Topics

- Nuclear Medicine (NM) patient radiation dose
- Image Gently/Image Wisely in Nuclear Medicine
- 2011 NM dose reduction project at Gundersen Lutheran Health System
Media Attention to Radiation Dose

- CT has been the main target of media attention related to radiation dose from medical imaging.

- Radiation dose from nuclear medicine procedures is frequently overlooked despite comparable effective dose.
# Effective Dose from Common Exams

## Nuclear medicine and PET

<table>
<thead>
<tr>
<th>Imaging Exam</th>
<th>Effective Dose mSv</th>
<th>Months of background radiation for same dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear medicine Bone Scan</td>
<td>6.3</td>
<td>27</td>
</tr>
<tr>
<td>Nuclear medicine PET Scan</td>
<td>7.1</td>
<td>27</td>
</tr>
<tr>
<td>Nuclear medicine Cardiac Perfusion SPECT</td>
<td>17.7</td>
<td>69</td>
</tr>
</tbody>
</table>

## Computed Tomography (CT)

<table>
<thead>
<tr>
<th>Imaging Exam</th>
<th>Effective Dose mSv</th>
<th>Months of background radiation for same dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head CT</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Chest CT</td>
<td>7</td>
<td>27</td>
</tr>
<tr>
<td>Abdomen and Pelvis CT</td>
<td>10</td>
<td>33</td>
</tr>
<tr>
<td>Cardiac CT for Calcium Scoring</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Cardiac CT Angiography</td>
<td>15</td>
<td>58</td>
</tr>
</tbody>
</table>

Although CT was the largest medical contributor to collective effective dose to the U.S. pop. in 2006 (24%);

NM was second (12%)

NCRP Report No. 160 Fig. 1.1. Percent contribution of various sources of exposure to the total collective effective dose (1,870,000 person-Sv) and the total effective dose per individual in the U.S. population (6.2 mSv) for 2006
Growth in NM

- Diagnostic NM procedures increased by a factor of 5.5 over 1972-2006, with 5% annual growth over the last decade.

- Reason: advances in instrumentation such as PET/CT and development of new radio-pharmaceuticals.

- PET annual growth rate has ranged from 25% to 50% (IMV Medical Information Division 2006a).

Images: Gundersen Lutheran Health System
Annual National Patient Volume

• The estimated number of NM procedures performed in the US in 2005 is 19.7 million (IMV Medical Information Division 2006b).

• Less than the estimated 62 million CT procedures performed in the US in 2006 (NCRP Report No. 160) but still a large number.

Photo: Gundersen Lutheran Health System
Wide Variation in Pediatric Dose

- A 2008 survey found wide variation in pediatric radiopharmaceutical administered doses among 13 leading pediatric hospitals in North America

NACG

• Pediatric Nuclear Medicine Dose Reduction Workgroup developed *North American Consensus Guidelines for Administered Radiopharmaceutical Activities in Children and Adolescents*

Guidelines recommend appropriate radio-pharmaceutical activities for 11 common pediatric NM procedures

Basis of Image GentlySM 2011 NM campaign, “Go with the Guidelines”

http://www.pedrad.org/associations
Image Gently

- Image Gently℠ was created in 2007 by a coalition of health care organizations (SPR, AAPM, ACR, ASRT)

- Goal: change practice by raising awareness of opportunities to lower radiation dose in pediatric imaging

http://www.pedrad.org/associations
Image Wisely

- ACR/RSNA Joint Task Force on Adult Radiation Protection launched Image Wisely℠ in 2010

- Aim: lower radiation doses used in medically necessary adult imaging studies and eliminate unnecessary procedures

http://www.imagewisely.org/
Gundersen Lutheran Health System

- 2011 implementation of Image Gently in Nuclear Medicine dept at Gundersen Lutheran Health System
  - 3 SPECT/CT units
  - PET/CT scanner
  - Annual NM & PET patient volume ~ 4250 exams
Comparison to NACG

• Site radiopharmaceutical doses for pediatric nuclear medicine procedures were compared with NACG

• Site procedures not included in NACG were compared with European Association of Nuclear Medicine (EANM) Paediatric Dose Card recommendations
  - Lassmann, Biassoni, Monesieurs, Franzius, & Jacobs 2007

• Total of 24 pediatric protocols compared
Some ranges decrease with weight because calculated value for 6 kg fell below minimum recommended activity.

