4D-CT Parathyroid for the General Radiologist: A Pictorial Essay of Illustrative Cases

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Educational Objectives

- Describe the purpose of 4D-CT for evaluation of primary hyperparathyroidism and pre-surgical planning
- Review 4D-CT imaging protocol and illustrate the typical appearance of parathyroid adenomas
- Review the embryology of the parathyroid glands, and use it to facilitate a systematic search for embryologic and ectopic adenomas
- Illustrate a variety of cases of parathyroid adenomas in embryologic and ectopic locations and cases of multi-glandular disease
- Illustrate important mimics of parathyroid disease and important "incidental" findings in the neck and upper chest

Hyperparathyroidism

- Increased parathyroid hormone causes increased osteoclastic activity
- Subtypes
  - Primary
    - Parathyroid adenoma
    - Parathyroid hyperplasia
    - Parathyroid carcinoma
  - Secondary
    - Caused by chronic hypocalcemia
      - Most often due to renal osteodystrophy, vitamin D deficiency or malnutrition
      - Leads to increased parathyroid hormone levels
  - Tertiary
    - Autonomous adenoma caused by chronic overstimulation of hyperplastic glands, usually in the setting of renal insufficiency

Hyperparathyroidism

- 3 to 4 times more common in women than men
- 50-70 most common age range
- Majority of cases of **primary hyperparathyroidism** are caused by adenomas, (~90%)
- Less commonly there are multiple adenomas (~5%), multigland hyperplasia (~5%), or parathyroid carcinoma (<1%)
- Approximately 20% of adenomas are in ectopic locations (numbers vary in literature)
- Surgical excision of adenoma is treatment of choice in primary hyperparathyroidism

Hyperparathyroidism

- Historically, multigland exploration/excision was performed without pre-operative imaging
- In the early 2000s, minimally invasive resection emerged, and preop planning importance rose
  - Single adenoma resected through small incision; remaining glands left unexplored if PTH level drops
- Radiologist role is to:
  - Describe/localize high suspicion nodules
  - Identify ectopic adenomas
  - Recognize multigland hyperplasia or multiple adenomas
  - Highlight any relevant anatomical considerations

Imaging Technique

- Ultrasound
  - Inexpensive, fast, can be done by surgeons in office to localize typical adenomas greater than 1 cm.
- Dual phase Tc-99m Sestamibi scan
  - Early images 10-20 min post injection (activity in both thyroid & parathyroid)
  - Delayed (90 mins), activity in thyroid washes out, persists in adenoma
  - Can do SPECT/CT for better localization
- 4D CT parathyroid
  - Improved sensitivity of localization, particularly in ectopic/mediastinal locations
  - Helpful for pre-operative planning

CT parathyroid technique

- “4D” – axial, sagittal, coronal, and dynamic enhancement characteristics
- Precontrast
- Arterial phase (25-30 seconds after injection of contrast commences)
- Venous phase (60-80 seconds after injection of contrast commences)
- At UCLA, our arterial phase extends from skull base to carina to help identify ectopic locations
- All three phases and planes should be evaluated; however the arterial phase is usually the most helpful

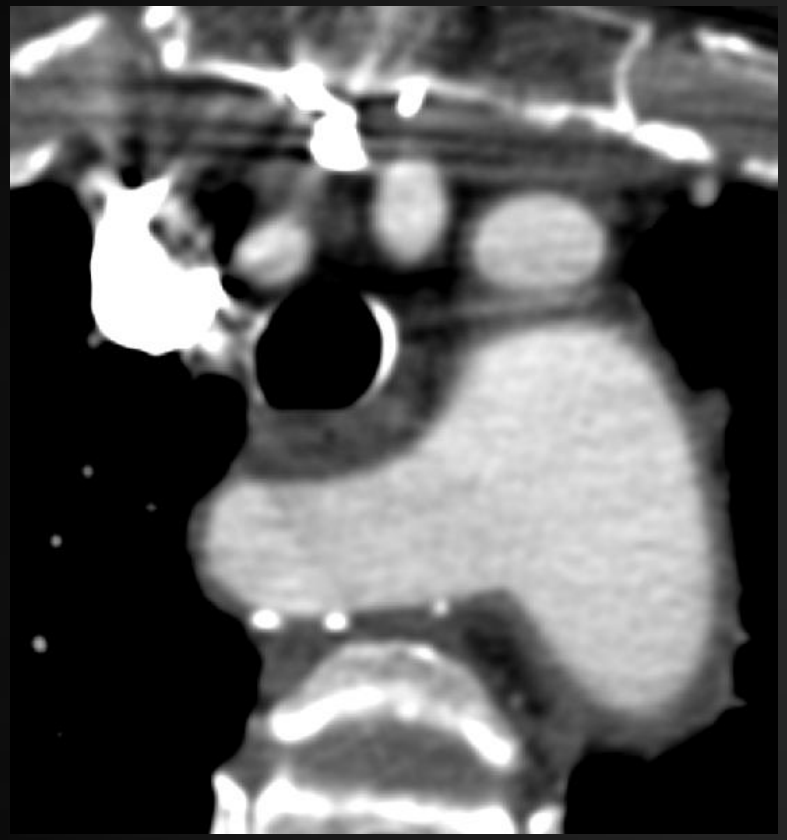
Anatomy

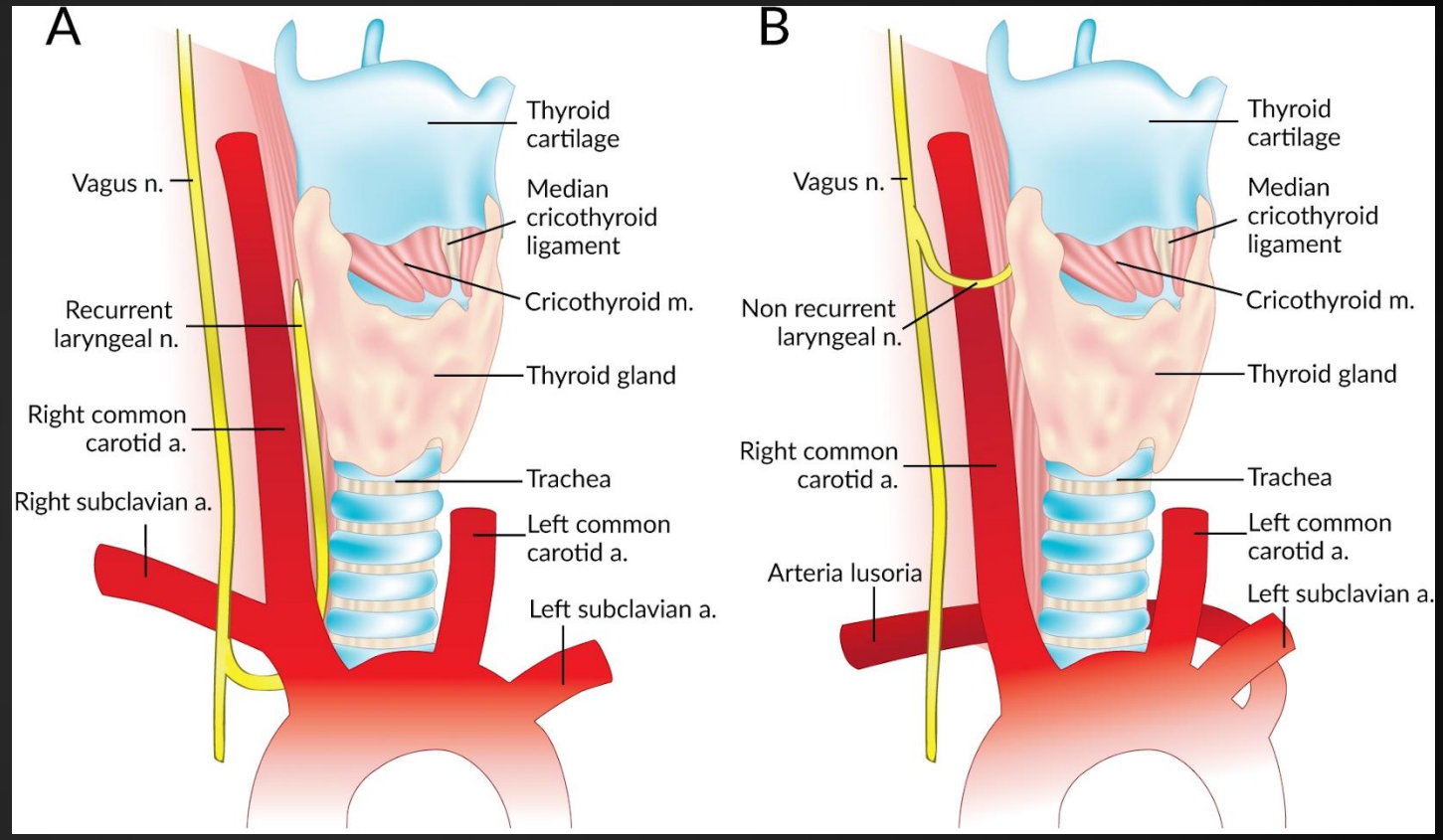
- Embryology is relevant to parathyroid adenomas
- Inferior glands (paired) arise from the 3rd branchial pouch
- Superior glands (paired) arise from the 4th branchial pouch
- These pouches are approximately at level of carotid bifurcation
- Parathyroid glands descend during development
- Inferior glands migrate with the thymus, and can be found from carotid bifurcation to carina, including within the thymus or thyroid gland
- Superior glands migrate with thyroid gland (less variable location)

Anatomy

- Embryologic superior glands are located posterior to the upper third of the thyroid gland, often paraesophageal or within the tracheoesophageal groove
- Embryologic superior glands can fall caudally (descended) and can be found as low as within the mediastinum (typically posterior in location)
- Embryologic inferior glands are usually closely associated with the inferior thyroid (immediately inferior, posterior, lateral or anterior to the tip of the gland).
- Embryologic inferior glands are located more anteriorly (paratracheal, anterior mediastinum, closely associated with strap musculature)

Important to mention: Aberrant SCA





Aberrant SCA associated w/ nonrecurrent laryngeal nerve (not in TE groove)!

