Hybrid Imaging of Parathyroid Tumors

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Embriology

- Branchial arches and Pharyngeal pouches from the 4th week
- Superior Parathyroids – the 4th Pharyngeal pouch w/ thyroid
- Inferior Parathyroids – 3rd Pharyngeal pouch w/ thymus.
Diagrammatic representation of routes of descent of thymus, parathyroid glands, and “last branchial body” during fetal life. Parathyroid glands originating more cranially in third branchial pouch migrate in close association with thymus to reach final position more caudally with respect to parathyroid glands originating in fourth branchial pouch. Final location of last branchial body is intimately embedded in thyroid gland, to constitute parafollicular C-cells producing calcitonin. Thyroid gland originates at “blind foramen” along midline and migrates down to first tracheal ring (modified from (115)).
HYPERPARATHYROIDISM
Complex clinical condition characterized by increased secretion of parathyroid hormone (PTH)

**PRIMARY**
- Inappropriate PTH secretion causing hypercalcemia
  - Adenoma (85%-96%)
  - Hyperplasia (15%, MEN 1-2)
  - Carcinoma (1%)

**SECONDARY**
- Increased PTH secretion in response to chronic hypocalcemia (renal failure, malabsorption, etc.)
  - Compensatory hyperplasia

**TERTIARY**
- Functional autonomy following prolonged secondary hyperparathyroidism
  - Persists after correcting hypocalcemia
Primary Hyperparathyroidism

Epidemiology

- Incidence of 1 per 1000 people
- In the US there are 25-30 new cases per 100,000 people per year.
- F>M
- Incidence increases with age
- Most in > 50 years old
Microscopic Anatomy

Thyroid tissue

Parathyroid tissue

Parenchymal cells

Adipocytes

Chief cells

Oxyphil cells

PTH
Therapy of Primary and Tertiary Hyperparathyroidism

Identification and surgical removal of hyperfunctioning/hyperplastic gland/s
Who should have surgery?

- All symptomatic

- If asymptomatic
  - Markedly elevated serum Ca.
  - H/of episode of life-threatening hypercalcemia
  - Reduced renal function
  - Kidney stone on radiograph
  - Markedly elevated urinary Ca excretion
  - Substantially reduced bone mass
Conventional surgical approach in use since 1925: bilateral exploration of the neck.

“In my opinion the only localizing study indicated in a patient with untreated primary hyperparathyroidism is to localize an experienced parathyroid surgeon” (JL Doppmann. Invest Radiol 1986)
Minimally Invasive Parathyroidectomy versus Open Surgery

- Small surgical incision with favourable cosmetic outcome.
- Reduced surgical time and length of hospital admission
- Reduced overall cost
- Possible also under local anesthesia
- Fewer surgical complications
Minimally Invasive Parathyroidectomy
$^{99m}\text{Tc-Sestamibi}$

**PREOPERATIVE LOCALIZATION**
Dual-Phase $^{99m}$Tc-Sestamibi Scintigraphy

15 min post-injection

2.5 h post-injection
Dual tracer protocol

Mariani G et al. JNM 2003
Soft tissue Lung reconstruction algorithm for CT images from Thyroid Cancer SPECT/CT - Evolution
What are the advantages of SPECT/CT?

- Better AC.
- Allows an accurate and precise localization of scintigraphic findings, through better coregistration/fusion of SPECT and CT images.
- Diagnostic characterization (specificity) of scintigraphic findings.
- Detection of additional (unsuspected) lesions by the CT images of the SPECT/CT.
- Potential for better dosimetry and quantification.
What are the limitations of SPECT/CT?

- **Higher cost** of equipment, shielding of room, need for more space, energy consumption and air conditioning.

- **Additional radiation** emitted by the CT (1-4 mSv).

- **Movement of patient and artifacts** that could be introduced by the CT.
Parathyroid Imaging with SPECT/CT

- Early and delayed planar imaging of the neck and chest.
- Between the planar imaging we do SPECT/CT of the same area.
- CT done in 2.5 mm cuts.
- SPECT images AC and N-AC processed with iterative reconstruction.
Case 1  
56 year old woman  
Primary hyperparathyroidism  
Ca = 10.4 mg/dl  PTH= 95 pg/dl  
(normal Ca = 8.4-10.2 mgr/dl  PTH intact= 10-65 pg/ml)
Case 1
Surgical Pathology:
Left superior parathyroid adenoma
0.6 x 0.5 x 0.5 cm. 0.092 g
Case 2

49 year old woman
Primary Hyperparathyroidism
Ca= 10.8 mgr/dl and PTH 183 pg/ml
Case 2
Case 2
Added Value of SPECT/CT versus SPECT for Parathyroid Surgery

- Large body of evidence indicating improved preoperative localization of parathyroid adenomas.

