Publishable Summary for 18NRM02 PRISM-eBT
Primary standards and traceable measurement methods for X-ray emitting electronic brachytherapy devices

Overview

Electronic brachytherapy (eBT) is a cost-effective radiotherapeutic modality for the treatment of skin lesions, intraoperative partial breast irradiation, intracavitary and interstitial sites, brain tumours and kypho-Intraoperative Radiotherapy (IORT). While it offers potential for an extensive utilisation, this is unlikely to be achieved whilst eBT systems rely on individual calibration procedures. In most cases these systems are not directly traceable to NMIs and rely on indirect calibration methods with uncertainties larger than clinically acceptable. This project will deliver a harmonised, simplified and traceable dosimetry for eBT, detectors and measurement devices for the determination of 3D dose distributions in water, and therefore ensure that these systems can achieve their full clinical potential.

Need

Currently, most commercial eBT systems rely on specific calibration tools and procedures. It is therefore difficult to adopt clinically established treatment plans from one system to another, which impedes progress in this modality of radiotherapy. Direct traceability to an NMI is non-existent in terms of absorbed dose to water, the standard quantity in radiation therapy. Traceability has only been achieved for one commercially available device – outside Europe - in terms of air kerma strength, a quantity for which dosimetry for this type of sources is less robust than in terms of absorbed dose to water. Thus, the core requirement of clinical medical physics that dosimetry should be subject to independent and traceable verification is not yet met. Additionally, typical uncertainties of ± 10-15 % (k = 1) for IORT procedures using eBT are reported, which are larger than clinically acceptable.

Therefore, primary standards and suitable transfer instruments must be established for internal radiotherapy as well as for superficial (skin) external radiotherapy. Additionally, it is necessary to provide traceability for 3D dose distribution measurements. In contrast to external beam therapy, this is hardly existent in brachytherapy in general, due to the high demands on the experimental work in positioning and dosimetry.

As the numbers of treatment plans, eBT systems (with different tube types and surface applicators), and radiation fields increase, providing traceability for each of these configurations would overburden the calibration service facilities and increase the cost for vendors and end users. Therefore, a methodology needs to be developed which requires only a single calibration chain for a simple generic set of radiation conditions for each device. Measurement procedures need to be established to facilitate quality assurance measurements and ensure traceability of commercial eBT treatment planning systems. As a basis for such studies leading to traceability, detectors and measurement devices for the determination of 3D dose distributions in water need to be established.

Objectives

The overall goal of this project is to carry out pre-normative research on eBT to simplify and harmonise eBT dosimetric procedures and provide metrological input to standardisation bodies.

The specific objectives are:

1. To establish primary standards for the absorbed dose rate to water for eBT devices at 1 cm depth of water for internal radiotherapy. To evaluate currently used transfer instruments and corresponding measurement procedures and to establish simple and robust tools for dissemination of the absorbed dose rate to water to clinical practice.

2. To establish a dosimetric methodology for superficial eBT aligned with or similar to the recommendations for superficial (skin) external radiotherapy given in International Atomic Energy Agency - Technical Reports Series (IAEA-TRS) 398, Deutsches Institut für Normung (DIN) 6809-4, Nederlandse Commissie voor Stralingsdosimetrie (NCS)-10 and Institute of Physics and Engineering in Medicine (IPEM). The target uncertainty for the conversion of dose at the surface (i.e. 70 µm) to dose at 1 cm depth is 5 %.
3. To characterise detectors and measurement instruments suitable for the determination of 3D dose distributions in water by eBT devices. To develop a standardised traceable calibration process for these detectors, allowing a reduction in the uncertainties in dose, dose distribution and dose-effect-relation to a level recommended in IAEA Human Health Report No 31. The aim is to achieve uncertainties (k = 1) for the calibration coefficients of not more than: 1 % - 2 % (NMIs) and 2 % - 3 % (clinic) for the scintillation detectors and for the small volume ionisation chambers, 3.5 % for the gel dosimeter and 2.5 % for the alanine pellets.
4. To provide traceable dosimetry for 3D dose distribution measurements for at least three eBT commercial systems for which no dosimetry system currently exists and to make them available for the end user community.
5. To contribute to the development of technical work of IAEA and others where appropriate to ensure that the outputs of the project are aligned with their needs, communicated quickly to those developing the standards and to those who will use them, and in a form that can be incorporated into the standards at the earliest opportunity.

Progress beyond the state of the art and results

Primary standards and traceability route for internal radiotherapy

Four primary standards will be developed for the realisation of the absorbed dose to water for internal radiotherapy with eBT devices at 1 cm depth within a water phantom. These will be developed to provide a more direct traceability to absorbed dose to water and hence achieve better uncertainties than attainable with currently available primary standards. Selected ionisation transfer instruments currently used in radiotherapy will be investigated to establish simple and robust measurement procedures and tools for dissemination of the absorbed dose rate to water to clinical practice. This will improve patient safety.

