Orbital Vascular Malformations: Current Concepts

2

Sathyadeepak Ramesh and Daniel Rootman

Introduction

Vascular anomalies are thought to be congenital lesions, although they can present across all age ranges. Diversity in the physiologic and anatomic characteristics of such lesions leads to a wide array of clinical presentations. Understanding the cellular and flow characteristics of vascular malformations, as well as their appropriate nomenclature, allows for systematic study and appropriate application of management techniques. In this chapter, we provide an overview of current concepts in the classification, diagnosis, and management of orbital vascular malformations.

Nomenclature

As our understanding of the histology and flow characteristics for vascular lesions has increased over time, so has our ability to classify them in a rational manner. Moving away from an array of disjointed naming systems focused on specific lesions such as hemangioma, lymphangioma, varix, etc., modern classification systems unify terminology as it relates to pathophysiologic characteristics.

The earliest classification systems were based on endothelial cell type [1], and later refined to include characteristics of intralesional flow [2, 3], resulting in a comprehensive systemic classification system now espoused by the International Society for the Study of Vascular Anomalies (ISSVA) [4]. This system allows for rational treatment and consistent scientific discussion (Table 2.1).

S. Ramesh · D. Rootman (✉)
Department of Orbital and Ophthalmic Plastic Surgery, UCLA Stein Eye Institute, Los Angeles, CA, USA
e-mail: Ramesh@jsei.ucla.edu; Rootman@jsei.ucla.edu

A. Gupta, P. Tahiliani (eds.), *Orbit and Oculoplastics*, Current Practices in Ophthalmology, https://doi.org/10.1007/978-981-13-8538-4_2

Table 2.1 ISSVA 2014 Classification of vascular anomalies

Tumors		Malformations	
Infantile hemangioma		Fast	Slow
Tufted angioma	Arterial	Arteriovenous malformation Fistula	Capillary Port wine mark Telangectasia
Kaposiform hemangioendothelioma	Venous		Distensible Non-distensible Cavernous malformation
Hemangiopericytoma	Lymphatic		Macrocystic: deep Microcystic: superficial
Pyogenic granuloma	Mixed	Capillary-venous	Venolymphatic Venous dominant Lymphatic dominant
Spindle cell hemangioendothelioma			

The ISSVA classification at its base level separates vascular tumors from malformations (Table 2.1). Vascular tumors are benign or malignant endothelial neoplasms which grow by abnormal cell proliferation. These are rarely present at birth and grow out of phase with the patient. Most commonly represented tumors of this group are infantile hemangioma, hemangiopericytoma, and hemangioendothelioma. These lesions are beyond the scope of the present discussion, which will focus solely on vascular malformations.

Vascular malformations are congenital lesions likely related to an embryologic error in the development. They tend to grow proportionally with the patient and are present throughout the life. Vascular malformations are subdivided based on vessel type (arterial, venous, lymphatic, or mixed) and flow characteristics (fast or slow).

Mixed lesions involve arterial, venous, and/or lymphatic components and represent a spectrum of disease. The most common of these phenotypes is the combined venolymphatic malformation, formerly known as lymphangioma.

Morphologic considerations within lesion type and flow categories further characterize malformations in important ways for diagnosis and management, particularly in the orbit [5]. Venous components are divided into distensible and non-distensible subtypes, lymphatic into microcystic and macrocystic morphologic groups, and venolymphatic malformations further characterized as lymphatic- or venous-dominant.

Imaging

Imaging modalities can be described as noninvasive (ultrasound, computed tomography (CT), and magnetic resonance imaging (MRI)) or invasive (catheter angiography), and further characterized as static or dynamic. Static imaging traditionally provides information regarding soft tissue components. Bony features on static imaging may be better assessed with computed tomography (CT), which is also useful for the identification of phleboliths, providing some clues regarding flow

characteristics. Static magnetic resonance imaging (MRI) protocols provide better soft tissue differentiation, with generally higher resolution. Additionally, information regarding tissue composition characteristics can be derived through comparison of relative signal intensity on T1 and T2 weighted sequences. Fat suppression is highly valuable in differentiating normal from abnormal orbital tissues that may both be relatively bright on T1 and T2 imaging.

Dynamic, time-resolved imaging is indispensable in evaluating vascular disease. Catheter angiography is likely the gold standard for such imaging, and may be combined with intravascular interventions to treat lesions in many circumstances. However, such interventions do carry some risk and it is ideal to evaluate with non-invasive imaging in advance of interventional procedures. These investigations are helpful in deciding whether angiography is appropriate and in planning for possible intravascular interventions with or without concurrent or subsequent surgery.

Dual-phase CT angiography (CTA) with post-contrast imaging in both arterial and venous phases can be useful in evaluating the progression of intralesional filling characteristics. The addition of Valsalva maneuver during the venous phase can be invaluable in the identification of distensible components that may not be identified clinically [6] and in the assessment of post Valsalva spatial relationships. Time resolved MRI sequences (TRICKS sequence, GE Healthcare, Wauwatosa, WI or TWIST sequence, Siemens Corporation, Washington DC, among others) can provide information regarding the phase of filling for different aspects of the lesions. They are however limited in spatial resolution and do not reveal washout or drainage patterns well due to luminal wall staining.

These various dynamic imaging modalities can provide invaluable information regarding composition (arterial or venous, based on time resolution), flow (distensibility and flow voids), and anatomic relationships (inflow and outflow pathways) that may be critical to optimal management. Specific imaging applications will be discussed in the appropriate sections below.

Arterial

Arteriovenous Fistula (AVF)

Pathophysiology

AVFs are rare lesions composed of a single, direct connection between the arterial and venous systems. These are not true embryologic malformations, but rather acquired lesions that may be spontaneous or initiated by trauma [7].

Clinical Features

Orbital AVFs present with typical congestive signs including proptosis (potentially pulsatile), chemosis, tortuous episcleral vasculature, and elevated intraocular pressure. Cavernous sinus findings may be evident, if the fistula is intra-cavernous, and may include motor and/or sensory nerve dysfunction. Intra-orbital fistula can occur

and may not demonstrate these classic findings [8]. Fundus examination may show venous engorgement and/or tortuosity. Proptosis is typically not enhanced with Valsalva or positioning, although venous engorgement may be exacerbated.

Imaging

Static imaging may reveal a dilated superior ophthalmic vein (SOV) along with orbital congestion and engorgement of the extraocular muscles. Cavernous sinus expansion may also be noted. Contrast enhanced imaging may further delineate the increased orbital vascularity, however, is not particularly additive to other static imaging. Non-invasive angiography (CTA or MR angiography (MRA)) may be able to demonstrate fistulous changes, although catheter angiography is often required for both diagnosis and management.

