Handheld Probes and Mini-Cameras for Intraoperative Guidance during Surgery

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DISCLOSURE

I have no potential conflict of interest to report
Intraoperative Gamma probes

– **Clinical Applications**
  Breast, gastrointestinal, head-neck, gynecologic, ureologic, thoracic, NET, ...

– **Isotopes**
  Tc99m, Iodine 125, 131
  Indium 111, Fluorine 18
  Gallium 68

– **Radiation detectors**
  Scintillation detectors, Semiconductor Ionization detectors

– **Performance**
  Radial Sensitivity distribution
  Spatial resolution
  Energy resolution
  Shielding and Collimation
  Display

*Povoski SP et al: A comprehensive overview of radioguided surgery using gamma detection probe technology.
Radioguided Sentinel Lymph Node (SLN) Surgery

Basic idea:
The tumor drains in a logical way through the lymphatic system.
The first node encountered (sentinel node) will most likely be the first affected by metastasis.

Involved departments
Nuclear medicine
Surgery, gynaecology
Setup

Detector unit
- Scintillator
- Si-Diode

Electronics

Battery

Collimator

Body

Bluetooth

Scintillation detectors:
NaI(Tl), CsI(Tl), CsI(Na), BGO, LSO

Semiconductor Ionization detectors:
CdTe, CZT, Hgl₂
Basic design of an intraoperative probe

The collimator is characterized by its aperture, length and wall thickness.

The probes FOV increases with increasing distance from the detector aperture.

Gamma Probes: Collimator

The collimation influences the sensitivity and spatial resolution.

Material: to maximize attenuation high-atomic number materials should be used: Lead, tungsten, gold, platinium
Energy resolution: Comparison

Full-Width at Half-Maximum (FWHM) expressed as the percentage of the photopeak energy

CZT

Co-57

FWHM: 6.46 keV
ER: 5.3 %

Scintillation detector

Co-57

FWHM: 34 keV
ER: 27 %
Sensitivity

- Max. radionuclide uptake: 0.01-1 %
- Applying 99mTc-Nanocolloid: 0.05% to 0.005% uptake in lymphnode is found intraoperativly
- Activity: 80MBq

- Sensitivity measurement for SLN ≥ 5cps/kBq

- Measurement procedure:
  Directly on the tip of the probe or collimator

- Typical values (Wengenmair, H. et al. Nuklearmediziner; v. 22(4); Oct 1999; p. 271-280)
  - 23-0.3 cps/MBq
Detector Performance: Radial sensitivity distribution

The sensitivity distribution is evaluated equidistant to the frontal radiation entrance window dependant on the polar angle. The full width at half maximum (FWHM) of the distribution function is a good quality criterion for the detectability of lymph nodes in presence of non target radiation (injection depot, background).

With a broad measurement cone the background signal can exceed the target signal of the lymph node, which then cannot be detected.

A small cone mainly reduces background maintaining a constant target signal. Therefore with increased background in the target area a smaller FWHM of radial sensitivity distribution is desired.
Radial sensitivity distribution

Broad radial sensitivity distribution

Signal [cps]

Target not detectable

Inhomogeneous background within the measurement field

Small radial sensitivity distribution

Signal [cps]

Target detectable

Typ. Values (Wengenmair, H. et al. Nuklearmediziner; v. 22(4); Oct 1999; p. 271-280)

60° collimator: 23°, 30° collimator: 13°, 15° collimator: 10°
Detector performance: Spatial resolution

Measurement procedure:
Probe is scanned laterally above a 9mmTc point source. The FWHM gives the minimal distances at which two point sources can be detected separately.

Typical values:
24 mm - 8 mm

Typ. FWHM values (Wengenmair, H. et al. Nuklearmediziner; v. 22(4); Oct 1999; p. 271-280)
60° collimator: 12 mm, 30° collimator: 8 mm, 15° collimator: 5mm
Shielding

Apparent SLN in the measurement cone by background activity nearby a shielding leak.

