Best Practice Review: Dosis-Verschreibung in der STX für kraniale, thorakale und abdominelle Indikationen

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Historically

- inhomogeneous dose was prescribed
- to a certain PTV encompassing isodose line,
- Normalization was done on the maximum dose or a representative dose point inside the target volume.

The problem

- Planner experience: highest variability
- Machine / technology: some variability
- Which leading planning objective leads to the most harmonized plans and is of clinical relevance?
- How many parameters do we need for dose prescription?

ICRU REPORT No. 91

PRESCRIBING, RECORDING, AND REPORTING OF STEREOTACTIC TREATMENTS WITH SMALL PHOTON BEAMS

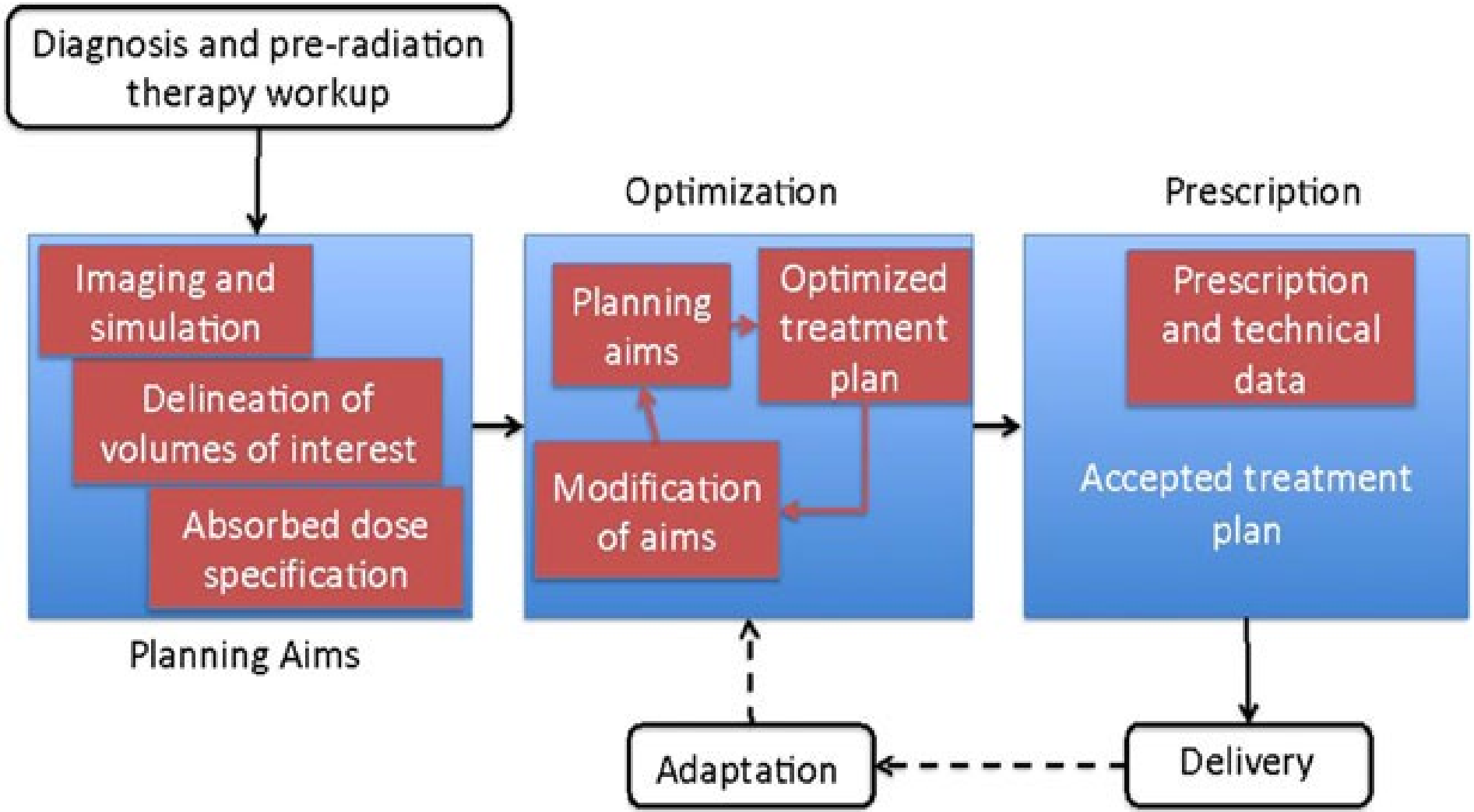
THE INTERNATIONAL COMMISSION ON
RADIATION UNITS AND
MEASUREMENTS
(Published July, 2017)

ICRU report 91

- The new ICRU report 91 recommends for stereotactic treatments to prescribe the dose to the isodose surface that covers an optimal percentage of the PTV.

- Additionally, it is recommended that the prescription does not only specify the prescribed dose and the normalization method but
- **a comprehensive set of accepted values for target coverage**
- and organ at risk doses.

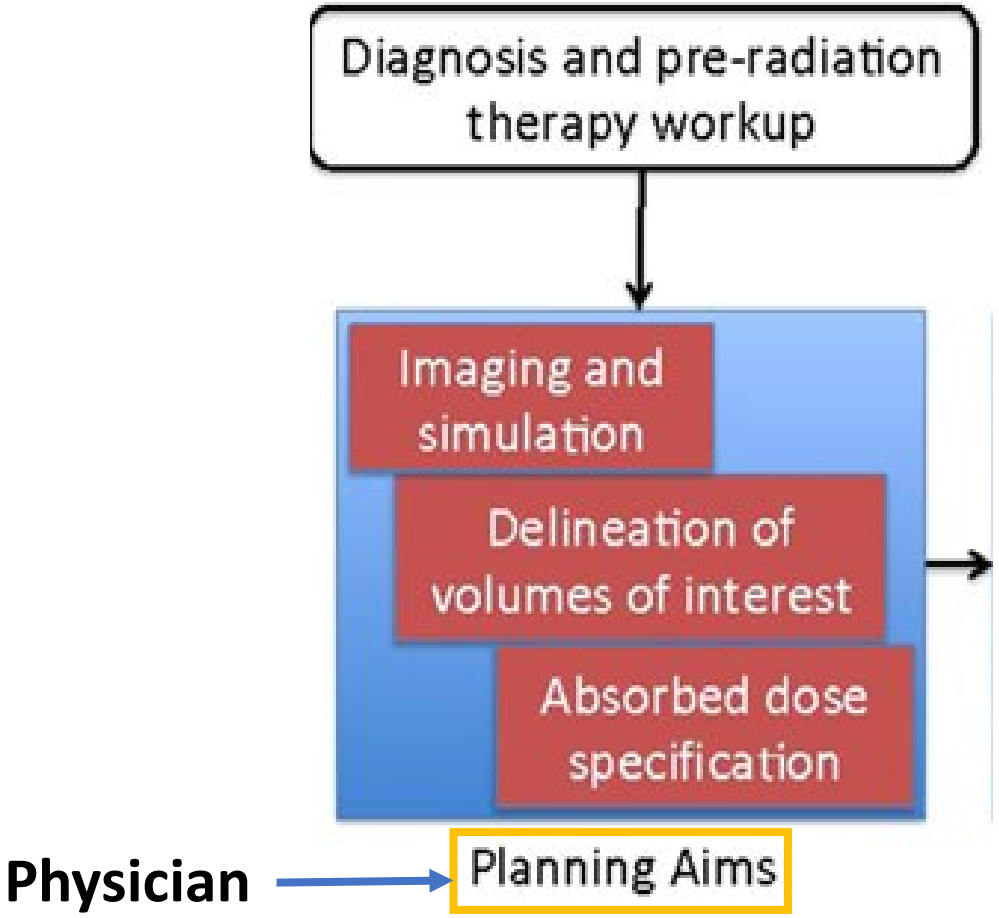
ICRU 91: Flowchart of a typical SRT course



ICRU 91, 2017

ICRU 91: Dose Prescription in SRT

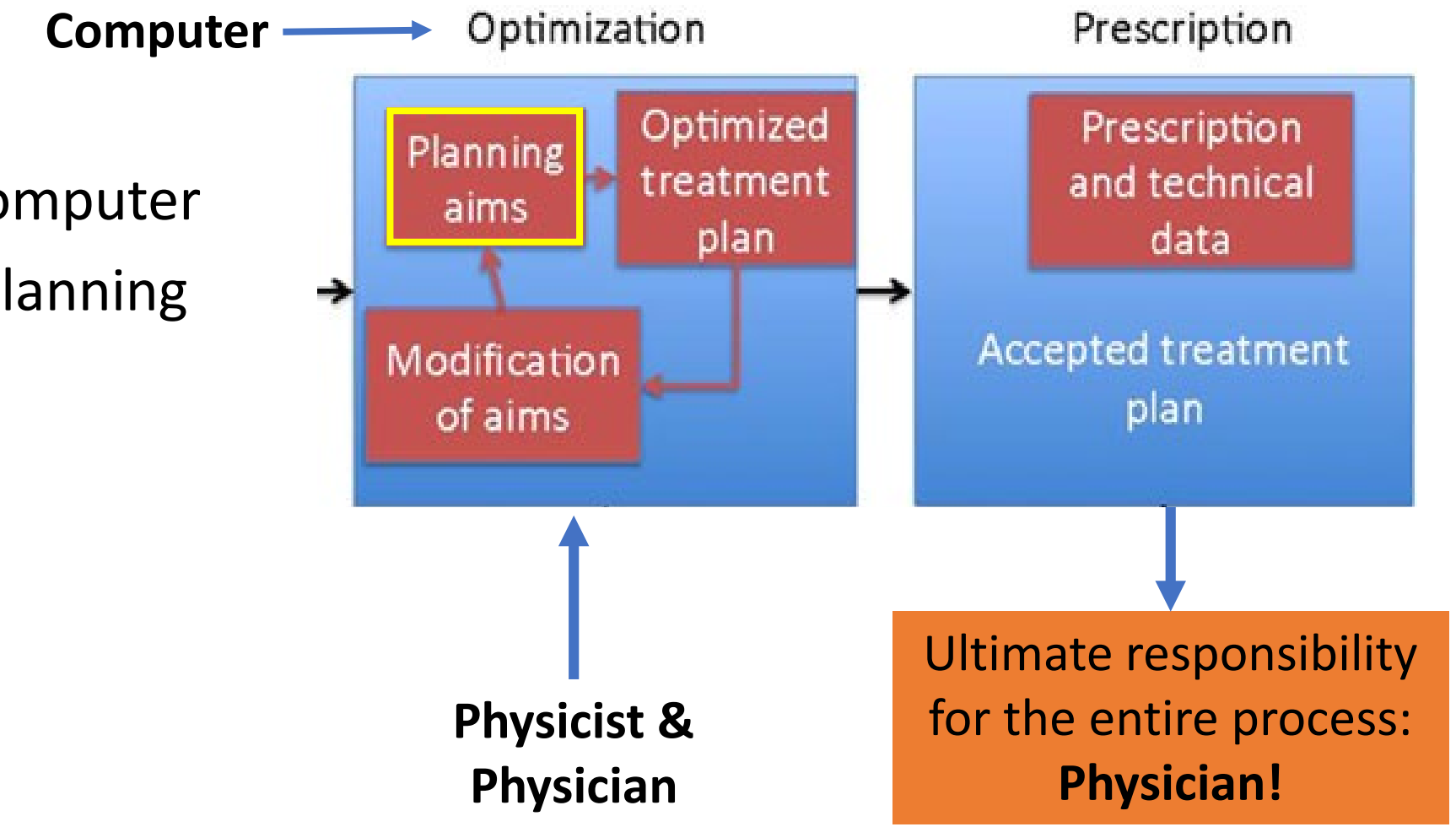
1. Describe & define the planning aims (treatment goals)
2. Aims are:
   a. Volumes of interest (PTV, PRV)
   b. desired dose levels in volumes
3. Usually, the planning aims are specified by the treating physician.



ICRU 91, 2017

ICRU 91: Dose Prescription in SRT

- Optimization by the computer
- Adjustment of initial planning aims if required
- By:
  - physicist/dosimetrist
  - physician



ICRU 91, 2017

Strahlenther Onkol (2019) 195:193–198
https://doi.org/10.1007/s00066-018-1416-x

REVIEW ARTICLE

ICRU report 91 on prescribing, recording, and reporting of stereotactic treatments with small photon beams

Statement from the DEGRO/DGMP working group stereotactic radiotherapy and radiosurgery

Lotte Wilke[1] · Nicolaus Andratschke[1] · Oliver Blanck[2] · Thomas B. Brunner[3] · Stephanie E. Combs[4] · Anca-Ligia Grosu[5] · Christos Moustakis[6] · Daniela Schmitt[7] · Wolfgang W. Baus[8] · Matthias Guckenberger[1]

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ICRU 91 dose prescription and reporting

- **prescribe to isodose surface: cover ‘optimal’ percentage of the PTV**
- “optimal” is then strongly depending on the actual treatment situation: brain versus lung, etc.
- PTV: median dose (D50%), PTV Dnear-min and PTV Dnear-max
- GTV/CTV/ITV: D50% (for lung SBRT required, for non-lung optionally)
- OAR: Dmean, Dnear-max & another relevant VD% value
- Dose homogeneity (e.g. Dmean to PTV % SD of Dmean to PTV),
- Dose conformity CI

Wilke L et al. STO 2019

Changes in dose prescription and dose reporting from ICRU reports 50, 62, 83 and 91

ICRU Report	Prescribing	Reporting		
		Level 1 Basic	Level 2 Advanced	Level 3 Developmental
50	ICRU reference point	ICRU reference point D_{min} D_{max}	Planes	Volumes
62	ICRU reference point	ICRU reference point D_{min} D_{max}	Planes Volumes	Novel methods, non-specified
83	Particular value of V in DV for prescription. Median dose likely to be good measure	n.a.	DVHs PTV: $D_{50\%}$ D_{mean} $D_{2\%}$ $D_{98\%}$ OAR, PRV: D_{mean} $D_{2\%}$ V_D	Dose- Homogeneity CI TCP EUD
91	Covering isodose surface of PTV	n.a.	DVHs PTV:	Integral dose Biology based parameters

ICRU 91: Prescribing to covering isodose

Level 2*:

(advanced)

- $D_{2\%}$
- V_D
- DVHs
- PTV:
- $D_{50\%}$
- D_{mean}
- $D_{near\text{-}min}$
- $D_{near\text{-}max}$
- OAR, PRV:
- D_{mean}
- $D_{near\text{-}min}$
- V_D
- Dose-Homogeneity
- CI
- GI

Level 3: Integral dose

Biology based parameters

(developmental)

GTV
CTV
ITV
?

***Level 1: not applicable**

Wilke L et al. STO 2019
ICRU 91, 2017

Mögliche Parameter der Dosisverschreibung

PTV	(ITV)	(CTV)	GTV
Covering isodose			
$D_{\_median}$	$D_{\_median}$	$D_{\_median}$	$D_{\_median}$
$D_{\_near\_min}$	$D_{\_near\_min}$	$D_{\_near\_min}$	$D_{\_near\_min}$
$D_{\_near\_max}$	$D_{\_near\_max}$	$D_{\_near\_max}$	$D_{\_near\_max}$
$D_{\_mean}$	$D_{\_mean}$	$D_{\_mean}$	$D_{\_mean}$
$D_{\_min}$	$D_{\_min}$	$D_{\_min}$	$D_{\_min}$
$D_{\_max}$	$D_{\_max}$	$D_{\_max}$	$D_{\_max}$

Indices: Conformity, Homogeneity, Gradient

Strahlenther Onkol (2020) 196:417–420
https://doi.org/10.1007/s00066-020-01603-1

CONSENSUS STATEMENT

Definition and quality requirements for stereotactic radiotherapy: consensus statement from the DEGRO/DGMP Working Group Stereotactic Radiotherapy and Radiosurgery

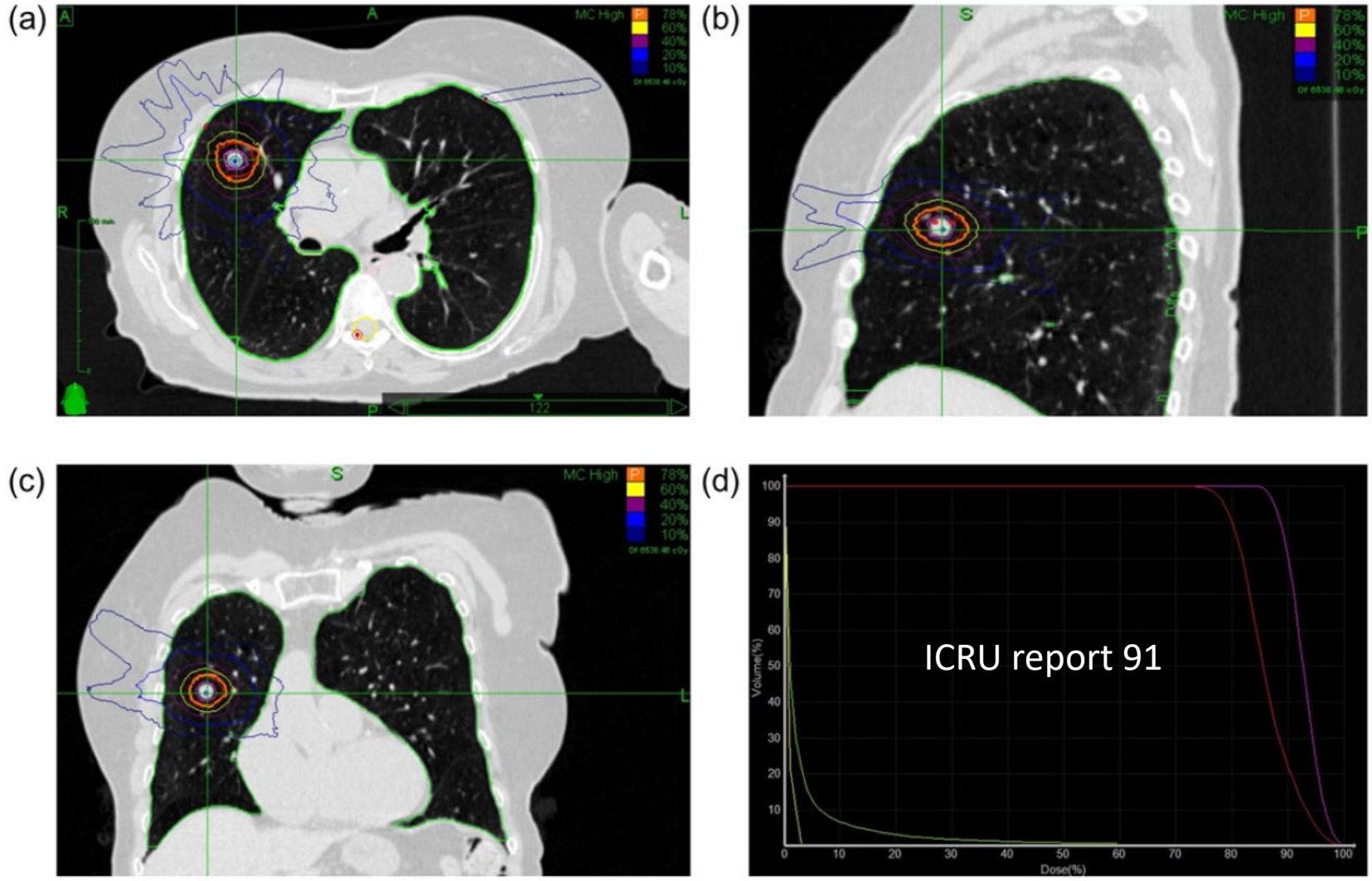
Matthias Guckenberger[1] · Wolfgang W. Baus[2] · Oliver Blanck[3] · Stephanie E. Combs[4] · Jürgen Debus[5] · Rita Engenhart-Cabillic[6] · Tobias Gauer[7] · Anca L. Grosu[8] · Daniela Schmitt[5] · Stephanie Tanadini-Lang[1] · Christos Moustakis[9]

