

## REVIEW ARTICLE

# Imaging of Pediatric Neck Masses

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## ABSTRACT

Pediatric neck masses comprise a wide spectrum of entities, benign and malignant. The role of imaging is to characterize these lesions, in order to better determine which can be expectantly managed and which require immediate intervention. An important consideration in the pediatric population is ionizing radiation; while X-ray and CT can be useful, radiation can have harmful effects, particularly in children. In this article, we review imaging feature of common pediatric neck masses, with emphasis on radiation sparing modalities (ultrasound and MRI) when possible.

**Keywords:** Computed tomography, Magnetic resonance imaging, Neck mass, Pediatric, Ultrasound.

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## INTRODUCTION

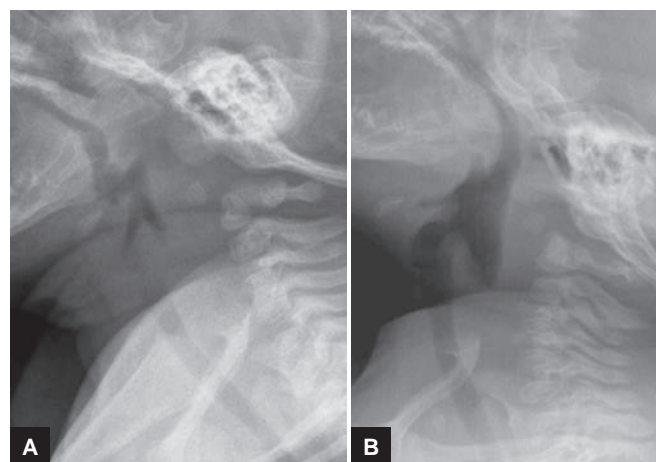
Neck masses in children comprise a broad range of entities. They can be divided into malignant and non-malignant pathology and may occur during or after development. Though the majority of neck masses can be managed conservatively, some require prompt and accurate diagnosis and possibly surgical intervention. Imaging plays an essential role in assessment, confirming suspected diagnoses, or providing additional differential diagnoses. In cases where a diagnosis has been made by exam alone, imaging can be useful in determining anatomic location and boundaries of the mass while also excluding possible complications.

Plain radiography and ultrasound are often used in initial evaluation. Anteroposterior and lateral radiographs of the neck can be extremely useful in children presenting with suspected airway compromise due to portability, speed, and ability to quickly assess for critical diagnoses requiring immediate intervention (e.g., epiglottitis). In critically ill patients, a single lateral view can be utilized.<sup>1</sup> However, radiographs are limited in characterizing the morphology of neck masses. Neck radiographs are also

limited by position dependence; specifically, patients who are not in an appropriate hyperextended position on lateral radiographs may demonstrate pseudothickening of the prevertebral soft tissues (Figs 1A and B).

Ultrasound (US) is considered the preferred modality in the initial assessment of most palpable or superficial pediatric neck masses. Ultrasound provides several advantages, including portability, accessibility, affordability, and lack of radiation exposure. Ultrasound is able to determine the presence of solid, cystic, and/or calcified components within masses while determining the presence of associated vascularity with color Doppler. However, US has its limitations. Primarily, it is inherently operator dependent, and visualization of masses is highly variable. In patients who are unable to lie still, US can be nondiagnostic. Finally, in deep neck lesions, the depth of US penetration may be insufficient.

Contrast-enhanced computed tomography (CT) is often the first step in the workup of adult neck masses, but its utilization in the pediatric population is limited because of concerns about exposure to ionizing radiation. Computed tomography provides many distinct advantages including its ubiquity, speed, and ability to characterize the composition and location of lesions while simultaneously determining its mass effect on regional structures. The spatial resolution of CT (the ability to distinguish objects from one another) is excellent, and exceeds that of magnetic resonance imaging (MRI), which is better suited for contrast resolution (the ability to differentiate objects by their intensity in an image, i.e., the crispness



**Figs 1A and B:** Pseudo-thickening of the prevertebral tissues on radiography is demonstrated with neck flexion; (A) but tissues decrease in thickness with extension; and (B) arguing against true swelling

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of an image). However, the radiation exposure of CT is high, far exceeding that of plain radiography, tempering its use in children. In the emergent setting, CT is a reasonable choice, particularly in imaging a lesion in the deep neck spaces.

