The in vivo Measurements of Radioactive Body Burdens:

Techniques and Practices

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Content

- Purpose of in-vivo measurements in the controle
- Historical aspect of detection means
- Problems & needs during the D.M.
- State of the art and promises
- Conclusions
Precaution:
- Keep distance
- Reduce time in vicinity of source
- Use shielding

Wear dosemeter!!!

Irradiation versus Contamination

External contamination

Cloths

Hair and skin
Internal contamination

Inhalation  Ingestion  Wounds

Radiation protection is a problem of comparison

Radiative Dosis to Belgian Population

Medical Applications 48%
Nuclear Energy & Weapons 1%
Cosmic Rays 7%
Radon 25%
Thoron 2%
Soil and Buildings 10%
R.A. in the body 7%

World: 3.75 mSv/y  Belgium: 4.5 mSv/y
Radioactive Body Burden of a human Being

Radiation protection is a problem of comparison

Position of Internal Dosimetry in Radiation Protection
Procedure for a measurement

- Shielded room
- Detector(s)
- Geometry
- Calibration
- Counting (acquisition time)
- Analysis of results
- Interpretation: Acceptation of radionuclide
  Effect of accuracy on dose
  Effect of charge distribution (organ dose,...)

Measurement in a radiative environment
Shielded room for WBC

- 5 ventilated shielding rooms (4 with low background for E>150 keV)
- Shielding is based on the shift of the gamma-rays towards the low energies.

Detectors for WBC:

History

- Ionisation chamber, quartz electrometer (1931)  
  \( L_D = 200 \text{ kBq} \ldots 40 \text{ Bq} \ 226\text{Ra} \)
- Geiger-Müller (Evans, 1937)  
  \( L_D = 4000 \text{ Bq} \ 226\text{Ra} \)
- Proportional Counters (Taylor & Rundo, 1962)
- Scintillators NaI(Tl): all thicknesses, Phoswich
- Semiconductors:
  - Ge(Li), HPGe: Coaxial, Planar
  - Si(Li), Si, CdZnTe, HgBrI₂
- Organ counter, Gamma Camera, …
Detector for WBC

- The person is positioned in a controlled geometry.
- A detector, adapted to the examined energy range, is placed in calibration position.
- The counting is limited to 1 hour.

Detectors for *in-vivo* counting

- **Scintillators**
- **Semiconductors (HPGe)**
- **CdZnTe, silicon array**
Detectors for \textit{in-vivo} counting

Proportional gas counters

Semiconductor (silicon)

New detectors

Quartuccio - IPSN (1999)

Souza, 1999
Calibration of the counting facility

1. Purpose
2. Calibration with human being: Not ethic, useless, impossible
3. Use of phantom: best solution

Calibration:
Use of phantoms

JAERI
Livermore
Bomab
Knee
(University of Cincinnati)
Many types of phantoms

GAEC- Canberra
Bomab (IAEA)
Torso Uranium
Thyroid (SCK-CEN)

Mathematical Phantoms

1. Calibrations of a WBC facility with M.C. calculations
2. Minimize the systematic errors
3. Reduce the detection limits? (effect of detector size)
1. Effect of detector position (distance end cup – torso) 
\((^{241}\text{Am})\) (Supine position)

![Graph showing efficiency vs detector position](image)

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1. Longitudinal scanning on tilted chair

![Diagram of longitudinal scanning on tilted chair](image)
Mathematical Phantoms

- Easy to modelize simple phantoms (not simple)
- Possibility to improve accuracy of measurement
  (if contamination position is known: obesity, infants, hot spots,…..)
- Optimization of geometry
- Possibility to manage detection limits
- Prospective study
- Improve the accuracy of the assessment of dose
Procedures

From measurement to spectrum – From spectrum to results

- Equivalent dose
- Effective dose
- Body burden
- Organ burden

ICRP, Regulation

Procedure:
From spectrum to results
Procedure:
From spectrum to results
Procedure:
From spectrum to results

$^{241}$ Am in the lungs
Procedures

Simple way to analyze a result

Working with detection limits

\[ L_{C} = \frac{2.33 \sqrt{B}}{\eta \cdot t_{\text{count}}} \]

\[ L_{D} = \frac{2.71 + 4.65 \sqrt{B}}{\eta \cdot t_{\text{count}}} \]
Procedures:
Least square fitting for NaI(Tl)

Detector choice then Analysis selected

Method developed for poor resolution detectors
PAM impossible when more than 3 overlapping photopeaks.

