter navigation. In such scenarios, the SOV provides an alternative route, leveraging its connection between the orbital venous system and the cavernous sinus. Access via the angular and facial veins is commonly attempted initially; however, small vessel caliber, sharp angulations, or stenotic segments can pose technical limitations that prevent successful catheterization. When these obstacles prevent conventional transvenous access, direct SOV cannulation through a medial canthal or surgical cutdown approach becomes a viable and sometimes necessary strategy [16].

The decision to employ direct SOV cannulation is guided by several factors, including the patient's clinical presentation, the severity of ocular and orbital symptoms, the anatomical configuration of the venous system, and the feasibility of alternative access routes. Patients with severe proptosis, vision-threatening venous congestion, or persistent symptoms despite conservative or conventional endovascular management are considered strong candidates for SOV access. Additionally, procedural planning considers the technical complexity of navigating the SOV, the presence of anatomical variations, and the potential risks of iatrogenic injury to surrounding structures, such as the optic nerve, extraocular muscles, or ophthalmic artery. Ultimately, direct SOV cannulation is indicated when anatomical, hemodynamic, or procedural factors render other venous access routes insufficient or unsafe. Its application allows for precise transvenous catheterization of the cavernous sinus and successful embolization of the fistulous communication, thereby alleviating orbital venous hypertension and mitigating the risk of progressive visual and neurological complications. The selection of this technique requires careful multidisciplinary evaluation, meticulous imaging assessment, and skilled interventional execution to optimize clinical outcomes [17].

Failed or Inaccessible Inferior Petrosal Sinus Approach

The inferior petrosal sinus (IPS) is widely recognized as the standard transvenous route for the embolization of carotid-cavernous fistulas (CCFs), serving both direct high-flow and indirect low-flow lesions. The IPS provides a direct venous pathway from the cavernous sinus to the jugular venous system, enabling precise catheter navigation and controlled embolization. However, anatomical variations, pathological changes, or previous interventions may render the IPS inaccessible, necessitating alternative approaches such as direct superior ophthalmic vein (SOV) cannulation [18]. Several anatomical and pathological factors can prevent successful IPS access. Chronic venous congestion may result in thrombosis of the IPS, obstructing catheter passage. Congenital hypoplasia or complete absence of the sinus may further limit the feasibility of traditional transvenous approaches. Additionally, prior surgical procedures or radiation therapy can cause sinus occlusion, fibrosis, or stenosis. Even in the absence of structural abnormalities, tortuosity or mechanical obstruction during attempted catheterization may result in failed access, highlighting the need for a secondary access route [18].

Patients with CCF often present with orbital venous congestion, elevated intraocular pressure (IOP), and associated ocular symptoms such as pulsatile proptosis, chemosis, diplopia, and ocular pain. These manifestations arise from retrograde arterialized flow into the orbital venous system. When conventional approaches fail to alleviate these complications, direct SOV cannulation allows for targeted embolization, reducing venous hypertension, restoring physiological venous drainage, and mitigating vision-threatening sequelae. Indications for this approach include severe pulsatile proptosis with corneal exposure, resistant secondary glaucoma, progressive optic neuropathy from chronic venous stasis, and orbital congestion refractory to medical therapy, including topical beta-blockers or carbonic anhydrase inhibitors [19]. Indirect dural CCFs, commonly seen in older adults or post-trauma, may occasionally resolve spontaneously; however, persistent lesions with cortical venous reflux, non-resolving orbital symptoms, or progressive visual deterioration necessitate intervention. SOV cannulation is indicated when transarterial or transvenous routes fail or are insufficient, allowing precise embolization in dural fistulas that are refractory to conservative measures [20]. Direct high-flow traumatic CCFs also represent an urgent indication for SOV access, particularly in cases of rapid orbital decompensation or acute visual compromise. These lesions, frequently associated with basilar skull fractures or penetrating injuries, can produce severe venous hypertension, optic nerve compression, and hemorrhagic complications. When conventional venous access routes are obstructed, SOV cannulation allows immediate intervention to restore venous outflow and prevent irreversible vision loss [21].

In complex vascular anatomy, SOV cannulation is particularly advantageous. Favorable SOV dilation, underdeveloped IPS, or absent facial venous connections make it the most direct and reliable route for accessing the cavernous sinus. Furthermore, SOV access facilitates controlled embolization in high-risk patients, reducing the potential for non-target occlusion and enhancing procedural safety [22]. Recurrent or residual CCFs following previous embolization may also necessitate SOV cannulation. Residual arterialized flow, incomplete fistula closure, or new-onset orbital symptoms after initial treatment often require repeat intervention. The SOV can serve as a reentry pathway for embolization when traditional transvenous routes have become compromised [23]. Overall, SOV cannulation provides a technically challenging yet highly effective alternative when IPS access is unsuccessful or unsafe. This approach enables direct transvenous access to the cavernous sinus, allowing precise embolization of high-flow direct CCFs, refractory dural fistulas, and severe orbital venous congestion. Successful outcomes depend on meticulous preprocedural planning, advanced imaging guidance, and a multidisciplinary approach involving interventional radiology, neurosurgery, and ophthalmology teams to minimize procedural risks and optimize patient outcomes [23].

Contraindications

Superior ophthalmic vein (SOV) cannulation is a critical endovascular technique for treating carotid-cavernous fistulas (CCFs), particularly when conventional transvenous pathways such as the inferior petrosal sinus (IPS) are inaccessible. While highly effective, the procedure carries significant technical challenges and potential risks. Understanding absolute and relative contraindications is essential to ensure patient safety, optimize outcomes, and avoid complications.