Treatment

Treatment often involves endovascular embolization or coiling. The fistula is typically approached endovascularly via a transfemoral venous or arterial access point. Rarely, direct cannulation of the SOV or other approaches utilizing lesser vessels of the face are required for access. Angiography may reveal a foreign body in case of traumatic etiology, and removal of the foreign body may be sufficient to allow closure of the fistula [7].

Arteriovenous Malformations (AVM)

Pathophysiology

AVMs are rare fast-flow lesions composed of tangles of arterial vessels which anastomose directly with veins, bypassing a capillary bed (Fig. 2.1). Histology demonstrates thick-walled musculature often with intrastromal hemorrhage, deficiencies in elastic layers and a nidus of cellular stroma between vessels [9]. This stroma may have a role in secreting cytokines that propagate the lesion [9]. They typically occur in anastomotic zones, and may be associated with retinal or cerebral AVMs, both syndromic (e.g., Wyburn-Mason) or non-syndromic in nature.

Clinical Features

Orbital AVMs typically present with mass effect, swelling, proptosis with or without ocular pulsations, bruit, and/or pain. Valsalva maneuver may unmask pulsatile proptosis. Rarely, vision loss from a steal syndrome, intralesional thrombosis, or hemorrhage can be the presenting symptom. Stimuli for growth include pregnancy, menarche and trauma, and lesions may be diagnosed around these times [9].

Imaging

Noncontrast imaging may only show a poorly-defined soft tissue mass with or without flow voids (Fig. 2.1b, d). Early phase CT or MR angiography may demonstrate

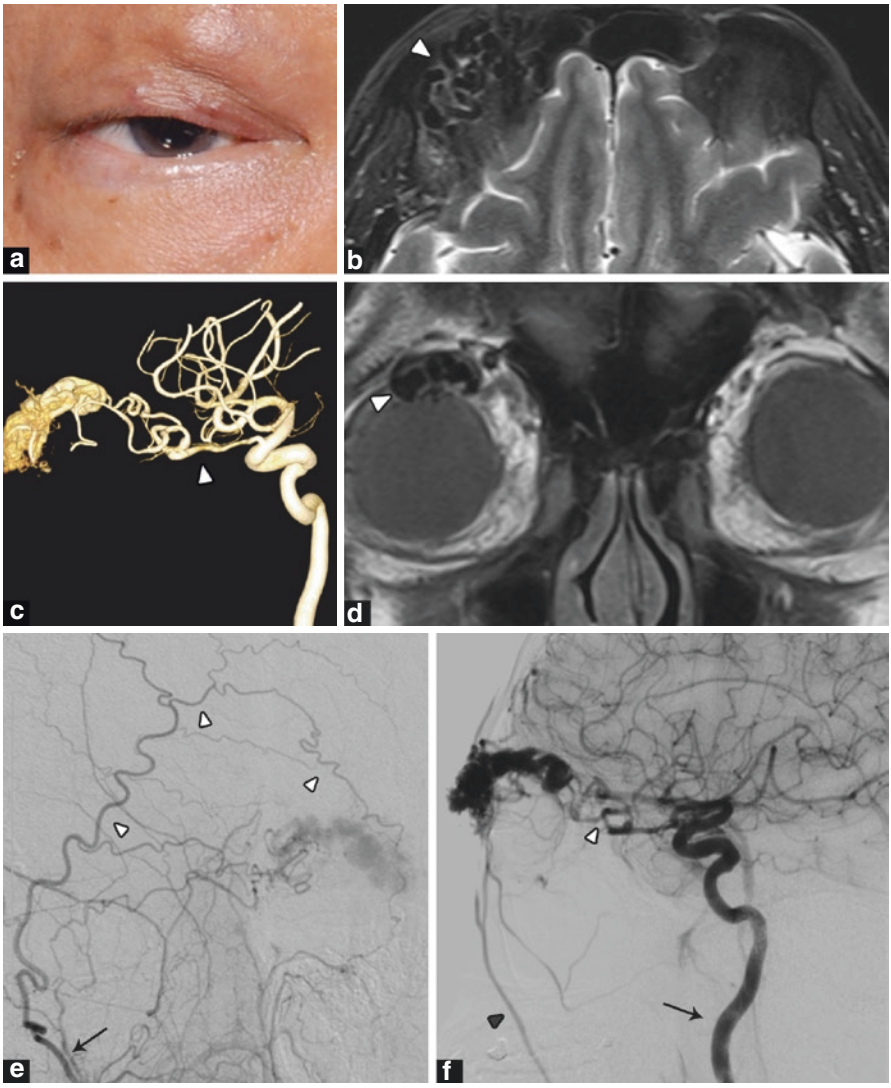

Fig. 2.1 Patient with right orbital arteriovenous malformation (AVM). Clinical photo (**a**) shows bluish subcutaneous discoloration and ptosis due to mass effect in the upper eyelid. Axial T2-weighted MRI with fat suppression (**b**) and coronal T1-weighted MRI with fat suppression and contrast enhancement (**d**) showing orbital AVM in the right superior orbit with dilated, tortuous vessels and flow voids (arrowhead). MR angiogram with 3D reconstruction (**c**) shows the lesion in detail with the primary feeding artery (ophthalmic artery, arrowhead) arising from the internal carotid artery. Catheter angiography from the external carotid (**e**, arrow) shows a secondary feeder from the superficial temporal artery (arrowheads) with slow filling of the lesion. Catheter angiography from the internal carotid (**f**, arrow) reveals brisk filling of the lesion through the ophthalmic artery (white arrowhead) and drainage through the facial vein (black arrowhead)

distinct vessels, although late phase sequences may simply show diffuse enhancement in the mass. Time-resolved MRI reveals arterial-phase filling within a distinct tangle of vessels. The venous phase of MRI sequences is poorly defined due to the collection of contrast in the vessels. Doppler ultrasound can demonstrate fast flow characteristics.

Invasive angiography is the standard for diagnosis and characteristically demonstrates early arterial flow of contrast into the distinct vessels, often followed by a blush of contrast into the smaller abnormal arterioles. Inflow is often derived from multiple feeder branches of both the internal and external carotid (Fig. 2.1e, f). Outflow is via significantly dilated and engorged veins leading variably to the facial veins, cavernous sinus, pterygoid plexus and/or anomalous communicating veins to the intracranial sinuses.

Treatment

Observation typically follows growth over time, periodically interrupted by thrombosis or hemorrhage events. Direct excision can be attempted; however, poorly defined borders make the lesion difficult to completely excise, and large inflow channels can lead to significant intraoperative bleeding. Intravascular embolization alone can be performed, however, recurrence is common. Management of arterial inflow with intravascular embolization and complete excision may be the best option for management. Complete excision offers the greatest chance for limiting recurrence, although this should be balanced with the functional and/or cosmetic consequences of such a procedure. Adjunctive sclerotherapy, laser and/or embolization may be useful in cases where incomplete resection may be necessary to preserve essential function and cosmesis.

