Financial Disclosures

- Bayer
- Janssen
Learning Objectives

• To learn the advantages and disadvantages of SPECT/CT
• Discuss how SPECT/CT can be incorporated into your practice
• To better understand contact and travel precautions after I-131 therapy
• I-131 dosimetry
I homeschool because I have seen the village and I don't want it raising my children.
“UNclear” Medicine

- Functional imaging is somehow less valid because of the lack of fine spatial resolution.
Synergistic Imaging

- Fusion of anatomic and molecular images with integrated systems, sequentially in time but without moving the patient from the imaging table
  - Optimal coregistration of anatomic and molecular images
    - Precise anatomic localization of lesions
      - Anatomic evaluation of lesions
      - Accurate attenuation correction
Hi, Mom and Dad! I'm e-mailing you a 3-D image of the baby I just took with the sonogram function. These iPhones are amazing...
Whole Body I-131 Diagnostic Study
(10 dy post ablation with 100 mCi I-131)
Koo PJ, Klingensmith WC, Bagrosky BM, Haugen BR. SPECT/CT of Metastatic Struma Ovarii. Clinical Nuclear Medicine 2013
SPECT/CT in DTC

- 17 patients who received a diagnostic dose and 54 patients who underwent therapeutic-dose scanning.
- Additional incremental value for 57% (41 of 71) of patients, with a substantial impact on clinical management.
- SPECT/CT improved indeterminate findings:
  - Definitely benign in 13% of patients
  - Precise localization of metastases to the skeleton in 17%, and to the lungs vs the mediastinum in 7% of patients.
- SPECT/CT improved localization and characterization of foci.

SPECT/CT Fusion Imaging in the Evaluation of Differentiated Thyroid Carcinoma

• 122 lesions, incremental diagnostic value was found in 43.
• No change in 69 of 122 of central neck foci.
• SPECT/CT:
  – Downstaging of 26 of 53 foci from equivocal or cervical lymph node to thyroid remnant
  – Upstaging of 11 of 53 foci from equivocal or thyroid remnant to cervical lymph node.
• 6 of 53 foci were reclassified as physiologic dental or salivary activity.

In all cases of distant metastasis, there was no change in focus classification:

- SPECT/CT improved lesion localization, provided additional anatomic information, and increased reader confidence.

$^{131}$I SPECT/CT has facilitated rapid, accurate, and confident assessment of radioiodine activity outside the expected biodistribution.
### Incremental Value of SPECT/CT with Respect to Planar Imaging in Relationship to Number of Foci of Radioiodine Uptake

<table>
<thead>
<tr>
<th>Planar and SPECT/CT imaging</th>
<th>No. of DTC patients (n = 117)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concordantly negative</td>
<td>58 (49.6%)</td>
</tr>
<tr>
<td>Concordantly positive</td>
<td>52 (44.4%)</td>
</tr>
<tr>
<td>With same number of foci on planar imaging and SPECT/CT</td>
<td>42 (35.9%)</td>
</tr>
<tr>
<td>With higher number of foci on SPECT/CT than on planar imaging</td>
<td>10 (8.5%)</td>
</tr>
<tr>
<td>Discordant</td>
<td></td>
</tr>
<tr>
<td>Planar imaging negative and SPECT/CT positive</td>
<td>7 (6.0%)</td>
</tr>
</tbody>
</table>

**Spanu A, Solinas ME, Chessa F, Sanna D, Nuvoli S, Madeddu G.**  
**$^{131}$I SPECT/CT in the follow-up of differentiated thyroid carcinoma: incremental value versus planar imaging.**  
Meta-Analysis

- SPECT/CT imaging had an incremental diagnostic value compared with WBS in 47.6–88 % of cases and resulted in the modification of therapeutic strategies in 23.5–25 % of DTC patients.
- SPECT/CT improved localization in 44 %.
- Reader confidence increased 71 %
- SPECT/CT imaging also decreased the number of cases classified as indeterminate from 29 to 7 %.
- SPECT/CT yielded a gain in information on nodal stage in 35–36.4 % (downstaging or upstaging) of cases.
- The change of nodal stage resulted in a new risk stratification in 6.4–25 % of patients