Enhancement Characteristics

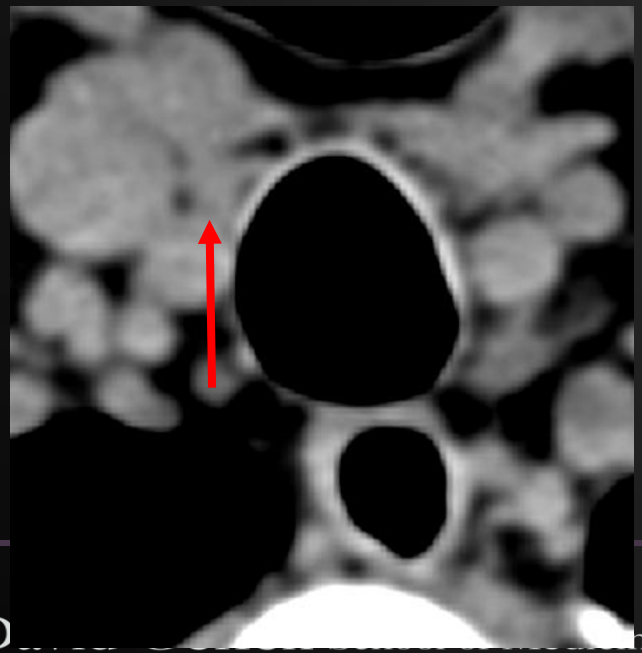
- Typical parathyroid adenomas are:
  - Hypoattenuating to thyroid on precontrast
  - Arterially hyperenhancing
  - Rapid washout on venous phase
- Precontrast sequence is very important to differentiate thyroid tissue from parathyroid
- Start with arterial phase to search for possible adenoma, and then confirm on precontrast and delayed phase
- DDx of possible adenomas include thyroid (use precontrast to distinguish), lymph nodes (typically progressively enhance on venous phase, do not wash out)

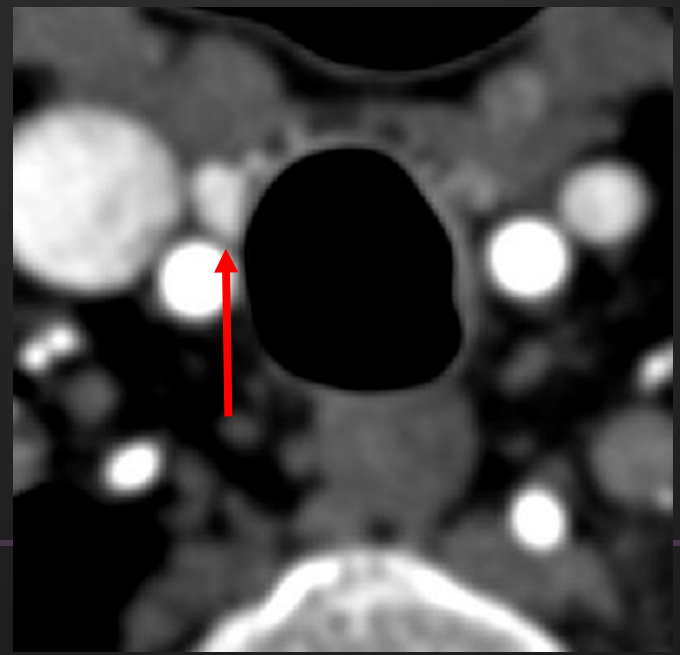
Enhancement Characteristics

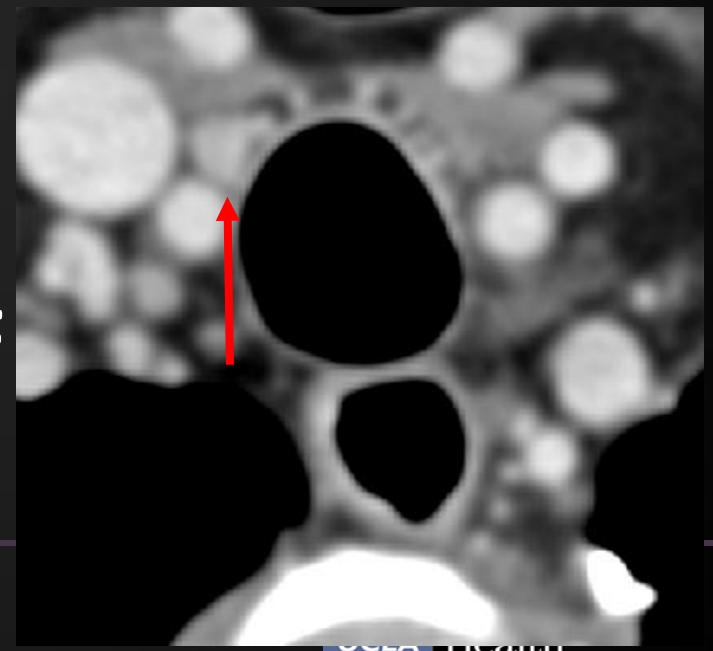
- Caveats:
  - In approximately one third of cases an adenoma will be isodense to thyroid on arterial and venous phases
  - Patients with hypothyroidism demonstrate a lower intrinsic attenuation of the thyroid gland limiting the usefulness of the pre-contrast scan (these patients do not organify iodine as those with normally functioning thyroid glands)
  - Cystic degeneration of an adenoma, streak artifact, suboptimal bolus timing, thyroiditis can alter enhancement characteristics

CASES

Case 1



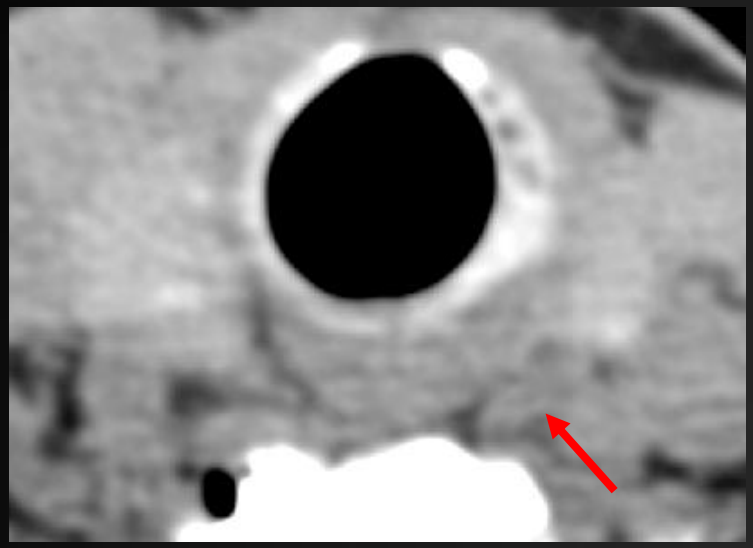


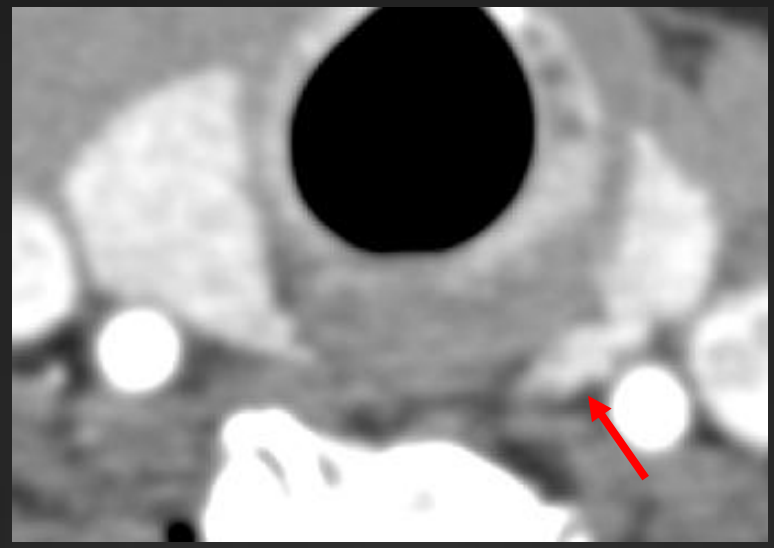


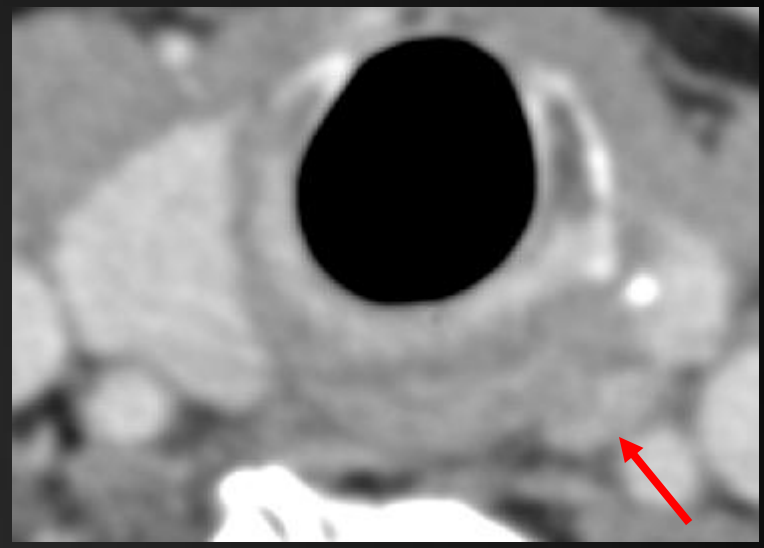
Case 1

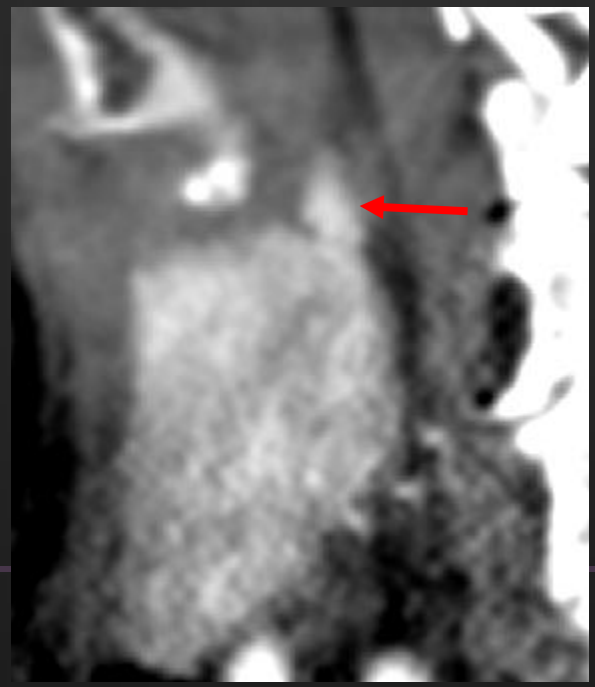
- **Right sided embryologic inferior parathyroid adenoma**
- Along inferior margin of right lobe of thyroid
- Paratracheal, closely associated with the overlying strap musculature
- Hypodense to thyroid on precontrast (A, D), arterially enhancing (B, E), and demonstrates washout on venous phase (C, F)

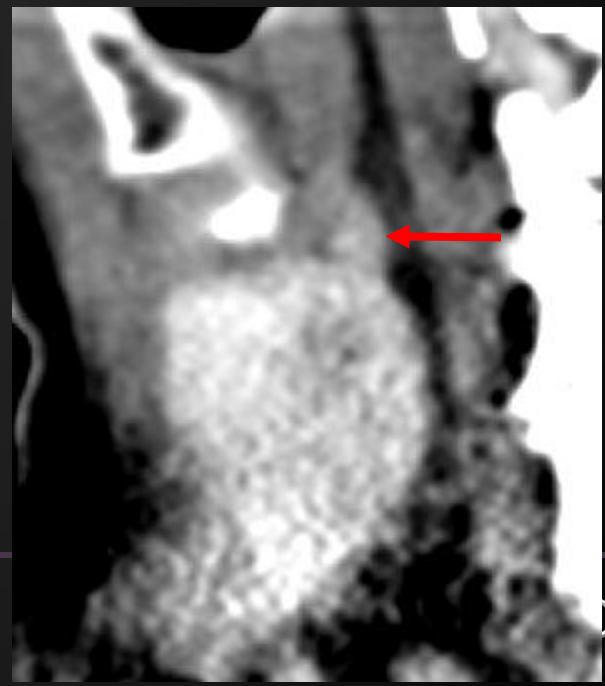
Case 2









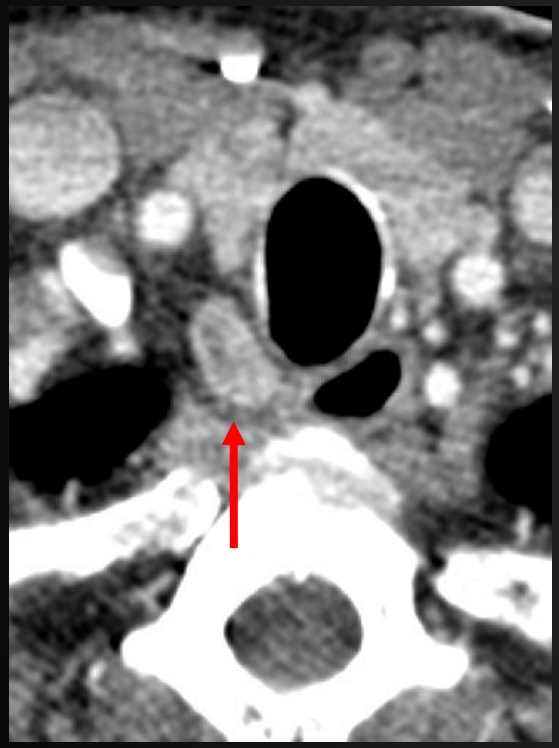


Case 2

- **Embryologic superior left parathyroid adenoma**
- Paraesophageal, posterior to the superior aspect of the thyroid lobe
- Hypodense to thyroid on precontrast (A, D), arterially enhancing (B, E), demonstrates washout on venous phase (C, F)

