Master's Thesis Engineering Technology

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Towards Traceable Dosimetry for Electronic Brachytherapy Devices

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INTRODUCTION

Approximately half of all cancer patients receive radiation therapy, which underlines the importance of innovation and improvements in the field of radiation treatments. **Electronic brachytherapy** (eBT) is an innovative way of treating surface lesions or skin cancer and has the potential to improve healthcare, not only in cost, but also in treatment. However, it still lacks in **standardized dosimetric methodologies** and **traceability** to primary standard labs. This research aims to contribute towards resolving this issue. Therefore, the primary objective is to establish calculated and measured correction factors necessary to operate a traceable standardized dosimetric formalism. The proposed formalism applies to various eBT systems that treat with **surface applicators** and is used to convert air kerma measurements, free in air, into **absorbed dose to water** at the surface of a water phantom. The eBT systems regarded are the Xoft Axxent® and the Zeiss Intrabeam® and the surface applicators used are the 35 mm surface applicator and the 40 mm surface applicator, respectively. This research is part of the PRISM-eBT project funded by the EMPIR programme, co-financed by the Participating States and by the European Union's Horizon 2020 research and innovation programme.

MATERIALS AND METHODS

- A combination of **Monte Carlo** (MC) measurements and ionisation chamber measurements are used to calculate the various correction factors.
- MC measurements are made with the TOPAS MC user-code and previously established models of both eBT systems (including surface applicator).
- Ionisation chamber measurements are preformed by the **National Metrology Institutes** VSL and PTB.
- The ionisation chambers used are the Exradin A20® and PTW 23342®

- Correction factors:
    - Mass energy-absorption coefficient ratio for water to air
    - Backscatter factor
    - Air kerma (ion chamber) calibration factor
    - Beam quality correction factor
    - Absorbed dose ratio from 70 µm to 1cm

- The proposed formalism is based on IAEA-TRS398, AAPM-TG61 and NCS-10.

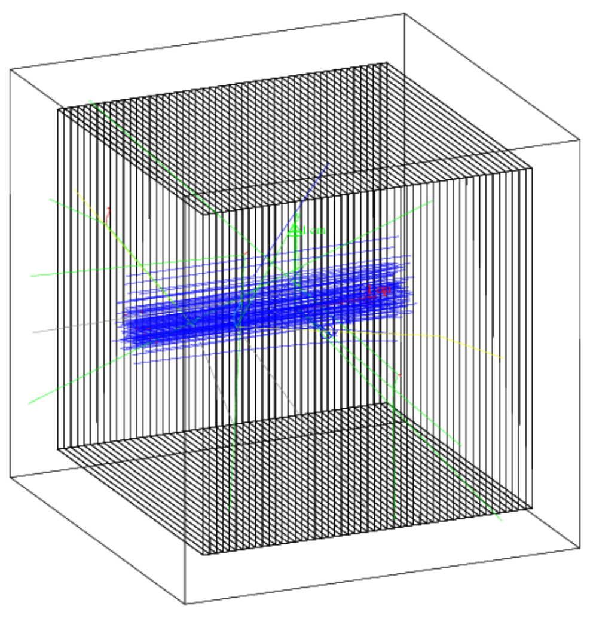

Figure 1: Simulation setup [1].

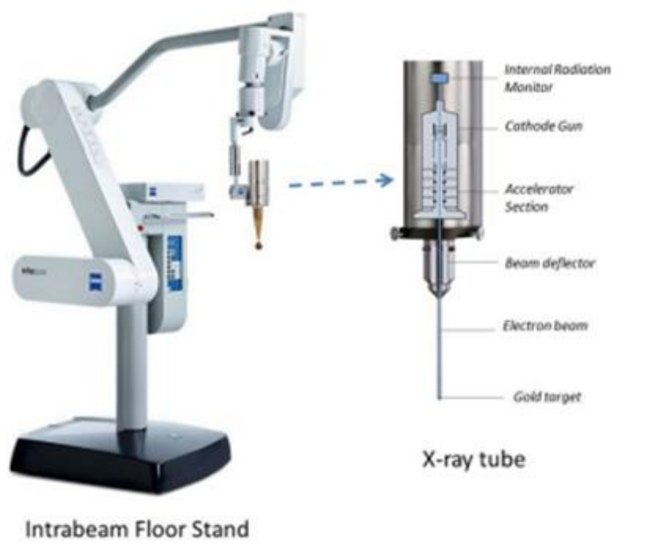

Figure 2: Zeiss Intrabeam eBT system [2].

$$\boxed{D_{w,z=0}} = (K_{air}) \cdot \left[\left(\frac{\bar{\mu}_{en}}{\rho}\right)^{W}_{air}\right]_{air} \cdot B_w = (M \cdot N_{K,Q_{eBT}} \cdot k_{Q_{eBT,surfac},Q_{eBT}}) \cdot \left[\left(\frac{\bar{\mu}_{en}}{\rho}\right)^{W}_{air}\right]_{air} \cdot B_w$$