Venous

Cavernous Venous Malformation

Pathophysiology

Cavernous venous malformations, previously known as cavernous hemangiomas, are common lesions (up to 9% of orbital masses [10]) that typically present in middle age, more commonly among females [11] (Fig. 2.2). The hemangioma label is likely inaccurate as they do not represent abnormally proliferating cells, but rather a collection of low-flow blood vessels growing slowly by the normal vascular processes of thrombosis and recanalization [12].

Cavernous malformations typically have a robust external capsule which may incorporate adjacent neurovasculature (e.g., the ophthalmic artery) as the lesion grows, particularly in the orbital apex [13]. Histologically, lesions are composed of dilated vascular channels with areas of thrombosis in a fibrous stroma. They can have a lobular structure and intralesional fat [13]. Endothelial cells express vascular endothelial growth factor (VEGF) and contain extensive smooth muscle actin (SMA)-positive myofibroblasts [12].

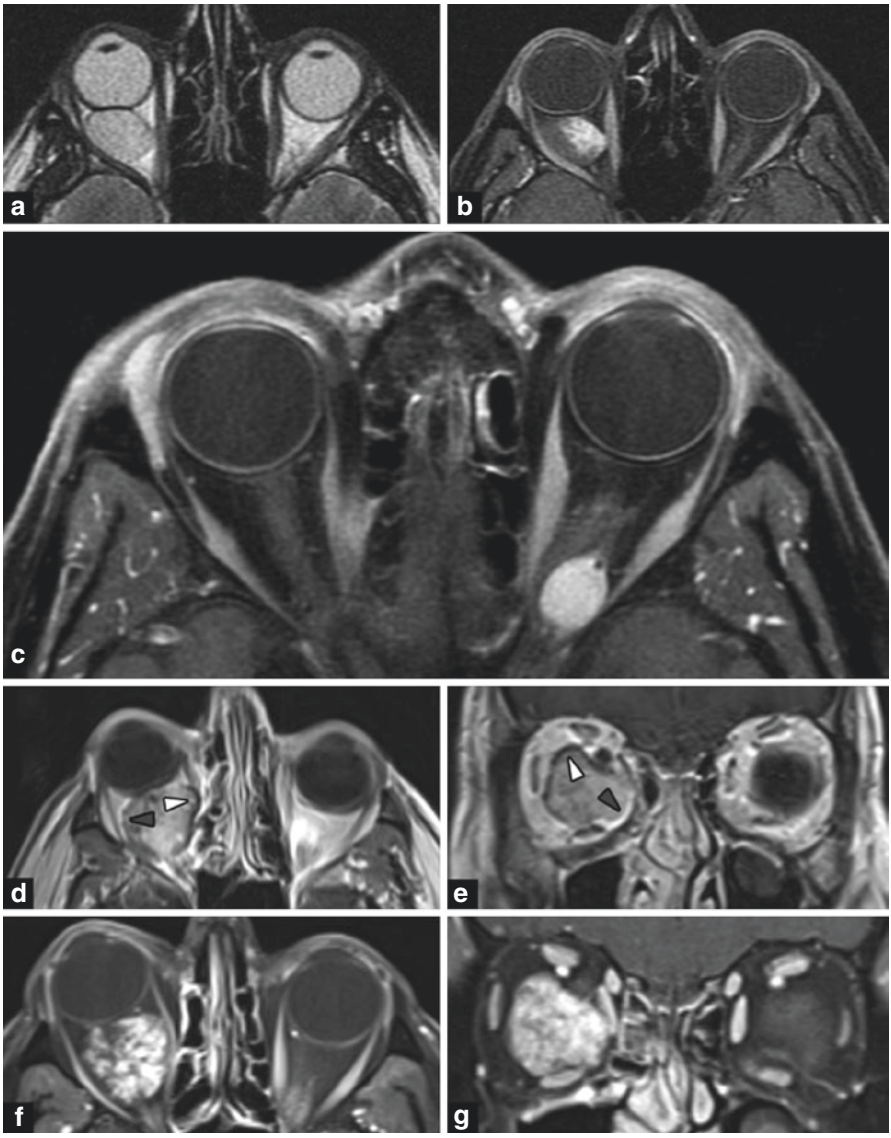

Fig. 2.2 Cavernous venous malformation depicted in axial T2-weighted (**a**) and T1-weighted post-contrast MRI (**b**) with the typical, intraconal location, indentation of the posterior aspect of the globe, and early, high-intensity enhancement. A posterior cavernous venous malformation with extension through the superior orbital fissure to the cavernous sinus shown in axial T1-weighted contrast-enhanced MRI (**c**); the anterior components of this lesion were exsanguinated and debulked transorbitally, allowing for sufficient reduction in proptosis to relieve the patient's optic neuropathy and uncontrolled pain. Cavernous venous malformation depicted in axial and coronal T2-weighted MRI (**d**, **e**) showing an intraconal location and the "double artifact sign" with a black line on the outer edge of the lesion (white arrowhead) and white line on the inner edge of the opposite edge of the lesion (black arrowhead). Contrast-enhanced T1-weighted image with fat suppression (**f**, **g**) of the same patient shows early, high-intensity enhancement

Clinical Features

Many lesions are discovered incidentally on brain imaging, and as such are asymptomatic. However, up to one third of patients do describe vague symptoms of dull orbital pain and/or headache, leading to brain imaging and lesion discovery [12]. Most often they present with slowly worsening proptosis [14]. Motility restriction, gaze-evoked amaurosis, diplopia and optic neuropathy are less common symptoms. Differential diagnosis includes hemangiopericytoma/solitary fibrous tumor, schwannoma, infantile hemangioma, and venolymphatic malformation.

Imaging

Static imaging demonstrates a well-defined, typically intraconal lesion, often in the middle third of the orbit [12]. These tend to indent rather than mold to the globe, are smooth bordered, spherical, and of variable internal density. Apical lesions may have intracranial extension through the superior orbital fissure (Fig. 2.2c).

On MRI, lesions are isointense to gray matter on T1 and hyperintense on T2, and may exhibit the "double artifact sign," which is a black line on the inner edge of the lesion and a white line on the outer edge of the opposite side of the lesion (Fig. 2.2d, e). Static contrast enhanced studies demonstrate late uniform enhancement (Fig. 2.2a, b) [15]. Due to the long capture time with MRI, differences in contrast enhancement may be noted from one sequence to the next. Examination of earlier sequences after contrast injection show high intensity multifocal enhancement, while images acquired later show diffuse, moderate enhancement (Fig. 2.2f, g). Dual phase CTA delineates the slow inflow characteristics of these lesions with patchy focal or multifocal enhancement early and diffuse moderate enhancement later [16].

