Intraoperative electron beam intercomparison of 6 sites using mailed thermoluminescence dosimetry: Absolute dose and energy

Anna Petoukhova [a], Wim Dries [b], Nicolas Hertsens [c], Piet Stevens [d], Valerie Jarbinet [e], Cathryn Huibregtse Bimmel-Nagel [b], Jan Weterings [b], Ko van Wingerden [a], Charlotte Bauwens [c], Verdi Vanreusel [d], Stéphane Simon [f]

[a] Haaglanden Medical Centre, Department of Medical Physics, Leidschendam, The Netherlands

[b] Catharina Hospital, Eindhoven, The Netherlands

[c] AZ Groeninge, Kortrijk, Department of Radiotherapy, Belgium

[d] Iridium Netwerk, Wilrijk, Belgium

[e] CHU Tivoli, La Louvière, Belgium

[f] Jules Bordet Institute, Brussels, Belgium

7 November 2024, 12th ISIORT conference Brussels, Belgium

Purpose/Objective

In 2018, the Netherlands Commission on Radiation Dosimetry (NSC) launched a subcommittee on the subject of intraoperative radiotherapy. We performed:

- a dosimetry audit specific to intraoperative irradiation
- with different equipment and accelerators among committee members in Belgium and The Netherlands.

Material/Methods: accelerators

In this study, three types of IOERT dedicated mobile accelerators were represented:

- Mobetron (IntaOp, USA) with electron energies of 6, 9 and 12 MeV
- LIAC HWL (S.I.T. Sordina IORT Technologies, Italy) with electron energies of 6, 8, 10 and 12 MeV
- LIAC (S.I.T. Sordina IORT Technologies, Italy) with electron energies of 6, 8, 10 and 12 MeV

Material/Methods: current dosimetry practices

Preceding the intercomparison, a questionnaire was sent to all 6 participating sites about accelerator equipment, dosimetry equipment and practice:

Full institution name	Catharina Hospital Eindhoven	Haaglanden Medical Centre	Jules Bordet Institute	Academic Medical Centre Tivoli	Iridium RT network	Algemeen Ziekenhuis Groeninge
Type of machine	Mobetron 2000	Mobetron 2000	Mobetron 2000	Mobetron 2000	LIAC HWL	LIAC
Protocol	NCS-18	NCS-18	TRS-398	NCS-18	S.I.T.	S.I.T.
Primary standard	Van Swinden Lab (calorimetric)	Van Swinden Lab (calorimetric)	PTW Calibration Lab	Van Swinden Lab (calorimetric)	Van Swinden Lab (calorimetric)	SCK CEN/LNK (Co-60)
In-house sec standard (detector, electrometer, phantom, beam)	PTW Roos pp-chamber with PTW Webline conversion from water to PMMA phantom with Elekta Versa HD 10x10cm electron beam	PTW Roos pp-chamber with Inovision cross-calibrated against NE 2571 IC in water phantom with Mobetron 2000, 10 cm in diameter 12 MeV electron beam	PTW Roos pp-chamber with Unidos electrometer	NACP cross-calibrated with farmer chamber in 20 MeV electron beam with Unidos (PTW) electrometer	Advanced Markus pp-chamber with PTW Unidos electrometer in PTW MP3-XS water phantom	PTW Roos pp-chamber with PTW Unidos E cross-calibrated against Farmer FC 65-G in water phantom with Varian TB 15x15cm electron beam

Material/Methods: TLDs

TLDs were ordered from the Radiation Dosimetry Services (RDS) (Houston, USA)[1]:

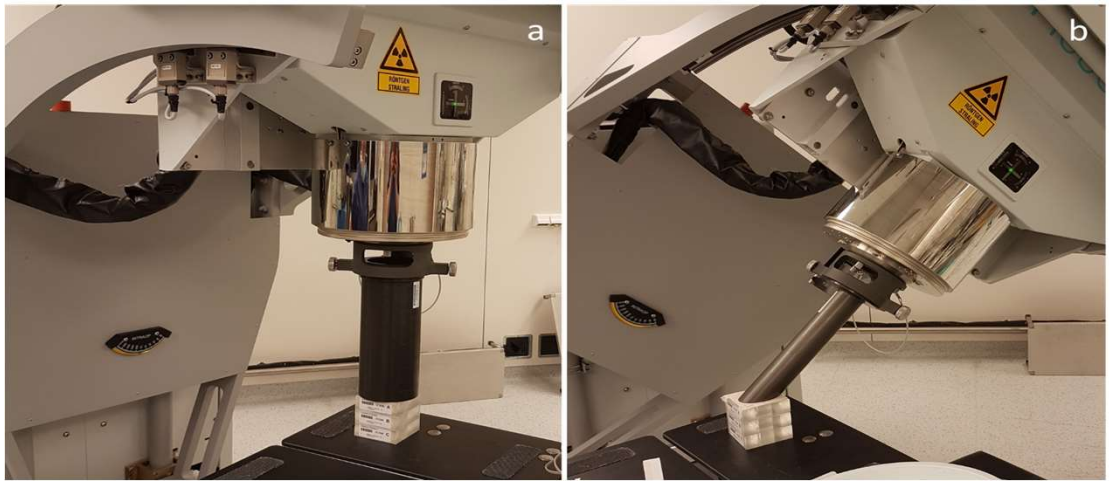
- A set of three 30×85×85 mm^3 PMMA slab phantoms was used (mailed).
- Each slab has a central hole designed to accommodate a PMMA insert (90×30×30 mm^3) in which two sets of three TLDs were positioned.
- TLDs were located, at users' specific depths, one set at depth as close as possible to D_{max} and one set around R50.
- TLDs were to be irradiated to 300 cGy at D_{max}.

1. Kirby TH, Hanson WF, Johnston DA. Med Phys 1992;19:1427–33. https://doi.org/10.1118/1.596797.

Material/Methods: TLDs

According to the RDS, a test is considered satisfactory if:

- the difference between the expected and the measured dose is less than 5%;
- the difference between the expected and the measured R50 is less than 5 mm.

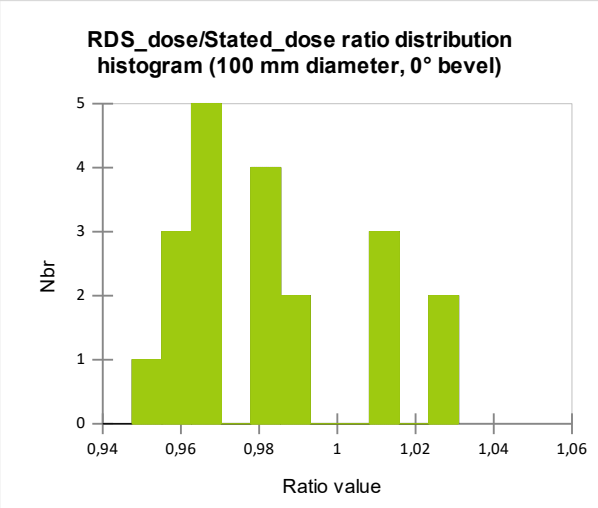


Measurement setup of RDS phantom for reference conditions (10 cm diameter 0° bevel applicator for all energies, a) and for 5 cm diameter 45° bevel applicator (b).

Results: 100 mm diameter 0° bevel

Audit measurements with the reference applicator were performed for 20 beams, 12 from Mobetron and 8 from SIT machines:

- All measurements came back as satisfactory, with a ratio between the RDS dose and the stated dose ranging from 0.95 to 1.03.
- The average value was 0.984.

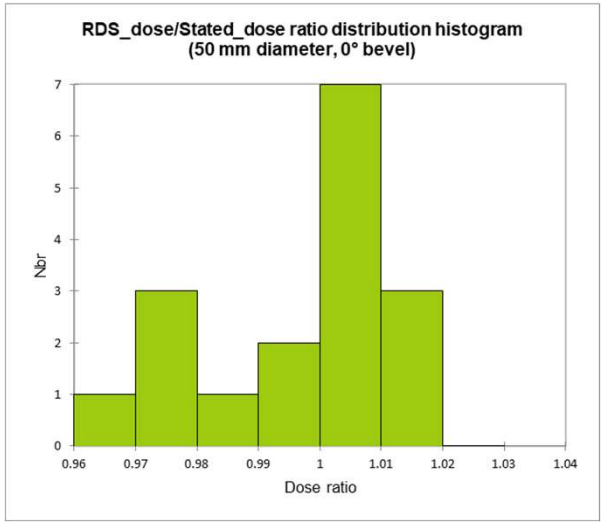


Histogram of ratios between RDS dose and stated dose at dmax for the reference field.

