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Tumors and tumor-like lesions of the neck: from childhood to adult

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Abstract In childhood, tumors and tumor-like lesions of the neck are rare and tend to be benign. Very common are congenital cystic lesions (thyroglossal duct cysts, branchial cysts, dermoid cysts, lymphangiomas, cystic hygromas). Common neoplastic lesions are hemangiomas and papillomas. The most common malignant tumors in the head and neck region are lymphomas and rhabdomyosarcomas. Lymph node enlargements, reactive or/and infectious, account also for a significant amount of cervical masses.

Keywords Tumors · Tumor-like lesions · Childhood imaging

Introduction

In childhood, tumors and tumor-like lesions of the neck are rare and they tend to be benign. Most of the median anterior neck masses represent congenital lesions (thyroglossal duct cysts, branchial cysts, dermoid cysts, lymphangiomas, cystic hygromas). The most common blastomatous lesions in children are laryngeal papillomatosis and Hemangiomas. Less common benign blastomas are neurogenic tumors and tumors arising from major and minor salivary glands in children. The most common malignant tumors in the head and neck region are lymphomas and rhabdomyosarcomas. Lymph node tumors (enlargements)—reactive and infectious—represent in the young and adult population very common abnormalities and account for a significant amount of lateral cervical masses [1, 2]; however, most of the soft tissue neck masses in the adult over the age of 40 years are metastatic nodal lesions.

Congenital lesions

During embryogenesis the anlage of the thyroid/parathyroid glands descends from the foramen cecum through the tongue base and floor of the mouth to its final position in the lower neck. During this caudal migration the anlage passes just anterior to the precursor tissue of the hyoid bone, leaving a tract of epithelial tissue called the thyroglossal duct (Fig. 1). The normal thyroglossal duct involutes by the eighth fetal week. Thyroglossal duct remnants may give rise to cysts, fistulae, or solid nodules of thyroid tissue. Thyroglossal duct cysts represent approximately 70% of all congenital cysts of the neck and are asymptomatic except when superinfected [1, 3]. Because this may be the only functioning thyroid tissue in the patient's body, a thyroid scintigram to search for other thyroid tissue should be performed before planned resection. Although most thyroglossal duct cysts (65%) occur in the infrahyoid neck, 15% are at the level of the hyoid bone and approximately 20% in the suprahyoid neck (Fig. 2). In the infrahyoid location it is embedded within muscles adjacent to the external margin of thyroid carti-

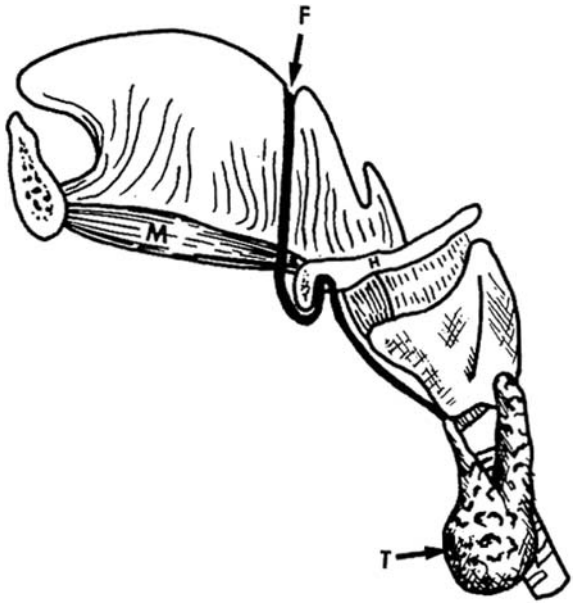

Fig. 1 Lateral drawing tracing the course of the thyroglossal duct cyst from the foramen cecum (*F*) downwards to the level of the normal thyroid bed (*T*). (Adapted from [1])

lage. This and an eventual relationship to the hyoid bone allow differentiation from other lesions which are hypodense on CT, such as necrotic lymph nodes, thrombosis of the anterior jugular vein, and abscesses. Depending on its protein concentration, the cyst may be hypo- or even hyperintense on T1-weighted MR-images. Both CT and MRI show a midline or paramedian cystic mass with characteristic features and a peripheral thin rim enhancement after i.v. contrast application. In superinfected cases the surrounding tissue is swollen and edematous.

First imaging choice should be ultrasound because it allows detection of these cysts in more than 95%. The mass may be anechoic, homogeneously or heterogeneously hypoechoic, or even hyperechoic. The location of cysts suggests the diagnosis. Ultrasonography plays an essential role, not so much for the diagnosis itself, which is generally suspected clinically, but as mentioned above, to document the presence of the thyroid gland. After therapy, recurrence of thyroglossal duct cyst is possible. Malignant transformation in 1% is well documented, resulting in the majority of cases in papillary thyroid carcinoma in adults.

In athyrosis sonography fails to show a normally located thyroid gland in patient with hypothyroidism. In the search of ectopic thyroid tissue scintigraphy is absolutely indicated, and CT and MRI may help to outline the "tumor" (Fig. 3). Sonography is unreliable for demonstration of ectopia.

Branchial cysts, sinuses, and fistulas are developmental pathologies arising essentially from remnants of the branchial arches forming the embryonic lateral cervical wall that normally disappear during fetal development.

Second, third, and fourth branch cysts may occur in the neck. While anomalies of the third arch are rare mimicking second arch cysts or thyroglossal duct cyst, second arch cysts occur in the lateral neck, anterior to the sternocleidomastoid muscle, near the angle of the mandible. It must pass between the internal and external carotid arteries and ends in the palatine tonsil. They represent 95% of all branchial cysts and are the second most common congenital cysts. The diagnosis is usually made clinically ("lateral cervical mass"; Fig. 4) [1, 4].

Sonographically, the mass is well defined and anechoic or only weakly echoic. The uniform echogenicity of the mass is characteristic. Aspiration cytology may be helpful for diagnosis. Sometimes differentiation from a cervical lymphangioma may be difficult.

Fourth branchial arch anomalies are most commonly left-sided (93%) piriform sinus fistulas [5]. Such congenital lesions can cause phlegmonous adenitis of the mid portion of the neck. A left-sided mass of the neck which is avascular, anechoic, or hypoechoic should suggest such a diagnosis. The additional presence of air is highly suggestive. A plain neck film may reveal the presence of air and contribute to the diagnosis. A barium swallow may be also helpful.

Laryngeal cysts are rare but serious lesions that can cause respiratory distress. They develop in an aryepiglottic fold following occlusion of a laryngeal mucous gland or secondary atresion of the laryngeal saccule orifice. Ultrasonography can accurately localize the laryngeal mass [6, 7].