Treatment

Lesions can be observed if symptoms are limited and tolerable. Treatment typically consists of surgical excision, where the lesion can be excised with the capsule intact. Exsanguination can assist with removal by reducing the size of the lesion. Care should be taken to ensure the lesion is not fixed to adjacent neurovasculature, especially in the apex.

Complex or apical lesions may also be treated with fractionated stereotactic radiotherapy (40 Gy in 20 sessions), and although this treatment does not typically lead to a large reduction in lesion size, it can be very effective in treating optic neuropathy [17]. Of note, posterior/apical lesions extending into the superior orbital fissure may resolve with even partial resection, possibly due to secondary induced thrombosis of residual mass [13].

Distensible and Non-distensible Venous Malformations

Pathophysiology

Venous malformations are comprised of distensible (enlarge with Valsalva) and/or non-distensible components. These lesions may arise from either a congenital weakness in the wall of a post-capillary venule (i.e., varix) or from dysmorphic vein

formation [16]. Internally, lesions can exhibit spongy, cavitary or dysmorphic morphology [18]. Outflow can be isolated into normal veins and ectatic veins, or the lesion as a whole can be completely ectatic [18]. Outflow anatomy is varied and can drain through single or multiple tributary networks into the cavernous sinus, pterygopalatine fossa, facial vasculature, and/or intracranial sinuses. Lesions may be isolated, in a combined venolymphatic malformation or as part of systemic vascular dysmorphism syndromes.

Clinical Features

Venous malformations are congenital lesions that typically present in the second or third decade of life without a predilection for either sex. Symptoms may include pressure sensation or pain and wasting and/or enophthalmos due to orbital fat atrophy after repeated episodes of hemorrhage and/or proptosis [19]. Distensible lesions are often associated with Valsalva-induced symptomatology including pain, vision loss and diplopia under conditions of elevated venous pressure such as bending and straining. Signs may also be Valsalva-induced and can include induction of an afferent pupillary defect, motility restriction and/or proptosis. Hemorrhage or thrombosis can occur and in these situations pateints may note sudden onset of pain and vision loss with or without ecchymosis in these situations. It is noteworthy that clinical changes with Valsalva may be evident in only 60% of patients with a radiologically dynamic lesion [6]. Non-distensible lesions may present with spontaneous hemorrhage due to the inability of the vessel to respond to changes in flow [18].

Speed of onset and subsequent resolution of distension on Valsalva maneuver provides clues as to the inflow and outflow characteristics of the lesion. Slow-filling or emptying lesions may have small and/or multifocal inflow or outflow networks, respectively, while faster-filling or emptying lesions will typically be associated with larger and more ectatic connections with the venous system.

Imaging

Static imaging may show a poorly defined soft tissue mass with variable enhancement with or without phleboliths. Non-distensible components may demonstrate early pooling of contrast. However, smaller or extremely collapsible lesions may be difficult to identify at all on static imaging (Fig. 2.3). Dynamic imaging is invaluable in assessing these lesions, and significant components of the lesion may be revealed (Fig. 2.3) with a Valsalva maneuver performed approximately 1 min after contrast administration. Large venous channels with complex inflow and outflow as well as small arterial components may also be identified (Figs. 2.4 and 2.5) [20].

Treatment

Indications for intervention include persistent pain, a functional deficit such as globe dystopia, vision loss, strabismus or cosmesis. Smaller, very low-flow lesions in the anterior orbit may be excised completely with meticulous surgical technique and standard hemostatic maneuvers. However, it is often prudent to manage these lesions in conjunction with invasive angiography teams.

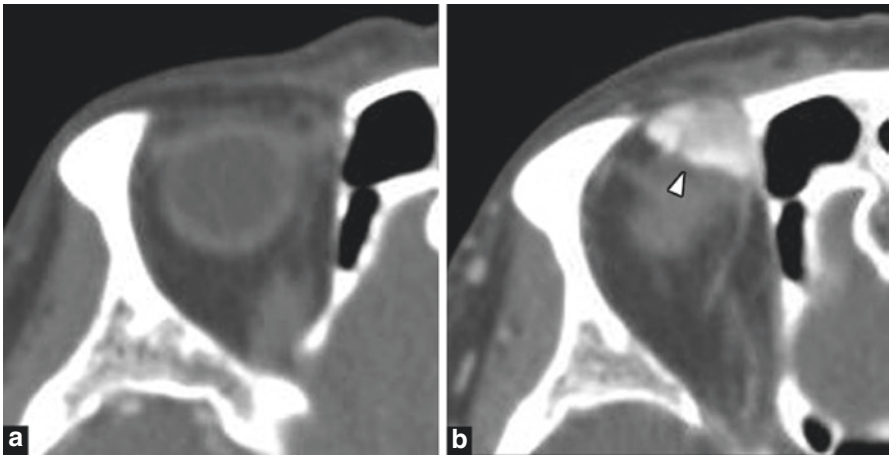

Fig. 2.3 Axial CT of orbital venous malformation with contrast, pre-Valsalva (**a**) and post-Valsalva (**b**) maneuver, highlighting the distensible nature of the lesion (arrowhead)

Direct puncture is the most focused access technique, and this can be performed after exposing the lesion surgically or in a percutaneous manner. Intraoperative Valsalva can be useful in expanding the target for puncture and can be induced by elevating the intrathoracic pressure with the help of the anesthesiologist. Puncture can be followed by mapping, and outflow channels can be assessed for size and drainage pattern.

The goal of this procedure is to control the lesion while avoiding collateral damage to the downstream structures. This can be accomplished in many ways. Slow-flow lesions with limited and/or safe drainage zones can be sclerosed, often with small aliquots to allow for concentration of agent within the lesion of interest (and dilution downstream). Very slow-flow lesions can be embolized directly with glue starting at the outflow and backfilling into the inflow. Faster-flow lesions may be filled with multiple glue polymerization configurations, with faster polymerizing glue at the outflow regions and more slowly polymerizing glue subsequently. Very fast-outflow channels can be controlled downstream with invasive venography and balloon catheterization, effectively blocking the downstream elements. This can be followed by direct puncture and embolization. Surgical excision of the malformation and embolic material follows in most cases.

Common sclerosants include sodium morrhuate 5%, sodium tetradecyl sulfate 3% (SDS), absolute alcohol, OK-432, bleomycin or tetracyclines [19, 21, 22]. OK-432 induces cytokine release which recruits inflammatory cells and incites thrombus, while the other sclerosants cause direct intimal injury leading to inflammation and thrombosis. Common complications include edema, blistering, or ulceration. Rare but serious complications include cerebral embolism in the presence of a patent foramen ovale, orbital compartment syndrome, or transient neuropathy of adjacent nerves (e.g., CN VII near the masseter) [23, 24]. Care must be taken to limit the amount of sclerosant given (e.g., a maximum of 3–4 mL of SDS foam into the orbit) to avoid complications.

