Report of ICRU Committee on Volume and Dose Specification for Prescribing, Reporting and Recording in Conformal and IMRT

A Progress Report

Paul M. DeLuca, Jr. 1, Ph.D., Vincent Gregoire2, M.D., Ph.D., Thomas R. Mackie1, Ph.D., André Wambersie2, M.D., Ph.D., Gordon Whitmore3, Ph.D., Reinhard Gahbauer4, M.D.

1University of Wisconsin, Madison, WI, USA
2Université Catholique de Louvain, Brussels, Belgium
3University of Toronto, CA
4Ohio State University, OH, USA
ICRU committee for 3D-CRT and IMRT

**Members**
- Wilfried De Neve MD PhD, Gent, Belgium
- Mary Gospodarowicz MD, Toronto, Canada
- Andrzej Niemierko PhD, Boston, USA
- James A. Purdy PhD, Sacramento, USA
- Marcel van Herk PhD, Amsterdam, The Netherlands

**Sponsors**
- Paul DeLuca PhD, Madison, USA
- Reinhard Gahbauer MD, PhD, Columbus, USA
- André Wambersie MD, PhD, Brussels, Belgium
- Gordon Whitmore PhD, Toronto, Canada

**Chairmen**
- Vincent Grégoire MD PhD, Brussels, Belgium
- T. Rock Mackie PhD, Madison, USA

**Consultants**
- Anders Ahnesjö PhD, Uppsala, Sweden
- Michael Goiten PhD, Windisch, Switzerland
- Nilendu Gupta PhD, Colombus, USA
Why is IMRT so dramatically different?

• Tight relationship between 3D volume imaging and 3D volume therapy!

• Essentially infinite beam directions and intensity choices!

• Result is generally dramatic dose gradients and highly irregular treatment volumes => much greater flexibility available!

• Treatment team needs to delineate numerous volumes, a set of hard/soft constraints, treatment objectives, …. 

• In effect, treatment optimization requires computational assistance and guidance, in effect an independent third party!
Overview of Report → Report Outline

• Introduction
• Optimized Treatment Planning for IMRT
• Special Considerations Regarding Dose and Dose Volume …
• Definitions of Volumes
• Planning Aims, Prescriptions, and Technical Data
• Conclusions and Recommendations
• Appendix A1: Physical Aspects of IMRT
• Appendix A2: Commissioning and Quality Assurance
• Clinical Examples: Three relevant cases
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Optimized Treatment Planning for IMRT

Problem Bounded by Two Types of Constraints:

First – Hard Constraints => Feasible Solutions

- Such constraints limit solutions to ensure NO violation occurs.
- The set of hard constraints defines a feasible but not necessarily ideal or optimized result.
- All feasible solutions are consider equally acceptable by algorithm!
Optimized Treatment Planning for IMRT

Second: Soft Constraints – Treatment Objective Function

• For every goal, a set of possible solutions
• There are many goals!
• Interrelationship between goals may not be defined!
• Solution space large with potentially multiple local extrema
• Solutions are hierarchal in nature!
Optimized Treatment Planning for IMRT

Optimal Solutions – Clinical Judgment

• Optimization algorithm now has deterministic and stochastic elements

• Results may depend on initial conditions.

• Unique results not likely, but range of acceptable solutions likely.

• Clinical judgment final arbitrator and absolutely essential
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Target volumes in Radiation Oncology: ICRU 50 and 62:

- Gross Tumor Volume: GTV
- Clinical Target Volume: CTV
- Internal Target Volume: ITV
- Planning Target Volume: PTV
- Organ at Risk: OAR
- Planning Organ at Risk Volume: PRV
Target volumes in Radiation Oncology

Right piriform sinus (ICDO-10: C12.9)
SCC grade 2
TNM 6th ed: T4N0M0

Fiberoptic examination

Before Rx-CH

46 Gy (Rx-CH)
Target volumes in Radiation Oncology

**Example 1: Boost during treatment**

\[
\begin{align*}
\text{GTV}_1 & \text{ (pre-RxTh CT+ iv contrast)} \\
\text{CTV}_1 & \\
\text{PTV}_1 & : \text{dose}_1 \\
\text{CTV}_2 & = \text{GTV}_1 \\
\text{PTV}_2 & : \text{dose}_2
\end{align*}
\]
Target volumes in Radiation Oncology

