Journal of Medical and Medical Specialities
Volume 1, Issue 1, March 2025; pp: 53-67
eISSN: 2455-2852 DOI: 10.65129/medical.v1i1.11

CASE SERIES

Characterisation of Soft Tissue Vascular Anomalies using Conventional and Dynamic MRI Sequences – A Case Series

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Abstract

Background: Soft tissue vascular anomalies encompass a heterogeneous group of lesions ranging from benign vascular tumours to complex high-flow malformations. Accurate diagnosis is essential for appropriate management, and Magnetic Resonance Imaging (MRI) plays a pivotal role in classification. **Objective**: To assess the diagnostic utility of conventional MRI and dynamic MRI- TWIST sequence in classifying soft tissue vascular anomalies. **Methods**: This case series evaluates three patients using spin-echo sequences (T1/T2), contrast-enhanced TWIST imaging, and clinical correlation, with diagnostic classification referenced to Park *et al*. **Results**: Case-wise analysis distinguished between hemangioma, combined venolymphatic malformation and Arteriovenous Malformations (AVMs) based on the presence or absence of flow voids, nidus, enhancement patterns, and vascular architecture. **Conclusion**: The dynamic MRI sequence, particularly TWIST, is highly valuable in differentiating low-flow (e.g., venolymphatic malformation) from high-flow lesions (e.g., AVM), thereby guiding targeted therapy.

Keywords: Arteriovenous Malformations (AVMs), Dynamic Imaging, Hemangioma, MRI, Spin Echo, Twist, Soft Tissue Tumour, Vascular Malformations, Venolymphatic Malformation

1. Introduction

Vascular anomalies of soft tissue encompass a diverse and often perplexing group of lesions that pose significant challenges in terms of diagnosis, classification, and treatment planning. These anomalies, comprising both vascular tumours and vascular malformations, represent a spectrum of pathologies that vary in biological behaviour, hemodynamic characteristics, imaging appearances, and clinical outcomes. The accurate differentiation of these entities is not merely academic but forms the cornerstone of effective and safe therapeutic intervention. Misclassification can lead to suboptimal treatment, potential recurrence, and even iatrogenic complications, especially when invasive procedures such as embolisation or sclerotherapy are undertaken without adequate imaging characterisation[1].

The traditional terminology surrounding vascular anomalies has historically been inconsistent and confusing. Terms such as "hemangioma" were often used generically to refer to all vascular lesions, regardless of their underlying pathophysiology. However, the seminal work by Mulliken and Glowacki in 1982 revolutionised this field by introducing a biologically based classification system, separating vascular anomalies into two broad categories: vascular tumours and vascular malformations[2]. Vascular tumours, such as infantile hemangiomas, exhibit endothelial proliferation, have a characteristic growth-involution pattern, and are usually self-limiting. In contrast, vascular malformations are congenital anomalies resulting from abnormal morphogenesis of blood vessels, exhibit normal endothelial turnover, and grow proportionately with the child without regression[2,3].

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Article Received on: 17 Jan 2025 Revised on: 10 Feb 2025 Accepted on: 28 March 2025

Within vascular malformations, further classification is based on flow characteristics and vessel type. According to the International Society for the Study of Vascular Anomalies (ISSVA), these are subdivided into low-flow lesions (venous, lymphatic, capillary, or mixed) and high-flow lesions AVMs and *Arteriovenous Fistulas* [AVFs])[3]. Each type of vascular anomaly possesses a distinct clinical behaviour and therapeutic implication. For instance, high-flow lesions such as AVMs often require embolisation due to their aggressive nature and risk of haemorrhage, whereas low-flow venous malformations are commonly managed with percutaneous sclerotherapy[4].

Given this complexity, imaging plays a pivotal role in the assessment and diagnosis of soft tissue vascular anomalies. Among all imaging modalities, Magnetic Resonance Imaging (MRI) has emerged as the modality of choice due to its superior soft tissue contrast resolution, multiplanar capability, and absence of ionising radiation. MRI not only delineates the anatomical extent of the lesion but also provides insights into tissue characteristics such as vascular channels, flow voids, signal intensity, enhancement patterns, and relationship with adjacent structures[5]. Moreover, the introduction of dynamic contrast-enhanced MR angiography, particularly techniques like TWIST (Time-resolved angiography With Interleaved Stochastic Trajectories), has greatly enhanced the radiologist's ability to distinguish between low-flow and high-flow vascular malformations by evaluating their hemodynamic behaviour in real time[6].

The diagnostic advantage of dynamic MRI sequences lies in their ability to detect early arterial enhancement, arteriovenous shunting, and venous drainage patterns. This becomes especially critical in differentiating AVMs, which exhibit early contrast filling of both nidus and draining veins, from hemangiomas or venous malformations, which show delayed, progressive, and often heterogeneous enhancement[7,8]. Furthermore, contrast retention in the lesion, presence or absence of flow voids on spin echo images, and the detection of cystic spaces or septa can be correlated with specific subtypes of vascular anomalies[9].

Another significant benefit of MRI is its utility in monitoring treatment response. For instance, post-sclerotherapy changes in venous malformations often result in fibrosis and reduction in lesion size, which can be well visualised as loss of hyperintensity on T2-weighted images and decreased enhancement on delayed contrast scans[10]. Similarly, residual flow or revascularisation in AVMs post-embolisation can be detected early using time-resolved dynamic imaging, enabling prompt re-intervention if needed[11].

In paediatric populations, where vascular anomalies are most prevalent, MRI provides a safe, non-invasive, and repeatable method for diagnosis and follow-up. Infantile hemangiomas, for instance, typically undergo spontaneous involution and often require no treatment unless they interfere with function or cause cosmetic concerns. However, differentiating them from more aggressive vascular malformations or vascular neoplasms such as kaposiform hemangioendothelioma is crucial to avoid inappropriate therapy[12].

Moreover, MRI can provide critical information on associated syndromic conditions. For example, in Klippel-Trénaunay syndrome, the co-occurrence of venous malformation, capillary malformation, and limb hypertrophy can be assessed effectively. Similarly, Sturge-Weber syndrome may involve leptomeningeal angiomatosis that is well visualised on MRI[13]. Accurate imaging diagnosis aids multidisciplinary decision-making involving radiologists, vascular surgeons, dermatologists, and paediatricians.

Despite its advantages, challenges remain. Interpretation of MRI in vascular anomalies requires familiarity with complex enhancement patterns, anatomical variants, and disease progression. Moreover, access to dynamic sequences like TWIST and high-field MRI may not be universally available, particularly in resource-limited settings. Nonetheless, even conventional spin echo sequences combined with post-contrast imaging provide valuable information when carefully interpreted in the context of clinical and Doppler findings.

The present case series focuses on the role of conventional and dynamic MRI sequences in evaluating soft tissue vascular anomalies in three patients. Each case demonstrates specific imaging features that, when correlated with clinical findings and the Park *et al.*[1] diagnostic framework, lead to a confident diagnosis. The goal is to emphasise the practicality and importance of MRI in not only classifying vascular anomalies but also in directing management and predicting prognosis.

By leveraging both anatomical detail and dynamic functional information, MRI stands out as the most comprehensive imaging modality in this domain. Continued advancements in MR technology and improved understanding of vascular pathophysiology will further refine the radiologic approach, ultimately enhancing patient outcomes.

2. Aim and Objectives

To evaluate the role of conventional MRI and dynamic TWIST sequences in the accurate classification of soft tissue vascular anomalies.

3. Review of Literature

The classification and diagnosis of vascular anomalies have undergone significant refinement over the past few decades, with increasing emphasis on biological behaviour and imaging features. Early confusion in nomenclature and classification led to improper diagnosis and treatment. Historically, all vascular lesions were referred to generically as "hemangiomas," resulting in ambiguity and therapeutic errors[14]. The evolution of classification systems, beginning with Mulliken and Glowacki's biological model and expanding with radiologic contributions from Jackson *et al.* and the ISSVA, has been instrumental in establishing a unified framework for clinical and radiological diagnosis[15-17].

3.1 Biologic and Clinical Classification

Mulliken and Glowacki's landmark classification divided vascular anomalies based on endothelial turnover and histopathological characteristics into two main categories: vascular tumours and vascular malformations. Vascular tumours, like infantile hemangiomas, are characterised by endothelial proliferation and a biphasic lifecycle with proliferative and involutional stages. In contrast, vascular malformations are structural anomalies of the vasculature without proliferation and are present at birth, growing proportionately with the patient[15].

