



Australian Government
Australian Radiation Protection
and Nuclear Safety Agency



ACDS in Review **2018**



Welcome to the inaugural Australian Clinical Dosimetry Service annual report, *ACDS in Review*.

The Australian Clinical Dosimetry Service (ACDS) has grown over the past eight years from an initial pilot programme to a significant patient safety service in Australian and New Zealand Radiation Oncology. This is the first of an ongoing series of annual reviews where we look across all our results and report on trends, known issues, and unexpected treatment planning system behaviour. The key findings provide information on the most common types of recommendations we issue for non-optimal outcomes and individual case studies. We also want to share with you the development work we are doing to increase the clinical coverage of our audits, and our ability to provide support and surety as new technologies are rolled out into regular clinical practice.

The successful realisation of a national dosimetry audit programme is due to active awareness and interest of professional colleges, collaboration with government, and the commitment from the medical community including physicists, radiation therapists, and radiation oncologists. The colleges' engagement with dosimetric risk is exemplified by the collaboratively designed Radiation Oncology Practice Standards which include a minimum dosimetric audit program commensurate with patient safety.

We hope that by sharing our observations and data with the entire radiotherapy community, we can continue to collectively improve the high quality of treatment and care in our region.

We hope that you find this report of interest and of use in your clinic, and as always we encourage your feedback and suggestions as we continue to grow the ACDS as a resource for the entire radiotherapy community.

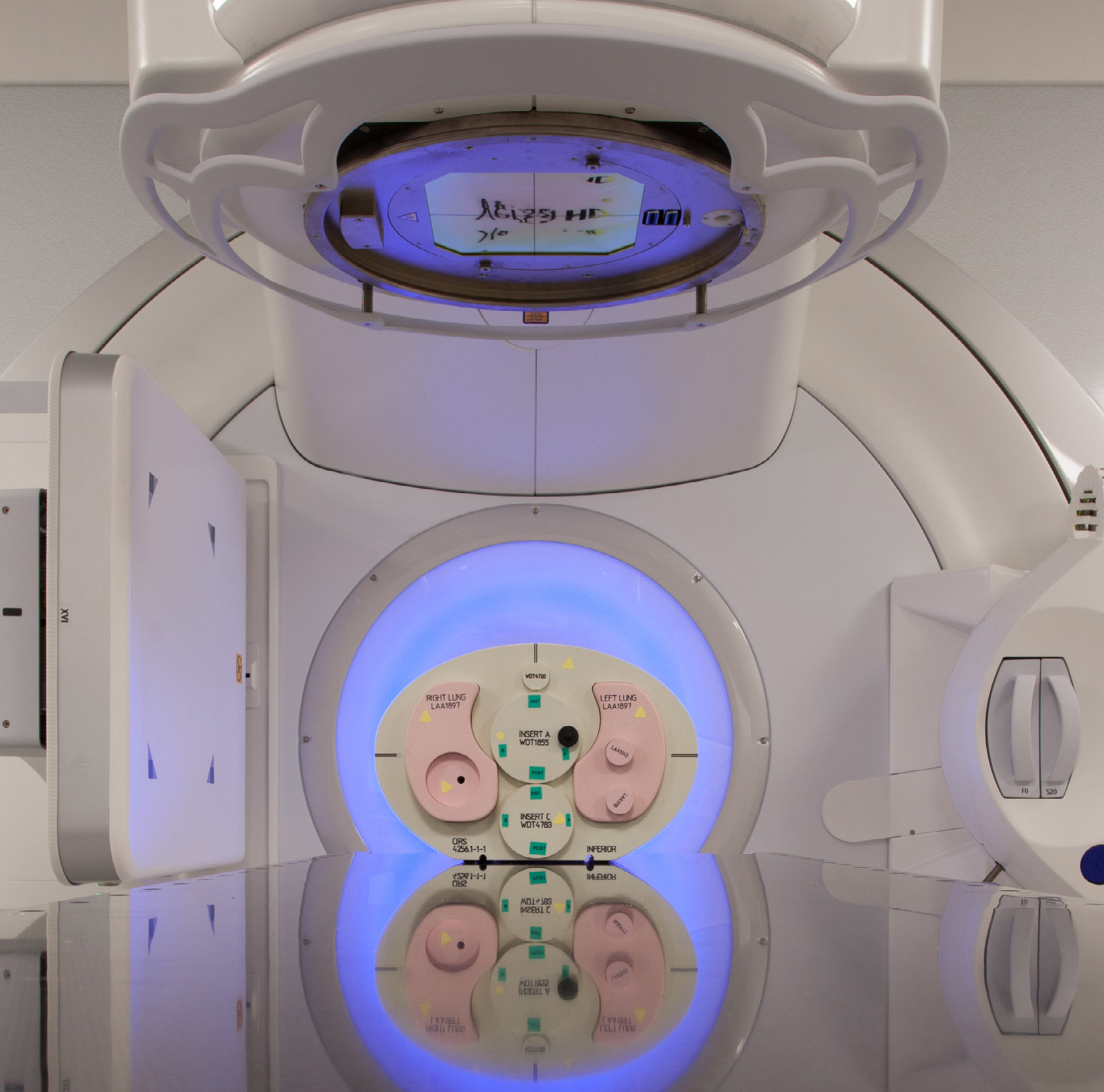


Carl-Magnus Larsson
CEO of ARPANSA



Jessica Lye
ACDS Director





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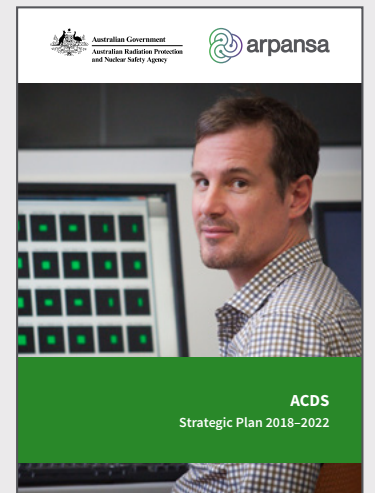


Our mission

To guide, support and improve patient safety and radiotherapy service delivery by:

- providing a comprehensive suite of audit modalities covering all common clinical practices
- improving national dosimetry capabilities in clinical treatment delivery
- offering services to Australian and overseas radiotherapy centres on a fee-for-service basis.

In this, we are fully aligned with ARPANSA's vision to promote the safe and effective use of radiation in medicine.



You can view the ACDS [Strategic Plan 2018-2022](#) on our website.

We are the Australian Clinical Dosimetry Service, or ACDS – a team of dedicated physicists, radiation therapists and support staff. We also engage external medical physicists from hospitals around Australia and New Zealand to help perform our independent audits.

We are part of the Commonwealth Government's Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). Our service is a world leader in developing and implementing radiation dosimetry audit programs, aimed at ensuring the highest level of quality, effectiveness and safety for patients undergoing radiation therapy as part of their cancer care journey.

We aim to be a resource to our subscribers and the broader radiation oncology community. We're committed to ensuring our audit programs are comprehensive and high accuracy, with investments into future development to ensure we're responsive to new and emerging radiation therapy treatments. At the same time we're committed to providing the best possible value to clinics with audits that are clinically relevant today.

