Departments of Oncology and
Medical Biophysics

Accuracy Requirements and Uncertainty Considerations in Radiation Therapy

Introduction and Overview

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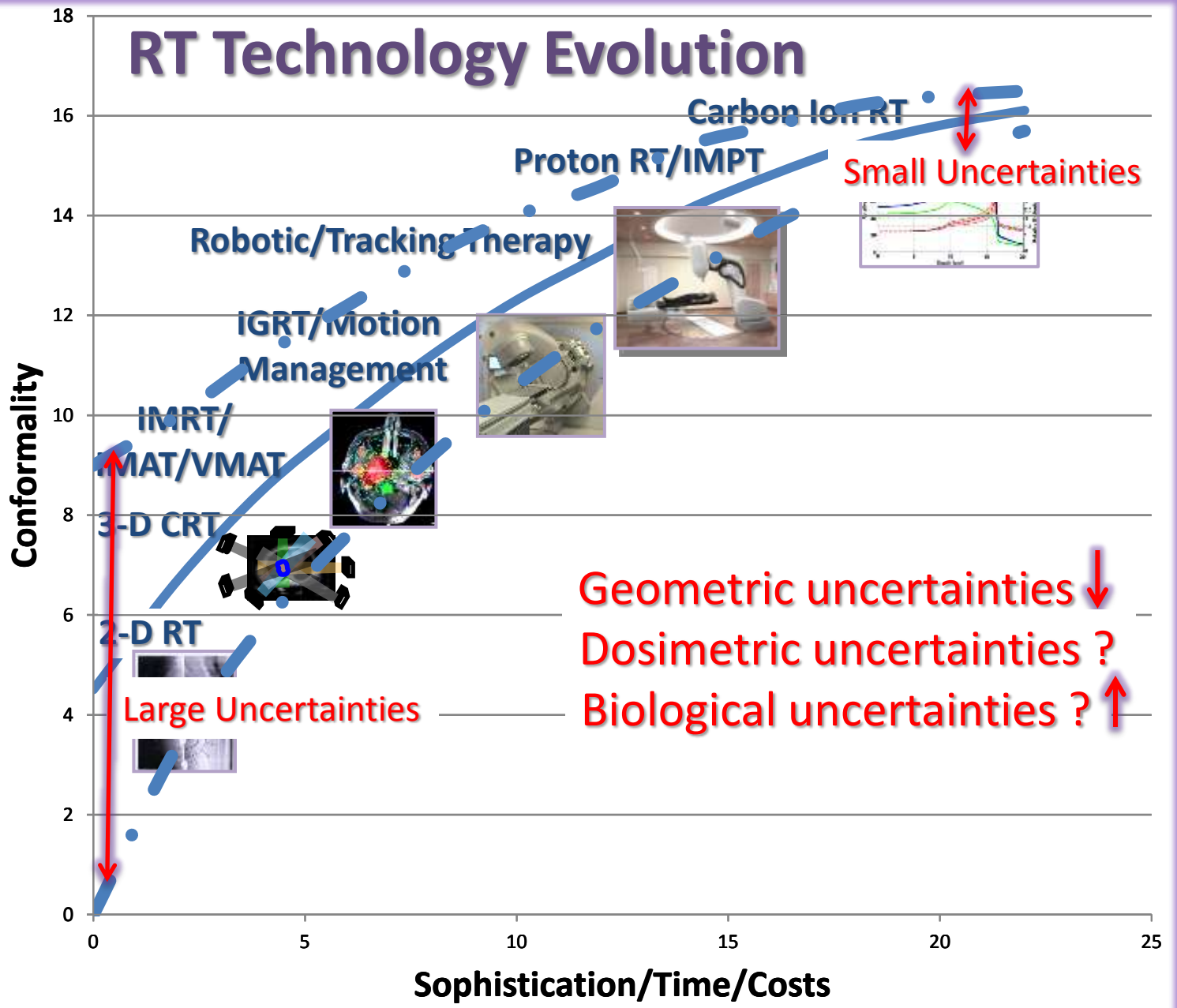
RT Technology Evolution



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 ***uncertainties*** in various stages of treatment process