Typ. values: 0.1-8.2%

Correlation between acoustic tone and measurement signal

Display

Countrate (cps)
Countrate max: 1503 cps 13 s
100 5000

Type of probe γ-probe
BGM
Nuclide
choice
auto
Nuclide
Tc-99m
Sample
time
1s
Sound
Melody
On
Pitch
x100
Different measurement conditions

**Melanoma:**
Mostly large distance between SLN and injection spot, good uptake in the SLNs

**Mamma carcinoma:**
short distance between SLN and injection spot, poor uptake in the SLNs

<table>
<thead>
<tr>
<th></th>
<th>Melanoma</th>
<th>Mamma carcinoma</th>
<th>Prostate carcinoma</th>
<th>Parathyroid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>(+)</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Spatial selectivity</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Spatial resolution</td>
<td>+ (head, neck, etc.)</td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Shielding</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Energy discrimination</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

## Minimal requirements for an intraoperative probe system

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Minimal requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial selectivity</td>
<td>FWHM ≤ 40°</td>
</tr>
<tr>
<td>Spatial resolution</td>
<td>FWHM ≤ 15 mm</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>&gt;&gt; 5cps/kBq</td>
</tr>
<tr>
<td>Shielding</td>
<td>≤ 0.1 % of maximum system sensitivity</td>
</tr>
<tr>
<td>Energy selection</td>
<td>energy selection possible</td>
</tr>
<tr>
<td>Display</td>
<td>Acoustic, digital/analogue</td>
</tr>
</tbody>
</table>

• Intraoperative gamma probes and additionally „blue-dye“ technique results in an overall sensitivity of more than 90% and a false negative rate of 8.4%.

• Possible improvement by Small-field-of-view gamma camera

In patient with melanoma cranial to left ear, lateral planar lymphoscintigraphy after 2 h (A) showed 2 hot spots caudal to injection area and weak preauricular hot spot. All 3 hot spots had already been visualized on dynamic scans and on static planar images after 15 min.

On 2-dimensional and 3-dimensional (B) SPECT/CT fusion, 2 sentinel nodes were localized just ventral to sternocleidomastoid muscle and 1 preauricular sentinel node was localized within upper part of parotid gland. In concordance with SPECT/CT, intraoperative images before incision showed injection area and 3 sentinel nodes in same relation to each other (C).

*After excision of first sentinel node, portable g-camera showed remaining sentinel nodes (D), which were then localized and removed.*
Why a portable gamma camera might be useful?

Small Field of View Gamma Camera

www.gem-imaging.com

http://crystal-photonics.com/


<table>
<thead>
<tr>
<th>Characteristics of the IHGC and other intraoperative gamma cameras.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small gamma camera</td>
</tr>
<tr>
<td>IHGC</td>
</tr>
<tr>
<td>POCI</td>
</tr>
<tr>
<td>Minicam®</td>
</tr>
<tr>
<td>Minicam®²</td>
</tr>
<tr>
<td>LumaGEM</td>
</tr>
<tr>
<td>eZ-SCOPE®</td>
</tr>
<tr>
<td>Second POCI</td>
</tr>
<tr>
<td>Sentinel POC10²</td>
</tr>
<tr>
<td>GE camera</td>
</tr>
<tr>
<td>CarolReSi</td>
</tr>
<tr>
<td>HRC</td>
</tr>
<tr>
<td>MediPROBE</td>
</tr>
<tr>
<td>SSGC (prototype)</td>
</tr>
<tr>
<td>SSGC (clinical)</td>
</tr>
</tbody>
</table>

**Detector:** NaI, CZT, YAP, CdTe, CsI, etc.

**Matrix size:** 16x16 – 256 x 256

**FOV:** 14x14 – 50 x 50 mm

**Weight:** 700 g – 2200 kg
Handheld-gamma camera
CrystalCam von CrystalPhotonics, Berlin

Standard energy range of the gamma camera is 40 – 250 keV.
Acceptance test handheld gamma camera: Intrinisic measurements

