Thyroid Imaging

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Outline

- Thyroid Anatomy
- Benign Thyroid Disease
- Thyroid Nodular Disease
- Thyroid Cancer
- Patient 1
- Patient 2
Thyroid Anatomy

- Thyroid: composed of two lateral lobes connected by isthmus
- Isthmus rests at level of 2nd to 4th tracheal cartilages
- Thyroid lobes measure approx 4 cm long, 1.5 cm wide, 2 cm deep
- Inferior pole extends to level 5th or 6th tracheal ring
- Superior pole occupies space between sternothyroid muscle ventrally, inferior constrictor and posterior thyroid lamina medially
- Gland covered by infrahyoid strap musculature ventrally
- Pyramidal lobe (present in approx 40%) can arise from superior aspect midline isthmus, or from right or left lobes
- Normal adult thyroid weight 15 to 25 g
Thyroid Anatomy

Thyroid Anatomy

www.thaiclinic.com/images/thyroid_anatomy.jpg
Thyroid: Vascular Supply

Arteries:

- Superior thyroid artery (external carotid)
- Inferior thyroid artery (thryocervical trunk)
- Thyroid ima (innominate, carotid, directly from aortic arch)
Thyroid: Vascular Supply

Veins:
- Superior thyroid vein
- Middle thyroid vein
- Inferior thyroid vein
Thyroid Gland Embryology

- Gland develops in 1st trimester
- Development begins in 5th week, completed by 9th to 10th week of gestation
- Median anlage arises in midline oropharynx: ventral diverticulum from endoderm of first and second pharyngeal pouches
- Lateral anlages thought to arise from ultimobranchial bodies (4th and 5th branchial pharyngeal pouches)
- Anlages fuse by 10th week to form bilobed gland
# Clinical Manifestations of Thyroid Disease

## Hypothyroidism

### Differential Diagnosis

<table>
<thead>
<tr>
<th>1.</th>
<th>Primary gland failure (common)</th>
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<tbody>
<tr>
<td>a.</td>
<td>Hashimoto’s thyroiditis</td>
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<tr>
<td>b.</td>
<td>Iodine deficiency</td>
</tr>
<tr>
<td>c.</td>
<td>Thyroiditis</td>
</tr>
<tr>
<td>d.</td>
<td>Radiation-induced</td>
</tr>
<tr>
<td>e.</td>
<td>Post-surgical</td>
</tr>
<tr>
<td>f.</td>
<td>Drugs (lithium, iodine)</td>
</tr>
<tr>
<td>g.</td>
<td>Hereditary</td>
</tr>
</tbody>
</table>

| 2. | Central hypothyroidism (rare) |

### Clinical Manifestations

- Fatigue, slow mentation, change in memory, depression, cold intolerance, hoarseness, brittle hair, dry skin, thick tongue, weight gain, constipation/ileus, menstrual disturbance, bradycardia, nonpitting edema, hyporeflexia, psychosis, hyponatremia, hypoglycemia, coma

- Infants: mental retardation, cretinism
# Clinical Manifestations of Thyroid Disease

## Hypothyroidism

### Differential Diagnosis

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<table>
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<tr>
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<tbody>
<tr>
<td>1.</td>
<td>Graves Disease</td>
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<tr>
<td>2.</td>
<td>Toxic nodule/ multinodular goiter</td>
</tr>
<tr>
<td>3.</td>
<td>Thyroiditis</td>
</tr>
<tr>
<td>4.</td>
<td>Exogenous hyperthyroidism/ Struma ovarii/ Functional thyroid cancer</td>
</tr>
<tr>
<td>5.</td>
<td>Thyrotropin, thyrotropin- like secreting tumor</td>
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### Clinical Manifestations

- Weight loss, fatigue, nervousness, tremor, palpitations, increased appetite, heat intolerance, muscle weakness, diarrhea, sweating, menstrual disturbance
Benign Thyroid Disease

