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

Selected Research Topic number: **SRT-h15**
Version: 1.0

Title: Metrology for MR guided radiotherapy

Abstract

Magnetic resonance (MR) guided radiotherapy, the simultaneous use of MR imaging (MRI) and megavolt (MV) photon irradiation, leads to a paradigm shift in radiotherapy and offers the capability of using high-quality imaging with tissue selectivity to guide the delivery of lethal doses of ionising radiation to tumours. Currently these mechanisms are not well understood, the traceability for radiation dosimetry is lacking and MRI becomes an integrated part of the radiotherapy treatment, which poses new demands on its accuracy. This Selected Research Topic would provide the metrological tools in dosimetry and MRI for the safe clinical introduction and application of MR guided radiotherapy.

Keywords

MR guided radiotherapy, traceable dosimetry, Monte Carlo simulation, dose calculation, quality assurance, MRI

Background to the Metrological Challenges

Throughout Europe, and worldwide, manufacturers are developing integrated radiotherapy MRI modalities with varying magnetic field strengths and radiation fields. MRI guidance allows high soft tissue contrast imaging during treatment without the need for imaging modalities using ionising radiation; and the benefit of MRI guidance increases accuracy in tumour volume definition, avoids additional exposure to diagnostic radiation and enhances verification of planned dose delivery. In 2012, cancer incidence in the EU was around 2.6 million people, with half being treated by radiotherapy.

Radiation dosimetry plays an important role in the safe delivery of lethal doses to patients during radiotherapy treatment, but the presence of a constant magnetic field has been shown to have about a 10 % effect on the response of radiation dosimetry detectors and secondary standards. Hence, detector characteristics for application in conventional radiotherapy cannot be directly translated to MR guided radiotherapy.

Several written standards have been developed for conventional radiotherapy specifying criteria for measurements on the acceptability of radiological equipment and quality assurance for treatment planning systems (TPS). However, as the selection of suitable detectors for these measurements is based on their characteristics, and these characteristics are affected by magnetic fields, this data is lacking for application in MR guided radiotherapy. Conventional radiotherapy detector responses have been simulated to a high degree of accuracy using Monte Carlo transport algorithms. Since conventional benchmark tests have failed for radiation transport in magnetic fields, this underpins the urgent need for benchmark tests of Monte Carlo transport algorithms in the presence of a magnetic field.

Primary standards based on calorimetry are state-of-the-art for standard dosimetry in conventional linear accelerators with uncertainties of 1 % (k=2) or lower and current codes of practice (CoPs) for conventional radiotherapy allow reference dosimetry traceable to these primary standards with combined uncertainties lower than 2 % (k=2). EMRP JRP HLT06 ‘MRI Safety’ has developed a water calorimeter and shown the feasibility for measurements in the presence of a magnetic field. However, traceable measured input data for CoPs is not currently available and CoPs for reference dosimetry in the presence of magnetic fields do not exist. This is a major obstacle for comparability of MR guided treatments.

The EU states [1] that “All (radiotherapy) test equipment used in measuring functional performance must be well maintained, regularly calibrated and traceable (where appropriate) to national standard laboratories”, emphasising the need for traceability of measurements in MR guided radiotherapy.

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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 development of metrological capacity in MR guided radiotherapy to establish traceability in dosimetry, dose calculation and imaging.

The specific objectives are

1. To develop a metrological framework (primary and secondary standards) for traceable dosimetry under reference conditions for MR guided radiotherapy. This should include determining input data for dosimetry protocols and defining reference conditions.
2. To develop methodologies for measurement of TPS input data for MR guided radiotherapy. This should include characterisation of commercially available detector systems and secondary standards, focussing on intrinsic and radiological responses in hybrid fields.
3. To develop methodologies for testing Monte Carlo based radiation transport algorithms in external magnetic fields.
4. To evaluate MR based dose deposition under static and dynamic conditions. This should include standardisation of MR sequences, accurate registration methods and development of phantoms for quantification of dose distributions for static conditions; and development of reliable MRI target and organ motion tracking methods and motion surrogate contactless techniques for dynamic conditions.
5. To facilitate the take up of recommendations for dosimetry and MR related quality assurance of MR guided radiotherapy developed by the project by clinicians and industry in order to enable hospitals to perform quality assurance based on traceable measurements and support improvements for dosimetry in MR guided radiotherapy.

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 HLT06 (MRI safety) ‘Metrology for next-generation safety standards and equipment in MRI’ and how their proposal will build on this.

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 MR guided 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.

Additional information

The references were provided by PRT submitters; proposers should therefore establish the relevance of any references.

[1] Radiation Protection 162: Criteria for Acceptability of Medical Radiological Equipment used in Diagnostic Radiology, Nuclear Medicine and Radiotherapy, Luxembourg: Office for Official Publications of the European Communities, 2012.