

## **Title: Metrology for MR guided radiotherapy**

### **Abstract**

There are approximately 5200 new cancer patients per million people per year in the EU and roughly half of these patients will be treated by radiotherapy. MR guided Radiotherapy (MRgRT), is the simultaneous use of beams of ionising radiation and Magnetic Resonance Imaging (MRI) to image a patient during treatment. MRgRT has the potential to be used for enhanced personalised dose management for cancer patients by using MR imaging to optimise patient radiotherapy treatment. Whilst initial MRgRT treatments have recently taken place in clinics, these have been with more 'basic' systems and therefore further work is needed for MRgRT for more complex treatment and for the full technical capabilities of MRgRT to be realised. This will require traceable and clinically relevant methods for MRI based adaptive treatment planning, accurate measurements for small field dosimetry and traceable methods for online quality assurance (QA) for adaptive dose delivery.

### **Keywords**

MR-guided radiotherapy, MRI, traceable dosimetry, Monte Carlo simulation, small field dosimetry, adaptive radiotherapy, real-time imaging, treatment planning

### **Background to the Metrological Challenges**

Despite significant innovations in radiotherapy over the last decades, further development is still needed for it to reach its full potential in terms of improving its accuracy for targeting tumours and reducing the irradiation of healthy tissue. MRgRT is a new powerful radiotherapy treatment modality that uses MR image guidance for high contrast, soft tissue imaging during radiotherapy treatment. The benefits of such online MR image guidance is an increased accuracy in tumour definition and avoidance of additional radiation exposure, such as from computed tomography (CT). It also allows hospitals to perform real-time imaging during treatment and to adapt the planned dose distribution based on actual patient anatomy.

In the adaptive treatment cycle, the planned dose distribution and its delivery is adapted based on feedback from the patient anatomy and the previously delivered dose. Therefore QA procedures are needed for medical physicists to ensure that the dose distribution is delivered and adapted as accurately as possible. However, because MRgRT treatment is adapted online, there is no time for pre-treatment QA measurements as per conventional radiotherapy. This means that QA methods need to be developed for both dynamic imaging and dose delivery during MRgRT treatment.

Adaptive radiotherapy extensively uses small field dosimetry in order to improve the measurement of dosimetry parameters and for the calibration of beam output. Therefore accurate measurement of small fields is essential. However, measurement of small fields is complex and an additional level of complexity is introduced in MRgRT as a magnetic field is always on during treatment and hence dosimetry measurements must be performed in its presence. Further to this, the first international code of practice dedicated to the dosimetry of small static fields used in radiotherapy was only published by the International Atomic Energy Agency (IAEA) in 2017.

One of the advantages of MRgRT, is the use of MR imaging instead of CT images. MRI provides increased soft tissue visibility and widens the range of patient information available during treatment (e.g. blood flow) which leads to greater flexibility and precision in treatment planning. However, before hospital's can base their treatment planning solely on MRI, an evaluation is needed of the accuracy of methods for translating MR pixel values into electron densities. This is because treatment planning requires electron densities information that is conventionally provided by CT imaging, but not directly available from MR imaging.

## 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 MR guided radiotherapy (MRgRT).

The specific objectives are

1. To develop measurement methods for small field dosimetry in MRgRT. This should include (i) external magnetic fields, (ii) suited detectors, (iii) small off-axis fields, (iv) the determination of correction factors using the concept of IAEA Technical Report Series 483, and (v) novel MRgRT modalities such as MR guided proton therapy, as well as input from clinical stakeholders.
2. To develop traceable and clinically relevant methods for MRI based adaptive treatment planning. This should include (i) the development of models for the generation of electron density maps based on MR-images and (ii) anthropomorphic phantoms for the validation of such models as well as (iii) an assessment of the accuracy and uncertainty propagation of MR images and automated segmentation algorithms.
3. To evaluate clinically relevant dose distributions and algorithms for dose calculation for treatment planning systems (TPS) in the presence of MRgRT device magnetic fields. This should include non-equilibrium conditions, complex conditions and methods for dosimetry audits for MRgRT facilities. In addition, to evaluate (i) the accuracy of beam models, and (ii) novel strategies for commissioning beam models used in TPS.
4. To develop validated and traceable methods for online quality assurance (QA) for adaptive dose delivery. This should include (i) online QA methods for dose delivery in the presence of organ and target motion (ii) deformation and dose reconstruction methods, and (iii) an evaluation of the effect of physiological motion on MR image quality, as well as input from clinical stakeholders.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain, standards developing organisations (e.g. those associated with the guidelines of the International Atomic Energy Agency (IAEA)) and end users. In addition, to produce and disseminate to stakeholders, clinically relevant recommendations for dosimetry and MR-related QA for online adaptive procedures in MRgRT.

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, 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 the EMPIR project 15HLT08 MRgRT 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 across all selected projects in this TP.

## 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 medical and health 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.