Progress of radiation medicine metrology at NIM

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Division of Ionizing Radiation metrology, NIM
Outline

1. radiation medicine application in China
2. Radiodiagnosis metrology
3. Radiotherapy metrology
4. Nuclear medicine metrology
5. Collaboration with NRC
Radiodiagnosis 放射诊断

- More than 400 million radioactive diagnosis per year in China.
- Around 21,600 CT scanners in 2016 (increase 2300 sets per year)

**Metrology requirement:**

To get better image quality with low radiation dose.

**Quantity:**

- Air kerma, Air kerma area product,
- Air kerma Length, kVp, mAs, HVL
Radiotherapy 放射治疗

- **3.8 million** tumor patients is confirmed per year in China, 60-70% patients need radiotherapy.
- **1413 hospitals** for radiotherapy
  - LINAC: **1931** sets, Co-60: **96** sets;
  - X knife: **171** sets, γ knife: **210** sets;
  - Brachytherapy **439** sets;
  - **919,339** radiotherapy per year
  - Proton and carbon therapy started to treat patient, 7 centers are establishing.

Metrology requirement:

- The radiotherapy techniques developing rapidly and require high accuracy and more complicated dosimetry measurement.
The use of short-lived radionuclides as a tool for diseases diagnosis (SPECT/PET) and treatment, particularly cancer, continues to rise at a rapid rate recent years.

Around 300 PET-CT in China in 2016, increasing 40 sets per year

Metrology requirement:

- Development of systems for performing activity measurements for short-lived radionuclides
- Quantitative nuclear medicine Positron Emission Tomography
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Metrology in Radiodiagnosis
放射诊断计量

Air kerma, Air kerma area product, Air kerma Length

BIPM.RI(I)-K2 ▲
Primary standard of air kerma in 10-60kV X-ray

BIPM.RI(I)-K3 ▲
Primary standard of air kerma in 60-250kV X-ray

BIPM.RI(I)-K7 ▲
Primary standard of air kerma mammography X-ray

Supplemental comparison ▲
National standard in kV, Image Quality

Cobia 库比奥型
全中文显示“1分钟”上手
大彩屏显示可旋转360°
交、直流2种供电方式
功能齐全，满足标准
现代时尚，小巧便携
性价比高

Semiconductor detector and ionizing chamber for diagnosis
放射诊断用半导体探测器和电离室剂量计的校准

Phantom
Primary standard for (10-60)kV X-rays
低能X射线基准

NIM designed and manufactured a parallel plate type free air chamber to realize air kerma of x-rays from 10kV to 60kV. The relative expanded uncertainty is around 0.28%. In 2010, we finished the APMP.RI(I)-K2 comparison.
Primary standard for (60-250)kV X-rays
中能X射线基准

For (60-250)kV X-rays, we established a new free air chamber (as shown in picture). The relative expanded uncertainty is around 0.22%.

APMP.RI(I)-K2 comparison is finished in July, 2016, and BIPM.RI(I)-K3 comparison is finished in 2017.
Primary standard for mammography
乳腺X射线基准

Mammography is the process of using low-energy X-rays to examine the human breast. The goal of mammography is the early detection of breast cancer.

In 2014, we designed a new cylindrical type Free Air Chamber for mammography X-rays to establish the traceability.
Secondary standard for diagnostic x-ray

The secondary standard for diagnostic x-ray is to offer calibration services for the air kerma, potential of x-ray generator (kVp) of semiconductor detector and ionizing radiation chamber.
Standard for Image quality control in radiography
放射影像质控标准

To develop technical performance standards for x-ray diagnosis, focusing particularly on image quality: Spatial Resolution, Contrast Sensitivity.