Magnetic resonance imaging often provides the most detailed characterization of soft tissue neck masses. Magnetic resonance imaging is often preferred over CT imaging in the nonemergent setting because of its lack of radiation exposure. However, MRI is limited by its high cost and relatively long scan times, which increase the likelihood of motion artifact. As a result, sedation is often required for MRI in younger patients, which carries its own risks. Given these considerations, MRI is not particularly useful in the emergent setting. A prominent advantage of MRI is in the evaluation of suspected vascular malformations, such that multiple phases of contrast enhancement can rapidly be acquired, allowing for distinction of the mass into a high- vs low-flow lesion; use of CT in such instances is prohibitive due to the high radiation dose of multiple phases.

Additional modalities may be utilized in specific clinical scenarios. Airway fluoroscopy has been employed in the work-up of inspiratory stridor, and allows dynamic visualization of the subglottic trachea. While this study is of most utility in assessing subglottic stenosis, subglottic masses, such as hemangiomas can be appreciated. Iodine-123 (I-123) scintigraphy can be performed to assess for ectopic thyroid tissue in a highly sensitive manner, as thyroid tissue will take up I-123 regardless of location.

Ultimately, some combination of different imaging modalities is often necessary in the diagnosis and/or management of a pediatric neck mass. The decision of which imaging modality to order often requires discussion with the radiologist as well as careful consideration of factors, such as radiation exposure, cost, and accessibility.

## INFECTIOUS/INFLAMMATORY

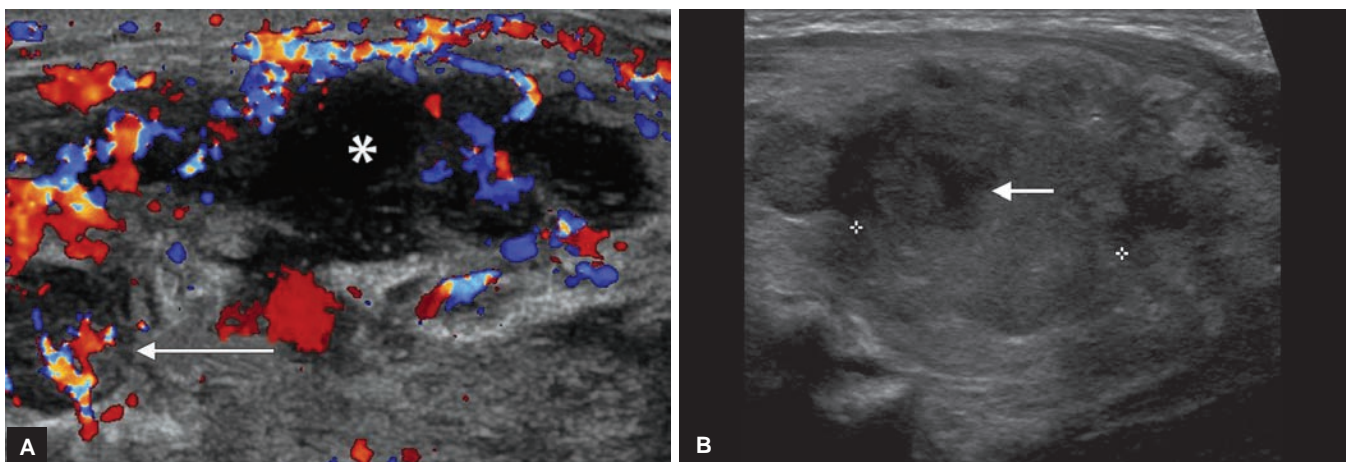
### Lymphadenitis

Enlarged cervical lymph nodes are the most common etiology for neck swelling in the pediatric population, often secondary to infection or inflammation. In the acute setting, bilateral cervical lymphadenitis is typically a result of viral upper respiratory infections. In contrast, the majority of cases involving acute unilateral cervical lymphadenitis are related to bacterial infections, most commonly streptococcal or staphylococcal.<sup>2</sup> Although most improve following medical management, infected nodes related to *Staphylococcus aureus* or group A strep have an increased predilection for suppuration and abscess formation, often requiring imaging.<sup>3</sup>

Ultrasound is the initial modality in assessment for possible complications (Fig. 2A). Simple reactive lymphadenopathy on US demonstrates preservation of normal nodal architecture, with an ovoid or elliptical shape along with a hypoechoic peripheral cortex and an eccentric hyperechoic fatty hilum. Color Doppler imaging may show variable vascularity. By contrast, suppurative nodes appear more hypoechoic, reflecting evolving liquefactive necrosis (Fig. 2B). On color Doppler, there is associated hypervascularity reflecting regional inflammation. Contrast-enhanced CT (or MRI) is beneficial in demonstrating extent of involvement. Suppurative nodes manifest with central cystic areas, demonstrating low attenuation on CT and hyperintense signal on T2-weighted imaging, with peripheral enhancement and regional inflammation.