RESULTS

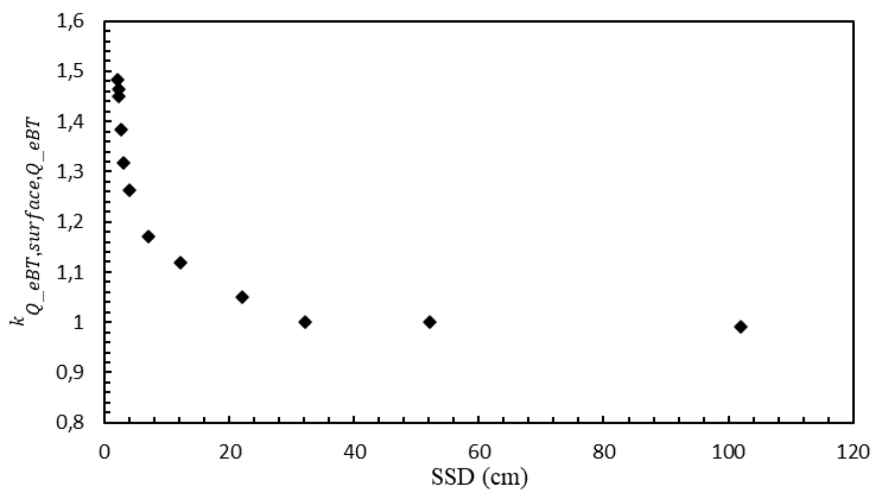

Figure 3: $k_{Q_{eBT,surface},Q_{eBT}}$ calculated for the Axxent (+35 mm surface applicator) with the Exradin A20 ionisation chamber.

- ➢ Excluding outliers, the difference in $k_{Q_{eBT,surface},Q_{eBT}}$ values between 30 cm and 1 m is 2.8%. This is in accordance with the uncertainty budget decided upon in the PRISM-eBT project. However, the correction factor at het surface is very high.

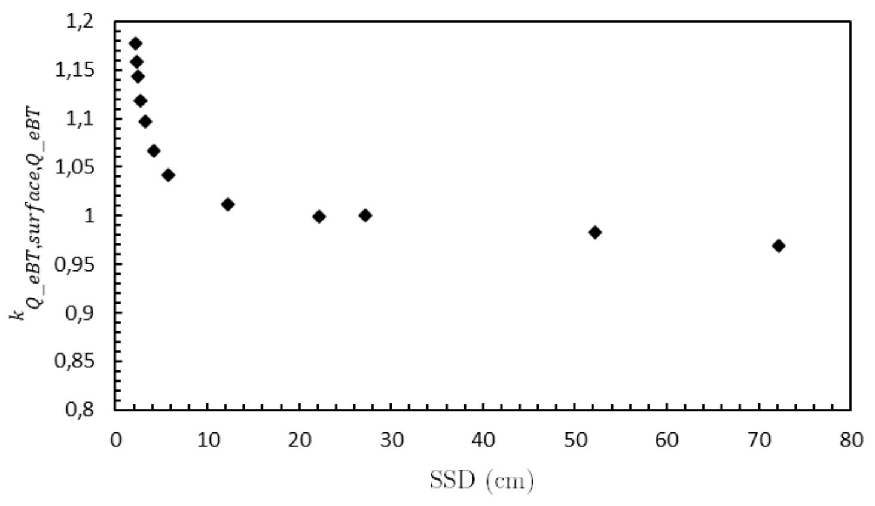

Figure 4: $k_{Q_{eBT,surface},Q_{eBT}}$ calculated for the Intrabeam (+40 mm surface applicator) with the Exradin A20 ionisation chamber.

- ➢ The difference in $k_{Q_{eBT,surface},Q_{eBT}}$ values between 25 cm and 75 cm, is 1.52%. This is in accordance with the uncertainty budget decided upon in the PRISM-eBT project.

Table 1: MC correction factors calculated for the Xoft Axxent and Zeiss Intrabeam, equipped with a 35 mm and 40 mm surface applicator.

	$[(\bar{\mu}_{en}/\rho)^{w}_{air}]_{in-air}$	B_w	$D_{70\mu m}/D_{1cm}$
Xoft Axxent	1.0175 ±0.30%	1.109 ±0.10%	3.119 ±0.043%
Zeiss Intrabeam	1.0316 ±0.50%	1.047 ±0.47%	8.485 ±1.21%

- ➢ The differences between the MC calculated correction factors and correction factors given by TG-61, with respect to beam quality, are <1%.

Table 2: Comparison between the absorbed dose rate at the surface of a water phantom, calculated according to the proposed formalism, TG-61 [3] and by [4].

Xoft Axxent	Formalism		
	Proposed $\dot{D}_{z=0}$ (Gy/min)	TG-61 $\dot{D}_{z=0}$ (Gy/min)	Fulkerson *et. al* $\dot{D}_{z=0}$ (Gy/min)
Exradin A20	2.22	1.80	1.71

- ➢ The proposed formalism does not show good agreement with other methodologies for the Xoft Axxent and Exradin A20 ionisation chamber.

CONCLUSION

In this research, a formalism is proposed for low energy electronic brachytherapy systems used with surface applicators. The main objective was to calculate all correction factors necessary to operate the formalism. These **correction factors agree** with TG-61. However, **improvements in the beam correction factors** need to be made, since implementation of the formalism for the Xoft Axxent and the Exradin A20 show large discrepancies with the literature. Therefore, it can not be concluded that the formalism is valid, in terms of absorbed dose to water at the surface of a water phantom, when using the Exradin A20 in the Axxent beam. Improvements in the beam correction factors can be made by increasing ionization chamber measurements at all distances.

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