PI Session: 2021.11.10_D and T_Radiology: Imaging of Endocrine system_ Preparatory_Marcus John Julius, M.D.

Objectives: At the end of this session, students will be able to:

1. Analyze the role of MR imaging in the assessment of the pituitary gland (including differentiation of pituitary microadenoma from pituitary macroadenoma)
2. Discuss the role of nuclear medicine imaging in the assessment of the parathyroid glands (including hyperparathyroidism)
3. Utilize a variety of radiologic examinations to assist in the workup and characterization of thyroid nodularity.
4. Describe the use of nuclear medicine in the assessment (and potential treatment) of thyromegaly (i.e. goiter)
5. Implement a logical imaging protocol in the workup of an incidental adrenal mass

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PITUITARY GLAND

-**Anatomy**

-Anterior lobe
- -Originates from epiblast of buccal cavity
  - -Constituent hormones
    - -TSH, LH, FSH, GH, ACTH, Prolactin

-Posterior lobe
- -Outgrowth of embryonic neural tissue
  - -Constituent hormones
    - -Vasopressin, Oxytocin

-**Physiology**

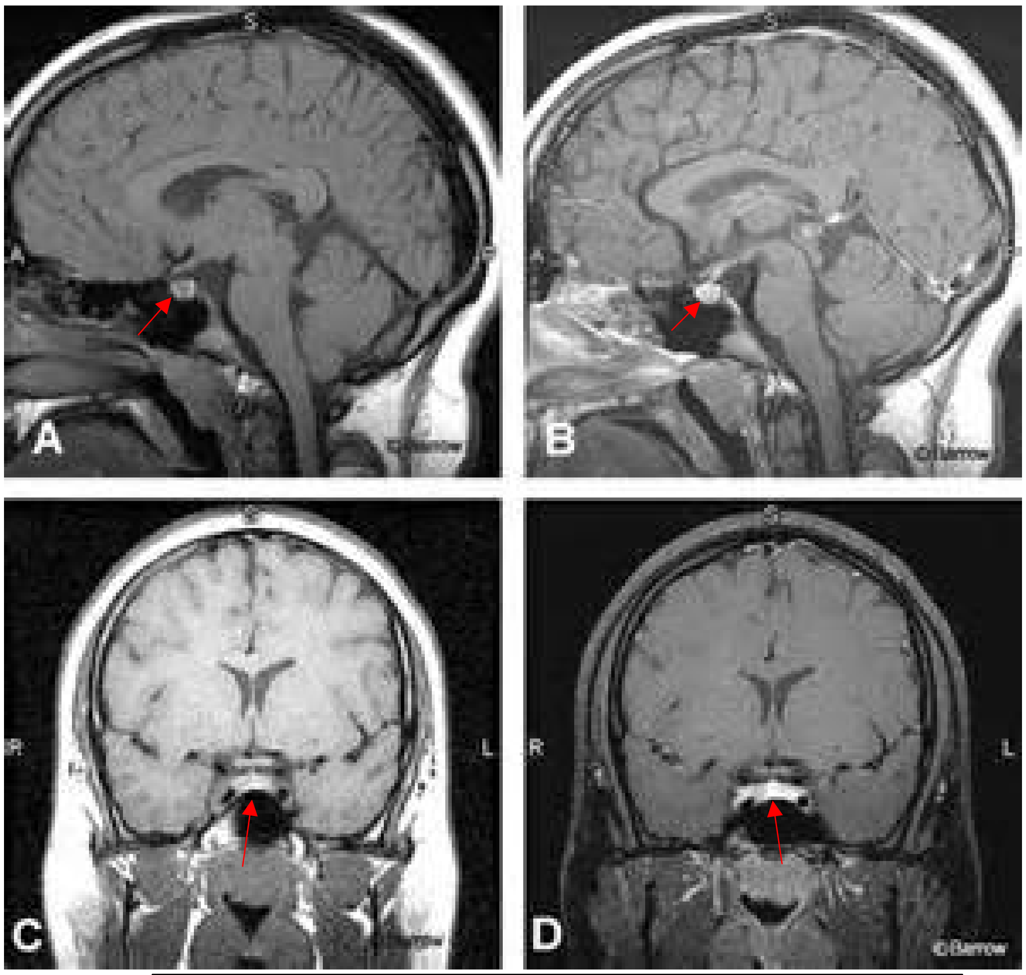
-Based on end-effect of myriad of constituent hormones

-**Normal Imaging**: Unenhanced and enhanced MR imaging is the preferred method of imaging the pituitary gland

-Enhanced imaging utilizes gadolinium (Gd) contrast administration (IV)
- -Gd contrast media warrants: Normal renal function; No Gd allergies

-Multiplanar MR imaging is performed: Axial, coronal, and sagittal planes (including thin-sectioning through the pituitary gland)

-CT imaging (prior to and after iodinated contrast administration) is performed in patients unable to undergo MRI
- -MRI contraindications: Unapproved medical devices (i.e. pacemaker, aneurysm clip, neurostimulator, ferromagnetic metallic foreign body).
- -Gd contraindications: renal failure; severe Gd allergy



Normal MRI pituitary gland (red arrows)
-'A' and 'B': unenhanced and enhanced sagittal, respectively

PITUITARY GLAND (abnormal imaging)

Pituitary *micro*adenoma

-Size: less than 10mm

-Clinical presentation: based on hormone production

- Neoplasm visualization is more optimal on MR imaging than on CT imaging (Imaging features cannot distinguish between different subtypes of pituitary adenomas)