Published online: 24 March 2020

Abstract

Stereotactic radiotherapy with its forms of intracranial stereotactic radiosurgery (SRS), intracranial fractionated stereotactic radiotherapy (FSRT) and stereotactic body radiotherapy (SBRT) is today a guideline-recommended treatment for malignant or benign tumors as well as neurological or vascular functional disorders. The working groups for radiosurgery and stereotactic radiotherapy of the German Society for Radiation Oncology (DEGRO) and for physics and technology in stereotactic radiotherapy of the German Society for Medical Physics (DGMP) have established a consensus statement about the definition and minimal quality requirements for stereotactic radiotherapy to achieve best clinical outcome and

Lung



DEGRO AG: Lung SBRT planning study prior ICRU 91

main planning objective:

- 3 x 15 Gy (BED = 112 Gy10) enclosing the PTV
- Dmax(PTV) = 69.23 Gy (Dmax BED = 229 Gy10) according to previous publications of the DEGRO AG*

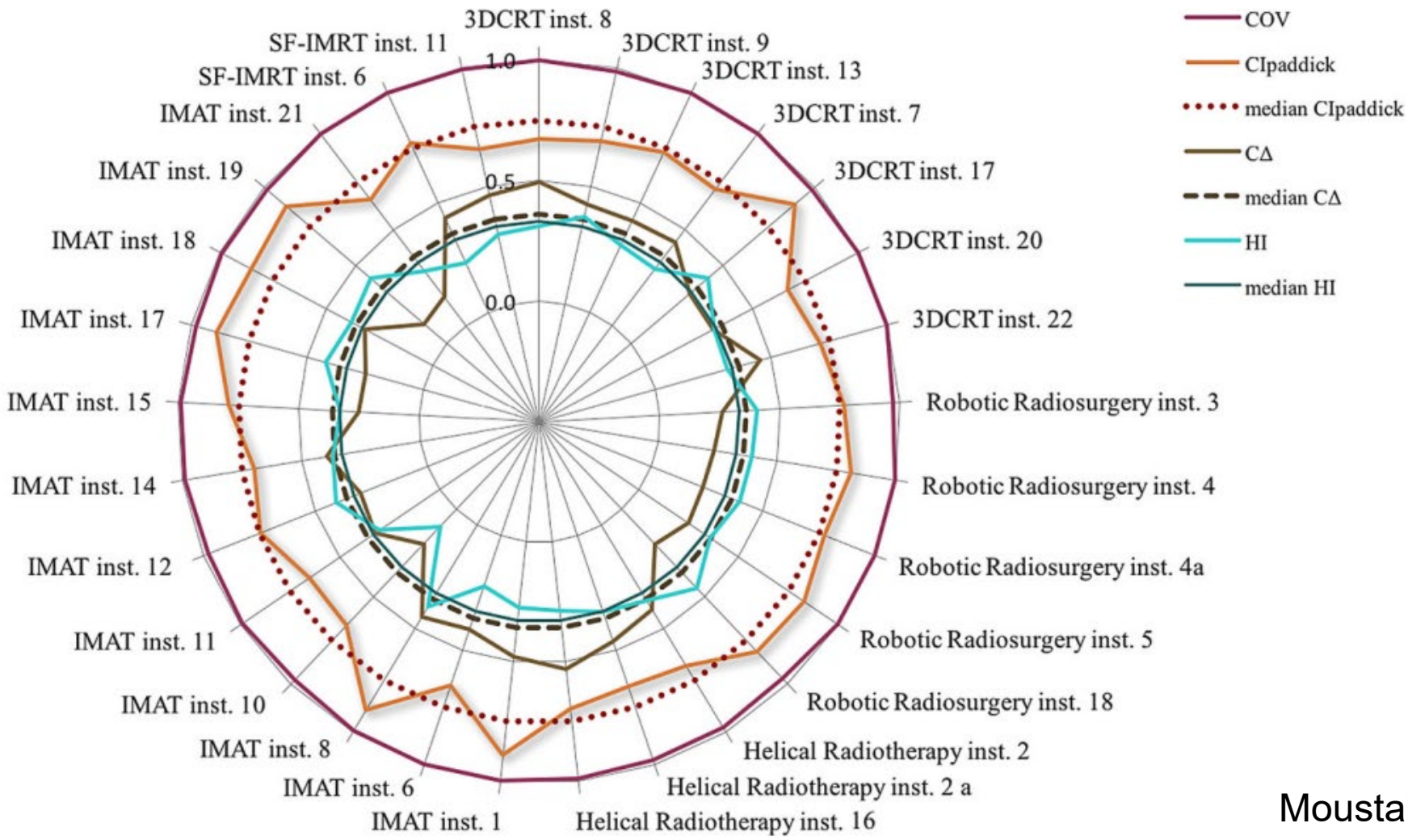
prescription to:

- PTV encompassing 65% isodose and
- D2% or D5% of the PTV

Moustakis C et al. Strahlenther Onkol 2017

*Guckenberger M et al (2013) J Thorac Oncol 8(8):1050–1058
*Guckenberger M et al (2016) Radiother Oncol 118(3):485–491

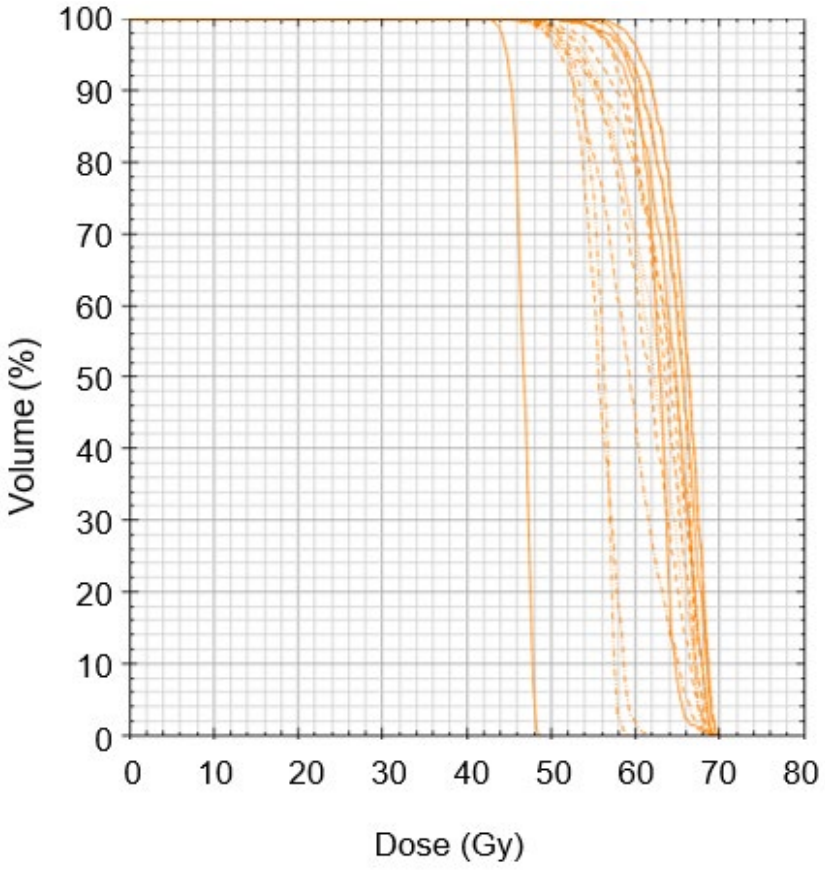
Ok: some differences but looks not too bad?



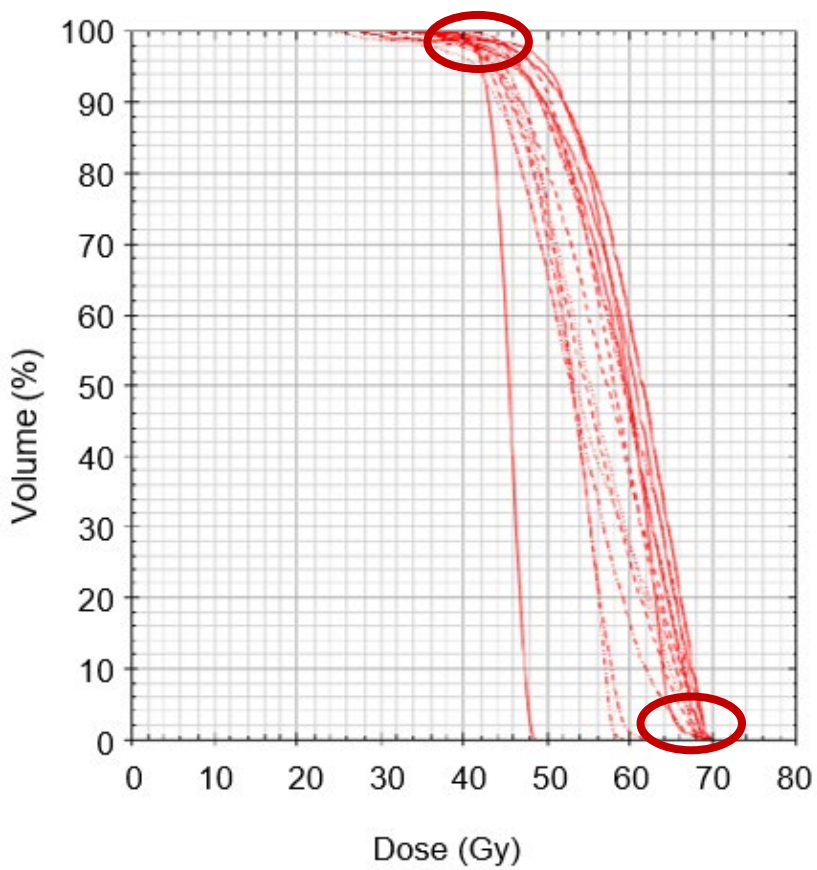
Moustakis C et al. STO 2017

DVHs lung case: the full truth of inhomogeneity

GTV



PTV



Planning goals:

- PTV encompassing dose
- D_{PTV_max}

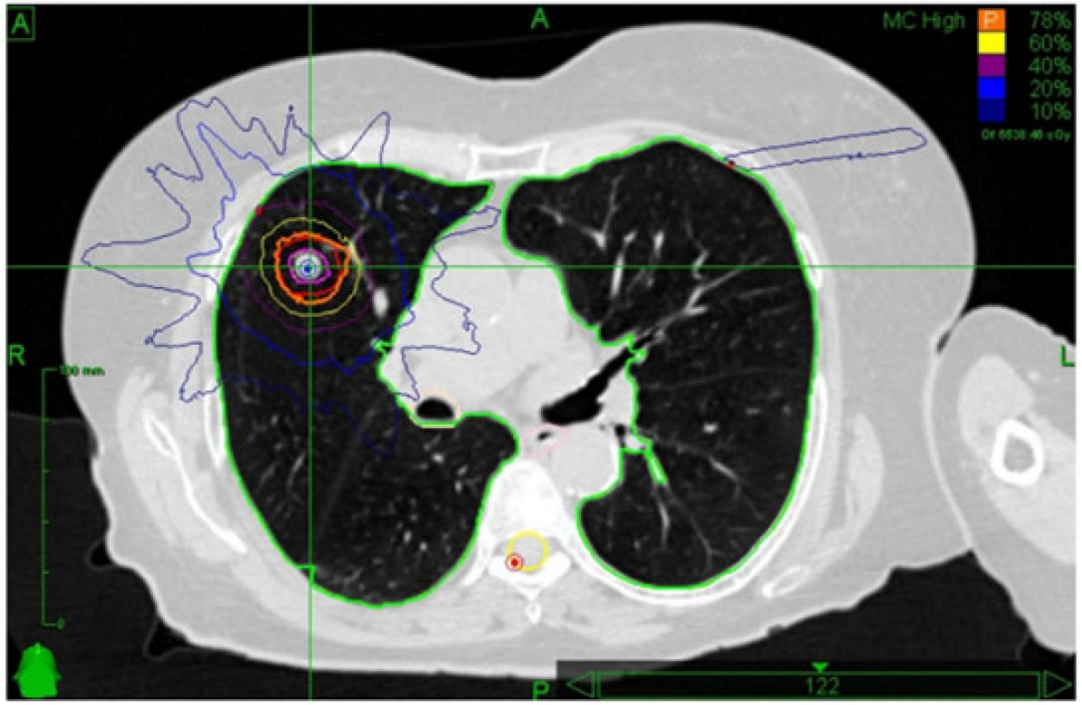
Moustakis C et al. RedJ22

Characteristics of lung SBRT dose prescription

- **neither Dmin, nor the reference point** can adequately describe the dose distribution generally delivered:
- a **substantially lower Dmin absorbed within the air** surrounding the GTV, which is inherently part of the PTV border zone, in comparison to the intended delivered dose due to the loss of charged particle equilibrium.
- Additionally, the reference point would be **a mere random point anywhere in the PTV**: of limited relevance for the **outcome** of lung SBRT

Example from the ICRU report 91

3 fractions	Dose to PTV (6.7 cm^3) Gy	Dose to GTV (1.5 cm^3) Gy
D98%	50.4	56.6
D50%	56.0	60.6
D02%	63.4	64.5



Prescription: 3 x 17 Gy -> 51 Gy to the 74% isodose

(100% isodose = 68.9 Gy)

Technique: Cyberknife (motion tracking)

Margins: PTV = GTV + 5 mm

ICRU report 91

Lung SBRT: preparation for the next step

- Focussing on 3 fractions
- Most common prescription for lung SBRT (in the periphery)
- Early NSCLC
- Pulmonary metastases

Do it once again! Post ICRU 91.

Strahlenther Onkol (2021) 197:836–846
https://doi.org/10.1007/s00066-021-01799-w

ORIGINAL ARTICLE

Improving interinstitutional and intertechnology consistency of pulmonary SBRT by dose prescription to the mean internal target volume dose

L. Wilke[1] · C. Moustakis[26] · O. Blanck[2] · D. Albers[28] · C. Albrecht[3] · Y. Avcu[4] · R. Boucenna[5] · K. Buchauer[6] · T. Etzelstorfer[7] · C. Henkenberens[8] · D. Jeller[9] · K. Jurianz[10] · C. Kornhuber[11] · M. Kretschmer[27] · S. Lotze[12] · K. Meier[13] · P. Pemler[14] · A. Riegler[15] · A. Röser[16] · D. Schmidhalter[17,18] · K. H. Spruijt[19] · G. Surber[20] · V. Vallet[21] · R. Wiehle[22] · J. Willner[23] · P. Winkler[24] · A. Wittig[25] · M. Guckenberger[1] · S. Tanadini-Lang[1]

Received: 13 May 2020 / Accepted: 10 May 2021 / Published online: 1 July 2021

Wilke L et al. STO21

Background for the chosen rationale of dose prescription

- de Jong et al.: prescribing and recording in line with ICRU 91 (& Based on ESTRO-ACROP)

- Result: between 8 experienced centers significant differences in the actual planned dose to the PTVs and GTVs!

- strong retrospective data indicating that this variation in GTV and PTV doses **is of clinical relevance**.

