Thyroid Ultrasound

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Evaluating the pediatric thyroid

Ultrasound => morphology
Scintigraphy => function
Thyroid function tests
=> indicators of disease

complementary
Indications for thyroid US

- Suspected congenital hypothyroidism
- Suspected hyperthyroidism or hypothyroidism
- Characterization of goitrous/lumpy neck
- Screening for thyroid anomalies/carcinoma
- Screening for iodine deficiency (epidemiologic studies)
- Follow-up of a known abnormality
- Guiding biopsy
Outline

- Appropriate technique
- How do we evaluate size/checklist
- Hypothyroidism congenital vs acquired
- Diffuse thyroid diseases hypo/hyperthyroidism
- Focal thyroid lesions
Appropriate Gray Scale Technique

- High-frequency linear-array ± hockey stick-shaped transducers (7-17 mHz)
- Focal zone placement
- Time gain compensation (TGC) and dynamic range (DR) settings
- Spatial and frequency compound imaging and tissue harmonic imaging

McQueen AS, Bhatia KS. Head and neck ultrasound: technical advances, novel applications and the role of elastography. Clin Radiol 2018
Appropriate Color Doppler Technique

- Color doppler settings:
  - high doppler frequency and high color gain
  - low pulse repetition frequency
  - low frequency filter

- Consistency in color doppler settings

McQueen AS, Bhatia KS. Head and neck ultrasound: technical advances, novel applications and the role of elastography. Clin Radiol 2018

Complete Ultrasound Exam
US of pediatric thyroid

- Presence-position-ectopia
- Shape
- Size
- Echogenicity
- Echotexture
- Vascularization
- ??? nodules / focal lesions
- Lymph nodes
- Pseudolesions: pyramidal lobe, cricoid cartilage
Pseudolesions - cricoid cartilage

- Seen on sag sections
- May contain Ca++
- May mimic nodule


Strauss S. Sonographic appearance of cricoid cartilage calcification in healthy children. AJR 2000
Pseudolesions-Pyramidal lobe

- Incidence 21% - 50%
- Axial + mid sag scans
- Thyroid tissue along thyroglossal duct course

Mortensen C, et al. The incidence and morphological features of pyramidal lobe on thyroid ultrasound. Ultrasound 2014

Pseudolesions-Pyramidal lobe

- May mimic nodule/lymph node
- Is affected by any diffuse parenchymal disease
- May contain a focal lesion
Pseudolesions - Pyramidal lobe

- May mimic nodule/lymph node
- Is affected by any diffuse parenchymal disease
- May contain a focal lesion
Thyroid Size Evaluation

Volume = Height × Width × Length × 0.523 (1)
Volume = Height × Width × Length × 0.47 (2)


* Thyroid volume depends on iodine burden/intake
* Comparison of thyroid volume to body parts (like thumb phalanx, BSA)


Arkadiusz Z. Are the normal values of thyroid gland in children fulfilling the role attributed to them? Thyroid Res. 2015
Th/Tr ratio = \frac{(a + b)}{c}

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>1.25</td>
<td>±0.19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>2.09</td>
<td>±0.19</td>
<td>1.7</td>
<td>2.9</td>
</tr>
<tr>
<td>Large</td>
<td>4.1</td>
<td>±2.42</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
congenital goitre

congenital hypothyroidism
Lt lobe hypoplasia

Normal
Euthyroid child

Hashimoto’s fibrotic stage
Hypothyroidism

CONGENITAL HYPOTHYROIDISM

Occurs 1 in 3000 - 4,000 births

Girls: Boys = 2:1

- Diagnosis by perinatal screening exams → CRUCIAL
- Missed or late diagnosis → Severe developmental disabilities

- Increased association with syndromes
  - Down syndrome
  - Turner syndrome
  - Noonan syndrome
  - Infantile hepatic hemangiomas
  - Type 1 diabetes
  - Celiac disease
  - Williams syndrome

Williams JL et al. Thyroid disease in children: state-of-the art imaging in pediatric hypothyroidism Pediatr Radiol 2013
Ruchala M et al. Diagnostic value of radionuclide scanning and US in thyroid developmental anomaly imaging Nuclear Medicine Review 2011
**Permanent or transient???

