FROM ICARO1 TO ICARO2:
THE MEDICAL PHYSICS PERSPECTIVE

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DISCLOSURES

My institution holds Strategic Partnership Research Agreements with Varian, Elekta, and Philips

I will be discussing devices that are not currently available for sale, and that do not have FDA clearance.
OBJECTIVES

- Look back at the topics and conclusions of ICARO1
- Consider changes in technology and resources since 2009
- Discuss role of physics and changes demanded by technology
- Anticipate advances to be made in the future
PHYSICS TOPICS IN 2009

1. What are the physics requirements for altered fractionation?
2. How to go about setting up a QA program?
3. What is needed for commissioning and QA of new technologies?
4. How do we transition from 2D to 3D and IMRT?
5. Are we ready to move to IMRT?
6. Is there a role for Co-60?
7. Do we need proton therapy?
NEW TECHNOLOGIES

- 3-D conformal radiation therapy (3D-CRT),
- Intensity modulated radiation therapy (IMRT),
- Image-guided radiation therapy (IGRT),
- Adaptive radiation therapy (ART),
- Respiratory-gated radiation therapy (RGRT),
- Particle radiation therapy, and
- Image-guided brachytherapy (IGBT)

INTERNATIONAL CONFERENCE ON ADVANCES IN RADIATION ONCOLOGY (ICARO): OUTCOMES OF AN IAEA MEETING


Key words: advances radiation oncology international conference

Abstract

The IAEA held the International Conference on Advances in Radiation Oncology (ICARO) in Vienna on 27–29 April 2009. The Conference dealt with the issues and requirements posed by the transition from conventional radiotherapy to advanced modern technologies, including staff training, treatment planning and delivery, quality assurance (QA) and the optimal use of available resources. The current role of advanced technologies (defined as 3-dimensional and/or image guided treatment with photons or particles) in clinical practice and future visions were discussed.

ICARO was organized – at the request of the Member States, by the IAEA and co-sponsored and supported by other international organizations – to discuss and assess advances in radiation technologies in radiation oncology in the face of economic challenges that most countries confront. Participants submitted research contributions, which were reviewed by a scientific committee and presented via 46 lectures and 103 posters. There were 327 participants from 70 Member States as well as participants from industry and government. The ICARO meeting provided an independent forum for the interaction of participants from developed and developing countries on current and developing issues related to radiation oncology.

INTRODUCTION

IAEA activities in advancing radiation oncology

All countries are facing an increased demand for health services. In cancer healthcare, there are many expensive demands in diagnosis and treatment, including radiation therapy, and systemic therapies. Radiation therapy can be a cost-effective method of treating cancer, yet it is unavailable in many low-income countries throughout the world. In high-income countries, the ratio of treatment machines to population may be as high as six per million individuals, but in many low and middle-income (LMIC) countries, the ratio may be as low as one per 10–70 million individuals. Twenty Member States have no radiotherapy services at all and many low-income countries have only basic equipment and often few qualified and trained staff, for which there is a global shortage.
REPORT RECOGNIZED THAT:

• Many low income countries have little or very basic diagnostic and treatment facilities

• Low and middle income (LMI) countries have an increasing number of cancer patients who present with advanced stage disease, with few radiotherapy facilities. Palliative treatment is common, but there are an increasing number of curative patients

• Demand for radiotherapy services in LMI countries will increase dramatically over the next 20 years
CONCLUSIONS (RELATED TO PHYSICS)

• There remains a role for cobalt teletherapy.
• Clinical trials must demonstrate the benefits of advanced technologies before they are adopted into widespread use.
• IMRT and stereotactic radiation therapy procedures brings special physics problems.
• Proton facilities are expensive to build and maintain
• Clinical trials will provide clinical data to support decision to implement
• Not clear if the clinical gains from proton therapy will outweigh the costs of treatment
• Brachytherapy remains an important treatment modality
HAVE THERE BEEN CHANGES SINCE 2009?

