Overview of the National Cancer Institute’s Radiation Epidemiology Branch and Key Challenges Faced when Reconstructing Patient Dose for Epidemiological Applications

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National Institutes of Health

27 institutions with 18,000+ researchers

National Cancer Institute (NCI)
National Eye Institute (NEI)
National Heart, Lung, and Blood Institute (NHLBI)
National Human Genome Research Institute (NHGRI)
National Institute on Aging (NIA)
National Institute on Alcohol Abuse and Alcoholism (NIAAA)
National Institute of Allergy and Infectious Diseases (NIAID)
National Institute of Arthritis and Musculoskeletal and Skin Diseases (NIAMS)
National Institute of Biomedical Imaging and Bioengineering (NIBIB)
National Institute of Child Health and Human Development (NICHD)
National Institute on Deafness and Other Communication Disorders (NIDCD)
National Institute of Dental and Craniofacial Research (NIDCR)
National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK)
National Institute on Drug Abuse (NIDA)
National Institute of Environmental Health Sciences (NIEHS)
National Institute of General Medical Sciences (NIGMS)
National Institute of Mental Health (NIMH)
National Institute on Minority Health and Health Disparities (NIMHD)
National Institute of Neurological Disorders and Stroke (NINDS)
National Institute of Nursing Research (NINR)
National Library of Medicine (NLM)
Center for Information Technology (CIT)
Center for Scientific Review (CSR)
Fogarty International Center (FIC)
National Center for Advancing Translational Sciences (NCATS)
National Center for Complementary and Integrative Health (NCCIH)
NIH Clinical Center (CC)
• National Cancer Institute

• Three areas of expertise in REB
  – Epidemiology
  – Statistics
  – Dosimetry

Epidemiology and Biostatistics Program
  • Radiation
  • Infections and immunology
  • Metabolic
  • Occupational & Environmental
  • Biostatistics

Human Genetics Program
Radiation Epidemiology Branch

• Mission
  – Identify, understand, and quantify the risk of cancer in populations exposed to different types of radiation

• General approaches
  – Research addressing public health and clinical needs
  – Develop dosimetric, epidemiological, and statistical methods
  – Train future researchers
  – Respond to the needs of the public and government agencies
REB Dosimetry Unit
Research Goals in Dosimetry Unit

To Provide **Accuracy** in organ dose

To Quantify **Uncertainty** in organ dose

To develop dosimetry systems for large-scale epidemiological studies
MEASUREMENT

• Expensive
• Labor intensive
• Not flexible

CALCULATION

• Cost-effective
• Automated
• More flexible
Virtual CT images with pre-contoured organs
Research Focus

Computational Phantoms + Computer Simulation
Research Focus

- Radiation Treatment
- Computed Tomography
- Nuclear Medicine
- Radiography Fluoroscopy
- Environmental
- Computational Phantoms + Computer Simulation
Collaboration on dose measurement:
National Institute of Standards and Technology
NIH Clinical Center
Yale New Haven Hospital
University of Michigan Medical Center
East Carolina University Medical Center
Maryland Proton Therapy Center
Ongoing Epidemiological Studies of Radiotherapy Patients
Ongoing epidemiological studies 1/4

• **Second cancer risk study of breast radiotherapy patients**
  – 7,000 breast radiotherapy patients in three Kaiser centers in the US
  – Case-control study for contralateral breast cancer in progress
  – In-house dosimetry system is being developed

• **Measurement needs**
  – In- and out-of-field depth dose and profile for LINAC 6X/16X
  – Scatter dose measurements for wedge
Ongoing epidemiological studies 2/4

- **International cohort study of pediatric proton therapy patients**
  - Pilot study to explore feasibility began in 2016
  - Interest group has been formed and met: NCI, ESTRO, SIOP
  - In-house dosimetry methods have been developed

- **Measurement needs**
  - Proton beam commissioning data: passive scattering, spot scanning
  - Out-of-field neutron dose profile
Ongoing epidemiological studies 3/4

- Late effects study in the National Wilms Tumor Study cohort
  - Collaboration with Northwestern University
  - 5,000 pediatric Wilms tumor patients
  - Treatment plans reconstructed from individual medical records
  - In-house dosimetry method is being used

- Measurement needs
  - In- and out-of-field depth dose and profile for LINAC 4X and Co-60
Ongoing epidemiological studies 4/4

• Clinical trial of proton/photon for breast radiotherapy patients
  – Collaboration with University of Pennsylvania
  – 1,700 proton or photon breast patients: DICOM-RT collected
  – Detailed heart contouring using atlas-based auto segmentation
  – In-house dosimetry system at NCI will be used for dosimetry

• Measurement needs
  – X ray and proton beam commissioning data from different centers
Measurement Resources
Golden beam data for LINAC commissioning

Radiotherapy

Radiotherapy (also known as radiation therapy) has two equally important goals: to control the growth of the tumor and to do so while minimizing exposure to the surrounding normal, healthy tissue. Used typically as a curative treatment, either alone or in conjunction with surgery and/or chemotherapy, the aim of radiation therapy has always been to eradicate a patient’s cancer. Radiotherapy uses high-energy radiation, usually x-rays, to damage cancer cells and treat tumors in the breast, prostate, head and neck, lung and anywhere in the body where radiation treatment is
Fetal Dose from Radiotherapy with Photon Beams
Revisiting fetal dose during radiation therapy: evaluating treatment techniques and a custom shield

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Phase-space database for external beam radiotherapy

IAEA NAPC Nuclear Data Section
IAEA NAHU Dosimetry and Medical Radiation Physics Section

Project Officer: Roberto Capote

Objective: To build a database and disseminate representative phase-space data of accelerators and cyclotrons used in medical radiotherapy by compiling existing data that have been properly validated.

NEWS

Jul. 2008: EGSnrc, PENELLOPE and Geant4 have implemented the interface to read/write native IAEA format.

How to produce and submit phase-space data: The IAEA phsp format was designed to interoperate both phase-space files and event generators (see phsp contents). We have implemented the phsp format in a set of read/write routines (Updated: September 2013, see readme file). The IAEA phsp format is available in EGSnrc and PENELLOPE Monte Carlo codes. Geant4 in user the native IAEA phsp format is also available. Unfortunately, MCNP does not have an implementation of the IAEA format. A generic converter from IAEA to ASCII is also available, iaea2ascii.zip. Once the validated phsp data is produced and documentation is published, submit your phsp for review using the upload link here.
Summary

- REB/DCEG/NCI/NIH studies cancer risk from medical, occupational, and environmental radiation exposures

- REB dosimetry unit conducts dosimetry projects supporting epidemiological studies of late effects after radiotherapy

- A variety of measurement needs have been identified.
The role of computational representation of human anatomy, called computational human phantoms, in researches of medical radiation and radiation protection becomes more and more critical. NCIPHANTOM is a library of computational human phantoms representing reference anatomy of children and adults with various body sizes.

REALISM AND DETAILS

The original format of the NCIPHANTOM library was created 100% based on patient images carefully selected from more than 1,000 CT image sets to make sure the anatomical realism in collaboration between the University of Florida and National Cancer Institute. A number of organs and tissues were
Thank you for your attention!