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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

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Abstract
The International Commission on Radiation Units and Measurements (ICRU) report 91 with the title "prescribing, recording, and reporting of stereotactic treatments with small photon beams" was published in 2017. This extensive publication covers different relevant aspects of stereotactic radiotherapy such as small field dosimetry, accuracy requirements for volume definition and planning algorithms, and the precise application of treatment by means of image guidance. Finally, recommendations for prescribing, recording and reporting are given.

Keywords Stereotactic radiosurgery · Stereotactic radiotherapy · Stereotactic body radiation therapy · Radiotherapy planning, computer-assisted · Organs at risk

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ICRU-Bericht 91 über die Verschreibung, Aufzeichnung und Dokumentation von stereotaktischen Behandlungen mit kleinen Photonenfeldern

Stellungnahme der DEGRO/DGMP-Arbeitsgruppe Stereotaktische Strahlentherapie und Radiochirurgie

Zusammenfassung

In 2017 wurde der Report 91 der International Commission on Radiation Units and Measurements (ICRU) zur Verordnung und Dokumentation von stereotaktischen Bestrahlungen mit kleinen Photonenfeldern veröffentlicht. Die umfassende Publikation geht auf diverse relevante Aspekte der Stereotaxie ein, wie die Kleinfelddosimetrie, die Genauigkeitsanforderungen der Volumendefinition und der Planungsalgorithmen sowie die präzise Applikation der Bestrahlung mithilfe von Bildgebung. Schließlich werden Empfehlungen zu Verschreibung und Dosisdokumentation bei stereotaktischen Bestrahlungen gegeben.

Schlüsselwörter Stereotaktische Radiochirurgie · Stereotaktische Strahlentherapie · Stereotaktische Körperstammstrahlentherapie · Strahlentherapieplanung, computergestützte · Risikoorgane

Introduction

In 2017 the International Commission on Radiation Units and Measurements (ICRU) published its report 91 on prescribing, recording, and reporting of stereotactic treatments with small photon beams [1]. Report 91 specifically addresses stereotactic radiosurgery (SRS, cranial treatment, single fraction), stereotactic radiotherapy (SRT, cranial treatment, 2–12 fractions) and stereotactic body radiation therapy (SBRT, extracranial treatment, 1–12 fractions) and acknowledges that practice in this field differs from both conformal radiotherapy as well as intensity-modulated radiotherapy in several aspects. Whereas the ICRU reports 50, 62, and 83 [2–4] aimed at standardization of target volumes, dose prescription and dose reporting for large field radiotherapy, various characteristics of small-fields, high-dose, extremely hypofractionated SRS/SRT/SBRT are now addressed in the ICRU 91.

Limitations of ICRU report 50, 62 and 83 for stereotactic treatments

The volume definitions in ICRU reports 50, 62 and 83 are well suited for use in small volume stereotactic treatments. However, target volume definition in stereotactic treatments needs to be of high accuracy due to small margins, thus adequate imaging and the respective quality assurance are of utmost importance. None of the abovementioned reports defined the imaging modality best suited for gross tumor volume (GTV) and organ at risk (OAR) delineation.

The most frequently used method of dose prescription in stereotactic treatments was not covered in the ICRU reports 50, 62 and 83, i.e. dose prescription to the target covering isodose lines << 100%, e.g. the 50% or 80% target covering isodose line in Gamma Knife or linac-based stereotactic radiosurgery. In ICRU report 83, dose prescription to a reference point was abandoned because of its limitations in intensity modulated radiotherapy (IMRT), where treatments with inhomogeneous dose distributions within the target volume was practiced more frequently, by intention or unintentionally. Instead, it recommends to have multiple dose–volume histogram (DVH) based planning aims such as the $D_{2\%}$ and the $D_{98\%}$ to obtain good homogeneity and to prescribe to a DVH parameter such as the $D_{50\%}$. Nevertheless, this prescription to a volume of more or less homogeneous dose as proposed in the ICRU report 83 does not comprehensively cover all aspects of SRS/SRT/SBRT because one single dose–volume histogram (DVH) value does not accurately describe the generally inhomogeneous SRS/SRT/SBRT dose profile within the target volume.

None of the basic (level 1) or advanced (level 2) requirements of the first two reports (50 and 62) achieved adequate dose reporting necessary for SRS/SRT/SBRT. This is especially apparent when looking at the example of a lung SBRT case where neither the minimal dose (D_{min}), nor the reference point can adequately describe the dose distribution generally delivered for such treatments: within the air surrounding the GTV, which is inherently part of the PTV border zone, a substantially lower minimum dose will be absorbed 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, and consequently of limited relevance for the outcome of lung SBRT [5, 6]. The same is also true for brain SRS/SRT [7] and liver SBRT [8].

