The new ICRU report on prescribing, recording and reporting light ion beam therapy

Oliver Jäkel for ICRU - Heidelberg Ion Beam Therapy Center and DKFZ
## History of the report

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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</thead>
<tbody>
<tr>
<td>2006 Jan</td>
<td>Vienna IAEA Meeting</td>
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<td>2006 Mar</td>
<td>Columbus IAEA-ICRU working party</td>
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<tr>
<td>2006 Aug</td>
<td>Letter of proposal for ICRU report by Bill Chu</td>
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<td>2006 Nov</td>
<td>Milan NIRS-CNAO meeting</td>
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<td>2007 Jan</td>
<td>IAEA publishes TecDoc</td>
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<td>2009 Sep</td>
<td>Heidelberg 1. ICRU working meeting</td>
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<tr>
<td>2010 Apr</td>
<td>Heidelberg meeting during PTCOG</td>
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<td>2010 Nov</td>
<td>Essen 2. working meeting (ICRU board)</td>
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<td>2011 Jun</td>
<td>Bethesda, 3. working meeting (ICRU board)</td>
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<tr>
<td>2011 Nov</td>
<td>Lyon meeting during NIRS-ETOILE</td>
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<td>2012</td>
<td>Discussions on RBE halted report</td>
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<tr>
<td>2014 Nov</td>
<td>Madison talk Paul/Oliver on continuation</td>
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<tr>
<td>2015 Jan</td>
<td>Tokyo 20th HIMAC Anniversary meeting</td>
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<tr>
<td>2018 Dec</td>
<td>Submission of report</td>
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</tbody>
</table>
Report Committee on Dose and Volume Specification for Prescribing, Recording and Reporting Ion-Beam Therapy

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ICRU 93

Prescribing, Recording and Reporting Light Ion Beam Therapy

Report is under proof reading after 13 years of work

Working Committee members:

Chair: Oliver Jäkel (HIT, DKFZ)
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Piero Fossati (CNAO/MedAustron)
Tadashi Kamada (NIRS)
Christian Karger (DKFZ, Heidelberg)
Naruhiro Matsufuji (NIRS)
Michael Scholz (GSI)
The pioneers at Berkeley: 1946-1992

1938: 1. patient treated with neutrons
1954: 1. patient treated with protons
1957: 1. patient treated with Helium ions (> 2000 patients)
1977: 1. patients treated with Ne, N, O, C, Si, Ar (total 433 pat.)

The 184 inch, 125MeV cyclotron

Ernest and John Lawrence
HIMAC Facility (Chiba, Japan)

Opened in 1994

3 rooms (passive)

2 rooms (scanning) since 2014

11000 patients treated by 2016

Gantry since 2017

Hypofractionation widely used for most patients (1-16fx)
Carbon Ion Therapy: Pilot Project at GSI 1997-2008
Cooperation between GSI, Heidelberg University Hospital, DKFZ, HZ Rossendorf

1. Patient treated on Friday Dec. 13th 1997

Gerhardt Kraft
Dep. Biophysics

Treatment of 435 patients using a scanned carbon ion beam
Ion Beam Centers in the world

Proton centers for comparison: 73 worldwide (PTCOG 2019)  
85 by 2022

ICRU 93 addresses the increasing clinical use of ion beam therapy
Content of the report

• 10 chapters on history, radiation biology, beam delivery, dosimetry, volumes, treatment planning, motion management, uncertainties, QA and recommendations.

• Special emphasis is put on RBE-weighted dose, its clinical use and reporting, in order to harmonize comparisons of clinical practices and results between ion beam centers, but also with centers using proton or X-ray therapy.

• Dosimetry recommendations are harmonized with TRS-398 and the base data from ICRU-90.