- Cobalt remains a valuable treatment modality
HAVE THERE BEEN CHANGES SINCE 2009?
- IMRT has been improved - better control over optimization
- Introduction of VMAT has reduced delivery times
IMAGE-GUIDED ADAPTIVE RADIATION THERAPY

- Many changes in recent years
- Benefits of imaging patient in treatment position
- Position can be assessed at time of beam-on
- Real-time corrections can be made
- Margins can be reduced
Why do we need image-guided adaptive RT?
Dosimetric effect of organ variability

Original Plan  Original Plan on New CT

CT scan a week later
CT-GUIDED RADIATION THERAPY

Courtesy L. Court
CT-IMAGE GUIDED RADIOTHERAPY

- Varian solution
- CBCT MV imaging
- Adaptive planning
- Treatment
DEVELOPING STATUS OF IGRT

- kV imaging widely used but relies on bony landmarks or fiducials
- CBCT IGRT has transformed RT practice and perception. Its potential may not have been fully exploited
- However, two issues remain …
  - Adequate soft tissue visualization
  - particularly in abdomen and pelvic anatomy
  - Intrafraction motion
    - Long acquisition time of CBCT largely limits it to pre-treatment or periodic imaging
WHAT DOES MR BRING TO IGRT?

- ‘Real time’ no radiation dose imaging
- Simultaneous with irradiation
- Soft tissue visualization
- Many targets and structures become easier to visualize
- Improved ability to adapt treatment
- Ability to see the tumor not just the organ
- Prostate, brain
- Potential for functional and molecular imaging
- Therefore addressing the two remaining IGRT problems

Images courtesy of Jing Cai, PhD
TARGET DELINEATION - BRAIN

- MRI allows visualization of pathology and anatomy
- Boundaries of tumor clearly defined, target clearly delineated from surrounding tissue

Image from Brian Kristensen, Univ. Hospital Herlev, Copenhagen
4D-MRI: VOLUME DELINEATION OF MOVING TARGET IN ABDOMEN

Courtesy of Jing Cai, PhD
ELEKTA MRI GUIDED RADIATION THERAPY

Purpose

Treat the patient while simultaneously imaging with a conventional 1.5T diagnostic MRI

1. Mount the Linac on a rotatable gantry around the MRI magnet
   *The radiation isocenter is at the center of the MRI imaging volume*
2. Modify the Linac to make it compatible with the MR environment
3. Modify the MRI system
   *Minimize material in the beam path*
   *Minimize magnetic field at the Linac*
PROGRESS IN MRI-GUIDED RADIATION THERAPY - ELEKTA UNITY
Atlantic can image and detect the target in real time simultaneous with irradiation

- Localization results for Kidney
- Alternating axial, coronal and sagittal slices
- Acquired and processed in 200 ms
MRI’s role is growing in radiation oncology

Expansion to on-line adaptive treatment

MRI scanner

MR Scanner with MR-RT Oncology Configuration

Treatment Planning S/W with MR support

MRI guided radiation therapy

MR Scanner Sequences and Post-processing S/W

Diagnosis Staging → Simulation → Treatment Planning → Treatment, Adaptation & Assessment → Off-line Response Assessment

MR images courtesy of Philips
Radiosurgery vs. whole-brain RT for brain metastases

- Multi-institutional RCT tested radiosurgery with or without whole-brain RT for pts with 1-3 brain metastases
- Addition of whole-brain RT
  - Reduced incidence of intracranial progression
  - Led to deterioration in cognitive functions and QoL
  - Did not improve survival

Brown PD et al, JAMA, 2016
SABR vs. surgery for operable stage I lung cancer

- Pooled analysis of STARS [NCT00840749] and ROSEL [NCT00687986] phase III trials
- Showed that SABR for early-stage lung cancer was better tolerated and may have led to better OS than surgery
- Suggests equipoise for 2 treatment modalities

Chang JY et al, Lancet Oncol, 2015

Improvements in Body Stereotactic Radiotherapy

Funding
NCI Clinical & Translational Science Award, AccuRay
PARTICLE THERAPY

- Role of proton beams continues to expand, new facilities constructed
- For some disease sites, lower toxicity
- Heavier particles show additional advantages:
  - Dose distribution
  - Radiobiological benefits
On the subcellular level
Which heavy ions?

Loeffler and Durante, Nature Rev 2014
This is different than photons

**Particle Irradiation Suppresses Metastatic Potential of Cancer Cells**

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ADVANCES IN TECHNOLOGY SINCE 2009

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We understand its place
Improved and advanced with VMAT

Significant advances
More appropriate use of protons, investigation into heavier ions
Improved imaging yields better targeting
THANK YOU FOR YOUR ATTENTION