Absolute Contraindications

Absolute contraindications represent situations in which SOV cannulation should not be attempted because the risk of severe adverse events outweighs potential benefits. One such condition is cavernous sinus thrombosis or extensive venous occlusion. In these cases, poor venous outflow prevents successful catheter advancement and increases the likelihood of procedural failure. Attempting cannulation can cause venous rupture, embolization, or worsening orbital congestion. In such scenarios, transarterial embolization or direct cavernous sinus puncture may serve as safer alternatives [11]. Orbital cellulitis or active ocular infection is another absolute contraindication. Active infection increases the risk of septic embolism, orbital abscess, or septic thrombophlebitis spreading to the cavernous sinus. Intervention should be delayed until infection resolution, often requiring broad-spectrum antibiotics and surgical drainage if necessary [11]. Severe proptosis with orbital compartment syndrome also precludes safe SOV cannulation. Overly engorged or tense veins are highly susceptible to rupture, leading to orbital hemorrhage and further compromise of visual function. In these patients, lateral orbitotomy or transarterial embolization may provide safer access [24]. Severe coagulopathy or ongoing anticoagulation therapy represents another absolute risk factor. Hemostatic abnormalities, including thrombocytopenia or anticoagulant use (e.g., warfarin, heparin, or direct oral anticoagulants), significantly elevate bleeding risk. Uncontrolled hemorrhage may lead to retrobulbar hematoma and sight-threatening orbital compartment syndrome. Optimization of coagulation parameters or alternative vascular approaches is necessary prior to intervention [25]. Acute ischemic stroke or intracranial hemorrhage constitutes a further absolute contraindication. Manipulation within the orbital venous system under anticoagulation could exacerbate intracranial pathology, precipitating secondary hemorrhagic transformation or rebleeding. Intervention should be deferred until stabilization of the acute event [26].

Relative Contraindications

Relative contraindications are conditions where SOV cannulation remains technically feasible but requires careful assessment of risks and benefits. Hypoplastic or absent SOV may make catheterization extremely difficult, increasing the likelihood of procedural failure or vessel injury. Preprocedural imaging, such as Doppler ultrasonography, can aid in evaluating vein suitability. Alternative access routes, including the facial or angular veins, may be considered [27]. Previous orbital surgery or trauma can result in fibrosis, scarring, or distorted anatomy. These changes complicate catheter navigation and increase the risk of arterial puncture or iatrogenic injury to orbital structures. Cross-sectional imaging (CT or MRI) is recommended for procedural planning [28]. Unstable cardiopulmonary status, including severe heart failure, pulmonary hypertension, or arrhythmias, increases the risk of intraoperative instability during sedation or anesthesia. Optimization of cardiopulmonary function is required before attempting SOV cannulation [29]. Advanced glaucoma with significant optic nerve damage is also a relative contraindication. Even transient venous congestion may worsen optic neuropathy, accelerating vision loss. Monitoring of intraocular pressure and consideration of alternative approaches is essential [30]. Inadequate imaging or poor patient cooperation can further complicate cannulation, leading to procedural failure or iatrogenic injury. Sedation, improved imaging modalities, or alternative transarterial access may be necessary in such cases [31].

Precautionary Considerations

Preprocedural planning is essential even in borderline cases. Imaging to assess orbital venous drainage patterns, use of real-time fluoroscopy or ultrasound guidance, and readiness for hemostasis management are critical. Contingency planning, including alternative access routes such as direct cavernous sinus puncture or transarterial embolization, should be established before the procedure. SOV cannulation is a technically demanding yet invaluable procedure for CCF management. Absolute contraindications, such as cavernous sinus thrombosis, orbital cellulitis, severe coagulopathy, and orbital compartment syndrome, render the procedure too high-risk. Relative contraindications—including small or absent SOV, prior orbital surgery, unstable cardiopulmonary status, advanced glaucoma, or inadequate imaging—require individualized risk-benefit assessment. Careful patient selection, thorough preprocedural imaging, and contingency planning are essential to optimize safety and outcomes in this high-stakes intervention [27].

Equipment

Superior ophthalmic vein (SOV) cannulation for carotid-cavernous fistulas (CCFs) is a technically demanding procedure requiring specialized equipment to ensure precision, safety, and efficacy. The procedure is typically performed in a fully equipped endovascular suite, with anesthesia support and imaging guidance. Proper orbital exposure and microsurgical instrumentation are essential for safe venous access and manipulation. Adequate orbital exposure is achieved using a combination of retractors, forceps, and cautery devices. Standard microsurgical instruments include Sewell retractors and ribbon retractors for gentle tissue separation, long bayonet forceps for deep orbital access, and bipolar cautery forceps to control bleeding. Neurosurgical cottonoids are used to protect orbital fat and isolate the SOV, while muscle hooks allow careful manipulation of the vein. Ligation bands or sutures facilitate temporary control of the vessel. An experienced surgical assistant is critical, as radiology equipment can limit the surgeon's mobility during the procedure [11][27]. Real-time imaging is central to safe and accurate SOV cannulation. Digital subtraction angiography (DSA) provides high-resolution visualization of venous anatomy and fistula characteristics. Fluoroscopy with road-mapping enables continuous catheter tracking during navigation. High-frequency ultrasound probes (7–15 MHz) allow identification of the SOV in situations where fluoroscopy alone is insufficient. Optional imaging enhancements include 3D rotational angiography, which improves visualization of the cavernous sinus and venous variations, and microscopes or surgical loupes for magnified percutaneous access [32].