Evelyn de Jong et al. RT&O 2020

Radiotherapy and Oncology 142 (2020) 217–223

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Radiotherapy and Oncology

journal homepage: www.thegreenjournal.com

Original Article

Variation in current prescription practice of stereotactic body radiotherapy for peripherally located early stage non-small cell lung cancer: Recommendations for prescribing and recording according to the ACROP guideline and ICRU report 91

Evelyn E.C. de Jong [h,*], Matthias Guckenberger [a], Nicolaus Andratschke [a], Karin Dieckmann [b], Mischa S. Hoogeman [c], Maaike Milder [c], Ditte Sloth Møller [d], Tine Bisballe Nyeng [d], Stephanie Tanadini-Lang [a], Eric Lartigau [e], Thomas Lacornerie [e], Suresh Senan [f], Wilko Verbakel [f], Dirk Verellen [g], Geert De Kerf [g], Coen Hurkmans [h]

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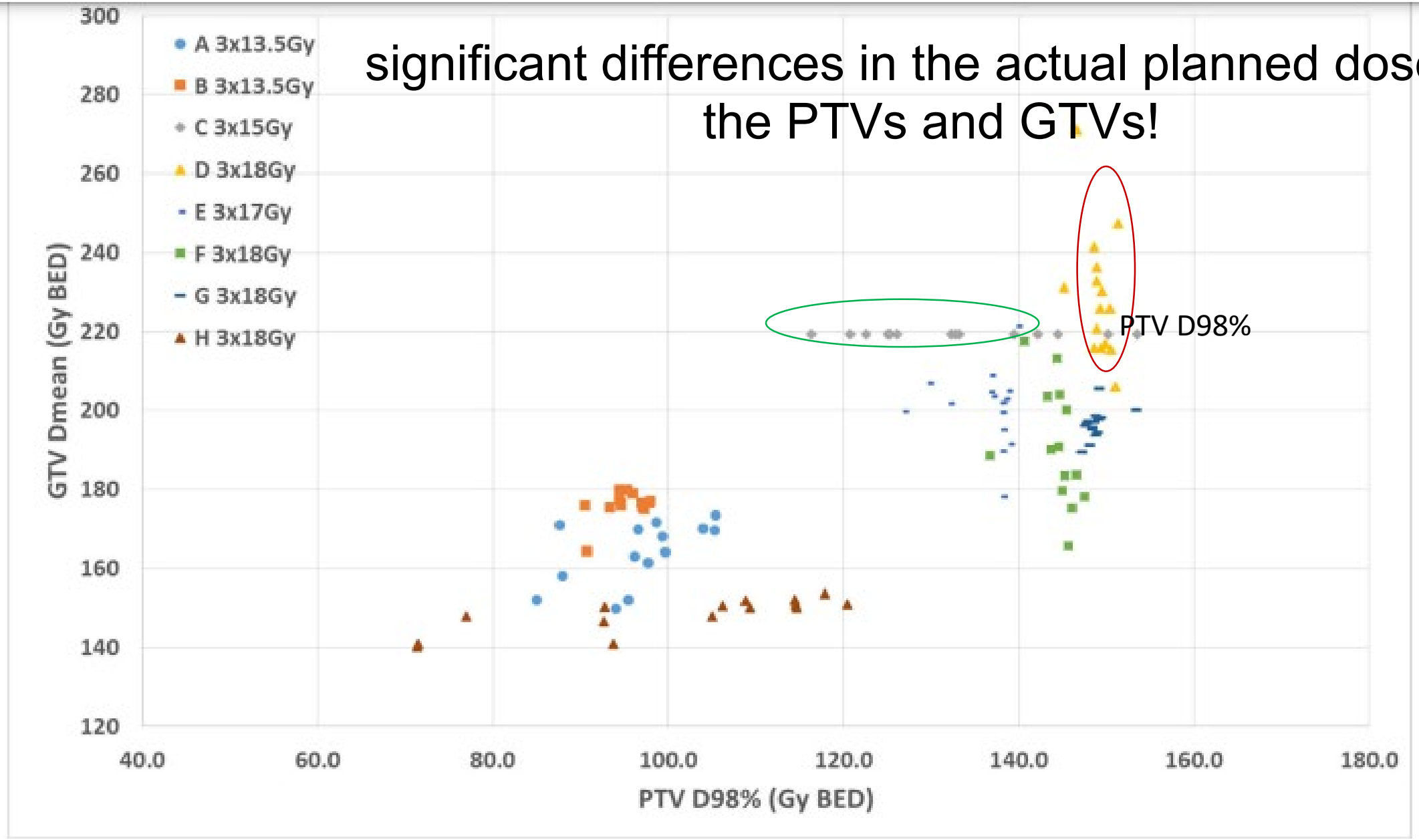
A



significant differences in the actual planned dose to the PTVs and GTVs!

de Jong et al. Green 20

Correlating Dose Variables with Local Control in SBRT for Early-Stage NSCLC: A Modeling Study on 1500 Individual Treatments

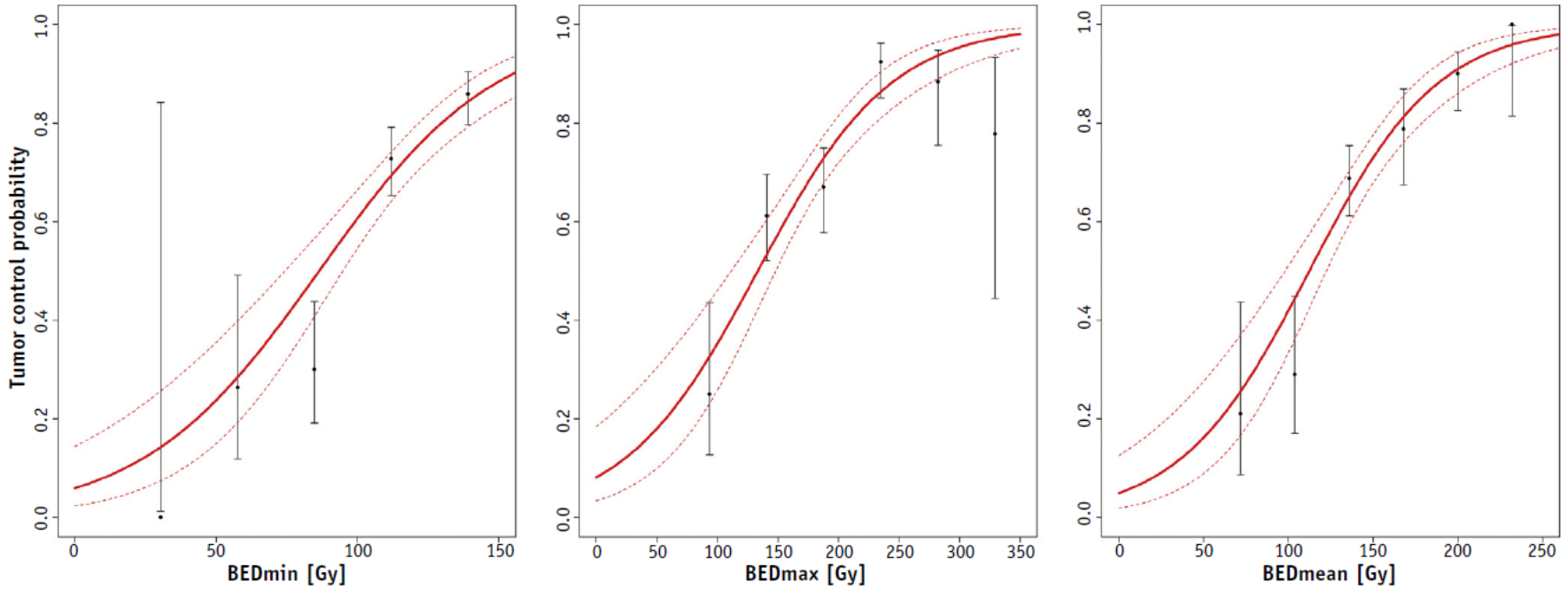
Table 2 Characteristics of the univariable logistic dose-response models*

Model parameter	TCD_{50}, Gy	k, Gy	AICc	Sensitivity†, %	Specificity†, %	Accuracy†, %	BED for 70% TCP, Gy_{10}
BED_{min}	50.9	29.7	423.7	79.4	61.0	70.2	77
BED_{max}	59.2	55.2	428.9	74.9	64.0	69.4	106
BED_{ave}	62.6	38.0	420.0	75.3	68.0	71.6	95

Abbreviations: AICc = Akaike information criterion with second-order bias correction; BED = biologically effective dose; TCP = tumor control probability.

* TCD_{50} and k are the TCP model parameters that can be computed from the logistic regression coefficients b_0 and b_1 (Equations 3 and 4).

† The classification performance is based on a probability threshold of 70% for classifying a tumor as locally controlled.



Klement et al. RedJ 20

Correlating Dose Variables with Local Control in SBRT for Early-Stage NSCLC: A Modeling Study on 1500 Individual Treatments

Table 3 Estimated test performance of the different classifiers

Model	AUC	Sensitivity at 90% TCP	Specificity at 90% TCP	Accuracy at 90% TCP	Sensitivity at 70% TCP	Specificity at 70% TCP	Accuracy at 70% TCP
LR: BED_{min}	0.737 ± 0.027	20.9 ± 21.6	92.0 ± 8.8	56.4 ± 6.5	55.4 ± 6.6	72.8 ± 5.9	64.1 ± 2.6
LR: BED_{max}	0.735 ± 0.028	18.5 ± 8.7	93.1 ± 3.7	55.8 ± 3.0	63.9 ± 5.1	68.6 ± 7.6	66.3 ± 2.9
LR: BED_{ave}	0.740 ± 0.027	24.2 ± 11.0	91.8 ± 4.6	58.0 ± 3.6	59.6 ± 5.9	75.0 ± 6.7	67.3 ± 2.2
LR: BED_{min} + BED_{max}	0.737 ± 0.028	26.4 ± 14.7	90.8 ± 5.9	58.6 ± 4.8	58.6 ± 6.6	73.5 ± 7.4	66.1 ± 3.0
LR: LASSO	0.738 ± 0.028	18.7 ± 14.3	93.4 ± 6.0	56.1 ± 4.5	58.4 ± 7.4	73.8 ± 7.6	66.1 ± 3.0
FFTs*	0.677 ± 0.027	55.3 ± 7.5	80.1 ± 10.0	67.7 ± 2.9	55.3 ± 7.5	80.1 ± 10.0	67.7 ± 2.9

Abbreviations: AUC = area under the curve; BED = biologically effective dose; FFT = fast and frugal tree; LASSO = least absolute shrinkage and selection operator; LR = logistic regression; TCP = tumor control probability.

* Note that the FFTs produce a discrete output (probability either 0 or 1).

Conclusions:

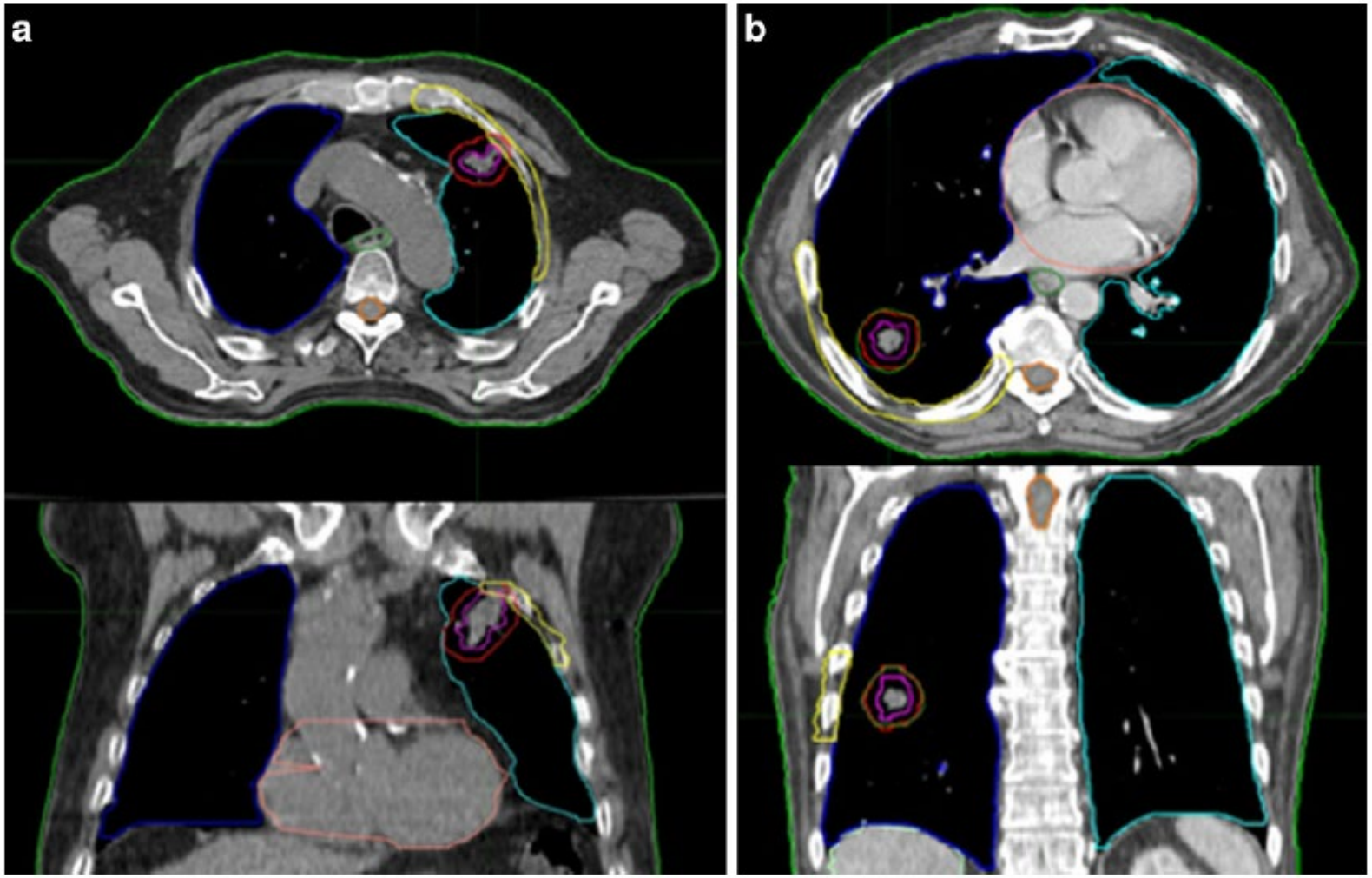
BED_{PTVave} correlated better with TCP than BEDmax or BEDmin.

BED_{PTVave} is highly correlated to $D_{GTVmean}$: seems good to prescribe to this!

GTV dose prescription is superior to PTV (needs further validation)

Klement et al. RedJ 20

Structures of the two patients used for the planning study



Wilke L et al. STO21

Multiparameter dose prescription

Primary parameter:

3 × 21.5Gy to the mean ITV dose (BED= 203 Gy10)

	Objective	Allowed deviation
PTV coverage	D95% > 70% (= 45.2 Gy, BED = 112 Gy_{10})	D90% > 70% (= 45.2 Gy, BED = 112 Gy_{10})
ITV coverage	D95% > 90% (= 58.1 Gy, BED = 170 Gy_{10})	D90% > 90% (= 58.1 Gy, BED = 170 Gy_{10})
CI_{RTOG} = V70%/V(PTV)	< 1.20	< 1.25
D0.1 ml	< 107% (= 69 Gy, BED = 228 Gy_{10})	< 110% (= 71 Gy, BED = 239 Gy_{10})

PTV planning taget volume, *D95%* dose to 95% of the volume, *BED* biologically effective dose, *ITV* internal target volume, *CIRTOG* Radiation Therapy Oncology Group conformity index, *V70%* volume recieving 70% of the prescribed dose, *V(PTV)* volume of the planning target volume

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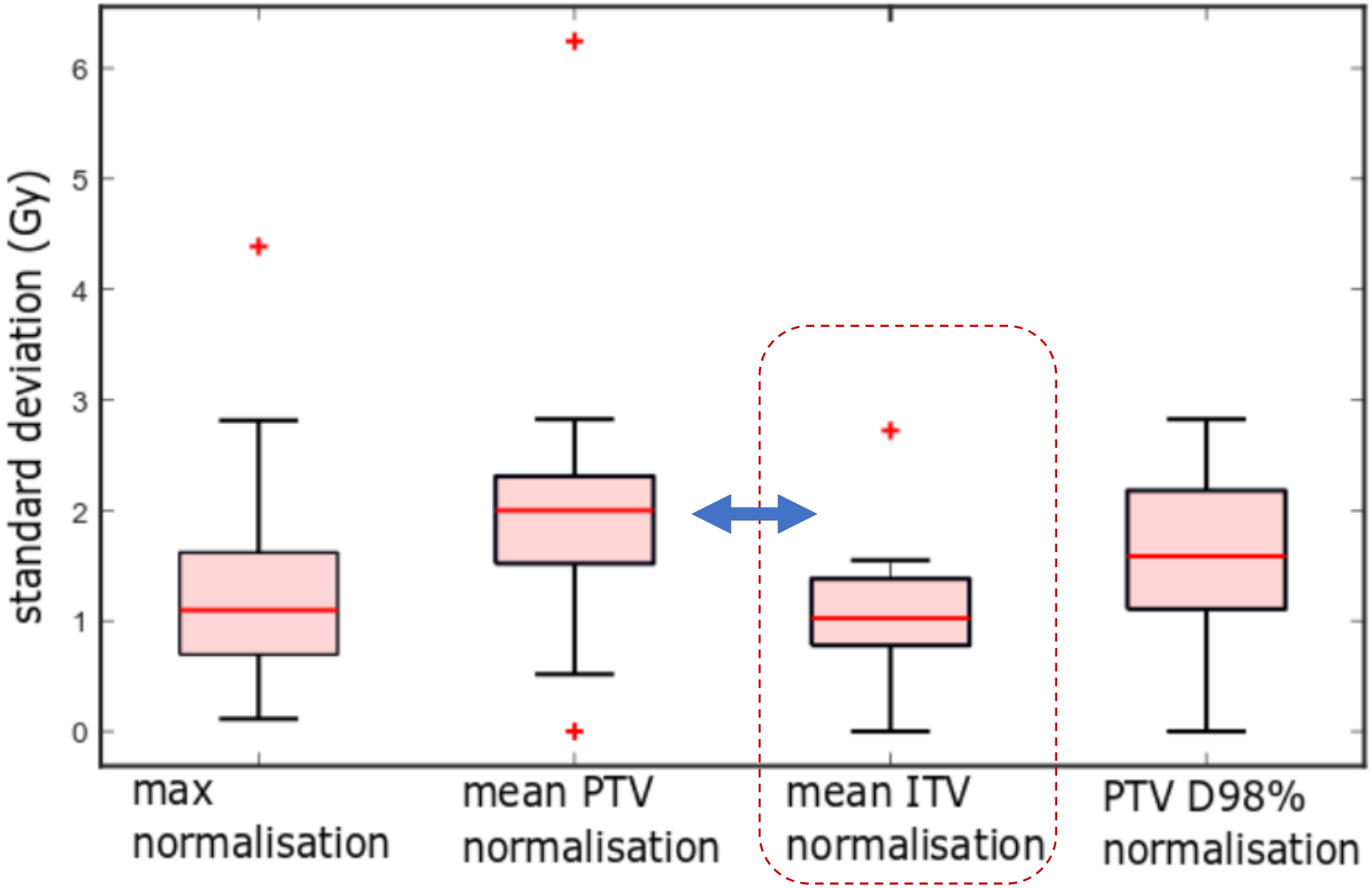
4 normalization methods: different dosimetric parameters prescribing dose to PTV (boxplots of SD)