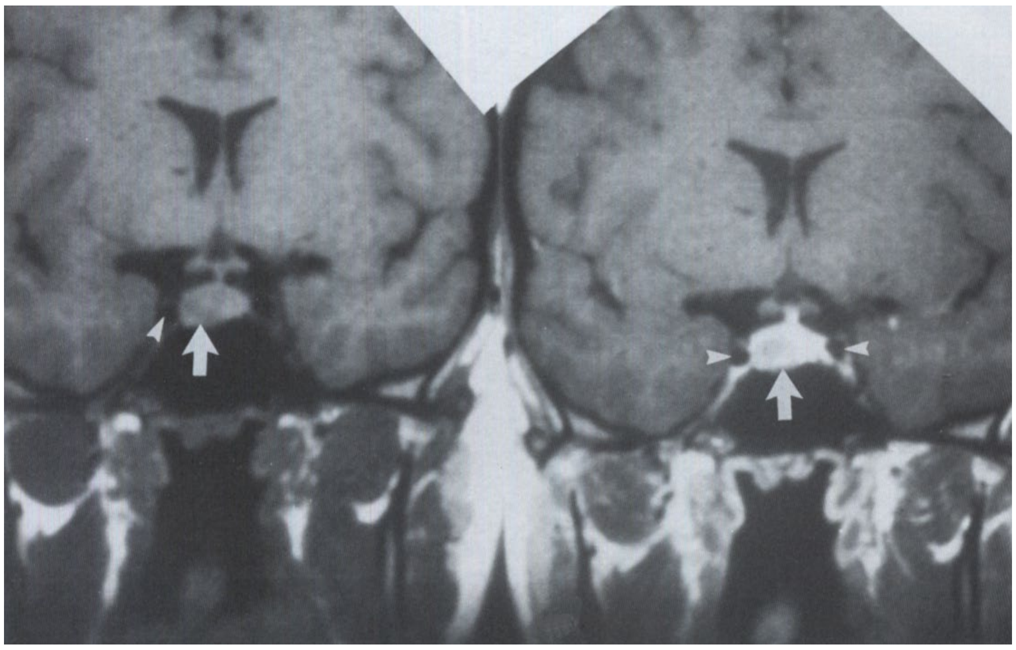
-Imaging characteristics

-Small non-enhancing foci represent the tumor itself (typical)

-Deviation of pituitary stalk (*away from* the side of the tumor)

-Accentuated superior convexity of pituitary gland

-[Depression of floor of the sella]



Pre-contrast T1 coronal image (left)
Arrow indicates pituitary microadenoma
(Arrowhead indicates cavernous ICA)

Post-contrast T1 coronal image (right)
Arrow indicates pituitary microadenoma
(Arrowhead indicates cavernous ICA)

Pituitary *macro*adenoma

-Size: greater than 10mm

-Clinical presentation: mass effect (i.e. bitemporal hemianopsia; hydrocephalus; cranial neuropathy; may be endocrinologically inactive)

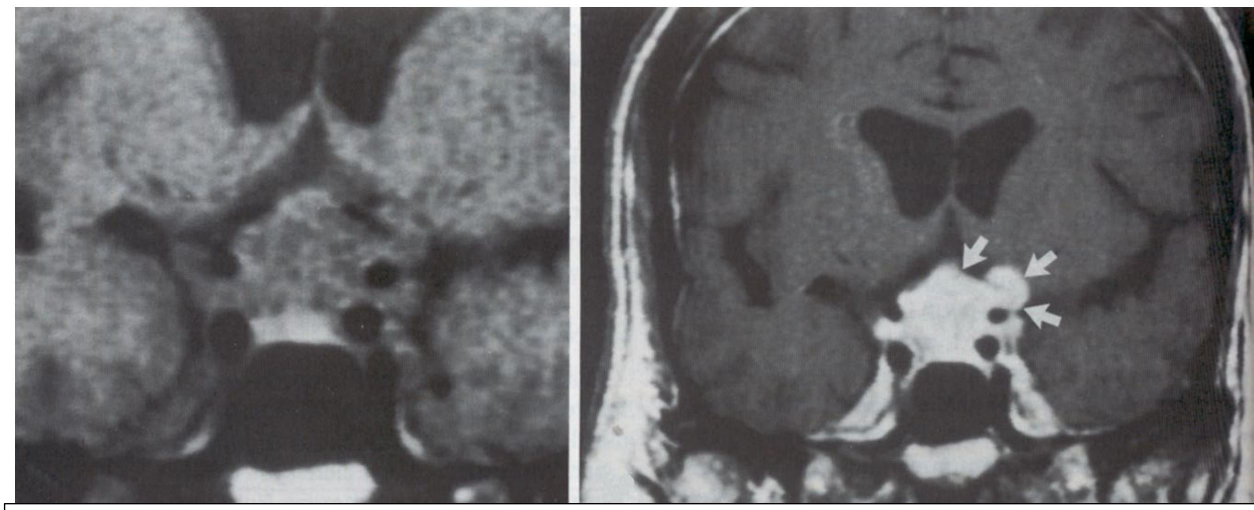
-Pituitary apoplexy may occur

-Intratumoral hemorrhage

-Headache/nausea/vomiting/stiff neck/visual defect/obtundation/hypopituitarism (if >70% gland destruction)

-Imaging characteristics (MR and CT)

- Heterogeneous appearance and enhancement
- Sellar expansion
- Cavernous sinus extension
- Mass effect
  - -Optic chiasm compression
  - -Secondary hydrocephalus
  - -Cranial nerve compression



Pre-contrast T1 coronal image (left) **Post-contrast T1 coronal image (right)**
(*Arrows indicate pituitary macroadenoma with extension to involve cavernous sinus*)

PARATHYROID GLANDS

-**Anatomy**

-Origins

-Inferior parathyroid glands

- 3rd pharyngeal pouch (dorsal part)

-Thymus arises from the ventral part of the 3rd pharyngeal pouch

-Superior parathyroid glands

-4th pharyngeal pouch

-Migrate with the ultimobranchial bodies

Altered migration pattern

-*Inferior* parathyroid glands have greater variability in their location

-**Physiology**

-Based on effects of parathyroid hormone, calcium and phosphate homeostasis is maintained

-End organs: Bone, GI tract, and kidneys

-**Imaging characteristics (abnormal imaging)**

-Nuclear medicine imaging (Single isotope imaging)

