A systematic approach to managing incidental findings during ultrasound evaluation of the thyroid in pediatric patients

Poster No.: C-2391
Congress: ECR 2015
Type: Educational Exhibit
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Keywords: Paediatric, Thyroid / Parathyroids, Ultrasound, Ultrasound-Colour Doppler, Elastography, Screening, Normal variants, Neoplasia
DOI: 10.1594/ecr2015/C-2391

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Learning objectives

1. Identification of the normal aspects, normal variants and unexpected or pathological ultrasonographic findings, among the pediatric population.
2. To define and describe the most frequent pediatric thyroid pathology specific to each age group.
3. To systematize the evaluation path of the ultrasound findings and the proper planning for further investigations.
4. To minimize the mismanagement due to errors resulting from lack of proper knowledge.
**Background**

The sonographic exam represents the standard technique in the evaluation of the thyroid gland. Its superficial location makes it easily accessible for visualization and the modern development of the ultrasound machines offer a wide range of information regarding size, echogenicity, echostructure, borders, vascularity, presence of cysts and nodules, associated pathology of the neighboring structures and others [1]. Additionally, the method is especially suitable for the pediatric population since it does not use radiation, is non invasive and is therefore easily accepted by both the parents and the children [2].

Although ultrasound may be helpful in the diagnosis of various thyroid conditions it is not diagnostic by itself. The main role of ultrasound is to determine the presence or absence of thyroid tissue, evaluate any rudimentary gland and to identify an enlarged gland or goiter. The limitation of this examination is in determining the presence of ectopic thyroid tissue in areas difficult to access with ultrasound (ex: mouth floor, hypopharynx) [3]. In these cases thyroid scintigraphy is a perfect complementary study. Studies have shown that ultrasound alone cannot be an alternative to thyroid scintigraphy in defining the cause of congenital hypothyroidism for example. The main role of scintigraphy (99mTcO4 or I-123) is to help determine if thyroid dysgenesis is the cause of hypothyroidism and to identify thyroid ectopia. The use of both procedures has shown to be more accurate in depicting congenital hypothyroidism than either study alone [4].

Another complementary study, that can be of use in the diagnosis of thyroid nodules is elastography. Although, this technique proved to be of value in characterizing pathology in some organs in the adult population (eg, breast, liver), there are some contradictory results of its diagnostic performance in thyroid nodules. Some studies have suggested that elastography might be of use in determining the "nature" of a thyroid nodule, but still, other more comprehensive studies must be conducted to prove its diagnostic utility. For elastography to be an adjuvant diagnostic tool to conventional US, a combination of both techniques is suggested to be used, for the specificity and sensitivity of depicting malignancy within a nodule is much higher [5]. There are almost no studies that have been conducted on a pediatric population to validate the utility of elastography in defining thyroid nodules.
Findings and procedure details

EXAMINATION TECHNIQUE

The child is placed on the examination table in a supine position. A small pillow or roll is placed under the patient's shoulders, the head of the patient is close to the right hand of the examiner and it is tilted backwards so that the anterior region of the neck is presented. In newborns, small babies and children the parent may be asked to place one of his/her hands under the shoulders.

A linear transducer (5-7.5 MHz) is placed on the anterior region of the neck and the thyroid is visualized. Transverse and longitudinal views are obtained in order to evaluate echogenicity, echostructure, volume, presence of nodules and the aspect of the surrounding structures, especially lymph nodes and large vessels of the neck [6]. It is important to use gentle compression, mainly when assessing volume and vascularity, since these will be influenced when stronger compression is used. (TIPP: use your pinky finger to support the weight of your hand and transducer then glide gently over the examined area.)

For volume determination three measurements must be performed for each lobe: length, depth and width and multiply these by a factor of 0.5. The added value of both lobes, expressed in ml, represents the volume of the gland.

Various authors have published the normal range volume for each age group. The thyroid volume is evaluated in relation to weight or age, the later is more frequently used. (Table 1)

NORMAL FINDINGS

The thyroid lobes have an ellipsoidal shape, a fine contour and are connected through the isthmus on the midline, anterior to the trachea. The gland has an intermediate echogenicity and a fine granular echostructure. In newborns and babies the gland is slightly hypoechoic compared with older children. There can be an asymmetry of the two lobes, the right lobe is usually a little larger than the left lobe and this is a normal finding. (Figure 1)

PATHOLOGY
The poster will present as follows the most frequent thyroid conditions encountered in pediatric population, with a peculiar focus on thyroid nodule characterization and its management.

