Departments of Oncology and Medical Biophysics

Accuracy Requirements and Uncertainty Considerations in Radiation Therapy

Introduction and Overview

6 August 2013 Jacob (Jake) Van Dyk

Western S Medicine & Dentistry





Uncertainties



- New technologies
 - Purpose
 - Minimize toxicity and maximize tumor dose
 - ... allows for dose escalation
 - ... allows for increases in dose/fraction

Further clinical gain with new technologies

 May be limited by <u>uncertainties</u> in various
 stages of treatment process

Uncertainties



Jse

New technolo ies

nose

Paraphrase from David Jaffray: "We need to get our uncertainties under control to advance the personalized medicine agenda."

stages of trea

nt proc

ologies

Accuracy and Uncertainty Issues in Radiation Therapy

Two considerations in RT



This Symposium ...

- Review the latest information
 - Accuracy requirements
 - Uncertainty considerations
- Introduction & Overview
 - Jake Van Dyk, Med. Phys., Professor Emeritus, London, Canada
- Radiobiological rationale
 - Søren Bentzen, Biomathematician, Professor Human Oncology, UW, Madison, WI
- Clinical Considerations
 - Mike Milosevic, Rad. Onc., Professor and Director of Research, PMH, University of Toronto, Canada
- Practical reality check
 - David Followill, Med. Phys., Director of RPC, MDACC, Houston, Texas



Determin

Absor

Patien

Beams

Ravs in Proced

ICRU REPORT 24

6: 2-D RT era ... need for an accuracy of ±5% the in the delivery of an absorbed dose to a target volume ..."



INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS



- 3.5% (1 σ) at specification point and 5% at other points in PTV for combined Type A and B uncertainties.
- This required accuracy cannot always be achieved even for simple geometries.

Issues

- Reports on accuracy requirements mostly written in 2-D to 3-D CRT era
- Emphasis on dose to reference point in the target volume
- Technology has evolved
 - 2-D RT to 3-D CRT to IMRT, IGRT, 4-D & motion management

In 1990s ...

- Added distance-to-agreement (DTA) to dose accuracy considerations
 - As part of treatment planning system (TPS) commissioning

ICRU 83



 ICRU 42 (1987) on TPSs suggested a goal of 2% in relative dose and 2 mm DTA

ICRU 83 – Dose Accuracy

- More statistical
- Two regions
 - Low dose gradient (<20%/cm)
 - 85% of target volume, dose within 5%
 - High dose gradient (≥20%/cm)
 - Specify distance to agreement
 - 85% of dose samples, within 5 mm

2010

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> RADIATION UNITS AND MEASUREMENT

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Prescribing, Recording, and Reporting Photon-Beam Intensity-Modulated Radiation Therapy (IMRT)



2011 AAPM Summer School

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Uncertainties in External Beam Radiation Therapy

Jatinder R. Palta T. Rock Mackie Editors

American Association of Physicists in Medicane Medical Physics Monograph No. 55

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Preface

Summer School Program Objectives:

- Provide in-depth understanding of sources of uncertainties in external beam radiotherapy planning and delivery
- Provide practical guidance in assessing the overall uncertainty of delivered dose to patients treated with different technologies
- Provide practical guidance on mitigating sources of uncertainties and strategies for dealing with residual uncertainties
- Impress upon the fact that "What You See Is Not What You Get (WYSINWYG)" and how to deal with it on patient-by-patient basis

Jatinder R. Palta, Ph.D., and T. Rock Mackie, Ph.D.

August 2011

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2011 AAPM SS Summary

- Considers all aspects of dosimetric uncertainties
 - Each stage of treatment process
 - In individual chapters
- No grand summary
- No specific consensus recommendations other than what is in individual chapters

New IAEA Report

- Draft
- Under final review
- To be published in 2013/2014

269 pages! 646 references! Accuracy Requirements and Uncertainties in **Radiation Therapy** DRAFT 2012-05-31 NOT FOR DISTRIBUTION

Accuracy Requirements and Uncertainties in Radiation Therapy, DRAFT 2012-05-31

Objective of IAEA Report

• To provide an "international guidance document on accuracy requirements and uncertainties in radiation therapy in order to reduce these uncertainties to provide safer and more effective patient treatments".