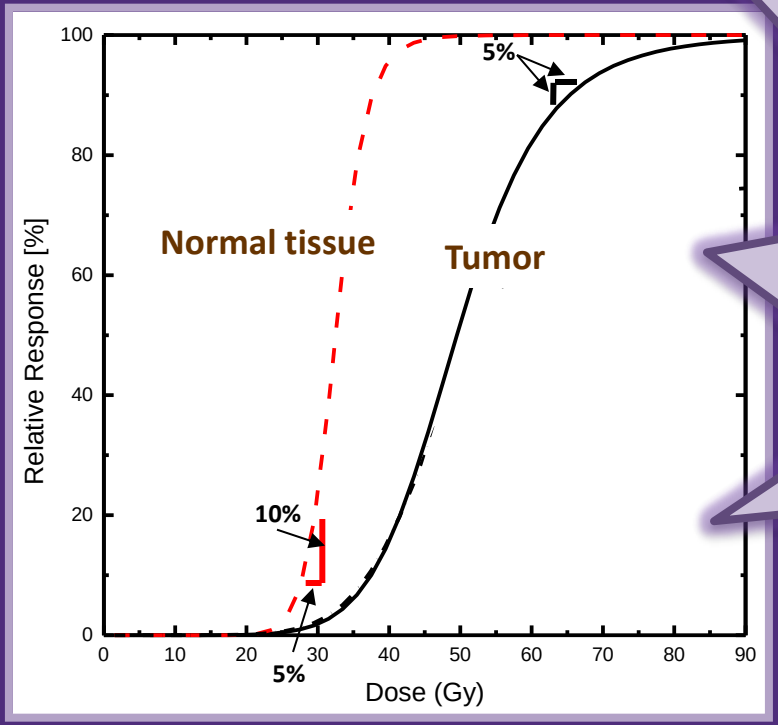
Uncertainties

- New technolo ies
  - nose
  - ose
  - nologies
  - May l mit *unc ties* in ous stages of trea nt proc

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

Accuracy and Uncertainty Issues in Radiation Therapy

- Two considerations in RT
  1. Need for accuracy in RT process
  2. Avoidance of treatment errors/misses



This session is about 1 … accuracy and uncertainties!

This Symposium …

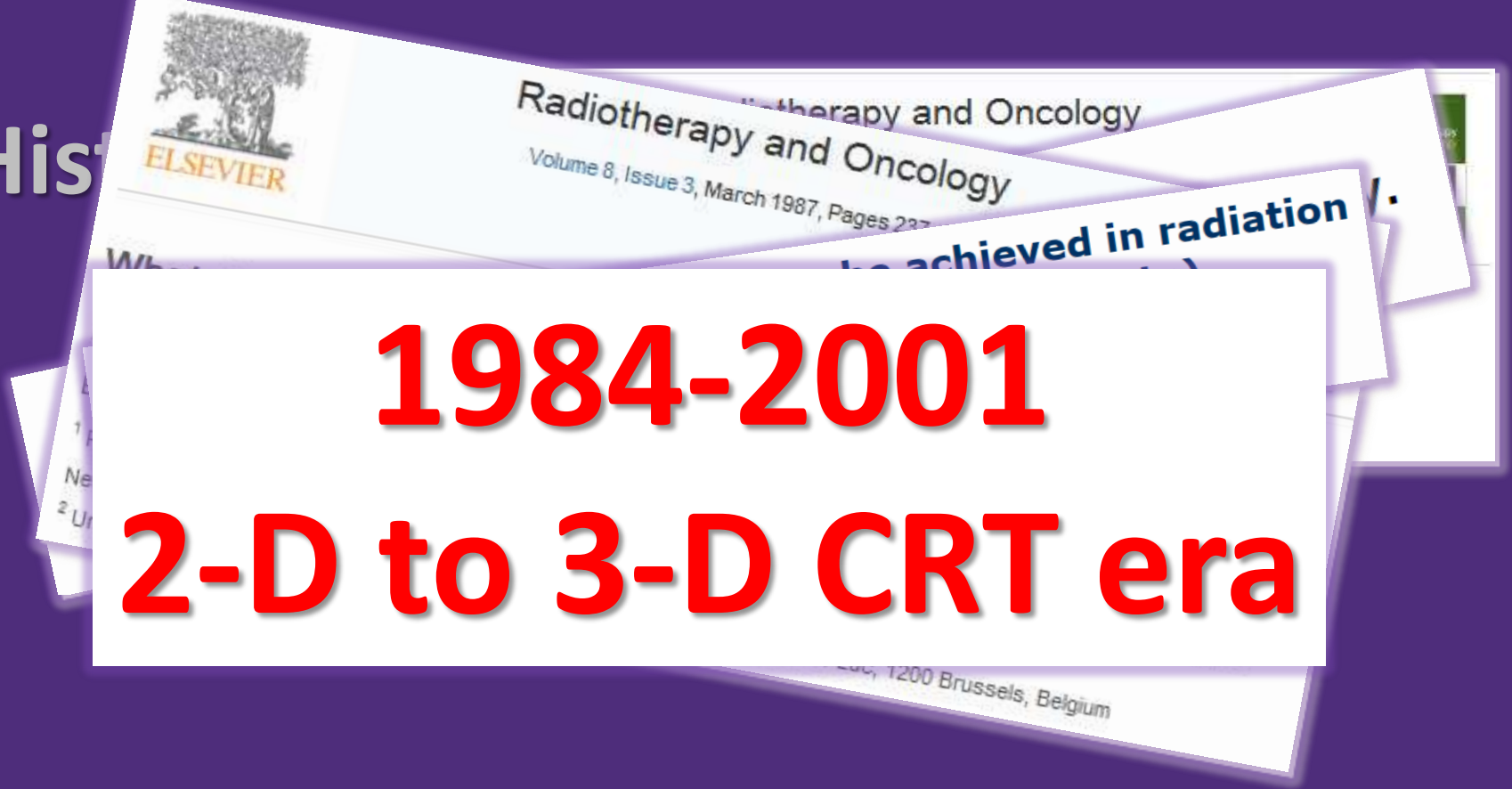
- Review the latest information
  - Accuracy requirements
  - Uncertainty considerations
- Introduction & Overview
  - Jake Van Dyk, Med. Phys., Professor Emeritus, London, Canada
- Radiobiological rationale
  - Søren Bentzen, Biomathematician, Professor Human Oncology, UW, Madison, WI
- Clinical Considerations
  - 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