### Retropharyngeal Abscess

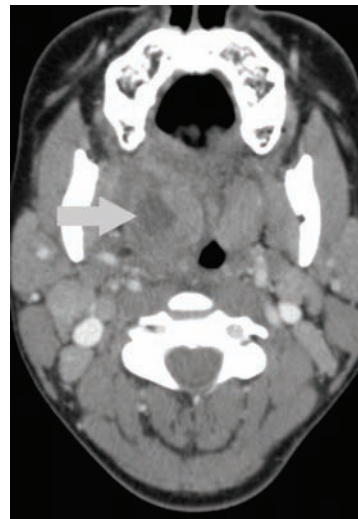
If untreated, suppurative lymph nodes can rupture leading to further spread of infection, most worrisome in the retropharyngeal space. Retropharyngeal abscesses most commonly present in patients less than 6 years old



**Figs 2A and B:** On US: (A) A debris filled abscess has formed (\*) in the setting of lymphadenitis (hypervascular node denoted by arrow). In a different patient; and (B) A hypoechoic focus (arrow) within an enlarged lymph node represents suppuration



**Fig. 3:** On MRI, postcontrast sagittal fat suppressed T1 demonstrates peripherally enhancing retropharyngeal fluid collections compatible with abscesses (arrows)



**Fig. 4:** Contrast enhanced axial CT demonstrates right tonsillar enlargement, with a hypodense irregularly marginated portion (arrow) demonstrating some but not complete peripheral enhancement, most likely representing phlegmon

and typically arise from infections involving the tonsils, nasopharynx, and adjacent spine. Patients often present with fever and neck pain, along with a limited range of neck motion. Lateral radiography demonstrates prevertebral soft tissue swelling with corresponding airway effacement. Rarely, gas within an abscess cavity may be appreciated on a lateral radiograph. If a retropharyngeal abscess is suspected, contrast-enhanced CT or MRI should be obtained, though CT is preferred in the emergent setting due to speed of acquisition. Computed tomography and MRI features include a peripherally enhancing collection with expansion of the retropharynx and corresponding airway compromise (Fig. 3). Cross-sectional imaging also assesses potential spread of infection inferiorly to mediastinum or laterally through the parapharyngeal space, and can evaluate for vascular complications such as internal jugular vein thrombosis or a carotid artery pseudoaneurysm. Prompt diagnosis and management with intravenous antibiotics as well as airway monitoring are essential.

### Tonsillitis/Peritonsillar Abscess

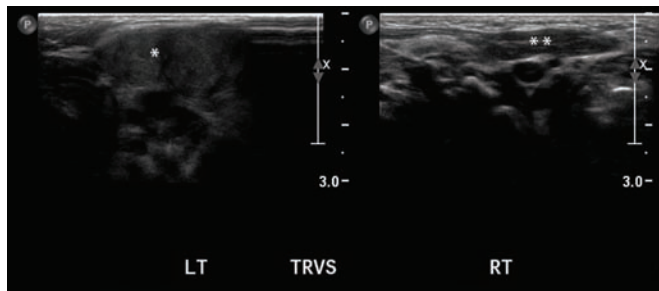
Though infrequent in patients under 10 years of age, tonsillitis is one of the more common head and neck infections of adolescence. Contrast-enhanced CT or MRI can be helpful in cases where the diagnosis is not clear on oropharyngeal examination or when concerned for complications such as an abscess (Fig. 4). As with a suspected abscess, CT is preferred in the emergent setting due to speed and accessibility. Contrast-enhanced CT will demonstrate enlarged inflamed tonsils with patchy, linear areas of enhancement. When purulent material extends beyond the tonsillar capsule, peritonsillar abscess can develop, and appears on CT as low-attenuation peripherally

enhancing collections in the parapharyngeal space, bordered medially by the tonsillar capsule and laterally by the superior pharyngeal constrictor muscle. These deep neck infections are critical and require emergent surgical drainage because of risk for further extension into the deep spaces of the neck and mediastinum.