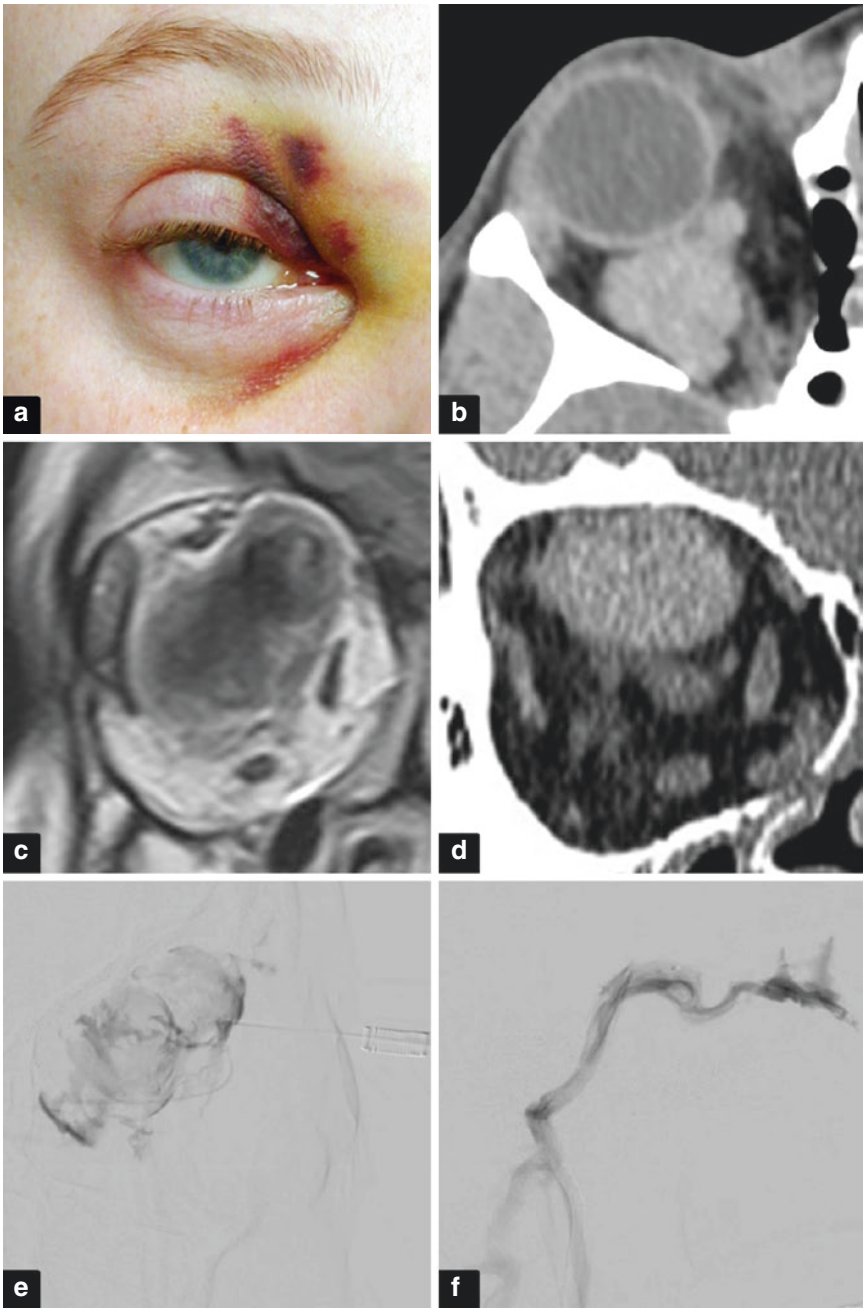

Fig. 2.4 Venous malformation of the orbit. Clinical photo (**a**) showing thrombosis and hemorrhage resulting in acute proptosis and pain, which was improved with oral corticosteroid. Axial and coronal non-contrast CT (**b**, **d**) showing an irregular soft tissue mass in the intraconal and superior orbit. Coronal T1-weighted MRI (**c**) showing irregular thrombosis within the lesion. Angiography through direct puncture showing slow filling of the lesion (**e**) and outflow through the cavernous sinus (**f**)

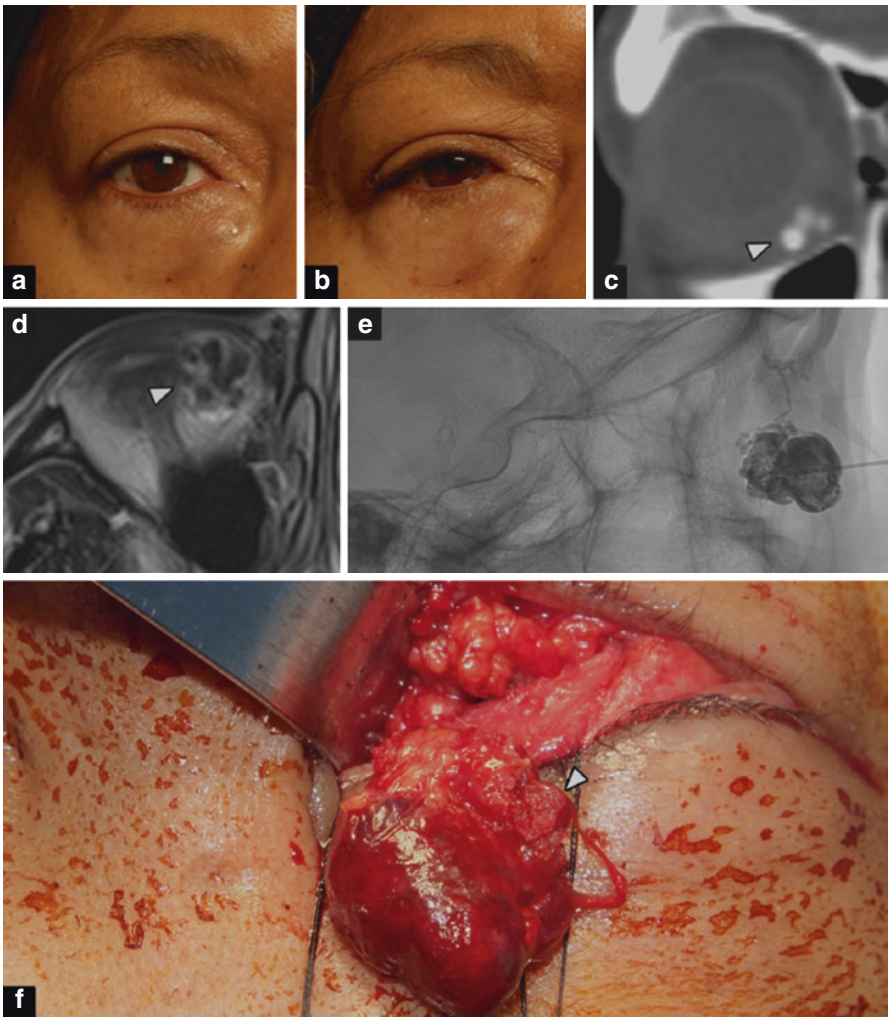

Fig. 2.5 Venous malformation in the inferomedial anterior orbit. Clinical photos pre-Valsalva (**a**) and post-Valsalva (**b**) show enlargement of lesion with edema in the lower lid after the maneuver. Coronal non-contrast CT (**c**) demonstrating phleboliths within the lesion (arrowhead). Axial non-contrast T1-weighted MRI (**d**) with flow voids and/or phleboliths (arrowhead), which appear similar on MRI. Catheter angiography via direct puncture (**e**) and gluing of the lesion with cyanoacrylate facilitates subsequent surgical excision (**f**); cyanoacrylate glue in a cut portion of the lesion is noted (arrowhead)