History

1976: 2-D RT era

… need for an accuracy of ±5% the in the delivery of an absorbed dose to a target volume …”

Hist



1984-2001

2-D to 3-D CRT era

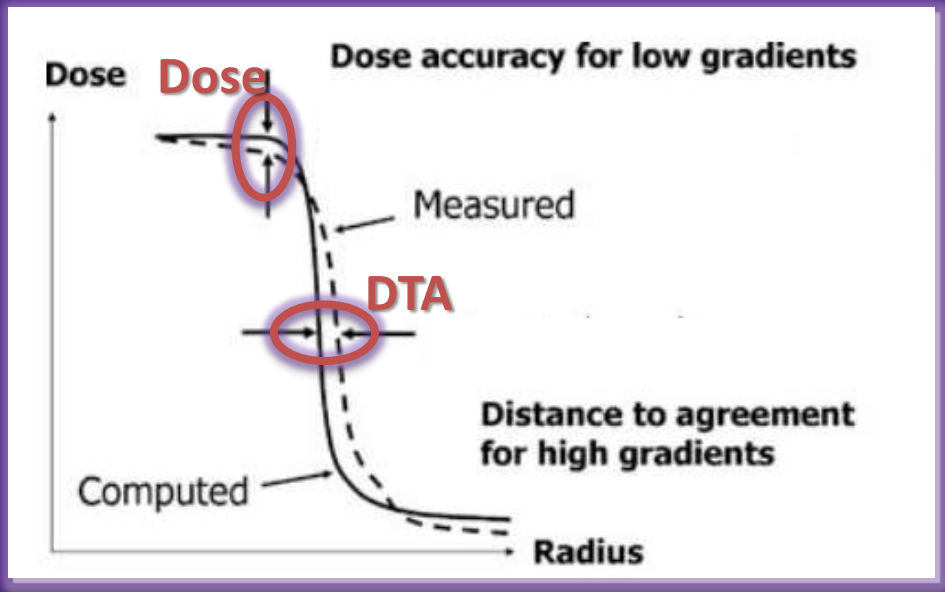
- ***3.5% (1 σ) at specification point and 5% at other points in PTV*** for combined Type A and B uncertainties.
- This required accuracy cannot always be achieved even for simple geometries.