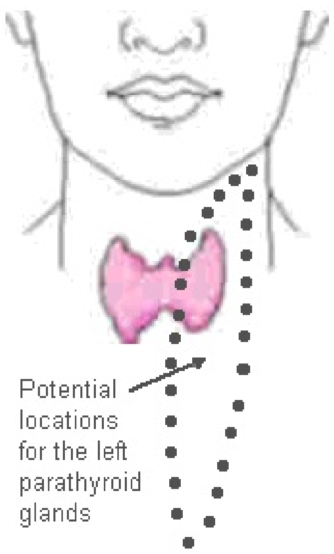
-Technetium (Tc)-99m-sestamibi

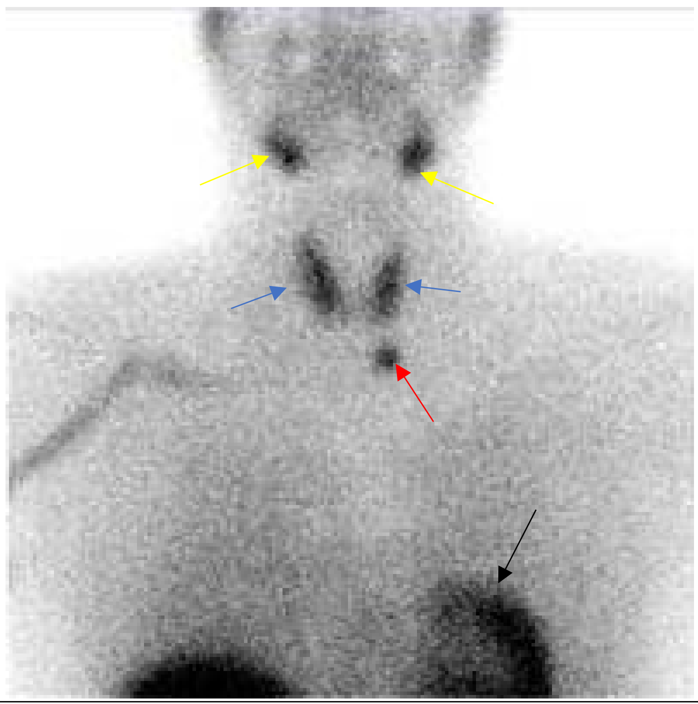
-Localizes to mitochondrial-rich tumors

-Initially localizes to thyroid and parathyroid tissues (within 30 minutes)

-Delayed imaging (2-hour) demonstrates "washout" from normal thyroid tissue (with retention within *abnormal* parathyroid glands, most commonly **parathyroid adenoma**)

-False negative (FN): small parathyroid size or diminished uptake of Tc-99m-sestamibi by parathyroid adenoma





Ectopic left inferior parathyroid adenoma (red arrow)
Thyroid gland (blue arrows)
Submandibular glands (yellow arrows)
Heart (black arrow)

-Hyperparathyroidism (HPT)

-Etiologies

-Primary

-Adenoma (85%)

-Hyperplasia (13%)

-Carcinoma (1-2%)

-Familial occurrence may be seen with adenoma/hyperplasia

-Secondary and tertiary HPT concepts will be presented in clinical sessions

Note: Osseous imaging findings of hyperparathyroidism will be presented in Spring D and T (rheumatology section)

THYROID GLAND

-**Anatomy**

-Thyroid gland is bilobed (with the thyroid lobes connected by thyroid isthmus)

-Origin: Midline diverticulum between fused portions of 1st and 2nd pharyngeal arches (with pharyngeal epithelium migrating from the base of the tongue to the cervical region)

-Normal thyroid migration

-Origin: *foramen caecum* (between tuberculum impar and copula linguae)

-Descends anterior to pharyngeal gut through the thyroglossal duct

-Final location: base of neck (anterior to hyoid bone)

-**Physiology**

-Trapping: iodides are actively transported into the thyroid gland

-Oxidation: under the influence of "thyroid peroxidase"

-Organification: binding of iodides to tyrosyl moieties [forming mono-iodotyrosine (MIT) and di-iodotyrosine (DIT)]

-Coupling: MIT+DIT= triiodothyronine; DIT+DIT=thyroxine

-**Imaging characteristics**

--Nuclear medicine imaging (NM)

-Thyroid uptake (generates a numerical value)

-NPO after midnight

-Iodine 123 by mouth (PO)

-Identical dose is placed in "neck standard"

-8 to 24 hours later, Pt activity is calculated as is neck standard activity

-Thyroid uptake:

-% Thyroid uptake= [Pt neck counts – Pt background counts (measured in Pt's thigh)]/counts in "neck standard"

-Increased (greater than 30% at 24 hours)

-Hyperthyroidism (diffuse or nodular)

-*Early* thyroiditis

-Iodine starvation

-Thyroid rebound after withdrawal of antithyroid medication

-Decreased (less than 10% at 24 hours)

-Hypothyroidism

-*Subacute/chronic* thyroiditis

-Iodine excess (dietary/recent iodinated contrast administration)

-Anti-thyroid medication

-S/P thyroid removal/ablation

-Ectopic thyroid tissue (struma ovarii)

-Thyroid imaging (creates an image of the gland)

-Iodine 123 by mouth (PO). Image at 24 hours

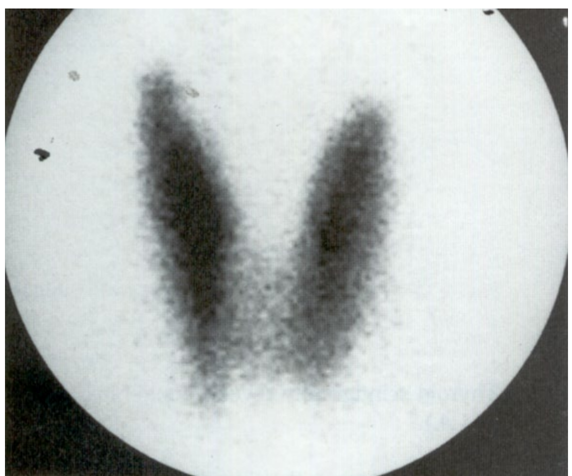
-Technetium 99m pertechnetate (5-10 millicuries) IV. Image within 1 hour

-Physical half-life of radiopharmaceuticals

I-131: 8.06 days (utilized in radioactive iodine therapy: hyperthyroidism, thyroid neoplasia): *Beta emitter*