**Hypothyroidism**

Hypothyroidism results from a deficient production of the thyroid hormones, either because of a malfunctioning thyroid gland (primary hypothyroidism) or because of reduced TSH stimulation (central). Therefore the primary diagnosis of the disease is based on the laboratory studies of the thyroid function. In the case of primary hypothyroidism the low values of thyroid hormones are associated with a high value of TSH and in the case of central hypothyroidism the TSH value is low [6].

Hypothyroidism can be classified as congenital and acquired. There are several causes for hypothyroidism among the pediatric population, the most frequent are listed and described in detail below (See causes and classification of hypothyroidism in table 2 and table 3).

1. **Congenital hypothyroidism**

The diagnosis of primary congenital hypothyroidism is usually made through the neonatal screening programs. The disease has multiple causes, but the one, that can cause most problems when examining the cervical area is probably thyroid ectopia. The underdeveloped thyroid gland can be located anywhere, from the back of the tongue to its normal place in the front of the neck and rarely in the mediastinum or other lateral locations [2].

Ultrasound findings - it is usually surrounded by soft tissue and has a cystic or hypoechoic appearance compared to the nearby soft tissues, it can be hyperechoic compared to the surrounding muscles. If it is located in base of the tongue, the ectopic tissue appears hypoechoic compared with the tongue. Normal ultrasound findings are also possible.

**Hypoplasia of the thyroid gland** is characterized by small area of glandular tissue, usually with a normal ecogenicity. Most frequently only one lobe is hypoplastic, but both lobes can be affected [7]. At this point it is mandatory to compare the thyroid volume with normative data. (Figure 2.)

In case of **thyroid aplasia** no thyroid tissue can be depicted, either by ultrasound nor by scintigraphy.

2. **Hashimoto thyroiditis (autoimmune thyroiditis)**
Acquired hypothyroidism is caused by many factors, but the most common one in iodine sufficient areas is Hashimoto’s thyroiditis (autoimmune thyroiditis). The diagnosis is made based on the measurements of anti-TPO, anti-TG and TSH receptor-blocking antibodies [6].

Ultrasonographic findings - are nonspecific; it is difficult to differentiate Hashimoto thyroiditis from other thyroid diseases. The thyroid gland is usually diffusely enlarged, relatively hypoechoic with coarse heterogeneous echostructure (Figure 3 and Figure 4). In rare cases, it can have a hyperechoic appearance compared to the surrounding muscles, while in the chronic phase a pseudolobulated appearance might be present due to fibrotic changes (Figure 5). Multiple micronodules (1-6 mm) are usually present, while in some cases larger nodules were also described (Figure 6 and Figure 7) [8]. Color Doppler examination can depict decreased, normal or increased vascularity similar to "thyroid inferno". (Figure 8) Some studies have suggested that it is important to evaluate the RI value, even in sonographycally normal thyroid glands, for a low RI could be more sensitive than other ultrasound parameters in the diagnosis. The RI should be evaluated near the center of each lobe and a mean value of RI should be calculated [9].

Hyperthyroidism

Hyperthyroidism is a group of diseases that involve excess synthesis and secretion of thyroid hormones by the thyroid gland. Although very rare, a congenital form of hyperthyroidism has been described [10]. It is usually encountered in babies born to mothers with a history of Graves's disease, but a non-autoimune form has also been found. Yet, the most common form of hyperthyroidism is represented by diffuse toxic goiter (Graves's disease). (See causes of Hyperthyroidism in thable 4)

Basedow-Graves disease

Hyperthyroidism in children and adolescents is most frequently caused by morbus Basedow. The diagnosis is made by determining TSH, T4, T3 and thyroid receptor antibodies values (TSH is suppressed; T4 and T3 are elevated; TSI, TGI, TBII are positive) [6]. In most cases imagining is not needed for the diagnosis, but it is valuable in detecting occult nodules.

Ultrasound finings - can show a diffusely enlarged, mostly hyperechoic thyroid gland with heterogeneous echotexture and diffuse hyperemia ("thyroid inferno"). (Figure 8, Figure 9 and Figure 10) Radionuclide imaging is performed only if a nodule is detected.

