Updates from the Pediatric Nuclear Medicine Dose Reduction Working Group

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• Physiologic and minimally invasive and delivers relatively low radiation doses to patients
• “NUCLEAR” elicits concern
• Hesitation to use NM, even though it may be the best diagnostic tool

The right test
For the right indication
At the right time
Objectives

• Dose standardization

• Dose reduction

• Image quality improvement
Lack of dose standards in Pediatric Nuclear Medicine

• Dose schedules derived by
  • tradition,
  • old schedules,
  • practitioners preference,
  • age of equipment,
  • lack of familiarity with children

• Lack of dose guidelines in the majority of radiopharmaceutical package inserts
Survey: Pediatric Administered Doses (*)

- Survey showed 3-20 fold variability, worse in the smallest children

- Results elicited enormous interest in the public and professional media

- The Pediatric Nuclear Medicine Group of The Image Gently Campaign was created in 2007 to work on pediatric administered doses and related issues

First Product from the PNM group: 

*Pediatric Nuclear Medicine: Brochure for Patients and Families*

Approved by

- SNMMI
- SPR
- Image Gently
- ACR

http://www.pedrad.org/associations/5364/ig/?page=641
• Expert Consensus Workshops @ the 2007 and 2008 Annual Meetings of SNM and SPR

• Product:

2010 North American Consensus Guidelines for Pediatric Radiopharmaceutical Administered Doses (*)

• Approved by SNM, SPR and ACR

Guidelines were widely Disseminated by IG through the “Go with the Guidelines” campaign (posters, inserts in journals, etc.)

### North American Consensus Guidelines for Administered Radiopharmaceutical Activities in Children and Adolescents*

<table>
<thead>
<tr>
<th>Radiopharmaceutical</th>
<th>Recommended administered activity (based on weight only)</th>
<th>Minimum administered activity</th>
<th>Maximum administered activity</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technetium-99m</strong></td>
<td>5.9 MBq/kg (0.37 mCi/kg)</td>
<td>5.1 MBq/kg (0.3 mCi/kg)</td>
<td>8.5 MBq/kg (0.5 mCi/kg)</td>
<td>BAPA Pediatric Dose Card (2007 version 13) may also be used.</td>
</tr>
<tr>
<td><strong>Bromide</strong></td>
<td>9.0 MBq/kg (0.5 mCi/kg)</td>
<td>7.6 MBq/kg (0.4 mCi/kg)</td>
<td>14.0 MBq/kg (0.8 mCi/kg)</td>
<td>BAPA Pediatric Dose Card (2007 version 13) may also be used.</td>
</tr>
<tr>
<td><strong>F-18</strong></td>
<td>0.5 MBq/kg (0.03 mCi/kg)</td>
<td>0.5 MBq/kg (0.03 mCi/kg)</td>
<td>0.5 MBq/kg (0.03 mCi/kg)</td>
<td>BAPA Pediatric Dose Card (2007 version 13) may also be used.</td>
</tr>
<tr>
<td><strong>C-11</strong></td>
<td>0.3 MBq/kg (0.02 mCi/kg)</td>
<td>0.3 MBq/kg (0.02 mCi/kg)</td>
<td>0.3 MBq/kg (0.02 mCi/kg)</td>
<td>BAPA Pediatric Dose Card (2007 version 13) may also be used.</td>
</tr>
<tr>
<td><strong>O-15</strong></td>
<td>0.3 MBq/kg (0.02 mCi/kg)</td>
<td>0.3 MBq/kg (0.02 mCi/kg)</td>
<td>0.3 MBq/kg (0.02 mCi/kg)</td>
<td>BAPA Pediatric Dose Card (2007 version 13) may also be used.</td>
</tr>
</tbody>
</table>

*This information is intended as a guideline only. Local practices may vary depending upon local population, access to equipment, and state requirements for medical radiation.

