

3.2 Promote the effective use of ionising radiation in medicine

ARPANSA continues to promote the safe and effective use of ionising radiation in diagnostic imaging by conducting dose surveys which result in the establishment of Diagnostic Reference Levels (DRLs) for CT scans and other diagnostic imaging procedures. ARPANSA also maintains the national standard for absorbed dose, performs calibrations, and audits linear accelerators used in radiation therapy; activities that collectively contribute to improved patient safety.

Major achievements

- Analysis of the first draft nuclear medicine DRL survey data.
- ARPANSA's research contribution to the Australian Synchrotron's research project into the potential for microbeams for cancer treatment.
- ARPANSA's research on the primary standard for absorbed dose.
- Successful pilot of a national dosimetry service for Australia: The Australian Clinical Dosimetry Service (ACDS).

Challenges

- Improving guidance to medical practitioners on how to balance diagnostic image quality and radiation dose to optimise patient outcomes.
- Securing the operation of the Australian Clinical Dosimetry Service.

Radiotherapy calibrations

ARPANSA provides a calibration service for instruments used to measure radiation in various commercial, medical and public sector applications. The service is a quality assurance tool which ensures the radiation dose, and dose placement, are accurately controlled to treat diseased tissue and to minimise damage to surrounding and adjacent healthy tissue. As a part of ARPANSA's regular calibration services for radiotherapy providers and industry users of radiation, 23 therapy dosimeters,

36 radiation survey meters, four neutron monitors and nine personal dosimeters were calibrated. Air kerma rate measurements were made on-site for two clients.

The primary standard for absorbed dose

The Australian primary standard for absorbed dose¹⁶ is a graphite calorimeter and ARPANSA is authorised to maintain this standard by the National Measurement Institute, Australia, under the *National Measurement Act 1960*. The primary standard of absorbed dose to water is of fundamental importance in radiological protection for calculating radiation dose and can be used to specify the amount of radiation to be used in radiotherapy. Absorbed dose is closely related to the biological effects of radiation and has the advantage that it can be measured more directly than the quantity of air kerma.¹⁷ The significance of ARPANSA's work in maintaining this standard is that it is used to assist medical practices safely calibrate radiotherapy procedures to ensure that patients are given the most appropriate doses to treat their illness. The primary standard is disseminated by providing vital calibrations of dosimeters used in cancer centres across Australia.

For many years the primary standard for absorbed dose has only been realised on a cobalt-60 source (Co-60). ARPANSA installed a linear accelerator in 2009 and a new Co-60 source in 2010. More recently, the primary standard has been adapted to work in linear accelerator beams, and the validation and comparisons based on this standard were published this financial year.¹⁸

This study is the culmination of three years of work establishing the Australian primary standard of absorbed dose on a medical linear accelerator. It reports the results of a comparison between ARPANSA and the international primary standards laboratory (the Bureau International des Poids et Mesures, BIPM) in France. International consistency of dose measurements is critically important in

16. Absorbed dose is the energy absorbed per unit of mass by ionising radiation.

17. Air kerma in air is the sum of kinetic energy of all charged (ionised) particles liberated per unit of mass.

18. Picard, S, Burns, D, Roger, P, Harty, P, Ramanathan, G, Lye, J, Wright, T, Butler, D, Cole, A, Oliver, C, and Webb, D, 'Key comparison BIPM.RI(1)-K6 of the standards for absorbed dose to water of the ARPANSA, Australia and the BIPM in accelerator photon beams', *Metrologia* 51 Tech. Suppl. 06006 (2014).

radiotherapy treatments where dose prescriptions are frequently based on clinical trials and dose measurements made overseas.

As a result of this work, a new calibration services for megavoltage photons was established and the first calibrations were performed as field trials for radiotherapy providers early in 2014. This service, and a similar new service for electron beams, allows radiotherapy providers to have their equipment calibrated directly in linear accelerator beams and will result in more reliable and simpler clinical dose measurements.

This financial year ARPANSA also published a technical report¹⁹ describing the theoretical basis, construction and operation of the graphite calorimeter used to realise the Australian primary standard of absorbed dose. The report describes the operation of the calorimeter with these beams. The calorimetry measurements have been validated through international comparisons with BIPM, National Physical Laboratory (United Kingdom), National Metrology Institute of Japan and National Research Council (Canada). Comparisons such as these demonstrate that the radiation dose delivered during radiotherapy treatment is the same in Australia as in other countries.

Synchrotron dosimetry

ARPANSA made a series of measurements at the Australian Synchrotron in 2013 and 2014 where they used a graphite calorimeter to assist the

synchrotron's Imaging and Medical Beam Line group to measure the high dose rate from their intense x-ray beam. The work was published in the journal *Medical Physics* in April 2014 ('*Absolute x-ray dosimetry on a synchrotron medical beam line with a graphite calorimeter*') and the innovative nature of this work was recognised by the journal authorising the entire contents to be made available on PubMed Central. The work is a significant breakthrough, since no previous dose rate measurements using a graphite calorimeter on similar beams have been reported in the scientific literature.