The ISSVA (International Society for the Study of Vascular Anomalies) classification adopted and expanded this model. It further subcategorised vascular malformations into low-flow (venous, lymphatic, capillary, or combinations thereof) and high-flow types (arteriovenous malformations and fistulas), based on their hemodynamic characteristics. This flow-based classification aligns well with imaging findings and has since become a cornerstone in the radiological evaluation of these lesions[17,18].

3.2 Role of Imaging in Vascular Anomalies

Historically, Ultrasound (US) with colour Doppler was the initial modality of choice for superficial vascular anomalies, due to its accessibility and ability to distinguish between high- and low-flow lesions[19]. However, it has limitations in assessing deeper structures, evaluating full lesion extent, and differentiating between complex combined malformations, especially when deep tissues or bone involvement is suspected.

MRI has emerged as the imaging modality of choice due to its high soft-tissue resolution, multiplanar capabilities, and superior contrast differentiation between lesion components[20]. It provides detailed information regarding anatomic extent, tissue composition, presence of flow voids, cystic areas, fat components, vascular enhancement, and relationship to adjacent neurovascular structures.

On spin-echo sequences, flow voids typically indicate fast-flowing blood in arteries or veins and are suggestive of AVMs or AVFs. In contrast, venous and lymphatic malformations often appear as T1 hypointense and T2 hyperintense lesions without flow voids, possibly with phleboliths or fluid-fluid levels due to thrombus or hemorrhage[21,22].

3.3 Dynamic MRI and Hemodynamic Assessment

The introduction of dynamic contrast-enhanced MRI techniques, especially TWIST (Time-resolved angiography With Interleaved Stochastic Trajectories), has transformed the functional evaluation of vascular anomalies. TWIST sequences permit the acquisition of rapid, high-resolution time-resolved 3D MR angiography, allowing visualisation of arterial inflow, venous drainage, contrast wash-in/wash-out, early venous filling, and shunting[23]. These dynamic sequences can distinguish:

- AVMs: Characterised by early arterial enhancement, presence of nidus, direct AV shunting, and prominent draining veins.

- Hemangiomas and venous malformations: Show delayed progressive enhancement, contrast retention, and absence of AV communication[18,22].

These findings are crucial for interventional planning, such as embolisation for AVMs or sclerotherapy for low-flow lesions, and for avoiding incomplete or inappropriate treatments.

3.4 Hemangiomas: Imaging Characteristics

Infantile hemangiomas, the most common vascular tumour of infancy, appear during the first weeks of life and undergo rapid proliferation followed by spontaneous involution. On MRI, they present as well-defined lobulated masses, T1 isointense, T2 hyperintense, and show intense early homogeneous enhancement during the proliferative phase. In the involution phase, they show fatty replacement and decreased enhancement[24]. Importantly, no arteriovenous shunting is seen, helping distinguish them from AVMs.

Congenital hemangiomas, in contrast, are fully formed at birth, do not follow the typical growth-involution cycle, and can be Rapidly Involuting (RICH) or Non-Involuting (NICH). On MRI, they may show central thrombosis, flow voids, or AV shunting, which may complicate diagnosis and necessitate histological confirmation[25].

3.5 Venous and Lymphatic Malformations

Venous malformations are the most common low-flow vascular malformations. Clinically compressible and bluish in appearance, they appear on MRI as lobulated T2 hyperintense masses, often with phleboliths visible as signal voids, and demonstrate slow progressive enhancement on delayed post-contrast images[26]. The presence of phleboliths is considered pathognomonic. These lesions are often treated with percutaneous sclerotherapy, and MRI is essential for planning and follow-up.

Lymphatic malformations are subdivided into microcystic and macrocystic types. Macrocystic variants show large cystic spaces, fluid-fluid levels, and rim/septal enhancement post-contrast. Microcystic types are more infiltrative, with diffuse enhancement, and often mimic venous malformations. MRI is key to classification, which directly influences treatment modality selection[27].

3.6 High-Flow AVMs and AVFs

AVMs, though less common, are high-flow lesions with potentially life-threatening complications including haemorrhage, cardiac overload, and functional impairment. MRI shows absence of a defined soft tissue mass, multiple flow voids, early arterial enhancement, and rapid venous filling on dynamic sequences[22,28]. TWIST MR angiography enables precise localisation of the nidus, identification of feeding arteries, and draining veins, essential for successful embolisation.

AVFs, though similar in imaging to AVMs, represent a single communication between artery and vein without a nidus. Chronic AVFs may enlarge and simulate AVMs[29]. Differentiating these lesions is important, as AVFs may be amenable to direct closure.

3.7 Post-Treatment MRI Monitoring

MRI is also indispensable in treatment follow-up. After sclerotherapy, venous malformations show T2 signal loss, volume reduction, and reduced enhancement, while residual or recurrent AVMs show persistent early enhancement and nidus perfusion[30]. Advanced imaging ensures that therapy is effective and helps avoid over- or under-treatment.

The literature clearly establishes that MRI, especially with dynamic sequences like TWIST, plays a central role in the classification, diagnosis, and follow-up of soft tissue vascular anomalies. The biologic and flow-based classification models are well complemented by the detailed anatomical and hemodynamic information provided by modern MRI. The differentiation between low-flow and high-flow lesions is critical, as it influences management strategy and prognosis. An integrated understanding of imaging features, clinical history, and classification systems enables precise, safe, and personalised treatment for patients with vascular anomalies.

4. Materials and Methods

Study Design: Descriptive study
Study Population: 3 patients with suspected vascular anomalies
Study Centre: Department of Radiodiagnosis at Madurai Medical College and Government Rajaji Hospital
Inclusion Criteria: Newly suspected case of vascular anomalies.

Exclusion Criteria: Patients with claustrophobia, implanted cardiac pacemaker, allergic to contrast material (Gadolinium) and patients with elevated renal parameters

4.1 Technique

All patients underwent MRI evaluation using a 1.5 Tesla SIEMENS Magnetom Amira scanner. Informed consent was obtained prior to imaging.

The imaging protocol was standardised and included both conventional and dynamic MRI sequences. Conventional sequences comprised axial and coronal T1-weighted, T2-weighted, and Short Tau Inversion Recovery (STIR) sequences. These were used to evaluate the anatomical extent of the lesion, tissue characteristics, and signal intensity. Special sequences such as Time-of-Flight MR Angiography (TOF-MRA) and MR Venography (MRV) were included when indicated.

Dynamic evaluation was performed using TWIST (Time-resolved angiography with interleaved stochastic trajectories), a contrast-enhanced MR angiography technique, followed by delayed postcontrast imaging using T1 Volumetric Interpolated Breath-hold Examination (VIBE).

All imaging findings were analysed for the presence of soft tissue components, flow voids, nidus formation, arterial or venous involvement, enhancement characteristics, and cystic areas. Based on the imaging profile, each case was classified as a vascular tumour or vascular malformation, and further subtyped into high-flow or low-flow categories. The diagnoses were correlated with clinical findings for final confirmation.

5. Results (Including Observations)

Three patients with suspected soft tissue vascular anomalies were evaluated using conventional and dynamic MRI sequences. Imaging findings were analysed in terms of anatomical extent, signal characteristics, enhancement patterns, vascular flow features, and classification into vascular tumours and vascular malformations (high- or low-flow lesions). Each case demonstrated distinct imaging characteristics that enabled definitive diagnosis (Table 1, Figures 1-11).