Cannulation requires precision tools to minimize vessel trauma. A micro-access kit (21–22G needle) is used for initial venous puncture, followed by a micropuncture introducer sheath (4F–5F, short-length) to stabilize access. Hydrophilic-coated guidewires (0.014–0.018 in) allow smooth catheter advancement, and angled or straight microcatheters (1.5–2.8 F, 110–150 cm) are used to deliver embolic agents accurately into the cavernous sinus [33]. After securing SOV access, embolization is performed using coils, liquid embolic agents, particulate embolics, or balloon-assisted techniques. Detachable or pushable coils (3–6 mm) provide gradual occlusion of the fistula. Liquid embolics, such as N-butyl cyanoacrylate (nBCA), Onyx, or Squid, enable permanent closure of high-flow lesions. Particulate embolics (polyvinyl alcohol, Gelfoam®, microspheres) are occasionally used for temporary flow reduction, while dual-lumen balloon catheters may assist in controlled delivery [34]. Due to the fragile orbital and cavernous venous anatomy, measures to control bleeding are essential. Hemostatic agents such as fibrin sealant, Surgicel®, or Gelfoam® help manage minor bleeding. Orbital compression devices prevent venous congestion or retrobulbar hematoma. Reversal agents such as protamine or tranexamic acid address unexpected anticoagulation-related bleeding. Emergency microsurgical instruments, including an orbital decompression set, are maintained on standby to address hemorrhage or vessel rupture [35].

Anesthesia and Patient Monitoring Equipment

Sedation and continuous monitoring are vital for procedural safety. Sedation infusions (dexmedetomidine, propofol, or midazolam) provide patient comfort while permitting cooperation. Intraoperative neuromonitoring evaluates optic nerve and ocular function, and standard noninvasive blood pressure and oxygen monitoring maintain stable hemodynamics throughout the procedure. SOV cannulation for CCF treatment requires integration of advanced imaging, precise vascular instrumentation, and appropriate embolization materials. Microsurgical tools, real-time fluoroscopy and ultrasound, microcatheters, embolic agents, and hemostasis equipment collectively ensure procedural success and minimize complications. The complexity of the orbit and cavernous sinus necessitates meticulous preparation, highly skilled personnel, and careful intraoperative monitoring to achieve optimal patient outcomes [36].

Personnel

SOV cannulation for CCF is a highly specialized, high-stakes procedure that requires a multidisciplinary team with expertise in neurointervention, orbital surgery, anesthesia, and critical care. Each team member plays a vital role in patient assessment, procedural execution, and postprocedure management, ensuring both safety and treatment efficacy. The interventional neuroradiologist serves as the primary operator, performing cannulation and embolization. Responsibilities include using digital subtraction angiography (DSA) and fluoroscopy for real-time visualization, selecting the optimal access route based on venous anatomy and fistula complexity, and delivering embolic agents precisely to achieve complete fistula closure [11]. Neuro-ophthalmologists and oculoplastic surgeons provide expertise in orbital anatomy and microsurgical technique. They assist with SOV localization, orbital exposure, and vessel manipulation when a surgical approach is required. Additionally, they evaluate ocular complications, venous congestion, and orbital stasis both before and after the procedure to optimize visual outcomes [37]. These specialists support procedural planning and decision-making, particularly for high- and low-flow CCFs. They provide backup for alternative access routes and manage postoperative neurological complications, including cranial nerve deficits [38]. Anesthesiology staff maintain hemodynamic stability, administer conscious sedation or general anesthesia, monitor airway and vital signs, and ensure patient comfort throughout the procedure [39]. Nurses prepare the patient, maintain sterile technique, administer medications, monitor vitals, and provide postprocedural care instructions. They also support emergency readiness during the procedure [40]. These personnel organize and maintain instruments, microcatheters, guidewires, and embolic materials. They preserve sterility and ensure seamless workflow during cannulation [41]. Imaging specialists optimize fluoroscopy and DSA settings, assist with 3D guidance and road-mapping, and troubleshoot imaging equipment to prevent procedural delays or errors [42]. Critical care specialists, vascular surgeons, and backup interventionalists are prepared to manage complications such as orbital hemorrhage, venous rupture, retrobulbar hematoma, or thromboembolism. SOV cannulation requires coordinated teamwork across multiple specialties. Collaborative expertise ensures precise access, safe embolization, and optimal outcomes in this complex and potentially vision-threatening procedure [27].

Preparation

Digital subtraction angiography (DSA) remains the definitive modality for both the diagnosis and initial therapeutic planning of carotid-cavernous fistulas (CCFs). Complementary imaging techniques, including computed tomography (CT), CT angiography, and magnetic resonance imaging (MRI), serve as adjuncts when diagnostic uncertainty exists or when alternative etiologies such as neoplasms, posterior communicating artery aneurysms, or orbital infections must be excluded. A comprehensive evaluation encompassing patient history and focused physical examination is conducted immediately prior to the procedure to ascertain the appropriateness and urgency of intervention [43]. The preparation phase extends beyond imaging to include thorough patient assessment, procedural strategizing, equipment organization, and interprofessional team coordination [44]. Patient selection begins with a meticulous clinical assessment of orbital and neurological manifestations. Symptoms such as proptosis, conjunctival chemosis, orbital bruit, and elevated intraocular pressure (IOP) are critically evaluated to determine the need for immediate intervention. Additionally, systemic comorbidities, including coagulopathies, uncontrolled hypertension, diabetes mellitus, and underlying cardiovascular disease, must be considered to mitigate perioperative risk and optimize patient safety [19].