Advantages

- Localization
- Morphologic evaluation
- Size data
- Attenuation correction

Improved specificity and accuracy
Improved reader confidence
Disadvantages

- Time
- Price
- Radiation
- Incidental findings
  - Clinically significant
  - Clinically insignificant
  - Unsure
  - Pulmonary nodules
  - Renal lesions
  - Nodes
Our Protocol

- Incremental Value
- SPECT/CT only performed to evaluated abnormality seen on planar images
- Only the area of interest is included
- Low dose CT parameters
Preablation 131-I Scans With SPECT/CT in Postoperative Thyroid Cancer Patients: What Is the Impact on Staging?

- **<45 yo:**
  - distant metastases in 5 of 138 patients (4%)
  - nodal metastases in 61 of 138 patients (44%)
  - unsuspected nodal metastases in 24 of 63 (38%) patients initially assigned pathologic (p) N0 or pNx.

- **> 45 yo:**
  - Distant metastases in 18 of 182 patients (10%)
  - nodal metastases in 51 of 182 patients (28%)
  - unsuspected nodal metastases in 26 of 108 (24%) patients initially assigned pN0 or pNx.

- Changed staging in 4% of younger, and 25% of older patients.

Avram AM, et al. JCEM. March 2013
Higher sensitivity in detecting metastases of differentiated thyroid cancer in comparison to I-131.

- (124)I PET identified as many as 50% more foci of radioiodine uptake suggestive of additional residual thyroid tissue and/or metastases in as many as 32% more patients who had WDTC.

I-124 allows high resolution three dimensional dosimetry of individual metastatic lesions.

- More scientific basis for determining the necessary activity for treatment with $^{131}$I.

1. Van Nostrand D, et al. (124)I positron emission tomography versus (131)I planar imaging in the identification of residual thyroid tissue and/or metastasis in patients who have well-differentiated thyroid cancer. Thyroid. 20 (8):879-83, 2010.
I-124 vs I-123 vs I-131 for Imaging Thyroid Cancer

I-124 PET-CT

48 hr MIP (7 mCi)

I-123

24 hr Planar (1.5 mCi)

I-131

7 dy Planar (150 mCi)
Contact and travel precautions after I-131 therapy
NO PETS ALLOWED

ALL PETS MUST BE ON LEASH
Team Effort

- Radiation Safety Officer
- Nuclear Physicist
- Endocrinology
- Nuclear Medicine
Basic Principles of Radiation Safety

- **TIME** – minimizing the time of exposure directly reduces radiation dose.
- **DISTANCE** – doubling the distance between your body and the radiation source will divide the radiation exposure by a factor of 4.
- **SHIELDING**
- **Retained activity**
Radiation Safety in the Treatment of Patients with Thyroid Diseases by Radioiodine $^{131}$I: Practice Recommendations of the American Thyroid Association

The American Thyroid Association Taskforce on Radioiodine Safety

PATIENT EVALUATION FOR OUTPATIENT TREATMENT WITH I-131

Patient: ___________________________  MRN: __________

Dose: ________ mCi of I-131  Administration Date: __________

In order to determine the suitability of the patient for outpatient treatment with I-131, the patient must be interviewed and an objective evaluation made to determine that the patient is able and willing to comply with the restrictions noted on the patient instruction form. Restrictions pertain for 2 days following administration of I-131.