Our associates and external auditors for 2018



Joerg Lehmann
ROMP External Auditor



John Kenny
ROMP Consultant



Johnny Laban
External Auditor



Ivan Williams
Chief Medical Radiation
Scientist, ARPANSA



Stephanie Keehan
External Auditor



Francis Gibbons
ROMP External Auditor

Not pictured:

Cameron Challens
ROMP External Auditor

Jason Morton
ROMP External Auditor



Clinical Advisory Group

The Clinical Advisory Group (CAG) serves as ACDS's independent expert authority on clinical practice, with perspective from Radiation Oncologists, Radiation Therapists and Radiation Oncology Medical Physicists. The CAG provides clinical advice to the ACDS Director on audit design priorities and contemporary technical advice on the development of audit methodologies. A key role of the CAG is to provide immediate clinical interpretation and advice on specific audit outcomes as required.

CAG membership is voluntary and comprises 6—10 members at anytime with a broad base of professional clinical experience and includes at minimum, representatives from the Royal Australian & New Zealand College of Radiologists (RANZCR), the Australian Society of Medical Imaging & Radiation Therapy (ASMIRT), the Australasian College of Physical Scientists & Engineers in Medicine (ACPSEM), the Trans-Tasman Radiation Oncology Group (TROG), a senior physicist from the ACDS and the ACDS Director (ex-officio).

ACDS Oversight Committee

The ACDS Oversight Committee (AOC) is an independent government appointed committee created via the Australian Health Ministers Advisory Council (AHMAC) as an oversight body (similar to an advisory board). The AOC's purpose is to ensure the ACDS effectively transitions from a fully Commonwealth funded organisation meeting the radiation oncology sector dosimetry audit requirements at no charge, to a sustainable cost recovery service where subscribers pay for the service

The AOC provides strategic, business and management advice to the ACDS. Under the terms of reference, membership must include commonwealth and jurisdictional government representation and business and professional expertise where possible. The AOC reports biannually to the Health Services Principal Committee – a principal committee of AHMAC.

Committee members for 2018



Madhavi Chilkuri (Chair)
Radiation Oncologist



Nick Hardcastle
Medical Physicist



Allan Fowler
Radiation Oncologist



Caroline Knipe
Radiation Therapist



John Shakeshaft
Medical Physicist



Tomas Kron
Medical Physicist



Annette Haworth
Medical Physicist

Not pictured:
Neal Molloy
Medical Physicist



Colin Hornby (Chair)



Simon Critchley



Gillian Shaw



Martin Naef



Sean Geoghegan



Michael Penniment



Megan Lavendar



Geoff Barbaro

Committee members for 2018

Annette Haworth, Caroline Knipe and Madhavi Chilkuri concluded CAG terms in 2018. Allan Fowler commences as chair from 2019.

Michael Penniment retired from the AOC from 2019, to be replaced by Angela Rezo.



The ACDS and TROG Cancer Research maintain an ongoing engagement aimed at ensuring each group is aware of the other’s development road map. The quality and scope of our dosimetric measurements combined with the mature audit management framework allows us to offer TROG comprehensive and reliable quality assurance for clinical trial dosimetry in the Australian and New Zealand context.

For our subscribers, this means routine ACDS audits will frequently meet credentialing requirements, without the need to conduct additional independent dosimetry, saving both facility staff and linac time. In addition to the trials listed below, the MRI-Linac audits and the ACDS proton audit will likely play a role in trial credentialing in the future.



Level II/III		
3DCRT/IMRT/VMAT	SABR	SRS
ANZ 1606/BIG 16-02/TROG 16.04 (EXPERT)	ICR-CTSU/2015/1005/TROG 16.03 (CORE)	TROG 17.02 (OUTRUN)
ICR-CTSU/2014/10049/TROG 14.02 (RAIDER)	ALTG 14/002/CTC0135/TROG 16.01 (NIVORAD)	TROG 16.02 (LOCAL HER-0)_
ANZMTG 01.09/TROG 08.09 (RTN 2)	TROG 15.03/ANZUP 16.001 (FASTRACK II)	EORTC 1308/TROG 15.02 (ROAM)
AGITG AG0407GR/TROG 08.08 (TOPGEAR)	TROG 18.01 (NINJA)	
	USYD/TD 17.03 (LARK)	

A Level I audit within the last two years is a general TROG prerequisite.



International collaboration

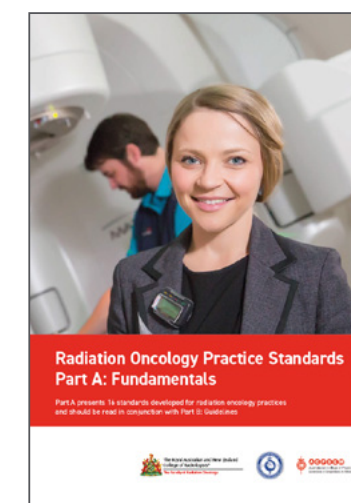
Clinical trials are increasingly happening in a global setting to ensure adequate statistical power and broadening the acceptance of trial results. We work together with other international radiotherapy quality assurance groups to promote a consistent standard in clinical trial credentialing. In 2018, Jessica Lye and Maddison Shaw participated in an audit inter-comparison hosted by the National Physical Laboratory (NPL) in the UK. The ACDS compared IMRT, VMAT and SABR measurement methods with NPL.



Standards



Both ACDS and the ARPANSA Primary Standards Dosimetry Laboratory (PSDL) maintain accreditation with the National Association of Testing Authorities (NATA). Accreditation goes beyond certification in compliance with systems and standards, it assesses technical competence.



ACDS audit services are recognised as meeting the Tripartite Radiation Oncology[#] Practice Standards criteria for independent dosimetric comparison/audit.

[#]The Tripartite Committee is now known as the "Radiation Oncology Alliance", reflecting the recent inclusion of the Cancer Nurses Society of Australia.