Preprocedural imaging serves multiple functions. DSA provides definitive characterization of the CCF, including flow dynamics and fistula type, guiding the endovascular approach. MRI and MR angiography delineate soft tissue involvement, orbital venous drainage patterns, and secondary complications, while CT angiography offers precise mapping of the superior ophthalmic vein (SOV) and its anatomical variations. Ultrasonography, including B-scan and Doppler assessment, aids in evaluating venous distension, thrombotic risk, and identifying optimal cannulation sites [22]. Anesthesia planning is tailored to the patient and procedural complexity. SOV cannulation may be performed under local anesthesia with conscious sedation or general anesthesia, depending on patient tolerance and anatomical considerations. Intravenous agents such as midazolam, fentanyl, or propofol are commonly used to ensure comfort and compliance, while local infiltration with lidocaine and epinephrine provides effective periorbital analgesia [39]. Anticoagulation and hemostatic status must be carefully reviewed. Patients on warfarin, direct oral anticoagulants, or antiplatelet therapy require individualized adjustments. Intraprocedural anticoagulation with heparin may be indicated to prevent catheter-related thrombosis. Preprocedural laboratory assessments, including complete blood count, prothrombin time/international normalized ratio, and activated partial thromboplastin time, are essential to evaluate coagulation status and ensure procedural readiness [45].

The surgical and endovascular setup emphasizes asepsis and precision. Sterile preparation of the periorbital region and meticulous draping are crucial. Microsurgical instruments, microcatheters, guidewires, fluoroscopy-compatible contrast agents, and embolic materials such as detachable coils, Onyx, or N-butyl cyanoacrylate (nBCA) must be prearranged for efficient workflow and rapid deployment during the intervention [46]. Interprofessional coordination ensures procedural efficacy. The interventional radiologist or neurosurgeon leads the cannulation and embolization, supported by neuro-ophthalmologists or oculoplastic surgeons who provide anatomical guidance and assist with orbital manipulation. Anesthesiology staff manage sedation, airway, and hemodynamics, while scrub nurses and radiology technicians maintain instrument readiness and sterile technique [47]. Emergency preparedness is critical, with protocols established to address potential complications including venous rupture, orbital hematoma, retinal ischemia from embolic reflux, and acute IOP elevation. Resuscitation equipment, anticoagulation reversal agents, and surgical backup must be immediately available [48]. Comprehensive preparation encompassing patient assessment, imaging evaluation, anesthesia strategy, equipment readiness, and coordinated team effort is indispensable for the safe and effective execution of SOV cannulation for CCF. Such meticulous planning minimizes procedural risks and enhances the likelihood of successful therapeutic outcomes.

Technique or Treatment

Superior ophthalmic vein (SOV) cannulation represents a critical intervention for managing carotid-cavernous fistulas (CCFs), particularly when conventional transfemoral or transarterial approaches are inaccessible or unsuccessful. This highly specialized endovascular technique enables direct access to the cavernous sinus via the orbit, allowing precise embolization and effective closure of the fistulous communication [27]. Prior to the procedure, informed consent is obtained, emphasizing potential risks and benefits. The angiography suite is fully equipped, and a femoral sheath is placed using standard angiographic protocols. The surgical field is prepared to include the periorbital region, encompassing the eye, eyebrow, forehead, and cheek to maintain strict asepsis [27]. Preoperative planning involves careful patient selection, imaging, anesthesia, and positioning. SOV cannulation is indicated for high-flow direct CCFs or low-flow indirect fistulas where standard venous access is unfeasible. Detailed imaging with digital subtraction angiography (DSA), computed tomography (CT) angiography, and magnetic resonance angiography (MRA) provides essential information on the anatomy of the SOV, vascular architecture, and fistula location. General anesthesia is typically employed to achieve patient immobilization, and supine positioning with slight head extension optimizes orbital access [49]. Surgical exposure begins with a small medial upper eyelid crease incision or a sub-brow approach. Blunt dissection through the orbicularis oculi muscle is performed while achieving meticulous hemostasis. Various techniques, including transcutaneous and transconjunctival approaches, facilitate access to the SOV, often augmented by Doppler ultrasound or fluoroscopic guidance when localization is difficult [14,50]. The orbital septum is opened, and the medial retroseptal fat pad is dissected to trace arterialized feeders to the main SOV trunk. In select cases, osteotomy or additional brow incisions may be used, though these are generally unnecessary when anatomical knowledge and exposure are adequate [2].

Once exposed, the SOV is isolated, freed from surrounding tissues, and encircled with silk sutures or rubber loops to maintain tension. Venous access is achieved with a micropuncture needle, and a microcatheter is advanced under fluoroscopic guidance toward the cavernous sinus. Confirmation of proper catheter placement is obtained via contrast injection [11]. Embolization is performed using detachable coils, liquid embolic agents such as Onyx or nBCA, or balloon-assisted techniques in select cases. Preservation of at least one ophthalmic vein is recommended to prevent acute increases in intraocular pressure. Post-embolization angiography confirms fistula closure before catheter withdrawal, and the SOV is ligated distal to the insertion site or closed primarily if the vein is robust. The orbit is irrigated with antibiotics to reduce infection risk [4]. Postprocedural care includes meticulous hemostasis, incision closure with absorbable sutures, and monitoring for complications such as orbital hematoma, venous thrombosis, or cranial nerve injury. Follow-up angiography at one and six months assesses fistula obliteration, while ophthalmologic evaluations monitor visual recovery and orbital function [52]. Functional outcomes typically demonstrate improvement in proptosis, diplopia, and visual acuity. SOV cannulation is technically demanding but offers a highly effective alternative when conventional endovascular routes fail. Success relies on precise surgical exposure, controlled catheter navigation, and targeted embolization, supported by a multidisciplinary team integrating interventional neuroradiology, ophthalmology, and neurosurgery to optimize patient outcomes [53].