The Australian Synchrotron is conducting a research project into the potential of microbeams for cancer treatment. Before they move to treating human patients, there are three key criteria to satisfy: the first is determining how much dose is being delivered to the patient; the second concerns patient positioning; and the third is to understand and predict the biological response to doses of hundreds of Gray (Gy) in very small volumes of tissue. ARPANSA's work has provided the central piece of the dose puzzle and brings clinical use of the Australian Synchrotron closer to reality.

The Australian Clinical Dosimetry Service

The Australian Clinical Dosimetry Service (ACDS) commenced auditing radiotherapy centres in 2011. The ACDS audits the accuracy of radiation dose delivery from linacs in treatment centres to assure correct delivery of radiation dose to patients. The



(Left) The linac at ARPANSA with which new calibrations services have been developed. (Right) Staff from the Medical Radiation Services staff setting up the primary standard graphite calorimeter on the linac.

19. Ramanathan, G, Harty, P, Wright, T, Lye, J, Butler, D, Webb, D and Huntley, R. The Australian Primary Standard for absorbed dose to water (graphite calorimeter) (2014) 2013, *Technical Report Series No. 166*, June 2014.

audits are conducted at a range of levels including: basic output audits of operational linacs (Level I); pre-operational audits of new linacs (Level Ib); audits of the whole radiation field using a two-dimensional detector array (Level II); and audits involving the pseudo-treatment of a simulated human torso made from tissue-equivalent plastic which allows end-to-end audit of the treatment planning and delivery process (Level III).

The ACDS auditing requirements are described in a Memorandum of Understanding (MoU) with the Department of Health. All of the requirements of the MoU were met by the time the MoU concluded in December 2013. The pilot phase was reviewed for the Department of Health by KPMG, and the resulting report was accepted by the Department of Health in January 2014. The Memorandum of Understanding was extended to continue operation through to June 2014, and the ACDS is expected to meet all of the objectives under the extension by August 2014. A decision on future funding by the Department of Health is expected early in the 2014–15 financial year.

During this financial year, the ACDS performed 26 Level I, 12 Level Ib, 15 Level II and 13 Level III audits which exceeded the 2013–14 target of 90% by five percent.

Diagnostic imaging and nuclear medicine

Most of the 15 000 000 medical procedures involving ionising radiation that Australians undergo each year are diagnostic imaging procedures. Each of these procedures should provide diagnostic images obtained with equipment and protocols which have been optimised for the radiation protection of the patient.

The multi-detector computed tomography (MDCT or CT) Diagnostic Reference Level (DRL) Service evaluated data for the 2013 surveys and there were no significant changes in collective patient doses noted. The introduction of iterative reconstruction software for MDCT has had a beneficial impact in lowering doses to patients. During this reporting period, the first draft survey for Image Guided Interventional Procedures was completed and analysed. BreastScreen Victoria provided 65 000 de-identified mammography patient datasets for initial analysis in developing a mammography DRL survey. The first draft Nuclear Medicine DRL survey was given to seven specific facilities for testing to assist future implementation. Results have been reviewed and compared with some international data and presented at local scientific meetings.

The Australian DRL Service gathers data that will be used to establish and update National DRLs for common diagnostic imaging procedures. DRLs are a quality assurance tool and ARPANSA's work on

Performance against deliverables

Quantitative Deliverables	2012–13 Revised Budget	2013–14 Budget Target	2014–15 Forward Year 1	2015–16 Forward Year 2	2016–17 Forward Year 3
<i>Promote the effective use of ionising radiation in medicine</i>					
Cumulative proportion of centres audited by the ACDS for accuracy in dose measurement of radiotherapy*	80%	90%	N/A	N/A	N/A
<i>RESULT</i>	<i>80%</i>	<i>95%</i>	<i>N/A</i>	<i>N/A</i>	<i>N/A</i>
* This program is operating on a trial basis and is funded until August 2014 when it will be reviewed and its future determined.					

the Australian National DRL Service is designed to provide individual medical facilities with a means of comparing their doses with National DRLs of patient doses received, in the first instance, from CT scans. The DRL service is expected to later encompass other medical radiation imaging modalities such as interventional/fluoroscopic, mammography and nuclear medicine and general examinations.

The CT survey is ongoing with 834 compliant surveys submitted in the 2013–14 period. In addition, approximately 25% of CT facilities have been registered for survey participation.

Existing modelling software, previously developed in-house, has been reviewed and adapted for contemporary computer platforms to calculate organ doses from various diagnostic imaging modalities.

