Pediatric Radiopharmaceutical Dosimetry

3rd International Symposium on Radionuclide Therapy and Radiopharmaceutical Dosimetry (ISRTRD)
Toronto, Canada
June 2009

S. Ted Treves, MD
Children’s Hospital Boston
Harvard Medical School
Society of Nuclear Medicine 2009 – Toronto, Canada
Dose Reduction and SPECT/CT in Pediatrics for Clinicians and Technologists Saturday June 13 9:00 AM- 4:15 PM

- **CT** - Slovis
- Weight-based vs. other methods for calculation - Drubach
- Legacy protocols without diagnostic info. - Gelfand
- Enhanced planar processing - Yahill
- Resolution Recovery - Treves
- 2D vs. 3D - Fahey
- PET and Diagnostic CT in one study - Parisi
- What types of CT studies? - Gelfand
- PET/MR - Lim
- PET/CT, SPECT/CT Bone - Sharp
- SPECT/CT MIBG (2) – Bar-Sever. Nadel
- SPECT/CT Parathyroid - Donohoe
- SPECT/CT, Image, Dosimetry – Gelfand, Lemen
- Panel Discussion – Lim, Parisi, Fahey, Treves, Yahill, Drubach, Gelfand, Slovis

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12:45-5:45 PM  Topics

- Pediatric Radiopharmaceutical Dosimetry
  Treves
- Challenges in Radiopharmaceutical Dose Estimates
  Stabin
- Pediatric and Customizable Phantom-Based Dosimetry
  Bolch
- Software and Instrumentation Approaches Towards Radiation Dose Reduction
  Vija
- The European Perspective
  Lassmann
- Physics and Methodology Approaches to Dose Reduction
  El Fakhri
- PET/CT Dosimetry
  Fahey
- Radiation Risk
  Adelstein
- Brainstorming Session: Issues Regarding Consensus and Standardization
SPECIAL CONTRIBUTION

Administered Radiopharmaceutical Doses in Children: A Survey of 13 Pediatric Hospitals in North America

S. Ted Treves, Royal T. Davis, and Frederic H. Fahey

Division of Nuclear Medicine, Children’s Hospital Boston, Harvard Medical School, Boston, Massachusetts

THANKS!!!
Kevin Edwards and Hongming Zhuang, Children’s Hospital of Philadelphia; Lorcan O’Tuama and James Mountz, Children’s Hospital of Pittsburgh; Abbey Studer and Richard Shore, Children’s Memorial Hospital Chicago; Greg Golsch and Michael Gelfand, Cincinnati Children’s Hospital; Nayan Pandya and Massoud Majd, Children’s Hospital Washington, DC; Lisa Aldape and David Rosenbaum, Children’s Hospital of Seattle; Maria Green, Ruth Lim, and Martin Charron, Hospital for Sick Children in Toronto; Jan Legget and Helen Nadel, British Columbia Children’s Hospital in Vancouver; Holly Doxrude and Hollie Jackson, Children’s Hospital Los Angeles; Leigh Ann Davis and Barry Shulkin, St. Jude Children’s Research Hospital; Ingrid Hall and David Blews, Children’s Healthcare of Atlanta at Scottish Rite; and Thomas Fisher, Richard Litt, and Cynthia Christoph, Miami Children’s Hospital.
No Pediatric Radiopharmaceutical Dose Guidelines in Package Inserts

- $^{99m}$Tc-Mebrophenin
- $^{99m}$Tc-Disoprophin
- $^{99m}$Tc-MDP
- $^{99m}$Tc-Phyrophosphate
- $^{133}$Xe gas
- $^{123}$I-Nal

- $^{99m}$Tc-MIBI
- $^{123}$I-MIBG
- $^{131}$I-MIBG
- $^{99m}$Tc-ECD
- $^{201}$TI-Thallium Chloride
- $^{99m}$Tc-RBC
- $^{131}$I-Nal

- $^{99m}$Tc-HMPAO
- $^{99m}$Tc-DMSA
- $^{99m}$Tc-MAG3
- $^{99m}$Tc-DTPA
- $^{67}$Ga Citrate

Pediatric Radiopharmaceutical Dose Guidelines in Package Inserts

- $^{99m}$Tc-Pertechnetate
- $^{99m}$Tc-MAA

- $^{99m}$Tc-Sulfur Colloid,
- $^{18}$F-FDG

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Package inserts. Orphan clause

- Pediatric Use: Safety and effectiveness in children have not been established.