Table 1. Data sheet of patients

Variable	Category	Frequency (n)	Percentage (%)
Age group	<15 yrs	2	66.7%
	≥15 yrs	1	33.3%
Sex	Male	3	100%
	Female	0	0%
Well-defined tumour	Present	1	33.3%
	Absent	2	66.7%
Flow voids	Present	1	33.3%
	Absent	2	66.7%
Nidus	Present	1	33.3%
	Absent	2	66.7%
Arterial feeders	Present	1	33.3%
	Absent	2	66.7%
Early arterial enhancement	Present	1	33.3%
	Absent	2	66.7%
Progressive enhancement	Present	2	66.7%
	Absent	1	33.3%
Delayed enhancement	Present	2	66.7%
	Absent	1	33.3%
Cystic spaces	Present	1	33.3%
	Absent	2	66.7%
Final diagnosis	Combined venolymphatic malformation	1	33.3%
	Arterio-venous malformation	1	33.3%
	hemangioma	1	33.3%

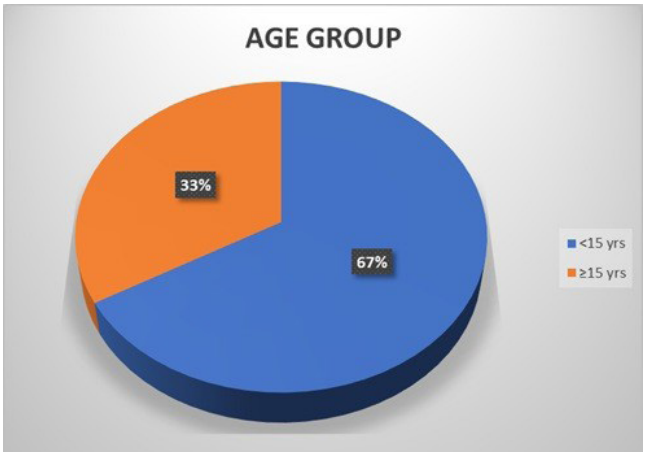

Figure 1. Distribution of participants by age group.

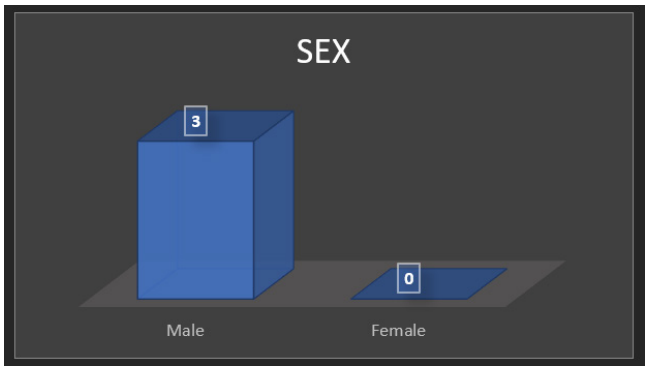

Figure 2. Distribution of participants by gender group.

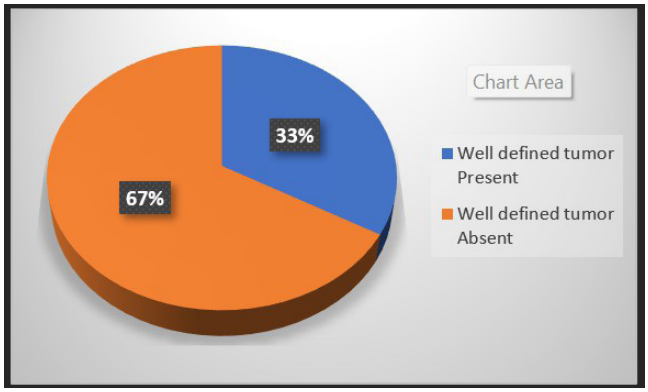

Figure 3. Distribution of participants by well-defined tumour.

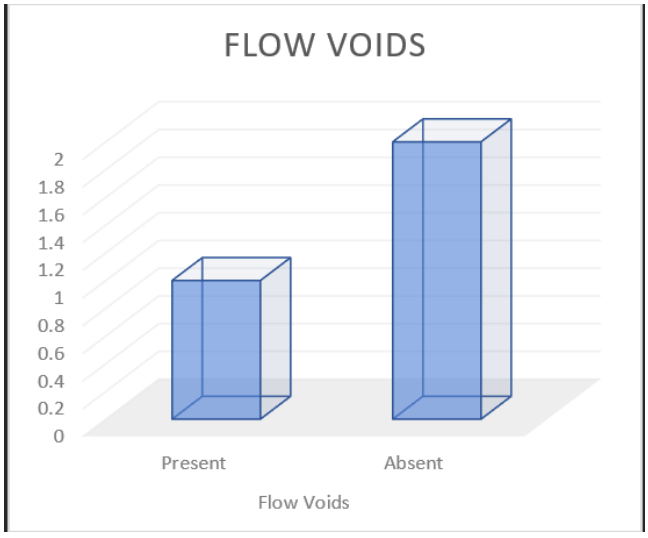

Figure 4. Distribution of participants by flow voids.

5.1 Case-wise Inferences

Case 1: (14 years, Male)

Diagnosis: Combined Venolymphatic Malformation

- Conventional MRI showed a septated soft tissue lesion with cystic spaces, involving the subcutaneous and muscular planes of the right buccal, pre-maxillary and pre-zygomatic region. No flow voids noted (Figures 12, 13). In dynamic MRI (TWIST), the lesion showed progressive enhancement in the late venous phase (indicating a low-flow lesion). No arterial and early venous phase enhancement (excluding high flow lesion). No dilated arterial feeders or draining veins. No direct arteriovenous

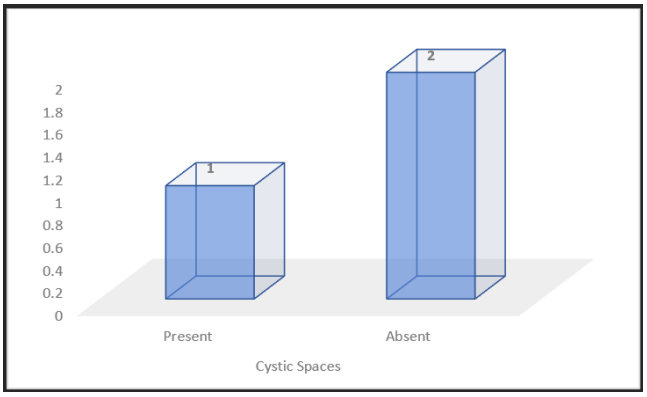

Figure 5. Distribution of participants by cystic spaces.

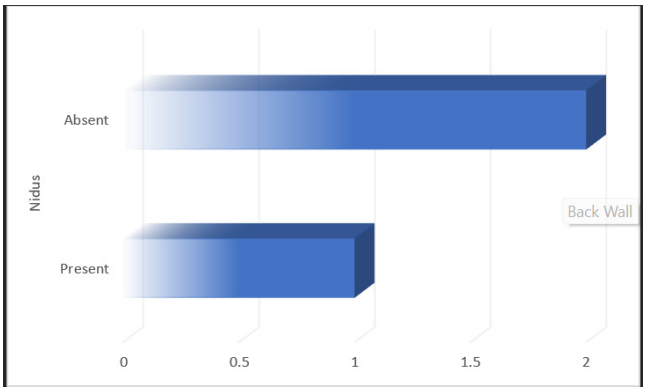

Figure 6. Distribution of participants by nidus.

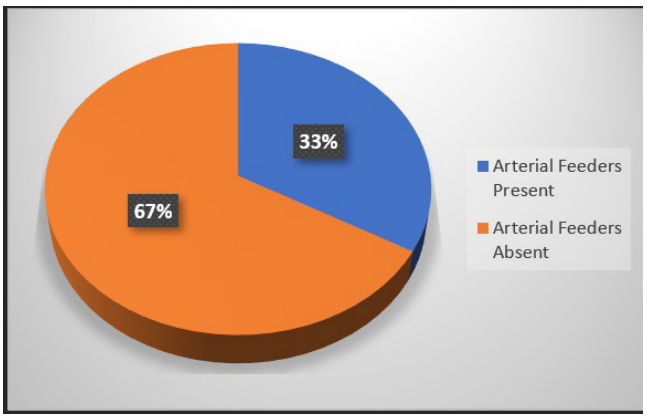

Figure 7. Distribution of participants by arterial feeders.

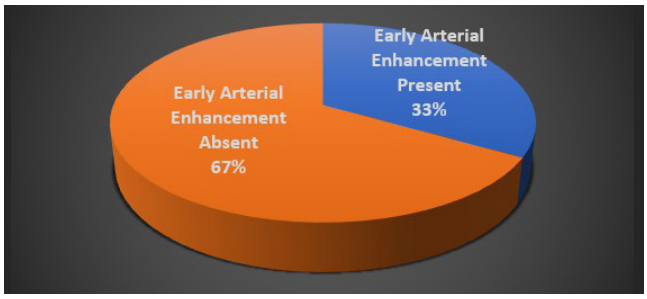

Figure 8. Distribution of participants by early arterial enhancement.