**Recommended administered activity may be reduced when appropriate by either the nuclear pharmacist or the practitioner for patients weighing less than 50 kg.** If no recommended administered activity is noted, all weight-based administered activities for a given radiopharmaceutical should be considered as safe and efficacious unless contraindicated. Other factors may, in some cases, exceed the weight-based administered activity for a given radiopharmaceutical. For example, contraindications to certain radiopharmaceuticals may be considered in all patients weighing less than 50 kg. Individual patient factors, such as administered activity, may be used for patients weighing more than 50 kg. Higher administered activities may be required for some patients. For more information about pediatric radiation safety, visit www.imagengently.org.
North American and EANM Guidelines

• Goal: To collaborate with the EANM to try to standardize/harmonize doses across both organizations
• First Joint meeting conducted at the EANM Annual Meeting in Milano, Italy in October 19, 2012
• International outreach efforts
Dose Reduction (Optimization)
Dose Reduction

- Communication of guidelines
- Utilization (right test, indication, time)
- Patient Education
- Optimization of current protocols
- Software
- Instrumentation
Appropriateness of Utilization

- 14 NM procedures
- 341 females, 315 males
- Mean age 9.5 years. Min 0.04 years
1 in 2,500 risk in comparison to 500 in 2,500. Example: a 10-year-old - MDP bone scan Excess attributable risk for cancer death is 1 in 2,500. Dark circles represent number of Individuals that will die from cancer. Lone star (red) represents one case in 2,500 having a bone scan that may contract fatal cancer.
Dose Reduction and Image Quality Improvement

As standardized pediatric dose guidelines are being developed, it is important to

1. Explore ways and means to further reduce radiation exposures in children

2. Preserve or even improve the diagnostic value of nuclear medicine images
Optimization of existing protocols resulting in lower doses

Examples
$^{99m}$Tc-Mag3, UHR collimator

*No Flow study - 10 kg. 9-month-old male with hydronephrosis.*

Given 0.22 mCi (8.14 MBq) or 0.022 mCi/Kg (0.814 MBq/Kg) (*)

(*) Standard = 1.0 mCi (37 MBq) or 0.15 mCi/Kg (5.55 MBq/Kg)

78% DOSE REDUCTION
99mTc-DISOFENIN – UHR collimator

No flow study - 2 day old boy - Choledochal Cyst
Given: 0.15 mCi (5.5 MBq) (*)

(* ) Standard min. dose = 0.5 mCi (18.5 MBq)

70% DOSE REDUCTION
Advanced Image Processing for image quality improvement and dose optimization

- **SPECT, PET** OSEM-3D (ordered subset expectation maximization) with Resolution Recovery

- **Planar Scintigraphy – Static and Dynamic**
  Enhanced Planar Processing (EPP)
OSEM-3D with Resolution Recovery in SPECT

• OSEM-3D better than Filtered Back Projection (FBP)

• Superior *image quality*

• Much lower counts = *lower patient administered radiopharmaceutical dose*
OSEM-3D with Resolution Recovery

• Alternatively, using conventional radiopharmaceutical dose, SPECT scan times can be cut in half, therefore

• Increasing patient comfort and

• Reducing motion and the need for sedation
Renal $^{99mTc}$ DMSA SPECT
Results: OSEM-3D vs. FBP

- Image quality significantly improved with OSEM-3D
- Cortical defects identified better with OSEM-3D
- OSEM-3D identifies defects not seen on FBP
- No significant difference in split renal function or size
Results: Overall Image Quality

- OSEM (50% lower counts), Mean score 4.3 +/- 0.7
- FBP (100% counts), Mean score 3.5 +/- 0.9, p<0.01
$^{99m}\text{Tc}$-DMSA SPECT

- **Full counts**
  - FBP

- **Half counts**
  - OSEM 3D

- **Full counts**
  - OSEM 3D

Half the dose, half the time or a combination
$^{99m}$Tc-MDP SPECT
OSEM 3D vs. FBP

- 50 studies, 36 females, mean age 15.5 years

- Image quality
- Ability to detect lesions
- Noise reduction
- Image sharpness

- Scoring 1 = best, to 4 = marginal

• 17 month old with a right suprarenal mass

• Neuroblastoma

\[ ^{99m} \text{Tc-MDP SPECT} \]
$^{99m}$Tc-MDP SPECT
OSEM-3D vs. FBP

- No differences between 100% or 50% counts with OSEM 3D
- All better with OSEM 3D, 100% or 50% counts
- Improved image quality with a dose reduction of 50% can be obtained with OSEM-3D with resolution recovery

Half the dose, half the time or a combination
Enhanced Planar Processing (EPP) Static and Dynamic

$^{99m}\text{Tc-Mag3}$ and $^{99m}\text{Tc-DISOFENIN}$
Enhanced Planar Processing (EPP)