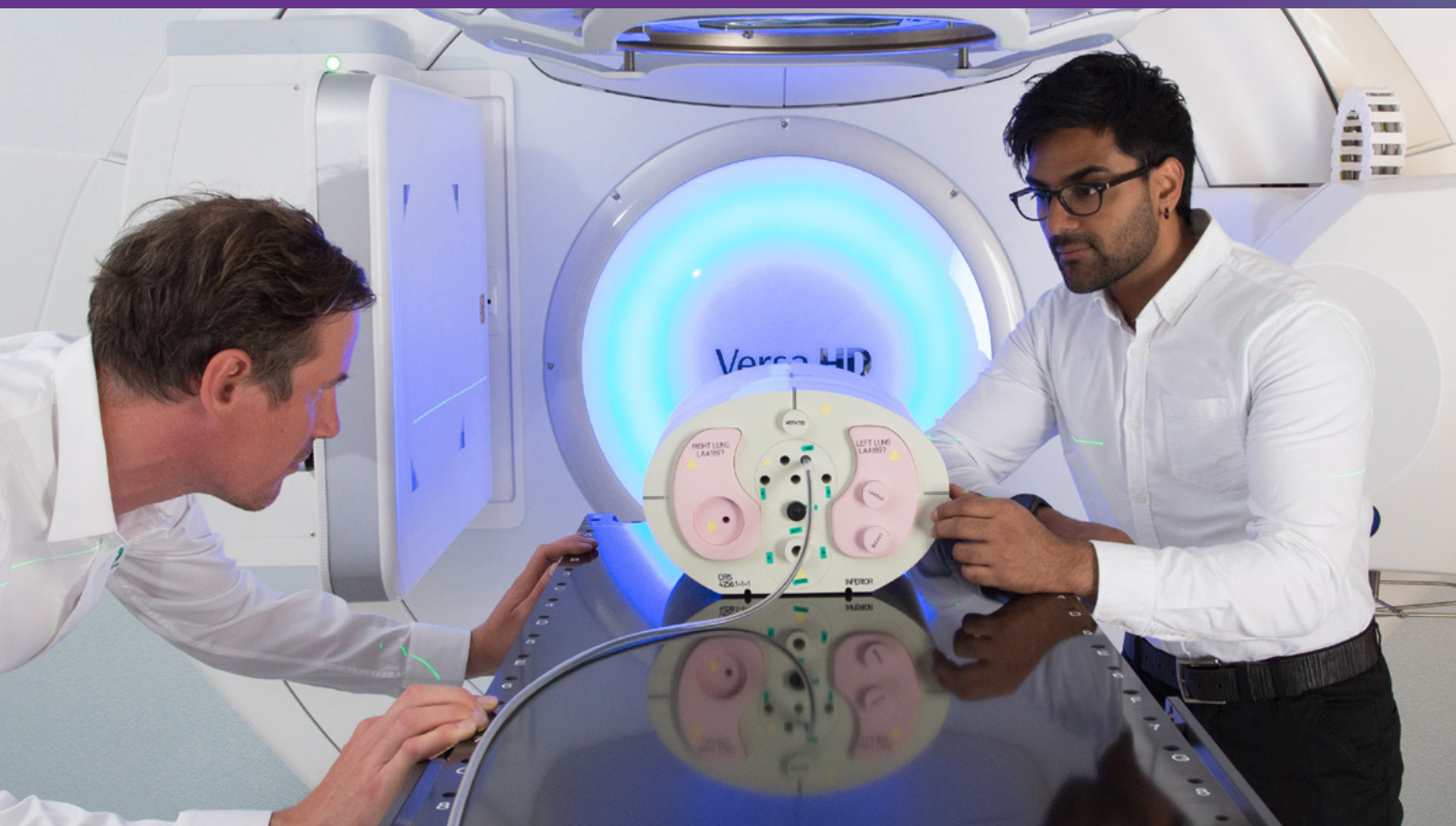
The ACDS is an active participant in the Global Quality Assurance of Radiation Therapy Clinical Trials Harmonisation Group (GHG).

The GHG aims to harmonise and improve the quality assurance of radiation therapy worldwide in support of multi-institutional cooperative clinical trials.



New developments

The ACDS aims to provide a comprehensive service covering clinical practice

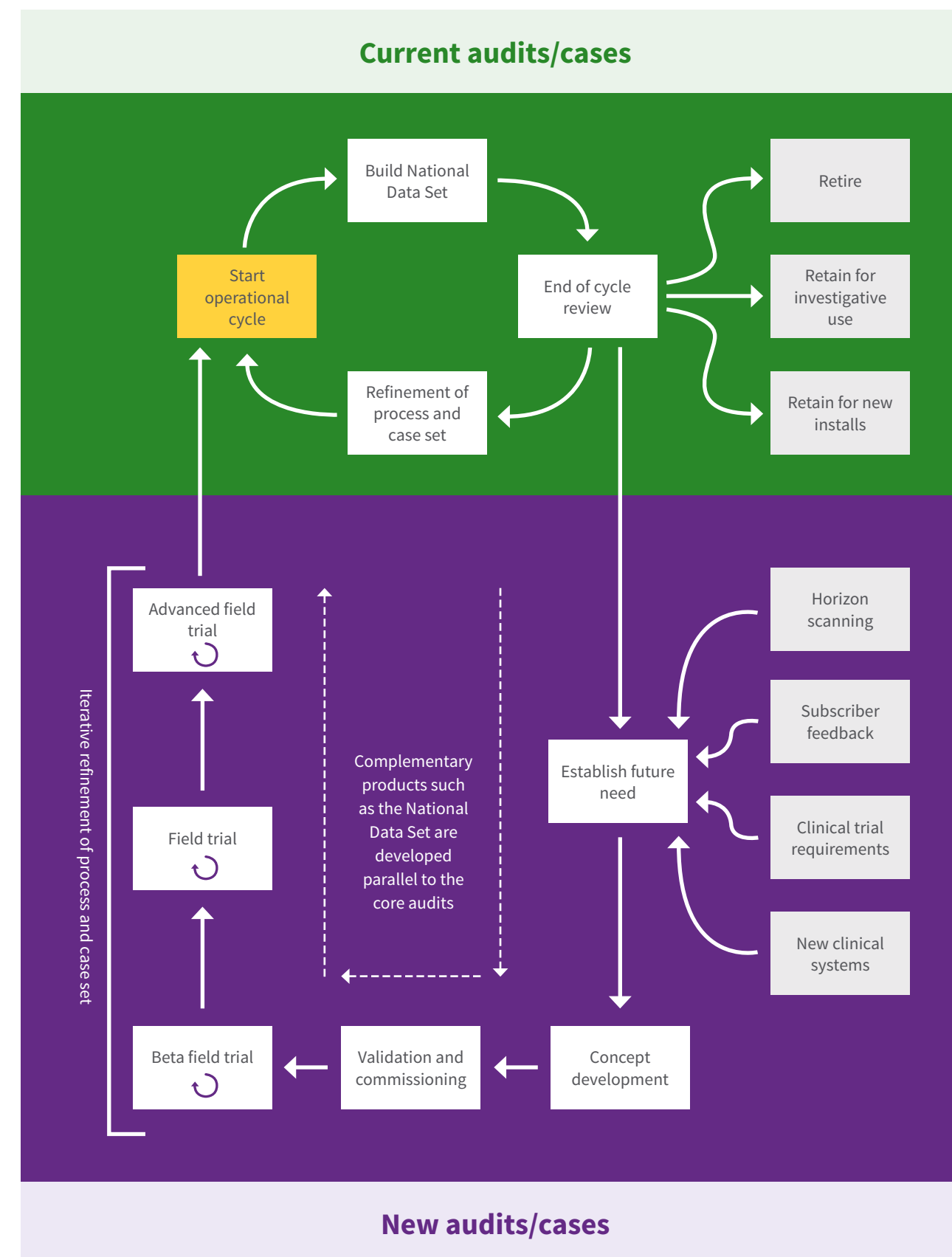


Commitment to continuous improvement

We have continued to improve and expand dosimetry audit capabilities since 2011, with the new operating model enabling significantly faster development cycles through 2018. The 2018 focus has been on ensuring facilities can access robust independent dosimetry for a much broader range of modalities and specialised treatment units. The full suite of audits undergo a continuous cycle of review, as captured in the diagram to the right.

Managing the audit continuous improvement and development roadmap rests on four core elements:

- actively seeking feedback from subscribers and stakeholders through a variety of surveys, informal feedback and formal engagement
- frequently reviewing individual audit cases, identifying items for revision, removal, or replacement for optimal relevance and streamlining
- horizon scanning and forward planning to maintain the ability to quickly respond to emerging systems and techniques
- identifying complementary activities and services such as the National Data Set to support safety and effectiveness in radiation oncology more broadly.