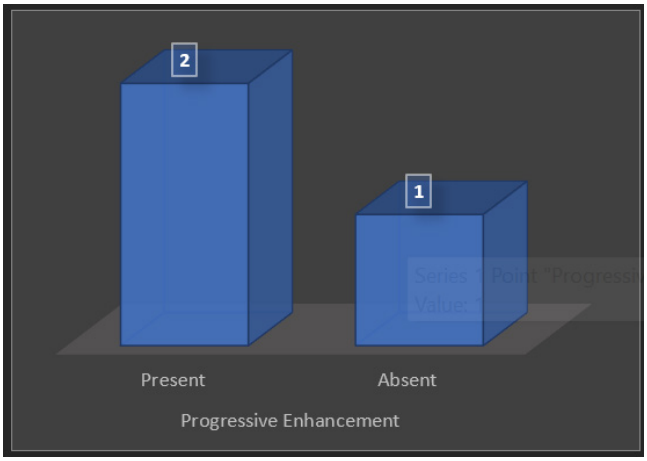

Figure 9. Distribution of participants by progressive enhancement.

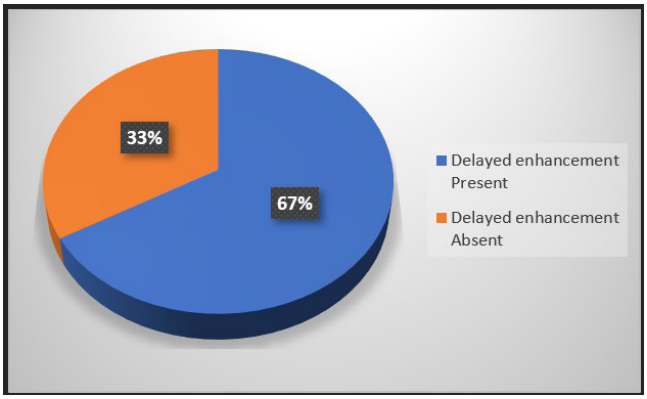

Figure 10. Distribution of participants by delayed enhancement.

communication (Figure 14). Post contrast T1 VIBE sequence showed delayed enhancement of the lesion with a few septated cystic spaces showing enhancement of the walls and septa (Figure 15).

- These findings were consistent with a low-flow vascular malformation, specifically combined Veno-lymphatic malformation.

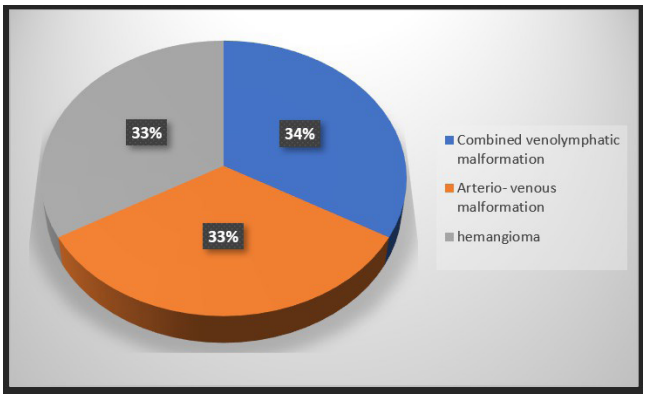

Figure 11. Distribution of participants by final diagnosis.

- Absence of nidus, arterial feeders and draining veins further supported the diagnosis and helped differentiate it from high-flow lesions like AVMs.

Case 2: (12 years, Male)
Diagnosis: Arteriovenous Malformation (AVM)

- Conventional MRI revealed dilated tortuous flow voids, with a nidus seen in the left mandibular region, involving the buccinator muscle, masseter muscle, gingivobuccal sulcus and extending to the alveolar processes of the mandible (Figures 16). TOF MR angiogram and venogram showed dilated arterial feeders and draining veins (Figure 17). Dynamic MRI (TWIST) showed early arterial phase filling of the nidus via dilated arterial feeders, and drains via dilated facial veins, which further drained into the left IJV. Early enhancement of the left IJV was noted in the arterial phase. The nidus showed progressive contrast washout (Figures 18, 19).
- These classic features indicate a high-flow AVM.
- Absence of progressive enhancement further excluded low-flow malformations.

Case 3: (32 years, Male)
Diagnosis: Hemangioma

- Conventional MRI revealed well well-circumscribed small soft tissue lesion with dilated vascular spaces in the middle finger, superficial to the middle phalanx (Figures 20). In the dynamic MRI -TWIST sequence, the lesion showed no arterial or early venous phase enhancement. Progressive enhancement noted in the late venous phases. No evidence of dilated arterial feeders or draining veins (Figure 21). Persistent delayed

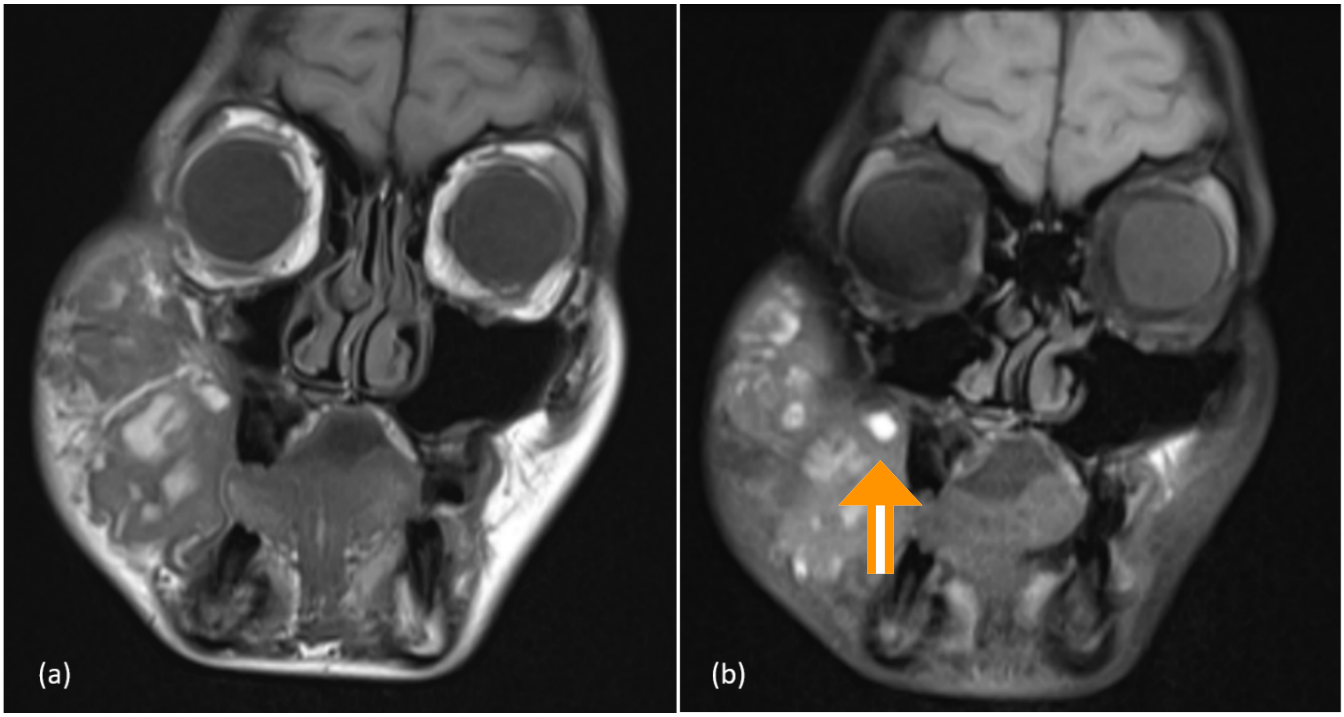

Figure 12. CASE 1: **(a)** T1, **(b)** T1 FS coronal sections of face showing soft tissue mass with dilated vascular spaces in the right cheek, containing blood components appearing as bright signal foci in T1 FS sequence (arrow).