- Hypothyroidism
- Hyperthyroidism
- Thyroiditis
- Nontoxic diffuse and multinodular goiter
Thyroid Function

• Thyroxine T4
• Triiodothyronine T3
• TH secretion regulated by TSH from anterior pituitary
Thyroid Imaging

- Nuclear Scintigraphy
- Ultrasonography
- Cross-Sectional Imaging
  - CT
  - MRI
Thyroid imaging: Nuclear Scintigraphy

- Excellent functional information
- Evaluation focal thyroid masses to determine if lesion “hot” or “cold”
- Iodine 123: preferred isotope for functional evaluation
- $^{99m}$ Tc pertechnate: preferred radionuclide imaging agent for anatomic thyroid evaluation
- Iodine 131: evaluation (24 hr uptake) and treatment of cancers that concentrate iodine, post-thyroidectomy followup
- Metastatic cancer imaged well with $^{131}$ I

www.firsthealth.org/services/imaging/images/thyroid.jpg
## Radionuclides Used in Imaging

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Administration</th>
<th>Dose</th>
<th>Half-Life</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>99m Tc</td>
<td>IV</td>
<td>2–10 mCi</td>
<td>6.02 h</td>
<td>140 keV</td>
</tr>
<tr>
<td>123 I</td>
<td>Oral</td>
<td>200-400 μCi</td>
<td>13.6 h</td>
<td>159 keV</td>
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<tr>
<td>131 I (diagnostic)</td>
<td>Oral</td>
<td>30-100 μCi</td>
<td>8.05 d</td>
<td>364 keV</td>
</tr>
<tr>
<td>131 I (whole body)</td>
<td>Oral</td>
<td>3-5 mCi</td>
<td></td>
<td></td>
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<tr>
<td>131 I (treatment)</td>
<td>Oral</td>
<td>100 mCi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>131 I (treatment)</td>
<td>Oral</td>
<td>100-200 mCi</td>
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</table>

- Diagnostic whole body scan s/p thyroidectomy
- Cancer txt: Ablation residual thyroid tissue
- Cancer txt: Ablation thyroid metastases
Thyroid Imaging: Ultrasonography

• Real-time U/S with 7.5 to 10 MHz high resolution transducers
• Carotid arteries and jugular veins: excellent anatomic markers posterior and lateral to thyroid lobes
• Thyroid gland normally uniformly hyperechoic
• More hypoechoic focal lesion is relative to NL thyroid, higher likelihood malignancy
Thyroid Imaging: Ultrasonography

Advantages of Ultrasound
• Accessible, inexpensive, noninvasive
• Quick, highly sensitive for cystic vs solid lesion
• Can identify cysts as small as 2 mm, solid lesions as small as 4 mm
• Can identify number, size, shape of cervical nodes surrounding, distant from thyroid: size, shape nodes correlated with presence nodal metastatic disease
• Useful for screening thyroid for small lesions in patients presenting with metastatic CA, for evaluation thyroid s/p head and neck irradiation

Limitations
• Quality, interpretation of images operator-dependent
• Inferior to cross-sectional imaging in identifying lymphadenopathy, extension thyroid disease
 Thyroid Imaging: Cross Sectional Imaging

Important adjunctive anatomic information!
• Better delineation lesion within thyroid
• Detection lymph node metastases
• Extension thyroid disease to adjacent tissues in neck
• Assess paraspinal muscle, esophageal, tracheal, jugular vein invasion
• Scans done in supine position with neck mildly hyperextended
• Contiguous 5-mm-thick axial sections from level of cavernous sinus superiorly extending inferiorly into superior mediastinum to include aortic arch
• Thin sections (1-3 mm) for small lesions
• No contrast with CT if patient to undergo scintigraphy (can do MRI with gadolinium instead)
Thyroid Imaging: Cross Sectional Imaging

MRI

- Dedicated surface coil centered over thyroid gland
- Nodules as small as 4 mm detected
- T1: Normal thyroid homogenous signal intensity slightly greater than neck musculature
- T2: thyroid gland hyperintense relative to musculature
- Contrast: gadolinium
- Multiple pulse sequences obtained:
  - Unenhanced sagittal and axial T1 weighted images
  - Axial fast spin-echo T2 weighted images with application fat saturation, repeated after administration gadolinium
Evaluation of Thyroid Nodular Disease

- Clinical Examination
- Thyroid function tests
- Palpation guided FNA
  augmented by....