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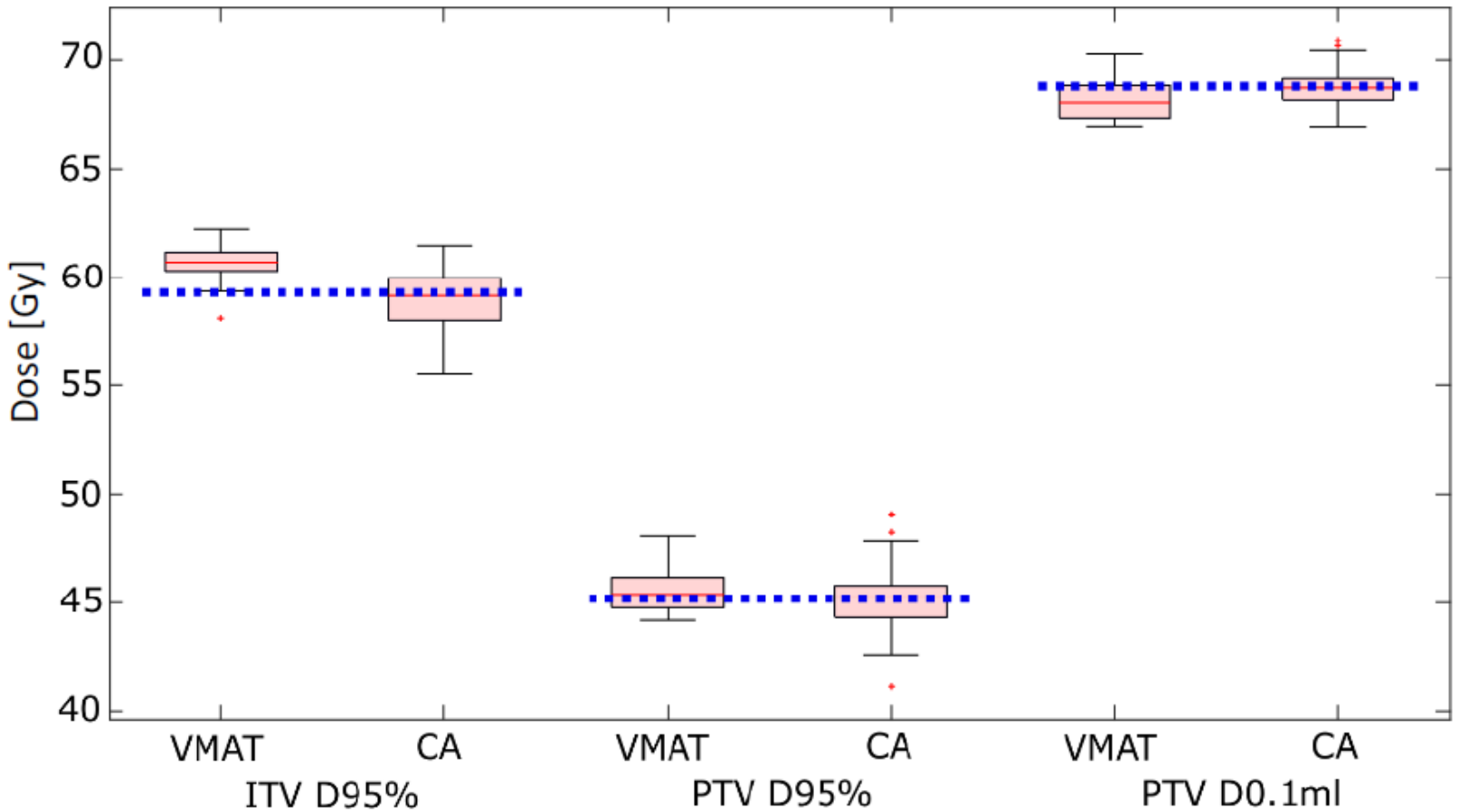

Fig. S2: ITV D95%, PTV D95% and PTV D0.1ml from the 40 patients planned in the pre-study and derived constraints (blue).

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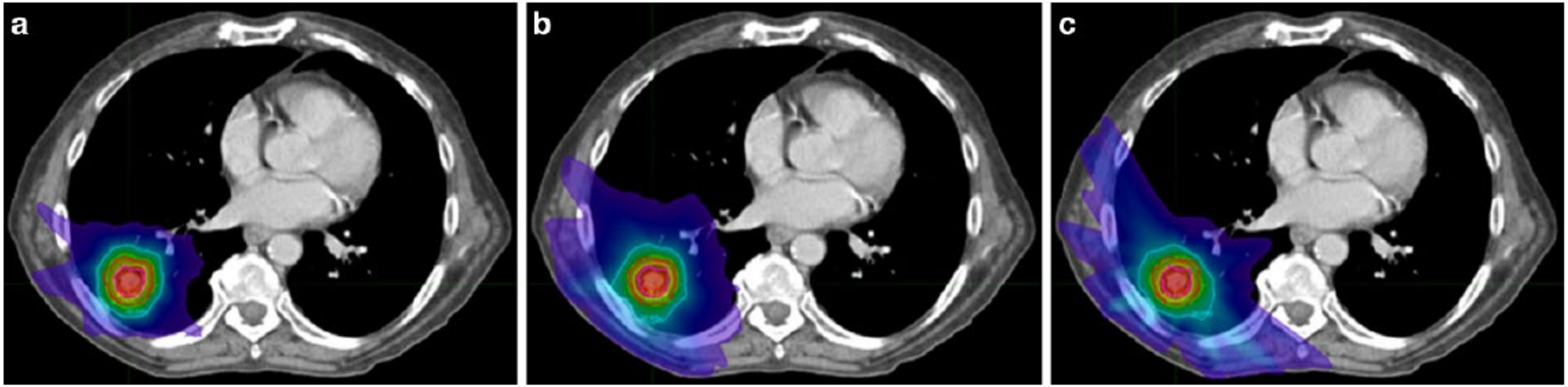
Dose distributions for the different techniques used

Robotic radiosurgery | **modulated RT** | **3D-conformal RT**



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Results for two patients and the different techniques

		Patient 1			Patient 2		
		RRS	MOD	3D	RRS	MOD	3D
ITV D_{median}	Median	65.0 Gy	64.7 Gy	65.0 Gy	64.7 Gy	64.6 Gy	64.7 Gy
	Mean	65.1 Gy	64.6 Gy	64.9 Gy	64.7 Gy	64.7 Gy	64.7 Gy
	Std	0.6 Gy	0.2 Gy	0.3 Gy	0.3 Gy	0.3 Gy	0.2 Gy
ITV V90%	Median	98.0%	99.6%	98.8	97.6%	98.9%	97.9%
	Mean	97.7%	99.0%	98.5%	97.5%	98.7%	97.5%
	Std	1.9%	1.1%	0.9%	1.7%	1.2%	2.3%
PTV D_{mean}	Median	56.2 Gy	56.9 Gy	57.8 Gy	55.6 Gy	56.6 Gy	57.2 Gy
	Mean	56.2 Gy	56.9 Gy	57.7 Gy	55.7 Gy	56.6 Gy	57.0 Gy
	Std	0.6 Gy	0.8 Gy	0.7 Gy	0.3 Gy	0.5 Gy	0.6 Gy
PTV D_{median}	Median	55.7 Gy	57.0 Gy	58.8 Gy	54.8 Gy	56.5 Gy	57.5 Gy
	Mean	55.5 Gy	57.2 Gy	58.4 Gy	54.9 Gy	56.7 Gy	57.1 Gy
	Std	1.2 Gy	1.2 Gy	1.0 Gy	0.4 Gy	1.1 Gy	1.0 Gy
PTV V70%	Median	97.8%	96.6%	96.2%	96.2%	95.9%	95.9%
	Mean	97.6%	97.0%	96.4%	96.4%	95.7%	96.9%
	Std	2.1%	1.7%	0.7%	0.8%	2.4%	0.8%
D0.1 ml	Median	68.6 Gy	67.7 Gy	67.8 Gy	68.9 Gy	67.5 Gy	69.4 Gy
	Mean	68.7 Gy	67.6 Gy	67.8 Gy	69.1 Gy	67.8 Gy	69.3 Gy
	Std	0.7 Gy	1.1 Gy	0.4 Gy	0.6 Gy	1.0 Gy	0.5 Gy
PTV D2%	Median	67.9 Gy	67.1 Gy	67.3 Gy	68.3 Gy	67.4 Gy	68.8 Gy
	Mean	67.8 Gy	66.9 Gy	67.2 Gy	68.6 Gy	67.3 Gy	68.6 Gy
	Std	0.6 Gy	0.8 Gy	0.3 Gy	0.7 Gy	0.8 Gy	0.4 Gy
PTV D98%	Median	45.0 Gy	44.2 Gy	43.8 Gy	44.2 Gy	44.0 Gy	43.2 Gy
	Mean	44.6 Gy	43.9 Gy	43.6 Gy	44.2 Gy	43.2 Gy	43.4 Gy
	Std	1.6 Gy	3.1 Gy	0.4 Gy	0.5 Gy	3.2 Gy	0.9 Gy
PTV CI_{RTOG}	Median	1.13	1.14	1.20	1.11	1.12	1.17

Wilke L et al. STO21

Harmonized planning with different techniques

		Patient 1		
		RRS	MOD	3D
ITV D_{median}	Median	65.0 Gy	64.7 Gy	65.0 Gy
	Mean	65.1 Gy	64.6 Gy	64.9 Gy
	Std	0.6 Gy	0.2 Gy	0.3 Gy
ITV V90%	Median	98.0%	99.6%	98.8
	Mean	97.7%	99.0%	98.5%
	Std	1.9%	1.1%	0.9%

Wilke L et al. STO21

Gradient Index (22.6 Gy isodose) for all plans

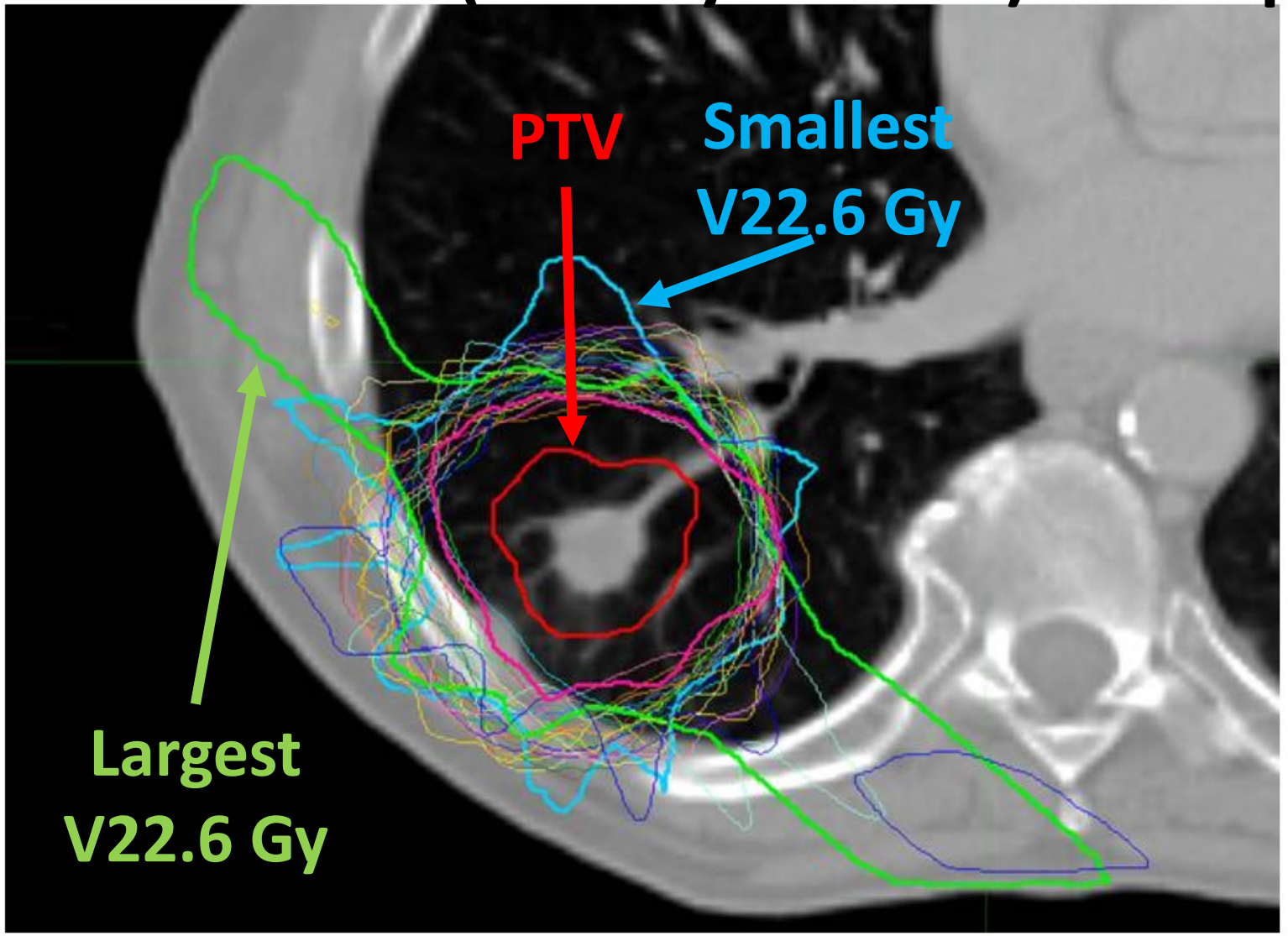

Fig. S 51: Distribution of the 22.6 Gy isodose line for all submitted plans for patient 2. The PTV contour is outlined in bold red. The smallest V(22.6Gy) is outlined in bold blue, the largest in green. Since this one was calculated with a 4mm dose calculation grid, we also display the V(22.6Gy) for the largest one complying with the DEGRO stereotactic working group recommendations in bold green.

Wilke L et al. STO21

Multiparametrische Verschreibung SBRT Lunge

PTV	ITV	(CTV)	GTV
Covering isodose			
$D_{\_median}$	$D_{\_median}$	$D_{\_median}$	$D_{\_median}$
$D_{\_near\_min\ 95\%}$	$D_{\_near\_min}$	$D_{\_near\_min}$	$D_{\_near\_min}$
$D_{\_near\_max}$	$D_{\_near\_max}$	$D_{\_near\_max}$	$D_{\_near\_max}$
$D_{\_mean}$	$D_{\_mean}$	$D_{\_mean}$	$D_{\_mean}$
$D_{\_min}$	$D_{\_min}$	$D_{\_min}$	$D_{\_min}$
$D_{\_max}$	$D_{\_max}$	$D_{\_max}$	$D_{\_max}$

CI_{RTOG} =V70%/V(PTV) <1.20

Liver

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PHYSICS CONTRIBUTION

Planning Benchmark Study for Stereotactic Body Radiation Therapy of Liver Metastases: Results of the DEGRO/DGMP Working Group on Stereotactic Radiation Therapy and Radiosurgery

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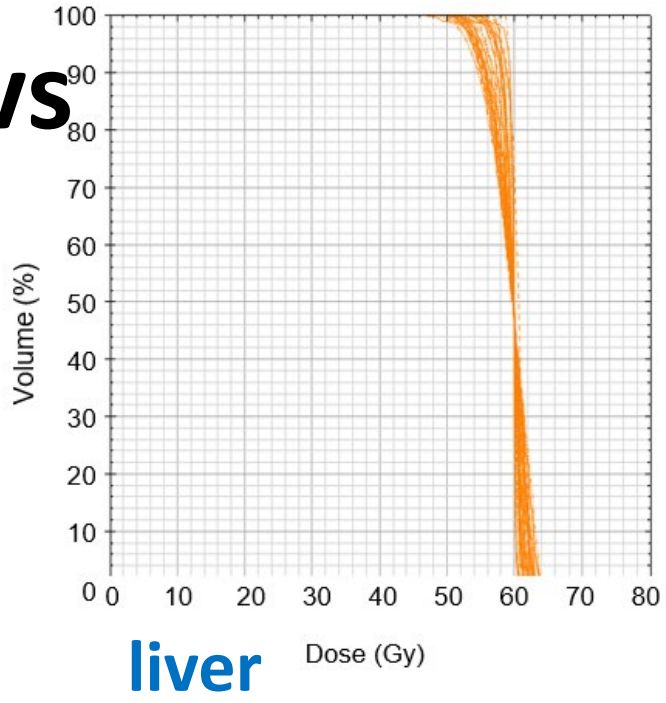
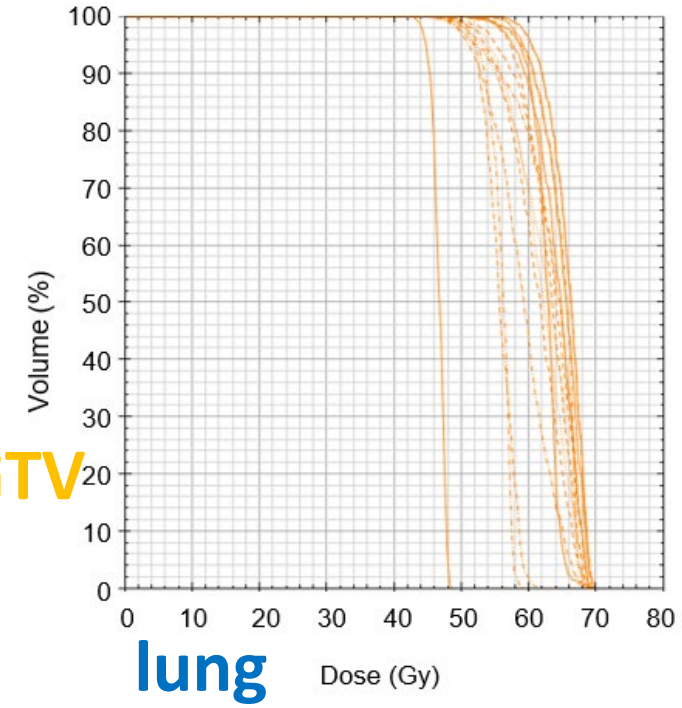
DVHs liver vs lung case

