Nuclear Medicine

Tamás Györke MD.
Definition

- **Diagnostic, therapeutic and investigative** work performed using **unsealed radioactive isotopes**.
NM

Diagnostics

In vivo

In vitro

Single photon methods

PET method

Therapy
In vivo NM

organ tissue function → specific material + radioactive isotope = radiopharmaceutical

Can be followed from outside targeted delivery

Tracer theory

George Hevesy
1885-1966
Nobel prize: 1943, „for introducing radioactive isotopes as indicators in chemistry research“
Radioactive isotopes

- Neutron excess → Beta radiation (Beta particle + gamma)
- Proton excess → Positron radiation (2 gamma)
  → Electron capture (characteristic X ray)
Imaging devices

- Gamma camera (Anger camera, scintillation camera)
Planar investigations

1. Static Investigation

2. Dynamic / functional investigations

Single Photon Emission Computed Tomography (SPECT)
Positron emitting molecule (e.g.: $^{18}$F-FDG)
Why we need PET?

- Most important positron emitting radionuclides and their half life:

\[
\begin{array}{ll}
^{11}\text{C} & 20,4 \text{ min} \\
^{13}\text{N} & 9,96 \text{ min} \\
^{15}\text{O} & 2,07 \text{ min} \\
^{18}\text{F} & 109,7 \text{ min}
\end{array}
\]
Why we need PET?

Sensitivity of imaging modalities

- RX / CT
- MRI
- US
- SPECT
- PET

Biological Sensitivity

- millimolar
- nanomolar
- picomolar

$10^{-6}$
General considerations

- Functional information
- Sensitivity
- Specificity
- Non-invasive
- (Semi)-Quantitative
- „Poor” spatial resolution
- Radiation exposure
Quantification-PET

Quantitative: Glucose Metabolic Rate ($M_{r_{glu}}$)

$$M_{r_{glu}} = \frac{C_P}{LC} \times \left\{ K_1 \times \frac{k_3}{(k_2+k_3)} \right\} = \left( \frac{C_P}{LC} \right) \times K_i$$

(µmoles/min/ml)

Semiquantitative: Standardized Uptake Value (SUV)

$$SUV = \frac{\text{tracer concentration (Bq/ml)}}{\text{injected dose (Bq) / body volume (ml)}}$$
Image fusion

Hybrid imaging, PET/CT
PET/SPECT

- Poor spatial resolution
- Long examination time
- Metabolic information
- Differentiation of scar, viable and necrotic tumor
- High specificity

CT

- High spatial resolution
- Short examination time
- Morphologic information
- Assessment of site and extension
- Low specificity

PET-CT combines advantages of both modalities
Applications:
- Oncology (~85 %)
- Neurology (~10%)
- Cardiology (~5 %)
Nuclear Oncology

- Sensitive detection of malignant lesions
  - functional, metabolic changes
  - High biological contrast

- Non invasive characterisation of a known lesion
  - Tumor specific
    - \(^{18}\text{FDG-PET}, 99m\text{Tc-MIBI, 67Ga}\)
  - Specific for a particular malignancy \(^{123/131}\text{I, receptor-, immunoscintigraphy}\)
Role of FDG-PET in oncology

- **Diagnosis**
- **Staging, restaging**
- **Therapy monitoring**

- Definition of optimal site for biopsy (Which LN?, metabolically active part in a larger lesion)
- Definition of malignancy grade (brain tumor low-grade or high-grade)
- Planning of radiotherapy
Role of FDG-PET in oncology

- **Staging** – cost effectiveness
- **Therapeutic relevant change in the stage** ~30%
  - ~20% - upstaging
  - ~10% - downstaging
Role of FDG-PET in oncology

- Diagnosis
- Staging
- Therapy monitoring and treatment management
  - Staging
  - Detection of treatment effect after therapy
  - Early detection of treatment effect during therapy
Early detection of treatment effect during therapy

- Distinguishing responders from non-responders
  - Treatment change
  - Prognostic relevance

- Conventional imaging – morphology

- PET - function
Established indications for FDG-PET

- **Diagnosis /differentiating benign from malignant lesions/**
  - in pulmonary nodules
  - residual masses after chemotherapy in malignant lymphoma
  - pancreatic masses
  - unknown primary