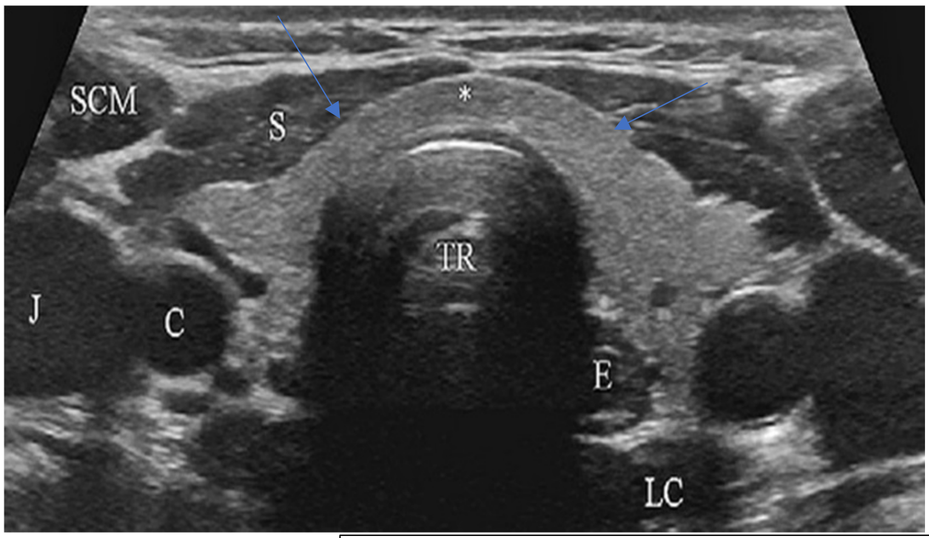
I-123: 13.3 hours

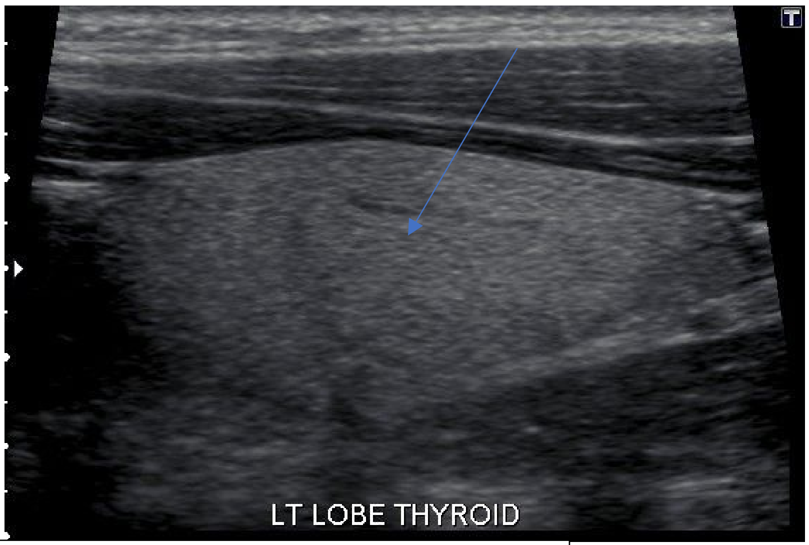
Tc99m: 6.02 hours



Normal scintigraphic image of the thyroid gland

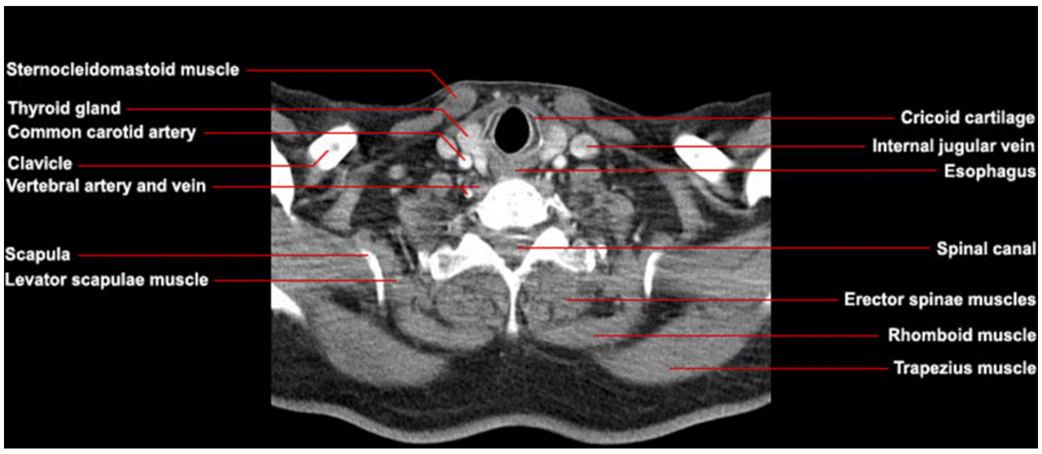
-Sonography
- -No ionizing radiation
- -Palpable abnormalities may be characterized as intraglandular or extragladular
- -Palpable nodules may be characterized as “cystic” or “solid”
- -Sonographic guidance aids in thyroid biopsy





Normal thyroid sonogram: Axial image (left) and sagittal image (right)
Thyroid gland (blue arrows). J: jugular vein. C: common carotid artery. E: esophagus.
TR: trachea. S: scalene muscle. SCM: sternocleidomastoid muscle. LC: longus colli muscle

-Computerized axial tomography (CT)
- -May incidentally visualize thyroid enlargement or thyroid masses (in examinations performed for other reasons)
- -Useful to assess for additional neck pathology (including lymphadenopathy) in the presence of thyroid neoplasia
- -Useful to assess for metastatic disease (including osseous and pulmonary metastases) in the presence of thyroid neoplasia



Normal enhanced neck CT

-Magnetic resonance imaging (MRI)
- -May be utilized to assess thyroid parenchyma but has somewhat *ancillary* role (to other imaging modalities)

-Positron emission tomography (PET)
- -May be used for assessing differentiated thyroid cancer (especially in patients with elevated thyroglobulin levels and negative whole body radioactive iodine scan)

-Radioactive iodine whole body scan (diagnostic and treatment scans)
- -Detection and ablation of residual thyroid tissue as well as functioning (metastatic) neoplastic thyroid tissue

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THYROID GLAND (abnormal imaging)