- Same hormonal replacement therapy regardless of etiology in infants ≤ 3 years

- Determination of cause significant
  - avoiding delayed diagnosis
  - guiding genetic counseling
  - predict severity and outcome
  - may affect therapy (lifelong LT4 without the one month trial off LT4 at 3 years of age)

- Imaging preferably performed at 1rst week of diagnosis within first 5 days of hormonal replacement prior to shrinkage of existing thyroid

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*Williams JL et al. Thyroid disease in children: state-of-the art imaging in pediatric hypothyroidism Pediatr Radiol 2013*

*Ruchala M et al Diagnostic value of radionuclide scanning and US in thyroid developmental anomaly imaging Nuclear Medicine Review 2011*
THYROID DYSGENESIS
Abnormal structural development of the gland

Remnants of ultimobranchial bodies
no isthmus, <5mm
hyperechogenicity, heterogeneity, small size, poor vascularity,
Anechoic and/or hypoechoic cysts
Extension of the tissue both around and behind the large cervical blood vessels

Thyoidal or non-thyroidal in nature tissue in the thyroid fossa?

Jones et al. Heterogeneous tissue in the thyroid fossa on US in infants with proven thyroid ectopia on isotope scan-a diagnostic trap. Ped Rad 2010
THYROID DYSGENESIS
Abnormal structural development of the gland

1. Lingual thyroid
2. Intralingual thyroid
3. Thyroglossal duct cyst
4. Low neck ectopia
5. Thyroid gland (normal position)
6. Intratracheal position
7. Mediastinal position

Empty fossa → search for **ectopic** thyroid tissue from floor of tongue to thyroid area and lower!
Lingual thyroid (in 75% of Congenital Hypothyroidism, is contains the only functional thyroid tissue):

US ↓ sens (44%),
↑ spec(100%)

Hemiagenesis: rare (0,05%), LT lobe 80%, incidental finding, symptomatic at puberty
Thyroid Dysgenesis
Abnormal structural development of the gland

Hypoplasia the most misdiagnosed form of CH

Freire R et al Sonographic evaluation of the thyroid size in neonates Clin Ultrasound 2015

Table 2 Normal dimensions of the thyroid gland as a function of height from neonates to adolescence, and those as a function of corrected gestational weeks in premature neonates (used with permission [5]). Thickness values are means±SD

<table>
<thead>
<tr>
<th>Corrected gestational weeks (male:female)</th>
<th>No. of subjects</th>
<th>Thickness (cm)</th>
<th>Width (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30–33</td>
<td>5 (14:1)</td>
<td>0.8±0.1</td>
<td>1.1±0.3</td>
</tr>
<tr>
<td>33–37</td>
<td>19 (13:6)</td>
<td>1.1±0.3**</td>
<td>1.4±0.3*</td>
</tr>
<tr>
<td>Height (cm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45–50</td>
<td>42 (20:22)</td>
<td>1.4±0.2**</td>
<td>1.7±0.2**</td>
</tr>
<tr>
<td>50–70</td>
<td>42 (27:15)</td>
<td>1.4±0.1</td>
<td>1.8±0.2</td>
</tr>
<tr>
<td>70–90</td>
<td>8 (6:2)</td>
<td>1.4±0.1</td>
<td>1.9±0.1</td>
</tr>
<tr>
<td>90–100</td>
<td>8 (3:5)</td>
<td>1.4±0.1</td>
<td>1.8±0.2</td>
</tr>
<tr>
<td>100–110</td>
<td>34 (12:22)</td>
<td>1.5±0.3</td>
<td>2.1±0.3</td>
</tr>
<tr>
<td>110–120</td>
<td>35 (20:15)</td>
<td>1.7±0.3</td>
<td>2.3±0.3</td>
</tr>
<tr>
<td>120–130</td>
<td>45 (23:22)</td>
<td>1.8±0.4</td>
<td>2.4±0.3</td>
</tr>
<tr>
<td>130–140</td>
<td>36 (21:15)</td>
<td>1.9±0.5</td>
<td>2.7±0.2</td>
</tr>
<tr>
<td>140–150</td>
<td>42 (20:22)</td>
<td>2.1±0.4</td>
<td>2.8±0.3</td>
</tr>
<tr>
<td>150–160</td>
<td>59 (25:34)</td>
<td>2.2±0.4</td>
<td>2.8±0.4</td>
</tr>
<tr>
<td>160–170</td>
<td>16 (14:2)</td>
<td>2.4±0.4</td>
<td>3.0±0.4</td>
</tr>
</tbody>
</table>

*P<0.05, **P<0.01, compared with 30–33 weeks

Th/Tr ratio = (a + b)/c

Reference intervals in normal neonates
1.7–2.9 (ratio)
0.45–1.53 ml (thyroid volume)
**THYROID DYSHORMONOGENESIS**

Defect in any step in thyroid hormone synthesis

**No gland visible at I\(^{123}\):** Not only dysgenesis...

- Agenesis, hypoplasia
- Dyshormonogenesis (some forms)
- Transient hypothyroidism
- Non functioning thyroid in thyroglossal duct cyst

**Gland visible at I\(^{123}\):** Not only normal...

- Normal
- Ectopia
- Dyshormonogenesis (some forms)
CH: Permanent or transient???