Dermoid cysts are thought to arise from epithelial rests that become enclaved during midline closure of the first and second brachial arches. Dermoid cysts may be classified into epidermoid (having only squamous epithelium), dermoid (having hair sebaceous glands and squamous epithelium), and teratoid forms, which contain connective tissue derivatives, additionally. They most often occur within the orbit floor of the mouth and the nasal region, rarely in the neck. They may have the typical signal intensity characteristics of these lesions elsewhere in the body. Although present at birth, in most cases they are not identified until the second or third decade of life. Fluid attenuation in epidermoid cysts and fat in dermoid cysts may differentiate the two. On both CT and MRI, the wall of the cysts usually enhances following intravenous administration of contrast material, whereas the bulk of the lesion stays unenhanced and may show fatty attenuation with multiple nodules.

Abberant thymus may occur in the lateral neck. When the aberrant thymus is connected by a bridge with the normal thymus, diagnosis is easy. When there is no bridge diagnosis is more difficult. It represents a homogenous, weakly well-defined echoic mass on ultrasound [8].

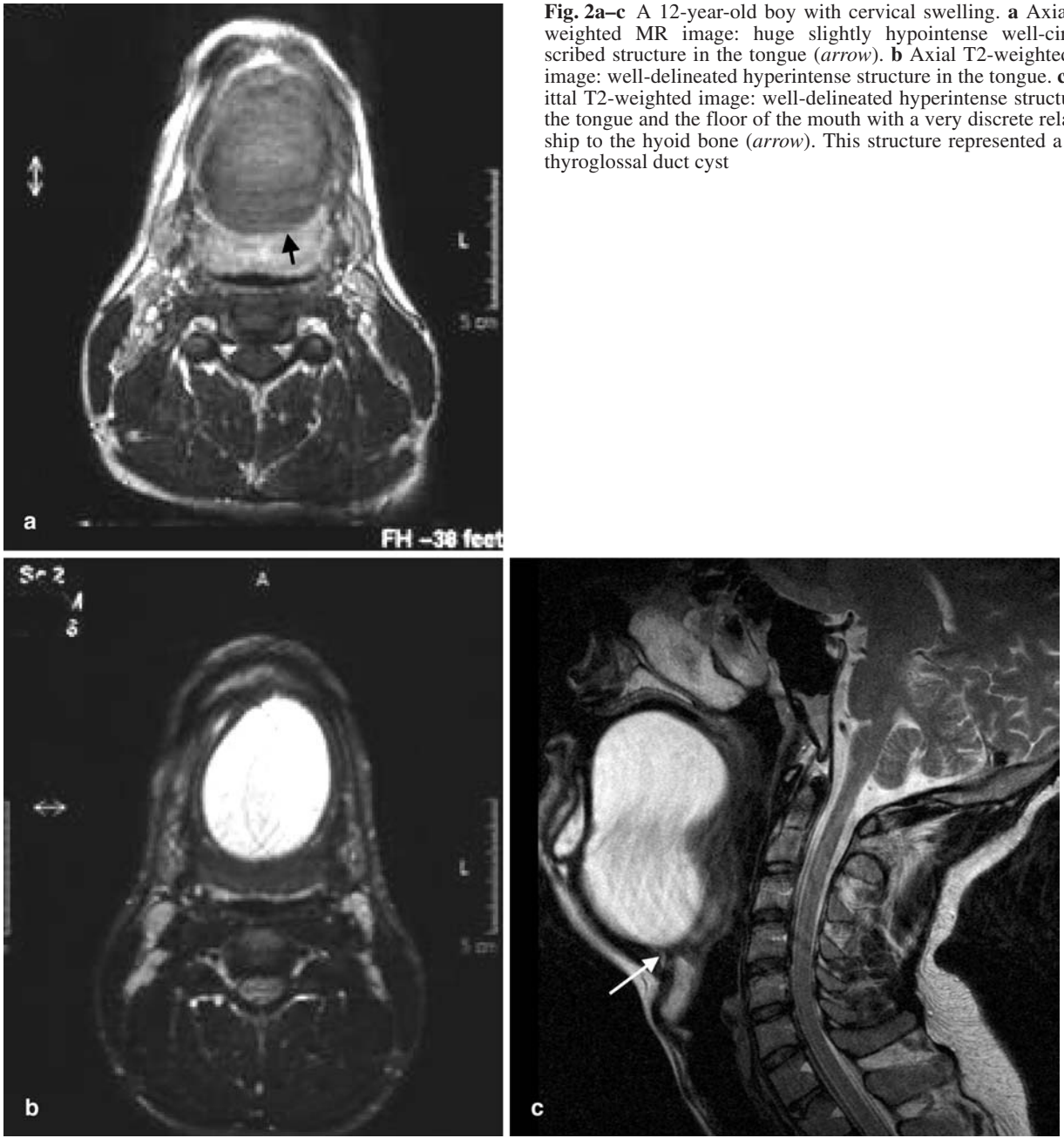

Fig. 2a–c A 12-year-old boy with cervical swelling. **a** Axial T1-weighted MR image: huge slightly hypointense well-circumscribed structure in the tongue (*arrow*). **b** Axial T2-weighted MR image: well-delineated hyperintense structure in the tongue. **c** Sagittal T2-weighted image: well-delineated hyperintense structure in the tongue and the floor of the mouth with a very discrete relationship to the hyoid bone (*arrow*). This structure represented a large thyroglossal duct cyst

Vascular lesions of the head and neck may be divided into hemangiomas and vascular malformations. Hemangiomas are neoplastic conditions characterized by an increased proliferation and turnover of endothelial cells, and typically display a rapid proliferation phase during the first year of life followed by an involution phase. Hemangiomas are the most frequent tumors in children and account for approximately 7% of all benign soft tissue tumors (Fig. 5). Color Doppler demonstrates the high vessel density of the tumors. Although they are rarely present at birth, hemangiomas typically become apparent during first month of life. Of hemangiomas, 96% are clinically evident by the age of 6 months; 70% of them resolve by 7 years of age [1, 2]. Hemangiomas are also the most frequent benign tumors of the larynx in children and are diagnosed in newborns. These immature hemangiomas regress spontaneously but may become life threatening during acute phases of progression.