Living Arrangements

Will the patient stay in a hotel? [ ] Yes [ ] No

Describe living arrangements (e.g., single-family home, apartment): ___________________________

[ ] House [ ] Apartment

Number of adults living with patient: ______

Number of pregnant females living with patient: ______

Number of infants and young children living with patient: ______

If patient does not live alone, does the patient have his/her own room or enough space to maintain a distance of at least 3 feet from others? [ ] Yes [ ] No

If patient has infants and/or young children at home, does the patient have assistance with child care and will he/she not share any living space with them? [ ] Yes [ ] No

Otherwise, is the patient able to have children stay outside the home? [ ] Yes [ ] No

Patient is able to sleep alone? [ ] Yes [ ] No

Patient has sole use of bathroom or agrees to follow detailed instructions for bathroom use? [ ] Yes [ ] No

Travel Arrangements

Will the patient travel by airplane or mass transport? [ ] Yes [ ] No

Will the patient have prolonged travel by automobile with others? [ ] Yes [ ] No

If the patient is driving home with others, how long is the trip (hours)? ______

Work Arrangements

Does the patient intend to return to work within 2 days of the treatment? [ ] Yes [ ] No

If yes: Describe type of working environment (e.g., office, retail, restaurant):

[ ] Office [ ] Retail [ ] Restaurant

Will the patient travel to/from work by mass transport? [ ] Yes [ ] No

Patient has own office or enough space to maintain a distance of at least 3 feet from other coworkers? [ ] Yes [ ] No

Patient has sole use of bathroom or agrees to follow detailed instructions for bathroom use? [ ] Yes [ ] No

I have interviewed the patient and determined that the patient is:

[ ] able and willing to comply with the instructions required for outpatient I-131 treatment,
[ ] unable or unwilling to comply with the instructions required for outpatient I-131 treatment and therefore should be hospitalized for ______ days following I-131 treatment.

[ ] Yes [ ] No

Interviewer: ___________________________  Date: __________

Version: 20000420  I-131 Therapy Nuclear Medicine
Release of Patient Containing Iodine-131
Calculations in Compliance with 10 CFR 35.75
Using NUREG 1556, Vol. 9, Rev. 2

Patient Name:  
MRN:  

Notes:
Instructions were reviewed with the patient by Jeremy Imon on 11/06/2012.

Calculation Parameters
Retention Basis: Post- Thyroidectomy for Thyroid Cancer
Formula: Equation B-5 has been modified to explicitly calculate all exponential terms.

\[
D(\infty) = \frac{34.6 \Gamma \Omega}{d^2} \left[ E_1 T_1 (0.8) \left( 1 - e^{- \frac{\ln(2) T_1}{24}} \right) + e^{- \frac{\ln(2) T_1}{24}} E_2 F_1 T_{1,eff} + e^{- \frac{\ln(2) T_1}{24}} E_1 F_2 T_{2,eff} \right]
\]

Spreadsheet Version: 20120622
Prescribed Activity, Q_p in mCi: 100
Dose rate constant, \(\Gamma\) (R cm²/mCi hr) @1cm: 2.2
Distance, r in cm: 100
Occupancy factor, \(E_p\) for 0 to 8 hours: 0.75
Occupancy Factor, \(E_p\) for 8 hours to total decay: 0.25
Extrathyroidal Uptake Fraction, \(F_1\): 0.95
Extrathyroidal Effective Half-Life, \(T_{1,eff}\) (days): 0.32
Thyroidal Uptake Fraction, \(F_2\): 0.05
Thyroidal Effective Half Life, \(T_{2,eff}\) (days): 7.3
I-131 Physical Half-life, \(T_p\) (days): 8.04

Resulting Dose to the General Public
\(D[0\rightarrow8\ hr]\) in rem: 0.104
\(D[8hr\rightarrow\infty, from\ Extrathyroidal\ Component]\) in rem: 0.056
\(D[8hr\rightarrow\infty, from\ Thyroidal\ Component]\) in rem: 0.067
\(D[\infty]\) in rem: 0.228

Outcome
Dose to Members of the Public is less than 0.5 rem. This patient may be released with appropriate instructions.