Although contrast-enhanced CT is highly sensitive in the detection of deep neck infections, the distinction between phlegmonous inflammation and abscess can be subtle. On CT, a phlegmon can appear as a low-attenuation mass, though the attenuation in a phlegmon is not as low as in an abscess, and often lacks a complete rim of peripheral enhancement.

### Tuberculosis

In the immunocompromised patient presenting with a superficial neck mass, particularly those with human immunodeficiency virus, adenitis secondary to tuberculosis (TB) should be considered. Often, no other manifestations of TB are identified at the time of presentation. Patients often present with extensive unilateral or bilateral cervical lymphadenopathy. Ultrasound demonstrates a strikingly hypoechoic lymph node, secondary to intranodal cystic necrosis, with a lack of well-defined borders. Lymph nodes are often described as matted or flat in appearance.<sup>4</sup> Contrast-enhanced CT or MRI reveals conglomerate nodes along a chain in the neck, and often delineates adenopathy not appreciated on clinical exam. The central necrosis which is the hallmark of active TB adenitis presents as areas of low attenuation on CT and hyperintense signal on T2-weighted imaging, with peripheral enhancement. Calcifications are characteristically seen in the chronic and/or treated phase of disease.<sup>5</sup>



**Fig. 5:** Side by side comparison US illustrating fusiform enlargement of the left sternocleidomastoid muscle compatible with fibromatosis colli (\*), in contrast to the normal appearing right sternocleidomastoid muscle (\*\*)

### Fibromatosis Colli

Fibromatosis colli, also known as pseudotumor of infancy, is an important consideration in patients presenting with a unilateral mass in the anterolateral neck within the first several weeks of life. Patients often have a pertinent history of birth trauma. Ultrasound is the modality of choice in assessment of fibromatosis colli due to lack of radiation combined with its ability to provide fairly accurate diagnosis. Characteristic features include fusiform enlargement of the inferior two-thirds of the involved sternocleidomastoid, with variable echogenicity (Fig. 5).<sup>6</sup> Prompt diagnosis and management with conservative therapy is recommended to prevent subsequent torticollis.

## CONGENITAL LESIONS

### Thyroglossal Duct Cyst

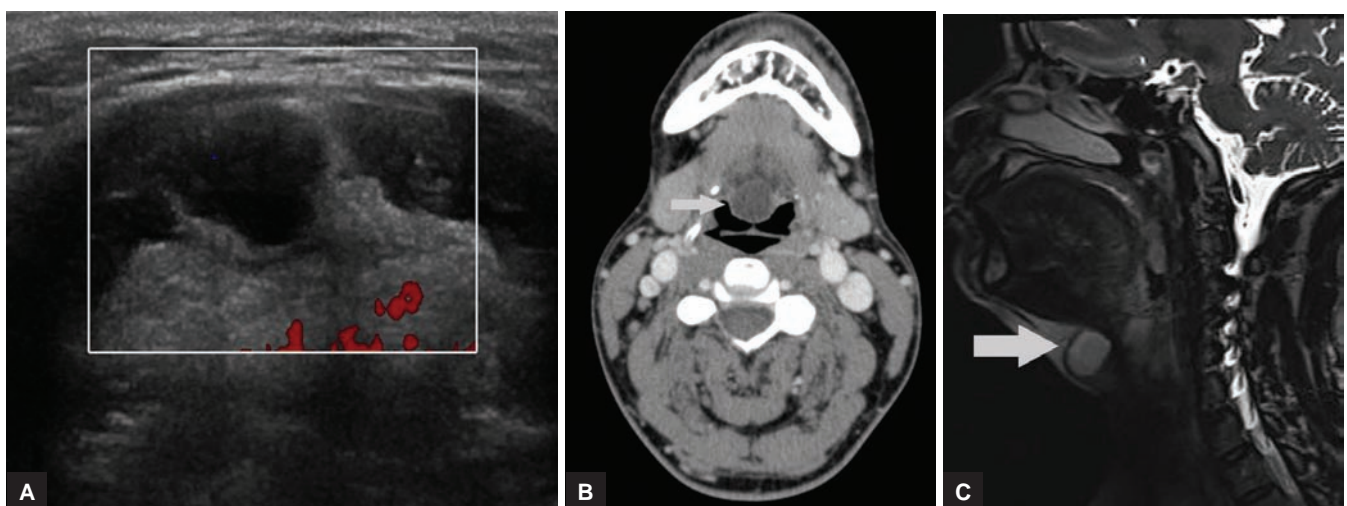
Thyroglossal duct cysts (TDCs) are the most frequently encountered congenital neck masses. These errors in development related to proximal remnants of the foramen cecum can be seen anywhere along the anterior midline of the neck, from the base of the tongue to the thyroid gland. Classically, TDCs present as painless enlarging masses at