Intrinisic energy resolution

<table>
<thead>
<tr>
<th>Intrinisic uniformity</th>
<th>Integral uniformity</th>
<th>3.2%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Differential uniformity</td>
<td>1.8%</td>
</tr>
</tbody>
</table>

Average: 5.2%
System uniformity

<table>
<thead>
<tr>
<th></th>
<th>int [%]</th>
<th>diff [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEHR</td>
<td>5.8</td>
<td>3.8</td>
</tr>
<tr>
<td>MEGP</td>
<td>5.3</td>
<td>3.5</td>
</tr>
<tr>
<td>LEHS</td>
<td>5.3</td>
<td>3.0</td>
</tr>
</tbody>
</table>
Acceptance test handheld gamma camera: System resolution without scatter

<table>
<thead>
<tr>
<th>Collimator type</th>
<th>Distance 0 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FWHM [mm]</td>
</tr>
<tr>
<td></td>
<td>x-direction</td>
</tr>
<tr>
<td>LEHR</td>
<td>1.93</td>
</tr>
<tr>
<td>MEGP</td>
<td>1.91</td>
</tr>
<tr>
<td>LEHS</td>
<td>2.27</td>
</tr>
</tbody>
</table>

System resolution without scatter: 0 mm distance, various collimators
Acceptance test handheld gamma camera: System resolution without scatter for various distances

<table>
<thead>
<tr>
<th>Distance from the detector</th>
<th>FWHM [mm]</th>
<th>FWTM [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>x-direction</td>
<td>y-direction</td>
</tr>
<tr>
<td>0.0 cm</td>
<td>1.93</td>
<td>2.03</td>
</tr>
<tr>
<td>2.5 cm</td>
<td>3.74</td>
<td>3.89</td>
</tr>
<tr>
<td>5.0 cm</td>
<td>5.02</td>
<td>4.78</td>
</tr>
</tbody>
</table>

System resolution without scatter: various distances, LEHR collimator

Data from Literature: 1.5-18mm*

Acceptance test handheld gamma camera: System planar sensitivity

The sensitivity measurements were done with 75 MBq $^{99m}$Tc that were filled in a bottle. The analysis of the acquired data was done with a software tool provided by the acquisition software.

<table>
<thead>
<tr>
<th>Collimator type</th>
<th>cps/MBq</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEHR</td>
<td>237</td>
</tr>
<tr>
<td>MEGP</td>
<td>177</td>
</tr>
<tr>
<td>LEHS</td>
<td>554</td>
</tr>
</tbody>
</table>

System planar sensitivity measured for various collimators

Data from Literature: 6.6 – 1600 cps/MBq*

The sentinel lymph node (SLN) is defined as the first lymph node that drains the primary tumor basin.

The SLN can be mapped by using a sulfur-colloid radiotracer labeled with 99mTc that is injected near the primary tumor. Approximately 18-37 MBq of tracer is injected near the primary tumor, with up to 74 kBq of activity accumulating in the sentinel lymph nodes after the tracer drains through the lymphatic channel.

Till now 27 patients were imaged using the novel handheld gamma camera system.
Pat, 70y, f, N. Mammae, left, Injection of 22 MBq 99m Tc Sentiscint

Millenium VG, GE Healthcare

Handheld, CrystalCam
Patient, 45Y, penis carcinoma

SPECT

Image fusion

Handheld

Infinia, GE Healthcare
SaveMe

Specimen Platform

Handheld gamma camera setup
Ga67-DOTA+ Nanoparticle + PTR
SurgicEye

The declipse® SPECT Ultrasound Fusion consists of a high precise optical navigation system, a gamma detector, and a high resolution ultrasound system.

SurgicEye GmbH, Munich, Germany
Thank you very much for your audience