NUCLEAR APPLICATIONS IN HEALTH
A UNIQUE MANDATE OF THE UN SYSTEM

“The Agency shall seek to accelerate and enlarge the contribution of atomic energy to health and prosperity throughout the world”

Article II of the Statutes of IAEA

Atoms for Health

BACKGROUND

• The utilization of radiation in medicine for diagnosis and treatment dates from the 19th century, almost from the time x-rays and radioactivity were discovered

• Now its use is deeply embedded in medical practice. For many purposes, it is indispensable – both for diagnosis and for treatment

THESE DISTINCT FIELDS

• Diagnostic radiology
  ➢ 100% diagnostic

• Radiotherapy
  ➢ 100% treatment

• Nuclear medicine
  ➢ 80% diagnostic
  ➢ 10% treatment
  ➢ 10% lab tests

Multidisciplinary team: physicians, physicists, radiographers...
THREE DIFFERENT TYPES OF RADIATION SOURCES

- Diagnostic radiology
  - X-rays
- Radiotherapy
  - High-activity sealed sources
  - Radioisotopes, solid, capsule
  - Medical accelerators
- Nuclear medicine
  - Low-activity unsealed sources (*)
  - Radioisotopes, mostly liquid radiopharmaceuticals
  - (*) except for therapeutic uses

DIAGNOSTIC X-RAYS

The left hand of Mrs Roentgen, some 100 years ago (1895)
Modern pelvic and thorax X-ray examinations using digital techniques

Are X-rays atomic/nuclear?

bremsstrahlung interaction

The goal of Diagnostic Radiology

A.L.A.R.A.

To deliver As Low radiation dose to the patient As Reasonably Achievable... ... in order to produce an image clinically useful.
Mammography - the "ultimate" challenge with regard to X-ray image quality

- Typically 25-30 kV; special anode-filter

High-resolution imaging in 3D using multi-slice Computed Tomography techniques and helical scanning

- 80-140 kV; typically 120 kV

Angiography and interventional procedures are performed using image intensifiers or flat panel detectors

- ~ 70-100 kV

The goal of Radiotherapy

- To deliver as high radiation dose as possible (Reasonably Achievable) to a "clinical target"...
**Teletherapy**
Sealed Co-60 source or electron/photon accelerator

**Modern accelerator teletherapy**

**Brachytherapy sources**
Brachytherapy applicators

**Brachytherapy treatments**
- Nasopharynx applicator
- Cervix applicator
- Afterloader system (nasopharynx)
- Afterloader system (cervix)
CANCER AND THE UN SYSTEM
The IAEA is the only player in technology transfer for Radiotherapy

- International Agency for Research on Cancer
- WHO Programme on Cancer Control
- IAEA research and technical cooperation on radiation therapy

Access to Radiotherapy

- Modified radiotherapy protocols
- TC: Establishment of new radiotherapy centres
- Clinical guides and manuals

Of the 260 million new cancer cases in 20 years, there will be

approx 150 million in developing countries

100 million will be suitable for radiation treatment

Programme of Action for Cancer Therapy (PACT)

- Cancer prevention and control
- Work with partners
- Raise public awareness
- Mobilize resources
NUCLEAR MEDICINE

IN-VIVO APPLICATIONS (90%): Diagnosis and Therapy
1. A radionuclide is tagged to a compound: Radiopharmaceutical
2. Administered to patient, injected or orally
3. Body metabolizes the radiopharmaceutical as if it were a "normal" substance (organ specificity)
4. Radionuclide distribution in the body is measured with an external detector
5. Computerized data is converted into images or analyzed
6. Clinician can visualize or track organ function (even at a molecular level) and diagnose

IN-VIVO APPLICATIONS (90%): Diagnosis and Therapy

Radiopharmaceuticals

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Pharmaceutical</th>
<th>Organ</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tc-99m</td>
<td>+ MAA</td>
<td>Lungs</td>
<td>Regional perfusion</td>
</tr>
<tr>
<td>+ colloid</td>
<td></td>
<td>Liver</td>
<td>RES</td>
</tr>
<tr>
<td>+ DTPA</td>
<td></td>
<td>Kidneys</td>
<td>Kidney function</td>
</tr>
</tbody>
</table>

Detector: gamma camera

Position X
Position Y -> computer
Energy Z

Radioactive source is inside the patient!

Whole body scanning
**Tomographic acquisition**

**Dynamic acquisition**

**Radionuclide Therapy**

**IN-VITRO APPLICATIONS:** Radionuclide based laboratory techniques

**Malaria drug resistance- A global challenge!**

Malaria kills one person every 30 seconds in the world. Conventional in vitro drug testing method takes up to 72 hours to perform. Nuclear molecular methods are faster and more sensitive than conventional techniques.
**PET imaging**

- Annihilation process
  - $\gamma$ (511 keV)
  - $\beta^-$ (1-3 mm)
- Detector
- Scanner principle

**Multimodality imaging (image fusion)**

- PET: function
- CT: anatomy

**NUCLEAR MEDICINE**

The IAEA is the only UN organisation with a programme

No other international organisation has specific mandate for promoting Nuclear Medicine

**THREE DIFFERENT TYPES OF RADIATION DOSE TO THE PATIENT**

- **Diagnostic radiology** (over 2 billions exam)
  - Low dose to patient (most exams)
  - Large population dose
  - Risk: stochastic effects
- **Radiotherapy** (5.5 millions treatments)
  - High dose to patient (intended!)
  - Risk: deterministic and stochastic effects
- **Nuclear medicine** (32 millions procedures)
  - Low doses (mostly)
  - Risk: stochastic effects
THE DIVISION OF HUMAN HEALTH
Sections

• Nuclear Medicine
• Radiotherapy and Radiobiology
• Dosimetry and Medical Physics
• Nutrition

QUALITY ASSURANCE AND QUALITY CONTROL
DISSEMINATION OF QA CULTURE

MALNUTRITION is the main contributor to the burden of disease in developing world

Improving Nutrition through Nuclear Science

Vitamins and Minerals
Stable and radio isotopes

Food fortification and bio-fortification

Obesity
Health-care for HIV/AIDS
Low birth weight
Maternal health

Body composition and energy metabolism
Stable isotopes

Bone density & fat distribution
DEXA & CT

Osteoporosis
Obesity
Stable isotopes for nutrition

- Deuterium dose to the mother
- Collection of saliva samples from the baby

Knowledge Management Activities in Health:

Educational

- Syllabus for education of Radiotherapy radiographers
- Syllabus on Medical Physics
- Distance assisted training programme for Technologists in Nuclear Medicine
- Distance assisted training programme for Radiation Oncology Trainees
- Tele nuclear medicine project involving network of 15 countries in Latin America

Knowledge Management Activities in Health:

Databases

- Natural Matrix Reference Materials, for Nutritional and Health-Related Environmental Studies
- Directory of Radiotherapy Centres (DIRAC), with the World Health Organization (WHO)
- IAEA/WHO Network of Secondary Standards Dosimetry Labs
- IAEA/WHO TLD Service, External Quality Audits in Radiotherapy Dosimetry

Knowledge Management Activities in Health:

Dissemination of information

Recent Publications

- Public information brochure: “Improving Nutrition through Nuclear Science”
- Public information brochure: “A Silent Crisis”
- TecDoc “Design and Implementation of a Radiotherapy Programme”
- TecDoc “Implementation of High Dose Rate Brachytherapy in Developing Countries”
- Practical radiation technical manual: “Mould Room Techniques”
- TRS: Commissioning and Quality Assurance of Computerized Radiation Treatment Planning