Case 3

A



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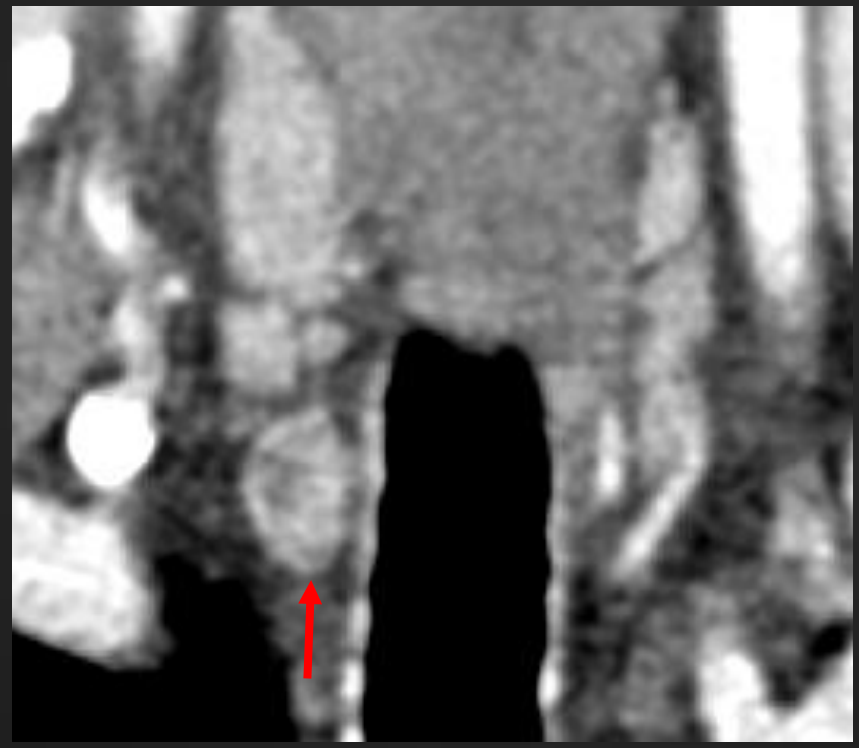


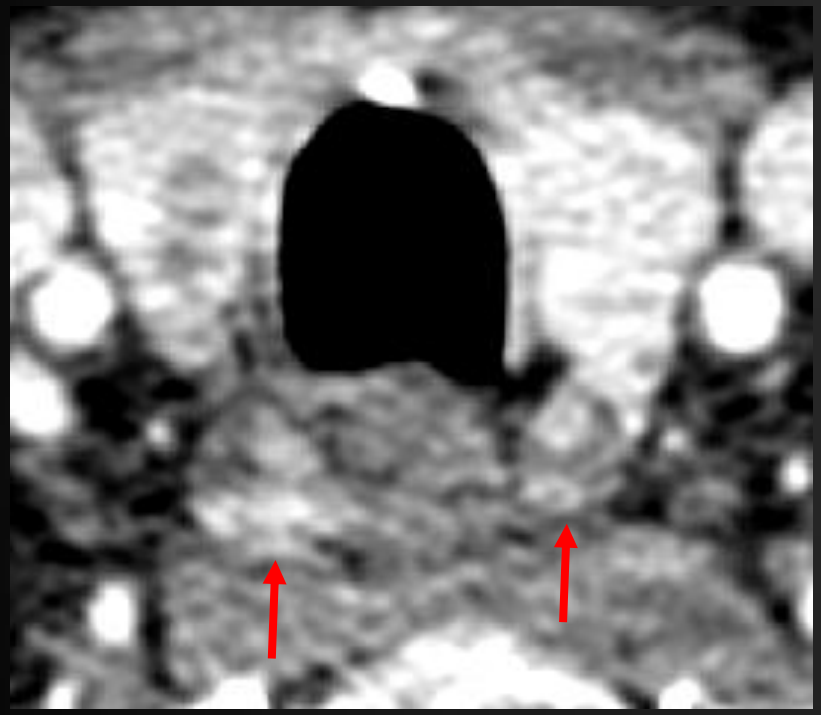
C

Case 3

- **Right sided descended embryologic superior gland adenoma**
- Parathyroid adenoma in right tracheoesophageal groove, along inferior aspect of the right thyroid lobe
- Arterial enhancement on axial (A), coronal (B), and sagittal (C) images with internal cystic change

Case 4

A



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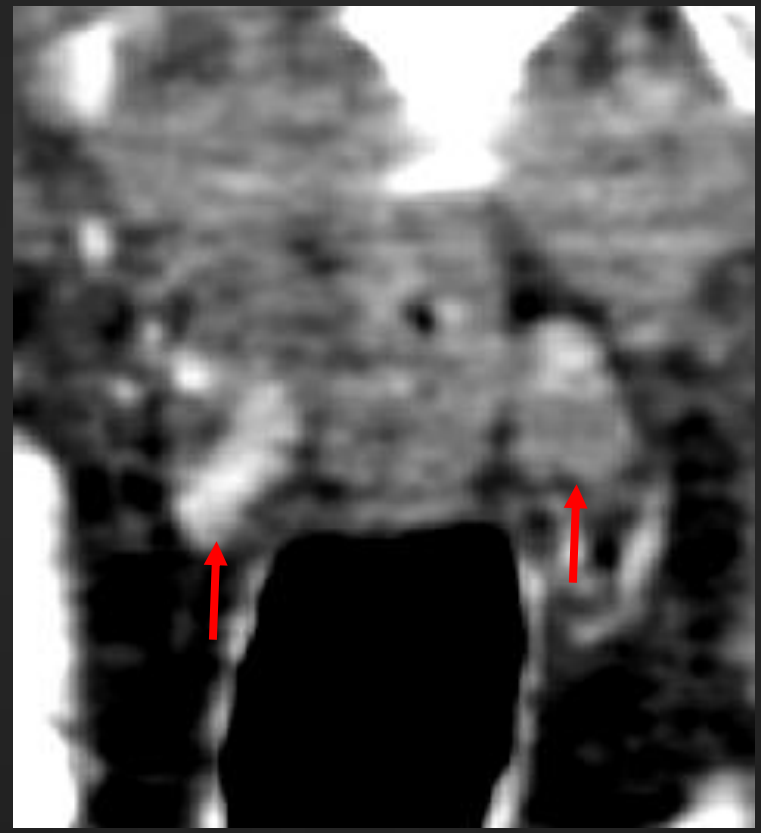

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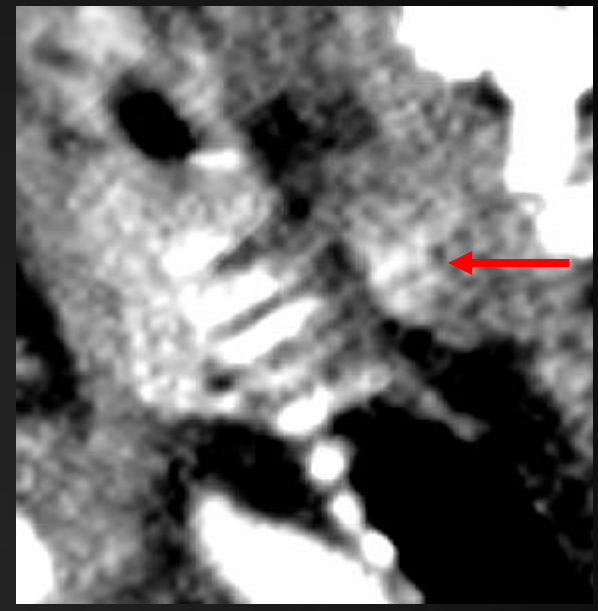
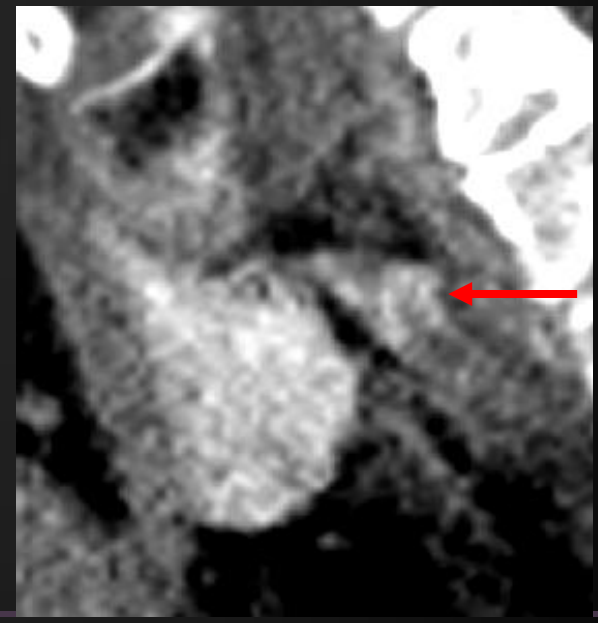


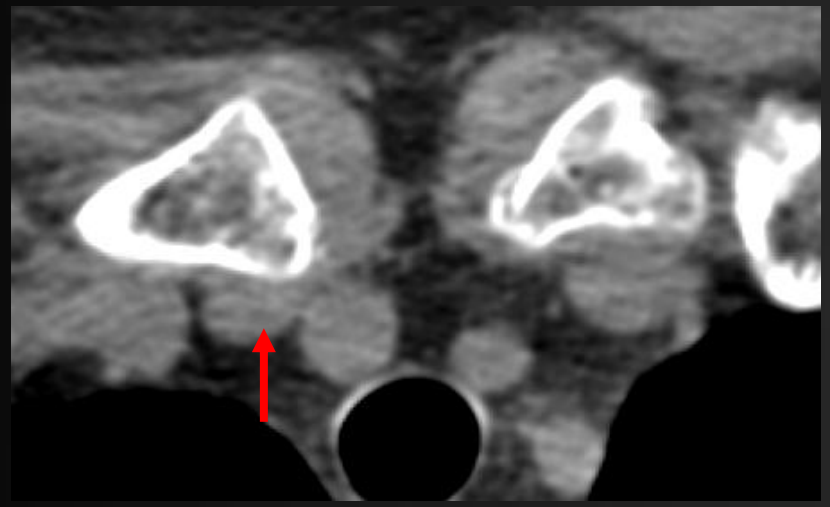
D



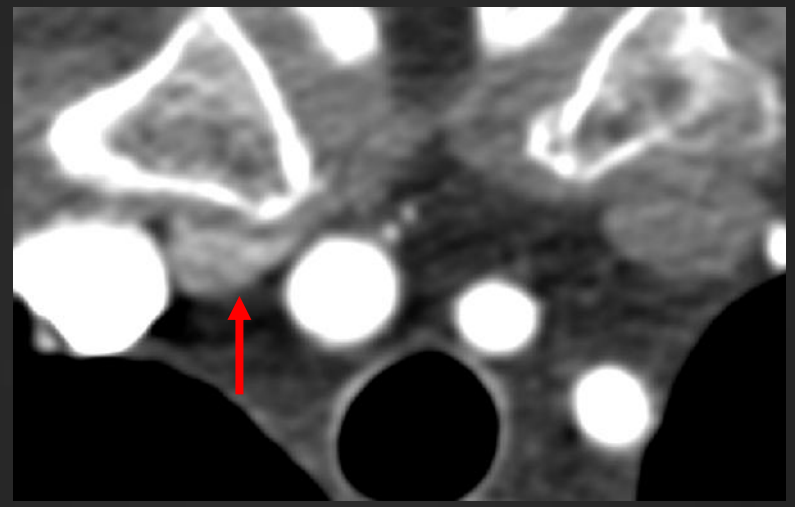
Case 4

- **Bilateral embryologic superior gland parathyroid adenomas**
- Arterial enhancement on axial (A), coronal (B), and off-midline sagittal (C, D) images