Common embolizing agents include cyanoacrylate glue (nBCA) and ethylene alcohol vinyl copolymer (Onyx, Medtronic, Northridge, CA). Embolization aids in surgical excision by allowing hemostasis as well as giving the lesion a firmness which allows easier dissection and excision (Fig. 2.5e, f).

Lymphatic/Combined

Venolymphatic Malformations

Pathophysiology

It is now generally recognized that the entity formerly known as lymphangioma, is more accurately described as a venolymphatic malformation. This is due to the persistence of both venous and lymphatic elements in the lesions and a lack of abnormally proliferating clonal cells more typical of lesions designated by "-oma." These lesions exist on a physiologic spectrum from venous-dominant to lymphatic-dominant, with some suggesting there are few if any truly isolated lymphatic lesions [25]. Morphologically, these malformations may be comprised of macrocystic (large, individually identifiable cysts) and microcystic (smaller, less distinct cysts) components, again existing on a spectrum of varying proportions of each.

Theories of their genesis generally suggest that they may be formed from arborization or embryonic sequestration of venous structures. The orbit is generally devoid of lymphatics and lymphatic and venous vessels share an embryologic predecessor [26]. Other theories presume that blood-derived cells may differentiate into lymphatic elements.

Vessels in the lymphatic components generally do not contain significant numbers of erythrocytes (unless a recent hemorrhage is evident), and flow is nonexistent or very slow. Lesions are mostly not encapsulated and tend not to respect tissue boundaries or anatomic planes, often interdigitating with and through adjacent structures. Some primarily macrocystic lesions can be somewhat encapsulated and certain lesions may demonstrate an internal and external lobular architecture (Fig. 2.7).

Clinical Features

Lymphatic malformations are relatively common congenital orbital lesions and may remain clinically unapparent until the early teens. They typically grow slowly although can be punctuated by episodes of hemorrhage characterized by acute onset of pain, proptosis, and vision loss due to rapid expansion of cystic elements ("chocolate cysts"). They may also expand at the time of antecedent respiratory tract infection leading to proliferation of the stromal immune system elements (e.g., follicles). Presenting signs include proptosis (with or without optic neuropathy), strabismus and ptosis. Blood-filled or xanthochromic cysts may be observed in the conjunctiva with bluish subcutaneous cysts in the eyelid. Venous elements may present in a similar fashion as described in previous sections regarding venous malformations.

Imaging

Static imaging may reveal macrocysts with or without fluid–fluid levels. These are often best identified on T2-weighted MRI sequences (Fig. 2.6b, c). Microcystic regions appear as poorly defined, diffusely enhancing and infiltrative masses (Fig. 2.6d). Dynamic imaging may demonstrate inflow character and/or internal

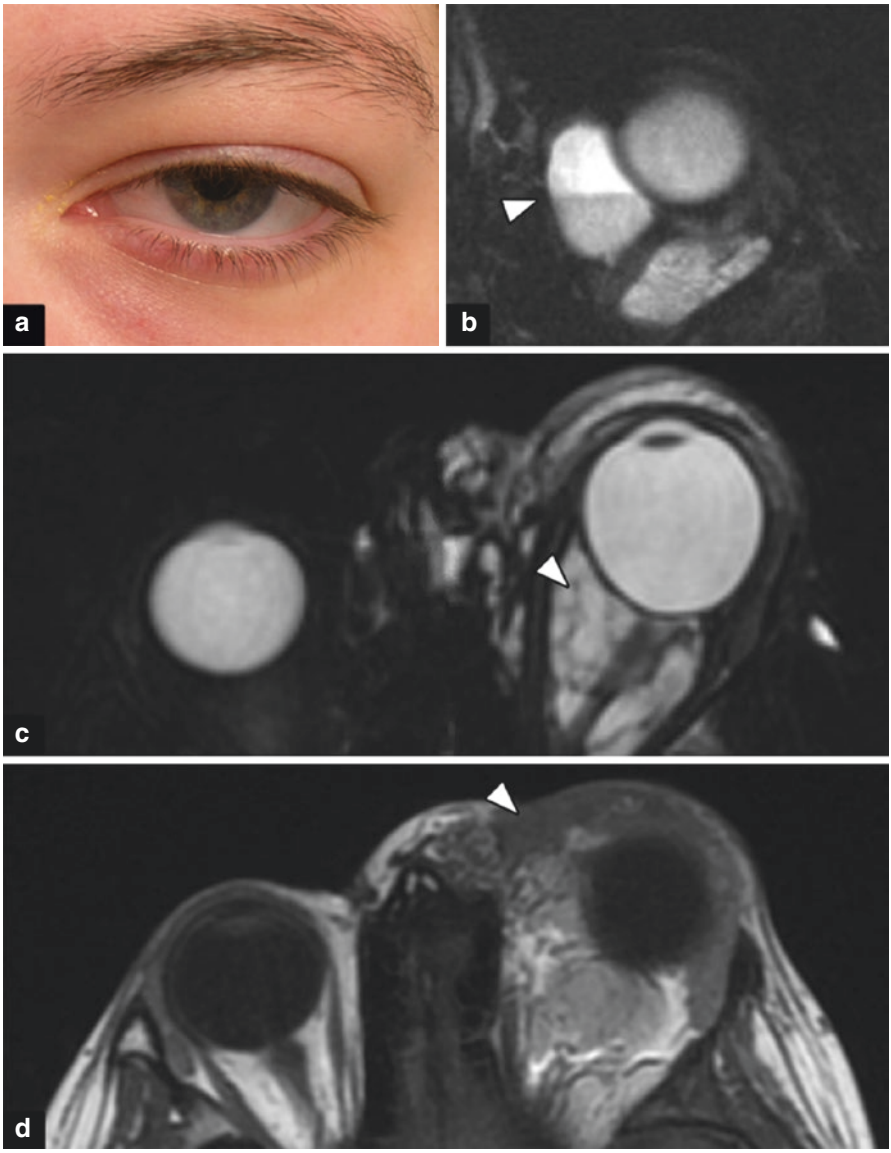

Fig. 2.6 Clinical photo of an orbital lymphatic malformation in a pediatric patient (**a**), presenting with chemosis, edema and fullness after an antecedent upper respiratory tract infection. Axial T2-weighted contrast-enhanced MRI (**b**) shows a large macrocyst with a fluid–fluid level. Axial T2-weighted post-contrast and T1-weighted non-contrast MRI of another pediatric patient with orbital lymphatic dominant malformation (**c**, **d**) depicting intraconal macrocysts (**c**, arrowhead) with an anterior microcystic component in the eyelid (**d**, arrowhead)

vascular architecture. Flow voids and/or phleboliths may be evident. Venous components are best defined on Valsalva-augmented sequences. Differential diagnosis includes cavernous venous malformations, infantile hemangioma, and orbital inflammatory disease.