Superficial eBT

This project will establish, for the first time, a dosimetric methodology for superficial (skin) treatment with eBT, in terms of absorbed dose to water at the surface of a water phantom. The basis of this traceability route will be formed by existing formalisms for low energy X-rays and implemented for eBT systems. Recommendations will be prepared for an IAEA Code of Practice for reference dosimetry for superficial (skin) treatment eBT devices equipped with surface applicators. The recommendations developed within the project will be aligned with the recommendations for superficial (skin) external radiotherapy given in TRS 398, DIN 6809-4, NCS-10 and IPEM.

Characterisation and calibration of detectors for 3D dose distribution measurements

Different radiation detectors will be characterised for the measurement of 3D dose distributions close to various commercially available low energy eBT X-ray devices with or without fitted applicators. A standardised traceable calibration process for these detectors will be established for the first time. The aim is to achieve uncertainties (k = 1) for the calibration coefficients of not more than: 2.5 % for the scintillation detectors, 2.5 % for the small volume ionisation chambers, 3.5 % for the gel dosimeter and 2.5 % for the alanine pellets. This will enable more accurate 3D dose distribution measurements close to eBT sources compared to currently used methods.

3D dose distribution measurements and comparison with vendor-supplied dose maps

Based on the detector characterisations, traceable dosimetry for 3D dose distribution measurements will be provided for eBT systems, for which no dosimetry system currently exists. The methodology will be validated by comparing the measured 3D dose distributions with the vendor-supplied dose maps. The methodology will be described in Good Practice Guides (GPGs) which will be provided to Standards Developing Organisations (SDOs).

Impact

This project will establish primary standards, develop measurement methods, and prepare Good Practice Guides of direct relevance to manufacturers, standards developing organisations and end users of eBT devices. Uptake will be facilitated by the advisory board representing European or national organisations or working groups of medical physicists (BRAPHYQS, DGMP WG-IORT) and standardisation groups (DIN/NAR and IAEA). In addition, all relevant eBT-vendors will be invited to collaborate with this project and their feedback will be sought.

Impact on industrial and other user communities

A calibration method for eBT in terms of absorbed dose rate to water directly traceable to NMIs will be available for the first time for all commercially available eBT devices. New calibration services for EU end users will be offered. Robust and efficient procedures will be established based on metrological standards and corresponding transfer instruments resulting in improved acceptance and marketability of eBT devices. Standardisation and harmonisation in calibration methods will improve health care, due to a more precise and less error-prone dose delivery, and harmonised and improved reporting within Europe. It will also reduce effort and costs of manufacturers of eBT systems, when developing quality assurance procedures and calibrations for their eBT devices.

Impact on the metrology and scientific communities

Primary standards for absorbed dose to water will be realised. Moreover, new “eBT equivalent” X-ray qualities will be established which can be adopted, without high costs, by NMIs in other countries enabling them to open a calibration service in their country. This will enable the dissemination of absorbed dose to water at ,1 cm depth in Europe and worldwide, which will improve the comparability of clinical studies with these devices.

As radiation fields in BT have step gradients in lateral and longitudinal extension, their dosimetric complexity is similar to external small field dosimetry. Therefore, this project will have impact on the metrology related to both detectors and measurement procedures. This project will also lay the dosimetric foundation for future topics, such as dose enhancement effects of gold nanoparticles in combination with eBT-devices.

Impact on relevant standards

Relevant standards comprising all eBT devices are non-existent and need to be established. This project will provide substantial contribution to an updated version of IAEA-TECDOC-1274, which will cover all topics of brachytherapy. This project will also provide valuable fundamental insight and missing information for the development of dosimetric methods for high energy photon emitting sources to the German DIN Standards Committee for Radiology (NAR). Additionally, the consortium will inform other standardisation bodies (e.g EURAMET-TC-IR, CCRI(I) and ISO TC85 SC2) on the progress of the project.

Longer-term economic, social and environmental impacts

According to the European Cancer Observatory the estimated cancer incidence in the European Union is set to reach 3.0 million people in 2018, and approximately half of these patients receive radiotherapy as part of their treatment course. Because the treatment costs for eBT are lower compared to conventional radiotherapy, a higher acceptance and wide use of eBT will contribute to a reduction in costs to the health systems of European countries. Standardisation and harmonisation in calibration methods, as promoted by this project, will improve health care due to a more precise and less error-prone dose delivery as well as harmonised and improved reporting within Europe.

List of publications

There are no publications yet.

Project start date and duration:	1 July 2019	
Coordinator: Thorsten Schneider, PTB Tel: +49 531 592 6346 E-mail: thorsten.schneider@ptb.de Project website address: *under construction*		
Chief Stakeholder Organisation: IAEA	Chief Stakeholder Contact: Paula Toroi	
Internal Funded Partners: 1. PTB, Germany 2. CEA, France 3. CMI, Czech Republic 4. ENEA, Italy 5. NPL, United Kingdom 6. VSL, Netherlands	External Funded Partners: 7. MAASTRO clinic	Unfunded Partners:
RMGx: --		