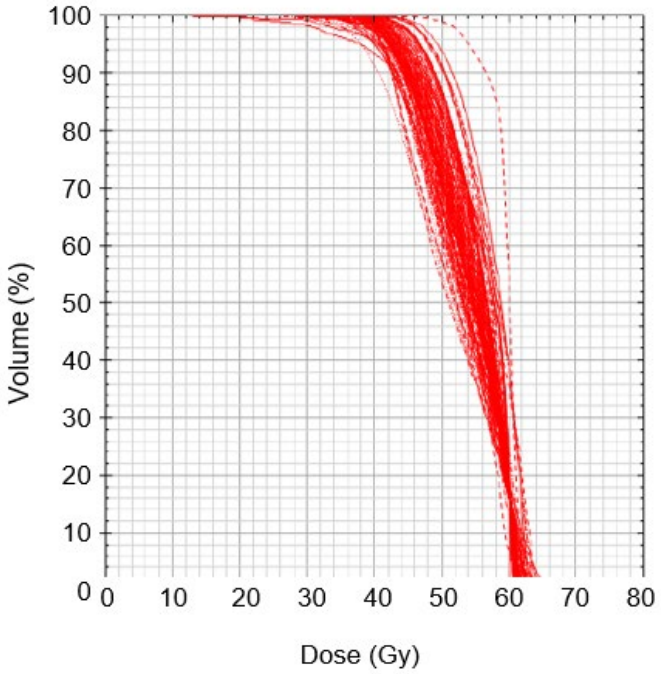


liver

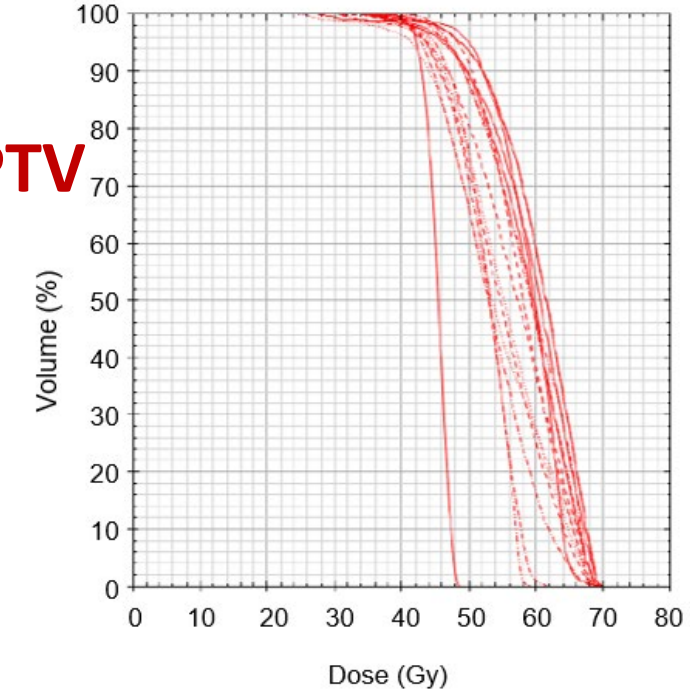


GTV

lung



PTV



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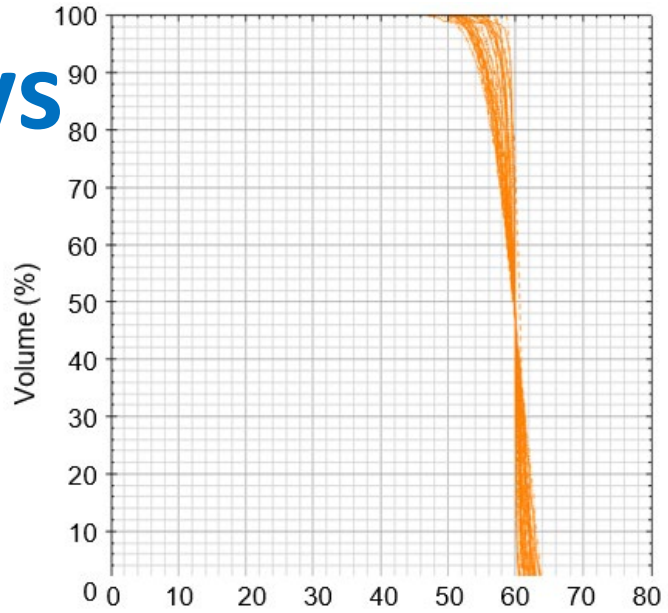
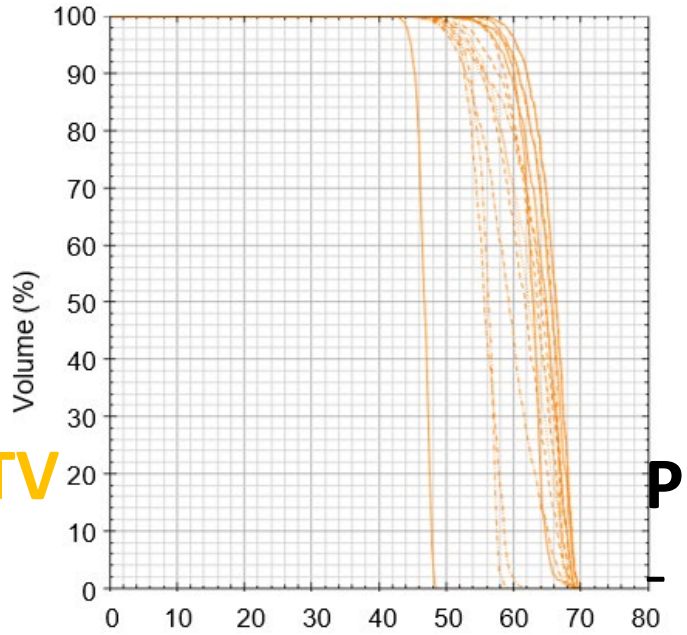
DVHs liver vs lung case

Planning goals:

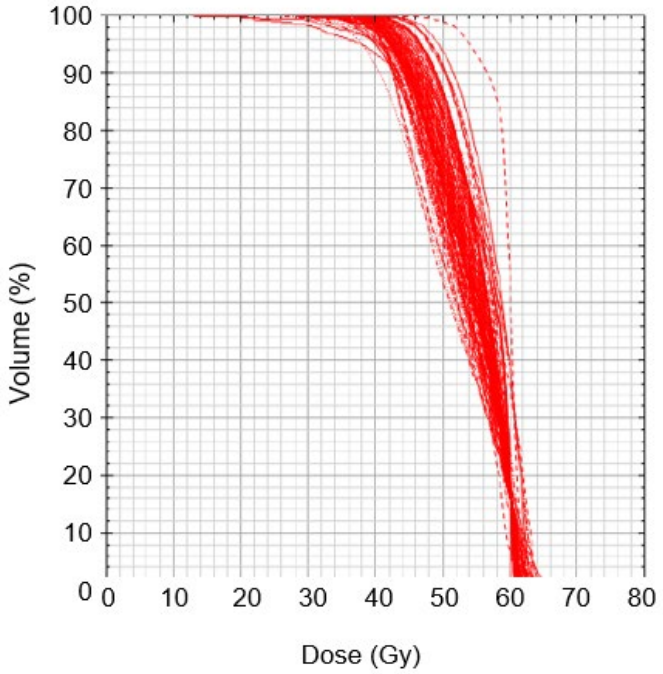
- **GTV $D_{50\%}$**
- **GTV $D_{0.1cc}$**
- **$GTV_{V90\%}$**
- **$PTV_{V70\%}$**



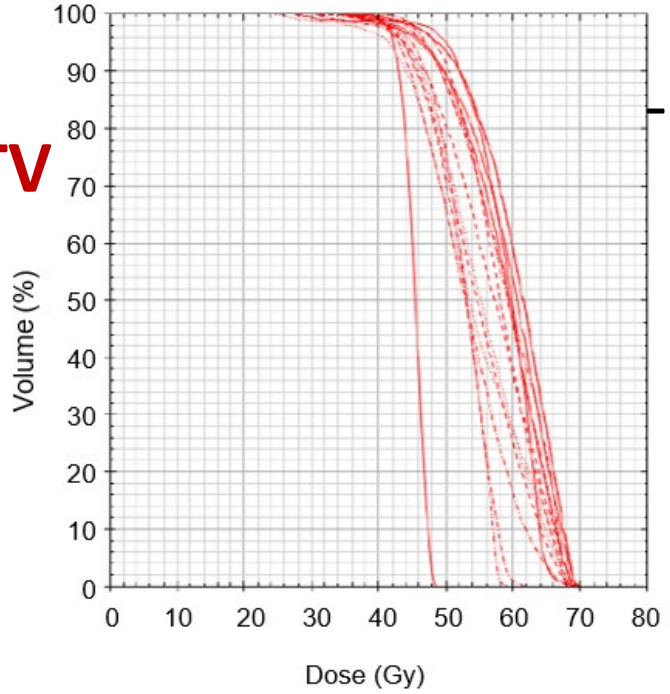
liver



GTV



PTV



lung

Planning goals:

- **PTV encompassing dose prescription isodose line**

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Aim of the DEGRO / DGMP planning study

- DEGRO/DGMP assessed the **harmonization of treatment plan quality** for liver metastases SBRT in a multi-institutional multiplatform context on an international level
- The **study shows the feasibility of harmonizing** liver SBRT treatment plans across different TPSs and delivery techniques when a sufficient set of clinical goals is given.
- **The method of GTV D50% prescription can be performed in all systems, improving overall consistency.**

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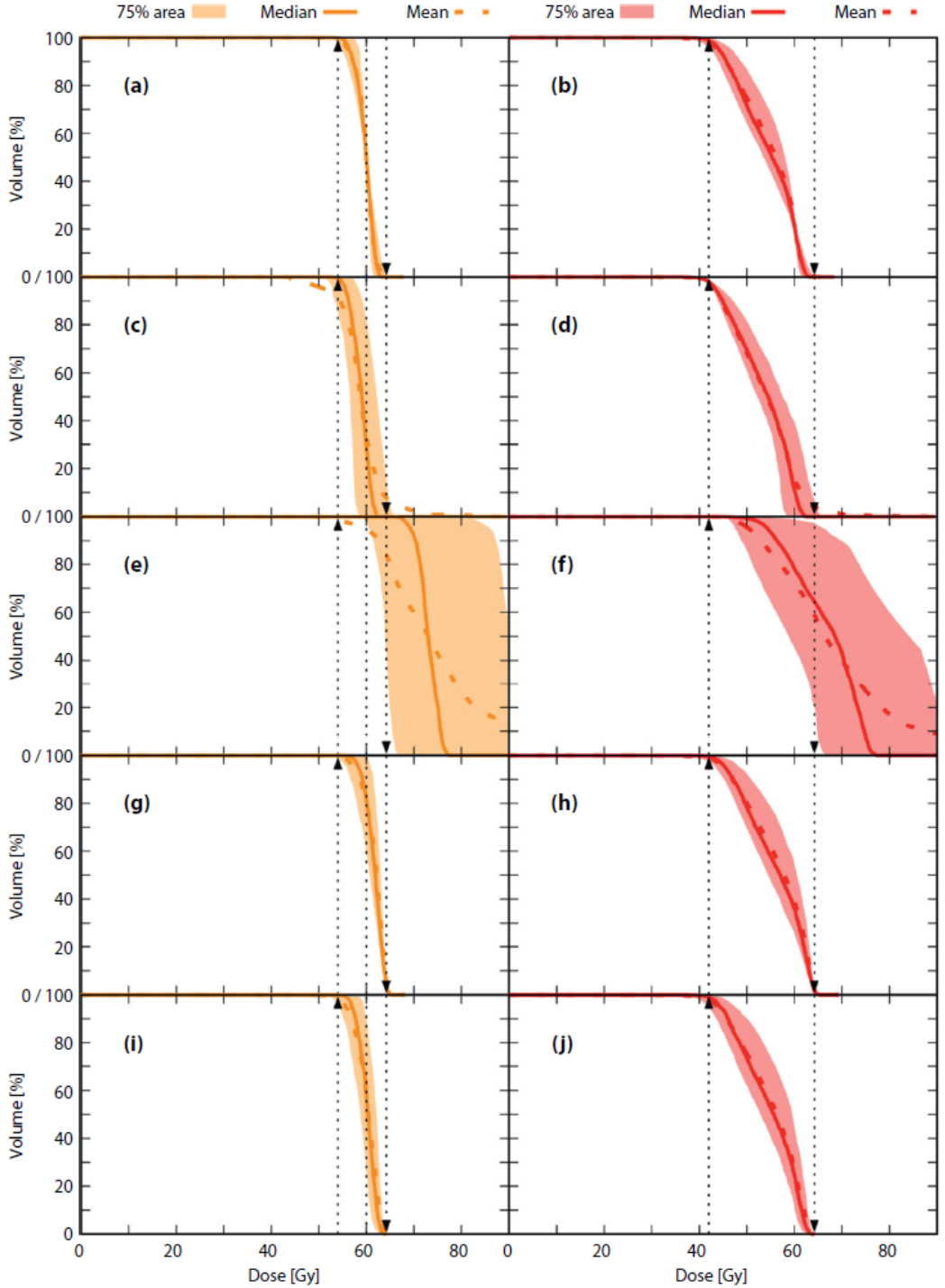
DVHs for different prescription methods for 660 plans

GTV

PTV



60 Gy to GTVD50%

42 Gy to PTVD98%

42 Gy to PTVDmin

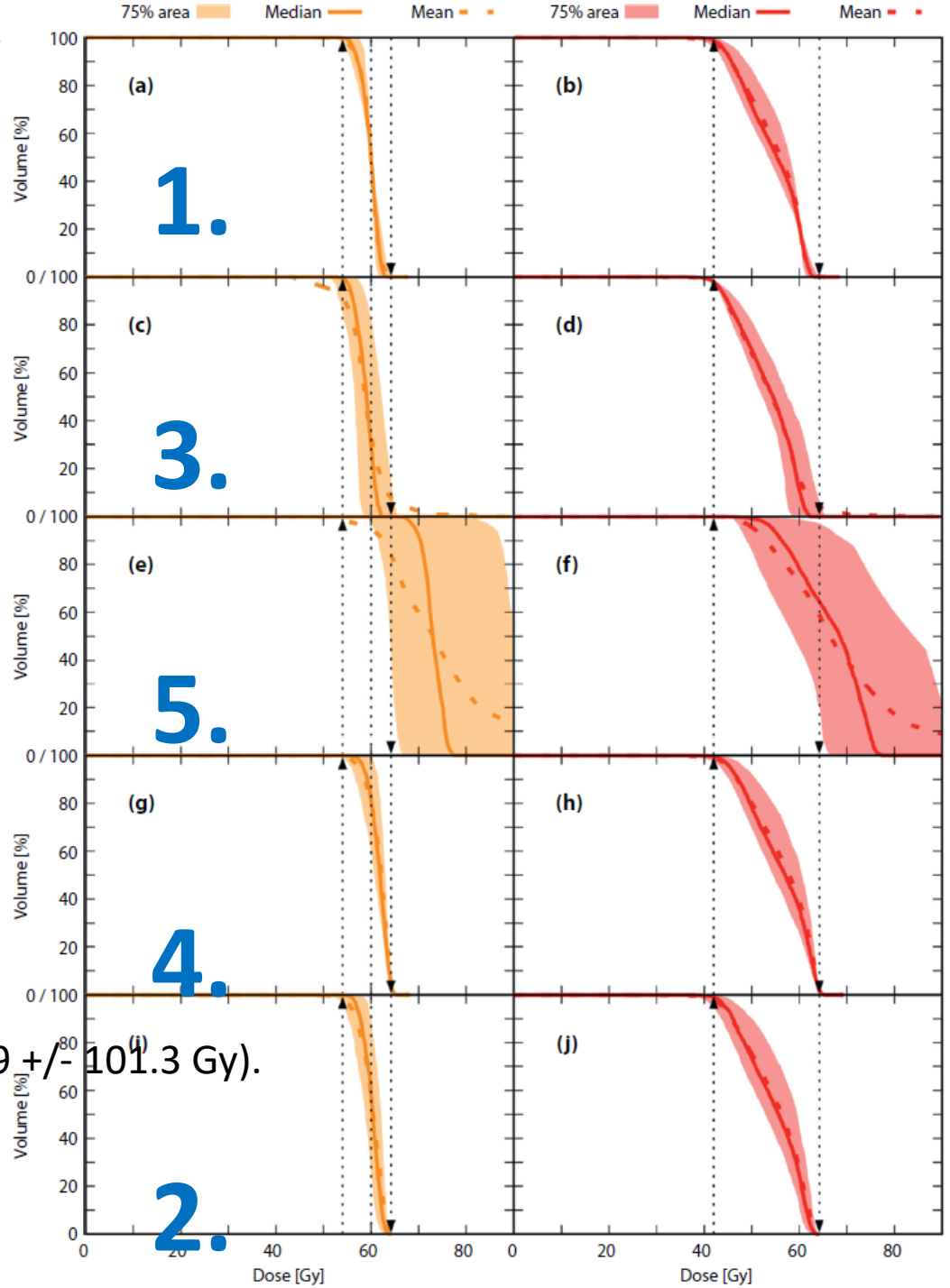
64.2 Gy to PTVD2%

64.2 Gy to PTVDmax

DVHs for different prescription methods for 660 plans

GTV

PTV



60 Gy to GTVD50%

42 Gy to PTVD98%

42 Gy to PTVDmin

64.2 Gy to PTVD2%

64.2 Gy to PTVDmax

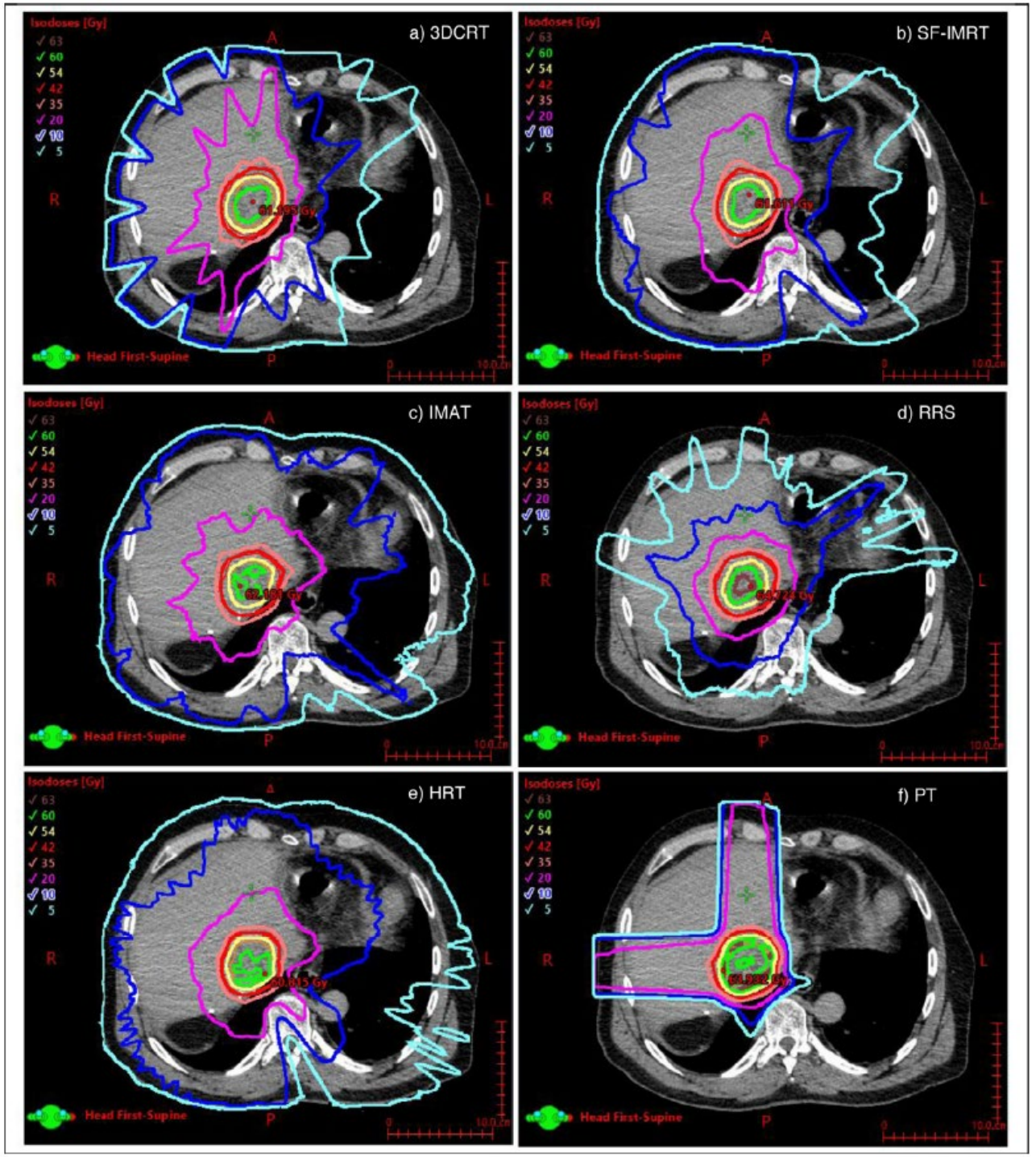
Ranking by the extent of differences (mean differences):

1. GTV D50% (5.5 +/- 3.9 Gy),
2. PTV Dmax, (6.5 +/- 4.2 Gy)
3. PTV D98%, (8.9 +/- 9.6 Gy)
4. PTV D2% , and 10.7 +/- 6.9 Gy) and,
5. finally, the PTV Dmin prescription (71.9 +/- 101.3 Gy).