Example 2: Active tumor volume change

\[
\text{GTV}_1 \text{ (pre-RxTh CT+ iv contrast)}
\]

\[
\text{CTV}_1
\]

\[
\text{PTV}_1 : \text{dose}_1
\]

\[
\text{GTV}_2 \text{ (FDG-PET @ 46 Gy)}
\]

\[
\text{CTV}_2 = \text{GTV}_2
\]

\[
\text{PTV}_2 : \text{dose}_2
\]
Normal tissues in Radiation Oncology

Organ At Risk (OAR) and Remaining Volume at Risk (RVR)

• Distinction between “serial-like” (e.g. spinal cord) and “parallel-like organs” (e.g. parotid gland),

• For “tubed” organs (e.g. rectum) wall delineation,

• Remaining Volume at Risk (RVR): optimization and late effects (e.g. carcinogenesis).
Normal tissues in Radiation Oncology

Organ At Risk (OAR)

Solid volume delineation

Tubular volume delineation
Normal tissues in Radiation Oncology

Planning Organ at Risk Volume (PRV)

• PRV is a geometrical concept \textit{(tool)} introduced to ensure that adequate sparing of OAR will actually be achieved with a reasonable \textit{probability},

• A positive OAR to PRV margin for serial organ.

• Dose-volume constraints on OAR are with respect to the PRV,

• Priority rules when overlapping PTVs or PTV-PRV(OAR),

• Dose is reported to the PRV.
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Absorbed dose in Radiation Oncology: ICRU 50 and 62:

Dose prescription:
- Responsibility of the treating physician.

Dose reporting:
- ICRU reference point,
- Three-levels of dose reporting,
- Point-doses: $D_{ICRU\ point}$, $D_{min}$, $D_{max}$, …

Dose recording.
Absorbed dose in Radiation Oncology:

Dose recording in 3D-CRT and IMRT

Level of reporting

• Level 1: not adequate for 3D-CRT – IMRT,
• Level 2: standard level for dose reporting,
• Level 3: homogeneity, conformity and biological metrics (TCP, NTCP, EUD, …) and confidence intervals.
ICRU Reference Point Not A “Typical Point” for IMRT

13 segment IM Field

From Jatinder Palta, University of Florida
Absorbed dose in Radiation Oncology:

Metrics for Level 2 reporting of PTV

• Dose-volume reporting:
  - $D_v$: i.e., $D_{50}$ ($D_{\text{median}}$), $D_{95}$
  - $D_{\text{mean}}$
  - “Near” minimum dose: $D_{98}$ or $D_{99}$
  - “Near” maximum dose: $D_2$ or $D_1$

• State the make, model and version number of the treatment planning and delivery software used to produce the plans and deliver the treatment.
Absorbed dose in Radiation Oncology: Dose-Volume Reporting

• $D_{50}$ may best conceptually correspond to the DICRU-point
Absorbed dose in Radiation Oncology: Dose-Volume Reporting

Dose-Volume Histogram

\[ D_{98} \]

\[ D_{50} \text{ is close to ICRU Reference Dose at a Point} \]

- \( D_v \) with \( v \neq 50 \) may require a change in prescription value
Absorbed dose in Radiation Oncology:

Metrics for level 2 reporting of PRV

• “Serial-like” organs:
  - $D_{\text{near-min}} = D_{98\%}$.

• “Parallel-like” organs:
  - $D_{\text{mean}}$ (e.g. parotid),
  - $V_d$ where $d$ refers to dose in Gy (e.g. $V_{20\text{ Gy}}$ for lung).
Absorbed dose in Radiation Oncology: Homogeneity and Conformity

- Low Homogeneity – High Conformity
- High Homogeneity – High Conformity
- Low Homogeneity – Low Conformity
- High Homogeneity – Low Conformity
Absorbed dose in Radiation Oncology:
Examples of metrics for level 3 reporting of PTV

• Homogeneity:
  - Standard deviation in dose to the PTV.

• Conformity Index:
  - $CI = TV/PTV$,

• Dice Similarity Coefficient (DSC):
  - $DSC = (TV \cap PTV)/(TV \cup PTV)$
Yet another clinical challenge!
Conclusions

• ICRU recommendations still needed even for 3D-CRT and IMRT to avoid unwanted treatment heterogeneity,

• New report based on ICRU foundations, e.g., volumes,

• Adjustments and modifications performed when necessary, e.g., dose-volume reporting,

• Final draft in production / publication in 2009-2010.