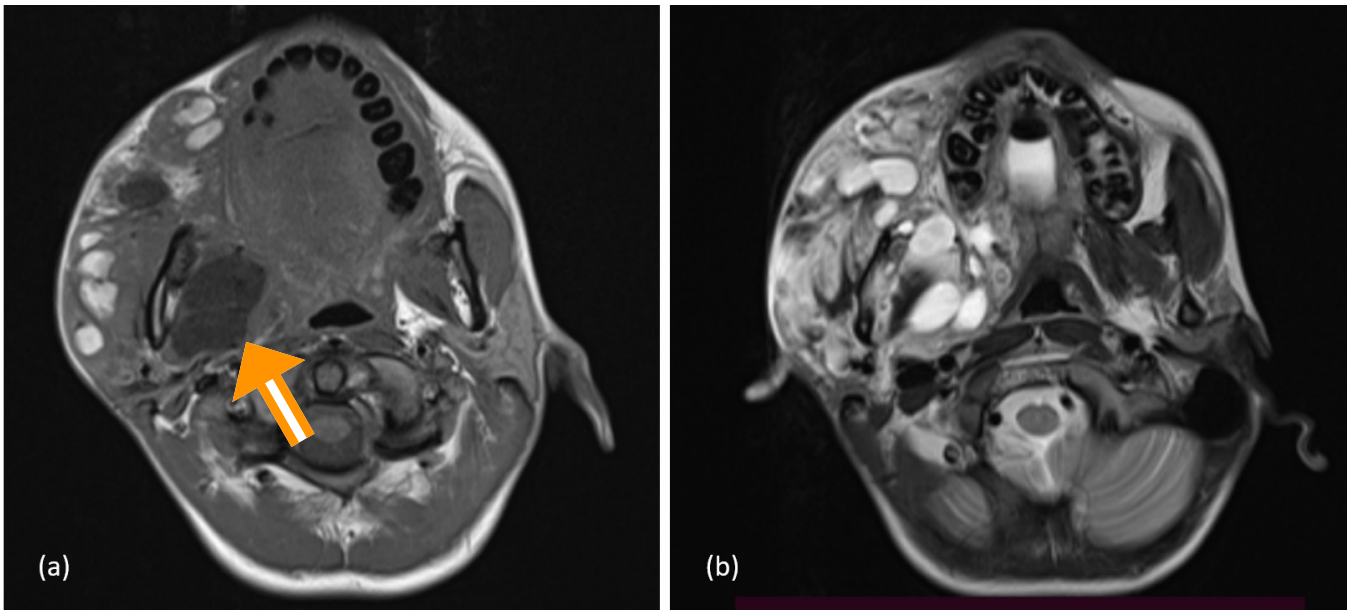

Figure 13. **(a)** T1 axial and **(b)** T2 axial sections show the lesion involving the right masticator space and premaxillary subcutaneous plane. A few T1 hypointense cystic spaces were noted (arrow). No evidence of flow voids noted within the lesion.

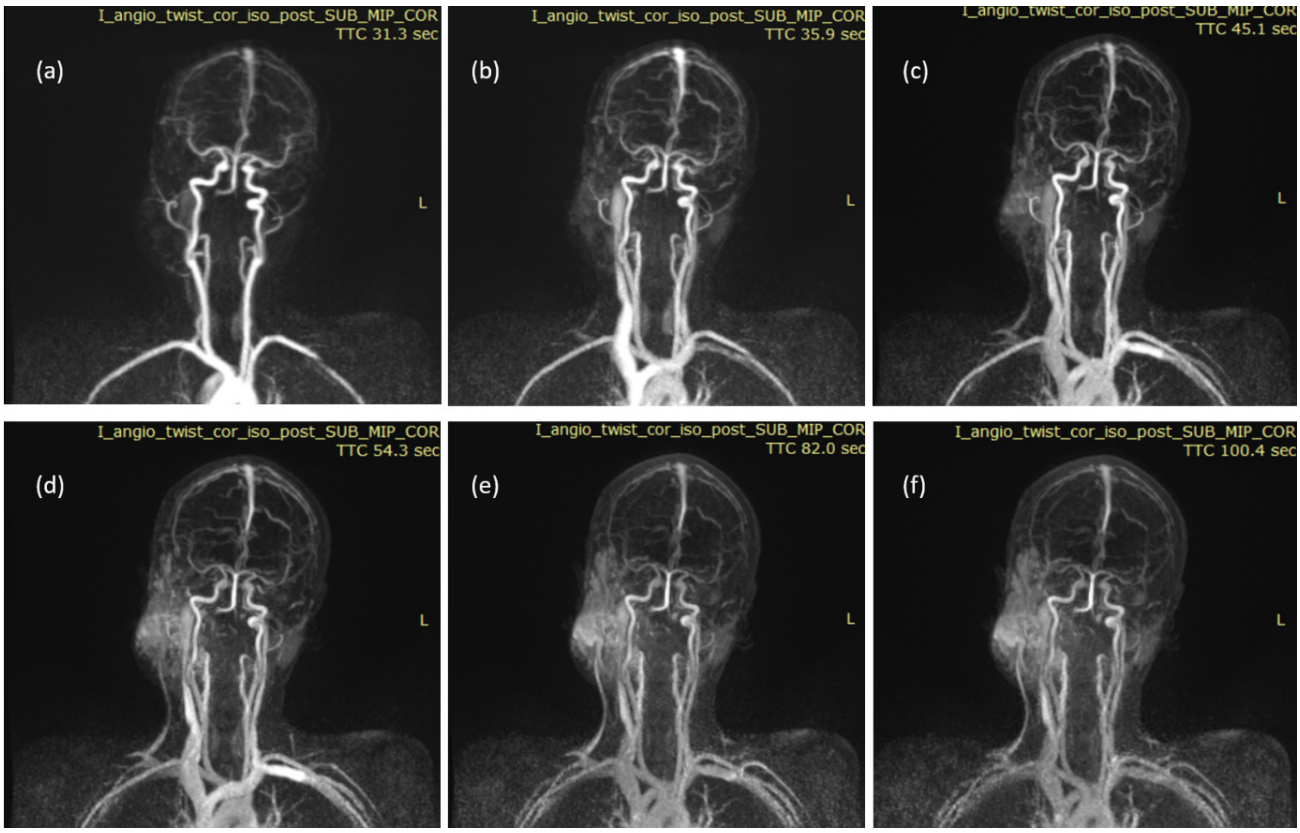

Figure 14. **(a-f).** Dynamic contrast MRI – TWIST sequence at various time points, showing progressive enhancement of the lesion in the late venous phase. No arterial and early venous phase enhancement. No dilated arterial feeders or draining veins.

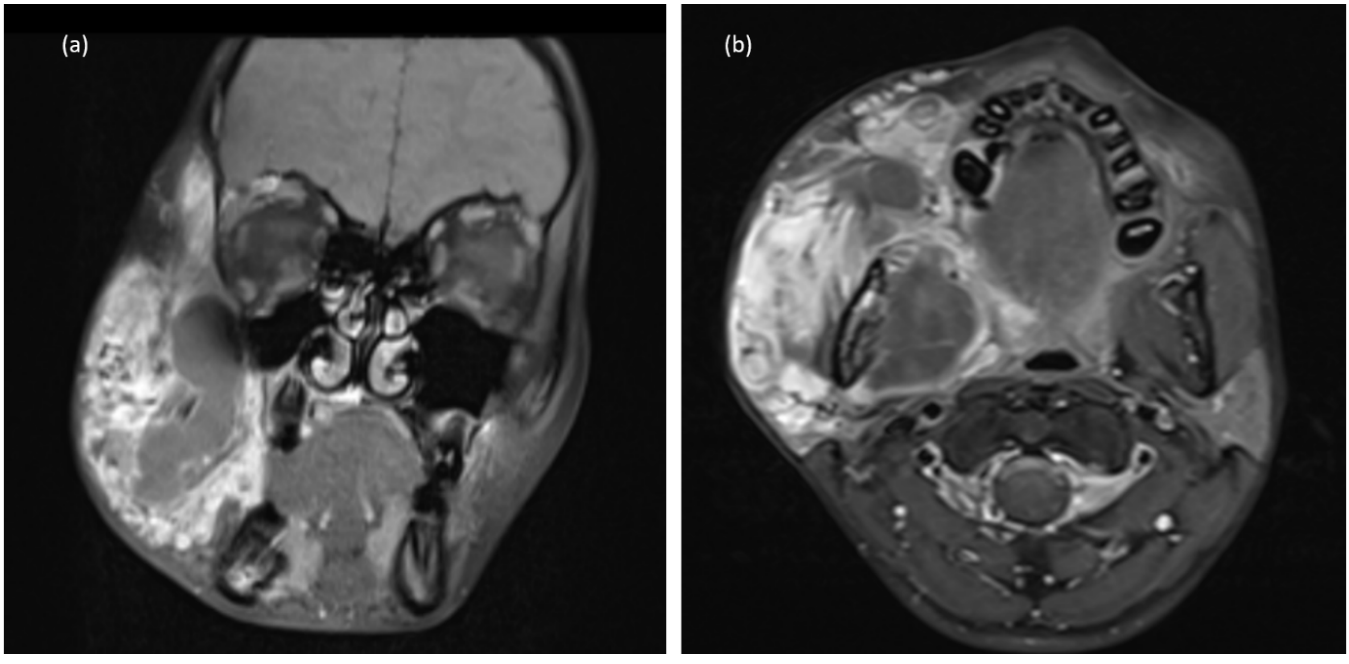

Figure 15. **(a)** Coronal and **(b)** axial post-contrast VIBE fat-suppressed sequence, shows delayed enhancement of the lesion with few septated cystic spaces showing enhancement of the walls and septa. Features suggestive of combined Veno-lymphatic malformation.