Case 5



A



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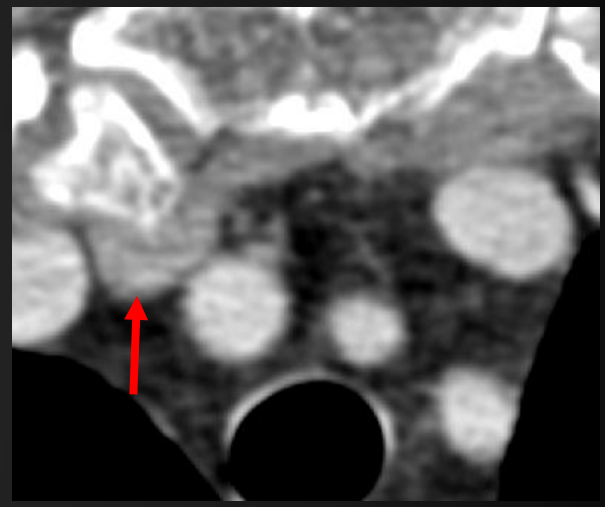
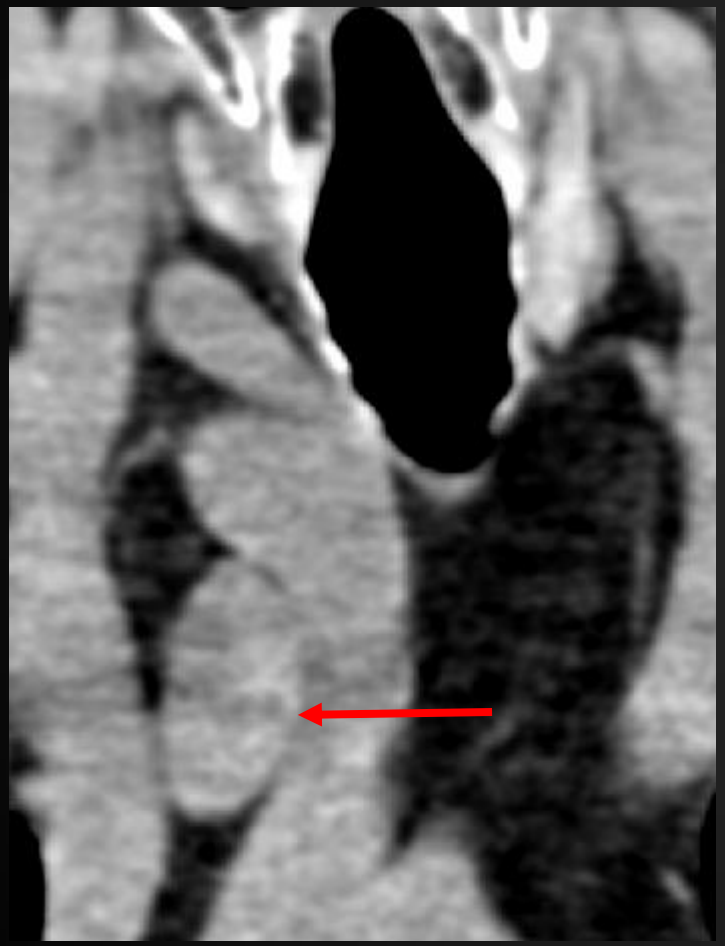


C

Case 5

D



E

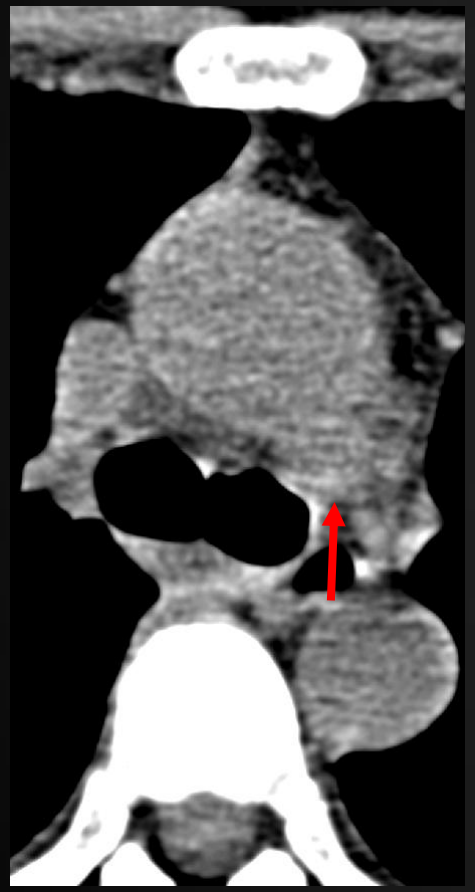
F

Case 5

- **Right sided mediastinal / intrathymic parathyroid adenoma**
  - Along posterior margin of the right clavicular head
- Hypodense to thyroid on precontrast (A, D), arterial enhancement with cystic change (B, E), and venous washout (C, F)
- Can be easy to overlook on axial alone (A-C)
- Best identified on coronal reformats (D-F)

Case 6

A



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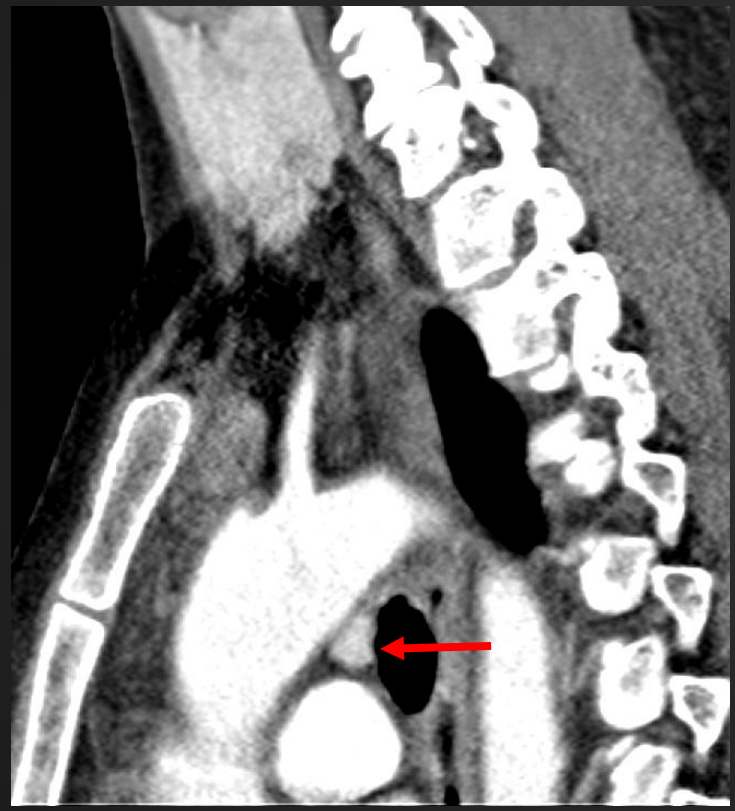


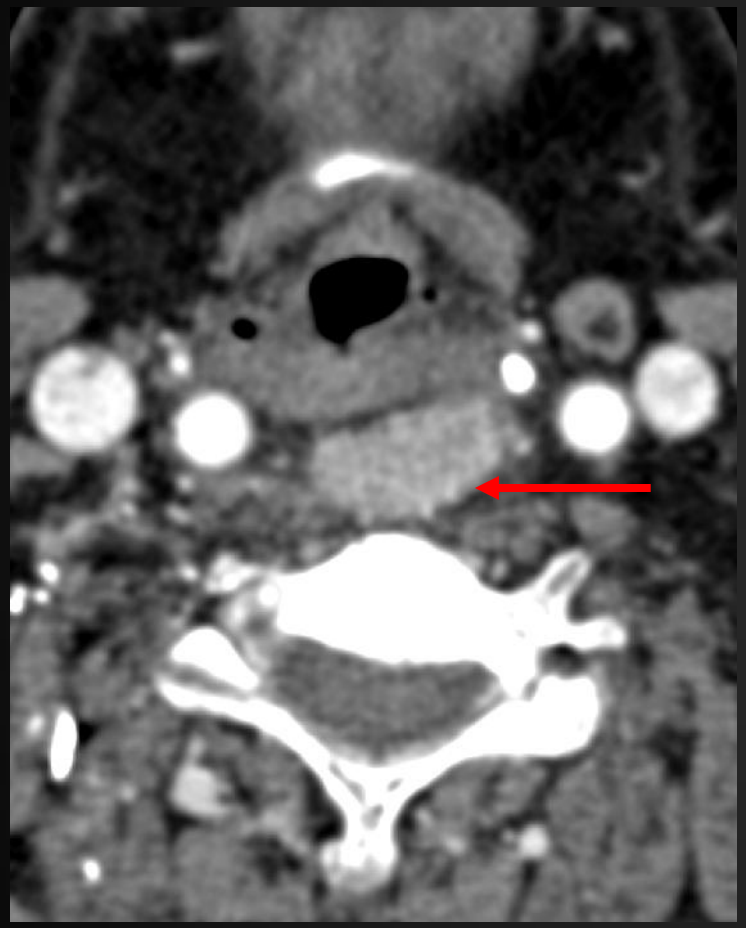
C

D

Case 6

- **Mediastinal (AP window) parathyroid adenoma**
- Nodule in the AP window that is hypodense to thyroid on precontrast (A), arterially enhancing (B, C), and demonstrates venous washout (D)
- Remember to look all the way down to the AP window for mediastinal adenomas
- The inferior parathyroid gland migrates with the thymus and can be seen as low as the AP window / carinal level