- **Staging and restaging**
  - malignant lymphoma
  - oesophageal cancer
  - breast cancer
  - malignant melanoma
  - head and neck cancer
  - recurrent colorectal cancer
  - lung cancer
  - relapsing thyroid cancer

- **Therapy monitoring**
  - malignant lymphoma, breast cc.
Limitations of FDG-PET

- Specificity for tumors is limited
- False positive findings
  - Inflammation
  - Activity of brown adipose tissue
  - Urine activity
  - Aspecific bowel activity
PET

- Metabolism
- Perfusion
- Oxygenation and hypoxia
- Receptors, gene expression
- Cell proliferation
- Apoptosis
- Angiogenesis
Thyroid

- Nodes
- Hyperthyreosis ddg
- Ectopic thyroid
  (I-123, I-131)

Radiopharmacon Tc-99m
Bone scintigraphy

- Tc-99m diphosphonate
- Bone metastasis
Dynamic renal scintigraphy (Renogrphy)

- **Indications:**
  - Acute anuria
  - One sided renal disease, preop.
  - Systemic diseases, nephrotoxic drugs
  - Obstructive uropathy
  - Hypertension, renovascular HT
  - Transplanted kidney

- **Obstructive uropathy - DIURETIC RENOGRAPHY**
  - Parenchymal function: Uropathy ---> Nephropathy?
  - Characterisation of outflow disturbance: Dilatation = Obstruction?
Nuclear Cardiology
Indications for myocardial perfusion SPECT

- Diagnosis
  - Dg. in case of 20-80 % pretest probability
  - Localisation, extension
    - But: „culprit lesion”
  - Evaluation of coronaryography – hemodynamical significance

- Prognosis
  - Known ischemic heart dis. – neg. exam - good prognosis, konservativ treatm.
  - Reversible perfusion defect – relevant cardiac event (infarct, cardiac death, revasc surgery) 7%/year \(\Rightarrow\) invasive dg.
  - Infarct + ischaemia - >20 %/year card. event \(\Rightarrow\) revascularisation
  - Before intervention on great abdominal vessels and great vessels (aorta, carotides)

- Myocardial viability

- Follow-up of therapy
Neurology

Cerebrovascular diseases
Differential diagnosis of dementia
Focal seizures

Receptor scintigraphy – investigation of neurotransmission
Inflammation

- Labelled leukocytes
- $^{67}\text{Ga}$
- Human immunglobuline (HIG)

- Labelled antibiotics
- FDG PET
### Radionuclide therapy

<table>
<thead>
<tr>
<th>Condition</th>
<th>Radionuclide</th>
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<tbody>
<tr>
<td><strong>Benign and malignant thyroid diseases</strong></td>
<td><strong>131I-NaI</strong></td>
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<tr>
<td>(differentiated th. cc., hyperthyreosis, goiter)</td>
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<td><strong>Palliative treatment of painful bone metastases</strong></td>
<td><strong>89Sr-cloride</strong></td>
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<tr>
<td><strong>186Re-HEDP</strong></td>
<td></td>
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<tr>
<td><strong>153Sm/90Y EDTMP</strong></td>
<td></td>
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<tr>
<td><strong>Radiosynovectomy</strong></td>
<td><strong>90Y-colloide</strong></td>
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<tr>
<td>Large joints</td>
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<tr>
<td>Mid., small joints</td>
<td><strong>186Re-sulfide</strong></td>
</tr>
<tr>
<td><strong>Phaeochromocytoma, neuroblastoma, medullary thyroid cancer</strong></td>
<td><strong>131I-MIBG</strong></td>
</tr>
<tr>
<td><strong>Carcinoid</strong></td>
<td><strong>90Y-</strong></td>
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<tr>
<td>somatostatin analogues</td>
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<tr>
<td><strong>Hepatocellular cancer</strong></td>
<td><strong>131I-lipiodol</strong></td>
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<tr>
<td><strong>Radioimmunotherapy (lymphoma)</strong></td>
<td><strong>131I/90Y-</strong></td>
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<tr>
<td>antibodies</td>
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</tr>
<tr>
<td><strong>Polycythaemia vera, essential thrombocytemia</strong></td>
<td><strong>32P-Na-</strong></td>
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<td>phosphate</td>
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