As opposed to hemangiomas, vascular malformations are not tumors but true congenital vascular anomalies

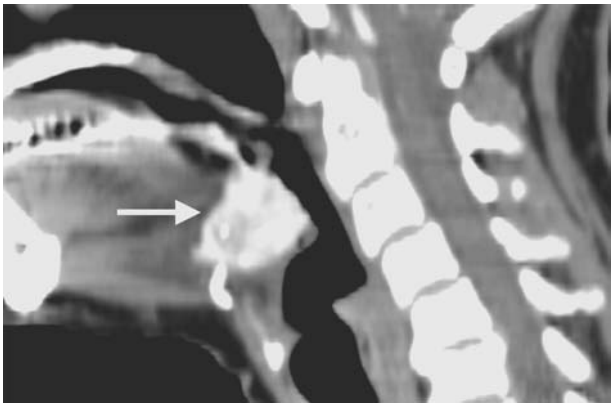

Fig. 3 A 21-year-old woman with swallowing problems for months. Sagittal reconstructed contrast-enhanced CT image: hyperintense structure within the base of the tongue which was compatible with an ectopic thyroid tissue (*arrow*)

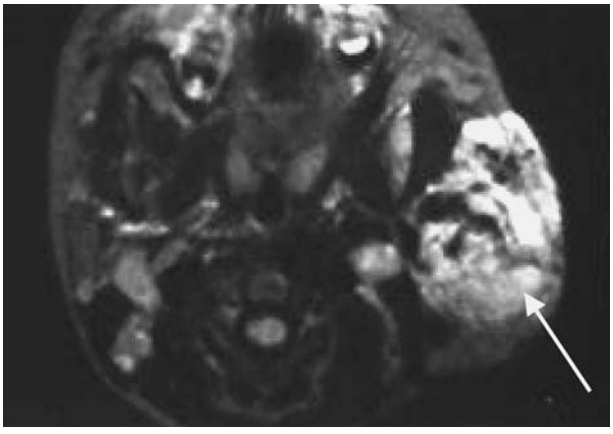

Fig. 5 A 3-year-old boy with left-sided neck/face mass. T2-weighted image: large soft tissue mass (*arrow*) replacing the parotid gland with serpiginous vascular flow voids, representing the vessels in a hemangioma

with a normal proliferation rate of endothelial cells. They do not regress and may rapidly enlarge in association with trauma or endocrine changes. Vascular malformations are further subdivided into capillary, venous, arterial, and lymphatic malformations. Arterial malformations are high-flow malformations. Capillary and venous malformations are low-flow lesions. Of all venous malformations, 40% involve the cervicofacial region. On MRI venous malformations are isointense or hyperintense to muscle on T1-weighted images, become very hyperintense on T2-weighted images, and typically enhance significantly following administration of contrast material. The presence of phleboliths, which are easily recognized with CT, is pathognomonic for these lesions.

Lymphangioma is a benign, nonencapsulated lesion that is believed to arise from abnormal sequestrations of primitive embryonic lymph sacs which fail to join the normal more central lymphatic channels; 80% appear before the age of 2 years. On the basis of the size of the abnormal lymphatic spaces, lymphangiomas are classified into three histological types: capillary; cavernous; and cystic (cystic hygroma; Figs. 6, 7). The cystic hygroma is the most common lesion. The characteristic CT and MR appearance—both are indicated in these malformations—includes a multiseptated cystic mass that may insinuate in and around normal structures making surgical resection very difficult. On T2-weighted MR images, cystic hygromas are typically isointense to cerebrospinal fluid (CSF), whereas they have a variable signal intensity on T1-weighted images due to the variable protein content. Rapid enlargement of a cervical cystic hygroma is usually due to hemorrhage into the cystic spaces of the mass. Multiple fluid-fluid levels, representing layering of blood and lymph are characteristic.

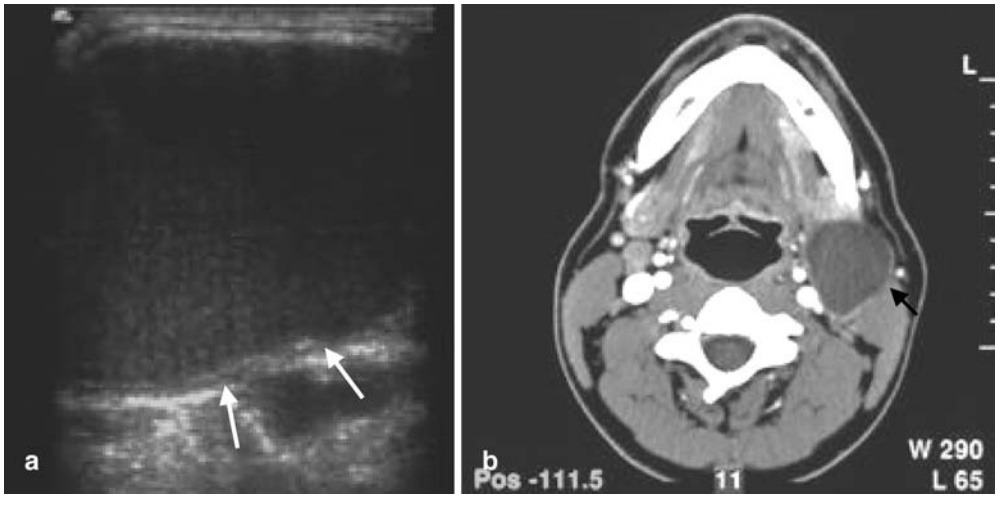

Fig. 4a, b An 8-year-old boy with lateral cervical mass. **a** Transverse sonography of the suprahyoid region: large avascular hypoechoic circumscribed mass (*arrows*), located anterior of sternocleidomastoid muscle and superficial to the large vessels of the neck. **b** Axial contrast-enhanced CT: well-circumscribed hypodense mass with a very thin rim-like enhancement of the upper capsule (*arrow*). The lesion is lying anteriorly of the sternocleidomastoid muscle and superficially of the larger vessels of the neck. The lesion proved to be a second-arch branchial cyst of the neck