Ultrasound examination of high risk patients

Ultra-sound guided FNA
Nodular Thyroid Disease

• COMMON
  • 4 to 7% of adult population
  • Sonography: adults age 19 to 50 have approx 30% incidence thyroid sonographic abnormality, >60% incidence in population above age 60 to 70
  • Most nodules represent follicular nodules that develop in adenomatous goiters after cycles of hyperplasia and colloid involution
  • About 1 in 20 nodules estimated to contain carcinoma
Differential Diagnosis of Thyroid Nodule

- Colloid Nodule
- Adenoma
- Cyst
- Focal Thyroiditis
- Thyroid Carcinoma
- s/p Hemithyroidectomy
- Hemiagenesis
- Metastasis to thyroid
- Nonthyroid:
  - Lymph Node
  - Parathyroid Cyst
  - Cystic Hygroma, dermoid, teratoma
  - Laryngoecele
  - Thyroglossal duct cyst

95%
Imaging: Benign vs Malignant?

Ultrasound:

- Focal lesions with ALL criteria simple cyst (thin wall with smooth margins, anechoic, distinct back wall, enhanced through transmission) usually benign
- Any complicated cyst may be carcinoma
- Calcifications nonspecific (seen in BOTH benign and malignant lesions)
- Ultra-sound guided FNA for cytology
Imaging: Benign vs Malignant?

Nuclear Imaging:
- Hot nodules 1 to 4% risk malignancy
- Warm nodules usually adenomas, risk of carcinoma up to 10%
- Low $^{123}$I uptake within single palpable cold nodule: 10 to 25% chance of malignancy
- Low $^{123}$I uptake within single palpable cold nodule if multiple nodules demonstrated: 1 to 3% risk of malignancy
- Most thyroid nodules warm or cold
- Even cold lesions misleading: up to 80% cold lesions benign
- Risk cancer in nodules with increased $^{99m}$Tc uptake approximately 29% (compared to 4% with increased uptake $^{123}$I) so these
- Hot $^{99m}$Tc lesions generally rescanned with $^{123}$I for further characterization
Imaging: Benign vs Malignant?

Cross Sectional Imaging:

- Helpful if extension/invasion, lymphadenopathy

CT SCAN: Differing growth patterns


- 29 benign (follicular adenomas), 29 malignant (papillary CA) tumors with findings arranged according to size

- Benign tumors:
  1. Grew expansively, made beak like appearance in marginal thyroid tissue (beak sign)
  2. Displaced vessels but kept fat plane or deep sulcus between them (sulcus sign)

- Malignant tumors:
  1. Grew invasively and reached trachea rapidly without beak sign
  2. Destroyed fat plane and contacted vessels without sulcus sign
Risk Factors for Thyroid Carcinoma

- Age (<20 or >60)
- Male sex
- Prior radiation
- Family history
- Gardner’s (polyposis coli) and Cowden’s (skin tags, breast CA, facial papillomas) syndromes
- Family history of medullary carcinoma, pheochromocytoma, hyperparathyroidism (MEN syndrome)
- Respiratory distress, voice changes, hoarseness, cough, dysphagia
- Rapid growth of lesion
- Ipsilateral lymph nodes
- Long-standing goiter
Thyroid Carcinoma

- Papillary
- Follicular
- Medullary
- Anaplastic
Fine Needle Aspiration (FNA)

