

**Improving Dose Prescriptions for
Safety, Reporting, and Clinical
Guideline Consistency**

Part III

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**Keeping Guidelines On Track:
The Effect On Clinical Practice of
Neglecting Guidelines for Dose
Prescription and Reporting**

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Why not go off the rails?

- Are guidelines followed?
- Why should the MD care?
- Why choose ICRU guidelines?
- How to get back on track?



ICRU 83

- "...allows dose-volume-based prescription and reporting. In modern radiation therapy, **the specification of the absorbed dose to relevant anatomic volumes rather than to single points is critical to the communication of the treatment intent.**"

ICRU 83 guidelines Prescription Format

- "The report does not recommend any particular value of V in D_v for a prescription. However, **the median absorbed dose, D50 %, is likely to be a good measure** of a typical absorbed dose in a relatively homogeneously irradiated tumor."

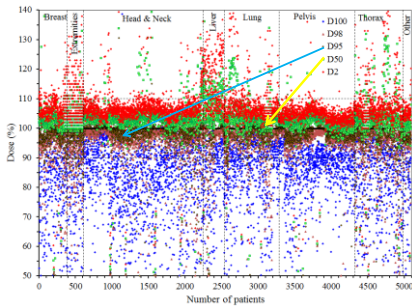
ICRU 83 Reporting

- "The report recommends that the **median absorbed dose, specified by D50 %, should be reported**, as it is considered to correspond best with the previously defined dose at the ICRU reference point."

ICRU 83
Reporting

- the following definition for homogeneity index is suggested:

$$HI = \frac{D_{2\%} - D_{98\%}}{D_{50\%}}$$



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NRG HN-001

Name of Structure	Dosimetric parameter*	Per Protocol	Variation Acceptable	Notes (Remove this column when notes are not needed)
PTV_7000 or PTV_7000_Eval	<100%[%]	95	90	
	D99%[%]	>=90	>=85	
	D0.03cc[%]	<=115	<=120	

NRG HN-002


Table 5.2.10: Planning Target Volume and Critical OAR Constraints and Compliance Criteria

Name of Structure	Dosimetric parameter*	Per Protocol Dose (Gy)	Variation Acceptable
PTV_6000	D _{95%} *(Gy)	60	> 60 and ≤ 63
	D _{98%} (Gy)	≥ 55.8	≥ 54
	D _{max} ***(Gy)	≤ 66	≤ 69

	Prescription	Protocol Target Dose Criteria
E1308 2010 ICRU 62 volumes referenced	5.1.2.6 IMRT Planning All plans shall be normalized such that at least 95% of the volume of the PTV is covered by the prescribed isodose surface.	PTV $V_{100\%} \geq 95\%$ $V_{108\%} \leq 3\%$ $D_{95} \geq 95\%$ $D_{93} \geq 93\%$ Body $V_{110\%} \leq 0\%$
NRG HN001 2014 ICRU 83 volumes referenced	6.1Dose Specifications (04May2017) 6.1.1 IMRT Dose Prescription to PTVs the PTV69.96 (CTV69.96 + margin) will receive 69.96 Gy at 2.12 Gy per fraction. PTV=GTV+11-13mm	PTV $V_{100\%} = 95\% - 90\%$ $D_{99} \geq 90\% - 85\%$ $D_{03\%} \leq 115\% - 120\%$ Acceptable → per protocol
NRG HN002 2014	5.2.8 The treatment goal is that 95% of the volume of all PTVs must receive the prescribed dose minimum dose (defined as dose to 99% of PTVs)	PTV $D_{99} = 100\% - 105\%$ $D_{99} \geq 93\% - 90\%$ $D_{03\%} \leq 110\% - 115\%$ Acceptable → per protocol

	Prescription	Protocol Target Dose Criteria
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NRG HN002 2014	5.2.8 The treatment goal is that 95% of the volume of all PTVs must receive the prescribed dose minimum dose (defined as dose to 99% of PTVs)	PTV $D_{99} = 100\% - 105\%$ $D_{99} \geq 93\% - 90\%$ $D_{03\%} \leq 110\% - 115\%$ Acceptable → per protocol

	Reporting	Protocol Target Dose Criteria
E1308 2010 ICRU 62 volumes referenced	Prescription Dose Maximum point dose PTV $V_{100\%}$, $V_{110\%}$, $V_{110\%}$, $V_{110\%}$, $V_{110\%}$, mean	PTV $V_{100\%} \geq 95\%$ $V_{100\%} \leq 3\%$ $D_{95} \geq 95\%$ $D_{95} \geq 93\%$ Body $V_{110\%} \leq 50\%$
NRG HN001 2014 ICRU 83 volumes referenced	Plan in DICOM RT Dose-Volume Analysis Review $V_{100\%}$, $D_{0.03cc}$ 	PTV $V_{100\%} = 95\% - 90\%$ $D_{95} \geq 90\% - 85\%$ $D_{0.03cc} \leq 115\% - 120\%$ Acceptable \rightarrow per protocol
NRG HN002 2014	Plan in DICOM RT Dose-Volume Analysis Review $V_{100\%}$, $D_{0.03cc}$, $D_{95\%}$, $D_{99\%}$, $D_{0.03cc}$	PTV $D_{95} = 100\% - 105\%$ $D_{95} > 93\% - 90\%$ $D_{0.03cc} \leq 110\% - 115\%$ Acceptable \rightarrow per protocol