Physicist:  
Date: 7-Nov-12
II. PRODUCTION:  o Applicable  o Not Applicable

I authorize Dr. ______________ and/or any assistant, residents, medical students working with this physician to conduct the following procedure described to me in plain language:

Your physician has referred you for a treatment of orally administered radioactive iodine for ablation of residual functioning thyroid tissue.

We are attempting to destroy all functioning thyroid tissue. Results are not always successful. There is an approximately 10-30% chance that the treatment will not destroy all functioning thyroid tissue. In this case an additional treatment or treatments may be necessary.

There are two possible major complications. First, there is an approximately 1% chance of developing a second cancer; the chances vary with the cumulative dose of radioactive iodine. Second, there is an approximately 1% chance of developing significant bone marrow depression. If this occurs, blood transfusions may be necessary. However, the bone marrow would be expected to recover.

There are several relatively minor, self-limiting, side effects which may occur. There is an approximately 30% chance that the treatment will cause nausea and vomiting for several days, a 20% chance that the treatment will decrease your taste sensation, possibly for as long as a year, and a 20% chance that the treatment will injure your salivary glands resulting in soreness and dryness of the mouth for several days. In addition, there is an approximately 20% chance of neck swelling and pain if large amounts of thyroid tissue are present initially. If any of these complications occur, you may contact your physician for symptomatic treatment.

You should refrain from eating for 1 hour following ingestion of the radioactive iodine.

Female patients who may be pregnant or who are breast feeding should not undergo this treatment. Pregnancy should be postponed for at least 3 months following treatment.

Patient: I hereby give my consent to the above.

Signature of Patient, Legal Guardian, or Patient's Representative

Relationship to Patient

Print Name of Signer

Date

Time

Physician:

I believe this patient is an appropriate candidate to undergo the procedure. I have explained the benefits, risks and alternatives of the procedure to the patient and have answered all the patient's questions. To the best of my knowledge, the patient has been adequately informed, understands, and has consented to the proposed procedure.

Signature of Informing Physician

Date

Time

Witness signature (for telephone and verbal consents)
**Patient Agreement**

I agree to abide by the recommendations on the previous page as a condition of my treatment on an outpatient basis. I have had the opportunity to ask questions about the limitations on my activities following release. I understand each of the items. I understand that if I do not follow the instructions fully that I may expose other to unnecessary radiation exposure. This may cause adverse health effect, especially if infants and young children are involved.

X Patient/Guardian Signature

Date

**Authorization for Release**

I authorize the release of the patient with the precautions listed on the previous page. The basis for this release is that the radiation exposure (total effective dose equivalent) to any other individual from the released patient is not likely to exceed 3 millirems (0.5 rem), as required by 9 CCR 1007-1, Part 7, 7.26.1.

X Authorized User

Date

*Patient must receive one copy and the original must be retained with patient records.*

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**Referral Information & Written Directive**

Referring physician: ___________________________ Patient name: ___________________________

Histologic diagnosis: ___________________________ Size of primary: ___________________________

Positive lymph nodes: ___________________________ Histologic capsule invasion: ___________________________

Completeness of thyroidectomy: ___________________________ Imaging proof of residual functioning tissue: ___________________________

Patient weight: ___________________________ Thyroglobulin level: ___________________________

No IV contrast ≥ 3 weeks: ___________________________ TSH level: ___________________________

Renal function: ___________________________ Last dose of T-4 & T-3: ___________________________

Pregnancy test (females of reproductive age): Pretreated with rTSH: ___________________________

Date for delayed post therapy whole body imaging (at about 7-10 days): ___________________________

Dose of Oral I-131 to be ordered: ___________________________ Treatment date: ___________________________

Authorized user: ___________________________ Today’s date: ___________________________
AIRPORT SECURITY 2012 AND BEYOND

1. Passenger arrives at check-in to deposit hold luggage before going through security with or without carry-on hand luggage.