Key components from the dosimetric evaluation for GTVD50% dose renormalization at 3 x 20 Gy

Mean ± standard deviation	All plans	3D-CRT	SF-IMRT	IMAT	RRS	HRT	PT
Plan D_{max} (Gy)	63.9 ± 1.6	63.2 ± 1.4	64.5 ± 1.2	64.0 ± 1.6	64.7 ± 1.3	62.5 ± 1.3	63.5 ± 2.0
GTV $D_{2\%}$ (Gy)	62.5 ± 1.1	62.5 ± 1.0	63.0 ± 0.9	62.5 ± 1.1	63.3 ± 0.7	61.6 ± 1.0	61.9 ± 1.0
GTV $D_{98\%}$ (Gy)	55.8 ± 1.9	55.8 ± 1.3	55.6 ± 1.4	55.9 ± 1.7	53.7 ± 1.9	56.9 ± 1.9	57.1 ± 1.8
PTV $D_{2\%}$ (Gy)	62.2 ± 1.0	62.2 ± 0.9	62.5 ± 0.8	62.3 ± 0.9	62.9 ± 0.7	61.4 ± 0.8	61.7 ± 1.1
PTV $D_{98\%}$ (Gy)	42.9 ± 3.3	42.0 ± 1.6	42.5 ± 1.7	43.4 ± 3.4	41.2 ± 3.6	42.6 ± 4.2	44.7 ± 4.8
PTV D_{mean} (Gy)	54.4 ± 1.5	55.5 ± 0.8	53.9 ± 1.9	54.4 ± 1.6	53.7 ± 0.9	55.2 ± 1.9	56.3 ± 1.0

Moustakis C et al. RedJ22



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Absolute deviations from planning objectives and the ranking evaluation of the absolute differences

Table 3 Absolute deviations from planning objectives and the ranking evaluation of the absolute differences

	Absolute deviations from planning objectives (Gy)					Ranking evaluation of the absolute deviations				
Prescription method	GTV $D_{50\%}$	PTV $D_{98\%}$	PTV $D_{2\%}$	PTV D_{min}	PTV D_{max}	GTV $D_{50\%}$	PTV $D_{98\%}$	PTV $D_{2\%}$	PTV D_{min}	PTV D_{max}
IMAT	5.26	7.71	10.0	66.12	6.04	2.03	1.78	2.12	1.81	2.10
SF-IMRT	4.27	6.83	9.7	35.71	4.58	2.00	1.81	2.27	1.27	1.78
HRT	7.46	12.54	12.87	107.52	9.34	2.50	2.25	2.67	2.33	2.75
RRS	4.43	9.45	7.24	60.84	5.21	1.87	1.81	1.50	2.06	1.87
PT	8.97	17.99	15.68	116.63	10.44	3.22	2.89	3.00	2.56	3.11
3D-CRT	4.57	7.19	9.07	80.30	6.41	2.25	1.87	2.06	2.50	2.31

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Best practice recommendations for liver SBRT treatment planning

A. Eclipse (V 15.5, Varian, Palo Alto, USA) planning for intensity modulated therapy (**IMRT/IMAT**)

B. RayStation (V 10A SP1, RaySearch, Stockholm, Sweden) planning for intensity modulated therapy (**IMRT/IMAT**)

C. **CyberKnife** (V 2.0.0.1, Precision, Accuray, Sunnyvale, USA) planning for multileaf collimator

D. **TomoTherapy** (V 2.0.0.1, Precision, Accuray, Sunnyvale, USA)

E. RayStation planning for **proton** therapy (V 6.1.1, RaySearch, Stockholm, Sweden for IBA, Louvain-la-Neuve, Belgium)

Details: see Appendix

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Weitere Parameter für die Dosisverschreibung

Radiotherapy and Oncology 123 (2017) 227–233

Contents lists available at ScienceDirect

Radiotherapy and Oncology

journal homepage: www.thegreenjournal.com

Oligometastases

Stereotactic body radiotherapy for oligo-metastatic liver disease – Influence of pre-treatment chemotherapy and histology on local tumor control

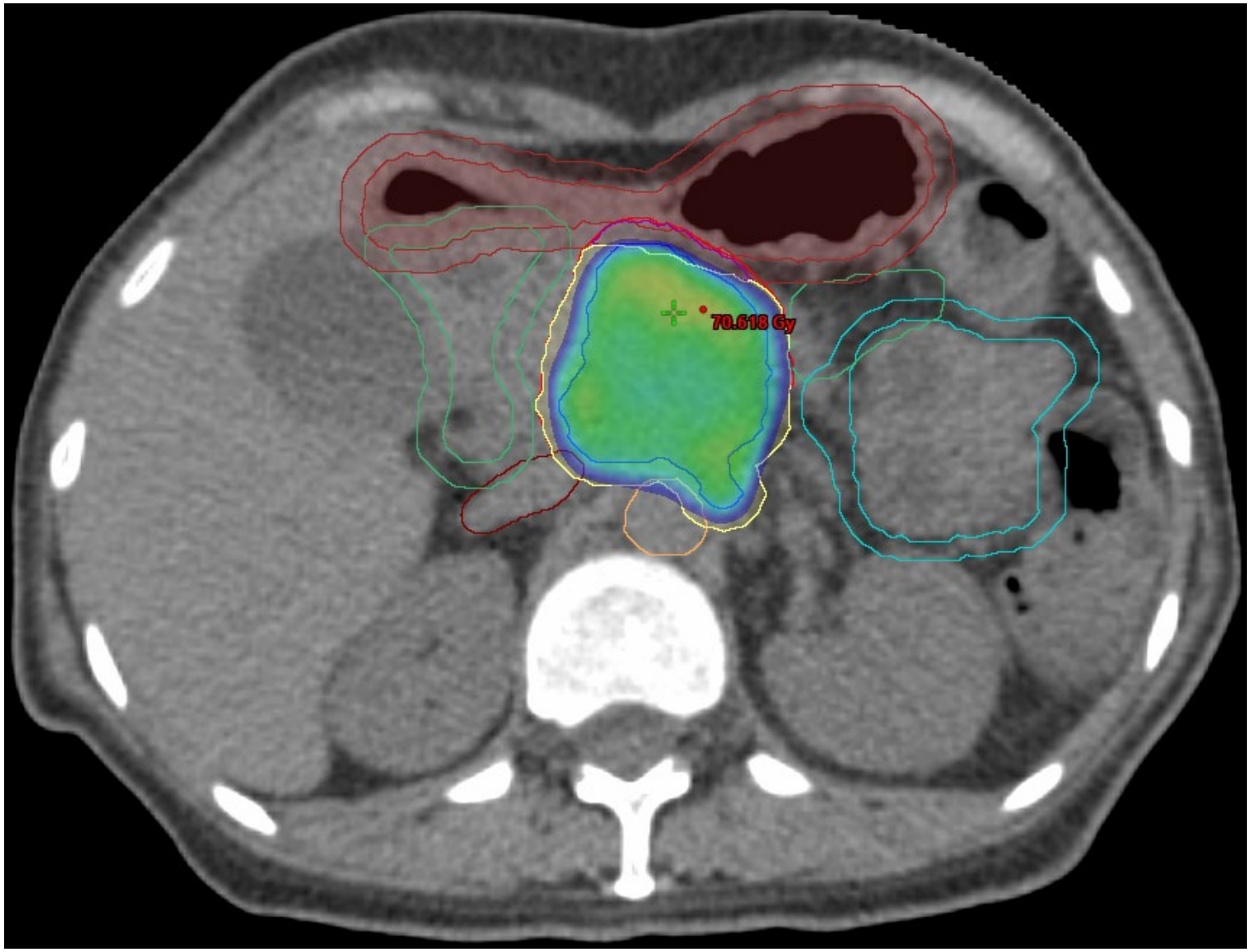
R.J. Klement [a], M. Guckenberger [b], H. Alheid [c], M. Allgäuer [d], G. Becker [e], O. Blanck [f], J. Boda-Heggemann [g], T. Brunner [h], M. Duma [i], S. Gerum [j], D. Habermehl [k], G. Hildebrandt [l], V. Lewitzki [m], C. Ostheimer [n], A. Papachristofilou [o], C. Petersen [p], T. Schneider [q], R. Semrau [r], S. Wachter [s], N. Andratschke [b,*]

Multiparametrische Verschreibung SBRT Leber

PTV	ITV	(CTV)	GTV
Covering isodose			
$D_{\_median}$	$D_{\_median}$	$D_{\_median}$	$D_{\_median}$
$D_{\_near\_min}$	$D_{\_near\_min}$	$D_{\_near\_min}$	$D_{\_near\_min}$*
$D_{\_near\_max}$	$D_{\_near\_max}$	$D_{\_near\_max}$	$D_{\_near\_max}$
$D_{\_mean}$	$D_{\_mean}$	$D_{\_mean}$	$D_{\_mean}$
$D_{\_min}$	$D_{\_min}$	$D_{\_min}$	$D_{\_min}$
$D_{\_max}$	$D_{\_max}$	$D_{\_max}$	$D_{\_max}$

*GTV coverage at 54 Gy (ie, $GTV_{V90\%}$) ≥ 98% (≥95%)

DGMP AK20 & DEGRO AG STX Planungsstudie 18 Zentren



Von Christos Moustakis in wenigen Minuten berichtet

Cholangiozelluläres Karzinom (CCC)

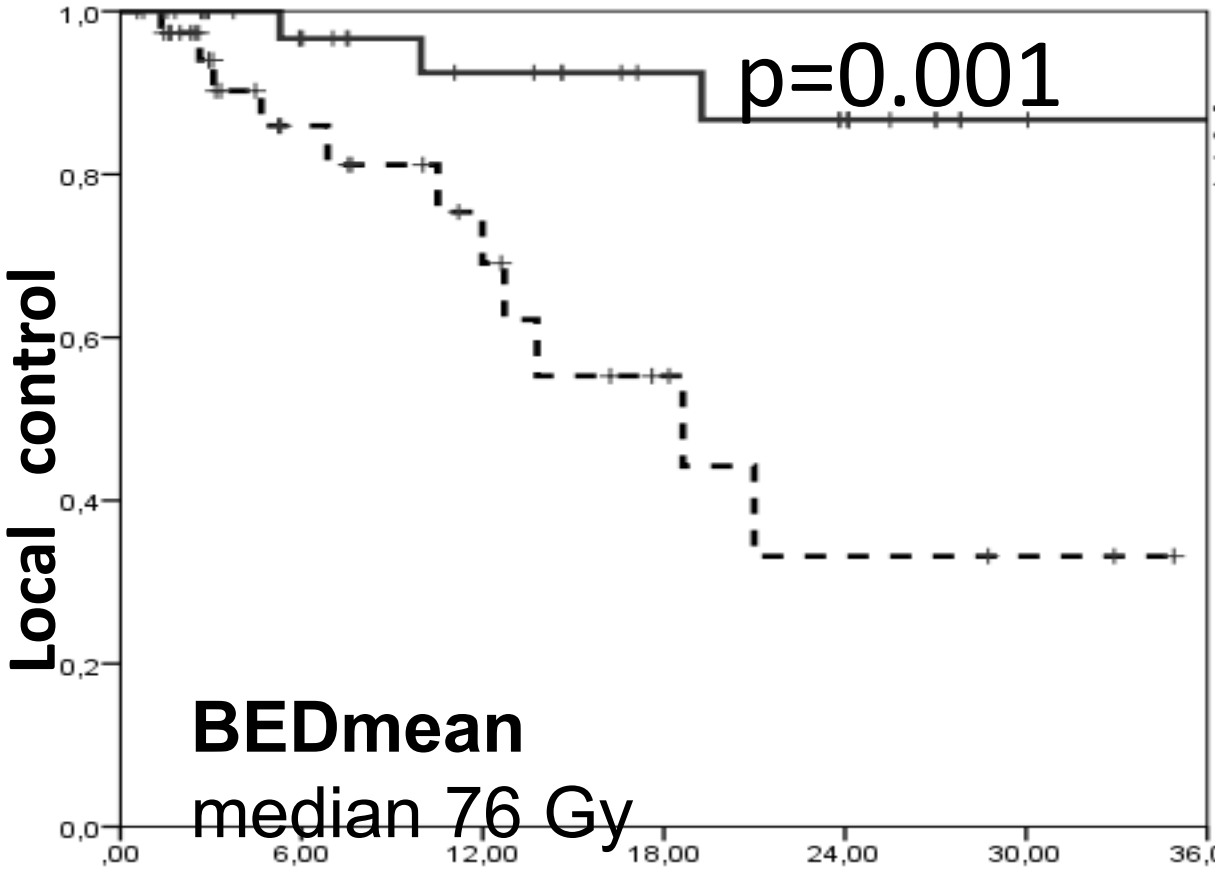
Kohorte der primären Lebertumoren: CCCs

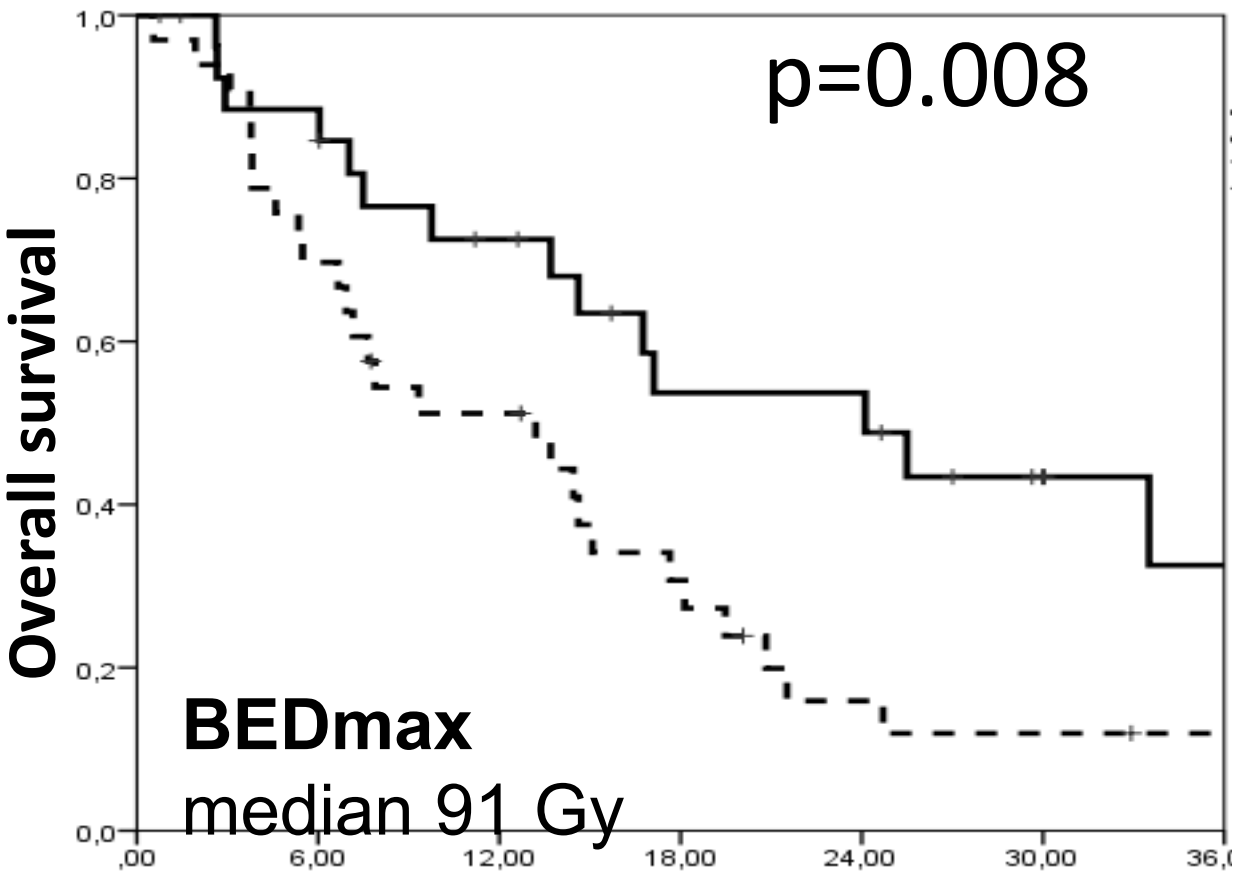
64 Patienten mit 82 Läsionen

	Local control		Overall survival	
Parameter	**HR (95% CI)**	**p§**	**HR (95% CI)**	**p§**
BED_{10} $D_{prescribed}$ (median 67.2 Gy)	0.17 (0.04-0.74)	0.008	-	0.439
BED_{10} D_{mean_GTV} (median 76 Gy)	0.14 (0.04-0.52)	0.001	-	0.074
BED_{10} D_{max} (median 91 Gy)	0.25 (0.08-0.76)	0.009	0.47 (0.25-0.87)	0.008