-Thyroid nodule
- -Most-common clinical indication for *nuclear* thyroid imaging
- -Provides data of *functional* status of the nodule
  - -“cold”: non-functioning
  - -“hot”: functioning

-Risk of malignancy (in thyroid nodule)

-Hot nodule: 1%

-Cold nodule: 15-25% (unless there is a history of prior neck irradiation, whereby the malignancy risk rises to 40%)

-Differential diagnosis of "cold" thyroid nodule

-Adenoma and colloid cyst (70-75%)

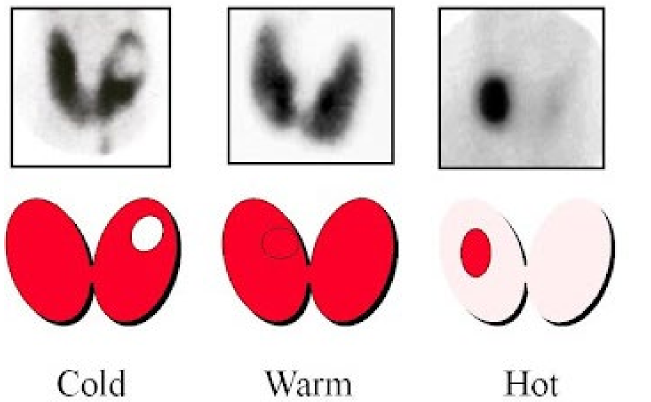
-Carcinoma (15-25%)

-Focal thyroiditis

-Abscess/hematoma

-Lymphoma/metastases/lymph nodes

-Parathyroid adenoma



Thyroid nodules (Intranet.tdmu.edu.ua)

Note: "Hot" nodules almost always relate to hyperfunctioning adenoma (with <1% chance of thyroid carcinoma)

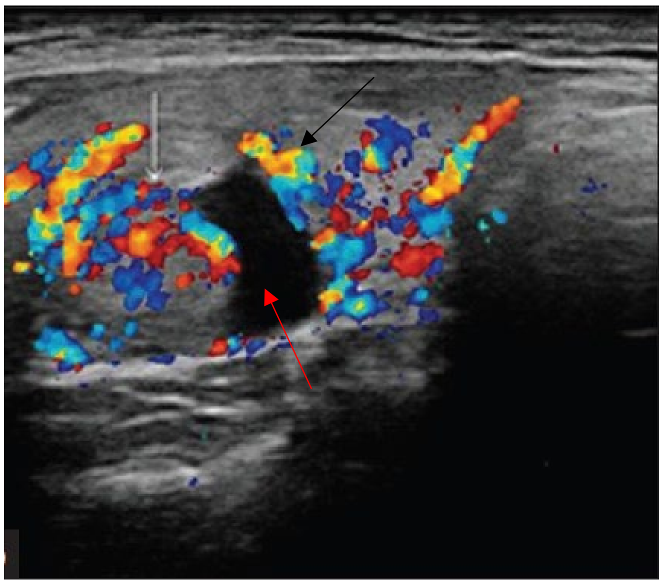
Note: Additional information regarding thyroid nodules

-History of prior neck irradiation (in Pt with solitary cold nodule) increases the chance of thyroid carcinoma to 40%

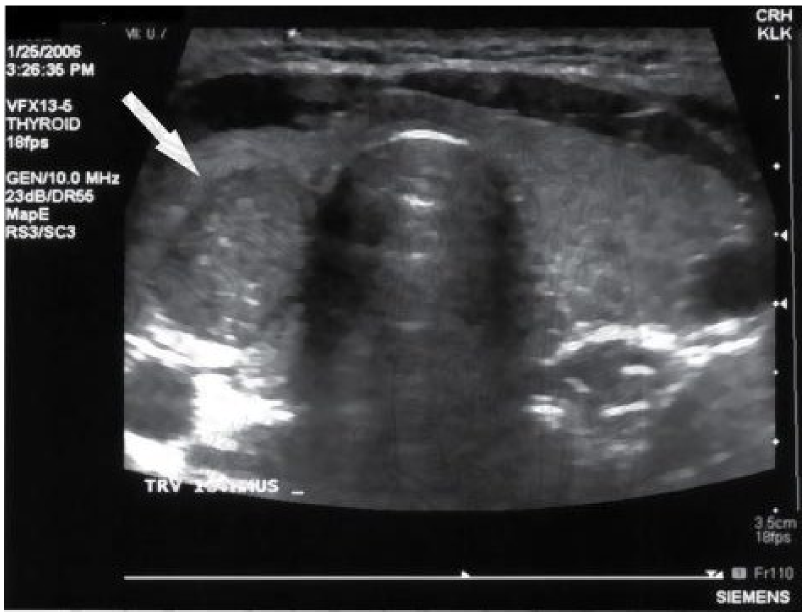
-In Pts with multinodular goiter (I.e. multiple hot and cold nodules), the chance of thyroid cancer in a given cold nodule ranges from 1-6%

-"Solitary" nodules by scintigraphy are found to be "multiple" with the use of sonography (20-25% of the time)

-Sonography can help to characterize "cold" thyroid nodules as cystic or solid (and can aid in guiding biopsy)



Sonogram of solid (white arrow) and cystic (red arrow) thyroid nodule.
Increased vascularity (black arrow)
(www,ijcm.in)



Sonogram of right-sided solid thyroid nodule (white arrow)
(www.elsevierimages.com)

-Thyromegaly/thyroid enlargement ('goiter')