Case 7



A

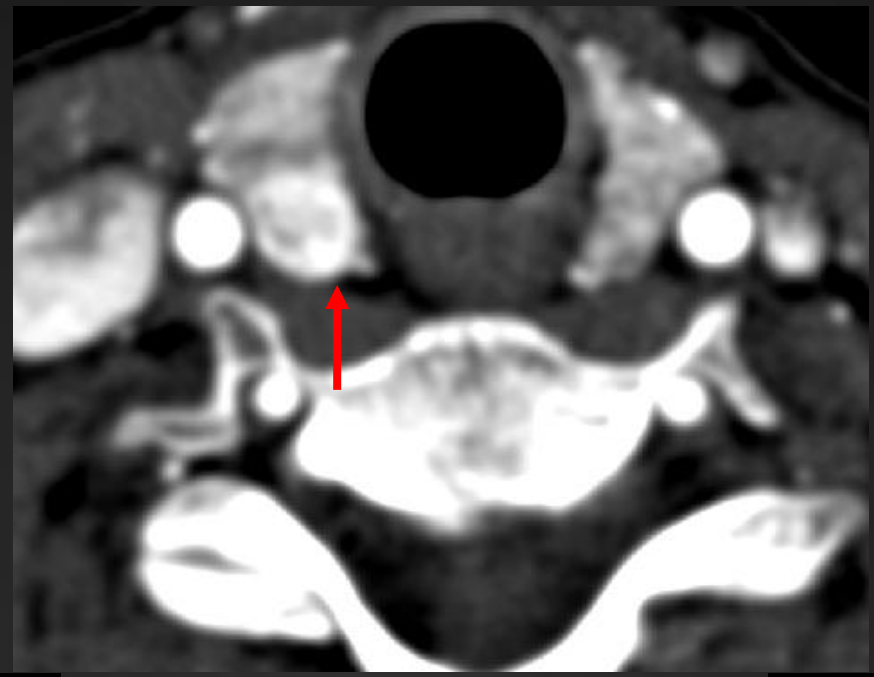
B

C

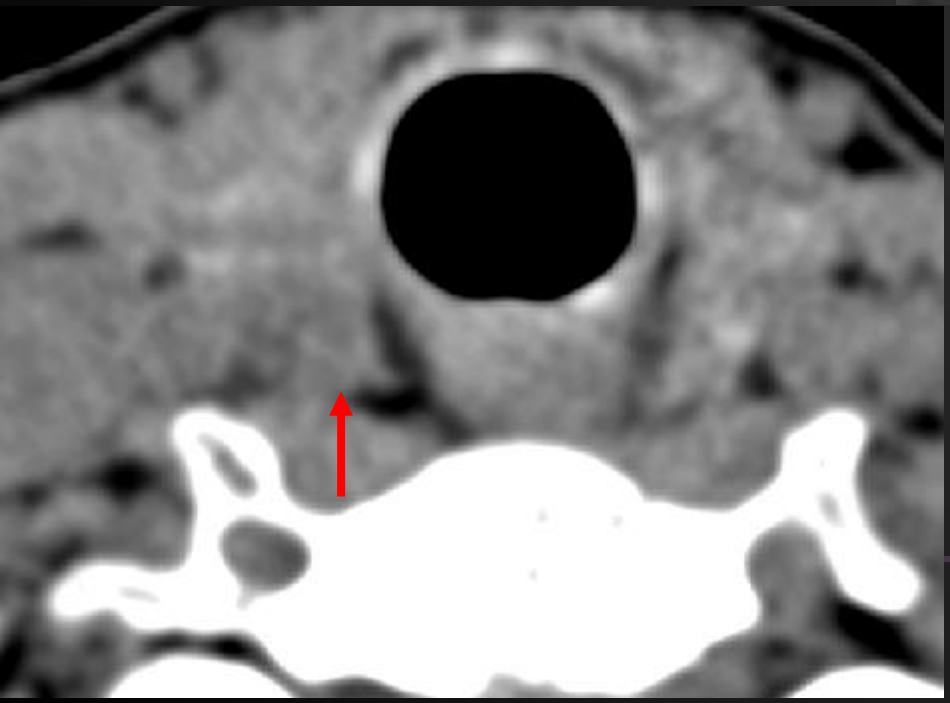
Case 7

- **Ectopic retropharyngeal parathyroid adenoma** at the level of the supraglottic larynx
- Large hyperenhancing mass is seen on axial (A), sagittal (B) and coronal (C) aterial phase images

Case 8

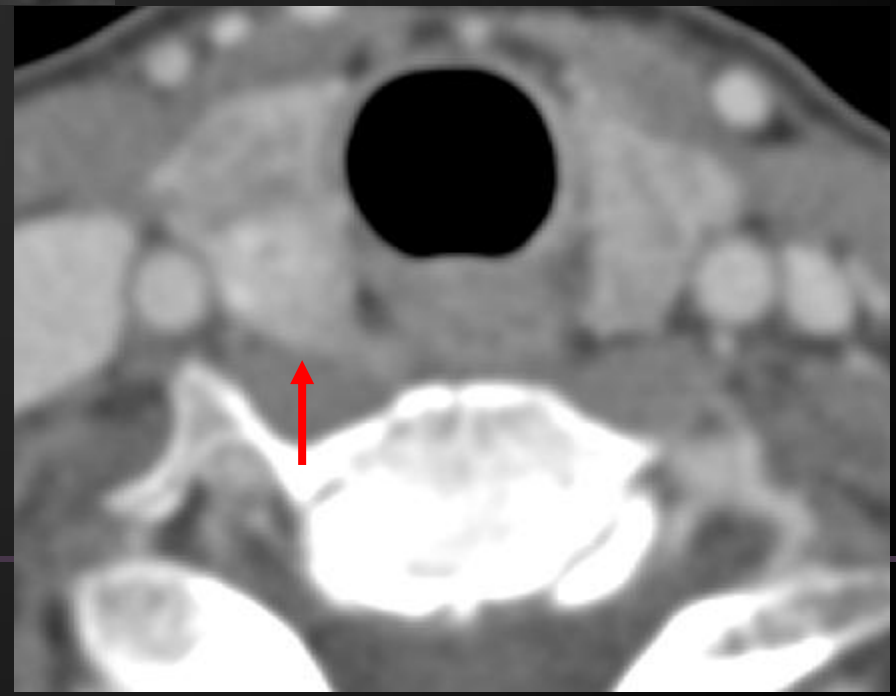


A



B

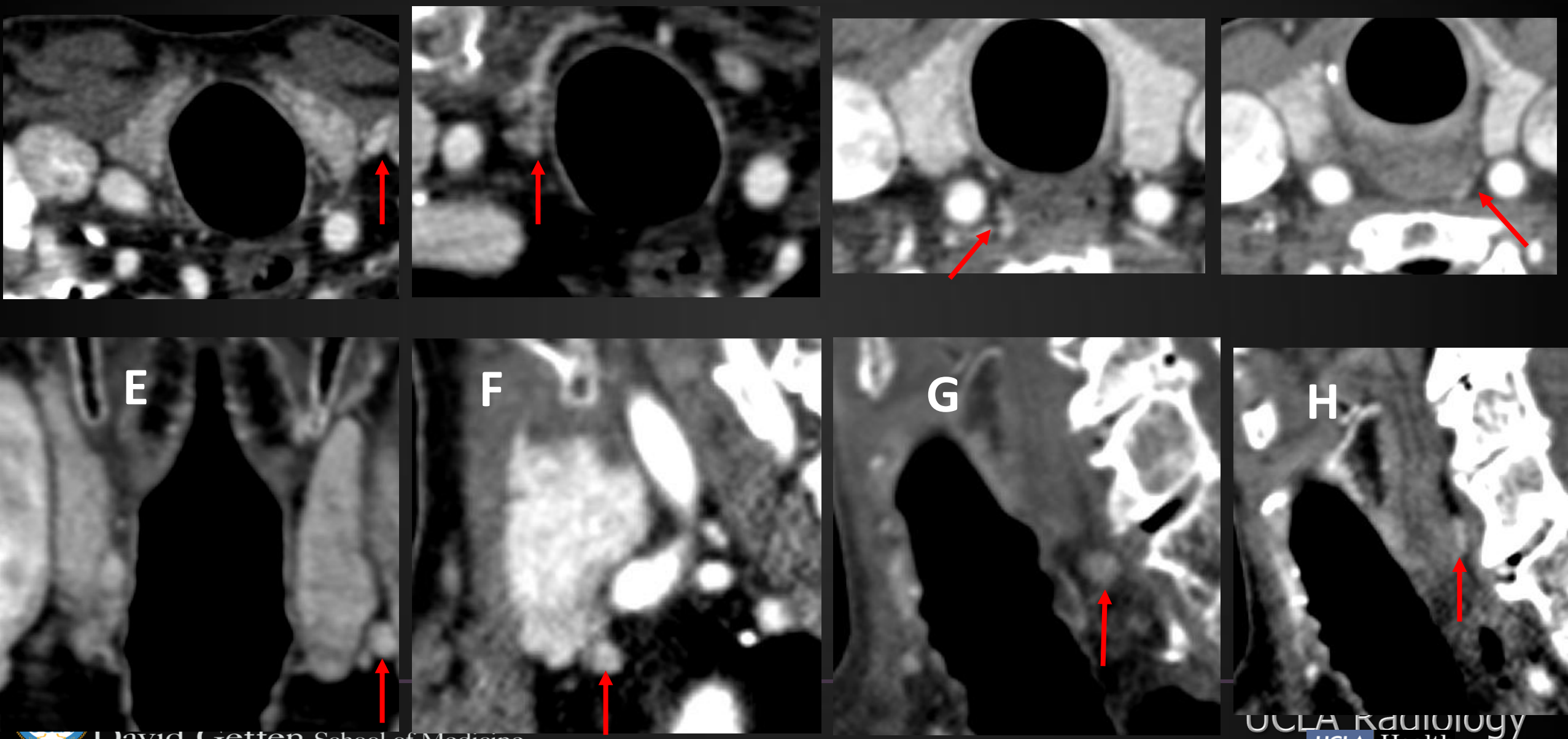
C



Case 8

- **Right sided intrathyroidal subcapsular parathyroid adenoma**
- Nodule along the posterior subcapsular aspect of the right thyroid lobe is hypodense on precontrast (A), hyperenhancing on arterial phase(B), and washes out on delayed phase (C)
- Note background heterogeneity of the thyroid gland