CENTRAL DIAGNOSTIC TEST in thyroid nodular disease

Ultrasound guided FNA

www.thyroidimaging.com
Thyroid Cancer: Papillary

- Majority of malignant thyroid cancer: 60-80%
- Low grade malignancy characterized histologically by papillae formation, unique nuclear features
- Purely papillary, mixed papillary and follicular, follicular
- Frequently multifocal (intraglandular lymphatic spread)
- Highest incidence for cervical node spread
- Hematogenous spread to lungs, bones, CNS may occur
- More frequent in women (2-3:1), peak incidence 3rd and 4th decades
- Scanning with $^{131}$I after thyroidectomy valuable to identify recurrent/residual thyroid disease in operative bed, distant metastases
- Good prognosis: mortality rate 8-11%
Thyroid Cancer: **Follicular**

- Well-differentiated thyroid malignancy with follicular differentiation, no features of papillary CA
- Typically seen as small follicular arrays or solid sheets of cells
- Cytologically cannot be diagnosed with certainty: overlap with benign follicular adenoma
- Pericapsular vascular invasion most reliable indication malignancy
- Slightly more aggressive than papillary carcinoma: mortality 24-33%
- Pathologically: capsular and vascular invasion in specimen
- Distant metastases to lung and bone (approx 16% cases) more common than lymph node spread
- Prognosis mostly dependent on degree of invasiveness
- Typically older age group, more advanced disease
- Like papillary CA, follicular cancers concentrate iodine, $^{131}$I imaging useful

[www.callosomed.mun.ca/~tscott/endotut.htm](http://www.callosomed.mun.ca/~tscott/endotut.htm)
Thyroid Cancer: Medullary

- Derived from parafollicular C-cells
- Calcitonin: tumor marker, useful for followup
- Relatively uncommon (5-10% all thyroid CA)
- Higher mortality rate than well-differentiated thyroid CA: 50%
- 75% sporadic: unifocal thyroid lesion without associated endocrinopathy
- All 3 forms hereditary MTC inherited as autosomal dominant traits, associated with multifocal MTC (MEN)
- May invade locally, spread to regional cervical lymph nodes, result in hematogenous seeding with distant mets (commonly lung, bones, liver)
- DOES NOT CONCENTRATE RADIOIODINE
- Radionuclides specific for neuroendocrine tissue ($^{131}$I meta-iodobenzylguanudine (MIBG) and somatostatin analog $^{111}$In pentetreotide used with some success)
- May uptake gallium or thallium

www.calloso.med.mun.ca/~tscott/endotut.htm
Thyroid Cancer: Anaplastic

- Rare (less than 5% thyroid malignancies)
- Usually presents in elderly women
- Commonly occurs in those with long-standing goiter
- Highly aggressive and rapidly fatal: mortality 75-90%, average survival 6 months
- Cancers grow rapidly, typically compress and invade aerodigestive tract and vessels
- Lymphatic metastases in majority patients, often necrotic
- Important to rule out lymphoma with biopsy
- Surgical treatment generally limited to isthmusectomy for biopsy, often combined with tracheotomy
Thyroid Cancer: Other

- Metastatic disease to thyroid
  - uncommon
  - renal carcinoma (clinically), lung and breast (autopsy)
- Lymphoma
  - uncommon
  - increased risk in Hashimoto’s patients
Patient 1

40-year-old woman with history of hypothyroidism diagnosed 2 years ago (formerly on thyroid replacement) presents with report of cold nodule on thyroid scan

Local symptoms leading to thyroid scan: “swollen glands” 3 months prior that have gone down but not completely on right

Initial symptoms when diagnosed with hypothyroidism: lethargy, cold sensation, oligomenorrhea

Now euthyroid
Physical Exam

Pleasant, well-appearing woman in NAD
P 96, regular  BP 134/70  weight 155
HEENT:  EOMI, no proptosis, no lid lag
Thyroid: obvious right-sided prominence
  firm, approximately 2.0 X 2.0 cm well-circumscribed nodule
  on right, moves easily with swallowing and is nontender
  very little palpable tissue on left
  Normal isthmus
  No LAD appreciated
Lungs: CTA
Cardiac: RRR, slightly hyperdynamic
Thyroid scan and uptake: 292 mCi given and uptake elevated at 41%. There was an asymmetric hyperfunctioning lower right pole and a cold nodule in the right upper pole.
Scintigraphy