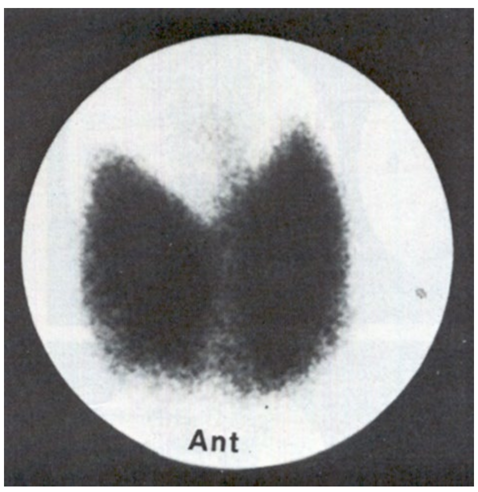
-Diffuse vs nodular

-Toxic (i.e. hyperfunctional) vs non-toxic

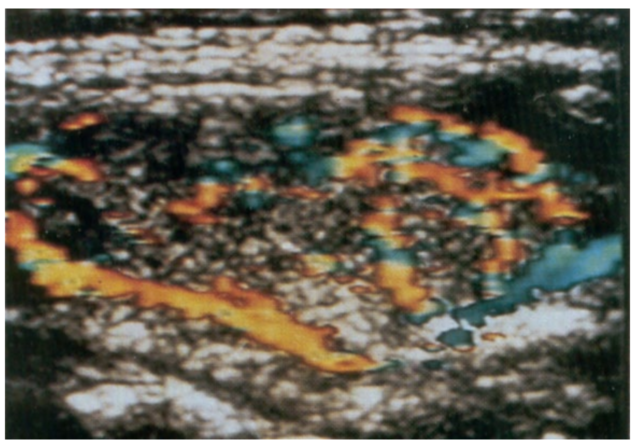
Subtypes of thyroid goiter

-Grave's disease

-Diffuse, toxic goiter (i.e. hyperthyroid state)



Graves' disease:
Scintigram (left) and sonogram (right)
(Access medicine)

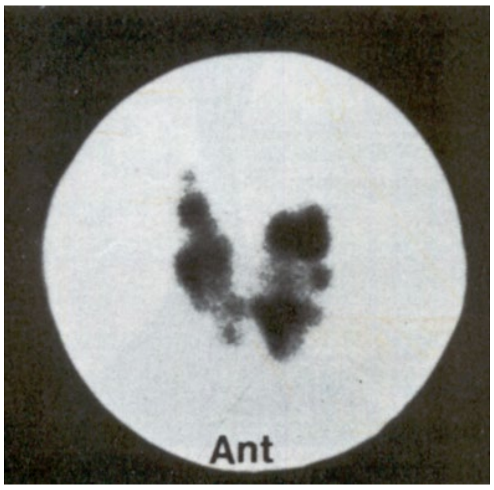


-Plummer's disease

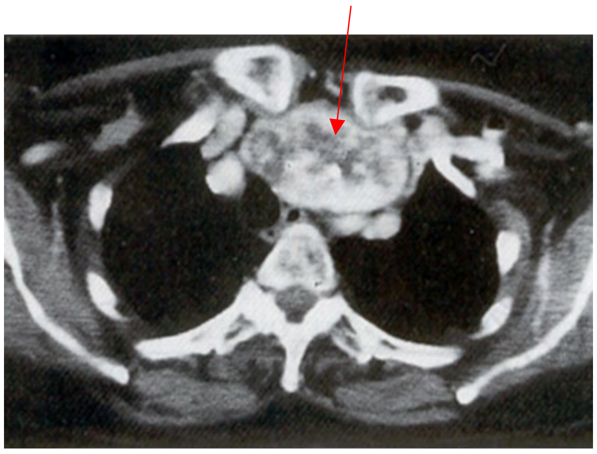
-Nodular, toxic goiter (i.e. hyperthyroid state)

-Non-toxic multinodular (MNG) goiter

-Nodular, non-toxic goiter (i.e. euthyroid state)



Scintigram of multinodular goiter (left)
CT of substernal extension of thyroid goiter (arrow on right image)



Thyroid Enlargement (Goiter), continued

-Imaging may utilize scintigraphy (for uptake and imaging) as well as sonography (for serial assessment/possible biopsy of dominant nodule)

-In those Pts necessitating treatment of hyperthyroidism (including Graves' or Plummer's disease), outpatient I-131 therapy may be utilized (as opposed to surgery or chronic antithyroid medication)

I-131: beta radiation of 192 keV; gamma radiation of 364 keV (radioactive iodine therapy, RAI)

-Dose for treatment of Plummer's disease is often greater than for treatment of Grave's disease

-Post-radiation ablation, Pts may enter a hypothyroid state (necessitating chronic thyroid hormone supplement)

Thyroid neoplasms

-Papillary, 80%

-Follicular, 15%

-Medullary, 3%

-Anaplastic, 1%

Note: Papillary carcinoma: lymphatic spread is more common than hematogenous spread

Note: Follicular carcinoma: hematogenous spread is more common than lymphatic spread

Note: Detailed discussion of thyroid neoplasia will be presented in clinical sessions

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ADRENAL GLAND (normal imaging)

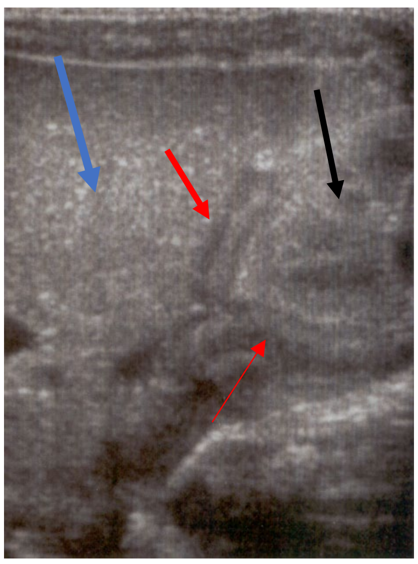
-Imaging modalities available for adrenal assessment

-Plain film: may visualize adrenal calcification (neoplastic vs sequela of prior adrenal hemorrhage): Incidental

-Sonography: allows for initial assessment of adrenal glands in infants/children (no ionizing radiation; user-dependent)

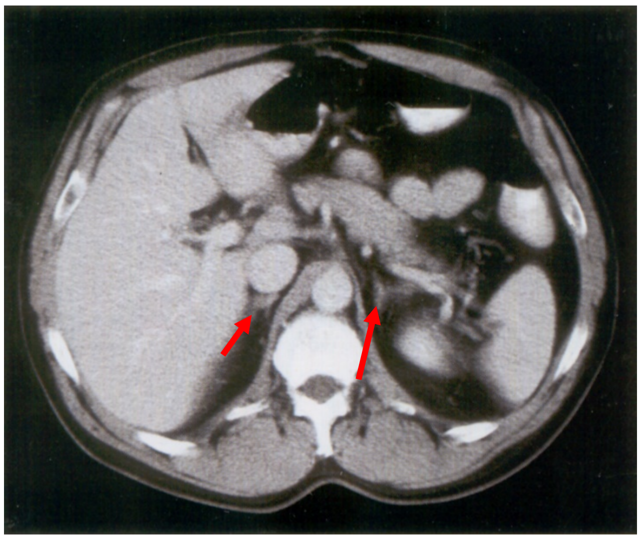
-Differentiate renal from adrenal location