Kohorte der primären Lebertumoren: CCCs

- 64 Patienten mit 82 Läsionen





brain

ICRU 91

- for very small PTVs <2cm³, which are often present in stereotactic treatments, the PTV D98% and D2% indices are hardly meaningful:
- here the ICRU report 91 recommends using
  - Dnear-min=DV-35mm³
  - Dnear-max=D35mm³
- Nevertheless, the value of 35mm³ as minimal meaningful 3D cube might evolve with time depending on the calculation grid size

Wilke L et al. STO 2019

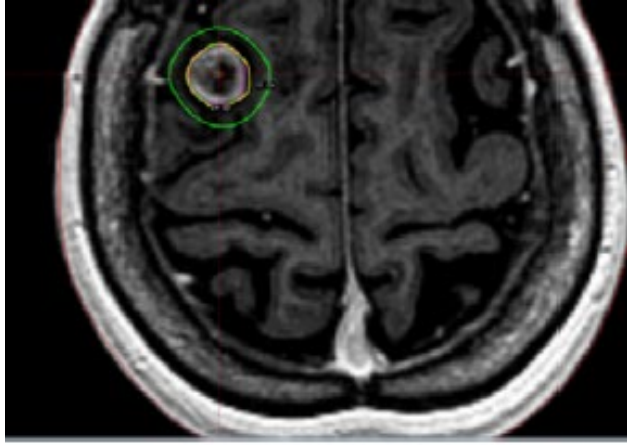
Radiosurgery: ICRU91 example Gammaknife

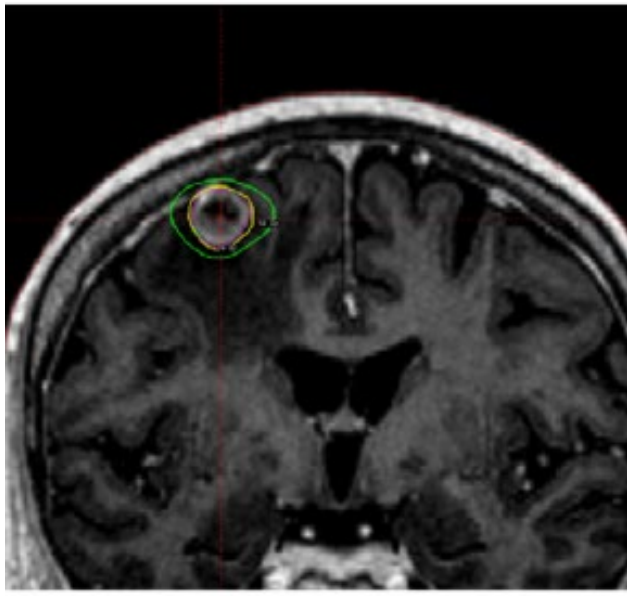
Main prescription	GTV (1.12 cm^3) = PTV	Isodose (Dmax = 100%)	Cf. With Dupic et al.
D100%	24 Gy	50%	*
	D98% = 24 Gy	50%	100%
	D50% = 31.2 Gy	65%	130%
	D02% = 44.7 Gy (0.0224 cm^3)	93%	186%
	Dmax = 48 Gy	100%	200%

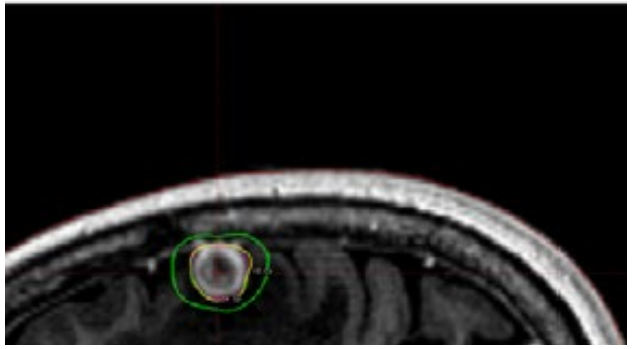
Cave: GTV + 0 mm = PTV

if PTV V <2 cm^3, near-max = 35mm^3: report *D0.0*35cm^3
if PTV V <2 cm^3, near-min = 35mm^3: report $D_{V\text{-}35mm^3}$.

ICRU report 91







Prescription recommendations DEGRO AG STX 2014

- Aims:
  - high dose conformity with the PTV
  - steep dose gradient on the edge of the PTV
- Prescription isodoses 60-80% (isodoses with steepest dose gradients)
- [coverage $D_{\geq 95\%\_PTV}$]
- Paddick conformity index* ≥ 0.5–0.6

* $(TV_{PIV})^2 / (TV * PIV)$

Kocher M. et al. STO 2014

Prescription recommendations DEGRO AG STX 2014

- SRS:
  - marginal dose of 20 Gy
  - 22–25 Gy may be used for <1 cm lesions
  - 18 Gy for ≥ 2.5 – 3 cm lesions
- Resection cavities: no clear dose prescription recommendations
  - SFRT if > 3 cm cavities

Kocher M. et al. STO 2014

Radiotherapy and Oncology 154 (2021) 260–268

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Original Article

Significant correlation between gross tumor volume (GTV) D98% and local control in multifraction stereotactic radiotherapy (MF-SRT) for unresected brain metastases

Guillaume Dupic [a,*], Lucie Brun [a], Ioana Molnar [b,c], Brice Leyrat [a], Vincent Chassin [d], Juliette Moreau [a], Véronique Dedieu [d], Toufic Khalil [e], Pierre Verrelle [a], Michel Lapeyre [a], Julian Biau [a]

Dupic G. et al. RT&O 2012

Nature of the analysis

- retrospective study
- 81 unresected large brain metastases (mGTV 7.2 mL; mPTV 12.4 mL)
- treated with Linac-based multifraction SRT (3#)
- according to the ICRU 91
- Aim: identify predictive factors associated with LC

Dupic G. et al. RT&O 2012

Patients characteristics

Brain metastases' characteristics		
Total		81
Tumor volume		
	GTV (cc)	7.2
	PTV (cc)	12.4
	Longest diameter (mm)	25.1
Prior treatment		
	WBRT	10 (12%)
	SRT	6 (7%)
Histological type		
	Adenocarcinoma	59 (73%)
	Melanoma	11 (14%)
	Squamous cell carcinoma	7 (8%)
	Other	4 (5%)
Mutation		
	Yes	14 (17%)
	No	67 (83%)
Location		
	Occipital lobe	11 (14%)
	Frontal lobe	29 (36%)
	Parietal lobe	12 (15%)
	Temporal lobe	8 (9%)
	Cerebellum	21 (26%)

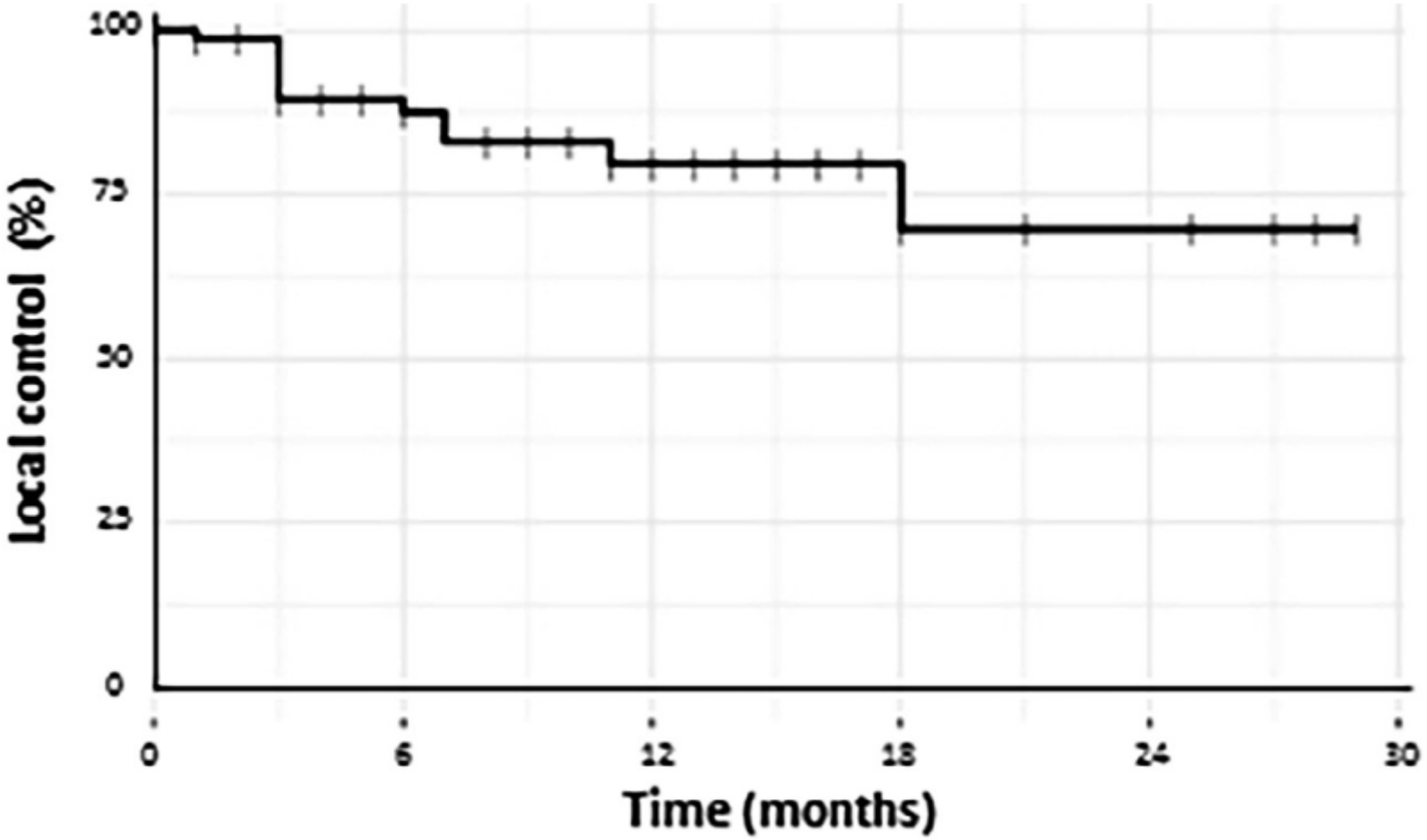
Dupic G. et al. RT&O 2012

Patients characteristics

SRT characteristics		
Treatment quality		
	CI	1.08
	HI	0.34
	GI	2.59
OTT (days) mean		6 (4–10)
Received GTV doses		
	D_{min} (Gy)	26.5
	$D_{98\%}$ (Gy)	28.5
	D_{moy} (Gy)	31.8
	$D_{2\%}$ (Gy)	33.4
	D_{max} (Gy)	33.8
Received PTV doses		
	D_{min} (Gy)	20.8
	$D_{98\%}$ (Gy)	23.1
	D_{moy} (Gy)	29.6
	$D_{2\%}$ (Gy)	33.3
	D_{max} (Gy)	33.8
	$V_{70\%}$ (%)	98.4

Dupic G. et al. RT&O 2012

Probability of local control



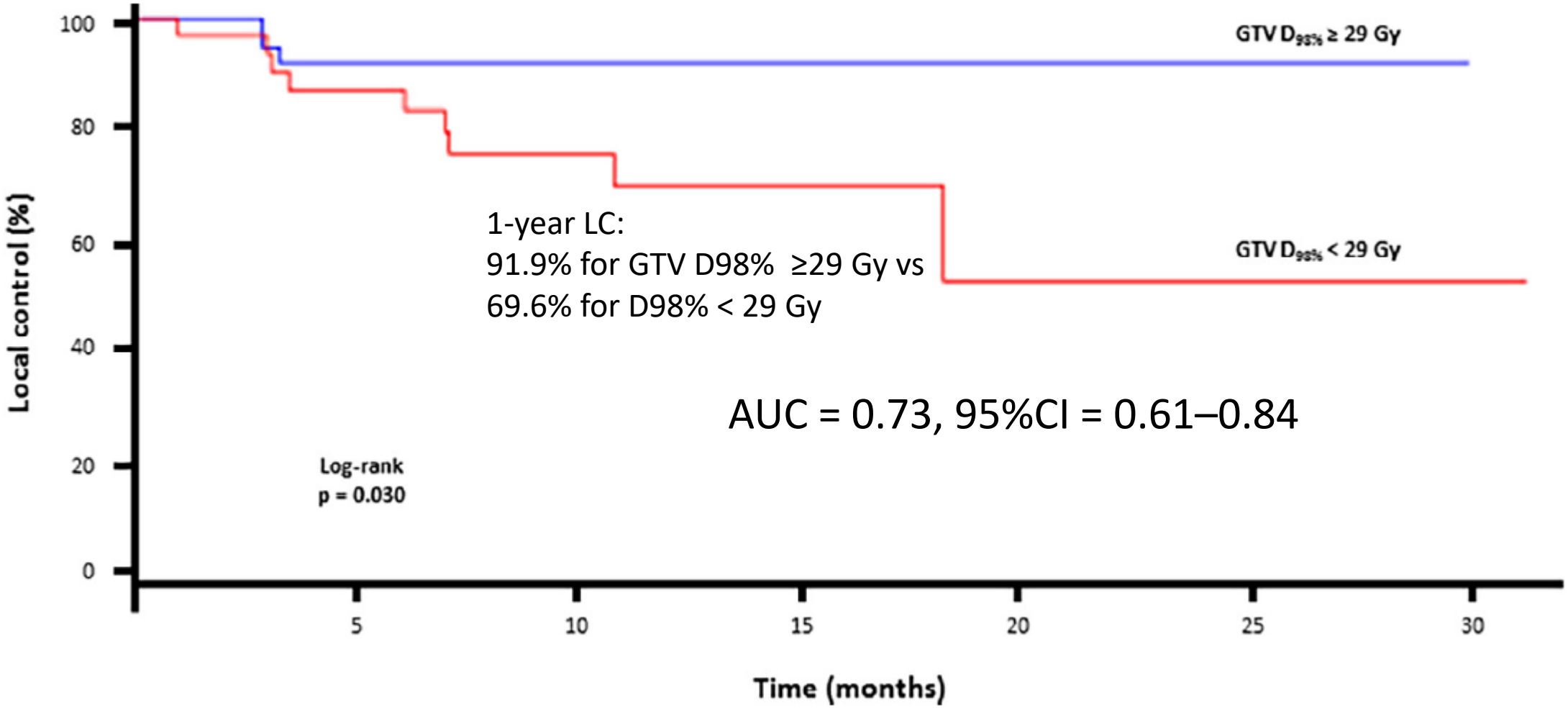
Dupic G. et al. RT&O 2012

Results of univariate and multivariate analyses on local control, overall survival and radionecrosis incidence

	Univariate analysis			Multivariate analysis	
	LC	OS	RN	LC	OS
SRT characteristics					
Treatment quality					
CI	0.12	–	0.08	–	–
HI	0.06	–	0.19	–	–
GI	0.92	–	0.51	–	–
OTT (days) mean	0.87	–	0.32	–	–
Received GTV doses					
D_{min} (Gy)	0.07	0.69	–	–	–
$D_{98\%}$ (Gy)	0.04	0.72	–	0.004	–
D_{moy} (Gy)	0.17	0.69	–	–	–
$D_{2\%}$ (Gy)	0.79	0.57	–	–	–
D_{max} (Gy)	0.91	0.40	–	–	–
Received PTV doses					
D_{min} (Gy)	0.08	0.58	–	–	–
$D_{98\%}$ (Gy)	0.09	0.50	–	–	–
D_{moy} (Gy)	0.22	0.69	–	–	–
$D_{2\%}$ (Gy)	0.46	0.63	–	–	–
D_{max} (Gy)	0.91	0.40	–	–	–
$V_{70\%}$ (%)	0.11	0.46	–	–	–
Received doses to Brain – GTV					
$V_{23.1Gy}$ (cc)	–	–	0.79	–	–
V_{21Gy} (cc)	–	–	0.71	–	–
V_{18Gy} (cc)	–	–	0.66	–	–
V_{14Gy} (cc)	–	–	0.71	–	–
V_{10Gy} (cc)	–	–	0.78	–	–
V_{5Gy} (cc)	–	–	0.99	–	–

Dupic G. et al. RT&O 2012

Comparison of local control curves of all 81 treated brain metastases by dose to $GTV_{98\%}$ in three fractions



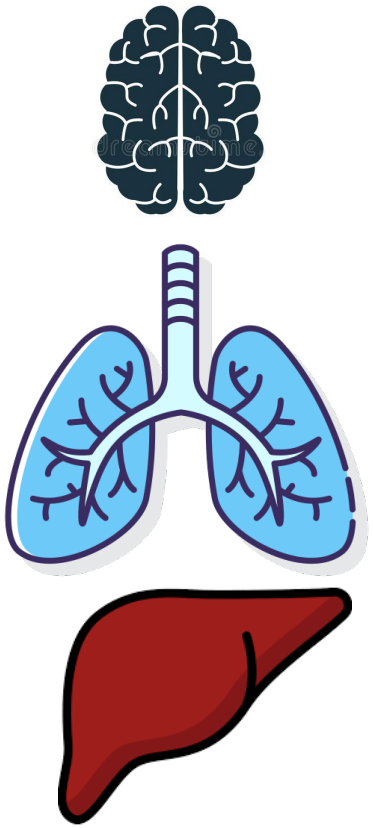
Dupic G. et al. RT&O 2012

Multiparametrische Verschreibung SFRT Hirn

PTV	[ITV]	(CTV)	GTV
Covering isodose			
$D_{\_median}$	n.a.	$D_{\_median}$	$D_{\_median}$
$D_{\_near\_min\ 99\%}$	n.a.	$D_{\_near\_min}$	$D_{\_near\_min}$*
$D_{\_near\_max}$	n.a.	$D_{\_near\_max}$	$D_{\_near\_max}$
$D_{\_mean}$	n.a.	$D_{\_mean}$	$D_{\_mean}$
$D_{\_min}$	n.a.	$D_{\_min}$	$D_{\_min}$
$D_{\_max}$	n.a.	$D_{\_max}$	$D_{\_max}$

