EMPIR Call 2018 – Health, SI Broader Scope, Normative and Research Potential

Selected Research Topic number: **SRT-h06**
Version: 1.0

Title: Measurements of phantom and tissue mimicking materials for quantitative MRI medical imaging

Abstract

Magnetic Resonance Imaging (MRI) is an indispensable, multi-modality, medical imaging tool that is used in more than 23 million patient examinations per year in the EU. But as medical imaging techniques become more quantitative, so the demands on test objects increase. This means that stable, reproducible anthropomorphic phantoms and tissue mimicking materials (TMM) that are more clinically relevant are required and this includes the metrology needed for their fabrication and characterisation. In particular, current phantom preparation methods often only address a subset of properties e.g. mechanical, thermal and electromagnetic. Further to this, although quantitative mapping of biomarkers can greatly increase the reliability and comparability of medical imaging data, there is currently a lack of standardised protocols (as well as characterised phantoms) needed to validate the accuracy of measurements, and to assess the reproducibility of measurements across imaging platforms.

Keywords

Multi modal imaging, quantitative MRI, diffusion, perfusion, tissue mimicking materials, phantoms

Background to the Metrological Challenges

The evolution of imaging techniques towards quantification has long been an objective of leading professional societies such as the International Society for Magnetic Resonance in Medicine (ISMRM) and the European Society for Magnetic Resonance in Medicine and Biology (ESMRMB). However, to ensure reproducibility across imaging platforms, quantitative imaging requires careful calibration and validation, and hence the development of stable, reproducible tissue-equivalent phantoms that are well characterised and clinically relevant.

Typically, the phantoms used in quantitative MRI imaging can be divided into 3 types; liquid, semi-solid and solid. But although each type has unique properties, current studies predominantly address water based phantoms (liquid or semi-solid) as the mimicking of biomarkers is closer to that in real tissues. Therefore there is a need for a standardised protocol, which using information on the MRI platform used and the desired application will determine which phantom is the most appropriate. For example, the electrical or thermal properties of semi-solid phantoms cannot be adjusted and have a shorter life compared to liquid phantoms, but temperature and perfusion investigations are almost unrealistic in liquid phantoms.

Currently, very few phantoms contain SI-traceable components or have been validated, and even less have been monitored for long-term stability. Existing phantoms also have simple geometries like spheres or cylinders, rather than anatomically relevant shapes. In addition to this, TMM and the filling material of phantoms mostly consist of commercial or synthetic polymers, polysaccharides, gels, water solutions enriched with conductive ions, antibacterial ingredients or contrast agents. The ingredients and their ratios in such TMM and filling materials can affect the electromagnetic, mechanical, thermal and functional properties of the phantom. Hence, the chemical composition and the functionality of the material is crucial for determining traceability and a thorough understanding of this is vital for researchers working on phantom design.

Diffusion-weighted and perfusion MRI are increasingly used for the assessment of functional tissue biomarkers for diagnosis, therapy planning and monitoring. However, both MRI techniques are vulnerable to a variety of technical factors affecting acquisition on different scanners and field strengths (e.g. magnetic field inhomogeneities, gradient non-linearities). Therefore, standardised procedures are needed to support the repeatability and reliability of measurements.

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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 traceable measurements for quantitative MRI medical imaging of phantoms and tissue mimicking materials.

The specific objectives are

1. To develop validated protocols based on tissue mimicking materials (TMM) and 3D printed anthropomorphic phantoms for a range of biomarkers in terms of (i) iso/anisotropic water diffusion constants as function of field strength, (ii) electrical properties for temperature sensing when using ultrahigh fields strength, and (iii) hemodynamics for perfusion measurements.
2. To accurately characterise a range of anthropomorphic phantoms and TMM, in terms of mechanical, thermal, electromagnetic and physiological properties and external parameters (i.e. time, temperature). The target uncertainty is 1 % - 5 %, depending on the parameter analysed. In addition, to develop models for the quantitative imaging of real tissues and to validate these with the characterisation data.
3. To evaluate the most promising prototype anthropomorphic phantoms and TMM from objective 2 using a variety of medical imaging instrumentation, and in collaboration with clinical end users. In addition, to use the results to calculate the reproducibility and measurement uncertainty of such quantitative imaging.
4. Using the data from objective 3, to establish the framework for a European tissue property database and to develop standardised protocols for significantly improving the reproducibility and accuracy of quantitative imaging, targeting overall uncertainties of between 5 % and 10 % (relative).
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain, standards developing organisations and end users (e.g. clinical laboratories, hospitals, the International Society for Magnetic Resonance in Medicine (ISMRM) and the European Society for Magnetic Resonance in Medicine and Biology (ESMRMB)).

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.

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.