The most important step forward in the ICRU report 83 for SRS/SRT/SBRT was to emphasize the importance of DVH analysis. However, the reporting of the PTV $D_{2\%}$ and $D_{98\%}$ represent a significant problem in small-volume radiotherapy as these indices may become minute in absolute volume measures. Furthermore, a number of relevant quality indices (homogeneity, conformity and gradient index) were missing or regarded to be solely of developmental

nature (level 3) in the previous reports, though they were frequently used for describing stereotactic treatments and their quality. Such parameters were therefore not commonly if at all recorded in daily practice for stereotactic treatments when institutions followed the previous ICRU reports.

ICRU report 91 on stereotactic treatments with small photon beams

Small field dosimetry and quality assurance

A relevant prerequisite for the treatment with small photon beams is adequate small field dosimetry, which is now comprehensively covered in ICRU report 91 [1] and is based on the International Atomic Energy Agency (IAEA) technical report series 483 [9]. This was recently also implemented into the German DIN Norm 6809-8 [10]. Concerning stereotactic treatments, accurate dose calculation is also a significant requirement and the ICRU report 91 recommends that the dose calculation should be performed with a type-B algorithm whenever heterogeneous tissue densities are present (e. g., in the lung [11]). Type-B algorithms explicitly consider changes in lateral electron transport, while type-A do not, making them more inaccurate in inhomogeneities. Another prerequisite for stereotactic treatments is the mandatory use of a stereotactic frame or image-guided beam delivery and accordingly a comprehensive quality assurance of the whole SRS/SRT/SBRT process. This is now also described in the ICRU report 91 and follows previously published guidelines [12–14].

Definition of volumes

ICRU report 91 does not introduce major changes compared to the recommendations given in ICRU reports 50, 62 and 83 in respect to volume definitions. Concepts for GTV, clinical target volume (CTV), internal target volume (ITV) and PTV as well as OAR and planning organ at risk volumes (PRV) remain unchanged. However, in the chapter on target and organ-at-risk definition for stereotactic treatments, specific recommendations for optimal imaging modalities in order to allow accurate target volume delineation are provided for liver, head and neck, brain, lung, pancreas, bone, prostate and even for vascular SRS/SRT/SBRT.

Prescribing, reporting and recording

ICRU report 91 recommends that the prescription should include the constraints for the target volumes as well as for the OAR or PRV. Traditionally, in stereotactic treatments, dose was prescribed to the target covering isodose line. New compared to this practice in ICRU report 91 is the volumetric approach, in which the absorbed dose is prescribed to the isodose surface which should cover the optimal percentage of the PTV while optimally restricting the dose to the PRV. The term "optimal" is then strongly depending on the actual treatment situation. For SRS/SRT of a single brain metastasis away from any OAR this might mean that close to 100% of the PTV should be covered by the prescription isodose while for lung SBRT only 95% PTV coverage might be safely reached or for spinal SBRT only 80–85% of the PTV can be covered by the prescribed isodose due to the constraints on the spinal cord.

The ICRU report 91 recommends that reporting for stereotactic treatments should contain the following information:

- Clinical decisions (e. g. reason for dose prescription and fractionation according to an organ at risk-adapted prescription approach, preceding surgical interventions; previous or simultaneous systemic treatment)
- Delineated volumes
- Prescription and planning aims
- Description of treatment planning system (i. e. algorithm, voxel size, calculation dose grid and uncertainty for MC-based systems)
- Dose documentation to target volumes and organs at risk:
  - Calculated dose–volume histograms
  - PTV median dose ($D_{50\%}$) as well as PTV $D_{\text{near-min}}$ and PTV $D_{\text{near-max}}$
  - Optionally the median dose ($D_{50\%}$) for existing GTV/CTV and ITV contours (for lung SBRT documentation of these values is required)
  - For OAR at least three values should be reported: mean dose, $D_{\text{near-max}}$ and another relevant $V_{D\%}$ value
  - Dose homogeneity (if available mean dose to PTV and standard deviation of mean dose to PTV),
  - Dose conformity CI is given by the volume encompassed by the isodose hypersurface with the prescribed dose (prescription isodose volume, PIV), the volume of the target (PTV) and the volume of the target receiving the prescribed dose or more (PTV_{PIV}). As an example the Paddick's CI is given here, other CI exist:

$$CI = \frac{PTV \times PIV}{PTV_{PIV}^2}$$

- For radiosurgery of the brain also the dose-gradient GI given by the volume encompassed by the isodose hypersurface with half the prescribed dose (PIV_{half}) and the volume encompassed by the isodose hypersurface with the prescribed dose (PIV):

$$GI = \frac{PIV_{half}}{PIV}$$

Table 1 Overview of changes in dose prescription and dose reporting from ICRU report 50, 62 and 83 through ICRU report 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: $D_{50\%}$ D_{mean} $D_{near\text{-}min}$ $D_{near\text{-}max}$ OAR, PRV: D_{mean} $D_{near\text{-}min}$ V_D Dose-Homogeneity CI GI	Integral dose Biology based parameters