- Sensitivity of SPECT/CT versus SPECT for localizing hyperfunctioning adenomas reported to be from moderately to markedly increased (in up to 40% of patients).

- Better specificity of SPECT/CT versus SPECT, even in patients with concomitant multinodular goiter and/or distorted anatomy because of prior surgery.
SPECT/CT in Parathyroid Scintigraphy

Correct localization:
- SPECT 61%
- SPECT/CT 100%
- Significant surgical impact in 39%
Case 3

51 year old woman
Primary hyperparathyroidism
Ca= 10.6 mg/dl   PTH= 163 pg/dl
Case 3

Perathyroid Head_Neck [AC Recon], 2/9/2006
Case 3

Right lower pole parathyroid adenoma
Case 3

Left thyroid lobe nodule
Case 3

Thyroid nodule on the left and Parathyroid adenoma on the right lower pole.

**Surgical Pathology:**
Right inferior parathyroid adenoma, 0.6 cm, 0.2 gr.
Review of the literature on SPECT/CT in parathyroid scintigraphy.

Understanding of parathyroid and neck anatomy is important for accurate reporting of the scans, because of their impact on the surgical approach.

The contribution of SPECT/CT over and above SPECT alone is greatest in terms of localization, particularly for ectopic tumours.

Controversial role of SPECT/CT for normotopic tumours, considering imaging time and the additional radiation dose.

Case 4

40 year old woman
Primary Hyperparathyroidism
Ca = 12.7 mg/dl   PTH = 450 pg/ml
Case 4
Enlarged parathyroid adenoma, descending posteriorly into the posterior mediastinum.

Surgical Pathology:  
6 x 3 x 1 cm parathyroid adenoma  
7.68 gm

- 32 patients with hyperparathyroidism.
- Accurate localization by SPECT alone: 22/32.
- Accurate localization by SPECT/CT: 31/32.
- Adenomas not detected by SPECT alone: <10 mm.
- SPECT/CT is superior to SPECT alone in the assessment of parathyroid tumors.
- It performs better in lesion localization and characterization, leading to fewer equivocal findings.
- SPECT/CT should be included in the clinical work up of all patients with diagnosis/suspicion of parathyroid tumors.
Case 5

66 year old woman
Primary hyperparathyroidism
Ca= 10.8 mg/dl   PTH= 272 pr/ml
Case 5

Parathyroid Head Neck [AC Recon], 2/16/2006

Transverse

Sagittal

Coronal
Case 5
Surgery: Right inferior parathyroid adenoma.
Surgical Pathology: parathyroid adenoma 1 cm and 0.38 g
Frequent surgical failure for secondary hyperparathyroidism in patients with end-stage renal disease on long-term hemodialysis or peritoneal dialysis.

- 5% - 10% persistent disease
- 20% - 30% recurrent disease at 5 yr.
- Significant incremental value of SPECT/CT in 30% - 40% of patients.
72 year old woman
Persistent Primary hyperparathyroidism
Ca= 12.7 mg/dl  PTH= 257 pr/ml

- 90 patients with secondary hyperparathyroidism, on hemodialysis.

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<th>PLANAR</th>
<th>SPECT/CT</th>
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<tbody>
<tr>
<td>Sensitivity</td>
<td>55.6%</td>
<td>78.9%</td>
</tr>
<tr>
<td>Specificity</td>
<td>100.0%</td>
<td>100.0%</td>
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<tr>
<td>Accuracy</td>
<td>55.6%</td>
<td>78.9%</td>
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- Not only does SPECT/CT detect a larger number of hyperfunctioning parathyroid glands, but also depicts their precise location more accurately than planar scintigraphy.
SPECT/CT Paratiroides

3D
Parathyroid SPECT/CT
+
ceCT
SPECT/CT in Parathyroid Imaging

- Better localization of parathyroid adenoma.
- Aids in the differentiation of parathyroid adenomas versus thyroid adenomas.
- Better definition of adjacent anatomical structures and true extension of the parathyroid adenoma → surgical planning.
- Characterization of unexpected findings in the 99mTc MIBI scan.
Thank You