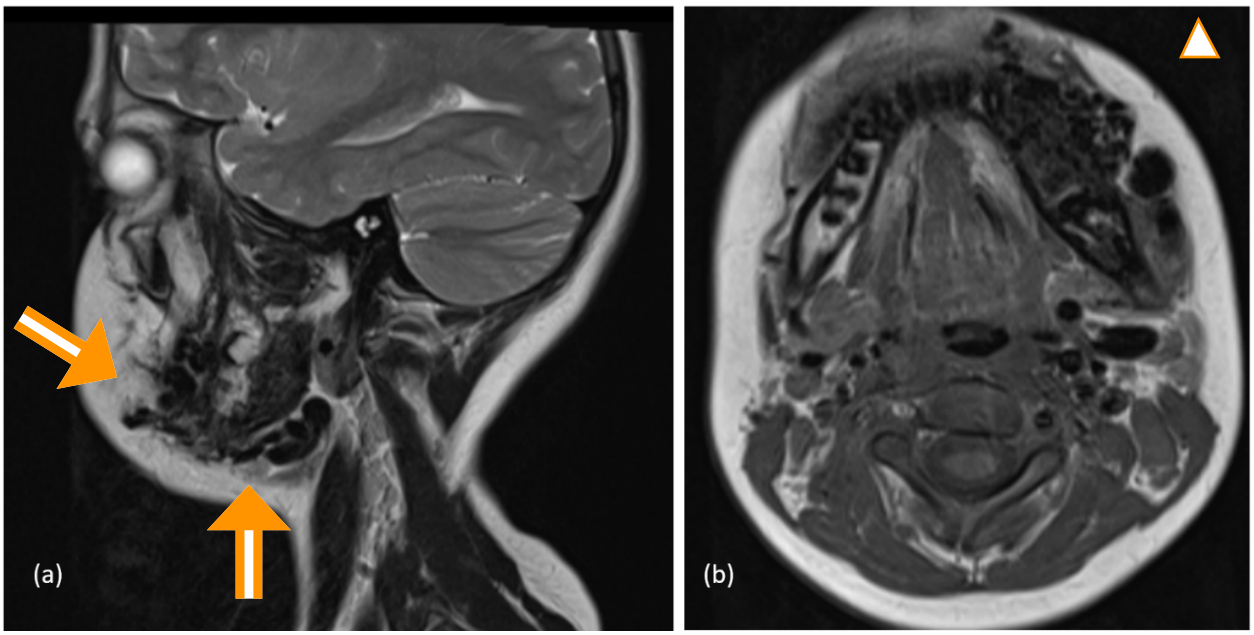

Figure 16. CASE 2: **(a)** T2 sagittal **(b)** T1 axial sections of the MRI neck show dilated tortuous flow voids (arrows), with a nidus seen in the left mandibular region (arrow head), involving the buccinator and body of mandible.

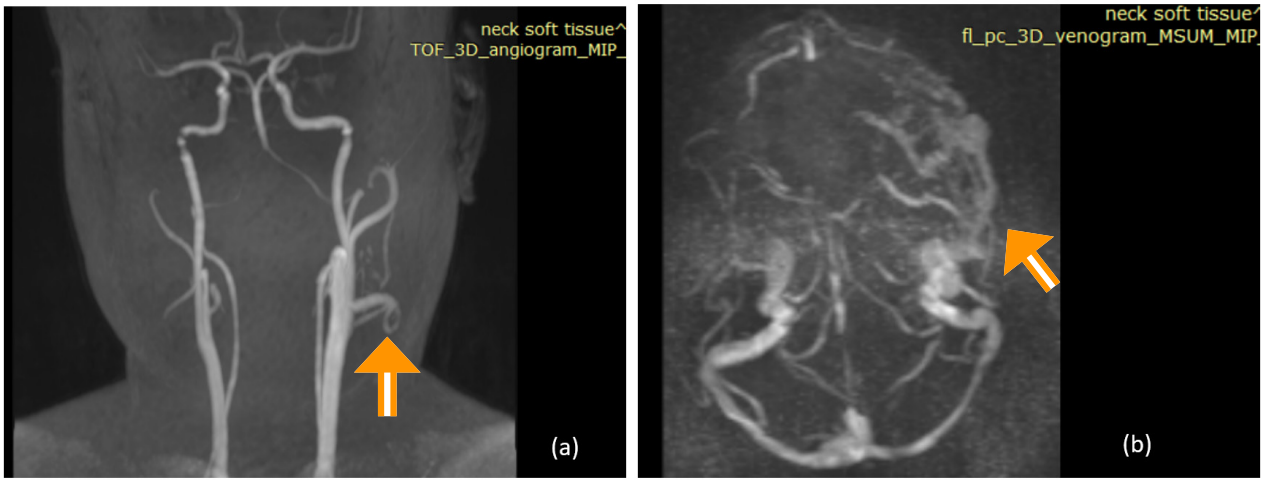

Figure 17. **(a)** TOF MR angiogram and **(b)** MR venogram show dilated arterial feeders and draining veins (arrows).

enhancement noted in the post-contrast T1 VIBE sequence (Figure 22).

- Findings suggestive of Hemangioma of the middle finger with low flow component.
- The absence of arterial feeders and early enhancement differentiates it from AVMs.

6. Discussion

The current case series analysed conventional and dynamic MRI features of three vascular anomalies, combined veno-lymphatic malformation, arteriovenous malformation (AVM), and hemangioma, using spin echo sequences and contrast-enhanced dynamic MRI (TWIST) and post-contrast T1 VIBE. The imaging features were consistent with previously documented diagnostic patterns and support the role of MRI in vascular anomaly characterisation (Table 2).

Case 1, diagnosed as a combined venolymphatic malformation, showed a soft tissue lesion with dilated vascular spaces and few cystic spaces without flow voids, nidus, or AV communication, and demonstrated progressive enhancement in TWIST sequence and delayed enhancement on post-contrast

