EMPIR Call 2015 – Health, SI, Normative and Research Potential

Selected Research Topic number: **SRT-h16**
Version: 1.0

Title: Accurate references and traceability for radiation quantities under non equilibrium conditions in radiotherapy

Abstract

Current standards on the use of non-equilibrium beams in external radiotherapy are unsatisfactory; and studies on radiotherapy doses delivered to patients using anthropomorphic phantoms and reports on radiotherapy accidents show large tumour dose errors are encountered (several tens of percent), despite the low primary standard uncertainty (about 1 %). Hence, there is much need to establish a primary standard and a traceability route for radiation quantities in non-equilibrium beams to reach a goal of ICRU 24 (Determination of Absorbed Dose in a Patient Irradiated by Beams of X- or Gamma Rays in Radiotherapy Procedures) in terms of relative standard uncertainties of about 2.5 %.

Keywords

Dose Area Product, non-equilibrium beam, electronic brachytherapy, 3D gel dosimeter, diamond detector

Background to the Metrological Challenges

With more than 3.5 million new cancer cases in Europe every year, most are treated with X-rays and the use of non-electronic equilibrium beams is increasing with new treatment modalities. Radiotherapy has been evolving over the last decade and today, treatment beams are smaller than three years ago due to improved tracking techniques. Such radiation beams are characterised by the lack of electronic equilibrium, making the implementation of the classic concept of point dose obsolete and the use of current dosimeters difficult. Hence, traceability of dose to tumour to primary standards in terms of absorbed dose to water is not ensured and attempts to update dedicated international protocols for dosimetry in non-equilibrium beams have failed.

Treatment modalities exist to minimise irradiation of healthy tissues within the vicinity of tumour volumes by using lower energies when and where possible. Thus, treatment modalities based on low-energy X-rays, and low- and high-energy X-ray beams with electronic non-equilibrium, must be studied in line with evolution of these techniques. Low-energy X-rays are meeting renewed interest as an alternative when high energies are not necessary for tumour irradiation, but traceability has not yet been established for these devices.

EMRP JRP HLT09 ‘MetrExtRT’ showed point dose and dose area product (DAP) approaches are complementary for high-energy X-rays, but the introduction of DAP in treatment planning system (TPS) calculations requires the use of correction factors to derive output factors and correct for the lack of lateral electronic equilibrium in non-equilibrium beams. For DAP quantity, a large area graphite calorimeter is an accurate primary standard for small fields able to overcome issues caused by lateral non-equilibrium irradiation conditions. However, to establish an efficient traceability chain, it is essential to also study field size and shape. Currently TPS manufacturers have not introduced DAP in TPS and the first step to achieve this is to convert DAP into point dose.

An alternative method of dealing with non-equilibrium beams is relying on absorbed dose measurements using point-like detectors. The behaviour of such detectors in complex radiation fields has been investigated and procedures for absorbed dose measurements developed. However, characterisation of spectral properties of the incoming radiation by current beam quality specifiers ($TPR_{20,10}$, $\%dd(10)_X$) is not sufficient to assess detector change response during dose measurement. To apply this technique to non-equilibrium beams, a different beam quality specifier is needed, which is local at the point of dose measurement and characterises the spectral properties of the radiation locally at this point.

The use of non-standard radiotherapy treatment modalities will continue to increase rapidly, emphasising the need to provide references, quality indexes and calibration procedures for more accurate patient dosing, better local tumour control and a better quality of life.

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Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The JRP shall focus on the traceable measurement and characterisation of radiation quantities in non-equilibrium beams to reduce the standard uncertainty of absorbed tumour dose to 2.5 %.

The specific objectives are

1. To develop and validate a methodology to measure DAP in non-equilibrium high-energy photon beams. This should include providing traceability from DAP to point dose for input into treatment planning system calculations, be expanded for use in hadron therapy and reduce the standard uncertainty of absorbed tumour dose to 2.5 %.
2. To determine a point dose quality index with small detectors leading to accurate point dose measurements in non-equilibrium energy beams. This should characterise spectral properties of the radiation at point of measurement and determine beam quality correction factors for absorbed dose measurements as a function of the local beam quality index.
3. To develop a new methodology for defining beam quality based on micro- and nano-dosimetry methods.
4. To develop references and traceability for new low-energy X-ray beams for use in contact therapy.
5. To facilitate the take up of traceable measurements for radiation quantities in non-equilibrium beams developed by the project by clinicians and industry to support the safety of radiotherapy patients by reducing the radiation dose.

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes, and it is expected that multidisciplinary teams will be required. To enhance the impact of the research, the involvement of the appropriate user community such as medical practitioners, medical (academic) hospitals and industry is strongly recommended, both prior to and during methodology development.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this. In particular, proposers should outline the achievements of EMRP JRP HLT09 (MetrExtRT) ‘Metrology for radiotherapy using complex radiation fields’ and EMRP JRP SIB06 (BioQuaRT) ‘Biologically weighted quantities in radiotherapy’ and how their proposal will build on those.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.8 M€, and has defined an upper limit of 2.1 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 35 % of the total EU Contribution to the project. Any deviation from this must be justified.

Any industrial partners that will receive significant benefit from the results of the proposed project are expected to be unfunded partners.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the “end user” community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the “end user” community (e.g. letters of support) is also encouraged.

You should detail how your JRP results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the radiotherapy sector.

You should detail other impacts of your proposed JRP as specified in the document “Guide 4: Writing Joint Research Projects (JRPs)”

You should also detail how your approach to realising the objectives will further the aim of EMPIR to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work

Time-scale

The project should be of up to 3 years duration.