or near the level of the hyoid bone. These can readily be evaluated via US, and when uncomplicated, TDC appears as a round thin walled avascular anechoic structure with posterior acoustic enhancement (Fig. 6A). If the TDC contains proteinaceous material, an inhomogeneous appearance can be appreciated, with intraluminal echogenic foci representing debris. When infected, as may occur following upper respiratory tract infections, imaging features overlap that of an abscess. Cross-sectional imaging can be obtained to further evaluate the composition of these masses and assess for mass effect on the adjacent airway. Contrast-enhanced CT shows a well-circumscribed, mucoid attenuation lesion with nonspecific, peripheral enhancement (Fig. 6B). On MRI, TDCs often exhibit high T2 signal, while T1 signal is variable. If uncomplicated, T1 signal is low, while prior or current infection or hemorrhage can result in T1 hyperintensity due to proteinaceous material or blood products (Fig. 6C).

An important mimic of TDC is ectopic thyroid tissue. Therefore, preoperative evaluation for surgical excision of presumed TDCs involves confirmation of normal thyroid gland tissue. Though I-123 scintigraphy of the thyroid gland was traditionally used to identify normal thyroid tissue, ultrasonography provides similar efficacy in less time and without radiation exposure.<sup>7</sup>

### Dermoid Cysts

Dermoid cysts are congenital lesions lined by squamous epithelium and characteristic skin-related appendages within the wall, a feature distinguishing this entity from epidermoid cysts. Dermoid cyst can mimic TDC given their propensity for the midline, suprahyoid location. However, distinction can often be made via clinical exam, as TDCs characteristically move cranially with swallowing as opposed to dermoid cysts which do not



**Figs 6A to C:** Thyroglossal duct cyst (TDC), on multiple modalities. On US, TDC appears as a thin walled anechoic avascular round structure (A) On contrast enhanced axial CT, a well circumscribed mucoid attenuation peripherally enhancing lesion is seen, (B arrow). On T2 weighted sagittal MRI, note high T2 signal within the well defined TDC, (C arrow)

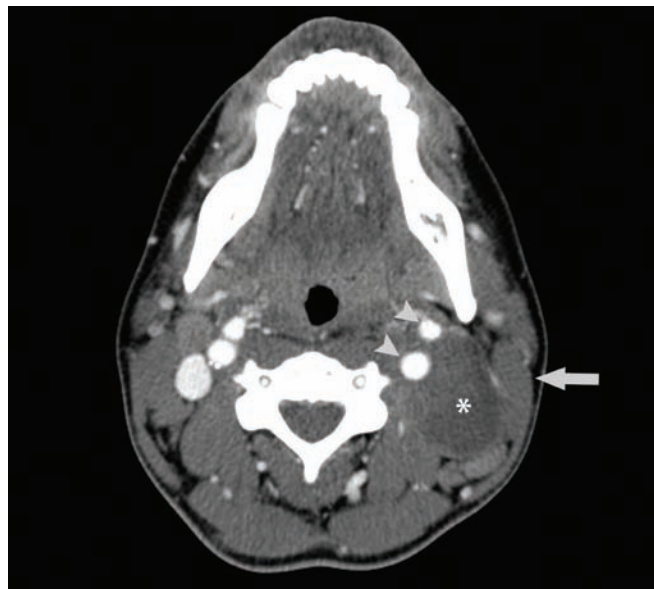
move.<sup>8</sup> Ultrasound is the preferred initial modality for evaluation of a suspected dermoid cyst and typically reveals a heterogeneously echogenic mass (related to the presence of fat) with possible hypoechoic and cystic components. Computed tomography features include a homogeneous hypodense appearance. Fat within the lesion may form distinct nodules giving rise to a “sack of marbles” appearance, considered pathognomonic for dermoid cyst.<sup>9</sup> Fat-fluid levels may be present. Magnetic resonance imaging can be helpful in delineating the surgical approach, and features include a well marginated lesion with variable T1 signal, often high due to the presence of fat, and high T2 signal.