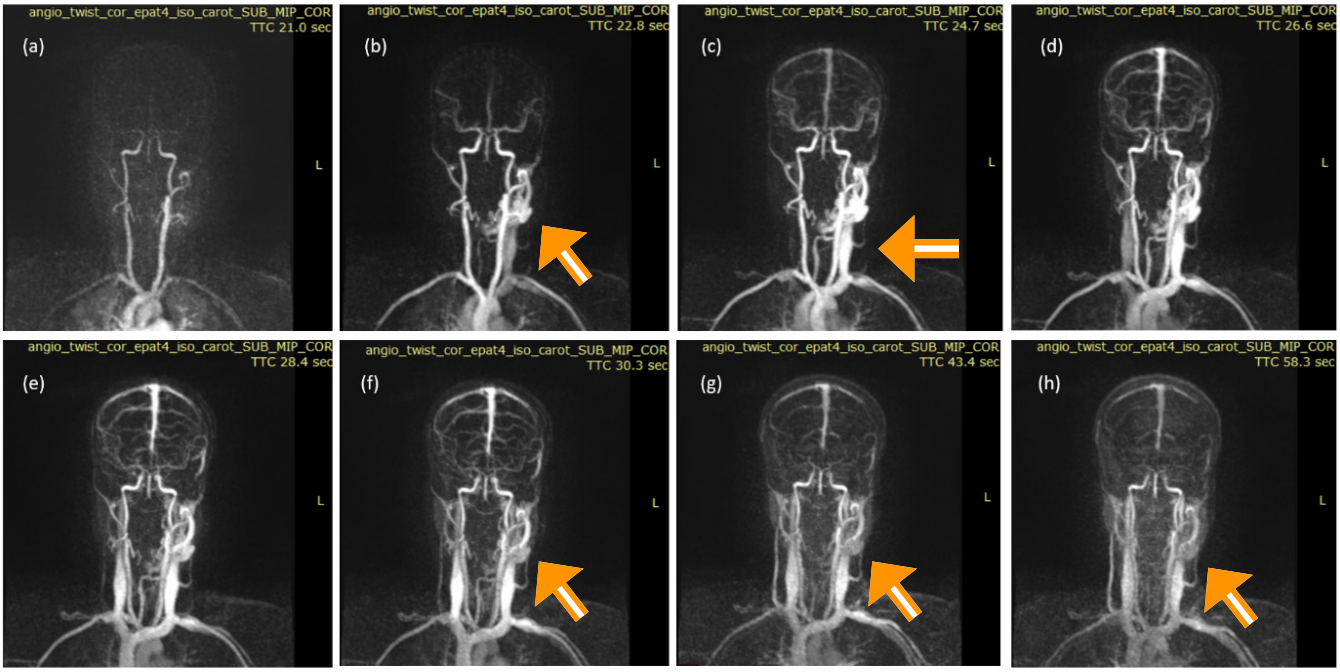

Figure 18. Dynamic contrast MRI TWIST sequence shows early arterial phase filling of the nidus via dilated arterial feeders **(b)**, and drains via dilated facial veins, which further drains into the left IJV. The nidus shows progressive contrast washout **(f-h)**.

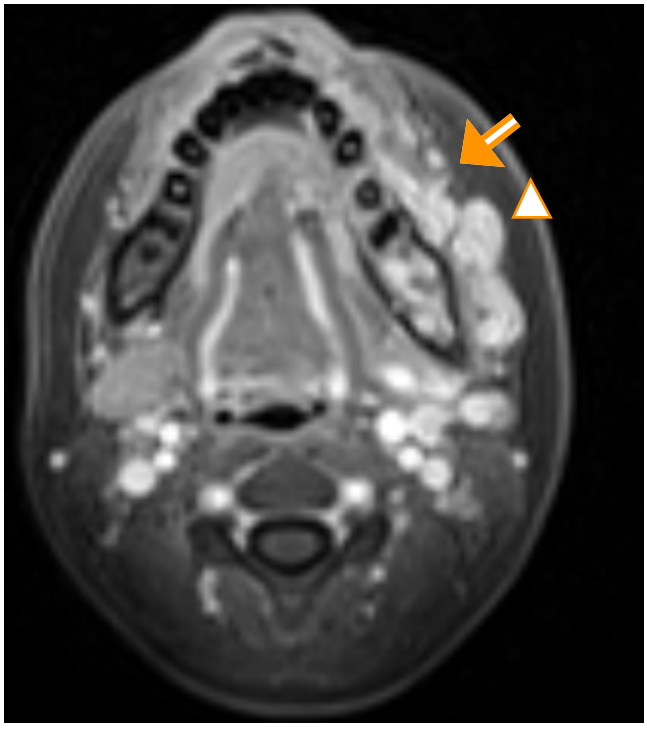

Figure 19. Axial post contrast VIBE fat suppressed sequence shows relative contrast washout in the nidus (arrow), compared to the dilated draining facial veins (arrow head). Features suggestive of arterio-venous malformation.

sequences. These findings are characteristic of low-flow malformations with lymphatic components, as described in the International Society for the Study of Vascular Anomalies (ISSVA) classification[14]. Similar results were reported by Dubois *et al.*, where MR imaging revealed multiloculated cystic spaces with gradual enhancement in lymphatic and veno-lymphatic malformations[15].

In Case 2, the imaging findings clearly supported the diagnosis of a high-flow AVM. The presence of flow voids, a nidus, arterial feeders, and draining veins with early arterial enhancement and contrast washout is pathognomonic for AVMs. These features are aligned with the observations made by Mulliken and Young[16], who emphasised that dynamic contrast imaging and early arterial phase enhancement are pivotal in diagnosing AVMs. Moreover, Bisdorff *et al.* emphasised the diagnostic value of TWIST sequences in delineating fast-flow lesions and AVMs with high accuracy[17].

Case 3 was identified as a hemangioma, which showed a well-defined lesion with no flow voids or dilated vascular spaces and exhibited progressive and delayed enhancement. These findings are indicative

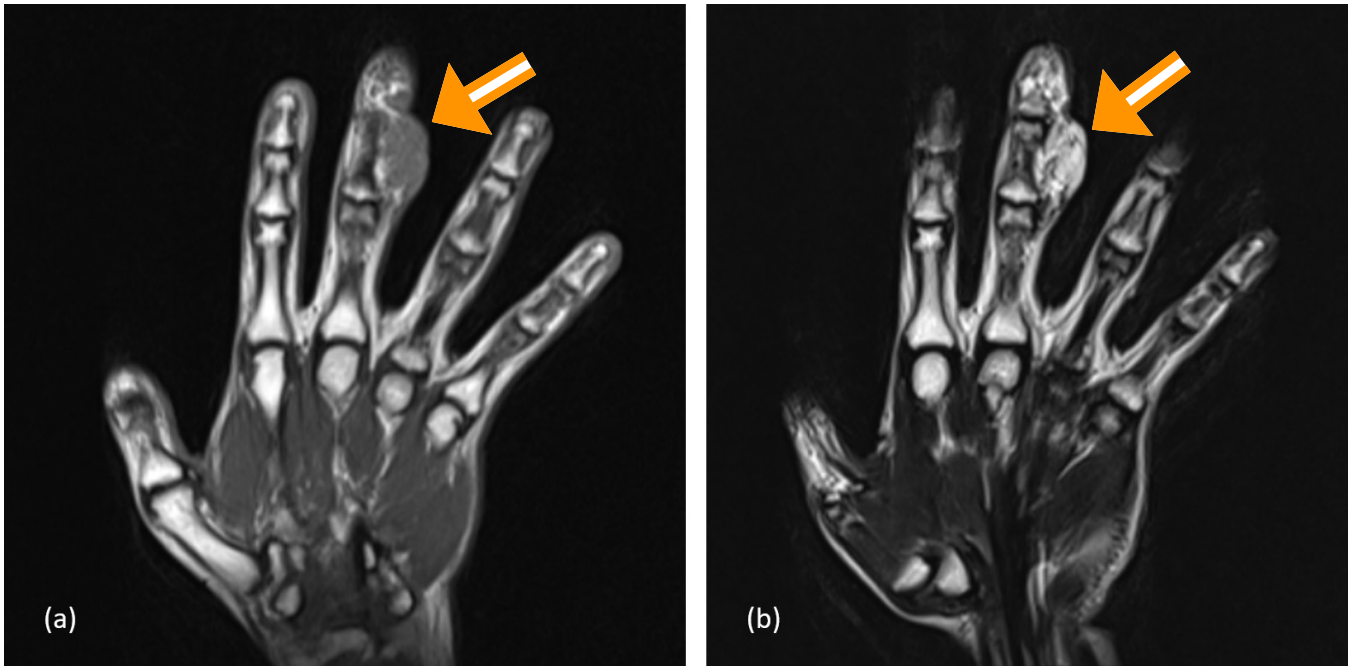

Figure 20. CASE 3: **(a)** T1 coronal section and **(b)** T2 coronal sections of the hand show a relatively well-circumscribed small soft tissue lesion with dilated vascular spaces in the middle finger, superficial to the middle phalanx (arrows).