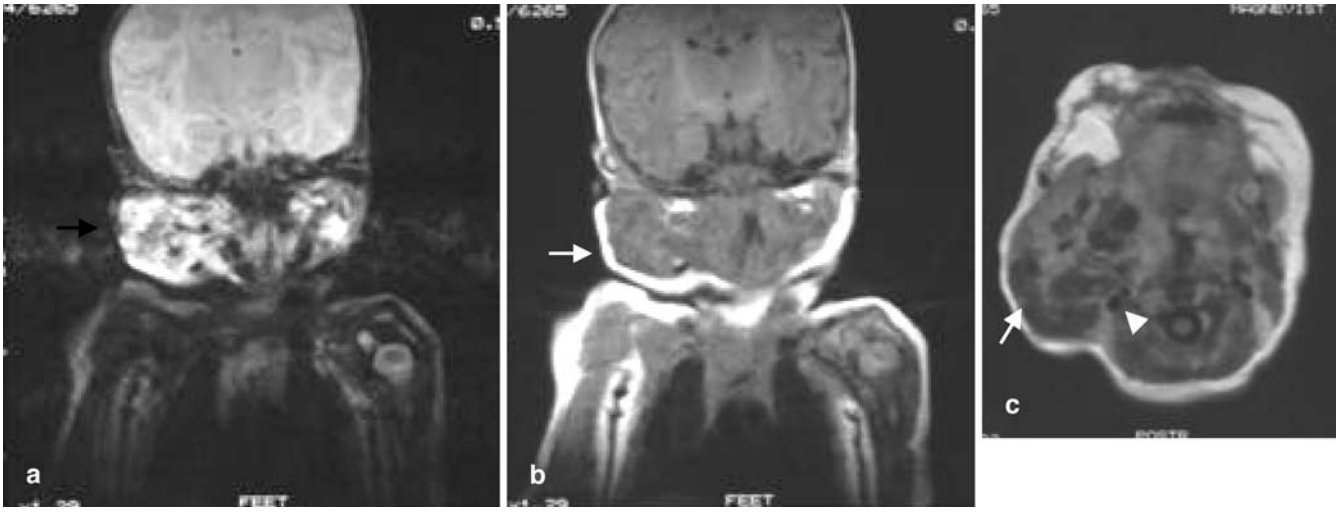

Fig. 6a–c A 2-year-old girl with huge lateral face and neck mass. **a** Coronal T2-weighted MR image: large, mostly hyperintense structure in the right face and neck (*arrow*). Also note the tube-like hypointense structures within the lesion. **b** Coronal T1-weighted image: moderately hypointense lesion of the right face and neck (*arrow*). **c** Axial T1-weighted image: mostly hypointense mass in the upper lateral neck region on the right (*arrow*). Also note the tube-like hypointense structures within the lesion (*arrowhead*). The lesion was compatible with a large lymphangioma of the neck

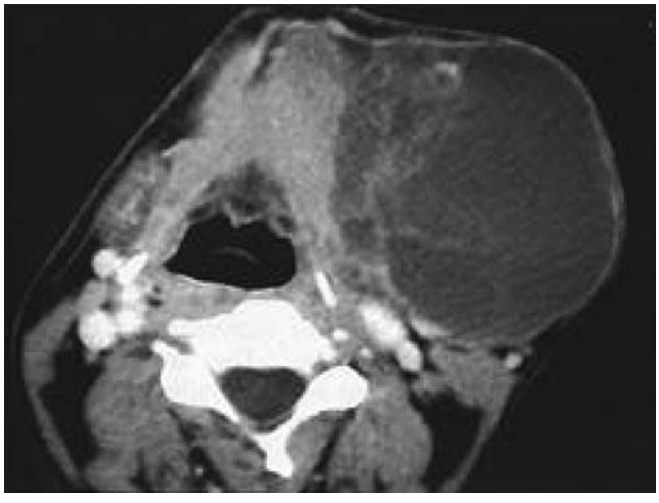

Fig. 7 A 4-year-old boy with huge cervical mass, left sided. Axial contrast-enhanced CT: solitary cystic mass representing a cystic hygroma

Fluid-fluid levels may be identified at CT; however, the conspicuity of this finding is more apparent on MR images. Ultrasonography permits localization of the largest cysts and is used during interventional procedures with sclerosing agents.

Childhood lesions

Most common lesions are laryngeal cysts (see above), which denote a variety of air or fluid-filled cysts, including laryngoceles and saccular cysts, and subglottic hemangioma; the latter may be located anywhere in the larynx but have a predilection for the subglottic region. They present, as mentioned above, during first year of life; however, squamous papillomas are the most common laryngeal tumors in children. This lesion is usually detected before 3 years of age.

A special form of "do not touch me lesion" is post-traumatic localized "fibromatosis colli." It is typically found within the lower third of the sternocleidomastoid muscle and is due to a birth-related trauma. It should be not mistaken for the well-known aggressive generalized fibromatosis. In more than 80% of cases the localized form resolves within 2 weeks, and in 14–20% it is a reason of a torticollis. In sonography it is well defined with abnormal muscle texture (edema, hematoma), and in CT it is isodense to muscle.

Twenty-five percent of malignant childhood tumors involve the head and neck. Hodgkin's disease and other lymphomas are the most likely neoplasms to arise in the extracranial head and neck.

Lymphoma is the most common malignant tumor of the head and neck region (Fig. 8). They are classified as Hodgkin's disease or non-Hodgkin's lymphoma. While Hodgkin's disease is most commonly detected in the adolescence, non-Hodgkin's lymphoma affects primarily children between 2 and 12 years of age. It may be further classified in B-cell, T-cell, histiocytic, and undefined groups. Although cervical adenopathy may be the presenting sign of disease, extranodal involvement is common. Burkitt lymphoma is a special B-cell non-Hodgkin's lymphoma which may involve the head and neck region. It is the fastest-growing human tumor.