D dose, $D_{x\%}$ dose recieved by a percentage x of a volume, V_D volume recieving dose above the threshold dose D, *DVH* dose volume histogram, *PTV* planning target volume, *OAR* organ at risk, *PRV* planning organ at risk volume, *CI* dose conformity, *GI* gradient index, *TCP* tumor control probabilty, *EUD* equivalent uniform dose

- Documentation of stereotactic frame settings or image guidance
- Plan verification and patient-specific quality assurance
- Number of treated fractions
- Follow-up schedule

The near-minimum and near-maximum dose to the PTV ($D_{near\text{-}min}$ and $D_{near\text{-}max}$) were introduced in ICRU report 83 as the $D_{98\%}$ and $D_{2\%}$. However, for very small volumes of $<2\,cm^3$, which are often present in stereotactic treatments, the PTV $D_{98\%}$ and $D_{2\%}$ indices are hardly meaningful: therefore, in accordance with previous reports [13] the ICRU report 91 recommends using $D_{near\text{-}min} = D_{V\text{-}35mm3}$ and $D_{near\text{-}max} = D_{35mm3}$ for volumes $<2\,cm^3$. Nevertheless, the value of $35\,mm^3$ as minimal meaningful 3D cube might evolve with time depending on the calculation grid size and calculation accuracy in a single voxel and the ICRU report 91 near minimum and near maximum dose description for tumors of extreme small size (e. g., PTV of <100 mm^3) is still debated. Table 1 gives an overview of changes in dose prescription and reporting from ICRU report 50 through ICRU report 91.

Limitations

In ICRU report 91 it is recommended to involve external experts when starting a stereotactic radiotherapy program. In addition, continuous exchange between centers within the framework of working groups or multicenter trials will further support and improve the quality of stereotactic treatments [15, 16]. However, no specific recommendations are given.

The ICRU report 91 describes the importance of PTV dose escalation for multiple indications. However, for cases with OARs located close to the target volume or even within the target volume restricting PTV dose escalation, the possibility of GTV dose escalation inside a PTV with a reduced PTV dose should also be mentioned as an alternative to strict full-volume PTV dose escalation [17–19].

Additionally, the ICRU report 91 does not specify the optimal dose inhomogeneity within the target volume of the stereotactic treatments, as there are no explicit constraints provided on the maximum dose relative to the prescribed isodose. This comes as no surprise as there is a lack of consensus on the most relevant dosimetric parameters influencing local tumor control, may they be (near) minimum, (near) maximum, median or mean PTV/CTV/GTV doses and the debate is ongoing [15, 20, 21].

Clinical implementation and conclusion

The detailed practice of SRS/SRT/SBRT according to ICRU report 91 is illustrated in the form of several patient cases, which is helpful for implementation of the report into clinical practice. However, it should be mentioned that the details of clinical practice—such as target definition and treatment doses—are only examples and have no guideline character.

Otherwise, rapid implementation of the report is highly recommended, serving two goals in particular. First, ICRU report 91 will homogenize the practice of stereotactic radiotherapy on an institutional level, which is the basis for any process of continuous improvement. Second and most importantly, many details of optimal SRS/SRT/SBRT planning, dose prescription and delivery are still unknown: standardized and more detailed reporting of stereotactic treatment will allow better investigation of these questions and further optimize clinical best-practice. All centers practicing SRS/SRT/SBRT are therefore encouraged to participate in registry activities such as the projects of DEGRO Working Group “Stereotactic Radiotherapy and Radiosurgery” [15, 22–26].

Conflict of interest L. Wilke, N. Andratschke, O. Blanck, T.B. Brunner, S.E. Combs, A.-L. Grosu, C. Moustakis, D. Schmitt, W. Baus and M. Guckenberger declare that they have no competing interests.