Thyroid nodules
Compared to the adult population thyroid nodules are rarely diagnosed in children. Unlike adults, children with thyroid nodules usually present with a palpable mass. Though most of the thyroid nodules are benign, malignancy in the pediatric population is much more frequent than in adults, therefore any nodule must be considered suspicious until proven otherwise [3]. Due to the fact that at the time of sonographic examination, little is known about the patient's history, it is important to be able to differentiate a benign nodule from a suspicious one by ultrasound. (Figure 11 and Figure 12)

The workup in thyroid nodules found in children must consist of: history and physical examination, thyroid laboratory studies, ultrasound, in selected cases - radionuclide imaging and fine needle aspiration.

A detailed description of thyroid nodules can be found in the following section, that could be helpful in determining whether a lesion is benign or malignant. Many have tried to categories thyroid nodules into benign or malignant, based on some ultrasound characteristics, but none of them succeeded in determining a clear sonographic feature for neither of them. Care must be taken, for ultrasound alone cannot determine the "nature" of a nodule. In table 5 a systematization of the features of these nodules and their possible significance can be found.

It is also very important to always assess the cervical lymph nodes during any routine thyroid ultrasound, for it is proven that children present a higher frequency of lymph node metastases at the time of diagnosis compared with adult patients [8]. (Figure 13, Figure 14, Figure 15)

Non-palpable nodules ("incidentalomas") in children are rare and usually are discovered during other imaging procedures (CT, MRI, PDG-PET) or ultrasound of the cervical area. (Figure 16 and Figure 17) These lesions present the same risk for malignancy as palpable nodules, therefore ultrasound and routine workup should follow [3].

In children the two most frequent malignancies are differentiated thyroid cancer and medullary thyroid carcinoma (MTC), these are usually clinically silent, asymptomatic with a normal thyroid function and present as solitary nodules [11]. (Figure 18 and Figure 19) For a detailed description of US characteristics of a malignant nodule please refer go to table 5.

For an accurate diagnosis it is recommended to use a combination of thyroid function tests, thyroid scintigraphy, ultrasound and fine-needle aspiration (FNA).

Thyroid scintigraphy is recommended in those patients who have low TSH values in order to determine the functional status of a nodule.

Fine-needle aspiration (FNA) is a simple and relatively safe procedure. In infants and younger children some sedation may be necessary. There are no specific guidelines
for pediatric patients, most authors recommend adapting the indications and algorithms used in adult population.

Indications for FNA are categorized according the presence or absence of risk factors for thyroid cancer (e.g., childhood head and neck irradiation, family history of thyroid cancer) (Table 6). If multiple nodules are present, the most suspicious nodule should be biopsied [12]. (Figure 21) If none of the present nodules shows suspicious sonographic features, the largest one should be punctured. The other nodules should be monitored and evaluated for growth [3]. (Figure 21)

"TROUBLE MAKERS"

Although these findings are rare it is of value to be aware of this condition when making a list of your differential diagnosis.

**Parathyroid glands**

The parathyroid glands (PG) are difficult to examine by ultrasound due to their small size and similarity to the thyroid echostructure. The PG is located on the upper and lower lobe of the thyroid and can be visualized more posterior. It has its own capsule, which could be seen by using a high frequency transducer, though it is very difficult to differentiate it from the surrounding tissues. There are some causes that can lead to the enlargement of the PG, such as hyperparathyroidism or malignant lesions, but in the pediatric patients these are very rare. It is difficult to make a differential diagnosis between PG and a lymph node or a peripheral thyroid nodule. There are few cases reported in the literature of an ectopic parathyroid gland found within the thyroid. The diagnosis could be made only by performing a biopsy.

**Thymus**

The normal thymus remains visible by ultrasound well beyond the age of 2 (Figure ...). This can lead to certain misdiagnosis if a sonographer is not familiar with the normal appearance of this gland. Usually the thymus is located inferiorly to the thyroid, in the upper mediastinum, but in some cases enlargement or ectopic thymus tissue can be found when evaluating the cervical area (Figure ).

Ultrasound characteristics of a thymus enclose a smooth and sharply defined margin, homogenous structure with tiny echogenic foci. It is usually closely molded to the adjacent structures and can present pulsations due to its close relation to the heart. The thymus can have an elongated shape that can extend superiorly. (Figure 26) It is hypoechoic compared to the thyroid gland, but if it is surrounded by soft tissue it is isoechoic and
has a relatively smooth internal structure. Ectopic thymus tissue has been reported in the literature, but it is very uncommon. (Figure 27)
Table 1: Normal Thyroid volume values in relation to age

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**Fig. 1:** The normal thyroid gland, grey scale ultrasound, transverse scan.