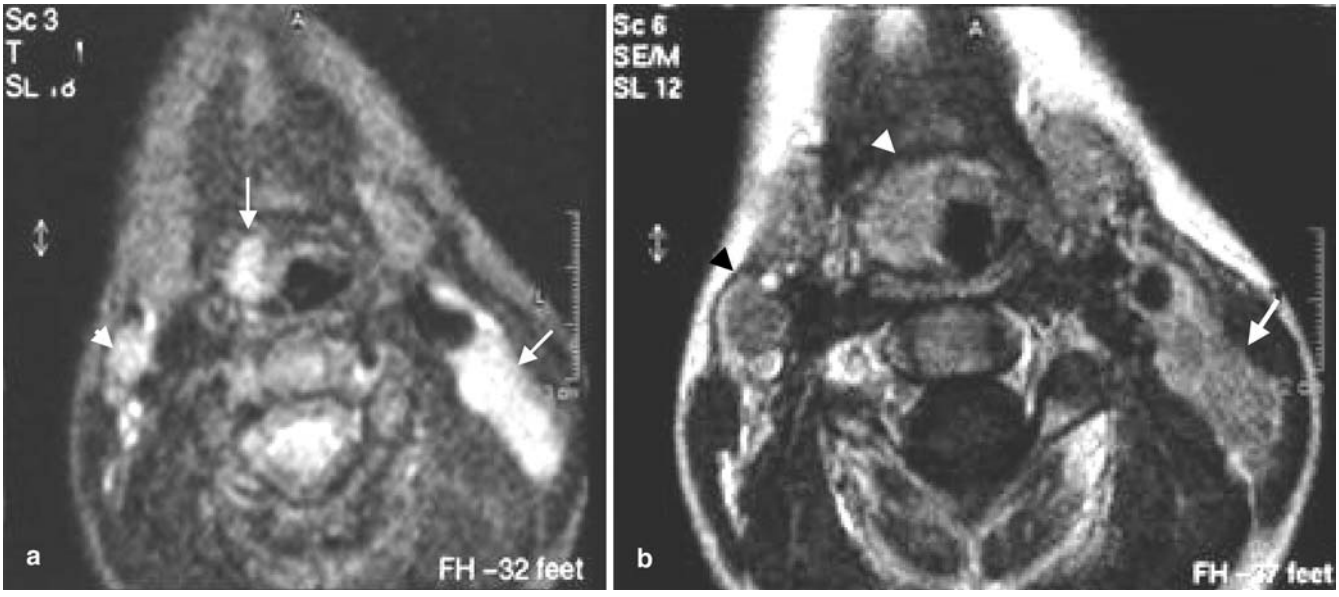

Fig. 8a, b A 6-year-old girl with growing mass in the neck. **a** Oblique axial inversion recovery image: large hyperintense mass posteriorly of the large vessels on the left (*arrow*). Also note hyperintense masses on the right and within the hypopharynx on the right (*arrow, arrowhead*). **b** Oblique axial contrast-enhanced T1-weighted image: moderate enhancement of the abnormal structures in the left and the right neck (*arrow, arrowheads*) which was histologically a non-Hodgkin's lymphoma

Differentiation of enlarged lymph nodes due to Hodgkin's disease, non-Hodgkin lymphoma, and reactive lymphadenopathy by ultrasound, CT, or MRI is very hard or almost impossible. Clues for the neoplastic nature of the disease may be nodal form, texture, necrosis, calcification, perinodal invasion, and various Doppler informations. Tumor vessels tend to form shunts that Doppler sonography can demonstrate by measurement of the resistive index and the pulsatility index. But there exists controversy as to the significance of Doppler values. Several authors classified nodal vascularity into four patterns: (a) hilar type with or without secondary branches; (b) spotted type (arterial or venous); (c) peripheral type (perinodal pattern of multiple vascular signals); and (d) mixed type. Of benign nodes, 83% were avascular or had a hilar type with vascular pattern, whereas 78% of malignant cervical node were of the nonhilar type.

Rhabdomyosarcoma is the most common soft tissue sarcoma in children and the second most frequent malignancy in the pediatric head and neck region. There is a bimodal peak for age of onset—2–5 and 14–18 years of age—and a slight male predilection (2:1). Of cases, 43% are found before 5 years of age.

Three main histopathologic types of rhabdomyosarcoma have been described: (a) embryonal, which accounts for 75% of tumours and is most common in younger children; (b) alveolar (20%), which has the worst prognosis; and (c) pleomorphic. Main locations in the head and neck region are the orbit and parameningeal. In the neck metastic cervical adenopathies may be found. The soft tissue tumor leads to bony destruction and may be hemorrhagic or necrotic. After contrast application the tumor and metastasis reveal significant enhancement. This allows excellent delineation of the tumor extent (Fig. 9).

The second most common sarcoma in children is fibrosarcoma, with 15–20% of cases occurring in the head and neck.

Teratomas are tumors of germ cell origin consisting of elements derived from all three germ cell layers. Approximately 7–9% of teratomas occur in the head and neck. Teratomas may arise in the neck, paranasal sinuses, nasopharynx, orbit, and pharynx. Teratomas arising in the neck are present at birth. Most teratomas are benign; however, malignant teratomas occasionally occur.

Cervical lymph nodes in children are larger than those of adults; thus, the standard measurements used to determine nodal enlargement are not entirely applicable for children. Normal internal jugular chain nodes may be as large as 25 mm in diameter. Presence of central foci of decreased attenuation that are not related to the fatty hili are abnormal.

The cervical adenopathies encountered in hemopathies tend to be larger, more rounded, and sonographically more markedly hypoechoic than infectious nodes. They almost always include numerous nodes and involve in particular the posterior chains and supraclavicular region. In any unexplained nodal enlargement, cytological aspiration biopsy is indicated (Figs. 10, 11) [2, 9, 10].

Cervical neurogenic tumors include ganglioneuromas and neuroblastomas. Cervical localizations of such neoplasmas are rare. Sonography reveals a solid hypoechoic or complex mass along a nerve trajectory. Ganglioneuromas show punctate calcifications with low density on

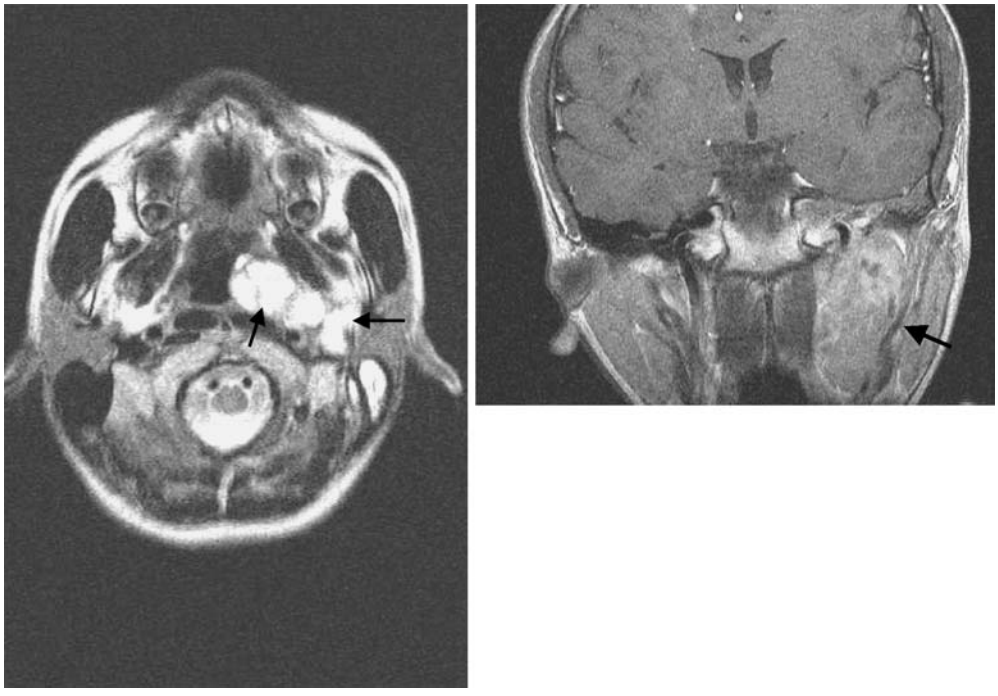

Fig. 9 A 12-year-old boy with fast-growing mass within the left face. *Left* Axial T2-weighted image: large lobulated hyperintense mass (*arrows*) in the left parapharyngeal space. *Right* Coronal contrast-enhanced T1-weighted image: large moderately contrast-enhancing mass in the left parapharyngeal space (*arrow*) which was compatible with a rhabdomyosarcoma