Least square fit
Procedures:
Advantages of NaI(Tl)

1. High efficiency low counting time
2. Lower detection limits
3. Possibility to measure **beta-emitters**
4. Usage of all types of interactions
5. No limitation in the number of photopeak when least square fit is adopted.
6. When distribution is different

Types of measurements

- **Fission and activation products** (nuc. reactor, part. Acceler.)
- **Medical radionuclides**: Iodines, $^{99m}$Tc, $^{201}$Tl,…

1. **WBC**: tilted chair
2. **Organ measurements**: Supine or prone position: detector – organ dependence
3. **Thyroid** measurement
4. **Wound** measurement
5. **Metabolism – Scanning** (study of new medicines)

Note: Single measurement is sometimes not possible.
From counting to burden to dose

1. The most difficult task: Estimation of the error on the burden measurement.
2. Error of 100% is common in WBC.
3. The lowest error occurs with Thyroid counting (NO coll.): 20%.
4. Bias of 800% is not unusual in burden assessment Lung with: Pu, Am
   ref. G. Kramer (Health Phys).
5. Possibility to reduce burden bias with multi-detector

New recommendations, New trends in *in Vivo*

- Improve accuracy: distance, position, ribs, hot spots,...
- New radionuclides: $^{125}$I, $^{103}$Pd, $^{109}$Pd, $^{241}$Am, $^{105}$Rh...
  Different concept for low energy photons.
- Effect of body size, CWT
- Mean Problems with D.M. (two types: $\varphi - \psi$):
  - delay incident - meas (distance) $\Rightarrow$ metabolism
  - Counting time ($<< 1$ hour)
Present R&D

- Acquisition concept
  - Small detectors for low energies
    - Localisation (Ikg!! - Hot spot - compartments)
    - Reduction of delay incident-results
    - Measurements out of shielded room.
    - Multi-diode array
  - New detectors (Si, CZT, HgBr₂, BGO, ...)

R&D:
Radiation Protection & Metabolism

0.4995 kBq/cpm \(^{99m}\text{Tc}\) (TcMDP)

Effective half-life = 5.5 h
Physical half-life = 6.0 h

(Souza, J.F, 1999)
Background study

Background Reduction is limited

1. & 2. Lab without shielding
2. Lab with 2-mm brass collar
3. In Hades (-225 m)
4. In shielded room
5. In UDO (-925 m) - ASSE (Braunschweig)
R&D: Multi-diode systems for *in vivo*

![Graph showing counts per zone with voltages of -10V, -20V, -40V, -50V.]

R&D: Optimizing diode dimensions

![Graphs showing energy and counts per channel with detector thickness and bias voltage.]

![Image of a multi-diode system.]

Voltages: -10V, -20V, -40V, -50V
Results and spin off:
Ceasium-137 in body of Belgian Population

Ecological half-life of Cs-137
(in Belgium)
**Treatment after incorporation**

**Absorption reduction**
- Cobalt salts
- Prussian Blue
- Adsorbant
- Anti-acids
- Iodides

**Excretion Stimulation**
- Prussian Blue
- Sodium Bicarb.
- EDTA, DTPA
- Calixarenes
- Iodides, perchlorates

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**R&D in WBC**

1. **OMINEX, IDEAS, IDEA**: European groups form FP5
2. Effect of ribs, cartilage, lymph nodes, contamination distribution,...
3. CWT assessment (ultrasonic way or new empirical method)
4. Practical problems (depend on facility)
R&D in WBC

5. Calibration with mathematical phantoms.
6. Background reduction.
7. Work on the detector size (application specific).
8. Reduce uncertainties – Improve accuracy.

Conclusions & Future aspects

• Correlation In Vivo - In Vitro techniques:
  • Difficult but useful for metabolic studies

• In Vivo:
  • Detector arrays, (position of the detector !)
  • Geometry has to be adapted in each case (organ or radionuclide)
  • A better precision is possible (comparative study)
  • Fast results
  • Spin-off: Metabolism, retention, induced excretion
  • Inter-comparisons
  • MonteCarlo Calibration (obesity, infant,...)
End of talk

THANK YOU