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**Table 1. Causes of Hypothyroidism in Children and Adolescents**

<table>
<thead>
<tr>
<th>Category</th>
<th>Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>• Hashimoto’s thyroiditis (chronic autoimmune thyroiditis)</td>
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<tr>
<td></td>
<td>• iodine deficiency or excess</td>
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<tr>
<td></td>
<td>• radiation therapy</td>
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<tr>
<td></td>
<td>• radioactive iodine therapy (ex. treatment of Graves’ hyperthyroidism)</td>
</tr>
<tr>
<td></td>
<td>• medication</td>
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<tr>
<td></td>
<td>• surgical removal of the thyroid gland as a treatment for thyroid cancer</td>
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<tr>
<td>Secondary (Pituitary)</td>
<td>• cerebral tumors (compressing the hypothalamus and/or pituitary gland)</td>
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<tr>
<td>and Tertiary (Hypothalamus)</td>
<td>• infiltrative processes</td>
</tr>
<tr>
<td></td>
<td>• langerhans cell histiocytois</td>
</tr>
<tr>
<td></td>
<td>• cystinosis</td>
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<tr>
<td></td>
<td>• radiation therapy</td>
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<tr>
<td></td>
<td>• head trauma</td>
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<tr>
<td>Other causes</td>
<td>• infections</td>
</tr>
<tr>
<td></td>
<td>• thyroid hormone resistance</td>
</tr>
<tr>
<td></td>
<td>• hepatic hemangiomas</td>
</tr>
</tbody>
</table>

**Table 2: Causes of Hypothyroidism in Children and Adolescents**

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Table 2. Causes of Congenital Hypothyroidism

<table>
<thead>
<tr>
<th>Primary</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>• Thyroid dysgenesis: ectopia, aplasia, hypoplasia</td>
<td></td>
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<tr>
<td>• Dyshormonogenesis (disorders in thyroid hormone synthesis)</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Central- Secondary (Pituitary) and Tertiary (Hypothalamus)</th>
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<tbody>
<tr>
<td>• disorders in development and/or function</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Other causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>• TSH resistance</td>
</tr>
<tr>
<td>• functional immaturity</td>
</tr>
<tr>
<td>• transplacental transfer of maternal medication or thyroid-blocking antibodies</td>
</tr>
<tr>
<td>• iodine deficiency or excess</td>
</tr>
</tbody>
</table>

Table 3: Causes of Congenital Hypothyroidism

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Fig. 2: Thyroid hypoplasia. A small gland is to be observed bilaterally with a hyper echoic appearance compared to the surrounding muscles.

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**Fig. 3:** Hashimoto's Thyroiditis. The thyroid gland is hypoechoic, diffusely enlarged, with a slightly heterogenous pattern.

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**Fig. 4:** Thyroiditis. Longitudinal scan of the thyroid shows a hypoechoic gland with heterogeneous echostructure.

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**Fig. 5**: Hashimoto’s thyroiditis with chronic evolution. Thyroid gland is diffusely enlarged, relatively hypoechoic with coarse heterogeneous echostructure and polilobulated.

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**Fig. 6:** Thyroiditis with micronodular pattern. The thyroid gland is diffusely enlarged with hypoechoic appearance and normal vascular pattern. Multiple micronodular, well defined lesions are present scattered throughout the thyroid tissue.

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**Fig. 7:** Hypothyroidism. Thyroid gland with a relative normal US appearance and size. Close to the istmus there is a heterogenous nodule to be observed. Its location can give some differential diagnosis problems, in such cases routine workup of the nodule should follow.

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Fig. 8: Hashimoto’s thyroiditis. Color Doppler examination shows a hypervascular pattern known as "thyroid inferno". Usually this pattern is seen in Hyperthyroidism, but it can be present in other thyroid diseases too.