Normal

Cold nodule right lower pole

www.thyroidimaging.com
Fine Needle Aspiration:

Ultrasound-guided FNA yielded microfollicular cells
Ultrasound Anatomy

Thyroid in Cross-Section

Ultrasound:

Agenesis of left lobe:

Right lobe

trachea

Absent left lobe

CT SCAN

www.thyroidimaging.com
Treatment:

**Surgery:**
Right thyroid lobectomy and isthmusectomy (Total thyroidectomy since agenesis of left lobe of thyroid)
Right superior parathyroid reimplanted into SCM
No postop complications

**Pathology Report:**
2.7 cm follicular carcinoma with vascular invasion
Intrathyroidal parathyroid tissue
Radionuclide Thyroid Scan

• To ensure no more functioning thyroid tissue
• Patient stopped thyroid hormone for 2 weeks period to increase TSH to high levels (> 30 or 40). This will stimulate any thyroid tissue to take up iodine given by radiologist. Patient also put on low-iodine diet for 2 weeks prior to scan.
• Patient received small dose radioactive iodine
• Patient returned next day for whole body scan
• Scan showed findings consistent with physiologic uptake in residual thyroid tissue in right upper neck, possibly pyramidal lobe
\(^{123}\text{I} \) Radionuclide Thyroid Scan

Approximately 24 hours after oral ingestion of tracer, uptake of tracer in thyroid bed is 2.7%. Scan of thyroid demonstrates linear focus of intense iodine accumulation in right upper neck.
Radioablation

• To ensure no more functioning thyroid tissue
• Patient given dose of 102.2 mCi $^{131}$I to destroy remaining thyroid tissue
• Patient rescanned one week after large dose radioactive iodine to determine if any remaining tissue
• Patient on levoxyl to suppress TSH
Postablation Radionuclide Thyroid Scan

No iodine uptake in neck or elsewhere

BIDMC PACS
Follow up

- Patient without recurrence to date
- Last ultrasound with no evidence residual thyroid tissue or abnormal mass

Follow up:
- endocrinology every 3 months, increase to 6 to 12 months as needed
- thyroid scan 6 months post-surgery, after one to two negative scans at increasing intervals (usually scanned yearly)
- thyroid function testing
- thyroglobulin
Additional
Follicular CA: Imaging

Ultrasound
Solitary nodule at Base of right lobe (21X16X28 mm)

Color Doppler

www.thyroidimaging.com
Patient 2


- possible history thymic radiation as child
Iodine-131 Total Body Scan

Abnormal study suggestive of metastatic lesion in lower neck, mediastinum, both lungs and possibly upper portion of liver
Iodine-131 Whole Body Scan s/p Treatment with 200 mCi Radioactive Iodine

Mets before

No mets s/p Radioactive Iodine ablation
Papillary Cancer Images

Large nodule in right lobe and isthmus of thyroid that alters anterior capsule profile.
Borders irregular.
Structure dishomogenous, hypoechoic.

Evident lateral cervical lymphadenopathy

Transverse

Longitudinal

www.thyroidimaging.com
Papillary Cancer Images: Lymph Node

Right cervical lymphatic node (7.2X11.8X22.6 mm), parenchymatous, heterogenous, with regular borders, very different from normal structure of inflammatory node (hypoechoic)

29 y/o F with Large thyroid nodule

www.thyroidimaging.com
References

- [www.callosomed.mun.ca/~tscott/endotut.htm](http://www.callosomed.mun.ca/~tscott/endotut.htm)
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- [www.univ-st-etienne.fr](http://www.univ-st-etienne.fr)
- [www.vesalius.com](http://www.vesalius.com)
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