Factors Determining Accuracy Requirements in RT

- Dose differences that can be detected clinically
- Steepness of dose-response curves
- Accuracy needed for clinical trials
- Dose accuracy that is *practically achievable*

Uncertainties in the **Radiation Treatment Process**

- Patient immobilization ullet
 - Reproducibility in setup
- Imaging for treatment planning \bullet
- Definition of target volume and normal tissues igodol
- Radiation dose measurements ۲
 - Beam commissioning/calibrations
 - For treatment planning systems
- Dose computations ullet
- Treatment plan optimization ullet
 - Forward planning
 - Inverse planning
- Radiobiological considerations/prescription ۲
- Verification imaging ۲
- Patient treatment



Radiation Therapy Planning Process

Back to referring

physician

Indications for

radiotherapy

Treatment

protocols

Protocols for

data acquisition

and target

Protocol for

Diagnosis - Staging

Decision to

treat

Yes

Treatment directive

Positioning and immobilization

Patient anatomical data acquisition

- Imaging (CT, MR)

- Contouring

IAEA Draft Report

Nine recommendations:

- 1. Accuracy statement
- 2. Implement ICRU reports and/or other recognized consensus group recommendations
- 3. Sample guide of uncertainty estimates for both external beam & brachytherapy
- 4. Independent dosimetry audit
- 5. Implement comprehensive QA program
- 6. Appropriate education and training
- 7. Uncertainty estimates should be reported in publications
- 8. Training by vendors on use of technologies
- 9. Areas for further research

IAEA: Recommendation 1

- "All forms of radiation therapy should be applied as accurately as reasonably achievable (AAARA), technical and biological factors being taken into account."
 - E.g., curative larynx vs SRS vs SBRT vs IMRT vs simple palliative treatments vs TBI
 - "... single statement about accuracy requirements in radiation therapy is an over simplification"

IAEA: Recommendation 3

• "The data of Tables 22 and 23 for external beam radiation therapy and brachytherapy, respectively, should be used as a guide for estimating the levels of accuracy that are practically achievable. The tables also provide suggested action levels in cases where deviations occur that are significantly beyond the normal range of values."

Table 22: External Beam

1. Quantity	2. Section	3. Dose Uncertainty (k=1)	4. Spatial Uncertainty (k=1)	5. Action Level ^{**} (~k=2)
Dose at the calibration point in water - Co-60 ion. chamber (SSDL)	5.1.3.1	0.75%		1.5%
- Other photon energy	5.1.5.1	1.5%		3.0%
- Electrons	5.1.5.1	1.4-2.1%		5.0%
Combined Uncertainty		1.6 - 2.6%		
TLD audits				
- RPC – photons	5.1.5.2, 5.2.4	1.7%		5.0%
- RPC - electrons	5.2.4	1.7%		5.0%
- IAEA - MV photons	5.1.5.2	2.1%		5.0%
- IAEA - cobalt-60	5.1.5.2	2.6%		5.0%
- IAEA – non-reference	5.2.2	1.2%		5.0%
Treatment machine-related uncertainties				
Lasers	5.3.5		1-2 mm	
Relative dose ratios (on axis and off axis)	5.2.2.1	2%		2 mm
Beam monitor stability	5.2.2.1	2%		3%
Machine jaw positioning	5.2.2.1		< 1 mm	3%
Wedges	5.2.2.1	2%	2 mm	2 mm
MLC static position	5.2.2.1		< 1 mm	3%/3 mm
MLC dynamic position	5.2.2.1		< 1 mm	2 mm
MLC transmission	5.2.2.1	Several%		2 mm
Table top/couch	5.2.2.1		Variable	-
	5771			

 High dose, low dose gradient High dose gradient Low dose, low dose gradient Build-up Non unit density tissues 	5.2 5.2 5.2 5.2 5.2 5.2	5% 50 2-20%	2-4 mm	3% 3% 4% 20% 4%
Patient (re)positioning				
- Intracranial	5.3		1-2 mm	+
- Head-and-neck	5.3		2-8 mm	+
- Spine	5.3		1-4 mm	+
- Thorax	5.3		10-20 mm	+
- Lung – SBRT	5.3		2-5 mm	+
- Breast	5.3		2-10	+
- Abdomen	5.3		5-15	+
- Prostate	5.3		3-15	+
- Pelvis	5.3		7-15	+
- Extremities [*]	5.3		3-5	+
EBRT end-to-end in phantom	5.2.4, 5.6.4	5%	4 mm	3%/3 mm
EBRT end-to-end in patient [*]	5.6.4	5-10%	5 mm	5%/4 mm

- Sample of issues that should be considered
- Cannot provide data for every clinical scenario
- Institutional protocols should be developed that include typical accuracies that are possible along with action levels

Summary

- New IAEA report provides summary of uncertainty issues in RT
- For common clinical external beam scenarios
 - End-to-end tests with <u>phantoms</u> are able to yield a dose accuracy of 5% and a spatial accuracy of 4 mm
 - End-to-end tests for <u>patient</u> treatments provide a realistic accuracy of 5-10% and 5mm
- For common clinical brachytherapy scenarios
 - End-to-end <u>phantom</u> tests provide realistic dose delivery accuracy of 4-10%