Case 9

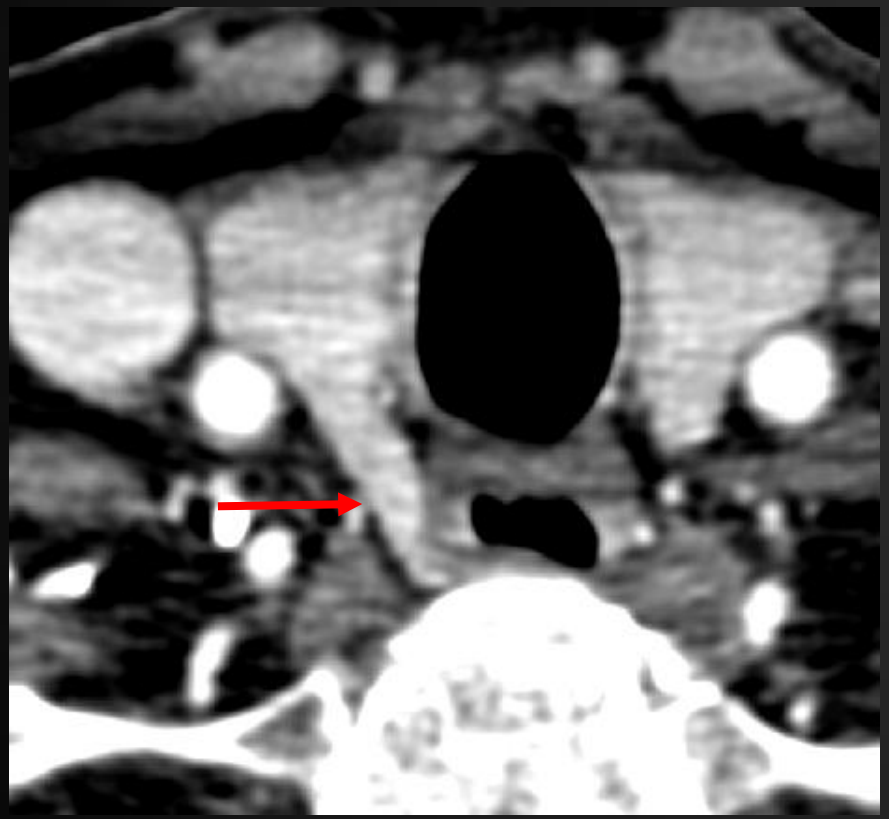


Case 9

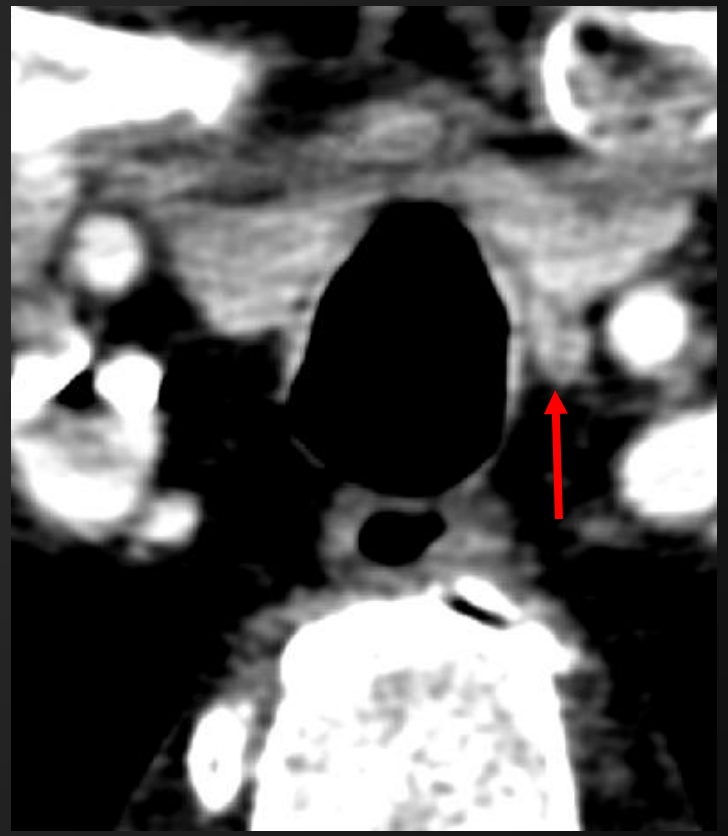
- **Multigland hyperplasia**
- All four embryologic glands are mildly enlarged:
  - Left inferior gland hyperplasia on axial (A) and coronal (E) images
    - Deep to the strap muscles, along inferior aspect of the left thyroid lobe
  - Right inferior gland hyperplasia on axial (B) and sagittal (F) images
    - Paratracheal, along inferior aspect of right thyroid lobe
  - Right superior gland hyperplasia on axial (C) and sagittal (G) images
    - Paraesophageal, along superior aspect of right thyroid lobe
  - Left superior gland hyperplasia on axial (D) and sagittal (H) images
    - Paraesophageal, along superior aspect of the left thyroid lobe

Case 10 – Which image shows the adenoma?

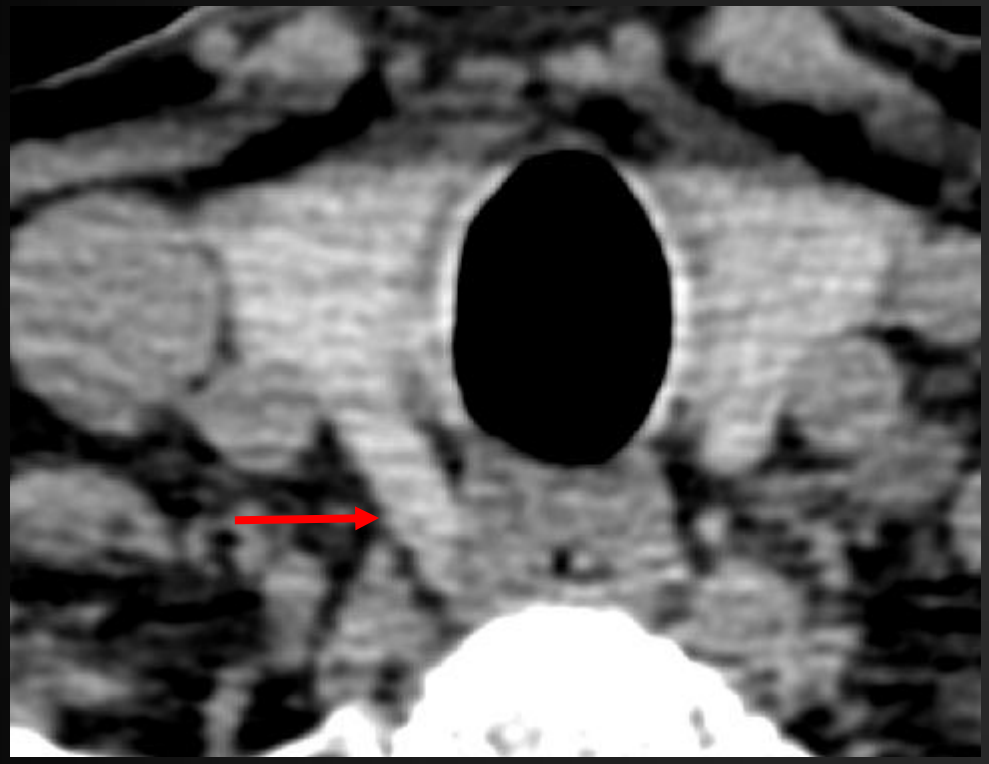
Axial arterial phase



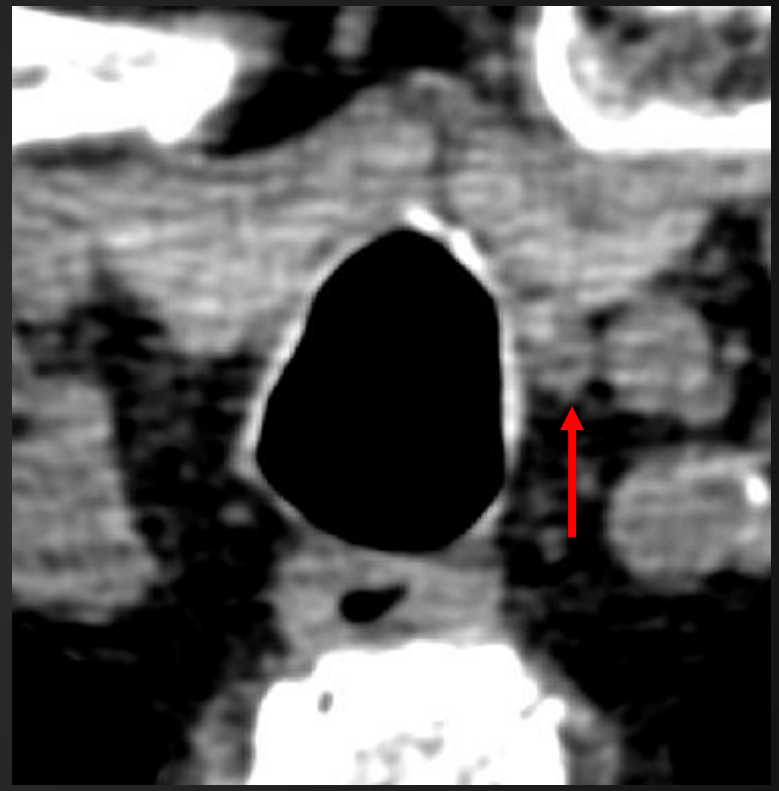
Axial arterial phase



Case 10 – Importance of Precontrast

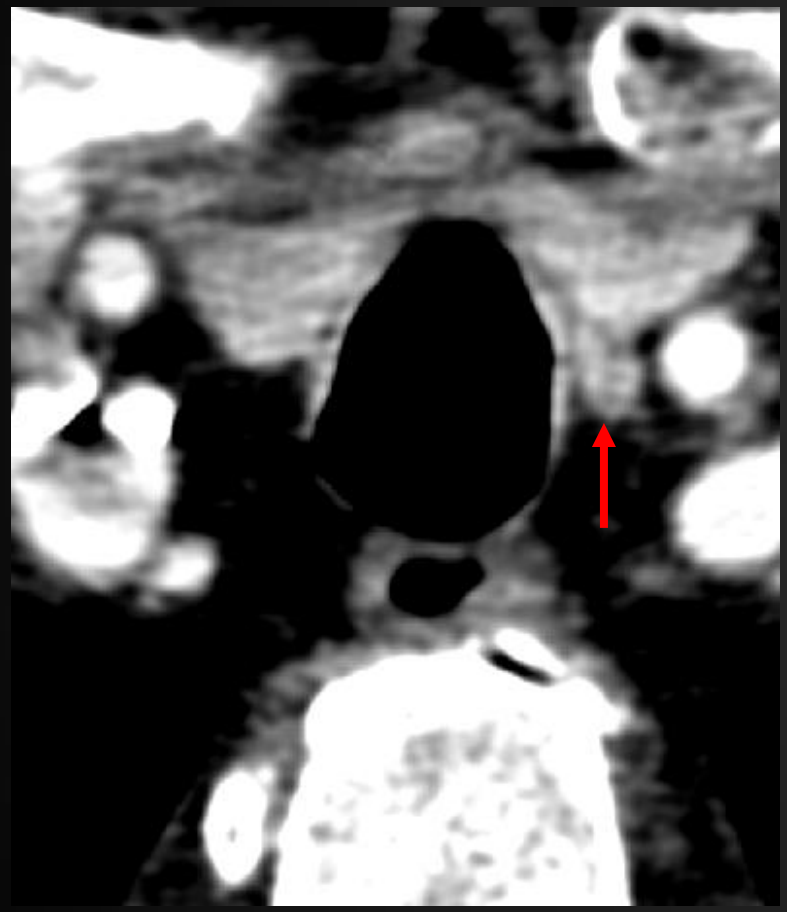


Axial precontrast: Right TE groove nodule isodense to thyroid, thus exophytic thyroid tissue (Zuckercandl tubercle of thyroid)



Axial precontrast: Left paratracheal nodule hypodense to thyroid on precontrast, therefore parathyroid adenoma

Case 10



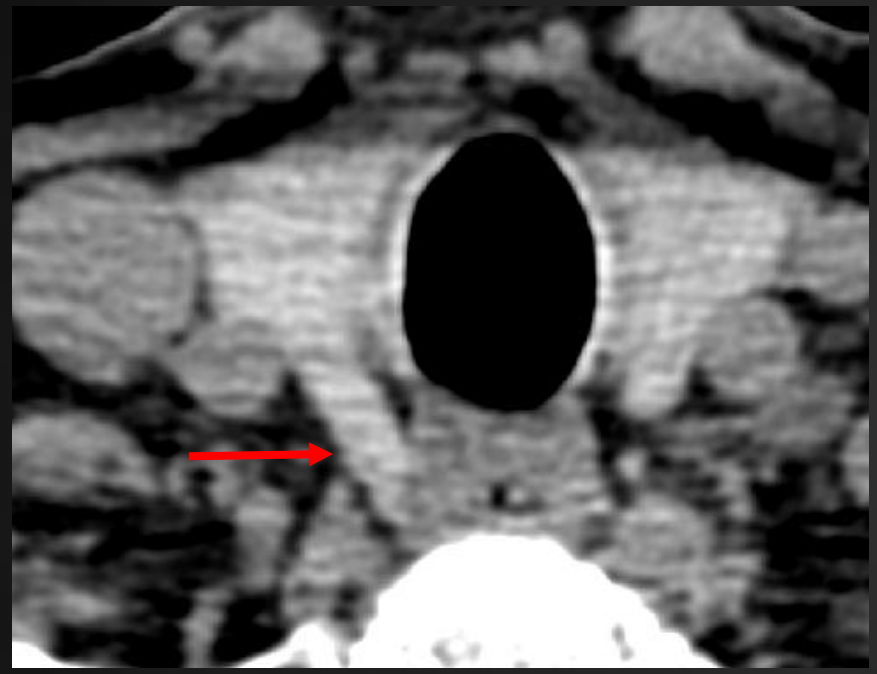
-Left sided embryologic inferior parathyroid adenoma