Nursing, Allied Health, and Interprofessional Team Interventions

Superior ophthalmic vein (SOV) cannulation for carotid-cavernous fistula (CCF) management requires a highly coordinated, multidisciplinary approach. Successful outcomes depend on seamless collaboration among nurses, anesthesiologists, interventional radiologists, ophthalmologists, neurosurgeons, and allied health professionals. This collaboration ensures procedural precision, enhances patient safety, and facilitates optimal recovery [54]. Preprocedural interventions focus on patient readiness and risk mitigation. Nurses play a central role in educating patients about the procedure, obtaining informed consent, and providing psychological support to reduce anxiety. Imaging specialists perform essential preprocedural studies, including CT angiography, MR angiography, and digital subtraction angiography, which inform procedural planning and delineate the anatomy of the SOV and cavernous sinus. The anesthesia team evaluates patient comorbidities, airway management needs, and sedation requirements to ensure both safety and comfort. Laboratory personnel assess coagulation profiles, renal function, and medication interactions, enabling individualized risk assessment and preparation [54]. During the procedure, intraprocedural interventions maintain stability, optimize technique, and prevent complications. Anesthesiologists monitor sedation, airway patency, and hemodynamics, minimizing physiological fluctuations that could compromise venous access. Nurses and radiology technologists assist with patient positioning, maintenance of the sterile field, and management of the microcatheter system under fluoroscopic guidance. Radiology personnel provide real-time imaging support, guiding catheter placement, facilitating safe embolic agent deployment, and confirming correct positioning within the SOV and cavernous sinus [55]. Vigilant monitoring of intraocular pressure, orbital swelling, and neurological status allows early detection of complications, including orbital compartment syndrome. Preprocedural prophylaxis with antihistamines or corticosteroids helps prevent contrast reactions, and emergency medications are prepared for immediate intervention [55].

Postprocedural interventions prioritize recovery, complication prevention, and patient education. Ongoing neurological assessment ensures early detection of cranial nerve dysfunction, venous congestion, or ophthalmoplegia. Pain management strategies must balance adequate analgesia with anticoagulation considerations to minimize thrombotic risk. Nurses provide instruction on activity restrictions, signs of complications, and the importance of follow-up imaging. Allied health professionals coordinate postprocedural appointments for neuro-ophthalmologic evaluations, imaging studies, and rehabilitation therapies when necessary. Nursing staff reinforce medication adherence and facilitate multidisciplinary follow-up to ensure fistula resolution and reduce the likelihood of recurrence [56]. The successful execution of SOV cannulation is contingent on a cohesive, interprofessional healthcare team. The integration of expertise from nursing, anesthesiology, interventional radiology, ophthalmology, and allied health disciplines ensures procedural safety, optimizes technical precision, and supports comprehensive postoperative care. Vigilant monitoring, timely intervention, and patient-centered guidance throughout the perioperative period significantly enhance clinical outcomes and enable a safe recovery for patients undergoing this complex and specialized neurovascular intervention [57].

Conclusion:

Superior ophthalmic vein cannulation represents a specialized yet indispensable option in the management of carotid–cavernous fistulas when conventional transvenous routes are inaccessible. Its effectiveness lies in providing direct access to the cavernous sinus, allowing targeted embolization and rapid reduction of orbital venous hypertension. However, the procedure's technical complexity and proximity to critical orbital structures demand meticulous preparation, advanced imaging guidance, and strict adherence to safety protocols. Nurses play a pivotal role throughout the peri-procedural continuum, including patient education, sterile preparation, intraoperative monitoring, and postprocedural neurological and ophthalmic assessment. Early detection of complications such as orbital hematoma, increased intraocular pressure, or cranial nerve dysfunction significantly improves clinical outcomes. Ultimately, successful SOV cannulation relies on a coordinated interprofessional approach integrating nursing, interventional radiology, ophthalmology, anesthesia, and allied health expertise. Such collaboration ensures patient safety, preserves visual function, and enhances recovery in this high-risk neurovascular intervention.

References:

1. Teng MM, Guo WY, Huang CI, Wu CC, Chang T. Occlusion of arteriovenous malformations of the cavernous sinus via the superior ophthalmic vein. AJNR. American journal of neuroradiology. 1988 May-Jun:9(3):539-46
2. Wolfe SQ, Cumberbatch NM, Aziz-Sultan MA, Tummala R, Morcos JJ. Operative approach via the superior ophthalmic vein for the endovascular treatment of carotid cavernous fistulas that fail traditional endovascular access. Neurosurgery. 2010 Jun:66(6 Suppl Operative):293-9; discussion 299. doi: 10.1227/01.NEU.0000369705.91485.38.
3. Lucas Cde P, Mounayer C, Spelle L, Piotin M, Rezende MT, Moret J. Endoarterial management of dural arteriovenous malformations with isolated sinus using Onyx-18: technical case report. Neurosurgery. 2007 Nov:61(5 Suppl 2):E293-4; discussion E294. doi: 10.1227/01.neu.0000303981.34622.39.
4. Han M, Chen T, Ediriwickrema L. Intra-operative visualization of the superior ophthalmic vein in carotid-cavernous fistula. Orbit (Amsterdam, Netherlands). 2025 Feb 12:():1. doi: 10.1080/01676830.2025.2460168.
5. Liang B, Moskalik AD, Taylor MN, Waldau B. Transvenous embolization of a carotid-cavernous fistula via the inferior ophthalmic vein: illustrative case. Journal of neurosurgery. Case lessons. 2024 Aug 12:8(7):. pii: CASE24183. doi: 10.3171/CASE24183.
6. Brunasso L, Casamassima N, Abrignani S, Sturiale CL, Incandela F, Giammalva GR, Iacopino DG, Maugeri R, Craparo G. Flow diversion for indirect carotid-cavernous fistula: Still an off-label indication? Surgical neurology international. 2023:14():65. doi: 10.25259/SNI_1113_2022.
7. Catapano JS, Srinivasan VM, De La Peña NM, Singh R, Cole TS, Wilkinson DA, Baranoski JF, Rutledge C, Pacult MA, Winkler EA, Jadhav AP, Ducruet AF, Albuquerque FC. Direct puncture of the superior ophthalmic vein for carotid cavernous fistulas: a 21-year experience. Journal of neurointerventional surgery. 2023 Oct:15(10):948-952. doi: 10.1136/jnis-2022-019135.
8. Steeg K, Krombach GA, Friebe MH. A Review of Needle Navigation Technologies in Minimally Invasive Cardiovascular Surgeries-Toward a More Effective and Easy-to-Apply Process. Diagnostics (Basel, Switzerland). 2025 Jan 16:15(2):. doi: 10.3390/diagnostics15020197.
9. Vladimir B, Ivan V, Zarko N, Aleksandra N, Mihailo M, Nemanja J, Marina M, Aleksandar S, Vuk S, Danica G. Transorbital hybrid approach for endovascular occlusion of indirect carotid-cavernous fistulas-Case report and systematic literature review. Radiology case reports. 2022 Sep:17(9):3312-3317. doi: 10.1016/j.radcr.2022.06.043.
10. Trennheuser S, Reith W, Kühn JP, Morris LGT, Bozzato A, Naumann A, Schick B, Yilmaz U, Linxweiler M. Transorbital embolization of cavernous sinus dural arterio-venous malformations with surgical exposure and catheterization of the superior ophthalmic vein. Interventional neuroradiology : journal of peritherapeutic neuroradiology, surgical procedures and related neurosciences. 2023 Dec:29(6):715-724. doi: 10.1177/15910199221110967.

11. Chalouhi N, Dumont AS, Tjoumakaris S, Gonzalez LF, Bilyk JR, Randazzo C, Hasan D, Dalyai RT, Rosenwasser R, Jabbour P. The superior ophthalmic vein approach for the treatment of carotid-cavernous fistulas: a novel technique using Onyx. Neurosurgical focus. 2012 May:32(5):E13. doi: 10.3171/2012.1.FOCUS123.
12. Reis CV, Gonzalez FL, Zabramski JM, Hassan A, Deshmukh P, Albuquerque FC, Preul MC. Anatomy of the superior ophthalmic vein approach for direct endovascular access to vascular lesions of the orbit and cavernous sinus. Neurosurgery. 2009 May:64(5 Suppl 2):318-23; discussion 323. doi: 10.1227/01.NEU.0000340781.34122.A2.
13. de Keizer R. Carotid-cavernous and orbital arteriovenous fistulas: ocular features, diagnostic and hemodynamic considerations in relation to visual impairment and morbidity. Orbit (Amsterdam, Netherlands). 2003 Jun:22(2):121-42
14. Brunozzi D, Alaraj A. Operative Nuances of Blind Catheterization of Occluded Sinuses Using Negative Road Map Technique: 2-Dimensional Operative Video. Operative neurosurgery (Hagerstown, Md.). 2020 Nov 16:19(6):E599. doi: 10.1093/ons/opaa222.
15. Rodriguez-Calero MA, de Pedro-Gomez JE, Molero-Ballester LJ, Fernandez-Fernandez I, Matamalas-Massanet C, Moreno-Mejias L, Blanco-Mavillard I, Moya-Suarez AB, Personat-Labrador C, Morales-Asencio JM. Risk Factors for Difficult Peripheral Intravenous Cannulation. The PIVV2 Multicentre Case-Control Study. Journal of clinical medicine. 2020 Mar 15:9(3):. doi: 10.3390/jcm9030799.
16. Miller NR, Monsein LH, Debrun GM, Tamargo RJ, Nauta HJ. Treatment of carotid-cavernous sinus fistulas using a superior ophthalmic vein approach. Journal of neurosurgery. 1995 Nov:83(5):838-42
17. Cappuzzo JM, Baig AA, Metcalf-Doetsch W, Waqas M, Monteiro A, Levy EI. First reported single-surgeon transpalpebral hybrid approach for indirect cavernous carotid fistula: illustrative case. Journal of neurosurgery. Case lessons. 2022 Jun 20:3(25):CASE22115. doi: 10.3171/CASE22115.
18. Hirata K, Tsuda K, Fujita K, Ishikawa E, Matsumaru Y. Transvenous Embolization for Isolated Superior Petrosal Sinus Dural Arteriovenous Fistula. NMC case report journal. 2024:11():7-11. doi: 10.2176/jns-nmc.2023-0224.
19. Al-Shalchy A, Al-Wassiti AS, Hashim MA, Al-Khazaali YM, Talib SH, Bani-Saad AA, Al-Taie RH, Ismail M. Neuro-Ophthalmic Manifestations of Carotid Cavernous Fistulas: A Systematic Review and Meta-Analysis. Cureus. 2024 Jul:16(7):e65821. doi: 10.7759/cureus.65821.
20. Henderson AD, Miller NR. Carotid-cavernous fistula: current concepts in aetiology, investigation, and management. Eye (London, England). 2018 Feb:32(2):164-172. doi: 10.1038/eye.2017.240.
21. Loggini A, Kass-Hout T, Awad IA, El Ammar F, Kramer CL, Goldenberg FD, Lazaridis C, Mansour A. Case Report: Management of Traumatic Carotid-Cavernous Fistulas in the Acute Setting of Penetrating Brain Injury. Frontiers in neurology. 2021:12():715955. doi: 10.3389/fneur.2021.715955.
22. Korkmazer B, Kocak B, Tureci E, Islak C, Kocer N, Kizilkilic O. Endovascular treatment of carotid cavernous sinus fistula: A systematic review. World journal of radiology. 2013 Apr 28:5(4):143-55. doi: 10.4329/wjr.v5.i4.143.
23. Pasquariello JL, Hariman RJ, Yudelman IM, Feit A, Gomes JA, El-Sherif N. Recurrent pulmonary embolization following implantation of transvenous pacemaker. Pacing and clinical electrophysiology : PACE. 1984 Sep:7(5):790
24. Murali S, Davis C, McCrea MJ, Plewa MC. Orbital compartment syndrome: Pearls and pitfalls for the emergency physician. Journal of the American College of Emergency Physicians open. 2021 Apr:2(2):e12372. doi: 10.1002/emp2.12372.
25. Gunasekaran K, Rajasurya V, Devasahayam J, Singh Rahi M, Chandran A, Elango K, Talari G. A Review of the Incidence Diagnosis and Treatment of Spontaneous Hemorrhage in Patients Treated with Direct Oral Anticoagulants. Journal of clinical medicine. 2020 Sep 15:9(9):. doi: 10.3390/jcm9092984.
26. Hong JM, Kim DS, Kim M. Hemorrhagic Transformation After Ischemic Stroke: Mechanisms and Management. Frontiers in neurology. 2021:12():703258. doi: 10.3389/fneur.2021.703258.
27. Park J. Superior ophthalmic approach in carotid-cavernous fistula: current concepts in indications, surgical techniques, and case reviews. Journal of cerebrovascular and endovascular neurosurgery. 2023 Sep:25(3):245-252. doi: 10.7461/jcen.2023.E2022.10.005.
28. Bernardini FP, Kersten RC, Devoto MH, Morton AD, Johnson TE. Outcomes after surgical excision of large and massive orbital tumors. Ophthalmic plastic and reconstructive surgery. 2008 Jul-Aug:24(4):280-3. doi: 10.1097/IOP.0b013e318177f12c
29. Anand S, Cronin EM. Arrhythmias in Patients with Pulmonary Hypertension and Right Ventricular Failure: Importance of Rhythm Control Strategies. Journal of clinical medicine. 2024 Mar 24:13(7):. doi: 10.3390/jcm13071866.