NWBD = no weight-based dose; NL = not listed
<table>
<thead>
<tr>
<th>Radiopharmaceutical Procedure</th>
<th>Site Protocol</th>
<th>North American Consensus Guidelines</th>
<th>European Association of Nuclear Medicine Paediatric Dose Card</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weight-based range [MBq/kg][6-64kg]$^1$</td>
<td>Min (MBq)</td>
<td>Max (MBq)</td>
</tr>
<tr>
<td>$^{99m}$Tc-IDA (biliary)</td>
<td>3.1 – 2.3</td>
<td>18.5</td>
<td>148</td>
</tr>
<tr>
<td>$^{99m}$Tc-MAG3 renal w/out flow</td>
<td>11.1-5.9</td>
<td>55.5</td>
<td>185</td>
</tr>
<tr>
<td>$^{99m}$Tc-MAG3 renal w/ flow</td>
<td>5.55</td>
<td>37</td>
<td>148</td>
</tr>
<tr>
<td>$^{99m}$Tc-MDP (bone)</td>
<td>24.4-12.7</td>
<td>74</td>
<td>740</td>
</tr>
<tr>
<td>$^{99m}$Tc-pertechnetate (cystography)</td>
<td>19.2-0.35</td>
<td>37</td>
<td>37</td>
</tr>
<tr>
<td>$^{99m}$Tc-pertechnetate (thyroid)</td>
<td>5.6-2.9</td>
<td>18.5 uptake, 37 imaging</td>
<td>18.5 uptake, 37 imaging</td>
</tr>
<tr>
<td>$^{99m}$Tc-RBC (blood pool)</td>
<td>38.9-20.4</td>
<td>74</td>
<td>1295</td>
</tr>
<tr>
<td>$^{99m}$Tc-spleen (denatured RBC)</td>
<td>12.2-20.0</td>
<td>74</td>
<td>1295</td>
</tr>
<tr>
<td>$^{99m}$Tc-Technegas (lung ventilation) (GL uses DTPA)</td>
<td>44.4-34.5 (post perf 88.8-57.7)</td>
<td>1110 (2960 post perf)</td>
<td>1480 (3700 post perf)</td>
</tr>
<tr>
<td>$^{99m}$Tc-MAA perfusion only or after vent</td>
<td>5.6-2.9</td>
<td>11.1</td>
<td>185</td>
</tr>
<tr>
<td>$^{99m}$Tc-MAA perfusion prior to vent</td>
<td>2.2-1.2</td>
<td>11.1</td>
<td>74</td>
</tr>
<tr>
<td>$^{99m}$Tc-pertechnetate Meckel’s diverticulum</td>
<td>5.6-2.9</td>
<td>18.5</td>
<td>185</td>
</tr>
</tbody>
</table>
Evaluation

• Dose comparison was evaluated by:
  ▪ two board-certified nuclear medicine radiologists
  ▪ two board-certified diagnostic medical physicists
  ▪ certified nuclear medicine lead technologist

• All radiopharmaceutical doses were determined to be comparable to NACG or EANM recommendations, except:
  ▪ minimum dose for the pediatric nuclear medicine renogram without flow, which uses $^{99m}$Tc mercaptoacetyltriglycine (MAG3).
MAG3 renogram w/o flow

- Site minimum dose was 55.5 MBq
  - NACG recommended minimum dose: 37 MBq
  - EANM recommended minimum dose: 40 MBq
- Minimum dose for this exam was reduced to 37 MBq. Clinical images showed no discernable decline in image quality or diagnostic capability, as determined by the two NM radiologists.
• This exam is done on a very young child, often a few months of age or less. Radiation dose estimates for an 8-day-old child were calculated using radiation dose data from the vendor’s package.