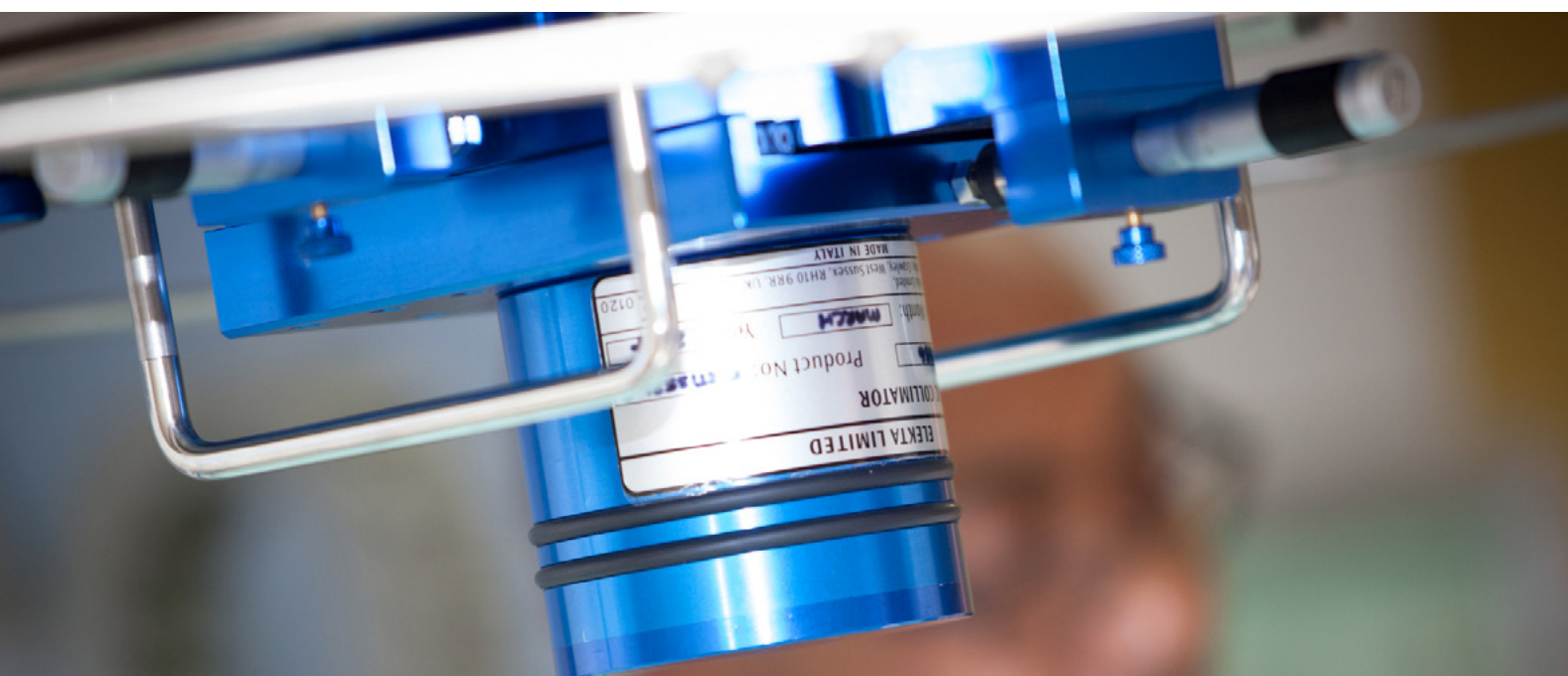
New developments

SRS

Initial concept validation and commissioning of the audit will commence in Q1 2019, with limited field trials rolling out from Q2/Q3 2019. Using a customised IMT-Max HD head phantom, this Level III audit includes classic SRS cases through to cases with complex planning, simulating treatments for multiple metastases. The audit has been designed with credentialing of TROG Cancer Research clinical trials in mind, in particular Local HER-O and OUTRUN.

Measurement methods and analysis will be leveraging off the existing development undertaken from microDiamond® detectors and film dosimetry for the Level Ib (small) field and Level III (SABR) audits respectively, but a considerable amount of custom commissioning and development remains to ensure the audit is both relevant and suitably robust.

The audit design uses a single phantom for CyberKnife®, Gamma Knife®, TomoTherapy®, Halcyon™ and C-Arm linac 6MV beams with or without flattening filters. This includes MR imaging and target delineation with fusion to CT for a truly end-to-end assessment of cranial stereotactic geometric accuracy. The target geometries include sets of both very small and extremely widely dispersed targets for robust assessment of single-isocentre/multiple target deliveries. Future capacity is also planned for the dosimetry of targets and organs at risk in treatments such as whole brain with hippocampal sparing and functional targets such as trigeminal neuralgia.



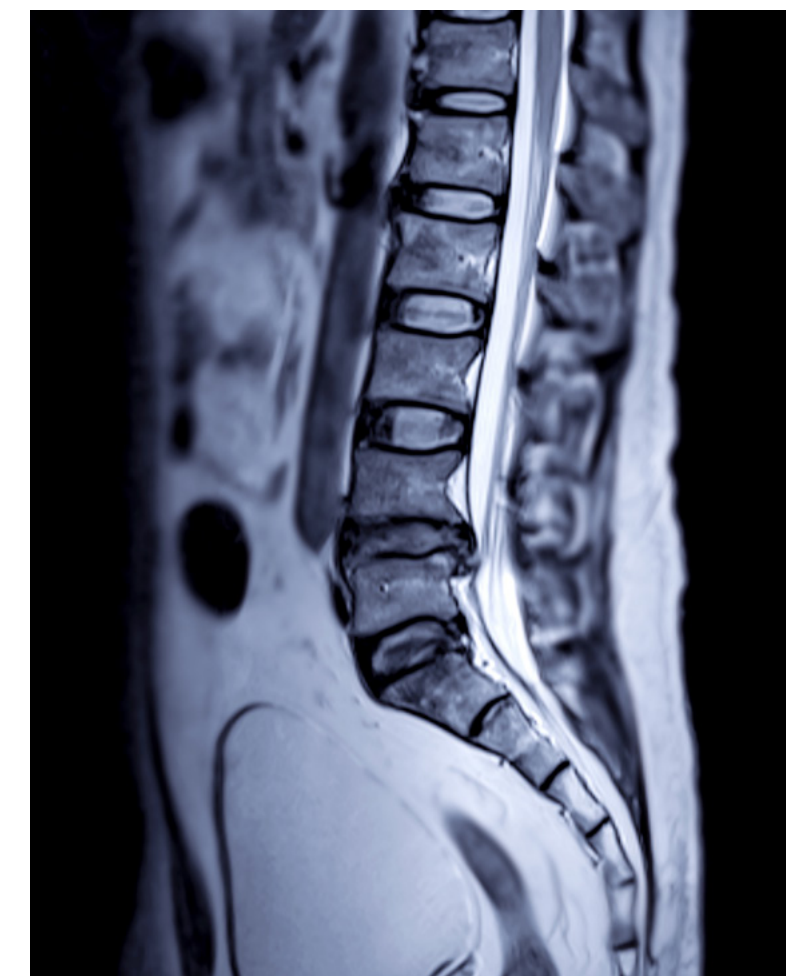
MRI linac

MRI-linacs, slated for Australian clinical introduction in late 2019, integrate a radiotherapy linear accelerator into a magnetic resonance imaging (MRI) system. The continuous real-time high quality imaging of soft tissues from MRI during treatment is a key enabler for 'on-line' adaptive radiotherapy where treatment plans are recalculated 'on the fly' to optimise them for each treatment fraction or perhaps even intra-fraction. The MRI-Linac represents a paradigm shift in both treatment delivery technology and process as we know it today.

These combined systems present significant technical challenges. As one such example, the MRI magnetic field forces electrons within the beam to move in a helical path. This presents a more challenging dose calculation problem, but an important one. Depending on the system configuration, this effect may make isodose curves appear skewed, increase exit doses and introduce significant hot and cold spots at air cavity interfaces.