**Ultrasound characteristics**

Dysgenesis: empty fossa???

Empty fossa/half empty fossa

Empty fossa & ectopia

Orthotopic small gland

Orthotopic large or normal gland

Orthotopic normal gland

**No gland visible at I 123: Not only dysgenesis...**

**US:** if orthotopic NL gland → NOT dysgenesis

- dyshormonogenesis
- transient hypothyroidism due to antibodies blocking TSH receptors

**Wait until 3 years of age**

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*Williams JL et al. Thyroid disease in children: state-of-the art imaging in pediatric hypothyroidism Pediatr Radiol 2013*

*Ruchala M et al Diagnostic value of radionuclide scanning and US in thyroid developmental anomaly imaging Nuclear Medicine Review 2011*
Diffuse thyroid diseases
Diffuse thyroid diseases hypo/hyperthyroidism

**Hashimoto’s thyroiditis**
- autoimmune lymphocytic infiltration of the thyroid gland
- euthyroid-mild hypothyroid-hypothyroid
- occasionally toxic=hashitoxicosis

**Grave’s thyroiditis**
- diffuse goiter, ophthalmopathy and hyperthyroidism

**Non-autoimmune thyroiditis**
- Acute bacterial (suppurative)
- Granulomatous –post viral
- Subacute –transient hashimoto-like
Hashimoto’s thyroiditis

Euthyroid, US: mild heterogeneity, Doppler: normal / ↑

US: ↑ size, heterogeneous, hypoechoic nodules: lymphocytic infiltration, Doppler: NL/↓

Increasing fibrosis, US: ↓ size, heterogeneous + hyperechoic lines Doppler: ↓
Hashimoto’s thyroiditis

Giraffe pattern, adjacent lymph nodes
Hashimoto’s thyroiditis

- Larger nodules should undergo FNA
- Increased risk for Ca
Enlarged hypevascular thyroids

Hashitoxicosis: initial ‘active’ state of Hashimoto’s thyroiditis, ↑ vascularity

Graves: ↑↑ vascularity (thyroid inferno), non-specific enlarged heterogeneous gland
Acute Suppurative thyroiditis

- Fever, tenderness, pain during swelling
- Mechanisms: haematogenous or lymphatic route, persistent pyriform sinus fistulae or thyroglossal duct cysts, penetrating trauma to the thyroid gland, immunosuppression.
- Streptococcus and anaerobes 70% of cases

Acute Suppurative thyroiditis

Imaging Findings in Acute Neck Infection due to Pyriform Sinus Fistula

YU Gan, MBCh, BAO, FRCP, SL Lam, MBBS, FRCP, FAMS


associated pyriform fossa sinus
Focal thyroid lesions
<table>
<thead>
<tr>
<th></th>
<th>children</th>
<th>adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevalence of thyroid nodules</td>
<td>0.05-5%</td>
<td>5-10%</td>
</tr>
<tr>
<td>Malignancy</td>
<td>25%</td>
<td>5-10%</td>
</tr>
<tr>
<td>Hot/autonomous nodule</td>
<td>Malignant 30%</td>
<td>typically benign</td>
</tr>
<tr>
<td>Papillary thyroid carcinoma</td>
<td>90% of malignant nodules</td>
<td>70-80% of malignant nodules</td>
</tr>
<tr>
<td>Recurrence rate after total thyroidectomy</td>
<td>30%</td>
<td>4.7-8%</td>
</tr>
</tbody>
</table>

*Essenmacher AC, et al. Sonographic evaluation of pediatric thyroid nodules. Radiographics 2017*


*Lee SJ et al. Diagnostic performance of thyroid ultrasonography screening in pediatric patients with a hypothyroid, hyperthyroid or euthyroid goiter. Pediatr Radiol 2016*
Nodule or not? This is the Q...