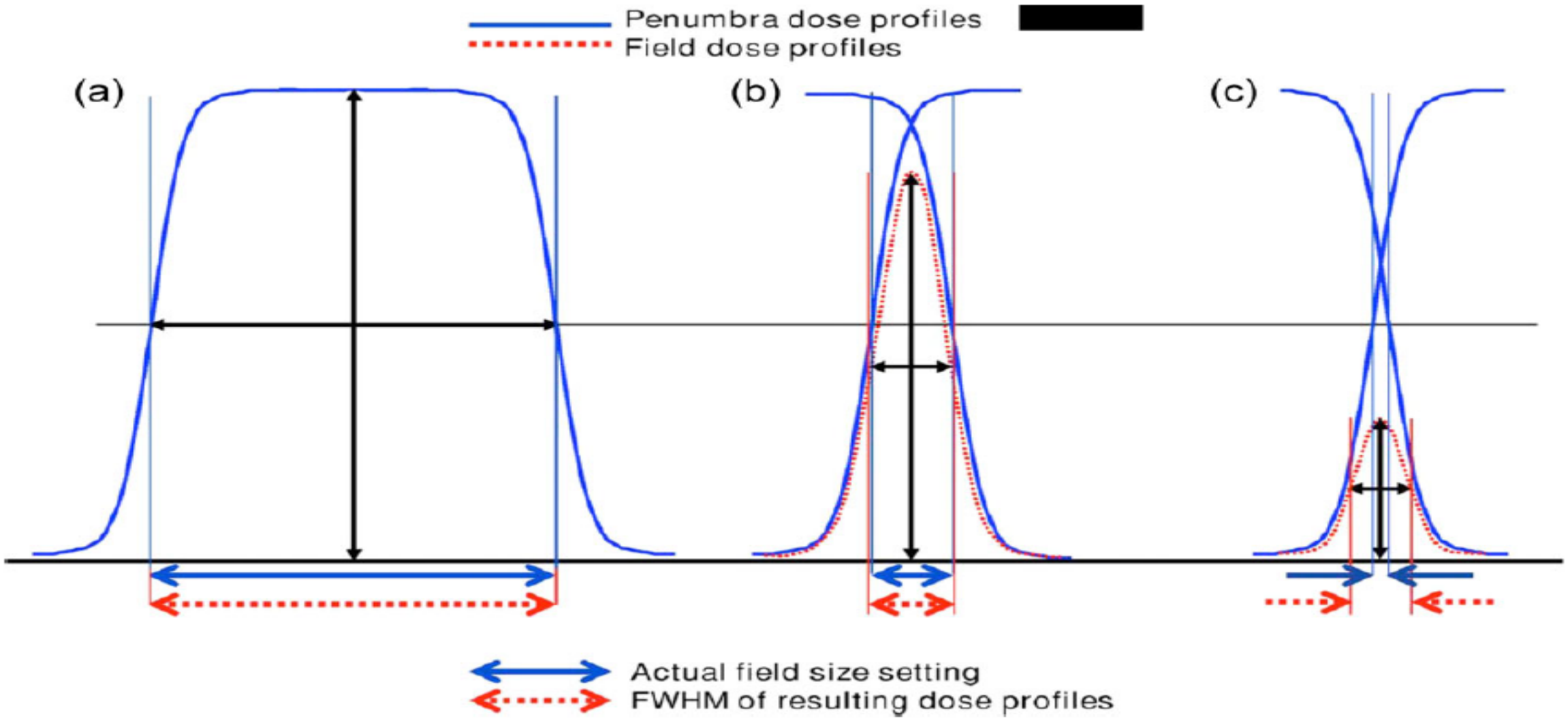
*GTV98%

Summary: Multiparametric planning



Site of SRT	Primary Prescription	Other TV parameters	Indices
Brain	$D(GTV)_{98\%}$ (?)	???	CI
Lung	$D(ITV)_{50\%}$	$D(PTV)_{95\%}$ $D(PTV)\_near\_max$	CI_{RTOG} = V70%/V(PTV) <1.20
Liver	$D(GTV)_{50\%}$	$D(GTV)_{near\_min}$ $D(GTV)_{near\_max}$ $D(PTV)\_98\%$	

PRESCRIBING, RECORDING, AND REPORTING SMALL BEAM SRT



ICRU report 91

Vielen Dank für Ihre Aufmerksamkeit

Cancer/Radiothérapie 25 (2021) 92–102

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Review article

Radiosurgery and stereotactic irradiation of multiple and contiguous brain metastases: A practical proposal of dose prescription methods and a literature review

Radiochirurgie et radiothérapie stéréotaxique des métastases multiples et contiguës : une proposition pratique de méthodes de prescription de la dose et une revue de la littérature

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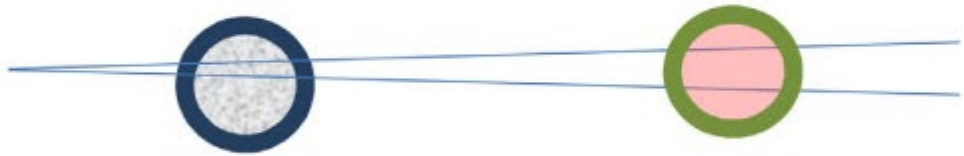
DOSIMETRIC SOLUTIONS

1st met irradiated **2nd met irradiated**

1.1 AGNOSIA

Contribution from dose to 1st met neglected

Increased dose max
Mind OAR



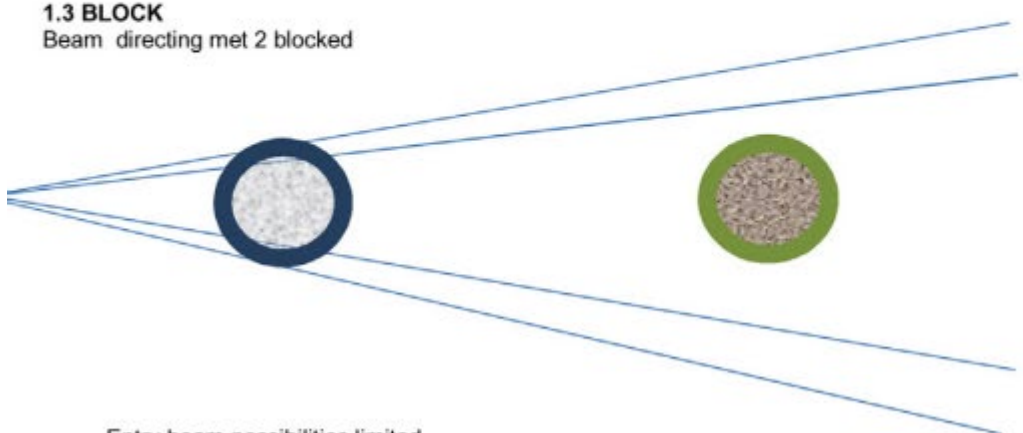
1.2 MEAN

Prescription based on mean dose (Dmean) on the sum of PTVs

Cold spots in GTV in met 1 and 2

1.3 BLOCK

Beam directing met 2 blocked



Entry beam possibilities limited
Mind OAR and GTV coverage

1.4 ADAPT ISO

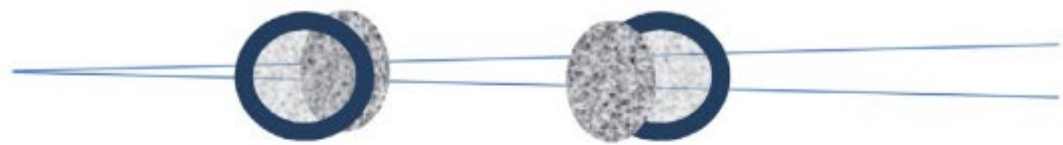
Summation of dose from met 1 and met 2, lower isodose prescription by 1 Gy gradually

Radiobiological equivalence ?

1.5 PTV union

Prescription on PTV union

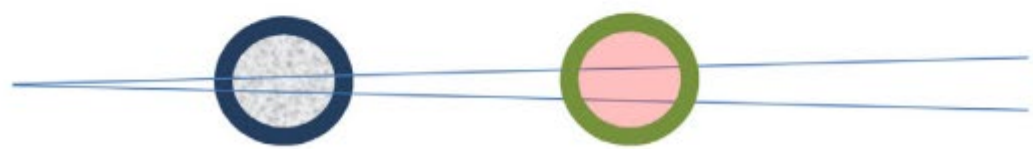
Concomitant irradiation of 2 localisations in 3 or 5 fractions
Mind CI in each met, and OAR between



1.6 AGNOSIA corrected

Systematic prescription +contribution to 1st met

If V12 to safe brain ≥ 10 cc : constraint added to previous met or brain *and corrects for V12*



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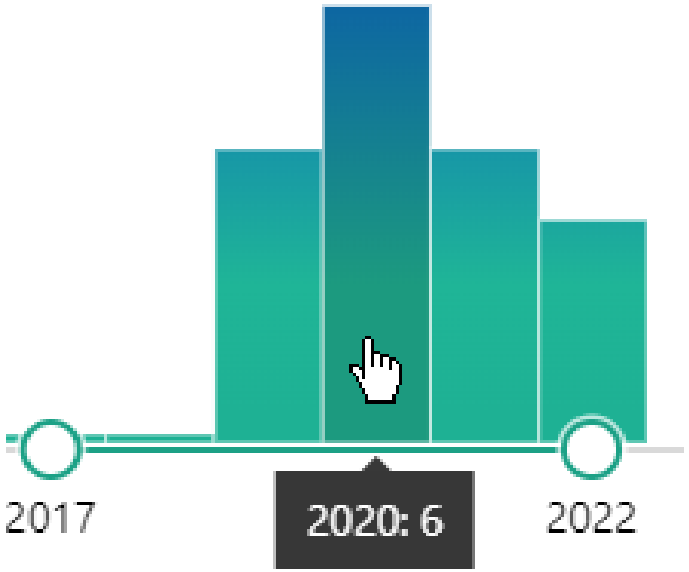
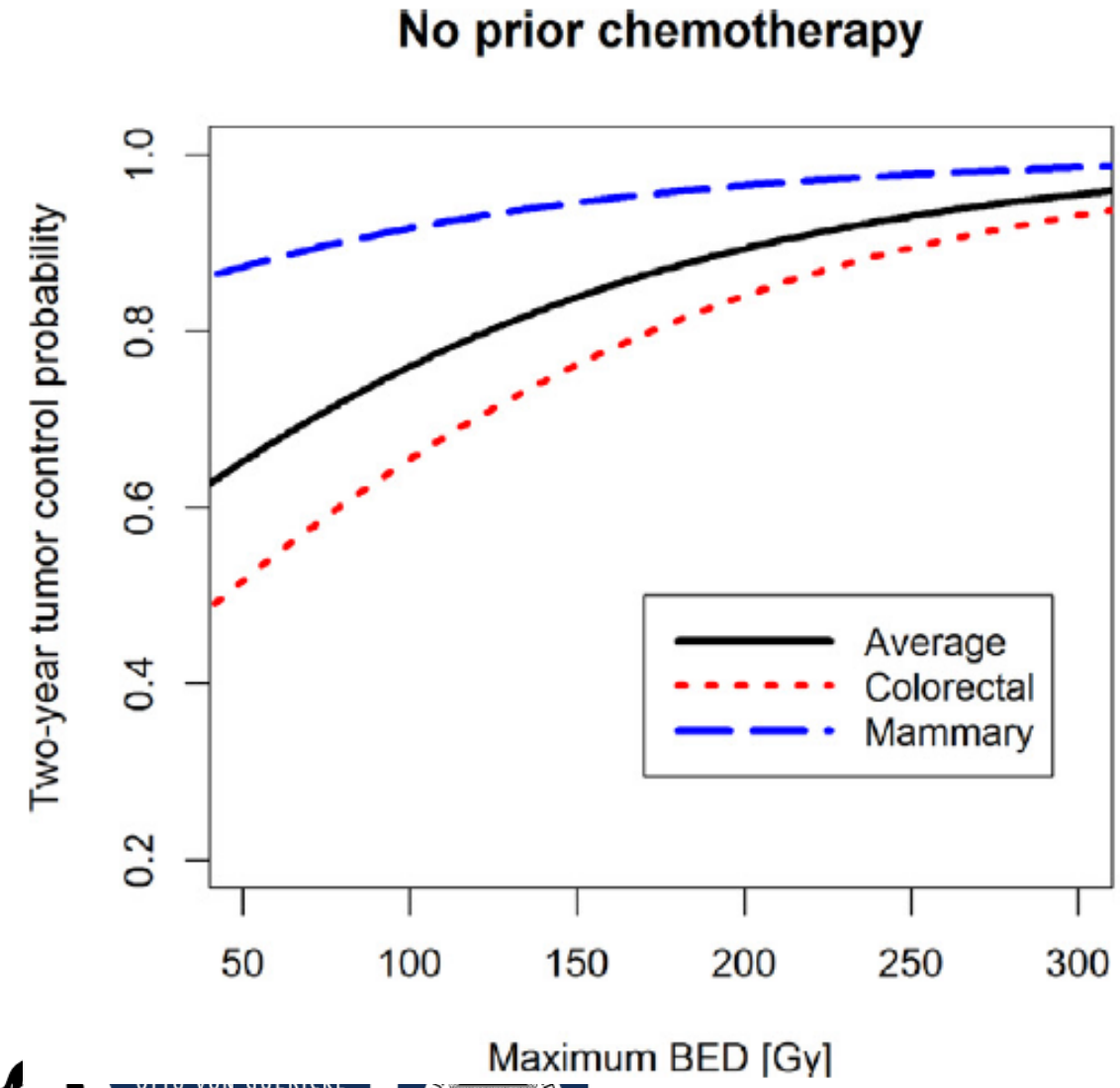
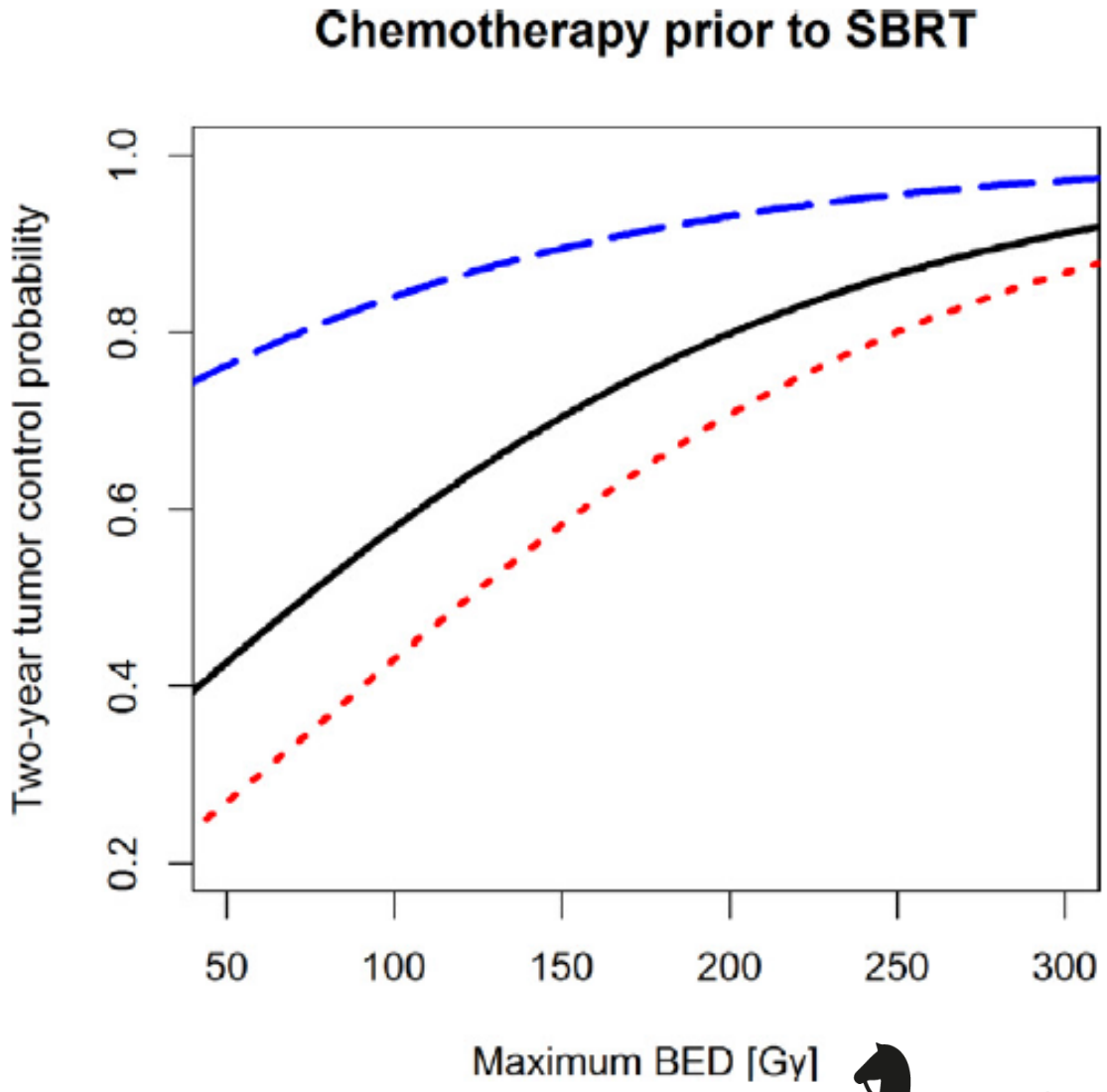
Summary and Conclusions



„ICRU report 91“; N = 12

EQD2: Vortherapie





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