• Seven extensively described clinical cases from 3 centres (CNAO, HIMAC, HIT) are attached.
RBE for various particles

RBE is a function of LET, Z, cell type, dose, endpoint

Durante & Loeffler, 
*Nature Rev Clin Oncol* 
2010
RBE modelling for carbon

Three models are currently used for TP in ion RT:

• Empirical Kanai model: Passive systems in Japan
• Local effect model (LEM): GSI, HIT, CNAO
• Modified Microkinetic Model (mMKM): HIMAC (Spot scanning)

Common aim:
Transfer of experimental to clinical RBE
Conversion from in-vitro to in-vivo

- Neutron experience at NIRS: RBE = 3 (skin tox.)
- C-12 at same LET (80keV/μm) has same RBE
- Scaling of biol. dose to clinical dose by 1.5 (2.41 in mMKM)

The different models are adapted to clinical parameters in very different ways and use very different endpoints, tissue parameters, …
Main recommendations of ICRU 93

- Due to the regulations of the SI-system, the use of the unit Gy (RBE) for RBE-weighted dose is strongly discouraged.

- Both, absorbed dose and RBE-weighted dose should be expressed in the unit Gray (Gy) without any modification.

- To avoid confusion, ICRU recommends to add a descriptor to the term dose: *absorbed dose or RBE-weighted dose*.

- For the reporting it is recommended to report RBE-weighted dose and absorbed dose and dose-weighted LET for each treatment plan, to clearly define the basis for RBE-modelling.

- All details of the RBE model used for the optimization of a treatment plan have to be clearly reported.

- The dosimetry protocol of TRS-398 should be followed in its updated form.
Example on plan reporting

Carbon Ion RT of a rec. glioblastoma (IV) - 45Gy/15Fx (from HIT)

Relative dose-weighted LET

RBE-weighted dose

absorbed dose

RBE distribution
Helium treatments at HIT are scheduled for May 2020.
Mapping of RBE-Weighted Doses Between HIMAC— and LEM-Based Treatment Planning Systems for Carbon Ion Therapy

Olaf Steinsträter, Ph.D.,* Rebecca Grün, M.Sc.,* †, ‡ Uwe Scholz, M.Sc.,*,§ Thomas Friedrich, Ph.D.,* Marco Durante, Ph.D.,* †, ‡ and Michael Scholz, Ph.D.*

Table 1  Comparison of median and EUD calculated for LEM estimated RBE-weighted dose distributions in dependence of prescribed HIMAC RBE-weighted doses, $d_{RBE}^{HIMAC}$, for 60-mm SOBPs (depth according to Fig. 1b) and both RBE tables (LEM I/LEM IV)

<table>
<thead>
<tr>
<th>Prescribed RBE-weighted dose HIMAC, Gy (RBE)</th>
<th>RBE-weighted dose LEM, G y (RBE)</th>
<th>LEM IV</th>
<th>LEM I</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median</td>
<td>EUD</td>
<td>Median</td>
</tr>
<tr>
<td>1</td>
<td>1.65</td>
<td>1.73</td>
<td>1.76</td>
</tr>
<tr>
<td>2</td>
<td>2.65</td>
<td>2.76</td>
<td>2.80</td>
</tr>
<tr>
<td>3</td>
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<tr>
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<td>4.81</td>
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<tr>
<td>6</td>
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<td>5.58</td>
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<td>6.52</td>
<td>6.70</td>
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<tr>
<td>9</td>
<td>7.04</td>
<td>7.23</td>
<td>7.30</td>
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<td>60</td>
<td>28.06</td>
<td>27.97</td>
<td>27.44</td>
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</tbody>
</table>

Abbreviations: EUD = equivalent uniform dose; HIMAC = Heavy-Ion Medical Accelerator facility, National Institute of Radiological Science, Japan; LEM = Local Effect Model (versions I and IV); RBE = Relative Biological Effectiveness; SOBP = spread-out Bragg peak.
Neo-Adjuvant Trials

PROMETHEUS Trial

Inoperable Liver Cancer

- Monocentric
- Dose escalation trial
- $4 \times 10^{-14} \text{ Gy (RBE(NIRS)) C12}$
- $4 \times 7.1 - 10.5 \text{ Gy (RBI(GSI)) C12}$
- Safety & Response
- Start 5/11

Combs et al., BMC Cancer 2011
Thank you for your attention