References

1. Seuntjens J, Lartigau EF, Cora S et al (2014) ICRU report 91. Prescribing, recording, and reporting of stereotactic treatments with small photon beams. J ICRU 14(2):1–160
2. Jones D (1993) ICRU report 50. Prescribing, recording and reporting photon beam therapy. J ICRU 26(1):1–72
3. Landberg T, Chavaudra J, Dobbs J (1999) ICRU report 62. Prescribing, recording and reporting photon beam therapy (supplement to ICRU report 50). J ICRU 32(1):1–52
4. DeLuca P, Jones D, Gahbauer R et al (2010) ICRU report 83. Prescribing, recording, and reporting intensity-modulated photon-beam therapy (IMRT). J ICRU 10(1):1–107
5. Guckenberger M, Andratschke N, Alheit H et al (2014) Definition of stereotactic body radiotherapy: principles and practice for the treatment of stage I non-small cell lung cancer. Strahlenther Onkol 190(1):26–33
6. Guckenberger M, Andratschke N, Dieckmann K et al (2017) ESTRO ACROP consensus guideline on implementation and practice of stereotactic body radiotherapy for peripherally located early stage non-small cell lung cancer. Radiother Oncol 124(1):11–17
7. Kocher M, Wittig A, Piroth MD et al (2014) Stereotactic radiosurgery for treatment of brain metastases. A report of the DEGRO Working Group on Stereotactic Radiotherapy. Strahlenther Onkol 190(6):521–532
8. Sterzing F, Brunner TB, Ernst I et al (2014) Stereotactic body radiotherapy for liver tumors: principles and practical guidelines of the DEGRO Working Group on Stereotactic Radiotherapy. Strahlenther Onkol 190(10):872–881
9. International Atomic Energy Agency (2017) Dosimetry of small static fields used in external beam radiotherapy. IAEA technical reports series, vol 483
10. Deutsches Institut für Normung (2014) Klinische Dosimetrie – Teil 8: Dosimetrie kleiner Photonen-Bestrahlungsfelder. DIN 6809-8
11. Zheng D, Zhu X, Zhang Q et al (2016) Target dose conversion modeling from pencil beam (PB) to Monte Carlo (MC) for lung SBRT. Radiat Oncol 11:83
12. Keall PJ, Mageras GS, Balter JM et al (2006) The management of respiratory motion in radiation oncology report of AAPM Task Group 76. Med Phys 33(10):3874–3900
13. Benedict SH, Yenice KM, Followill D et al (2010) Stereotactic body radiation therapy: the report of AAPM Task Group 101. Med Phys 37(8):4078–4101
14. Halvorsen PH, Cirino E, Das IJ et al (2017) AAPM-RSS medical physics practice guideline 9.a. for SRS-SBRT. J Appl Clin Med Phys 18(5):10–21
15. Moustakis C, Blanck O, Ebrahimi F et al (2017) Planning benchmark study for SBRT of early stage NSCLC: results of the DEGRO Working Group Stereotactic Radiotherapy. Strahlenther Onkol 193(10):780–790
16. Lambrecht M, Melidis C, Sonke JJ et al (2016) Lungtech, a phase II EORTC trial of SBRT for centrally located lung tumours – a clinical physics perspective. Radiat Oncol 11:7
17. Andratschke N, Parys A, Stadtfeld S et al (2016) Clinical results of mean GTV dose optimized robotic guided SBRT for liver metastases. Radiat Oncol 11:74
18. Baumann R, Chan MKH, Pyschny F et al (2018) Clinical results of mean GTV dose optimized robotic guided SBRT for lung metastases. Front Oncol 8:171
19. Brunner T, Nestle U, Adebahr S et al (2016) Simultaneous integrated protection: a new concept for high-precision radiation therapy. Strahlenther Onkol 192(12):886–894
20. Moustakis C, Blanck O, Ebrahimi F et al (2017) Time for standardization of SBRT planning through large scale clinical data and guideline-based approaches (In regard to Mancosu et al). Strahlenther Onkol 193(12):1068–1069
21. Lebredonchel S, Lacornerie T, Rault E et al (2017) About the non-consistency of PTV-based prescription in lung. Phys Med 44:177–187
22. Rieber J, Abbassi-Senger N, Adebahr S et al (2017) Influence of institutional experience and technological advances on outcome of stereotactic body radiation therapy for oligometastatic lung disease. Int J Radiat Oncol Biol Phys 98(3):511–520

23. Tanadini-Lang S, Rieber J, Filippi AR et al (2017) Nomogram based overall survival prediction in stereotactic body radiotherapy for oligo-metastatic lung disease. Radiother Oncol 123(2):182–188
24. Andratschke N, Alheid H, Allgäuer M et al (2018) The SBRT database initiative of the German Society for Radiation Oncology (DEGRO): patterns of care and outcome analysis of stereotactic body radiotherapy (SBRT) for liver oligometastases in 474 patients with 623 metastases. BMC Cancer 18(1):283
25. Guckenberger M, Klement RJ, Allgäuer M et al (2013) Applicability of the linear-quadratic formalism for modeling local tumor control probability in high dose per fraction stereotactic body radiotherapy for early stage non-small cell lung cancer. J Thorac Oncol 8(8):1050–1058
26. Klement RJ, Allgäuer M, Appold S et al (2014) Support vector machine-based prediction of local tumor control after stereotactic body radiation therapy for early-stage non-small cell lung cancer. Int J Radiat Oncol Biol Phys 88(3):732–738