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

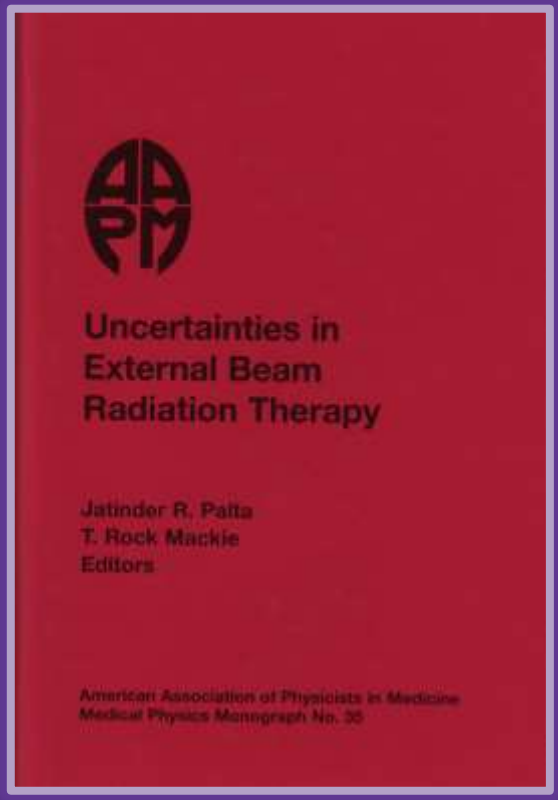
ICRU 83

2010

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

2011 AAPM Summer School



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

Contents

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

Objective of IAEA Report

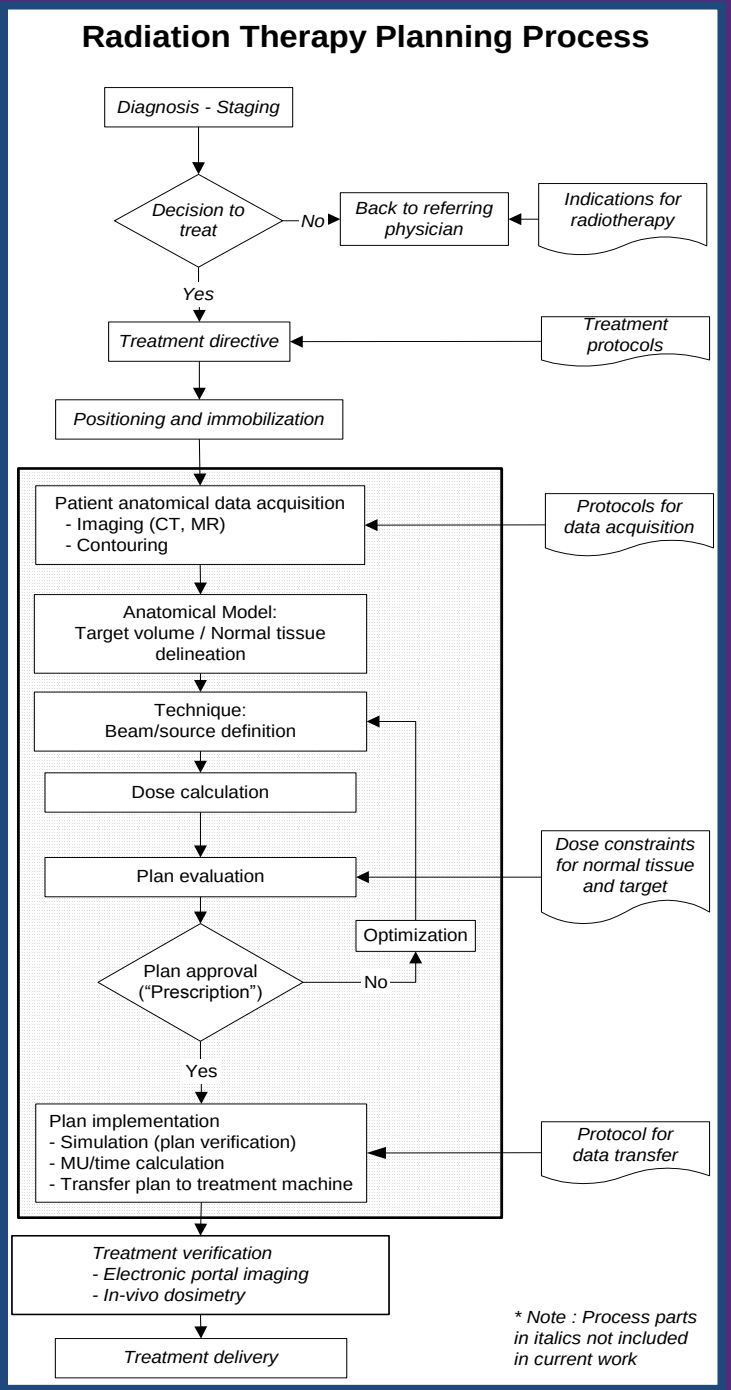
- To provide an "*international guidance document on accuracy requirements and uncertainties in radiation therapy in order to reduce these uncertainties to provide safer and more effective patient treatments*".

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



IAEA TRS 430
Fig. 1

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	-
	5.2.2.1			

axis, high dose, low dose gradient	5.2			**3%**
- High dose gradient	5.2		2-4 mm	**3%**
- Low dose, low dose gradient	5.2	5%		**4%**
- Build-up	5.2	50		**20%**
- Non unit density tissues	5.2	2-20%		**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 phantoms are able to yield a dose accuracy of 5% and a spatial accuracy of 4 mm
  - End-to-end tests for patient treatments provide a realistic accuracy of 5-10% and 5mm
- For common clinical brachytherapy scenarios
  - End-to-end phantom tests provide realistic dose delivery accuracy of 4-10%