-Further imaging is likely to be performed (for the workup of renal and/or adrenal masses)



Retroperitoneal sonogram: Right adrenal gland (red arrows)
Liver (blue arrow). Right kidney (black arrow)

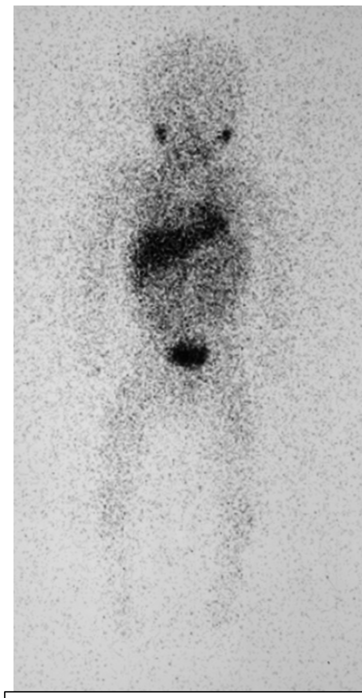
-<u>Computerized axial tomography (CT):</u> unenhanced and enhanced imaging (with 60-sec and 15-min delayed imaging) is useful for 'absolute contrast wash-out' characterization of adrenal masses (specifically adenoma vs malignancy)



Normal adrenal gland CT (red arrows)

– <u>Magnetic resonance imaging (MRI)</u>: includes in-phase and out-of-phase imaging can assess/characterize adrenal masses (specifically adenoma vs metastasis)

MRI: coronal plane (representative image)
Normal adrenal glands (white arrows)



Normal I-131 MIBG scan)

– <u>Nuclear medicine</u>: useful for assessment of functional tumors
  I-131-MIBG (metaiodobenzylguanidine)
  -Guanethidine analog: acts as a norepinephrine analog
    -Useful for neuroendocrine tumoral assessment
      -90% of neuroblastomas concentrate I-131-MIBG
      -80-90% of paragangliomas concentrate I-131-MIBG
      -60% of carcinoid tumors concentrate I-131-MIBG
      -50% of medullary carcinoma of the thyroid concentrate I-131-MIBG
    -Physiologic uptake: liver, spleen, urinary bladder, salivary glands
    -Helpful in detecting skeletal metastases and in differentiating post-treatment scarring/healing mass from viable tumor

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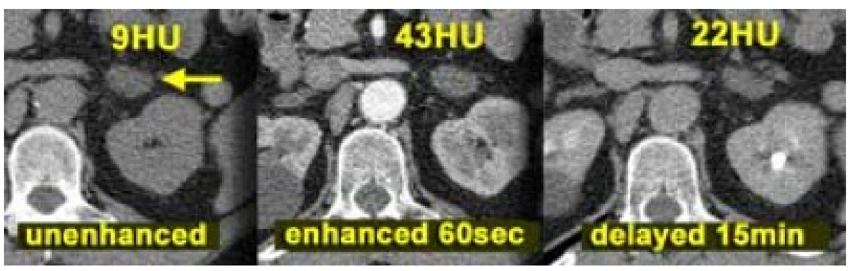
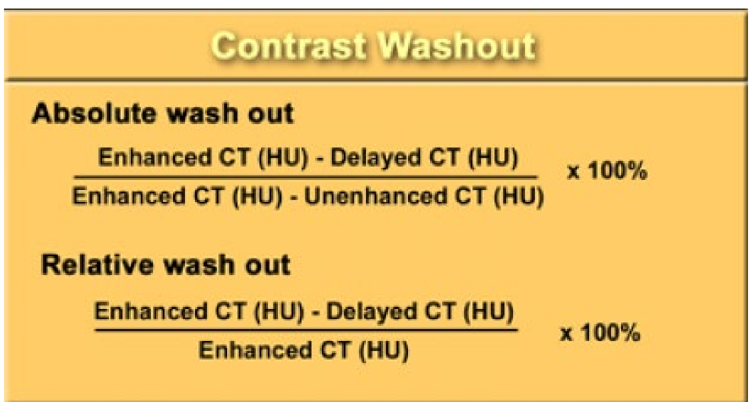
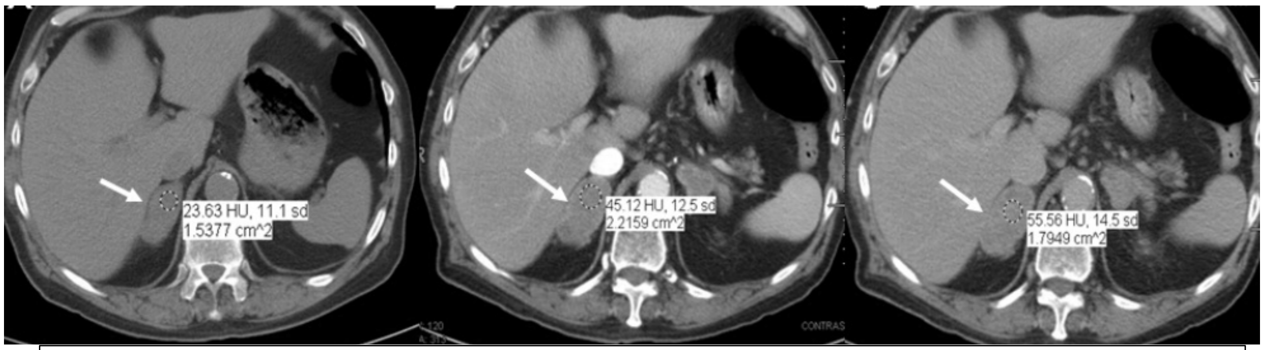
<u>ADRENAL GLAND (abnormal imaging)</u>: Please refer to American College of Radiology (ACR) flow chart (on page 10)



