NUCLEAR MEDICINE

gradual, 2x45’

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DEFINITION
OF NUCLEAR MEDICINE

Medical applications of unsealed radioisotopes for

- Diagnostic
- Therapeutic
- Research

into the living organism!

(Not the brachytherapy. In vitro diagnostic use??)

Independent medical specialty (5 yr specialization)

Diagnosis + Therapy of diseases (not only imaging)

HEVESY GYÖRGY
Georg von Hevesy

Isotopes:

same chemical (and biochemical) characteristics, no biological differences

First use in biological systems (1924)

Tracer principle: to follow functions

small amount, same biochem.

radioactive labelled

„Father of nuclear medicine"

Nobel prize in chemistry 1943

RADIOISOTOPES IN MEDICINE

Isotope: same number of protons

- chemically the same element! (e.g. C-11, O-15)
- Proton : neutron. Stability? !
- Unstable nucleus changes: radiation

Types of isotopes (and radiations)

- plus protons:
  - positron emission
    - meets electron: annihilation 2x 511 keV
  - K-electron capture
    - characteristic Xray + gamma
- plus neutrons:
  - beta (from nucleus) + gamma

Production: cyclotron and reactor (arteficial isotopes)

IMPORTANT RADIONUCLIDES

Diagnostic: electromagnetic radiation (photons)

plus neutron:

Tc-99m, I-131, Xe-133: gamma

plus proton:

- Ga-67, In-111, I-123, Tl-201: Xray +gamma
- C-11, N-13, O-15, F-18, Ga-68: annihilation

Therapeutic: particle (absorption in tissue: dose)

beta: Y-90, I-131, Sm-153, Re-186,-188…

(alpha: At-211, Bi-212, Ra-223)

ADVANTAGES OF Tc-99m

(m=metastable)

in 80 % of SPECT examinations

Physical (for detection)

140 keV ideal for gamma camera (70-400 keV)
monoenergetic (ideal for imaging)

Biologic: low radiation dose

high amount of activity, No. of photons (Poisson)

”pure” gamma (from Mo-99), T1/2: 6 h, optimal

Practical

from generator (Mo-99) elution, phys. saline (!)

stable complexes with many molecules

RADIOPHARMECEUTICALS

Organ- tissue- molecular-

function-specific labelled molecules

Diagnosis:

Functions: organ, tissue, molecular (quantitative)

Tissue characterization – identification

Therapy:

targeted, selective radiation therapy

(high dose: continous radiation)

„tailored", „personalized"

Role of radioisotope

for detection or for therapy

„Theranostics": the same molecules (I-131, SMS,.)

DETECTION: IMAGING

Gamma camera

scintillation crystal, rectangular detector

static and dynamic aquisitions

spot, whole-body

planar or SPECT (emission CT: projections)

ECG-gated

dedicated for organs

Positron camera: PET („double-photon ECT”)

ring derectors (small crystals)

16-21 cm axial FOV

coincidence detection (3D data aquisition)

DETECTION: NON-IMAGING

Ex vivo measurements of biological samples

e.g. clearance (blood), Schilling test (urine)

Small dedicated instruments

Dynamic function studies (e.g. kidney, heart)

Thyroid uptake test

radioiodide therapy, activity calculation

Intraoperative probes for localization

e.g. sentinel lymph node detection

SCINTIGRAPHY

In vivo imaging of distribution of activity (radiopharmaceuticals = functions)

planar or SPECT

static or dynamic

gated or ungated

whole body

pinhole

dedicated (heart, breast)

PET vs. SPECT

double-photon single-photon

1. More sensitive (no collimator!)
2. Spatial resolution is better (anatomic details)

    SPECT: 10 mm, PET: 3 - 4 mm

3. Quantitative

    absolute (e.g. mL/min/g, mol/min/g)

4. Biomolecules !!!

C-11, N-13, O-15, F-18, (but Ga-68)

(glucose, tyrosine, thymidine, H_2O, etc…..)

SLICE OF LIFE

DISADVANTEGES OF NM

- Geometric-spatial resolution (anatomy?)
  contrast (see stars !)
  e.g. thyroid but liver

- Radiation burden
  Indication !!! (other, non-ionizing ?)
  ALARA principle
  Diagnostic reference levels
  (gravidity, children)
  risk-benefit

HYBRIDE IMAGING SYSTEMS

Function + morphology

on the same gantry: „simultaneous" (image fusion?)

Improvement of diagnostic capabilities

1 +1 = 3 !

PET/CT (only)

SPECT/CT („good" SPECT= SPECT/CT)

role of CT: localization + attenuation correction

„low dose" ! (non diagnostic CT)

PET/MR

no radiation (paediatry, brain, oncology, …?)

PET/MR

- No ionizing radiation
- Pediatric, breast, serial
- Soft-tissue contrast
- Functional MR techniques

- Expensive
- Indications ?

FUNCTIONS

Organ: heart, liver, ventillation, blood flow, lymph flow

e.g. kidney: glomerular, tubular, secretion,

urinary flow, clearance

Cellular: tissue characterization

e.g. antigens, receptors, enzyme expressions

Molecular: biochemical, metabolic processes

e.g. angiogenesis, apoptosis, hypoxia, etc.

Genetic: DNS („nuclear imaging”), RNS

oligonucleotides

ROLE OF NM IMAGING

Functional imaging

organ- cell- biochemical functions

tissue characterization

molecular imaging (at molecular level)

Radiology: morphological

co-operation

PET/CT, SPECT/CT

education

diagnostic algorythms

Noninvasive methods (i.v. injections + radiation)

no toxic effect (low amount: pico-, nanomolar)

IMPORTANCE OF MOLECULAR IMAGING

Disease: functional changes

Function before morphology

Early diagnosis

Targeted diagnosis

Targeted therapy

MOLECULAR IMAGING METHODS

- Nuclear medicine !
- MR
- Optical
- CT
- UH

MOLECULAR IMAGING

Functions at molecular et cell levels

„commodore” in molecular imagin: PET

Reasons:

pico-nano-femto-molar amount

hundreds of biomolecules can be labelled

clinicly today: 30-40 subtances

MOLECULAR NUCLEAR MEDICINE TARGETS

Enzyms – substrates
- FDG, FLT, FET, FEC, FDOPA

Receptors – ligands
- D2, SMS

Antigens – antibodies (fragments)
- PSA, CEA, TAG72, CD20

Transzportproteins – substrates
- NIS

Deposits – bindings molecules
- beta-amyloid

PERSPECTIVES

• Apotosis	Annexin V, ML
• Angiogenesis	VEGF, integrin antibodies
• Hypoxia	misonidazol, FMISO
• MDR	sestamibi
• ….	
• Oncogens	F-18 oligonukleotides
• Genexpressions	Gen therapy (reporter gen)
	HSV-Tk co-expression with
	F-18-deoxytimidine

Etc.

IMMUNOSCINTIGRAPHY

- Monoclonal antibodies
- Fragments: Fab, humanized, chimeric, affibody, minibody (specific group)
- Chelating agents: Tc-99m, In-111 or I-131
- Clinical use:

    colorectal, prostate, ovarial cancers

- (NHL-Radioimmuntherapy

    antibodies against CD20+ B-lymphocytes)

RADIONUCLIDE THERAPY

- Specific
- Effective
- Low side-effects
- Excellent palliation
- Repeatable
- Relatively inexpensive
- Individual dosis