Industrial CT for image quality research

Phantom 图像质控标准
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Primary standards for Radiotherapy

**Primary standard in Air kerma**
- BIPM.RI(I)-K1: $^{60}\text{Co}$
- BIPM.RI(I)-K2,K3: X-Ray
- BIPM.RI(I)-K8: $^{192}\text{Ir}$

**Primary standard in absorbed dose to water**
- BIPM.RI(I)-K4: $^{60}\text{Co}$
- BIPM.RI(I)-K6: (4-25) MV LINAC
- BIPM.RI(I)-K9: X-ray

Trace

Ionizing chamber used in radiotherapy

放疗电离室剂量计校准

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Primary standard of $^{60}$Co water absorbed dose

$^{60}$Co水吸收剂量基准

- Water absorbed dose measured by graphite calorimeter and cavity ionization chamber.
- Took part the APMP.RI(I)-K4 comparison.
- Finished the comparison with IAEA on 2015 for the SSDL network.
Water Calorimeter for high energy photon absorbed dose

In collaborating with NRC, NIM is developing a primary standard for absorbed dose to water at radiotherapy dose levels. The developing standard for water absorbed dose is based on a water calorimeter and is designed to operate in Co-60 and megavoltage photon beams from a linear accelerator.

The draft B of the BIPM.RI(I)-K6 comparison was finished.

Attempt to measure the high energy electron (18MeV) with calorimeter core used for the photons.
Dosimetry for Small and composite fields
小野与复杂野剂量学

- Determine the range of the dimension for the small field dosimetry;
- Determine the absorbed dose measurement method for small field dosimetry;
- Establish the reference radiation condition for small field dosimetry; Research the transfer method for small field dosimetry;
- Determine the available scope of the absorbed dose measurement method in small field dosimetry.

与临床剂量结合，进行放射剂量学研究
Proton and heavy ion dosimetry

• Proton and heavy ion have been used for radiotherapy in China, there are 3 radiotherapy centers for heavy ion and 4 centers for proton.
• To develop absorbed dose standard for proton and heavy ion based on calorimeter under the cooperation with radiotherapy center.
Collaborate with medical physic society
与医学物理领域的合作

Participate in the quality assure (QA) workshop of radiotherapy for the hospital in Beijing every year. Peking union medical college hospital take charge of the radiotherapy QA center of Beijing.

Supply the training course to the medical physicist in china by the collaboration with medical physic society.

Apply the national fund together with cancer centers and the CDC of China, focus on the radiotherapy dosimetry research.
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Radioactivity metrology

医用核素计量

- **Tc-99m**, half life about 6h, widely applied for imaging in SPECT
- **F-18**, half life about 1.8h; **Ga-68**, half life about 67.8min used for imaging in PET
- **I-131**, half life about 8d, applied for thyroid disease treatment
- **Ra-223**, half life about 11.4d; **Y-90**, half life about 2.67d widely applied for the treatment of liver cancer

短寿命医用核素量传链条
A new and more realistic TDCR model by Penelope

液闪三双符合比方法（LNHB合作）

With more detailed geometrical and material descriptions for optical chamber, chamber cap, photomultipliers

An example of the computed absorption spectrum for the interaction of γ ray with a liquid scintillator

国际水平的放射性核素测量方法
Completed the standardization for nuclides Tc-99m

- **Standardization of Tc-99m activity by primary standard**
- **Calibration of 4πγ ionization chamber**
- **Participated in the BIPM.RI(II)-K4.Tc-99m international comparison, and equivalence achieved**
- **Provide services for activity meter and SPECT for medical diagnosis**

**Comparison results for Tc-99m**
90Y separation from 90Sr and the impurity measurement
钇锶分离与杂质测量

- 90Y (Iridium) was separated from 90Sr (Strontium) using an extraction chromatographic resin consisting of DtBuCH18C6,2mimNTf2 and a polymer.
- After the separation, the activity ratio of 90Sr/90Y was less than 0.002%.

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NRC and NIM

NRC in Ottawa and NIM in Beijing
Overview of technique exchange in recent year

Agreement signed

NRC staff visited NIM

NRC and NIM signed MoU

NRC staff visited NIM

NIM staff worked in NRC

Meeting today

NIM staff visited NRC

NRC and NIM signed MoU

NRC staff visited NIM

Agreement signed

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Thanks for your attention!