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### Table 3. Causes of Hyperthyroidism in Children

<table>
<thead>
<tr>
<th>Thyroid gland</th>
<th>Pituitary causes of thyrotoxicosis</th>
<th>Other causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Basedow-Graves disease</td>
<td>• pituitary adenoma and pituitary resistance to T4</td>
<td>• exogenous thyroid hormone</td>
</tr>
<tr>
<td>• toxic adenoma or toxic nodular goiter</td>
<td></td>
<td>• iodine-induced hyperthyroidism (ie, Jod-Basedow phenomenon)</td>
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<tr>
<td>• subacute thyroiditis</td>
<td></td>
<td>• human chorionic gonadotropin (hCG)–secreting tumors</td>
</tr>
<tr>
<td>• Albright syndrome</td>
<td></td>
<td></td>
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<tr>
<td>• chronic lymphocytic thyroiditis</td>
<td></td>
<td></td>
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<tr>
<td>• bacterial thyroiditis</td>
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</tbody>
</table>

### Table 4: Causes of Hyperthyroidism in Children

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**Fig. 9:** Hyperthyroidism. Diffusely enlarged thyroid gland, with a heterogenous echostructure.
Fig. 10

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**Fig. 11**: Benign nodule. Isoechoic, well defined, homogenous nodule, with a hypoechoic halo. The US appearance suggests a benign nature, though routine follow up must be done.

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Fig. 12: Suspicious nodule. Nodule in a Hashimoto’s thyroiditis with a hypoechoic appearance, ill defined margins. There is no vascularity to be observed within the nodule. Further evaluation must follow with scintigraphy and FNA.

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**Table 5: Ultrasound characteristics of Thyroid Nodules**

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Fig. 13: Lymph node with hyperechoic center. Normal aspect even tough it has a lobulated appearance.

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Fig. 14: Normal vascularisation of a benign lymph node.

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Fig. 15: Malignant lymph node (papillary thyroid carcinoma). Although its size is relative small, the rounded and hypoechoic appearance is highly suggestive of malignancy.

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Fig. 16: Benign nodule. Subcapsular, heterogenous nodule with a predominantly peripheral vascular pattern.

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Fig. 17: Benign nodule. The elastography examination suggests a benign nature of the nodule. The procedure is highly dependent on the sonographer and its diagnostic value has not been fully evaluated.

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**Fig. 18:** Malignant nodule (Papillary carcinoma). Hypoechoic, relatively homogenous ecostructure with a polilobulated margin. There are no sign for invasion.

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**Fig. 19:** Malignant nodule (Papillary carcinoma). The vascular pattern or the US appearance are not of diagnostic value in determining the nature of the nodule. Some microcalcification are present, that can suggest a malignancy.

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Table 6: Indications for FNA

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**Fig. 20:** Multinodular goiter. This entity is rare in children. The thyroid is enlarged with multiple micro and macronodular lesions, some of them present a complex echostructure. The most suspicious or largest has to punctured in some cases.

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Fig. 21: Multinodular goiter. The nodules present a variety of vascular pattern. In some cases, if malignancy is suspected, scintigraphy must be performed to evaluate the functionality of the nodules.

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Fig. 22: Simple cyst (typical US appearance of a cyst). It is a rare entity in pediatric patients. Care must be taken when diagnosing a simple cyst, cystic degeneration of a nodule is far more frequent.

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**Fig. 23:** Simple cyst. When located in the periphery Color Doppler examination can make the differentiation between a vessel and cyst.

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**Fig. 24:** Benign cystic nodule (cystic degeneration of a benign nodule). When a lesion presents a solid, mural component (ever so small) it is to be considered a nodule with a cystic component rather than a cyst. Follow up has to be done to evaluate the nature of the lesion.

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Fig. 25: Benign cystic nodule. A large, cystic nodule is observed at the periphery of the thyroid gland. It is difficult to clearly determine the origin of the lesion. Color Doppler examination shows the vascularisation of the solid component.

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**Fig. 26:** Normal ultrasound appearance of the thymus.

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**Fig. 27:** Ectopic thymic tissue neighboring the great vessels and the thyroid.
Conclusion

- The evaluation of the thyroid in children must take under consideration the normal aspects or variants, the growth of the gland and specific pathological conditions associated with childhood.
- Ultrasound represents an excellent first choice investigation for the initial detection as well as the characterization of thyroid pathology, further studies being reserved for specific situations.
- The evaluation of thyroid conditions in children should include: thyroid function testing, ultrasound and in certain situations scintigraphy.
- With basic knowledge, presented in this pictorial review, even untrained personnel in pediatric pathology can recognize these lesions and make proper decisions on the following management.
References