The ACDS and Primary Standards Dosimetry Laboratory, has been steadily building the required knowledge and systems to support the introduction of this exciting new technology into the clinic, from fundamental dosimetry to understanding the evolved treatment planning systems catering for MRI-linacs.

A challenge for clinics and the ACDS alike, current clinical phantoms are designed for X-ray computed tomography (CT) radiotherapy simulation and planning with kilovoltage cone-beam CT image guided treatments. They are not visible on MR imaging. New inserts are being designed to be visible on both CT and MR images thus enabling image registration for planning and positioning on the treatment unit. Further work is planned to develop audit phantoms suitable for MR-only radiotherapy simulation and planning.





New developments

Specialised units

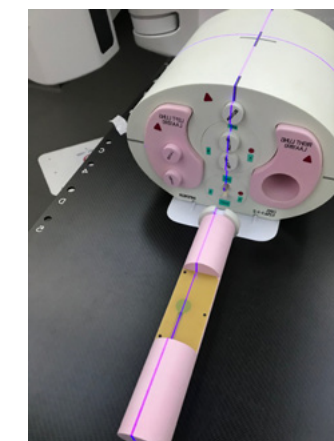
With transition to the new operating model, the inclusion of a broader array of treatment delivery systems has been fast-tracked. Beyond the traditional 'C-Arm' linear accelerator (linac), audits have now been conducted for TomoTherapy®, CyberKnife® and Halcyon™ megavoltage therapy systems, along with a variety of kilovoltage therapy systems. Gamma Knife® systems have been included in the stereotactic radiosurgery (SRS) audit entering field trials in 2019.

By using the well-established core methodology and infrastructure built by the ACDS, these systems have been readily integrated into the existing audit suite, establishing a model for the future so that whatever new systems emerge, subscribers will have access to independent dosimetry support.



SABR

The Stereotactic Ablative Body Radiation (SABR) audit is now a matured field trial, with approximately 50 beam models audited. This extension of the Level III Audit has been utilised by TROG Cancer Research for clinical trial site credentialing (CORE & NIVORAD trials).

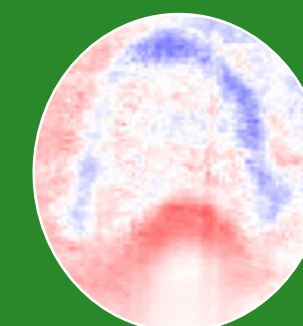


The team is currently undertaking a deep analysis of audit results, especially the high resolution film measurements, with the aim of moving the SABR audit from field trial to full clinical deployment by the end of 2019. Preliminary analysis of the point dose measurements in the target volume indicate robust dosimetry despite the challenging dose gradients in SABR treatments. The standard deviation in the difference between the planned and ACDS measured doses were 2.1%, 2.8% and 2.8% for the soft tissue case, the spine case, and the lung case respectively. Analysis of the 50% isodose between the spine and spinal cord showed that greater than 80% of the deliveries were within 1 mm of prediction.

The audit is open to all megavoltage beam types and modalities (for body irradiation) and has included both C-arm linac and CyberKnife® systems to date. With geometric accuracy of such crucial importance to SABR, the ACDS has taken extreme care to develop film analysis methods in-house and collaborate with international auditing bodies to determine the acceptability criteria. The audit requires the utmost geometric accuracy, in addition to precision dosimetry. This additional capability may be beyond what is routinely available in a clinical setting.

Dose to bone

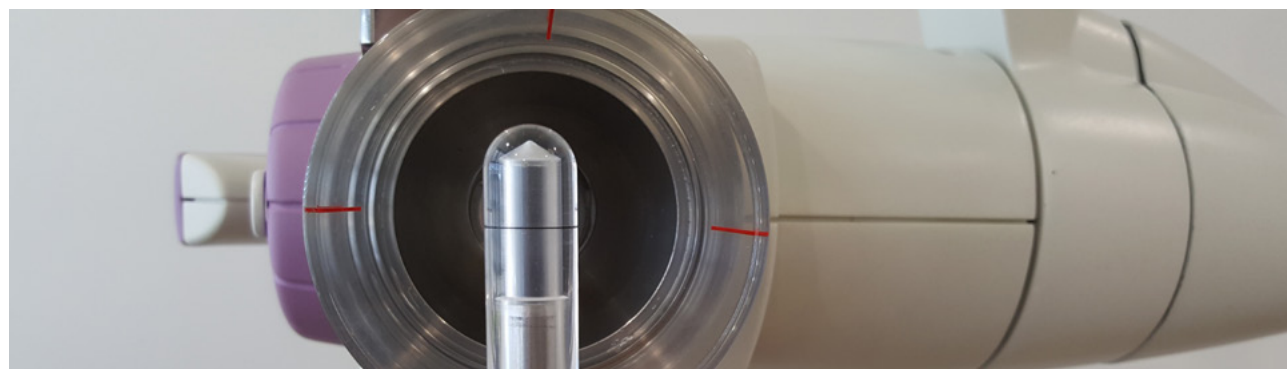
Treatment of bone targets is increasing with the expansion of deliveries like SABR spine. So what is the dose given to the bone? The ACDS is now directly measuring the spine dose using synthetic bone and developing the answer to this challenging problem through Monte Carlo modelling techniques.





New developments

Kilovoltage therapy



Radiation therapy for superficial lesions with kilovoltage (kV) beams is an often forgotten, but still widely used modality. Despite the relative simplicity of kV treatment devices compared to linear accelerators, kV measurements and dosimetry can be paradoxically more complicated to perform accurately. There are different international protocols in use throughout Australia and New Zealand that can lead to significant differences in the calibration of the kV unit.

Improved consistency of kV treatment beam dosimetry is anticipated through a combination of efforts. Firstly, standardisation of dosimetry practices will be improved with the introduction of Australasian College of Physical Scientists and Engineers in Medicine (ACPSEM) recommendations for kV quality assurance¹. The ACDS was a contributor to these recommendation through the

ACPSEM kilovoltage dosimetry working group. Secondly the availability of ACDS dosimetry audits for kV will allow facilities to benchmark beam output calibration.

The kV audit has progressed well with measured data in the initial stages from 70 beams over nine facilities to date. The trials have highlighted the variations in clinical practice, with dosimetry measurements compared against three different codes in use (TRS-398, TG-61 and IPEMB). The ACDS follows TG-61 in line with the ACPSEM recommendations. For facilities that also follow TG-61, there was an average difference between facility and ACDS measurement of -0.1%, and a standard deviation of 0.7%. Based on the anticipated tolerances for reference kV dosimetry, this has far exceeded expectations. Larger variations, of 5.8%, were seen when comparing to TRS-398.

¹ Hill R, Healy B, Butler D, Odgers D, Gill S, Lye J, Gorjiara T, Pope D, Hill B. Australasian recommendations for quality assurance in kilovoltage radiation therapy from the Kilovoltage Dosimetry Working Group of the Australasian College of Physical Scientists and Engineers in Medicine. *Australasian Physical & Engineering Sciences in Medicine*. 2018;41(4):781-808. doi:[10.1007/s13246-018-0692-1](https://doi.org/10.1007/s13246-018-0692-1)

TEAP training

The ACDS is participating in TEAP training as a training centre with specialised scope focusing on dosimetry, primary standards and audits. The first placement round has now been completed by **Atousa Montaseri**. Registrars also have the opportunity to work and interact with other sections of the Medical Radiation Branch.