CT of adrenal adenoma (62% washout of contrast)
(www.radiologyassistant .nl)



<u>Note</u>: CT findings consistent with fat-containing adenoma
    -Unenhanced CT: <10HU
    -Absolute wash-out (>60%) or relative wash-out (>50%)
      - Follow-up (with CT imaging) at 6 and 18 months to assess for stability



CT of suspicious adrenal mass (persistently-enhancing mass, primary vs secondary neoplasia)
Unenhanced (left image); 60-second enhanced (middle image); delayed phase (right image)
(www.discoverymedicine.com)

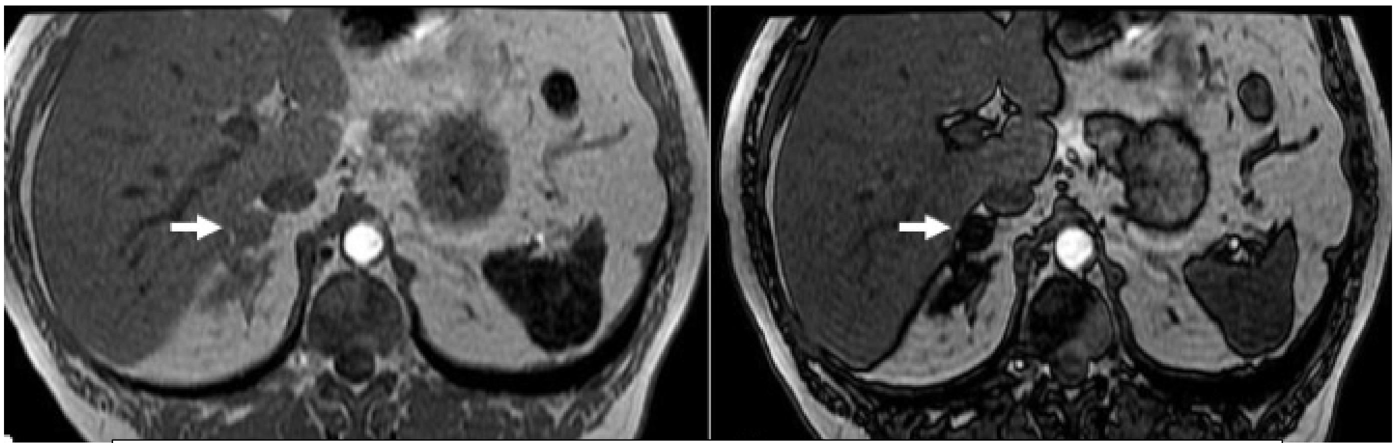
Note: CT findings ***not*** consistent with fat-containing adenoma

- Undergo follow-up MR imaging (or percutaneous biopsy)

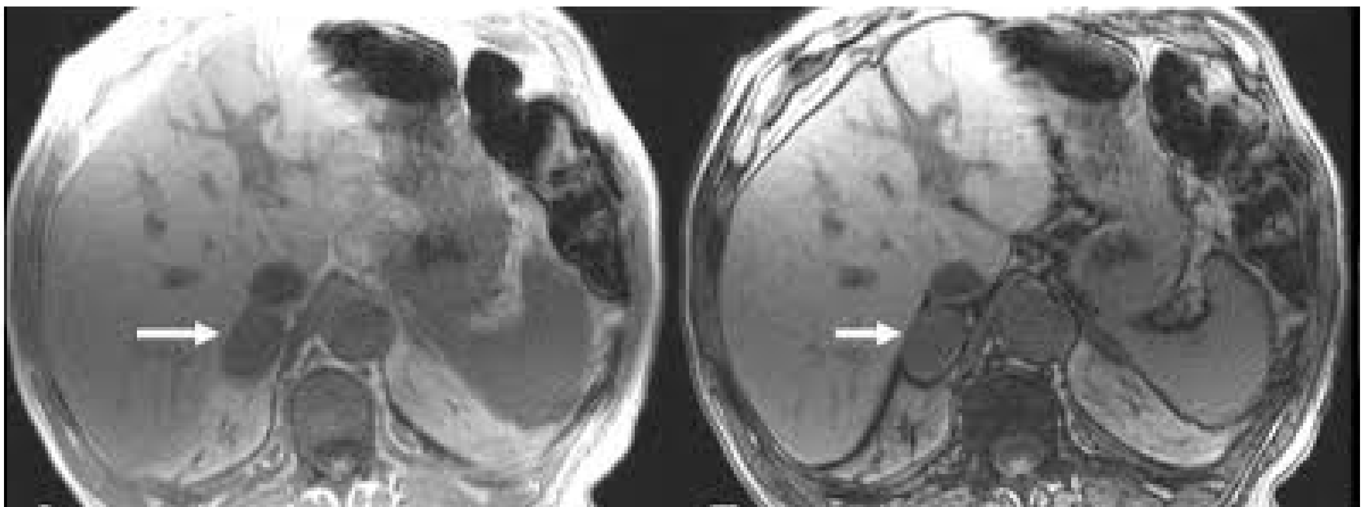
-MR imaging

-Signal loss on out-of-phase imaging indicates the presence adenoma (i.e. fat and water signals *cancel* each other out)

-Lack of signal loss on out-of-phase imaging: 'indeterminate lesion' (consider percutaneous biopsy)



In-phase (left) and out-of-phase (right) MRI: Signal loss within right adrenal mass on opposed phase imaging (right image)
(www.discoverymedicine.com)



In-phase (left) and out-of-phase (right) MRI: *Lack* of signal loss within right adrenal mass on opposed-phase imaging (right image)

Note: Pancreatic imaging will be presented in Gastrointestinal Module

References:

-Clinical Radiology: The Essentials. Daffner et al. 4th ed. (Chapter 9).

-Primer of Diagnostic Imaging. Weissleder et al. 4th ed. (Chapter 4).

-Genitourinary Radiology: The Requisites. Zagoria et al.

-Note: Medical images are from anonymized patient data and online archives (as detailed)

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www.auntminnie.com

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