“ImPaD: Improving patient dosimetry in molecular radiotherapy: quantitative imaging of $^{131}$I”

Theme: Medical Physics (molecular radiotherapy, dosimetry, quantitative imaging, anthropomorphic phantoms)

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Background

The use of radiopharmaceuticals in targeted cancer therapy is undergoing significant expansion worldwide. One of the challenges of this molecular radiotherapy is accurate patient dosimetry, to ensure that the treatment is safe to deliver, and that its efficacy has been optimised to the individual patient. As with all forms of radiotherapy, the radiation dose must be sufficient to destroy the cancer whilst sparing surrounding healthy tissue. In molecular radiotherapy, accurate dosimetry requires measurements of the time-dependent bio-distribution of the radiopharmaceutical in the patient. However, current medical imaging equipment and associated software systems have generally been optimised for qualitative diagnostic scans using relatively low-energy, gamma emitting radionuclides (e.g. $^{99m}$Tc). For cancer therapy, the images must be quantitative and show the distribution of activity (Bq/ml) in the body. This can be challenging for therapeutic radionuclides whose properties have been chosen for their cytotoxic effects rather than for ease of imaging.

The aim of this project is to study the techniques for imaging of distribution of radioactivity in the body for radiopharmaceuticals based on one of the most common therapeutic radionuclides, $^{131}$I, and to optimise methods for quantifying these images to enable accurate dosimetry. Despite being widely used for over 50 years to treat thyroid cancer, there are no widely-accepted standardised quantitative imaging protocols for $^{131}$I. The scientific challenges of this project will centre on the development of methods to calibrate the medical imaging systems so that quantitative information can be obtained. The problem involves understanding the interaction of radiation with matter, radiation detection technology, pulse processing electronics, complex image processing algorithms, as well as clinical issues, and bringing these together to minimise measurement uncertainties.

Timeliness and Project Team

This project is timely as it is closely aligned with the EMPIR project MRTDosimetry, so will also contribute to harmonisation across the EU. Furthermore, the EC Directive 2013/59/EURATOM, due to be implemented in member states by 2018, demonstrates an increased need for regulation in nuclear medicine therapy to bring it in line with External Beam Radiotherapy services. This project will contribute directly to this overall goal.

A key strength of this project is that it brings together clinical expertise from the Royal Surrey County Hospital (RSCH), imaging and simulation expertise from the University of Surrey and radioactivity metrology from NPL. On the practical side, the Royal Surrey County Hospital will offer clinical guidance and expertise as well as access to medical imaging systems (SPECT/CT), enabling the experimental work to be performed using ‘phantoms’ (radioactive reference sources that mimic the body). NPL will provide the radioactive standardised solutions that will be needed to perform this work as well as expertise on characterising the uncertainty budget. The University of Surrey will contribute expertise in simulation and image processing. There are already close links with The University of Surrey in nuclear physics (through the joint appointment of Prof Regan) and (shortly) in radiochemistry (through the joint appointment of Prof David Read); this project will add medical physics to the collaboration and also contribute to the proposed NPL Medical Physics Institute.
**Outputs and Timescales**

The likely outputs from the project are: a review of the ‘state-of-the-art’ in the field, an experimental study to compare different techniques for quantifying the images, an investigation of the causes of any differences and a recommended standardised method (which NPL in collaboration with the medical physics community would take forward for use in clinical practice). The work will include investigating dead time effects and measurement uncertainties; NPL has extensive experience of both of these topics.

Outline project plan:

- **Year 1:**
  - Familiarisation – clinical imaging and radionuclide metrology
  - Literature review and survey of current clinical practice and standards
  - Identification of physical parameters that can affect the measurements (including dead time correction, scatter corrections, attenuation, partial volume effects)
  - Experimental studies to fully characterise the response of a typical SPECT/CT system to $^{131}$I

- **Year 2:**
  - Development of Monte Carlo model of SPECT/CT system and validation against experimental data
  - Use of Monte Carlo model to investigate physical factors affecting quantitative accuracy, and to optimise image acquisition protocols
  - Application of optimised protocols in various commercial software packages used to generate quantitative images (Bq/ml)

- **Year 3:**
  - Comparison of outputs from software packages, investigation of differences between results
  - Calculation of full uncertainty budget
  - Conclusions and recommendations for calibration protocols
  - Writing up

**Funding**

The funding will be underwritten by the EMPIR MRTDosimetry project (scheduled to start June 1\textsuperscript{st} 2016) and the NMS AIR programme, which has an on-going project in the field. Additional costs will include provision of the $^{131}$I isotope for measurements (already budgeted in MRTDosimetry). Standard clinical phantoms are available at RSCH and at NPL, but the development of any specialist phantoms would be funded within the budgets of the above projects. Standard laptops are available at NPL or the University; the Radioactivity Group also has two high specification PCs for running simulation packages, and cluster computing facilities are available at the University. RSCH will provide access to the clinical imaging systems and commercial imaging software packages, and hospital facilities for preparing phantoms. The student would aim to present at one national and one international conference per year; expenses will be covered by the NPL NMO programme.