30. Weber AJ, Harman CD, Viswanathan S. Effects of optic nerve injury, glaucoma, and neuroprotection on the survival, structure, and function of ganglion cells in the mammalian retina. The Journal of physiology. 2008 Sep 15:586(18):4393-400. doi: 10.1113/jphysiol.2008.156729.
31. Heran MKS, Volders D, Haw C, Shewchuk JR. Imaging-Guided Superior Ophthalmic Vein Access for Embolization of Dural Carotid Cavernous Fistulas: Report of 20 Cases and Review of the Literature. AJNR. American journal of neuroradiology. 2019 Apr:40(4):699-702. doi: 10.3174/ajnr.A5994.
32. Modic MT, Berlin AJ, Weinstein MA. The use of digital subtraction angiography in the evaluation of carotid cavernous sinus fistulas. Ophthalmology. 1982 May:89(5):441-4
33. Winslow MN, Trammell L, Camp-Sorrell D. Selection of vascular access devices and nursing care. Seminars in oncology nursing. 1995 Aug:11(3):167-73
34. Plasencia AR, Santillan A. Endovascular embolization of carotid-cavernous fistulas: A pioneering experience in Peru. Surgical neurology international. 2012:3():5. doi: 10.4103/2152-7806.92167.
35. Krayenbühl N, Hafez A, Hernesniemi JA, Krisht AF. Taming the cavernous sinus: technique of hemostasis using fibrin glue. Neurosurgery. 2007 Sep:61(3 Suppl):E52; discussion E52
36. Bidkar PU, Dey A, Chatterjee P, Ramadurai R, Joy JJ. Target-controlled infusion - Past, present, and future. Journal of anaesthesiology, clinical pharmacology. 2024 Jul-Sep:40(3):371-380. doi: 10.4103/joacp.joacp_64_23.
37. Maroon JC. Perspective on Importance of Orbital Surgery. Journal of neurological surgery. Part B, Skull base. 2020 Aug:81(4):317-318. doi: 10.1055/s-0040-1713770.
38. Kirmani JF, Janjua N, Al Kawi A, Ahmed S, Khatri I, Ebrahimi A, Divani AA, Qureshi AI. Therapeutic advances in interventional neurology. NeuroRx : the journal of the American Society for Experimental NeuroTherapeutics. 2005 Apr:2(2):304-23
39. Viazis N, Vlachogiannakos J, Apostolopoulos P, Mimidis K, Tzouvala M, Tsionis T, Goulas S, Thomopoulos K, Paraskeva K, Paspatis G, Kofokotsios A, Liatsos C, Manolakis A, Christodoulou D, Rokkas T, Michopoulos S, Papatheodoridis G, Tassios P, Mantzaris G. Sedation during endoscopic procedures: a Hellenic Society of Gastroenterology Position Statement. Annals of gastroenterology. 2023 May-Jun:36(3):231-243. doi: 10.20524/aog.2023.0789.
40. Taslakian B, Sridhar D. Post-procedural Care in Interventional Radiology: What Every Interventional Radiologist Should Know-Part II: Catheter Care and Management of Common Systemic Post-procedural Complications. Cardiovascular and interventional radiology. 2017 Sep:40(9):1304-1320. doi: 10.1007/s00270-017-1709-y.
41. Sharei H, Alderliesten T, van den Dobbelsteen JJ, Dankelman J. Navigation of guidewires and catheters in the body during intervention procedures: a review of computer-based models. Journal of medical imaging (Bellingham, Wash.). 2018 Jan:5(1):010902. doi: 10.1117/1.JMI.5.1.010902.
42. Christoph M, Wunderlich C, Moebius S, Forkmann M, Sitzy J, Salmas J, Mayer J, Huo Y, Piorkowski C, Gaspar T. Fluoroscopy integrated 3D mapping significantly reduces radiation exposure during ablation for a wide spectrum of cardiac arrhythmias. Europace : European pacing, arrhythmias, and cardiac electrophysiology : journal of the working groups on cardiac pacing, arrhythmias, and cardiac cellular electrophysiology of the European Society of Cardiology. 2015 Jun:17(6):928-37. doi: 10.1093/europace/euu334.
43. Catapano JS, Lang MJ, Koester SW, Wang DJ, DiDomenico JD, Fredrickson VL, Cole TS, Lee J, Lawton MT, Ducruet AF, Albuquerque FC. Digital subtraction cerebral angiography after negative computed tomography angiography findings in non-traumatic subarachnoid hemorrhage. Journal of neurointerventional surgery. 2020 May:12(5):526-530. doi: 10.1136/neurintsurg-2019-015375.
44. Brzozowski K, Narloch J, Zięcina P, Podgórski A, Piasecki P. Superior ophthalmic vein and ophthalmic artery in immediate evaluation after endovascular treatment of carotid-cavernous fistulas. Polish journal of radiology. 2019:84():e32-e40. doi: 10.5114/pjr.2019.82807.
45. Lucà F, Oliva F, Abrignani MG, Di Fusco SA, Parrini I, Canale ML, Giubilato S, Cornara S, Nesti M, Rao CM, Pozzi A, Binaghi G, Maloberti A, Ceravolo R, Bisceglia I, Rossini R, Temporelli PL, Amico AF, Calvanese R, Gelsomino S, Riccio C, Grimaldi M, Colivicchi F, Gulizia MM. Management of Patients Treated with Direct Oral Anticoagulants in Clinical Practice and Challenging Scenarios. Journal of clinical medicine. 2023 Sep 13:12(18):. doi: 10.3390/jcm12185955.
46. Newton J. Assisting during microsurgery: tips for success. Community eye health. 2023:36(120):6-7
47. Daigle P, Brenna CTA, da Costa L, Yang V, Gill HS. Gaining Access to the Superior Ophthalmic Vein for Endovascular Embolization of Indirect Carotid-Cavernous Fistulas. The Journal of