Colloid goiter
Echogenic foci with comet tail, reverberation artifacts

Colloid follicles ≤ 0.3 cm
Colloid cysts >0.3 - 1 cm

Intra-thyroid thymus
Hassall’s corpuscles
Identical to mediastinal thymus

Colloid goiter
Intrathyroid thymus

- 0.2-1.7% in general population, 1.6-4.2% incidental
- Location: posteriorly at lower 2/3 of thyroid lobes
- Echo-texture = patient’s visible mediastinal thymus.
- Angulated borders resulting in a geometric or geographic shape
- Any age, usually pre-school and school-age
- Small, less than 1 cm

Raissaki M et al. Hell J Radiol 2018; 3(2): 42-51
• Echo-texture=patient’s visible mediastinal thymus.
• Potential extra-thyroid extension and connection with cervical and mediastinal thymus
• No/sparse internal vascularity on color Doppler

Raissaki M et al. Hell J Radiol 2018; 3(2): 42-51
If Cystic ....look for solid parts!

Color Doppler without pressure
Echogenic avascular hemorrhage vs solid hyperemic part
## Thyroid cancer in children

<table>
<thead>
<tr>
<th>Type</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Papillary thyroid cancer</td>
<td>85-90%</td>
</tr>
<tr>
<td>Follicular thyroid cancer</td>
<td>8-10%</td>
</tr>
<tr>
<td>Medullary thyroid cancer</td>
<td>2-5%</td>
</tr>
<tr>
<td>Anaplastic cancer</td>
<td>1-2%</td>
</tr>
<tr>
<td>Rare mixed types</td>
<td>&lt;0.1%</td>
</tr>
</tbody>
</table>

### Risk factors

- Radiation exposure, especially those <5 years of age, are the most sensitive
- Iodine deficiency
- History of autoimmune thyroiditis
- Genetic disorders that predispose to thyroid neoplasia RET, DICER1 or PTEN gene mutations
- Positive family history
- RT for other childhood malignancies (girls 12-16y: boys=2:1)

*Essenmacher AC, et al. Sonographic evaluation of pediatric thyroid nodules. Radiographics 2017*
If solid, look for

Hypoechogenicity
Microcalcifications
Vascularity
  intranodular
  central-chaotic
Taller than wide (h>\(w\))
Irregular borders-no or interrupted halo
Anterior/subcapsular location
Extrathyroidal extension
Metastatic lymphadenopathy
Size does not matter if strongly suspicious
If solid, look for

Hypoechogenicity

**Microcalcifications**

Vascularity
  - intranodular
  - central-chaotic

Taller than wide (h>\(w\))

**Colloid nodules**
- Iso-hypoechoic
- Internal cystic or heterogenous change
- Echogenic foci with comet tail, reverberation artifacts
If solid, look for

Hypoechogenicity
Microcalcifications

**Vascularity**
- intranodular
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AP to horizontal diameter ratio in transverse plane > 1
Hypoechogenicity
Microcalcifications
Vascularity
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Taller than wide (h>w)
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Metastatic lymphadenopathy
Diffuse sclerosing variant of papillary thyroid Ca (uncommon in adults but more common in the pediatric population), can be hidden in the background of thyroiditis.

Koo JS, et al. Thyroid 2009; 1225-1231
Differentiation between thyroid malignancy and intrathyroid thymus

Focal bulging, age vascularity
ACR TI-RADS discriminates well between malignant and benign nodules in children,

particularly at TI-RADS category 5.

useful in malignancy risk stratification.

! high rate of false-positives at higher TIRADS categories,

! false-negatives, especially in subcentimeter nodules.

Significant relationship between criteria for malignancy (TIRADS-ATA) with the «radiologist’s impression»

**Microcalcifications**

- size > 35 mm
- ill defined margins

Together most predictive of malignancy in children

- Sensitivity 80.7% & Specificity 79.2%

**Spectrum of Thyroid Nodules Categorization According to the ATA**

Benign Very low Low Intermediate High Non-classifiable

**Under investigation in children**

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Modern applications

Elastography

↑ stiffness indicates ↑ possibility for malignancy
↑ possibility for fibrosis

• Complementary, useful for FNA guidance

Take home messages

- US checklist + age + thyroid function aid in the approach of thyroid disease
- Beware of predisposing factors and US findings favoring thyroid malignancy-low threshold for FNA
- Remember pitfalls!
- Innovative techniques face challenges in children
THANK YOU!