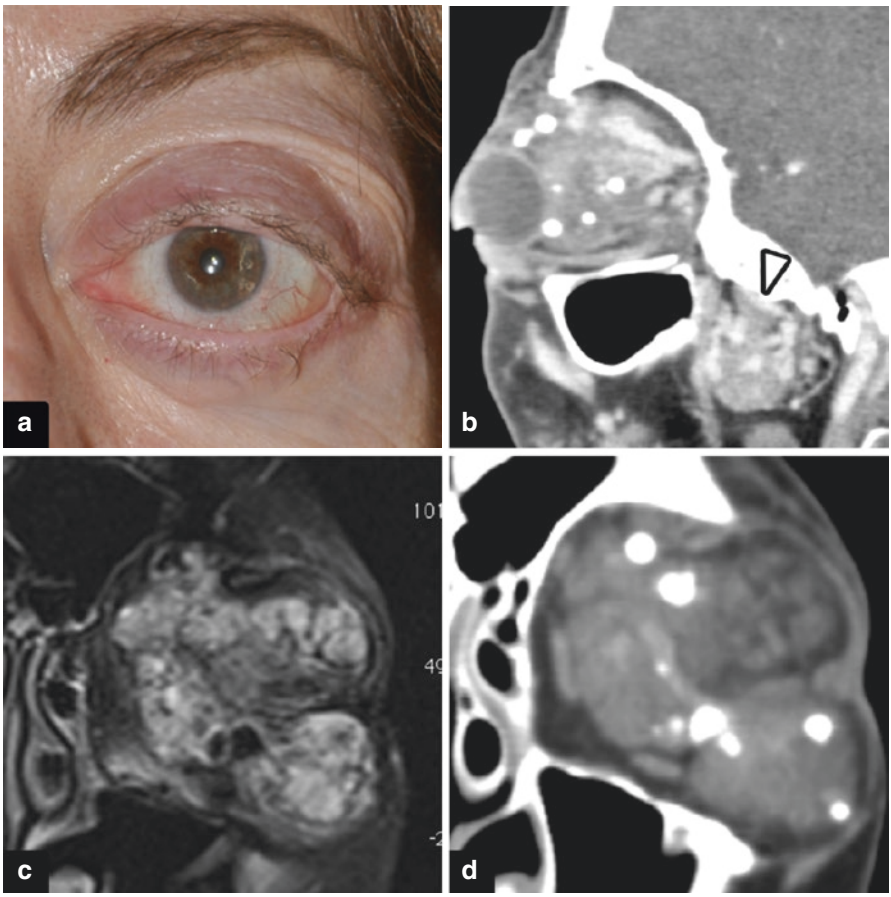

Fig. 2.7 Complex combined venous-predominant venolymphatic malformation. Clinical photo (**a**) demonstrates proptosis. Contrast-enhanced CT (**b**, **d**, **f**) and T1-weighted MRI (**c**, **e**) demonstrate a complex lesion with intraconal, extraconal and eyelid involvement, numerous phleboliths, and infiltration of orbital soft tissues as well as the pterygopalatine fossa (**b**, arrowhead). Catheter angiography via direct puncture (**g**) shows the internal architecture of a lobular lymphatic component, and another superolateral microcystic lymphatic component with minimal connection to the medial portion. Immunohistochemistry shows rich staining for vascular endothelial growth factor (VEGF) (**h**, brown)

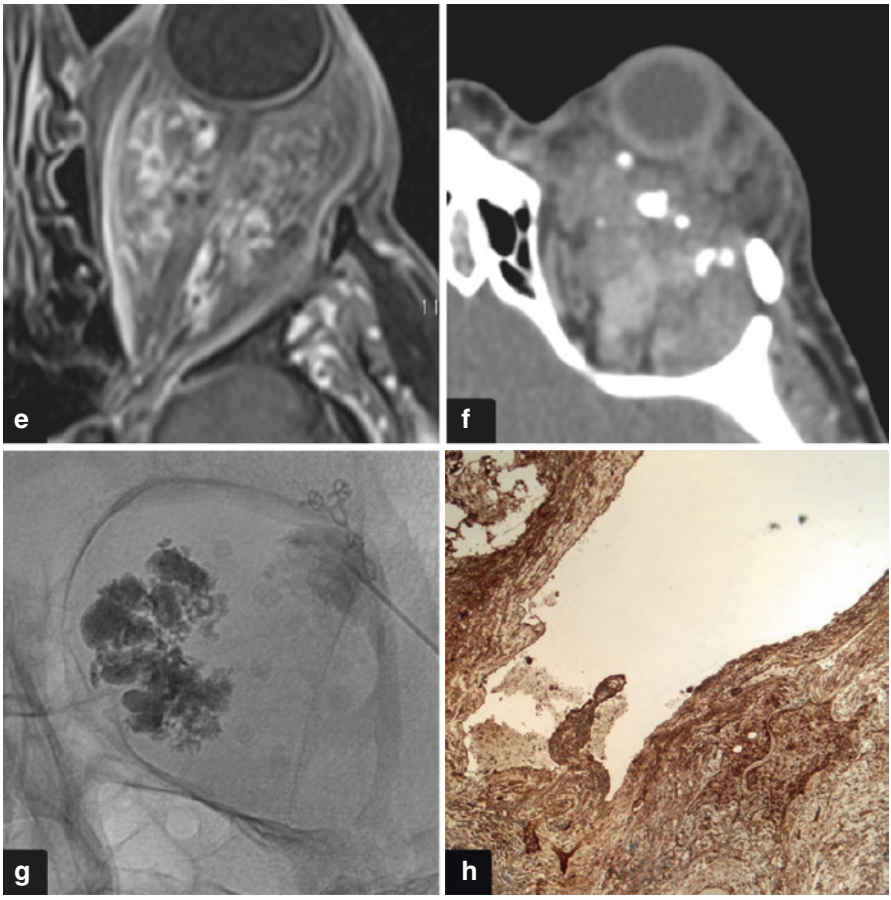

Fig. 2.7 (continued)