-Seen along the inferior margin of the thyroid lobe

-Often paratracheal or closely associated with the strap musculature

Case 10

A



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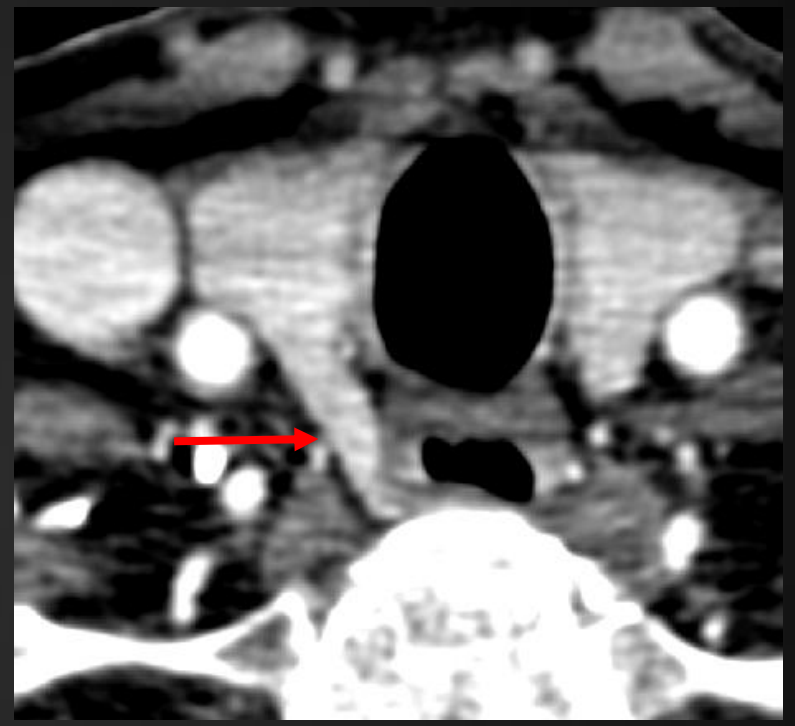
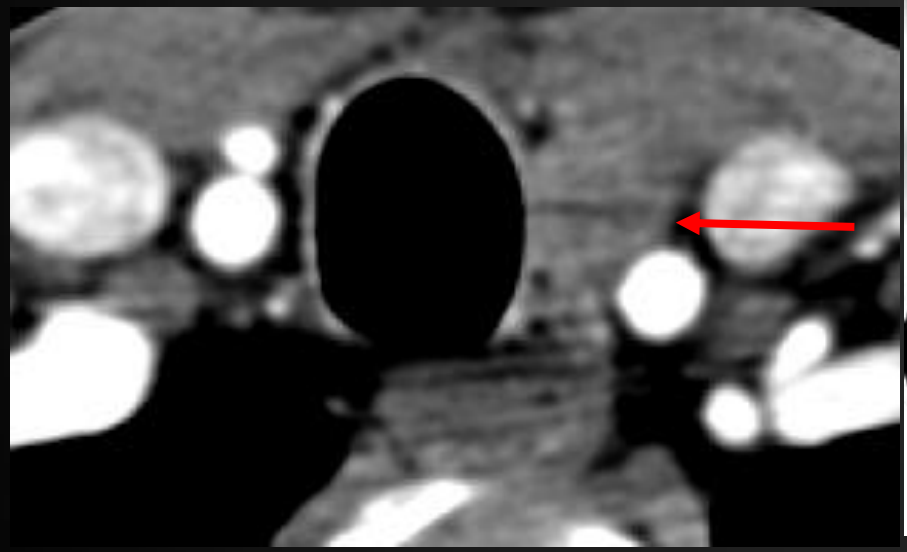


Zuckercandl tubercle. Right sided exophytic thyroid tissue in the tracheoesophageal groove, an anatomic variant characterized by tissue that is isodense to thyroid on precontrast phase (A) and iso-enhancing to thyroid on arterial phase (B)

Case 11

A



B

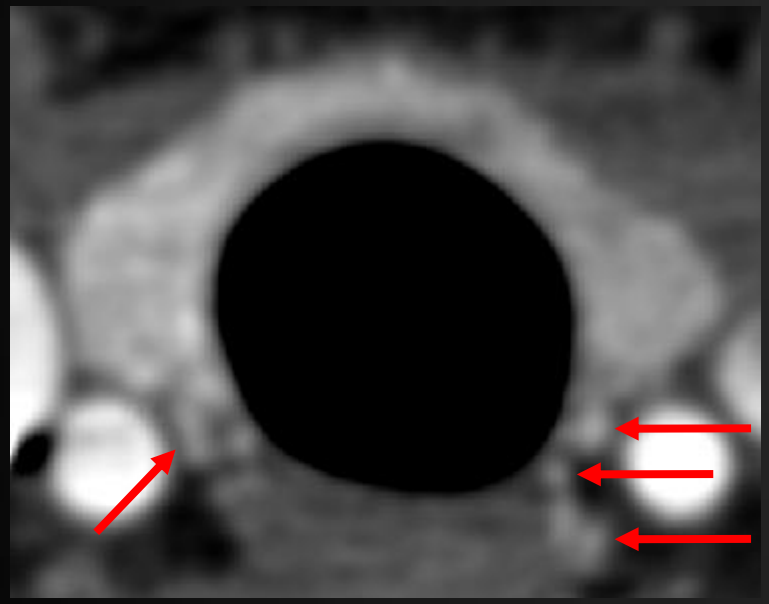
C

Case 11

- **Parathyroid carcinoma**
  - Recurrent primary hyperparathyroidism after parathyroidectomy
- Poorly defined hypoenhancing mass with irregular borders in the parathyroidectomy bed on arterial phase axial (A), coronal (B) and sagittal (C) images
- Surgical clips from prior parathyroidectomy

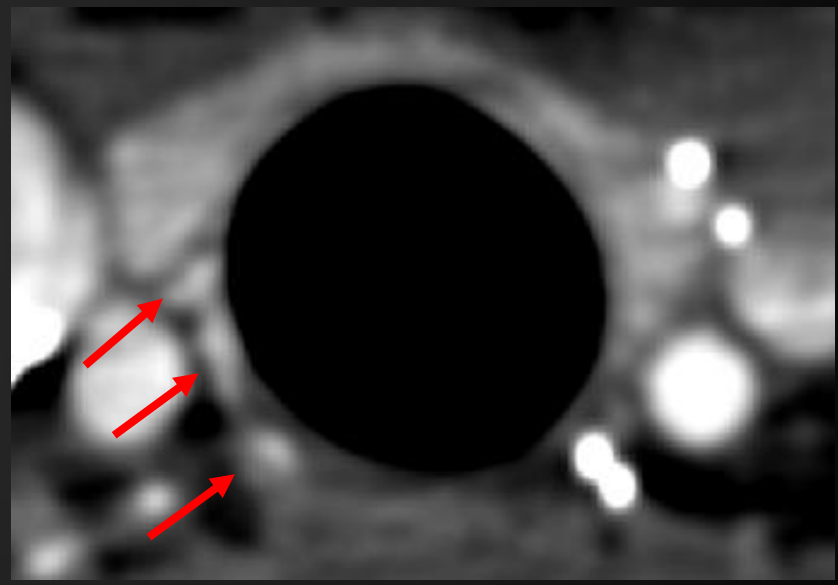
Case 12

A



B

C



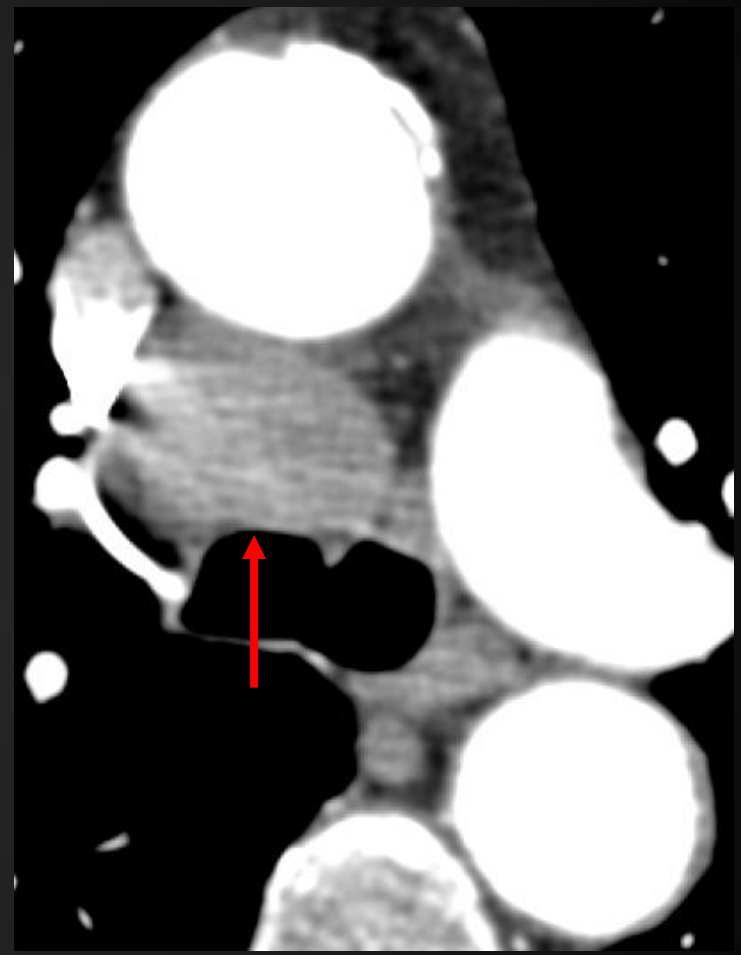
Case 12

- **Parathyromatosis after parathyroidectomy**
- Multiple tiny nodules bilaterally in the tracheo-esophageal grooves seen on axial arterial phase images (A-C) .
- Surgical clips from prior parathyroidectomy

Case 13

A

B



C

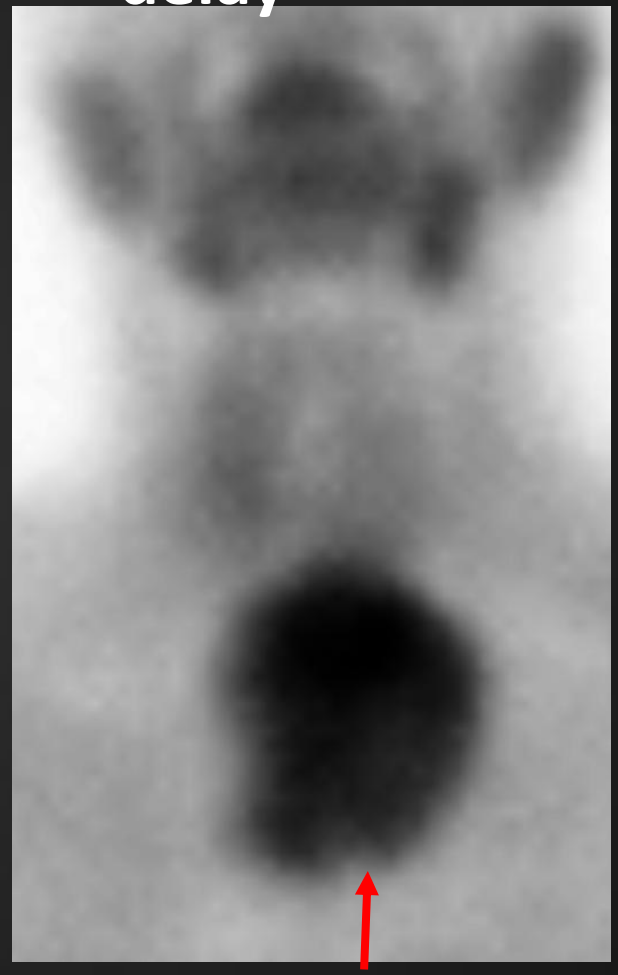
Case 13

- Biopsy confirmed **poorly differentiated carcinoma of unknown primary**
- Precarinal mass with only mild enhancement on arterial phase coronal (A), sagittal (B), and axial (C) images