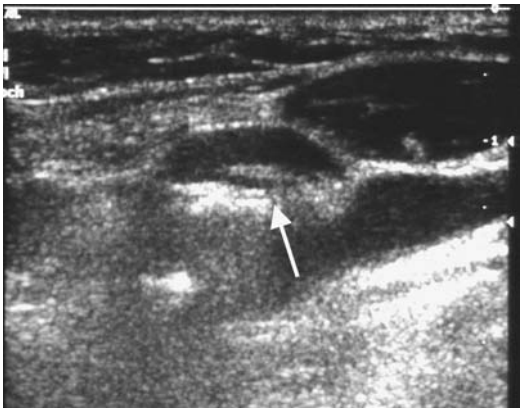

Fig. 10 A 14-year-old boy with painful cervical lymph nodes. Transverse sonography of the suprahyoid neck: a lymph node with a hyperechoic hilus structure (*arrow*) which was compatible with a reactive lymphnode

CT, and marked hyperintensity on T2-weighted images with gradual increasing enhancement on dynamic MR images. CT and MRI are indispensable to determine the exact extent of the tumor prior to surgery and search for intraspinal extension.

Lipomas are benign fatty tumors. The fatty nature of these tumors is occasionally suggested by sonography, but CT and MRI are indispensable parts of the preoperative work-up of these patients. On CT they show the typically fatty low densities, except their tissue textures are built up myxomatous (=30%). The MRI reveals a mass with characteristic high signals on T1-weighted images.

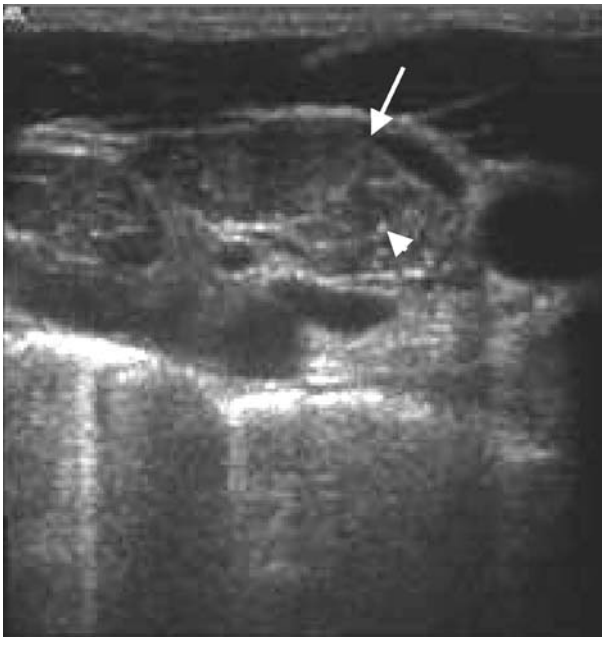

Fig. 11 A 17-year-old female: nodular enlargement of the thyroid. Transverse sonography of the neck: a oval-shaped slightly hypoechoic lymphnode (*arrow*) with small punctuate hyperechoic structures (*arrowhead*) within node. The node represented a lymphnode metastases in a patient with a papillary carcinoma of the thyroid gland

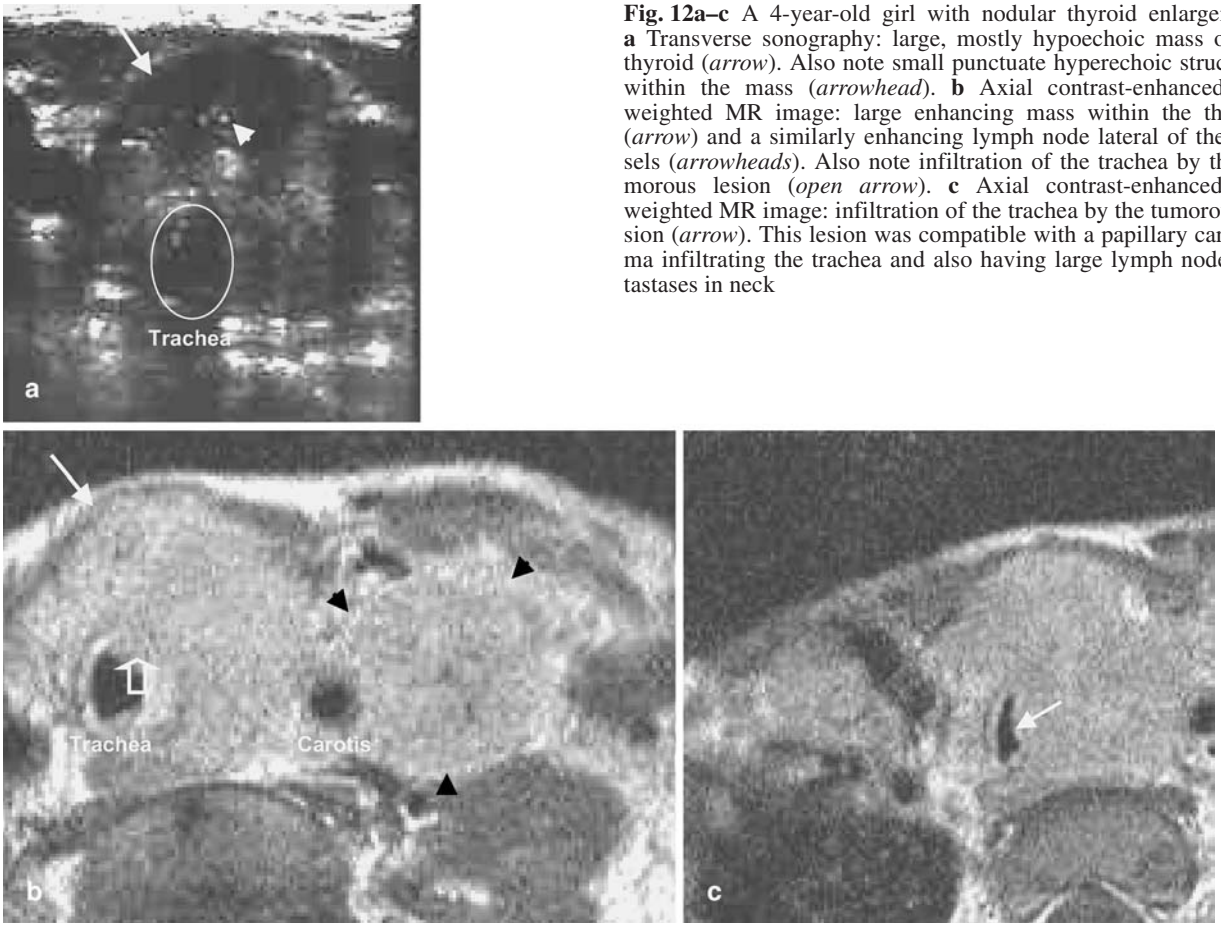

Fig. 12a–c A 4-year-old girl with nodular thyroid enlargement. **a** Transverse sonography: large, mostly hypoechoic mass of the thyroid (*arrow*). Also note small punctuate hyperechoic structures within the mass (*arrowhead*). **b** Axial contrast-enhanced T1-weighted MR image: large enhancing mass within the thyroid (*arrow*) and a similarly enhancing lymph node lateral of the vessels (*arrowheads*). Also note infiltration of the trachea by the tumorous lesion (*open arrow*). **c** Axial contrast-enhanced T1-weighted MR image: infiltration of the trachea by the tumorous lesion (*arrow*). This lesion was compatible with a papillary carcinoma infiltrating the trachea and also having large lymph node metastases in neck