Results: 50 mm diameter 0°bevel

A total of 17 beams were checked and considered as satisfactory with the 50 mm 0° bevel applicator, 9 with a Mobetron and 8 with a SIT machine:

- The RDS dose to stated dose ratios ranged from 0.96 to 1.01.
- The mean value was 0.992.



Histogram of ratios between RDS dose and stated dose at dmax for the 50 mm diameter field (0° bevel).

Results: 50 mm in diameter 45° bevel

The last verification concerned a typical beam used in pelvic irradiation (50 mm 45° beveled, 6 MeV):

- A difference of +14% compared to the expected dose at Dmax.
- This difference was confirmed by additional measurements.
- After the intercomparison, the measurement procedure has been redefined and output factors for all beams have been corrected at this institute.

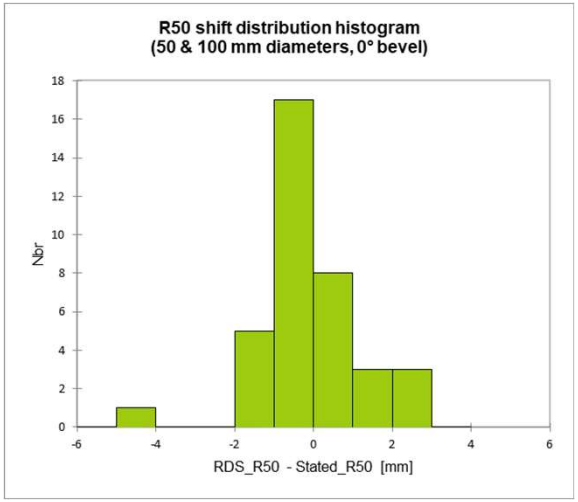
Results: 100 mm diameter 0° bevel

- No statistically significant difference in calibration checks could be found between IntraOp users (mean ratio : 0.982) and SIT users (mean ratio : 0.986) (p-value 0.667).
- No difference was found either between the 3 calibration protocols used (NCS-18, SIT, IAEA TRS 398) (p-value = 0.083), or between beam energies (6, 8, 9, 10 and 12 MeV) (p-value = 0.200).
- Neither between users's calibration lab (VSL, PTW, SCK CEN) (p-value = 0.084).
- A significant difference was noticed between measurements with the different reference ion chambers (p-value = 0.026).

Results: R_{50} determinations

For the R_{50} determinations, 37 beams were checked and considered satisfactory:

- The differences ranged from -5 to 2 mm.
- The average difference was -0.62 mm.



Histogram of R_{50} shifts between RDS measurements and stated PDD (50 and 100 mm diameters, Bevel 0°).

Conclusions:

Based on our intraoperative electron beam intercomparison[1]:

- **All except one absolute dose values of non-reference beams and all energy values are well within measurement accuracy of RDS TLDs.**
- **Deviations were not significantly dependent on manufacturer, energy, diameter and calibration protocol.**
- **Still, one outlier could be found and this demonstrates the relevance of redundant output factor determinations and independent verification.**

1. Dries W, Petoukhova A, Hertsens N, Stevens P, Jarbinet V, Bimmel-Nagel CH, Weterings J, van Wingerden K, Bauwens C, Vanreusel V, Simon S. Phys Med. 2024;119:103302. doi: 10.1016/j.ejmp.2024.103302.

Recommendations:

Based on our results, we recommend:

- **To check clinical applicators for cracks before use, mechanically checked annually.**
- **To check all clinical applicators and clinical beam combinations output factors every 2 years**

According to the AAPM TG72 Report[1] recommendations, the applicator factors should be measured annually with a tolerance of 2-3%.

1. A. Sam Beddar, Peter J. Biggs, Sha Chang, *et al.* Med. Phys. 2006; 33:1476–892.

Acknowledgements

This study has been made possible by an unrestricted sponsoring by NCS, IntraOp and SIT which covered the mailed TLD-dosimetry costs.

Thank you very much for your attention!