### Lingual Thyroid

Errors in normal migration of the thyroid gland result in ectopic thyroid tissue, commonly located at the tongue base near its embryological origin.<sup>10</sup> Its location is not readily accessible via US. Instead, CT or MRI is most often used, with imaging characteristics similar to that of normal orthotopic thyroid tissue. Unenhanced CT demonstrates a well-defined hyperdense lesion at the base of the tongue secondary to its inherent iodine content, with avid enhancement if contrast is given. Ectopic thyroid tissue demonstrates iso- to hyperintense signal on T1-weighted imaging and mildly hyperintense signal on T2. Superimposed nodules and/or calcification may be seen, similar to the normal thyroid gland. Imaging is essential in evaluating for presence of orthotopic thyroid tissue, generally with US. Normal thyroid tissue can be absent in up to 70 to 90% of cases and has important implications in determining the approach to management.<sup>11</sup>

### Branchial Cleft Cysts

Branchial cleft anomalies arise secondary to failure of regression of the branchial clefts, which separate the branchial arches (those that ultimately give rise to many important craniofacial structures including the ear). The most common anomalies are cysts, true epithelial lined lesions. While cysts fall into four categories, the vast majority of branchial cleft cysts relate to the second cleft (90–95%). Imaging features on US of second branchial cleft cysts include a well-defined thin-walled mass displacing adjacent soft tissues. On CT and MRI, the typical location of these lesions is readily appreciated: anteromedial to the sternocleidomastoid muscle, posterior to the submandibular gland, and lateral to the carotid sheath. Beaking of the lesion between the internal and external carotid arteries is considered pathognomonic (Fig. 7).<sup>9</sup>