Treatment

Lesions may be observed for many years as asymptomatic; while they are unlikely to regress, they may stop growing at adulthood [25]. The infiltrative nature of such lesions makes them poorly amenable in most cases to complete surgical excision due to the involvement of vital orbital structures. Incomplete management is often followed by recurrent growth. Sclerosing therapy has become the mainstay of management and may involve the use of various agents including sodium morrhuate, sodium tetradecyl sulfate, OK-432, or bleomycin. This can be performed with direct puncture in an outpatient or surgical setting for smaller, anteriorly located lesions or under fluoroscopic guidance in conjunction with interventional radiology. The latter technique has the advantage of understanding complex interactions between these lesions and internal venous components and can assure adequate treatment breadth. Recent advances in our understanding of the biochemistry in these lesions suggest a role for VEGF mediated processes in the development and

propagation of venolymphatic malformations [25]. In the future, VEGF blocking agents may be useful in the management of these malformations (Fig. 2.7g). Whatever the methodology, lesions may require multiple treatments for adequate management.

Summary

Thorough understanding of the flow characteristics and anatomic distribution of a vascular malformation is critical to optimal treatment. Advances in biomaterials, fluoroscopy-guided therapy, and our understanding of the pathophysiology of these lesions have contributed to better management. Future research should strive to understand the embryologic and biochemical pathways by which these lesions grow, to provide a targeted therapy with powerful and durable effect.

Pearls and Pitfalls

- Pearl #1: Understanding the flow characteristics of each lesion is key to optimal treatment.
- Pearl #2: A multidisciplinary approach with interventional radiology aids in addressing complex lesions.
- Pitfall #1: Improper nomenclature confuses understanding and inhibits optimal treatment.
- Pitfall #2: Primary surgical excision has a high risk of hemorrhage, collateral damage, or incomplete excision with recurrence of.

References

1. Mulliken JB, Glowacki J. Hemangiomas and vascular malformations in infants and children: a classification based on endothelial characteristics. Plast Reconstr Surg. 1982;69:412–22.
2. Garzon MC, Huang JT, Enjolras O, Frieden IJ. Vascular malformations: part i. J Am Acad Dermatol. 2007;56:353–70. quiz 71-4.
3. Jackson IT, Carreno R, Potparic Z, Hussain K. Hemangiomas, vascular malformations, and lymphovenous malformations: classification and methods of treatment. Plast Reconstr Surg. 1993;91:1216–30.
4. Issva classification of vascular anomalies. ISSVA General Assembly, Melbourne, Australia; 2014. issva.org/classification.
5. Harris GJ. Orbital vascular malformations: a consensus statement on terminology and its clinical implications. Orbital society. Am J Ophthalmol. 1999;127(4):453–5.
6. Rootman J, Heran MK, Graeb DA. Vascular malformations of the orbit: classification and the role of imaging in diagnosis and treatment strategies∗. Ophthal Plast Reconstr Surg. 2014;30:91–104.
7. Yazc B, Yazc Z, Erdogan C, Rootman J. Intraorbital arteriovenous fistula secondary to penetrating injury. Ophthalmic Plast Reconstr Surg. 2007;23:275–8.
8. Konstas AA, Rootman DB, Quiros PA, Ross IB. Transarterial embolization of a spontaneous intraorbital arteriovenous fistula with n-bca glue. Ophthalmic Plast Reconstr Surg. 2017;33(3):e63–4.
9. Warrier S, Prabhakaran VC, Valenzuela A, et al. Orbital arteriovenous malformations. Arch Ophthalmol. 2008;126:1669–75.

10. Bonavolonta G, Strianese D, Grassi P, Comune C, et al. An analysis of 2,480 space-occupying lesions of the orbit from 1976 to 2011. Ophthalmic Plast Reconstr Surg. 2013;29(2):79–86.
11. Alfred PRCD. Cavernous hemangiomas of the orbit. Orbit. 1996;15:59–66.
12. Rootman DB, Heran MK, Rootman J, et al. Cavernous venous malformations of the orbit (so-called cavernous haemangioma): a comprehensive evaluation of their clinical, imaging and histologic nature. Br J Ophthalmol. 2014;98:880–8.
13. Harris GJ. Cavernous hemangioma of the orbital apex: Pathogenetic considerations in surgical management. Am J Ophthalmol. 2010;150:764–73.
14. Rootman DB, Rootman J, White VA. Comparative histology of orbital, hepatic and subcutaneous cavernous venous malformations. Br J Ophthalmol. 2015;99:138–40.
15. Khan SN, Sepahdari AR. Orbital masses: CT and MRI of common vascular lesions, benign tumors, and malignancies. Saudi J Ophthalmol. 2012;26:373–83.
16. Heran MK, Rootman J, Sangha BS, Yeo JM. Dynamic arterial and valsalva-augmented venous phase multidetector ct for orbital vascular lesions: a pictorial review∗. Ophthal Plast Reconstr Surg. 2014;30:180–5.
17. Rootman DB, Rootman J, Gregory S, et al. Stereotactic fractionated radiotherapy for cavernous venous malformations (hemangioma) of the orbit. Ophthal Plast Reconstr Surg. 2012;28:96–102.
18. Legiehn GM, Heran MK. Venous malformations: classification, development, diagnosis, and interventional radiologic management. Radiol Clin N Am. 2008;46:545–97, vi.
19. Lacey B, Rootman J, Marotta TR. Distensible venous malformations of the orbit. Ophthalmology. 1999;106:1197–209.
20. Callahan AB, Meyers PM, Garrity JA, et al. Low-flow arterialized venous malformations of the orbit. Ophthal Plast Reconstr Surg. 2017;33:256–60.
21. Schwarcz RM, Ben Simon GJ, Cook T, Goldberg RA. Sclerosing therapy as first line treatment for low flow vascular lesions of the orbit. Am J Ophthalmol. 2006;141:333–9.
22. Stacey AW, Gemmete JJ, Kahana A. Management of orbital and periocular vascular anomalies. Ophthal Plast Reconstr Surg. 2015;31:427–36.
23. Colletti G, Deganello A, Bardazzi A, et al. Complications after treatment of head and neck venous malformations with sodium tetradecyl sulfate foam. J Craniofac Surg. 2017;28:e388–e92.
24. Tessari L, Cavezzi A, Frullini A. Preliminary experience with a new sclerosing foam in the treatment of varicose veins. Dermatol Surg. 2001;27:58–60.
25. Nassiri N, Rootman J, Rootman DB, Goldberg RA. Orbital lymphaticovenous malformations: current and future treatments. Surv Ophthalmol. 2015;60:383–405.
26. Rootman J. Vascular malformations of the orbit: hemodynamic concepts. Orbit. 2009;22:103–20.