• A spatially variant smoothing filter

• Size of smoothing kernel varies with local image content


Enhanced Planar Processing (EPP)

\[ ^{99m} \text{Tc-Mag3} \]

2 min image

Original (100 % counts)

50% Subsampled

30% Subsampled

10% Subsampled

50% Subsampled + NR

30% Subsampled + NR

10% Subsampled + NR

NR = Noise Reduction EPP
Comparison of MAG3 Studies

Percent Rated ‘Excellent’ **BEFORE**
Noise Reduction

<table>
<thead>
<tr>
<th>Dose</th>
<th>Split Function</th>
<th>Cortical Transit</th>
<th>Overall Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>90%</td>
<td>80%</td>
<td>75%</td>
</tr>
<tr>
<td>50%</td>
<td>75%</td>
<td>65%</td>
<td>70%</td>
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<td>30%</td>
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<tr>
<td>20%</td>
<td>50%</td>
<td>50%</td>
<td>60%</td>
</tr>
<tr>
<td>10%</td>
<td>40%</td>
<td>40%</td>
<td>50%</td>
</tr>
</tbody>
</table>

36 consecutive MAG3 studies (200 μCi/kg)

Comparison of MAG3 Studies

Percent Rated ‘Excellent’ AFTER Noise Reduction

36 consecutive MAG3 studies (200 μCi/kg)

Percentage with Acceptable Image Quality

Acceptability (%)

<table>
<thead>
<tr>
<th>Dose</th>
<th>Acceptability (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>99.3%</td>
</tr>
<tr>
<td>50%</td>
<td>95.7%</td>
</tr>
<tr>
<td>50% + NR</td>
<td>100%</td>
</tr>
<tr>
<td>30%</td>
<td>93.6%</td>
</tr>
<tr>
<td>30% + NR</td>
<td>98.6%</td>
</tr>
<tr>
<td>10%</td>
<td>77.1%</td>
</tr>
<tr>
<td>10% + NR</td>
<td>92.9%</td>
</tr>
</tbody>
</table>

*NR = Noise Reduction EPP
Hepatobiliary Scintigraphy: Minimum Administered Dose

Currently accepted minimum administered dose in children is:

18.5 MBq (0.5 mCi). (*)

Dose Reduction with Enhanced Planar Processing

<table>
<thead>
<tr>
<th>Baseline</th>
<th>50% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td>+ EPP</td>
</tr>
</tbody>
</table>
Dose Reduction with Enhanced Planar Processing

Baseline

50% Reduction

75% Reduction

18.5MBq (0.5mCi) 9.25MBq (0.25mCi) 4.6MBq (0.125mCi)

50% 50% 75% 75% + EPP + EPP
Image Acceptability with EPP versus without EPP

Acceptability %

Dose Reduction

Baseline

93%

50%

88% 92%

75%

81% 91%
Effective Doses with EPP

![Bar chart showing effective doses with EPP reduction.]

**Baseline**: 1.85 mSv

**50% Reduction**: 0.92 mSv

**75% Reduction**: 0.46 mSv

Stabin M. Internal Dosimetry In: Treves ST (ed) Pediatric Nuclear Medicine/PET III ed. 2007
Potential of New Imaging Equipment for Dose Optimization
Newer detectors (CdZn, CZT)
Improved energy resolution
Improved geometry and spatial resolution
Faster acquisition
Improved processing
Advanced robotics
Pediatric Nuclear Medicine Dose Optimization and Improved Image Quality Moving Forward

- Continue to refine and disseminate Guidelines
- Improve communications with patients, caregivers and referring physicians about benefits of NM
- Optimize Existing Protocols. Task specific and personalized approach
Pediatric Nuclear Medicine Dose Optimization and Improved Image Quality Moving Forward

- Advanced Image Processing. i.e. OSEM – 3D, EPP
  - Improve image quality
  - Allow significant reduction in the administered doses to reduce radiation exposure to patients
  - Reduce imaging time with and increase patient comfort and a reduction for the need for sedation

- Equipment: higher sensitivity detectors, Larger FOV, More detectors

- The right test for the right indication at the right time
SAM Question
What activities should be considered towards dose reduction in Pediatric Nuclear Medicine?

A. Education
B. Appropriateness of Indications
C. Optimization of acquisition and display protocols
D. Application of Advanced Image Processing
E. All of the above
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