European Partnership on Metrology
Call 2025 – Health, Integrated European Metrology, Regulation and Research Potential

Selected Research Topic number: **SRT-s13**
Version: 1.0

Title: Robust, reliable and traceable metrological system for dosimetry after the phase-out of Cobalt-60

Abstract

At present, the measurement of absorbed dose in radiotherapy is largely based on the use of dosimeters calibrated in Cobalt-60 beams. However, purchasing and operation of Cobalt-60 radiation sources is becoming increasingly challenging. Although calibrations in beams other than Cobalt-60 are available, a comparably low uncertainty cannot be achieved today. In view of the expectation that fewer and fewer calibration laboratories will be able to offer calibrations in Cobalt-60 beams in the future, there is a need to investigate, develop and harmonise alternative reference fields and calibration methods that will provide traceability of absorbed dose measurements with the same uncertainty that is achievable today for Cobalt-60 calibrations.

Keywords

Ionising radiation, absorbed dose, dosimeter calibration, reference dosimetry, linear accelerator, beam quality, radiotherapy

Background to the Metrological Challenges

Ionising radiation is used in radiotherapy to kill tumour cells and is an essential component of effective cancer therapy. Nowadays, roughly 50 % of all cancer patients (about 2.75 million people each year in the European Union) require radiotherapy during their treatment. To ensure the treatment success, reduce unwanted side effects and assure patient safety, medical physicists need to perform reliable dose measurements and to calibrate the radiotherapy facility monitor chambers as part of regular quality assurance. These measurements and calibrations are carried out based on national or international Codes of Practice (CoPs), such as IAEA TRS-398.

All modern CoPs are based on the use of dosimeters calibrated traceable to a primary standard of absorbed dose to water carried out by a calibration chain from a Primary Standard Dosimetry Laboratory (PSDL) to the end user in a radiotherapy clinic usually via Secondary Standard Dosimetry Laboratories (SSDL). At present, almost all PSDLs and SSDLs provide dosimeter calibrations in gamma ray beams using high-activity Cobalt-60 sources with similar dose rates as the one delivered by radiotherapy devices, while most radiotherapy clinics use linear accelerators (linacs) producing either high-energy x-ray, electron or proton beams. The main reason for the continued use of Cobalt-60 sources in ionising radiation metrology is that it provides an unrivalled stable dosimetry basis for the dissemination of absorbed dose standards. However, the highly active Cobalt-60 radiation sources required for dosimeter calibrations are becoming difficult to replace due to increased costs due to reduced Cobalt-60 availability as nuclear reactors capable of its production are decommissioned leaving a potential dependence on Russian supplies, and stringent regulations surrounding their use and disposal.

These difficulties have an impact on decisions regarding the replacement of decayed radiation sources or the operation of irradiator facilities and thus on the calibration services offered by PSDLs and SSDLs. These challenges are recognised by the EURAMET Technical Committee for Ionising Radiation (EURAMET TC-IR), the CCRI Task Group on Radioactive Sources and Alternative Technologies, and the National Academies of Science, Engineering and Medicine (NASEM), which see a focus on the future removal of high-activity radiation sources as required for dosimeter calibrations and other purposes (e.g. sterilisation).

Although some PSDLs and SSDLs already offer calibrations in beams other than Cobalt-60, mainly with high energy photon and electron beams generated by clinical linacs, the uncertainty and robustness of this

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traceability route remain inferior to calibrations in Cobalt-60 beams. The clinical linacs currently used to calibrate dosimeters are not specifically designed for metrological applications in calibration laboratories. While the spectral properties (beam quality) of all Cobalt-60 beams used in PSDLs and SSDLs are nearly identical, linac beams at different laboratories have different spectral properties – even for linacs of the same type and manufacturer. Additionally, the application of traditional beam quality specifiers (e.g., for flattening filter free linacs or MR-linacs) may not be suitable for new irradiation technologies. This variability makes comparisons between calibration laboratories difficult, which is a key element of a robust measurement system. Also, the procedures and data currently given in CoPs to convert the dosimeter response between different radiation beams (beam quality specifier and correction factors) are intended for a single conversion (from Cobalt-60 to another beam quality). Whilst the multiple conversions required in the extended calibration chain from PSDL to clinic lead to unacceptably increased uncertainties. An advantage from the introduction linac beams for use as the primary dosimetry standard realisations would introduce calibration flexibility through the availability of several beam energies or the spectral similarity between calibration laboratories and clinical beams. However, for this to happen current absorbed dose measurement CoPs will need to be re-written.