• Whole-body dose decreased from 0.36 mSv for 55.5 MBq to 0.24 mSv for 37 MBq (33.3% reduction)
  - Urinary bladder wall dose decreased from 17.2 mSv to 11.5 mSv
  - Gallbladder wall dose decreased from 4.1 mSv to 2.7 mSv.
Low Clinical Impact

- Evaluation of the site pediatric administered doses was a good quality and patient safety project. But clinical impact was low.

- 7232 NM procedures were done at Gundersen Lutheran in 2010-2011.
  - 217 were on patients 0-17 years of age (3.0%)
  - 7015 were on patients 18+ years of age (97%)
  - 7 pediatric renograms were done
    - 3.2% of pediatric exams
    - 0.1% of all exams

Image: http://www.pedrad.org/associations
Unusual Patient Distribution? No.

- Of NM patients in the US in 2003 (NCRP Rep No 160):
  - 2.3% were 0-17 years of age
  - 97.7% were 18+ years of age.

- This is because most exams are cardiac and bone studies, which adults are more likely to require than children.

- Because our Image Gently project affected only a very small fraction of our patients, we added a second phase to the project.
Phase 2: Image Wisely

- Site radiopharmaceutical doses for 52 adult diagnostic nuclear medicine procedures were obtained.

- Comparison with a standard was more difficult because there are no guidelines comparable to NACG or EANM for adult patient radiopharmaceutical doses.
Dose Comparison

• Site doses were compared to doses in NCRP Rep No 160 Table D.5, *Radionuclides, administered activity, dose conversion coefficient, and effective dose per procedure in nuclear medicine*

  ■ Table D.5 doses are based on suggested ranges from textbooks, the Society of Nuclear Medicine (SNM) website, and nuclear medicine practices in a few large hospitals.

• Also compared our doses to those in IAEA Safety Rep No. 40 (2005)
CPT codes

• The names of the site procedures did not always match the procedure names listed in NCRP Report No. 160.

• We used CMS Current Procedural Terminology (CPT) codes to ensure the proper comparison.

• Too much in tables to show it all. Next slide is one page of table.
<table>
<thead>
<tr>
<th>Billing Code</th>
<th>Radiopharmaceutical Procedure</th>
<th>Site Protocol</th>
<th>NCRP Report No. 160&lt;sup&gt;1&lt;/sup&gt;</th>
<th>IAEA Report No. 40&lt;sup&gt;2&lt;/sup&gt;</th>
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</thead>
<tbody>
<tr>
<td>78223</td>
<td>Hepatobiliary imaging&lt;sup&gt;99&lt;/sup&gt;Tc-Lidofenin (chol)</td>
<td>NL</td>
<td>148</td>
<td>NL</td>
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<tr>
<td>78290</td>
<td>Meckel's diverticulum&lt;sup&gt;99&lt;/sup&gt;TcO&lt;sub&gt;4&lt;/sub&gt;</td>
<td>NL</td>
<td>NL</td>
<td>18.5</td>
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<tr>
<td>78264</td>
<td>Gastric emptying with small bowel transit&lt;sup&gt;99&lt;/sup&gt;Tc-sulfur colloid</td>
<td>NL</td>
<td>18.5</td>
<td>NL</td>
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<tr>
<td>78216/06</td>
<td>Liver spleen imaging&lt;sup&gt;99&lt;/sup&gt;Tc-sulfur colloid</td>
<td>NL</td>
<td>185</td>
<td>NL</td>
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<tr>
<td>78262</td>
<td>Gastroesophageal reflux&lt;sup&gt;99&lt;/sup&gt;Tc-sulfur colloid</td>
<td>NL</td>
<td>7.4-37</td>
<td>NL</td>
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<td>78707/8</td>
<td>Renogram with and without Lasix MAG3/DTPA</td>
<td>185/kidney</td>
<td>370</td>
<td>NL</td>
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<td>78710/00</td>
<td>Renal scan&lt;sup&gt;99&lt;/sup&gt;Tc-DMSA</td>
<td>NL</td>
<td>185</td>
<td>NL</td>
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<tr>
<td>78740</td>
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<td>37</td>
<td>NL</td>
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<tr>
<td>78807</td>
<td>Gallium imaging&lt;sup&gt;67&lt;/sup&gt;Ga-citrate - Infection</td>
<td>NL</td>
<td>185</td>
<td>NL</td>
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<tr>
<td>78805/7</td>
<td>WBC study&lt;sup&gt;111&lt;/sup&gt;In-oxine</td>
<td>NL</td>
<td>18.5-37</td>
<td>NL</td>
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<tr>
<td>78805</td>
<td>WBC study&lt;sup&gt;99&lt;/sup&gt;Tc-HMPAO CereTec</td>
<td>NL</td>
<td>370-740</td>
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<tr>
<td>78803</td>
<td>Prostastint&lt;sup&gt;111&lt;/sup&gt;In-capromab pendetide</td>
<td>NL</td>
<td>185</td>
<td>NL</td>
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<td>18.5-27.8</td>
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<td>78650</td>
<td>CSF leak&lt;sup&gt;111&lt;/sup&gt;In-DTPA</td>
<td>NL</td>
<td>18.5-27.8</td>
<td>NL</td>
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<td>78580</td>
<td>Lung perfusion scan&lt;sup&gt;99&lt;/sup&gt;Tc-MAA (perfusion only or after lung vent)</td>
<td>NL</td>
<td>185</td>
<td>NL</td>
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<td>78588/0</td>
<td>Lung perfusion scan&lt;sup&gt;99&lt;/sup&gt;Tc-MAA (before lung ventilation imaging)</td>
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<td>74</td>
<td>NL</td>
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<td>78596</td>
<td>Lung perfusion scan&lt;sup&gt;99&lt;/sup&gt;Tc-MAA (quant. lung only)</td>
<td>NL</td>
<td>185</td>
<td>NL</td>
</tr>
</tbody>
</table>
Evaluation