The majority of benign solid thyroid tumors are adenomas [11]. These solid lesions can be solitary or multiple. Cystic and calcific degeneration is possible. The final diagnosis is made by fine-needle aspiration biopsy. The incidence of adenomas is increased in children with a history of therapeutic irradiation in infancy. Thyroid carcinoma is uncommon in children, but there is also a relationship with previous radiation. Papillary carcinomas are the most common one with an excellent prognosis, basically. The imaging features are usually completely non specific: a more or less well-defined, hypoechoic single nodule or multiple nodules (Fig. 12). Punctate calcifications, central necrosis, invasion in the surrounding tissues, localized thrombosis, and atypical, enlarged lymph nodes are signs of malignancy. The definite proof is made by fine-needle aspiration cytology. Children with previous radiation need a long-term clinical and imaging monitoring.

Imaging

Standard imaging procedures are ultrasound with power Doppler and fine-needle aspiration cytology (FNAC), spiral CT, and MRI. In thyroid and parathyroid abnormalities scintigraphy is as important as ultrasound. Videofluoroscopy with barium sulfate may be used in hypopharynx tumors to visualize function during swallowing. In subglottic hemangiomas lateral radiographs of the neck may show a soft tissue mass extending into and/or narrowing the tracheal air column, especially below the level of the vocal cords. This narrowing tends to be asymmetric.

Almost all laryngopharyngeal primaries are accessible to direct endoscopic visualization and biopsy; however, deep tumoral extension cannot be seen by the ENT or pediatric surgeon. The goal of the radiologic examination is to delineate exactly the tumor margins so that the tumors can be localized and classified.

Ultrasound

The main advantage of ultrasonography continues to be its portability. Bedside imaging is basically possible.

The child is examined in supine position with neck hyperextended. Two types of probes are useful, a high-frequency (7–12 MHz) linear transducer for accurate ex-

aminations of the most superficial regions and a lower frequency (5–8 MHz) sector probe for the analysis of the deeper regions and for sagittal scans in newborns and infants in whom the small dimensions of the neck prevent the use of larger probes. Both coronal and sagittal scans are obtained [1, 2].

Blood flow can be studied using Duplex sonography, in which gray-scale 2D sonography is combined with pulsed Doppler. With color Doppler imaging (CDI), the pulsed information is encoded for flow direction and flow velocity. Power Doppler shows the intensity of flow. The CDI is generally used to examine intravascular flow, and the more sensitive power Doppler is used to detect parenchymal flow. The high jugular and subdigastric region (=level 2), the midjugular (=level 3) and low jugular (=level 4), and the posterior triangle (=level 5) should be evaluated craniocaudally and in the axial plane. The thyroid gland should be imaged entirely in both transverse and longitudinal planes. All nodes that are visible on ultrasound are measured in axial and longitudinal plane. For ultrasound-guided FNAC a 22-G noncutting needle equipped to 10-ml aspiration syringes should be used. An ideal specimen for cytologic analysis consists of one or two drops of orange red fluid. Spring-activated automated biopsy guns may also allow more histologic diagnosis without a significant increase in the complication rate.

Spiral computed tomography

Spiral computed tomography examination is done with the patient in supine position, with the neck in a neutral position, the shoulders down as far as possible, and the CT examination of the neck should extend from the sternum to the skull base. Until the age of 6 years (<50 kp) a voltage of 80 kVp is used, and beyond that age the voltage is increased accordingly to body weight and age to 120–140 kVp. The tube current is also adapted to weight and height of the patient, and the display matrix is 512×512 pixels. Generally, a high-resolution edge-enhancing algorithm is recommended. For a minimum of partial-volume artifacts slice thickness is 2–3 mm and in babies 1–2 mm. The reconstruction increment corresponds with the collimation. The rotation time should be no longer than 1.5 s and the pitch factor should be 1.5 in order to reduce the time of the data acquisition. Until the age of 3–4 years sedation (or even deep sedation) of the child is unavoidable in most cases. This unsatisfactory situation may change with the routine use of multi-detector CT, which allows high-detail examinations of the whole neck in 5–10 s. If the larynx and the hypopharynx have to be studied in detail, sections must be parallel to the true vocal cords or the laryngeal ventricle. On the lateral scout view, the plane of the hyoid bone or the intervertebral joint space at the appropriate level or the hard palate can be used to adjust the gantry angle. Moreover, this way, artifacts from the hyoid bone, teeth, bracelets, and dental fillings do not affect the level of interest. During the data acquisition the patients do quiet breathing rather than breath holding. The time spent educating the older child to minimize neck movements and not to swallow is worthwhile. Especially, the performance of ephonation and/or Valsalva maneuver have to be explained and practiced with the child prior to the examination.

Table 1 Applied contrast doses in children

Age (years)	Dose ml/kg b.w.	Maximum (ml)
1	3.0	12–20
2	2.5	20
3	1.5	25
4–12	1.0	40

Computed tomography of tumors and tumor-like lesions in the neck includes in many cases the use of intravenous contrast agent. Intravenous contrast agent helps delineate the lesion, its borders, and texture. Moreover, vascular enhancement helps to distinguish pathologically enlarged cervical lymph nodes and see vascular abnormalities. If contrast-enhanced CT is to be performed, we administer between 1.5 and 3 ml/kg body weight (up to a total of 80 ml) of non-ionic contrast (300 mg/ml concentration) depending also on the age of the patient (Table 1); however, in most cases in which a contrast-enhanced CT seems to be indicated, we recommend MRI instead. In any questionable thyroid disease contrast medium application is contraindicated because of the iodine content [1, 3].

In addition to a soft tissue setting we recommend also a “bone” setting. Coronal and/or sagittal reconstructions may add information to the final diagnosis, particularly concerning the longitudinal extension of a lesion. With modern multi-detector CT these reconstructions are done very easily and quickly with no loss of detail resolution. These reconstructions save radiation and examination time. Both may be critical in the examination of children.