To ensure that a high-quality and robust international system of standards and calibration capabilities for dosimetry in radiotherapy can be maintained in the future, methods for providing traceability and dissemination of absorbed dose standards through calibration services in beams other than Cobalt-60 must be investigated, developed and harmonised at international level. This requires collective action of national metrology institutes, PSDLs, SSDLs, standards developing organisations, manufacturers, and end users.

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 proposal shall focus on the traceable measurement and the development of a future international system of standards and calibration capabilities for providing traceability of absorbed dose measurements in radiotherapy after the phase-out of Cobalt-60.

The specific objectives are

1. To determine the high-energy photon beam characteristics that influence radiotherapy dosimeter uncertainties during calibrations (e.g., beam energy and filtration, time structure of the beam, short- and long-term variations of the beam output). Then using this information to identify radiation sources (e.g., linear accelerators) with potential as replacements for Cobalt-60 irradiators in dosimeter calibrations.
2. To identify and develop alternative methods to characterise the spectral fluence of high-energy photon beams (beam quality specifier) and to compare the newly developed beam quality specifiers to those currently used. This is to include the development of methods to determine the spectral photon fluence of linear accelerators by measurements and numerical simulations as well as the determination of detector beam quality correction factors dependent on the new beam quality specifiers.
3. To determine the suitability of different types of detectors for the dissemination of the unit of absorbed dose to water, for the determination of beam properties, and for beam monitoring purposes. This is to include long-term beam response stability, beam energy dependence, time structure dependence and the beam's spatial distribution, as well as how differing detector properties effect responses.
4. To establish dosimeter calibration reference fields and reference condition specifications in beams other than Cobalt-60 with a target uncertainty corresponding to that currently achieved by Cobalt-60 calibrations. This is to include the demonstration of the proof of applicability of using the new dosimeter calibration method based on a comparison exercise. In addition, the impact of this new traceability route on existing radiotherapy dosimetry Codes of Practice should be determined including the potential implementation effect on dosimetric key and auxiliary comparisons, and the ability to link past comparison results to those in the future. To provide guidance on the consequences for radiation protection in such an implementation.
5. To demonstrate the establishment of an integrated European metrology infrastructure and to facilitate the take up of the technology and measurement infrastructure developed in the project by international metrological and scientific organisations (CIPM CCRI, ICRP, EURAMET TC-IR, European Federation of Organisations for Medical Physics (EFOMP), the European Radiation

Dosimetry Group (EURADOS), The European Society for Radiotherapy and Oncology (ESTRO)), standards developing organisations (IAEA) and end users (PSDLs, SSDLs).

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. To enhance the impact of the research work, the involvement of the larger community of metrology R&D resources both within and outside Europe, plus engagement with existing European research infrastructures and European Partnerships is recommended. A strong industry involvement is expected in order to align the project with their needs and guarantee an efficient knowledge transfer into industry and end users. Where relevant, proposals are encouraged to build on, or seek collaboration with, existing projects and develop synergies with other relevant European, national or regional initiatives and funding programmes. In particular, links are encouraged with (i) the projects funded under earlier relevant topics of the Horizon Europe programme; or (ii) other relevant European Partnerships.

Proposers should establish the current state of the art and explain how their proposed project goes beyond this.

Proposers should note that the programme funds the activity of researchers to develop the capability, not the required infrastructure and capital equipment, which must be provided from other sources.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 2.1 M€ and has defined an upper limit of 2.6 M€ for this proposal.

EURAMET also expects the EU Contribution to the external funded beneficiaries to not exceed 25 % of the total EU Contribution across all selected projects in this TP.

Any industrial beneficiaries that will receive significant benefit from the results of the proposed project are expected to be beneficiaries without receiving funding or associated 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 proposal's 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,
- Facilitate improved industrial capability, or improved quality of life for European citizens in terms of personal health, protection of the environment and the climate, or energy security,
- Transfer knowledge to the healthcare 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 the Metrology Partnership 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.

Timescale

The project should be of up to 3 years duration.