The second and third placements are now underway for 2018–19.



Atousa Montaseri

I spent six months of my TEAP program at ARPANSA, an experience that made my TEAP training to be different from an ordinary one. At ACDS I got involved in different levels of audits, travelled with friendly ACDS staff and learned a lot on audit sites. Also wonderful projects which were identified and planned very well, provided me with the opportunity of learning in depth, through discussions with members of ACDS and primary standards group. I hope this opportunity will continue to be available in future for ROMP and DIMP registrars to benefit from knowledge and experience at ARPANSA environment.



We began performing audits in 2011 and since that time we’ve conducted 416 audits on site at hospitals and 343 mailout audits. Throughout these audits we have issued 143 recommendations from action level or out of tolerance outcomes. The most common recommendations relate to wedge and lung modelling and fundamental photon calibration.

With the implementation of IMRT/VMAT testing in 2016, we’ve begun to identify dosimetry issues related to multileaf collimator (MLC) leaf modelling, couch modelling and dosimetry for out of the treatment volume/organs at risk. Sub-optimal dosimetry has also been observed with flattening filter free (FFF) beams. Over time we expect the number of recommendations stemming from conformal beam problems such as wedge factors to decrease and the number of recommendation from IMRT/VMAT modalities to increase.

Recommendation type	Frequency
Off-axis wedge factor	17%
Lung	17%
Photon calibration	14%
Multileaf collimator (MLC)	11%
Electron calibration	10%
Failing to follow internal protocol	8%
Temperature/pressure correction	7%
Wedge factor	5%
Beam symmetry	4%
Photon percentage depth dose (PDD)	3%
Small field size output factors	2%
Couch model	1%
Out of treatment volume	1%
Flattening filter free (FFF)	<1%



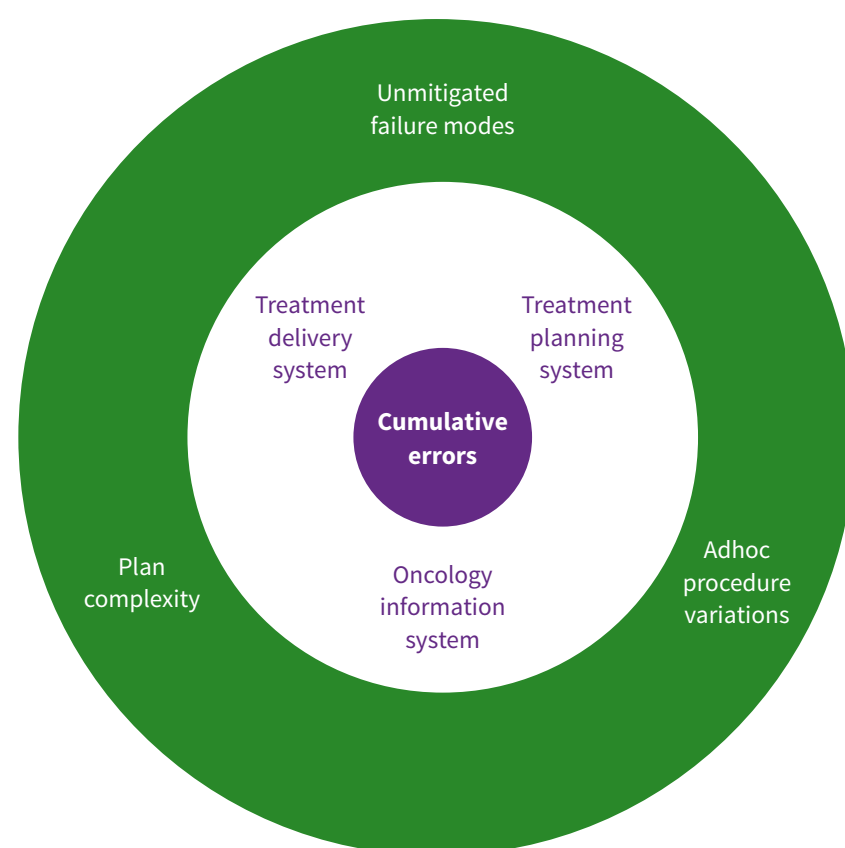
Key findings

Key themes have emerged from the ACDS dosimetry audit findings across our eight years of operation. These themes and trends are summarised in the following pages. In addition we also present a series of case studies, some of which are tangible examples of the key themes, while others are more anecdotal, but nonetheless serve to illustrate how errors can and have occurred and the need for constant vigilance.

Cumulative errors

A core finding is that a sub-optimal audit outcomes result not from a single large error, although that does happen, but from the accumulation of multiple small errors. Taken in isolation, these are typically unremarkable but in aggregate they can approach clinical significance.

This finding highlights the importance of understanding the contributing factors to overall uncertainty and optimising each component to the extent practical i.e. *address the errors that can be controlled so that the errors that can't be controlled matter less.*



Fundamentals of linac performance

Audits continue to identify basic linac beam parameters as the sole or more often a contributing cause to Action Level and Out of Tolerance outcomes across the span of audits. When the basic dosimetry errors combine with otherwise acceptable errors in the dosimetry chain including treatment planning, patient setup and treatment delivery, it is inevitable that some patients could exceed the generally accepted threshold for clinical impact ($\sim \pm 5\%$).

Discrepancies up to approximately 2% in the photon beam output calibration under reference conditions have been identified by ACDS audits. Also, the linac calibration reference value in the treatment planning system was identified as a contributing cause to action level and out of tolerance outcomes.

Similarly, errors $\geq 3.5\%$ were identified in electron beam output calibration under reference conditions, which is large in reference dosimetry terms. Fortunately in these cases the audit was for new installations and the errors were detected prior to patient treatments commencing.

Sub-optimal beam steering, in the order of 2% has also been a contributing factor in some cases.

Up to 8% of the ACDS recommendations stem from simple errors in thermometer and barometer calibrations. This includes up to 4 degrees error in thermometer readings and up to 1% in barometer readings. These errors feed directly into beam output calibration.

Calibration errors are not limited to reference conditions, frequently the weak link is actually the routine measurement/adjustment or 'physics output check', generally performed on a weekly or monthly basis. Errors here range from incorrect transfer of calibration from reference to output check method, spreadsheet and/or manual entry errors, excessively complicated set-ups and methodology, use of multiple equipment combinations, poor documentation systems, and lapsed or infrequent equipment quality assurance.



Key findings

MLC modelling

Complex IMRT and VMAT plans require a high degree of control and understanding of MLC calibration and modelling limitations. Multiple audits have identified a dosimetry bias in IMRT/VMAT cases even with optimal 3D conformal dose delivery. The patient specific QA processes, depending on the device used and implementation at a centre, do not always have the sensitivity to detect the dosimetry bias.

In several audit cases, sub-optimal results have occurred where the plan was identified to have a higher than usual level of complexity, as defined by the Modulation Factor (MU/cGy). In one specific instance a VMAT plan had a measured 2D gamma pass rate of 86.6% at 3%/3mm. The modulation factor was 10. After re-planning, the modulation factor dropped to 4 and the pass rate increased to 97%.

Asymmetric wedged fields

The most frequent recommendation issued relates to wedge factors. The key single issue contributing to the high failure rate is the inaccurate modeling of the 60° asymmetric wedge with the following linac/treatment planning system combinations: Elekta/XiO, Elekta/Pinnacle, or Siemens/XiO, Siemens/Pinnacle. Dose discrepancies of up to 9% were seen across the beam profile. This is a systemic problem with the treatment planning and delivery system combinations and does not appear to be due to the individual facility commissioning of the systems.