Magnetic resonance

The MR examination should be performed with a “high field” machine (1.5 T). The use of an adapted coil (head-, neck-, knee coil) is standard to get high-resolution images of the neck. Section thickness is 1–4 mm (depending on the size of the child) with no gap. The display matrix size is 170×256 pixel minimum. The patient is in the supine position during the data acquisition. Children older than 7–10 years usually cooperate if gently coached.

Younger children between 1 and 6 years are sedated. Between 0 and 1 year most children are just fed prior to the examination and they keep motionless in most cases. If the child stays restless sedation or even anaesthesia is necessary. In the latter case a strong evident indication for the MRI examination must be existent. Regional extent of the examination is similar to CT.

In comparison with CT, it is even more important to instruct the patient not to swallow, cough, or move during the time of the data acquisition [1, 9].

During a standard MR examination T2-weighted fast-spin-echo (FSE) sequences should be obtained in the axial and coronal/sagittal planes. In contrast to a conventional T2-weighted SE sequence, FSE sequences (turbo factor 5–7) are faster and, therefore, motion artifacts can be reduced and image quality improved. A disadvantage of T2-weighted FSE sequences is the high signal of fat which can result in a poor contrast between tumor and fat. T2-weighted FSE sequences with fat saturation or inversion recovery (SPIR) may result in a better identification of lesion margins helping to separate the enhancing tumor from background fat. Prior to the injection of the contrast agent, a nonenhanced T1-weighted SE and/or FSE sequence should be performed in the axial plane so that fat with high signal intensity will not be confused with enhancement. Gadolinium diethylenetriamene penta-acetic acid (Gd-DTPA), administered with a dosage of 0.1 mmol/kg body weight, yields a signal increase of the tumor on T1-weighted images. This results in a better evaluation of the lesion extension, demarcation, and tissue texture (e.g., exclusion of cysts, necrosis, etc.). To increase contrast between the lesion and fat after the administration of Gd-DTPA, fat-saturation sequences are often helpful.

Scintigraphy/PET

The domain for scintigraphy/FDG-PET is screening for metastasis and/or occult primary tumors. In children lymphomas and, to a lesser extent, rhabdomyosarcomas, may be localized. “Conventional” scintigraphy or SPECT are absolutely indicated in thyroid abnormalities (e.g., unclear nodules, search for ectopic thyroid tissue, etc.). The used standard tracers are J-123-NaI or Tc-99m-pertechnetate.

General pathological aspects in imaging

The tumor matrix can be solid, cystic, proteinaceous, fatty, hemorrhagic, calcified, or necrotic. Preserved fatty/soft tissue structures are benign signs, while infiltration of the neighboring tissue, destruction of the laryngeal skeleton, and thrombosis of the neighboring vessels are signs of malignancy. The presence of enlarged, deformed and atypically textured lymph nodes can be an indirect sign of malignancy, although in children this may not be such a reliable sign as in adults. Usually tumors and tumor-like lesions, except cysts and epidermoids, will enhance after i.v. contrast application. In rare cases tumors may remain isodense to muscle. Due to perilesional inflammation overstaging of lesions may be a problem.

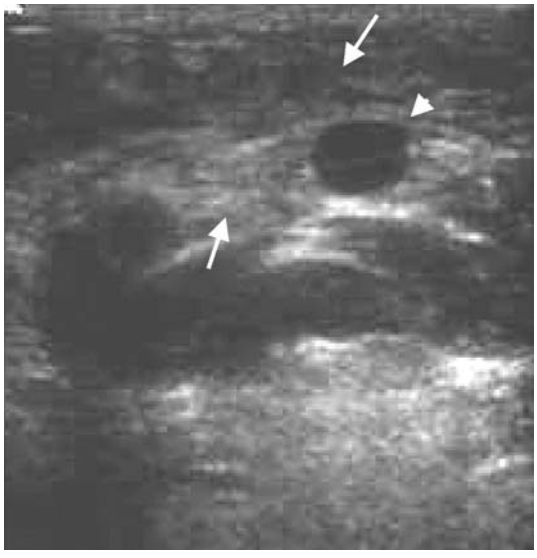

Fig. 13 A 9-year-old boy with pain, swelling of tongue, and fever. Transverse sonography of the floor of the mouth: diffuse hyperechoic structures within the subcutaneous fat and the muscles (*arrows*) and a reactive lymphnode (*arrowhead*). This finding proved to be a phlegmonous infiltration of the floor of the mouth

Ultrasound is especially useful for soft, fluctuant masses, because the ultrasonographic appearance of each of these lesions may be quite distinct.

As in CT, the domain of MRI is the evaluation of deep lesion extension. While on T1-weighted images fat may delineate the margins of the tumor, T2-weighted images allow a differentiation of the mostly hyperintense tumor from muscle. By injecting i.v. contrast medium this latter delineation may even be clearly enhanced. The problematic differentiation of fatty tissue and contrast-enhanced tumor masses may be overcome by the use of fat-suppressed sequences. Peritumoral inflammation, edema, and reactive changes may be also a problem in exact staging as with CT.

There are three spaces in the infrahyoid neck region separated by fascia: (a) carotid space; (b) perivertebral space, and (c) visceral space. In each space special tumors and tumor-like lesions may arise. This can help in the differential diagnosis particularly in acquired diseases, whereas congenital lesions usually do not follow those spaces.

A lesion in the carotid space is most likely to present enlarged lymph nodes or an abscess, phlegmona, or cellulitis (Fig. 13). In the pediatric age group thrombosis or

phlebitis/arteritis, which may be also localized in the carotid space, are very rare. Schwannomas and paragangliomas are typically found in the adult population.

In the perivertebral space muscle abnormalities, schwannomas (brachial plexus) and metastasis may be found.

The large so-called visceral compartment contains the thyroid and parathyroid gland, larynx, trachea, hypopharynx, esophagus, recurrent laryngeal nerve, and the paratracheal lymph nodes. It may be divided into a retropharyngeal, retrovisceral and pretracheal part. In this space the majority of the congenital lesions (thyroglossalduct cysts, angiomas, branchial cysts, lymphangiomas, etc.) thyroid abnormalities (e.g., goiter), lymphadenopathies, abscesses, and phlegmonas are found very commonly.

Conclusion

In children, tumors and tumor-like lesions of the neck are rare. They tend to be benign. In the majority of cases they represent enlarged lymph nodes, (congenital) cysts, or hemangiomas. The most common malignant tumors are lymphomas and rhabdomyosarcomas. First imaging modalities should be ultrasound (with FNAC) and MRI or CT. In thyroid abnormalities a scintigraphic analysis is mandatory.

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