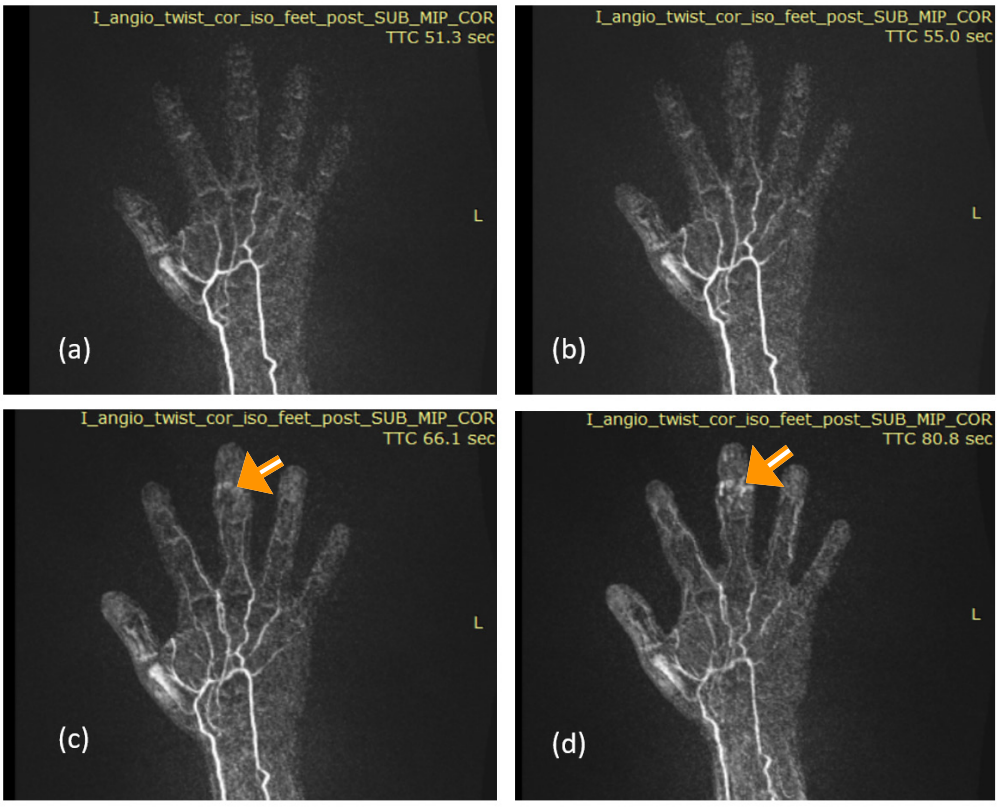

Figure 21. **(a-d)** Dynamic contrast MRI TWIST sequence: the lesion shows no arterial or early venous phase enhancement. Progressive enhancement noted in the late venous phases. **(c, d)**. No evidence of the dilated arterial feeders or draining veins.

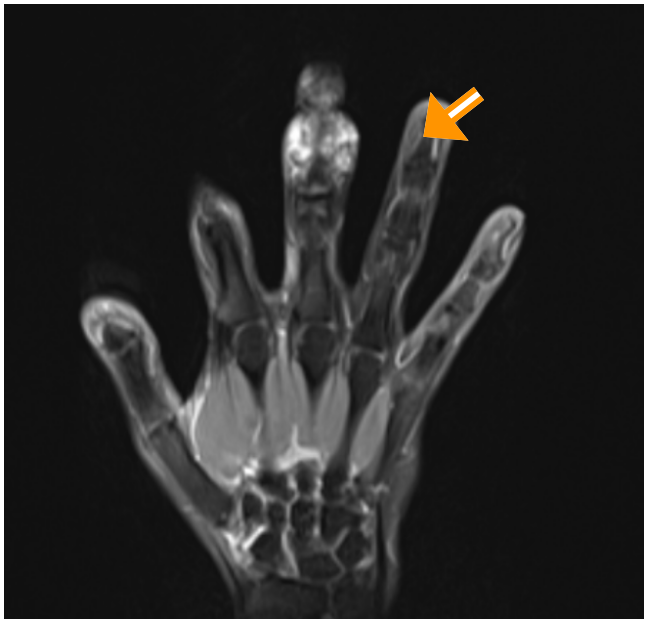

Figure 22. Coronal post-contrast VIBE fat-suppressed sequence: The lesion shows persistent delayed enhancement. Features suggestive of Hemangioma of the middle finger.

Table 2. Case-wise summary table

S. No.	Age	Sex	MRI Features	Diagnosis
1	14	M	Soft tissue lesion with Cystic spaces and septa, absent flow voids, progressive enhancement, enhancing septa and wall, no nidus, no arterial feeders, no direct AV communication.	Combined venolymphatic malformation
2	12	M	Flow voids, nidus, arterial feeders, draining veins, early arterial enhancement, AV shunting, contrast washout	Arteriovenous malformation
3	32	M	Well-defined soft tissue tumour, absent flow voids, showing progressive enhancement, post-contrast delayed enhancement, no direct AV communication, no nidus, no arterial feeders.	Hemangioma

of a slow-flow benign vascular tumour, in agreement with the study by Itkin *et al.*, who demonstrated that hemangiomas typically show centripetal enhancement with no arterial feeders or washout[18]. This pattern helps differentiate hemangiomas from AVMs and venolymphatic malformations, supporting accurate non-invasive diagnosis.

Comparison across the cases illustrates how MRI features—particularly flow voids, cystic spaces, vascular architecture, and enhancement dynamics—play a vital role in differentiating vascular anomalies. These observations are reinforced by literature suggesting that accurate MRI characterisation prevents unnecessary biopsies and aids treatment planning[19].

This series highlights the significance of combining spin echo and dynamic contrast-enhanced sequences like TWIST and post-contrast T1 VIBE sequence to enhance the diagnostic confidence in vascular lesions. MRI remains a gold standard, particularly in paediatrics and young adult populations, where ionising radiation should be minimised[20].

7. Summary and Conclusion

Vascular anomalies encompass a wide spectrum of congenital and acquired lesions involving abnormal development of blood vessels or lymphatic structures. Differentiating between vascular tumours (such as hemangiomas) and vascular malformations (such as venolymphatic malformations and arteriovenous malformations) is crucial for guiding appropriate clinical management.

This case series evaluated three patients across a wide age range, 12, 14, and 32 years each, diagnosed with a different vascular anomaly. Detailed analysis of spin echo sequences (T1WI and T2WI), dynamic TWIST imaging, and post-contrast sequences facilitated accurate differentiation based on lesion morphology, vascularity, enhancement kinetics, and presence or absence of flow-related features.

A major strength of this study is the application of MRI, which offers several critical advantages in the evaluation of vascular anomalies. Unlike CT or conventional angiography, MRI is non-ionising, making it particularly suitable for paediatrics and young adult populations. Its superior soft-tissue contrast allows for detailed visualisation of lesion architecture, including

the identification of cystic components, septations, and tissue infiltration. Additionally, MRI provides a multiparametric assessment combining structural and functional data, which aids in distinguishing between slow-flow and high-flow lesions. Spin echo sequences reveal tissue composition and basic morphology, while dynamic sequences like TWIST capture hemodynamic flow characteristics in real time, helping identify AV shunts, early enhancement, or delayed washout patterns.

Another advantage of MRI is the ability to perform comprehensive imaging in a single session without exposing the patient to iodinated contrast or ionising radiation. This is especially important for vascular lesions requiring repeated imaging during follow-up or after intervention. Furthermore, MRI offers multiplanar capabilities, allowing accurate pre-surgical or pre-interventional planning by defining lesion extent, proximity to vital structures, and flow dynamics.

Comparative analysis with the literature reinforces the findings. Dubois *et al.* highlighted the importance of progressive enhancement and cystic components in diagnosing venolymphatic malformations[21]. Mulliken and Young underscored the value of early arterial enhancement and flow-related features in AVMs[22], while Itkin *et al.* described the slow and delayed enhancement patterns typical of hemangiomas[23]. Donnelly *et al.* further confirmed MRI's pivotal role in differentiating vascular tumours from malformations, which has a direct impact on clinical decisions and avoids unnecessary biopsy or treatment delay[24].

The current series demonstrates that incorporating dynamic contrast-enhanced MRI, especially TWIST and post-contrast T1 VIBE sequences, significantly enhances diagnostic confidence. The ability to visualise real-time flow, detect nidus formation, differentiate enhancement patterns, and assess lesion boundaries allows for precise classification based on ISSVA guidelines and supports appropriate clinical pathways such as sclerotherapy, embolisation, or surgical resection.

In conclusion, MRI is an indispensable tool in the diagnosis and evaluation of vascular anomalies. Its non-invasive nature, high soft-tissue contrast, dynamic imaging capabilities, and radiation-free protocol make it ideal for repeated assessments, especially in children and young adults. Through three varied cases combined venolymphatic malformation, AVM, and hemangioma, this study illustrates the power of MRI in providing accurate, detailed, and clinically relevant information. Recognising and interpreting the unique imaging features of each lesion type using spin echo and dynamic sequences is essential for timely diagnosis, proper classification, and successful management of vascular anomalies.

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