Case 14

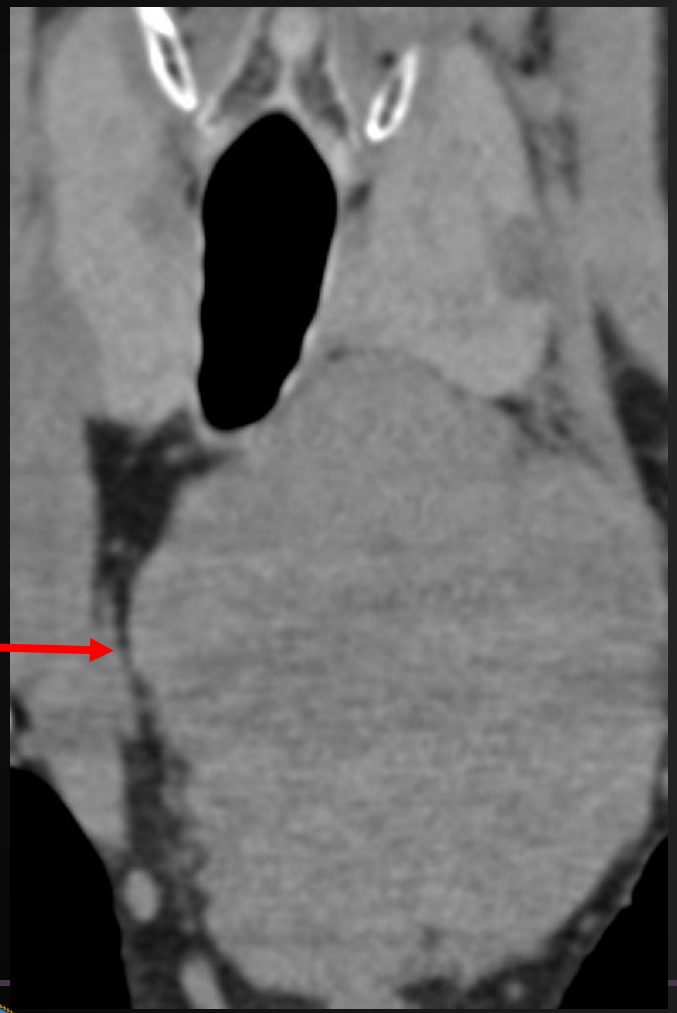
Sestamibi immediate

Sestamibi delay



Case 14

A



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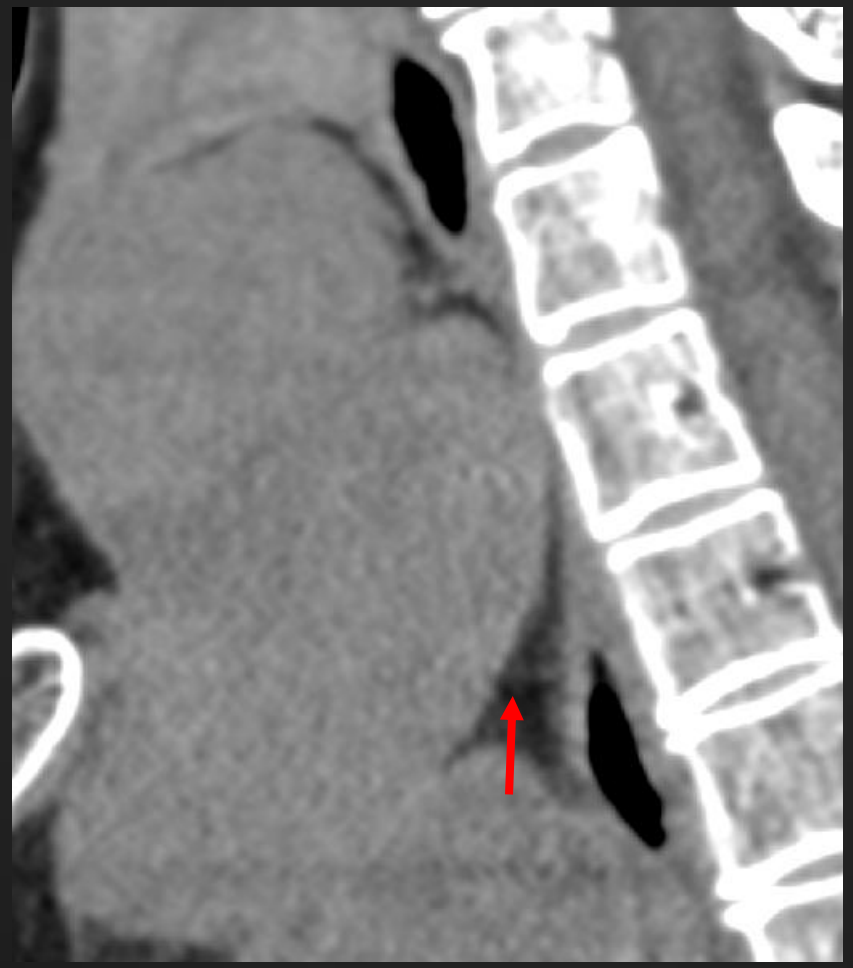
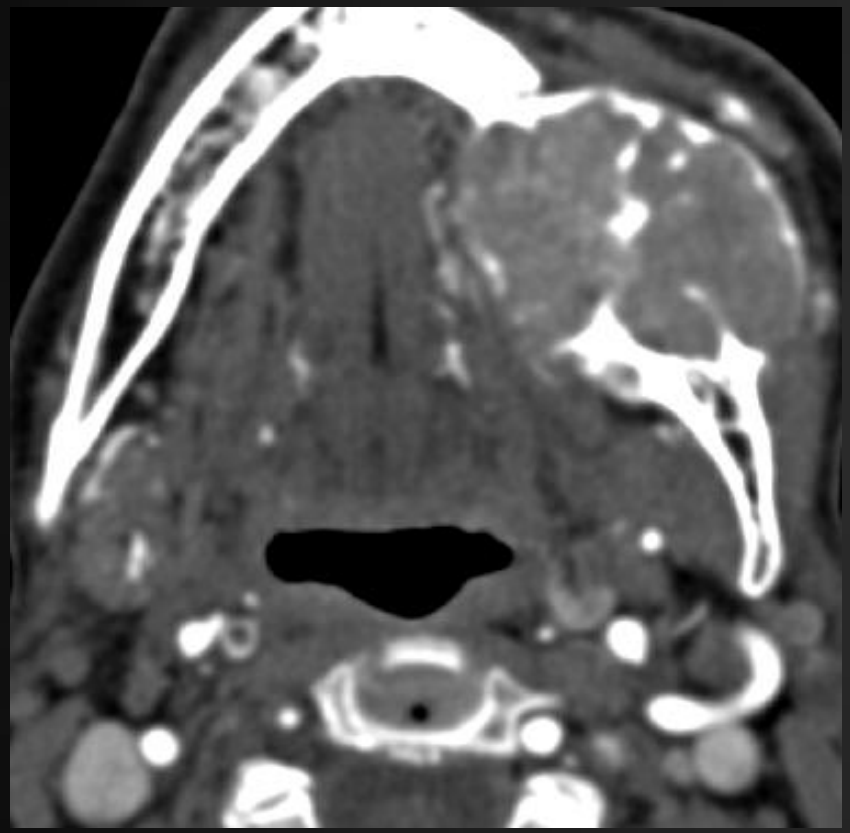


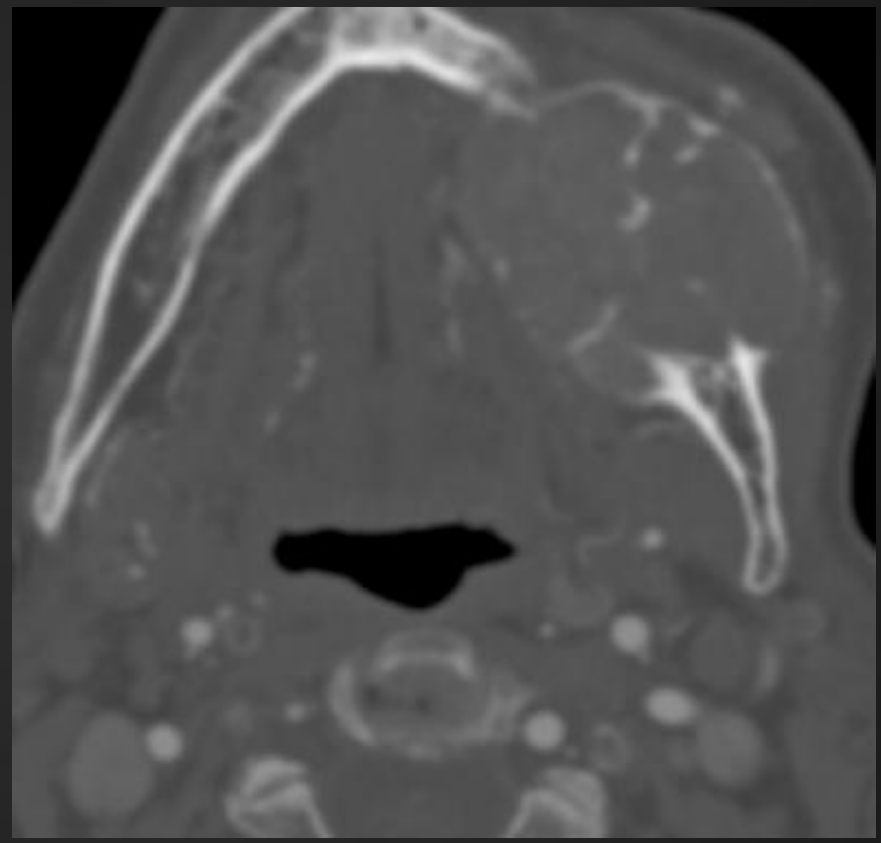
C

Case 14

- **Thymoma**
  - Large lobulated anterior mediastinal mass
  - Can mimic parathyroid adenoma on Sestamibi parathyroid or myocardial perfusion scans
    - Demonstrates increased uptake on the immediate phase Sestamibi with persistent uptake on delayed phase (same as parathyroid adenoma)
  - Hypodense to thyroid on precontrast coronal and sagittal images (A, B) and ***hypoenhancing*** on arterial phase sagittal (C) images
  - Can have areas of calcification and cystic/necrotic change

Case 15





Case 15

- **Brown tumor of the mandible**
- Expansile, lytic mass with internal calcification and internal hypderdense components (representing hemorrhage) in the left mandibular body related to primary hyperparathyroidism

Case 16

A

B

C

Case 16

- **Commonly encountered incidental findings**
- Spiculated left upper lobe mass compatible with pulmonary neoplasm on axial lung window CT (A)
- Superiorly directed left supraclinoid internal carotid artery aneurysm on axial arterial phase (B)
- Proximal internal carotid artery occlusion on sagittal arterial phase (C)

Take Home Points

- Primary Hyperparathyroidism is a relatively common disease associated with significant morbidity.
- Parathyroidectomy is a highly effective and definitive treatment for primary hyperparathyroidisim.
- Accurate preoperative localization is essential in planning for minimally invasive parathyroidectomies.
- 4D CT Parathyroid is emerging as the first line tool for preoperative localization, both for re-operation and initial presentation.
- High quality interpretation of 4D CT examinations should be part of the general radiologist's skillset.

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