2. Radiation detectors disguised as security barrier poles scan passengers for traces of radioactivity. A radiation detector sits just under the pole's roll-out extendable belt mechanism. The battery sits in the base. It can send warnings wirelessly to a central control unit.

3. Smart camera scans the area looking for suspicious faces or movements.

4. Hand luggage scanner checks for explosives, dangerous liquids, drugs. New portable scanners take a swab from skin or bags to check for traces of suspect materials.

5. Archway detector seeks out metal and can 'sniff' for other suspect substances.

6. Hand luggage scanner checks for explosives, dangerous liquids, drugs. New portable scanners take a swab from skin or bags to check for traces of suspect materials.

7. Biological threat Aerosol detectors monitor the air for airborne biological threats such as anthrax, plague bacteria, smallpox viruses or deadly ricin poison. Shutting down the air conditioning system and sealing off rooms to contain the toxic threat and prevent it spreading across an entire airport or being carried onto planes.

8. Command and control centre, receives data from all the scanners, cameras and radar detectors giving an overview of whole airport security.

Source: Farnborough International Air Show / FLH/ www.farnborough.com
Dosimetry Determination of Maximum Tolerated Activity: When and How?

2017 SNMMI Annual Meeting
Denver, CO
June 14, 2017

Jennifer Kwak, MD
Assistant Professor of Radiology
Division of Nuclear Medicine and Molecular Imaging
University of Colorado School of Medicine
Prescribing I-131 Therapy for Thyroid Cancer

• Empiric fixed activity method

• Dosimetry based activity method
  – “Whole body” dosimetry
    • Based on the red marrow absorbed dose or lung deposited activity limit method (Benua\(^1\) et al. 1962)
  – Lesion-based dosimetry
    • Based on the absorbed dose to the thyroid remnant and metastases (Maxon\(^2\) et al. 1983)

Prescribing I-131 Therapy for Thyroid Cancer

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Empiric Fixed-Activity Method

  - Cervical lymph nodes metastases: 150-175 mCi
  - Lung metastases: 175-200 mCi
  - Bone metastases: 200 mCi

- 2012 SNM Practice Guideline for Therapy of Thyroid Disease with I-131
  - Postoperative ablation: 30-100 mCi
  - Cervical or mediastinal lymph node metastases: 150-200 mCi
  - Distant metastases: 200 mCi or higher

✓ Simple.
✓ Convenient.
✓ Long history of use.
Whole Body Dosimetry

• Administer the maximum activity of I-131 without causing life-threatening critical organ damage => bone marrow failure or lung fibrosis

**Recommendations:**

• Absorbed dose limit to blood/red marrow -> 2 Gy
• Whole body retention @48 hours:
  • < 120 mCi
  • < 80 mCi in the presence of diffuse lung metastases
*whichever is more limiting
Counts from gamma probe/gamma camera and blood samples converted to activity (uCi/MBq) using standards to create time activity curves.
Indications for Dosimetry

- High prescribed activity to treat metastases
- Elderly patients
- Diffuse lung metastases
- Renal insufficiency

Haugen BR et al. 2015 American Thyroid Association Management Guidelines for Adult Patients with Thyroid Nodules and Differentiated Thyroid Cancer. Thyroid. 2016; 26(1):1-133.
I-131 dosimetry protocol

Clinical protocol

Administer small dose (~2 mCi)

Day 1 emission
Day 2 emission
Day 3 emission
Day 4 emission
Day 5 emission

*Slides Courtesy of Adam Kesner, PhD
I-131 dosimetry protocol

Physics portion of protocol

• Formatted output auto-populated, images inserted
• Can be exported to pdf report

*Slides Courtesy of Adam Kesner, PhD
I-131 dosimetry protocol

- Multi-disciplinary team of physicians reviews report and decides on a treatment plan
  - Clinicians may choose to be more or less aggressive.

*Slides Courtesy of Adam Kesner, PhD*
MTA: 140 mCi
Prescribed activity: 140 mCi