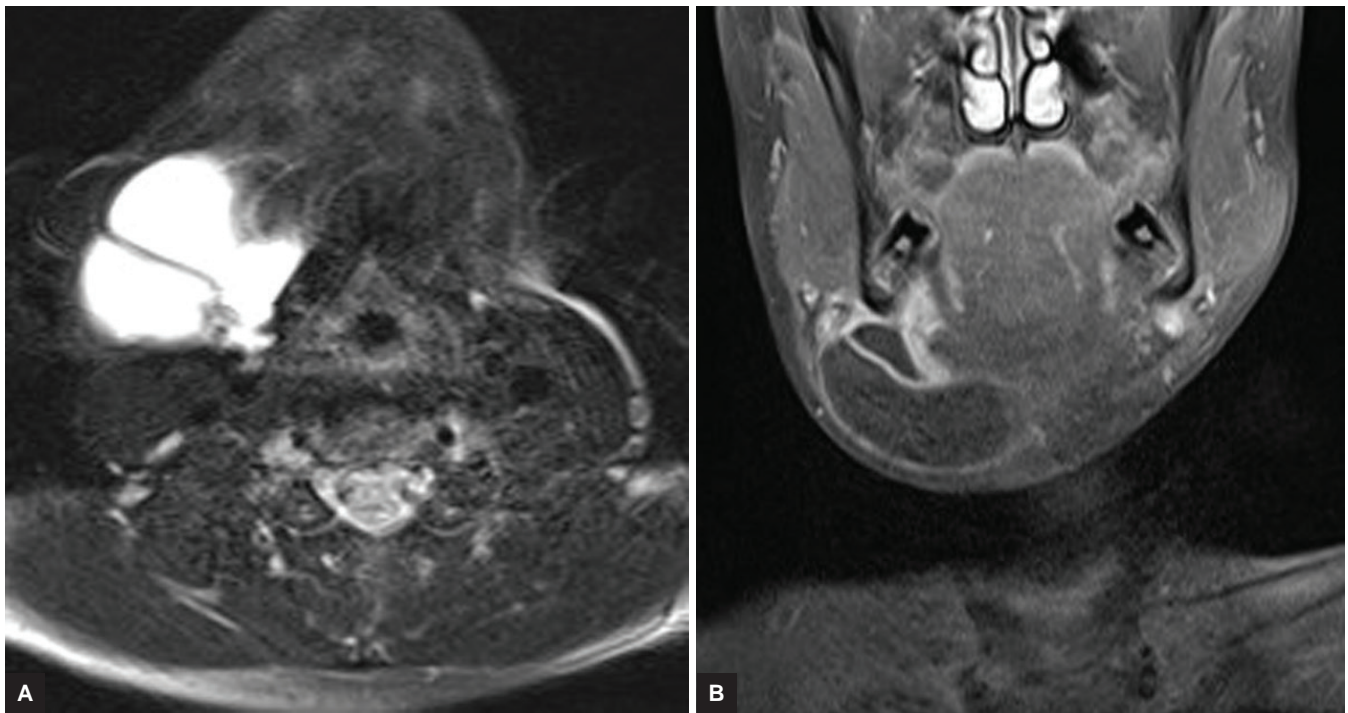


**Fig. 7:** On contrast enhanced axial CT, a hypodense lesion (\*) medial to the left sternocleidomastoid (arrow) is noted, which splay the internal and external carotid arteries (arrowheads), considered pathognomonic for a branchial cleft cyst

## VASCULAR TUMORS

### Lymphatic Malformations

Lymphatic malformations are benign, low-flow lesions composed of endothelial-lined cysts. While these lesions can be seen anywhere in the body, they are predominantly located in the head and neck, specifically in the posterior cervical and submandibular spaces, with propensity to cross different tissue planes. Lymphatic malformations are delineated into microcystic and macrocystic forms. On US, macrocystic forms appear as multiseptated anechoic or hypoechoic lesions with vascularity along the walls and septa. In contrast, microcystic lymphatic malformations appear as hyperechoic masses. Contrast-enhanced MRI is helpful in specifying the location and extent of the malformation, and in excluding a coexisting venous component in the setting of a mixed lesion. Lymphatic malformations follow fluid signal on MRI (T1 hypointense and T2 hyperintense), but T1 hyperintensity may be seen, representing proteinaceous or hemorrhagic material (Fig. 8A). Following contrast administration, macrocystic lymphatic malformations demonstrate wall and septal enhancement (Fig. 8B). In contrast, there is typically relative lack of enhancement in microcystic forms secondary to its small cystic composition, though occasionally there is apparent diffuse enhancement related to septal enhancement of tiny cysts.<sup>12</sup> Appropriate classification is important in determining the course of management, as microcystic are generally more resistant than macrocystic lesions to sclerotherapy.<sup>13</sup>



**Figs 8A and B:** On MRI, axial T2 (A) demonstrates a multiseptated hyperintense lesion, which exhibits wall and septal enhancement on coronal postcontrast fat suppressed T1; and (B) consistent with macrocystic lymphatic malformation

### Venous Malformation

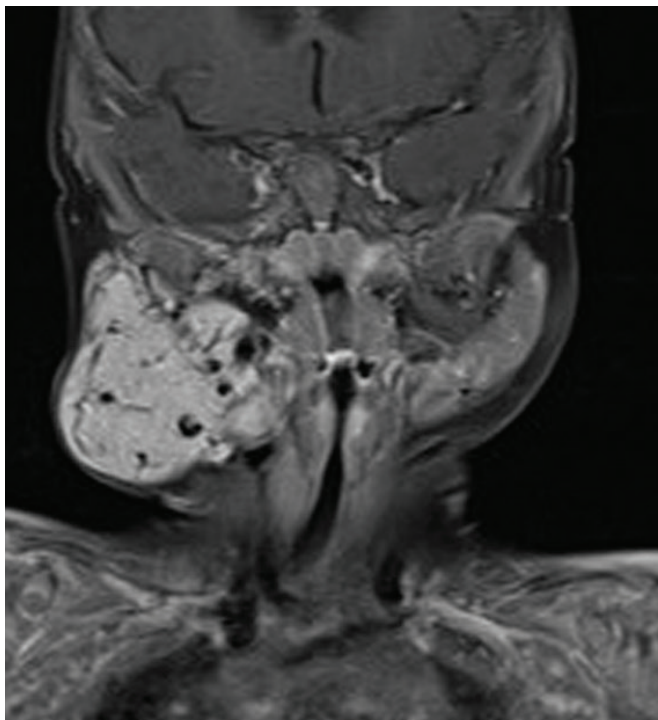
Venous malformations are vascular lesions related to abnormal development of venous channels. Similar to lymphatic malformations, venous malformations are low-flow lesions which increase in size with age. Although often isolated findings, venous malformations can also be seen as part of systemic conditions, including blue rubber bleb nevus syndrome (which presents with gastrointestinal and skin-based venous lesions).<sup>14</sup> Ultrasound and MRI are often both part of the standard work-up of venous malformations, as with lymphatic malformations. Ultrasound typically demonstrates a heterogeneously hypoechoic collection, with limited associated vascularity and low-velocity waveforms on spectral analysis. Magnetic resonance imaging findings include intermediate signal on T1-weighted imaging and hyperintense T2 signal, with progressive delayed enhancement. Often, venous and lymphatic malformations can be difficult to distinguish via imaging because of overlapping characteristics. The hallmark imaging feature of venous malformations is the presence of phleboliths, seen as echogenic foci with posterior shadowing on US or as hypointense foci on all magnetic resonance sequences, which are not present in lymphatic malformations.<sup>15</sup> Phleboliths are often best depicted on plain radiographs due to their calcific nature.