ARPANSA has signed a Memorandum of Understanding with the Department of Health in partnership with the Australian Commission on Safety and Quality in Health Care to produce a Radiation Protection of Patients module for medical imaging referrers. Stakeholder engagement has commenced with preliminary work being undertaken on the design of the module.

What are DRLs?

DRLs are a quality assurance tool designed to provide individual medical facilities with a means to benchmark their practice with national DRLs of patient doses received. ARPANSA's work on the National Diagnostic Reference Level Database (NDRLD) allows radiology practices to log patient doses and receive Practice Reference Level reports with which they can compare their practice dosimetry against those of their peers. While a nationally determined DRL is not a dose limit, in cases where the practices are delivering higher doses than Australian DRLs, it is expected that the practice will investigate and, where appropriate, reduce doses while maintaining the diagnostic outcome, thus optimising radiation protection of the patient.

Performance against key performance indicators

Qualitative Indicator	2013–14 Reference Point or Target
<i>Promote the effective use of ionising radiation in medicine</i>	
Establish DRLs for Interventional Cardiology and Radiology as tools for quality improvement in diagnostic radiology	Improved diagnostic practice using lower dose levels
<i>RESULT</i>	<i>Draft survey developed - the DRL project has successfully raised the profile of radiation exposure of the patient within the radiological community. ARPANSA is seen as an important resource in this area. Ongoing analysis of CT DRL data indicates that the introduction of improved scanner software has led to patient dose reduction.</i>

CASE STUDY

Developing a Draft Diagnostic Reference Level Survey for Image Guided Interventional Procedures

During this financial year, ARPANSA conducted an initial survey of selected medical facilities (nine practices and fourteen rooms) that perform coronary angiographic procedures. Participants were asked to complete and comment a draft NDRL survey form for interventional angiography procedures. Testing was only conducted on patients with clinically diagnosed 'normal' coronary arteries. Most practices delivered the requested thirty patients undergoing a standard coronary angiogram showing an unremarkable (or healthy) outcome.

Data was collected for a total of 305 patient cases which is a well-sized data set for this type of preliminary analysis. The survey results indicated that Australian dosimetry for diagnostic coronary artery angiography is similar with current European practice values. Any variation from a larger non-selected survey should be investigated as required by section 3.1.8 of ARPANSA's Radiation Protection Series 14 - *Code of Practice for Radiation Protection in the Medical Applications of Ionizing Radiation (2008)*.

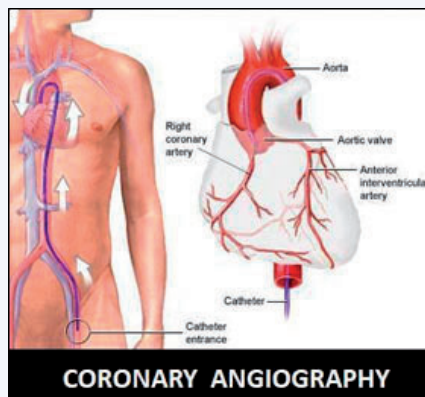
The outcomes of this survey showed that the draft survey structure is appropriate for the data types to be collected. Potential exists for the survey to be expanded further to cover other interventional angiographic procedures for the development of interventional fluoroscopy DRLs.

Developing DRLs

ARPANSA undertakes national DRL surveys on behalf of the Commonwealth. Notwithstanding this important role, ARPANSA acknowledges that DRLs should be owned by the respective professions and can only be constructed with appropriate consultation and influence from the relevant stakeholders.

To obtain a clearer assessment of the potential radiation risk from diagnostic imaging it is imperative that a review of the doses delivered from common radiology procedures is undertaken both at the facility and consolidated into a regional or national analysis. DRLs can then be constructed and used as a comparative indicator of radiation efficiency at the facility, regional, national and international levels. Once facility DRLs are established they can be regularly reviewed against national DRLs and used as a baseline for the implementation of an optimisation program to maximise the efficient use of radiation while maintaining diagnostic image quality.

The CT survey will be based on common dosimetry metrics. This will be recorded for twenty patients, for seven common protocols, for as many facilities as wish to participate. It is estimated that there are approximately 1000 CT platforms registered/licensed in Australia. ARPANSA has developed a web-based survey form where practices can log their dose data and receive a calculated practice DRL to comply with RPS 14. ARPANSA will then log the practice data into the national DRL dose database. ARPANSA will also develop DRLs for interventional fluoroscopy, nuclear medicine and mammography.



The above diagram shows the passage of a catheter into the aortic root or other major vessels for the purpose of angiography of the native coronary arteries. Angiograms can be conducted through entering the femoral artery or radial artery.

* 'Normal' coronaries are defined as those with no or physiologically insignificant diameter stenosis (<50% coronary diameter narrowing) by visual inspection in patients studied specifically to assess coronary anatomy'.