INNOVATIONS IN SINGLE PHOTON EMISSION COMPUTED TOMOGRAPHY

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Moscow Bavarian Joint Advanced Student School 2011
March 20-27 2011, Moscow
1) Walkthrough on SPECT
2) Introducing with multiplexed measurement systems (MMS)
3) Advances in modeling MMS
4) Introducing with other types of coding devices in MMS
5) Conclusions
WHEN WE HAD TO USE SPECT?

- **Myocardial perfusion imaging**
  - Diagnosis of coronary artery disease (CAD) and various cardiac abnormalities.
  - Identifying location, criticality of existing coronary stenosis and degree of coronary artery disease (CAD) in patients with a history of CAD.
  - Prognostication (risk stratification) and evaluation of patients that are at risk of having a myocardial or coronary incident. (ex: myocardial infarction, myocardial ischemia, coronary aneurysm, wall motion abnormalities)
  - Assessment of viable myocardium in particular coronary artery territory following heart attacks to justify revascularization
  - Post intervention revascularization evaluation of heart.
WHEN WE HAD TO USE SPECT?

- Functional brain imaging
  - Alzheimer’s Disease/Dementia
  - Brain Trauma
  - Stroke
  - Seizures
  - Executive Dysfunction
  - Obsessive-Compulsive Disorder and Cognitive Rigidity
  - Bipolar Spectrum Disorders
  - Depression
## HOW LONG DOES IT WORKS?

<table>
<thead>
<tr>
<th>Study</th>
<th>Half-life of radiopharma</th>
<th>Activity (MBq)</th>
<th>Radiation poisoning (μSv)</th>
<th>Rotation (degrees)</th>
<th>Projections</th>
<th>Time / projection (s)</th>
<th>Whole procedure time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bone scan</td>
<td>6 hours</td>
<td>800</td>
<td>8</td>
<td>360</td>
<td>120</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>Myocardial perfusion scan</td>
<td>6 hours</td>
<td>700</td>
<td>7</td>
<td>180</td>
<td>60</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Brain scan</td>
<td>6 hours</td>
<td>555-1110</td>
<td>11</td>
<td>360</td>
<td>64</td>
<td>30</td>
<td>32</td>
</tr>
<tr>
<td>Tumor scan</td>
<td>13 hours</td>
<td>400</td>
<td>9</td>
<td>360</td>
<td>60</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>White cell scan</td>
<td>67 hours</td>
<td>18</td>
<td>invitro</td>
<td>360</td>
<td>60</td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>

Limit dose 1000 μSv / Year
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USING OF MMS IN MEDICAL DIAGNOSTIC

Traditional diagnostic scheme

Diagnostic scheme with usage coded aperture

Object

Coded aperture

Detector

Multichannel collimator

Detector

Multichannel collimator
WHY CAN’T WE USE LENS

Optical radiation

Ionizing radiation

Parallel beams

Lens
ANOTHER WAY TO CODE RADIATION

Flat radiating object

Opaque plate with a small hole (pinhole)

Position sensitive detector (PSD)

Volume radiating object
MULTI-PINHOLE CODED APERTURE (MPCA)

The shadow on the detector is a copy of the coded aperture. Decoding is required.

The shadow on the detector represents more difficult picture.
CODED APERTURE CONSTRUCTION METHODS

On the basis of **one** PRS:

1  2  3  4  5  6  7  8  9  10  11  12

Line-by-line method:

1  2  3  4
5  6  7  8
9 10 11 12

Diagonal method:

1  10  7  4
5  2  11  8
9  6  3 12

On the basis of **two** PRS:

First PRS:

1  2  3  4  5  6  7  8  9

Second PRS:

1  2
3  4
5  6
7
Focused image of the flat source

Focused image of the volume source in case 3 planes

Focused image of the volume source in case 5 planes
ITERATIVE RECONSTRUCTION METHODS

- Steepest Descent Method
  + Rapid convergence in case of low transparent and small dimensional apertures
  - Slow convergence in other cases

- Directed Divergence Method
  + Rapid convergence in case of special types of test distributions (most part is zeros)
  - Slow convergence in other cases

- Back Projection Method
  + Rapid convergence in all cases (different transparent and dimension, different types of test distributions)
  - Requires large computational time
COMPARISON OF THE ITERATIVE ALGORITHMS

NMSD

Steepest Descent Method
Directed Divergence Method
Back Projection Method
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Focal plane for both coded apertures simultaneously

Focal plane for both coded apertures simultaneously
HOW BIPOLAR SCHEME CAN BE REALIZED

1) Direct unipolar scheme

2) Reverse unipolar scheme
COMPARISON UNI- AND BI- POLAR SCHEMES
MULTIPLANE RECONSTRUCTION
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HEXAGONAL CODED APERTURES
Focused images for HEX'S

Focused image of the flat source

Focused image of the volume source in case 2 planes
POINT SPREAD FUNCTION FOR HEX’S

FOCAL PLANE

HEXAGONAL CODED APERTURE

Upper PSF
Middle PSF
Bottom PSF
$$I = \frac{S_1}{S_1 + S_2}$$

$$I_N = I \cdot \frac{V}{k}$$
FEW EXAMPLES OF PSF

Square aperture 60x60 (3600 pinholes)
Hexagonal aperture rank 34 (3571 pinholes)
1. SPECT is one of the most intelligent and promising diagnostic procedure.

2. Using MMS allows to replace rotating motion by the translating motion, which also can be applied when rotating around object is impossible.

3. Bipolar measurement scheme double number of measurements but more then five times decrease mean-squared deviation in the iterative algorithms.

4. Using hexagonal coded apertures is new and promising direction of the MMS development.