• Same committee evaluated the comparison of the 52 site protocols.

• All doses were comparable to NCRP Report No. 160 values or IAEA Report No. 40 values except:
  - $^{99m}$Tc sulfur colloid egg yolk gastric emptying study
**99mTc Sulfur Colloid Egg Yolk Gastric Emptying Study**

- Site administered Dose was 111 MBq
  - NCRP Rep No 160 dose: 14.8 MBq
  - IAEA Report 40 dose: 12 MBq

- Dose was reduced to 37 MBq

- Trial of 10 patients was done. Clinical images of the 10 examinations using the revised protocol showed no discernable decline in image quality or diagnostic capability
Radiation Dose Reduction

- Radiation dose estimates for a 70-kg adult were calculated using radiation dose data from the vendor’s package insert.

- Whole-body dose decreased from 0.67 mSv for 111 MBq to 0.19 mSv for 37 MBq (72% decrease).
  - Upper large intestine wall dose decreased from 14.4 mSv to 4.8 mSv.
  - Small intestine dose decreased from 7.8 mSv to 2.6 mSv.
Clinical Impact

• Of the 7015 NM procedures done at Gundersen Lutheran in 2010-2011 on patients 18+ years of age:
  • 163 were Tc-99m sulfur colloid egg yolk gastric emptying studies
    • 2.3% of all adult exams
    • 2.3% of all exams
Limitations

• Small number of clinical cases reviewed after changes
• Qualitative rather than quantitative review
• Inherent verification bias
• Phantoms for dose estimates not truly patient equivalent
• Adult patient radiation dose estimate based on a 70-kg patient; most patients vary from that
Conclusions

- Nearly all administered radiopharmaceutical doses were comparable to those recommended by national and international advisory bodies.

- Those that were not comparable were adjusted to match the recommendations with no noticeable decline in image quality or diagnostic capability.

- Site doses had not previously been comprehensively evaluated in this manner, so this was useful for quality and patient safety.
Recommended Additional Actions:

- Use embedded decision support in electronic ordering to reduce inappropriate imaging

- Optimize technique and use dose methods for CT portion

- Use new camera and software technology for dose reduction

- Use high-sensitivity 3D mode PET acquisition or high-sensitivity SPECT collimators to reduce activity required

- Scale administered activity by patient weight
Acknowledgements

- Thanks are extended to Jacqueline D. Moga, Ph.D., for assistance with evaluation of adult Nuclear Medicine dose and comparison with standards.
References


Questions?

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