Facilities have changed clinical practice by implementing limitations to ensure the system performance was considered when creating treatment plans. Further information can be found in our publication:

Lye J, Kenny J, Lehmann J, Dunn L, Kron T, Alves A, Cole A, Williams I. A 2D ion chamber array audit of wedged and asymmetric fields in an inhomogeneous lung phantom. Medical Physics. 2014;41(10):101712-1 - 101712-11. doi:10.1118/1.4896097

Unexpected OIS and TPS behaviour

A number of audits have been impacted by unexpected behaviours within the Oncology Information System (OIS) and Treatment Planning System (TPS). These have generally, but not always been observed when a procedure or work practice was not performed as it normally is intended for routine clinical patients, and led to significant errors in some cases. Specific examples are provided in the case studies section.

AAA modelling behind and in lung

The National Data Set of Level III audits demonstrates a systematic under-dose when the Varian Eclipse AAA algorithm is utilised for dose calculation in regions distal from lung-tissue interfaces. An average discrepancy of $2.9 \pm 1.2\%$, was observed across all facilities using the algorithm. This can be compared to non-AAA users (including Eclipse Acuros) where an average difference of $-0.4 \pm 1.7\%$ was measured. The 2.9% offset from AAA easily leads to out of tolerance results when combined with what are otherwise considered generally acceptable 1-2% errors from dosimetry and setup. Of particular importance to note, measurements in slab phantom geometries, with similar measurement points downstream from inhomogeneities do not detect the error. This was found to be because the algorithm works optimally for slab geometries but uses approximations in curved (patient type) geometry. Further information can be found in our publication:

Dunn L, Lehmann J, Lye J, Kenny J, Kron T, Alves A, Cole A, Zifodya J, Williams I. National dosimetric audit network finds discrepancies in AAA lung inhomogeneity corrections. Physica Medica: European Journal of Medical Physics. 2015;31(5):435-441. doi:10.1016/j.ejmp.2015.04.002.

The algorithm also demonstrates a systematic over-dose in lung tissue itself, meaning the actual normal lung dose is higher than intended from the plan.



Case studies

Data transfer

An out of tolerance result occurred in one radiation field because only 50% of the planned dose (MU) was delivered. The dose mismatch occurred in the transfer from the treatment planning system (TPS) to the record and verify system (R&V), which were independent 3rd party systems. The workflow required manual entry of the prescription dose per fraction into the R&V and facility in-house software was used to electronically verify the manual data entry.

The facility suspects that 1 Gy was entered instead of 2 Gy and demonstrated the R&V ‘flagged’ a data mismatch for over-dose data mismatches but not under-dose. Data entry verification software was not run for the audit cases due to time pressures. As standard practice, like many facilities, independent dose calculation was performed on plans exported from the treatment planning system. If instead the independent dose calculation was performed on plans exported from the record and verify system, the dose mismatch would have been identified.

The facility logged the incident in their hospital incident register as a ‘near miss’, which was subsequently discussed at a radiation safety meeting, where the regulator was present.

VMAT with collimator at zero degrees

A Facility planned a VMAT case using collimator angle of zero degrees. The Facility quality assurance process passed the plan, although usual clinical practice was to plan with non-zero collimator angle. An overall dosimetry bias of greater than 5% was observed in a VMAT case with the largest discrepancy 7.5%. The Facility re-planned the cases with non-zero collimator rotation. The planned MU was halved when the collimator angle was rotated.

Both the original and re-planned cases were measured during follow-up. The result for the original case plan remained consistent and the re-planed case showed optimal dosimetry with average dose differences less than 1%.



Key findings

MLC leaf speed and non-clinical TPS functions

Some treatment planning systems allow beam models and patient data to be contained within distinct 'partitions' to separate data used for different clinical and non-clinical purposes, for example, there may be multiple clinical, research or testing partitions defined. In this case a Volumetric Arc Therapy case was planned in a non-clinical partition of the TPS which had an MLC speed limit of 3.0 cm/s, whilst in the clinical partition it was set at 2.25 cm/s. The audit outcome was Action level. The facility audit result resolved to optimal on their own quality assurance device when re-optimised and delivered in the clinical TPS partition.

Beam symmetry

The ACDS identified beam asymmetry as contributing to a non-optimal audit outcome. The facility subsequently checked 10MV photon symmetry with Sun Nuclear IC Profiler™, indicating adjustment was required. This was confirmed and corrected with water tank scans. The facility tightened the beam symmetry tolerance from 3% to 1.5% for daily quality assurance with the intention to purchase additional software to integrate IC Profiler™ into quality assurance trend analysis on a monthly basis instead of post-beam tuning. The ACDS was invited back to the facility for a repeat audit measurement.

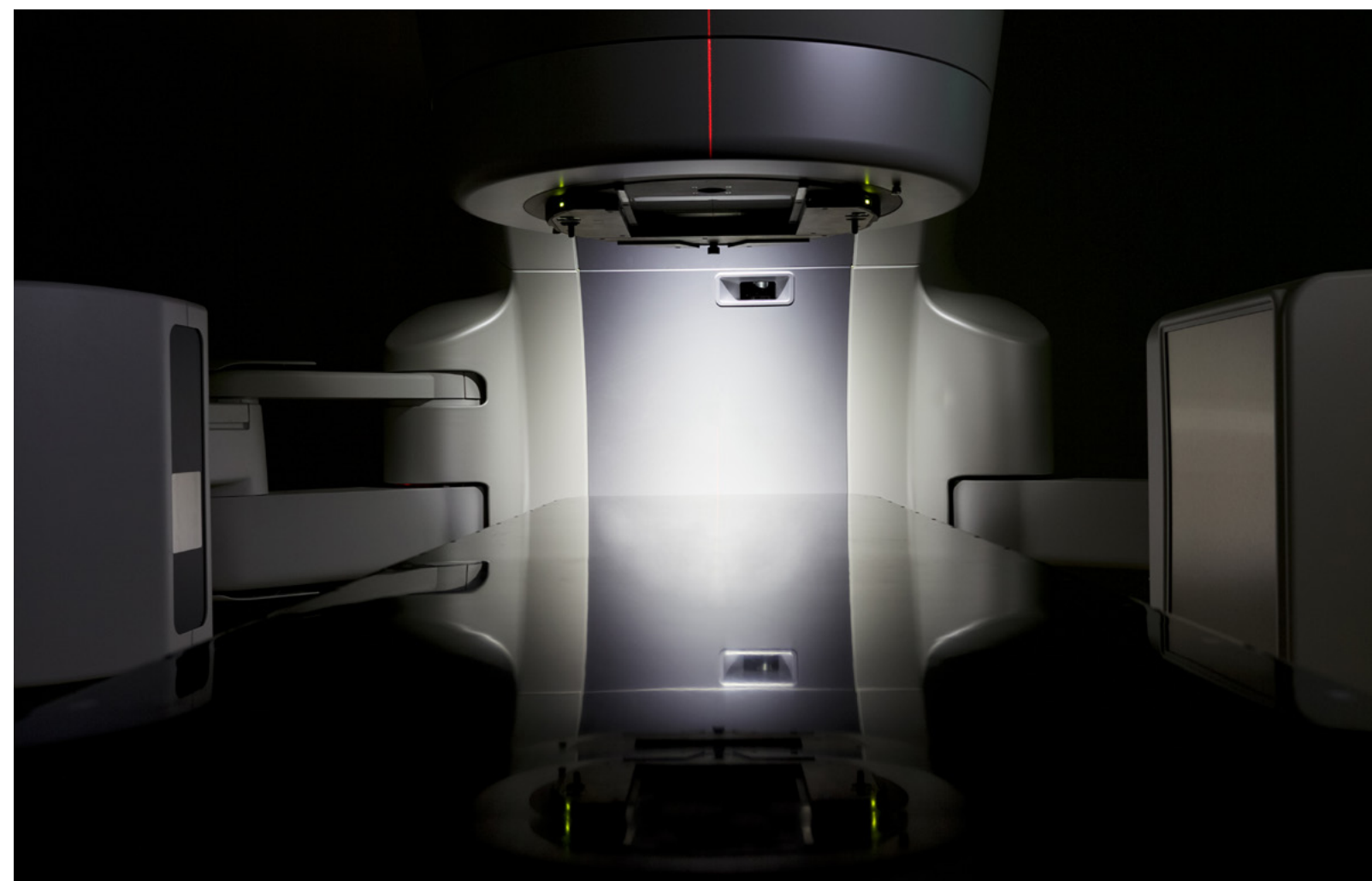
A follow up audit was performed after the symmetry adjustments with a pass (optimal) outcome.