- Radiopharmaceuticals should be used only by physicians who are qualified by training and experience in the safe use and handling of radionuclides and whose experience and training have been approved by the appropriate government agency authorized to license the use of radionuclides.
Pediatric Administered Dose Survey

- Requested information on 16 studies commonly performed in Pediatric NM
  - Administered dose per kg
  - Maximum administered dose
  - Minimum administered dose

# Pediatric Administered Dose Survey

<table>
<thead>
<tr>
<th>Radiopharmaceutical</th>
<th>Parameter</th>
<th>Number of Respondents</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Median</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tc-99m DMSA</td>
<td>Activity/Mass MBq/kg (mCi/kg)</td>
<td>8</td>
<td>1.11 (0.030)</td>
<td>3.70 (0.100)</td>
<td>2.22 (0.060)</td>
<td>2.35 (0.064)</td>
</tr>
<tr>
<td></td>
<td>Minimum Activity MBq (mCi)</td>
<td>11</td>
<td>5.55 (0.150)</td>
<td>74.00 (2.000)</td>
<td>18.50 (0.500)</td>
<td>26.40 (0.714)</td>
</tr>
<tr>
<td></td>
<td>Maximum Activity MBq (mCi)</td>
<td>11</td>
<td>74.00 (2.000)</td>
<td>222.00 (6.000)</td>
<td>185.00 (5.000)</td>
<td>151.36 (4.091)</td>
</tr>
<tr>
<td>Tc-99m MAG3</td>
<td>Activity/Mass MBq/kg (mCi/kg)</td>
<td>8</td>
<td>1.85 (0.050)</td>
<td>10.36 (0.280)</td>
<td>5.55 (0.150)</td>
<td>5.69 (0.154)</td>
</tr>
<tr>
<td></td>
<td>Minimum Activity MBq (mCi)</td>
<td>12</td>
<td>18.50 (0.500)</td>
<td>148.00 (4.000)</td>
<td>37.00 (1.000)</td>
<td>53.96 (1.458)</td>
</tr>
<tr>
<td></td>
<td>Maximum Activity MBq (mCi)</td>
<td>13</td>
<td>111.00 (3.000)</td>
<td>370.00 (10.000)</td>
<td>370.00 (10.000)</td>
<td>278.92 (7.538)</td>
</tr>
<tr>
<td>Tc-99m MDP</td>
<td>Activity/Mass MBq/kg (mCi/kg)</td>
<td>8</td>
<td>7.40 (0.200)</td>
<td>13.32 (0.360)</td>
<td>11.10 (0.300)</td>
<td>10.87 (0.294)</td>
</tr>
<tr>
<td></td>
<td>Minimum Activity MBq (mCi)</td>
<td>13</td>
<td>22.20 (0.600)</td>
<td>185.00 (5.000)</td>
<td>92.50 (2.500)</td>
<td>99.90 (2.700)</td>
</tr>
<tr>
<td></td>
<td>Maximum Activity MBq (mCi)</td>
<td>13</td>
<td>666.00 (18.000)</td>
<td>925.00 (25.000)</td>
<td>740.00 (20.000)</td>
<td>819.69 (22.154)</td>
</tr>
<tr>
<td>Tc-99m DISIDA</td>
<td>Activity/Mass MBq/kg (mCi/kg)</td>
<td>7</td>
<td>1.85 (0.050)</td>
<td>3.70 (0.100)</td>
<td>2.78 (0.075)</td>
<td>2.97 (0.080)</td>
</tr>
<tr>
<td></td>
<td>Minimum Activity MBq (mCi)</td>
<td>13</td>
<td>14.80 (0.400)</td>
<td>74.00 (2.000)</td>
<td>37.00 (1.000)</td>
<td>36.17 (0.978)</td>
</tr>
<tr>
<td></td>
<td>Maximum Activity MBq (mCi)</td>
<td>13</td>
<td>92.50 (2.500)</td>
<td>370.00 (10.000)</td>
<td>185.00 (5.000)</td>
<td>200.65 (5.423)</td>
</tr>
</tbody>
</table>