craniofacial surgery. 2021 Jun 1:32(4):e337-e340. doi: 10.1097/SCS.0000000000007131.
48. Baharvahdat H, Blanc R, Termechi R, Pistocchi S, Bartolini B, Redjem H, Piotin M. Hemorrhagic complications after endovascular treatment of cerebral arteriovenous malformations. AJNR. American journal of neuroradiology. 2014 May:35(5):978-83. doi: 10.3174/ajnr.A3906.
49. Duangprasert G, Thitiwichienlert S, Tantongtip D. Operative Cannulation of the Superior Ophthalmic Vein for Embolization of Cavernous Sinus Dural Arteriovenous Fistulas: Surgical Techniques and Clinical Outcomes. World neurosurgery. 2022 Sep:165():e412-e422. doi: 10.1016/j.wneu.2022.06.076.
50. Kalsi P, Padmanabhan R, Prasad K S M, Mukerji N. Treatment of low flow, indirect cavernous sinus dural arteriovenous fistulas with external manual carotid compression - the UK experience. British journal of neurosurgery. 2020 Dec:34(6):701-703. doi: 10.1080/02688697.2020.1716947.
51. Amir MM, Bugvi NA. Caroticocavernous Fistula: Successful Reversal by Endovascular Treatment. Journal of the College of Physicians and Surgeons--Pakistan : JCPSP. 2018 Mar:28(3):S54-S55. doi: 10.29271/jcpsp.2018.03.S54.
52. Tobisch A, Stelzner S, Hellmich G, Jackisch T, Witzigmann H. Total fistulectomy with simple closure of the internal opening in the management of complex cryptoglandular fistulas: long-term results and functional outcome. Diseases of the colon and rectum. 2012 Jul:55(7):750-5. doi: 10.1097/DCR.0b013e3182569b29.
53. Ambekar S, Gaynor BG, Peterson EC, Elhammady MS. Long-term angiographic results of endovascularly "cured" intracranial dural arteriovenous fistulas. Journal of neurosurgery. 2016 Apr:124(4):1123-7. doi: 10.3171/2015.3.JNS1558.
54. Bulsara KR, Vasudevan R, Erdem E. Superior ophthalmic vein approach to carotid-cavernous fistulas. Technical note. Neurosurgical focus. 2005 Feb 15:18(2):ECP3
55. Tobias JD, Leder M. Procedural sedation: A review of sedative agents, monitoring, and management of complications. Saudi journal of anaesthesia. 2011 Oct:5(4):395-410. doi: 10.4103/1658-354X.87270.
56. Lima V, Burt B, Leibovitch I, Prabhakaran V, Goldberg RA, Selva D. Orbital compartment syndrome: the ophthalmic surgical emergency. Survey of ophthalmology. 2009 Jul-Aug:54(4):441-9. doi: 10.1016/j.survophthal.2009.04.005.
57. Geary SM. Nursing management of cranial nerve dysfunction. The Journal of neuroscience nursing : journal of the American Association of Neuroscience Nurses. 1995 Apr:27(2):102-8