ICRU 83 Guidelines are not Always Followed

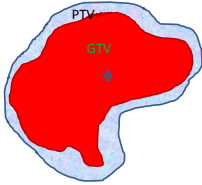
- Absorbed dose is not specified to a volume
We don't see $Rx = D_v$
- Dose bounds are placed on D_{95} but not D_{50}
- Homogeneity Index is not reported
- Maximum dose is determined as $D_{abs vol}$.
- Minimum dose is determined as D_{99}
- Reporting misses D_{50}

Why should the MD care?

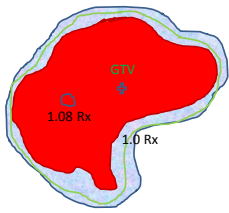
- Why should there be guidelines?
- Why ICRU?

Why a Guideline?

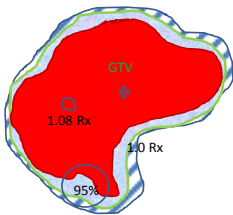
Absent a Prescription Rule,
The Dose Plan is Undetermined under Competing Aims



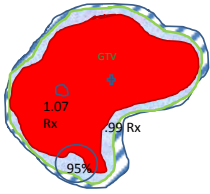
- Goals
- $D_{95} \geq 95\% \text{ Rx}$
 - $D_{.03\text{cc}} \leq 107\% \text{ Rx}$
 - $V_{100} \geq 95\% \text{ Rx}$



- Goals
- $D_{95} \geq 95\% \text{ Rx}$
 - $D_{.03\text{cc}} \leq 107\% \text{ Rx}$
 - $V_{100} \geq 95\% \text{ Rx}$

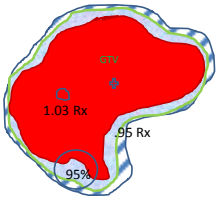


- Achieved
- ✓ $D_{95} = 100\% \text{ Rx}$
 - ❖ $D_{.03\text{cc}} = 108\% \text{ Rx}$
- Goals
- $D_{95} \geq 95\% \text{ Rx}$
 - $D_{.03\text{cc}} \leq 107\% \text{ Rx}$



Achieved
 ✓ $D_{95} = 99\% \text{ Rx}$
 ✓ $D_{.03cc} = 107\% \text{ Rx}$

Goals
 $D_{95} \geq 95\% \text{ Rx}$
 $D_{.03cc} \leq 107\% \text{ Rx}$



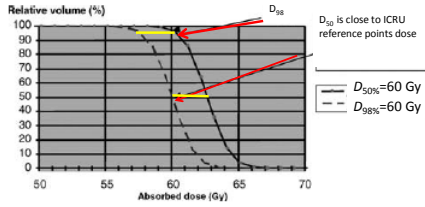
Achieved
 ✓ $D_{95} = 95\% \text{ Rx}$
 ✓ $D_{.03cc} = 103\% \text{ Rx}$

Goals
 $D_{95} \geq 95\% \text{ Rx}$
 $D_{.03cc} \leq 107\% \text{ Rx}$

MD Directive ~~————— X ———>~~ Dose Distribution
 Published Guideline ~~————— X ———>~~ Dose Distribution

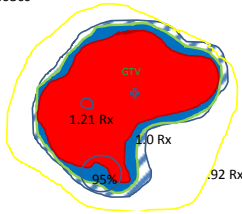
- “It is strongly recommended that if the method of prescription in a protocol or treatment aim is changed from a point-dose to a dose-volume approach, the impact on the absorbed dose received by patients should be determined.”