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Results: Variability of Administered Doses in Pediatrics

- The *maximum/minimum* for a parameter, the range factor

- *Admin dose/kg* and *Maximum dose* range factor varied, on average, by a factor of 3, and by as much as a factor of 10

- *Minimum total dose* range factor varied, on average, by a factor of 10 and as much as a factor of 20

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Minimum Total Administered Dose

• Definition: *The minimum total radiopharmaceutical administered dose is a dose that ensures a diagnostic study no matter the patient’s age or body mass*

• Based on clinical task, physician’s experience, subjective appearance, tradition and instrumentation

• May or may not be based on current state-of-the-art

• No universally accepted values

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Physics Solutions

- Evaluate *task specific* imaging factors considering
  - Patient’s ability to cooperate
  - Equipment
  - Study objective
  - Photon Flux
  - Dynamic vs. Static

- One method may not fit all needs
Software Solutions

- Imaging Processing
- Resolution Recovery
- OSEM 3D (ordered subset expectation maximization)
- ...
\( ^{99m}\text{Tc}-\text{DMSA SPECT} \)

- 3 year old female with a UTI
Pediatric \(^{99m}\text{Tc-DMSA}\) SPECT Performed by Using Iterative Reconstruction with Isotropic Resolution Recovery: Improved Image Quality and Reduced Radiopharmaceutical Activity\(^1\)

Niall Sheehy, MB FFR(RCSI), Tracy A. Tetrault, CNMT, David Zurakowski, PhD, A. Hans Vija, PhD, Frederic H. Fahey, DSc, and S. Ted Treves, MD

\(^1\) From the Division of Nuclear Medicine, Department of Radiology (N.S., T.A.T., F.H.F., S.T.T.), and Departments of Anesthesia and Orthopaedic Surgery (D.Z.), Children's Hospital Boston and Harvard Medical School, 300 Longwood Ave, Boston, MA 02115; and Siemens Medical Solutions USA, Molecular Imaging, Hoffman Estates, III (A.H.V.). Received August 13, 2008; revision requested September 24; revision received October 21; accepted November 25; final version accepted December 11. Address correspondence to S.T.T. (e-mail: treves@childrens.harvard.edu).

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1 year old male with a neuroblastoma

\[ ^{99m}\text{Tc-MDP SPECT} \]

- Full Counts
- Half Counts
- FBP
- OSEM 3D

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123I-MIBG SPECT

- 3 year old male with a neuroblastoma

Full Counts
FBP

Half Counts
OSEM 3D
Hardware

- **SPECT:**
  - Larger FOV,
  - Larger detector mass. 3, 4 detectors?
- **PET:**
  - Larger FOV and detector mass.
  - More sensitive detectors
- **CT:**
  - Lower exposures
  - Selective FOV
PET

• Have we found the lowest limits of administered doses?
• An example or two....
16 year old girl. Nausea, vomiting and dizziness for 3 weeks. Weight loss MR enhancing and non-enhancing lesions in the posterior fossa

(*) RDRC Limit
$^{18}$F-FLT  0.5 mCi (*)

(*) RDRC Limit

$^{18}$F-FLT MIP

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• 18 day old female. Biliary atresia?
• 2.2 Kg, Dose 0.15 mCi  (our minimum dose is 0.5 mCi)
Pediatric Nuclear Medicine Dose Optimization
What can be done?

• *Physics Solutions*: Task specific methodology, Modeling. What method for what task?

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Pediatric Nuclear Medicine Dose Optimization

What can be done?

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- **Software Solutions**: Image processing. i.e. OSEM – 3D, Enhance planar processing, resolution recovery
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- **Hardware Solutions**: Equipment: higher sensitivity detectors, Larger FOV, More detectors
Pediatric Nuclear Medicine Dose Optimization

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- **Hardware Solutions**: Equipment: higher sensitivity detectors, Larger FOV, More detectors
- **Expert Consensus**: Guidelines
Mini-Symposium on Pediatric Radiopharmaceutical Dosimetry
June 14, 2009. 12:45-5:45 PM

3rd International Symposium on Radionuclide Therapy and Radiopharmaceutical Dosimetry (ISRTDR)
in conjunction with the
2009 SNM Annual Meeting in Toronto, Canada - June 13-17

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