### Hemangioma

Infantile hemangiomas are high-flow, vascular soft tissue lesions that can be seen throughout the body.

These benign lesions are the most common tumors of infancy, with a predilection for the subglottic airway.<sup>16</sup> In contrast to low-flow vascular lesions described above, hemangiomas are composed of mature endothelial cells with high cellular turnover.<sup>17</sup> Not surprisingly, growth of these lesions along the airway will result in stridor and airway compromise. Anteroposterior and lateral neck radiographs are used in initial evaluation of a stable patient, demonstrating asymmetric soft tissue density in the subglottic region resulting in airway narrowing. Airway fluoroscopy can also be performed, which provides increased sensitivity compared with plain radiography given its real-time approach.<sup>18</sup>

In the nonemergent setting, treatment is often deferred as the natural progression of hemangiomas is typically involution. Ultrasound can be valuable in the routine setting to aid in establishing diagnosis. As high-flow vascular soft tissue masses, hemangiomas show hypervascularity with high-velocity and low-resistance waveforms on spectral Doppler imaging. High vessel density (greater than five per square centimeter) has been described. Differential considerations based on spectral Doppler US include other high-flow vascular anomalies such as arteriovenous malformations or arteriovenous fistulas, or possibly soft tissue malignancies such as sarcomas.<sup>19</sup> Magnetic resonance imaging reveals a well-defined lesion with heterogeneous signal on T1-weighted imaging and hyperintense signal on T2-weighted imaging. Flow voids seen as hypointense tubular structures are often present as well as pronounced



**Fig. 9:** Coronal postcontrast fat suppressed T1 MRI demonstrates an avidly enhancing lesion in the right facial soft tissues, with a number of hypointense foci representing flow voids, characteristic of infantile hemangioma

enhancement on postcontrast imaging, beginning in the arterial phase (Fig. 9).

## MALIGNANCY

### Lymphoma

In the subacute to chronic stages of cervical lymphadenopathy, additional etiologies such as malignancy or atypical infection are considered. In the pediatric population greater than 6 years of age, Hodgkin's lymphoma is the most common malignancy in the head and neck.<sup>20</sup> By contrast, in patients younger than 6 years, neuroblastoma and leukemia are the most common malignancies associated with cervical adenopathy. Imaging features can help in the diagnosis. Although US is considered somewhat limited in distinguishing reactive *vs* malignant adenopathy, several studies have identified characteristic US features to help distinguish malignant from benign causes. For example, a lymph node with a rounded shape, long to short axis ratio (L/S) of less than 2, and absence of an echogenic, fatty hilum favor lymphoma secondary to tumor infiltration. Benign features include preservation of normal nodal architecture with L/S typically greater than 2.<sup>21</sup> In cases of suspected cervical node malignancy, CT or MRI is important in staging disease.

## CONCLUSION

The differential for pediatric neck masses is broad and includes inflammatory/infectious, congenital, vascular,

and malignant etiologies. Imaging plays a vital role in differentiating these entities and guiding management. Multiple modalities may be of utility, but an important factor in pediatric imaging is limiting radiation exposure.

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