ICRU 83



ICRU 83

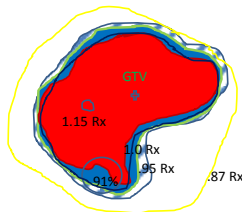
Goals
 $V_{100} = 95\% \rightarrow 90\%$
 $D_{99} = 90-85\%$
 $D_{.03cc} \leq 115-120\% \text{ Rx}$



Achieved

- ✓ $V_{100} = 95\% \text{ Rx}$
- ❖ $D_{.03cc} = 121\% \text{ Rx}$
- ✓ $D_{99} = 92\% \text{ Rx}$

Goals
 $V_{100} = 95\% \rightarrow 90\%$
 $D_{.03cc} \leq 115-120\% \text{ Rx}$
 $D_{99} = 90-85\%$

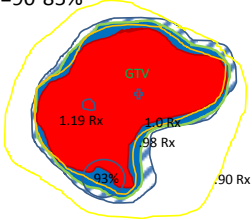


Achieved

- ☐ $V_{100} = 91\% \text{ Rx}$
- ✓ $D_{.03cc} = 115\% \text{ Rx}$
- ☐ $D_{99} = 87\% \text{ Rx}$

Goals

- $V_{100} = 95\% \rightarrow 90\%$
- $D_{.03cc} \leq 115 - 120\% Rx$
- $D_{99} = 90 - 85\%$



Achieved

- $V_{100} = 93\% Rx$
- $D_{.03cc} = 119\% Rx$
- $D_{99} = 90\% Rx$

Standardization Fosters Outcome Comparisons by Reducing Noise

Agent	Population		
	Rx D_{95}	Rx D_{50}	Total
A =60	652	771	1423
B =60	648	770	1418
C =60	581	571	1152
D =60	718	231	949
E =60	589	445	1034

Agent	Proportion of Cures in Sample		
	Rx D_{95}	Rx D_{50}	All
A	0.6	0.57	0.583
B	0.62	0.55	0.583
C	0.56	0.53	0.545
D	0.59	0.58	0.588
E	0.6	0.59	0.596

Actual Cures			
Agent	Rx D ₉₅	Rx D ₅₀	Total
A	391	439	830
B	402	424	826
C	325	303	628
D	424	134	558
E	353	263	616

Observed Cures		
Agent	Cures	Not Cures
A	830	593
B	826	592
C	628	524
D	558	391
E	616	418

Probability if Independent by Chi Square= 0.13089

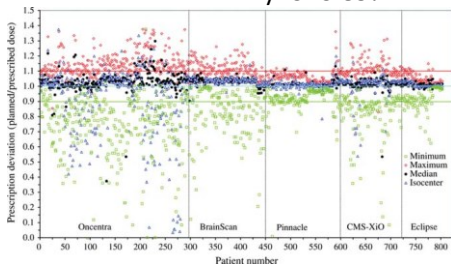
Agent	Population		Observed Cures	
	Rx D ₉₅	Rx D ₅₀	Rx PTV	Rx D ₅₀
A	1423	0	854	0
B	1418	0	879	0
C	1152	0	645	0
D	949	0	560	0
E	1034	0	620	0

Probability if Independent by Chi Square = 0.042547

Agent	Population		Actual Cures	
	Rx D ₉₅	Rx D ₅₀	Rx PTV	Rx D ₅₀
A	0	1423	0	811
B	0	1418	0	780
C	0	1152	0	611
D	0	949	0	550
E	0	1034	0	610

Probability if Independent by
Chi Square= 0.035309

Why ICRU 83?

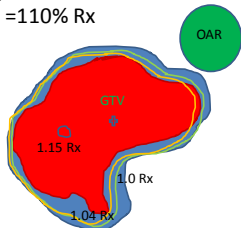


From ICRU 83, taken from Das, I (2008)

Goals

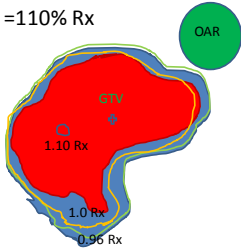
D₉₅ = 100%
D₀₂ = 110% Rx

D₉₅ is easily manipulated

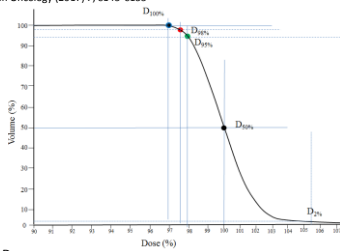


Achieved
✓ D₉₅ = 100%
❖ D₀₂ = 115% Rx

Goals
D₉₅ =100%
D₀₂ =110% Rx



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$\Delta D / \Delta V$ is small near D₅₀

"The greatest slope for the cumulative DVH is at or close to the median absorbed dose D50" ICRU 83

Why Report D₅₀

- Without D₅₀ we lack information on dose given to the majority of the tumor
 - "You can't cure the tumor if you don't hit it"
- Looking at min and max point doses discounts error in calculation and boundary position of the tumor

How to get back on track

- Specify a prescription value relative to $D_v = D_v$
- Plan to reach D_v under the constraint bounds
- Demand proof if D_v infeasible
- Use $D_v = D_{50}$
 - If D_{50} taken as mean, the formulation of the objective is not combinatorial.
- List all critical values in treatment guidelines



Next Generation of Treatment Guidelines
Training that is Hype, Hyper or Loopy