Pixel by Pixel heterogeneity correction

The initial Out of Tolerance finding was approximately 15% dose difference, for a 12 cm x 12 cm field downstream lung. Facility staff conducted investigations and contacted the TPS manufacturer on the day of audit. This communication revealed that the 'Pixel by Pixel' heterogeneity correction was not enabled, leading to the TPS not recognising the density of the lung, and thus calculating the incorrect dose. A post audit discussion with the RT treating on the day, revealed that this error was due to a deviation from usual practice for planning.

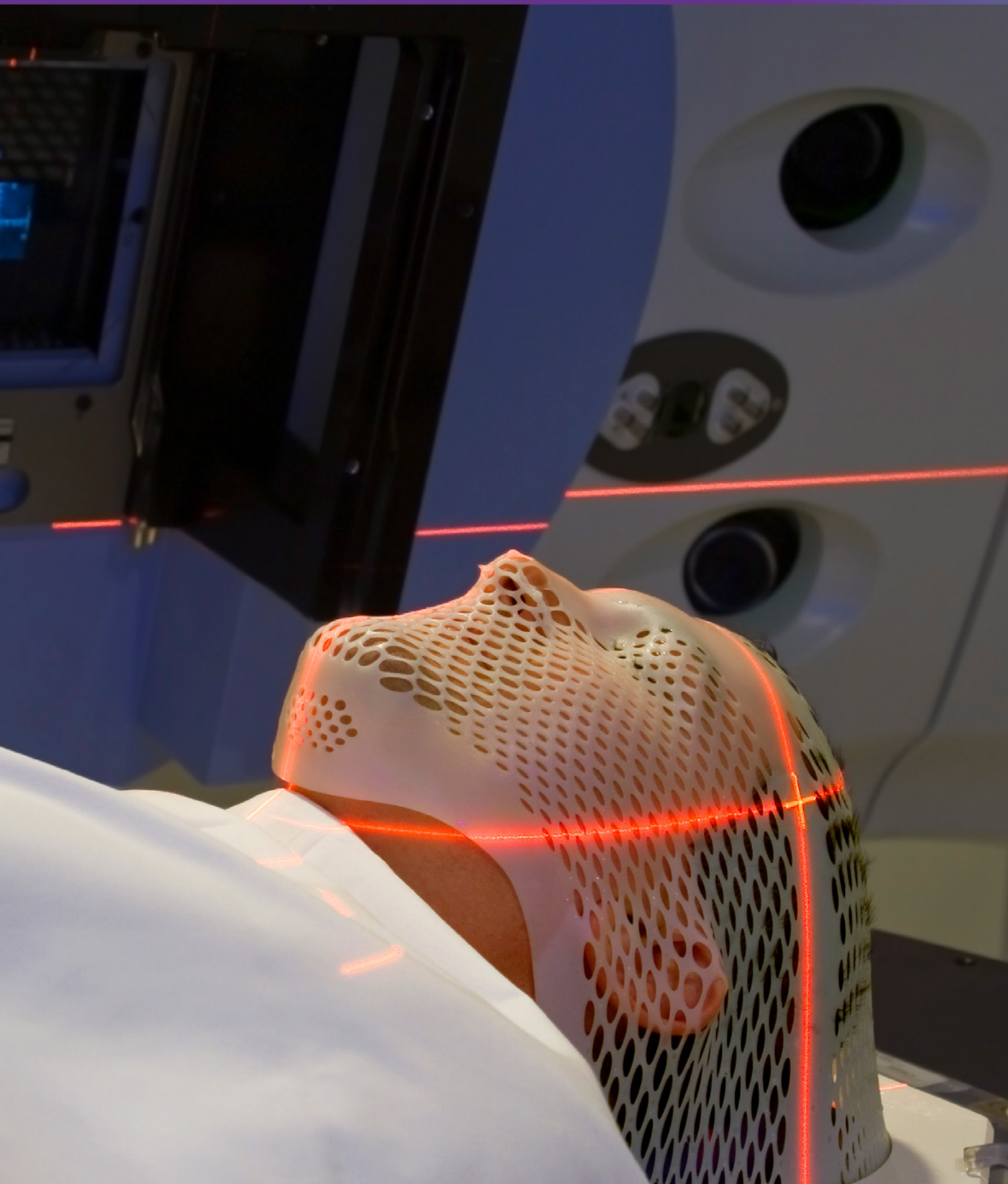
The facility uses two TPS, with standard departmental practice to create patient plans in TPS-1, where the pixel by pixel correction is defaulted to 'ON'. For the audit, the plans were created in TPS-2 and transferred to TPS-1 for dose calculation. The pixel by pixel correction was switched 'OFF' in TPS-2 this carried over to TPS-1 for calculation. This deviation from usual practice was carried out due to time and resource pressures.

The audit result was attributed by the facility to a deviation from standard clinical practice and identified as a 'near miss' in the facility risk management system. Initial review by the facility of some clinical patients undergoing thorax treatment determined that the issue had not occurred in those patients reviewed. The ACDS recommended a thorough review of clinical patients, particularly patients undergoing thorax treatment, to determine if this issue had previously occurred. The facility has changed the settings in TPS-2 to ensure the near miss identified in the audit does not occur in clinical practice.



★ Benchmarking

The ACDS has data from all radiotherapy facilities across the country allowing you to benchmark the quality of your radiotherapy dosimetry.



The ACDS National Data Set (NDS) comprises all information collected during the course of developing, executing and analysing ACDS audits. The core of the data set is the dosimetric measurements made across each audit, when now comprises approximately 15 000 data points.

The National Data Set is used to benchmark a facility's dosimetry performance against all other radiotherapy departments and also against facilities with similar equipment and systems.

Over the longer term audit development and deployment cycle, all results are critically reviewed regularly to inform the ACDS on the relevance and effectiveness of particular audit case designs and the suitability of tolerances used. The National Data Set is mined to provide insights into the root causes behind audit outcomes and dosimetry errors with the long term aim of informing clinical practices.

A detailed summary of the national data for each audit level is publicly available [on our website](#). Further information from the National Sata Set is available to ACDS audit subscribers on request.

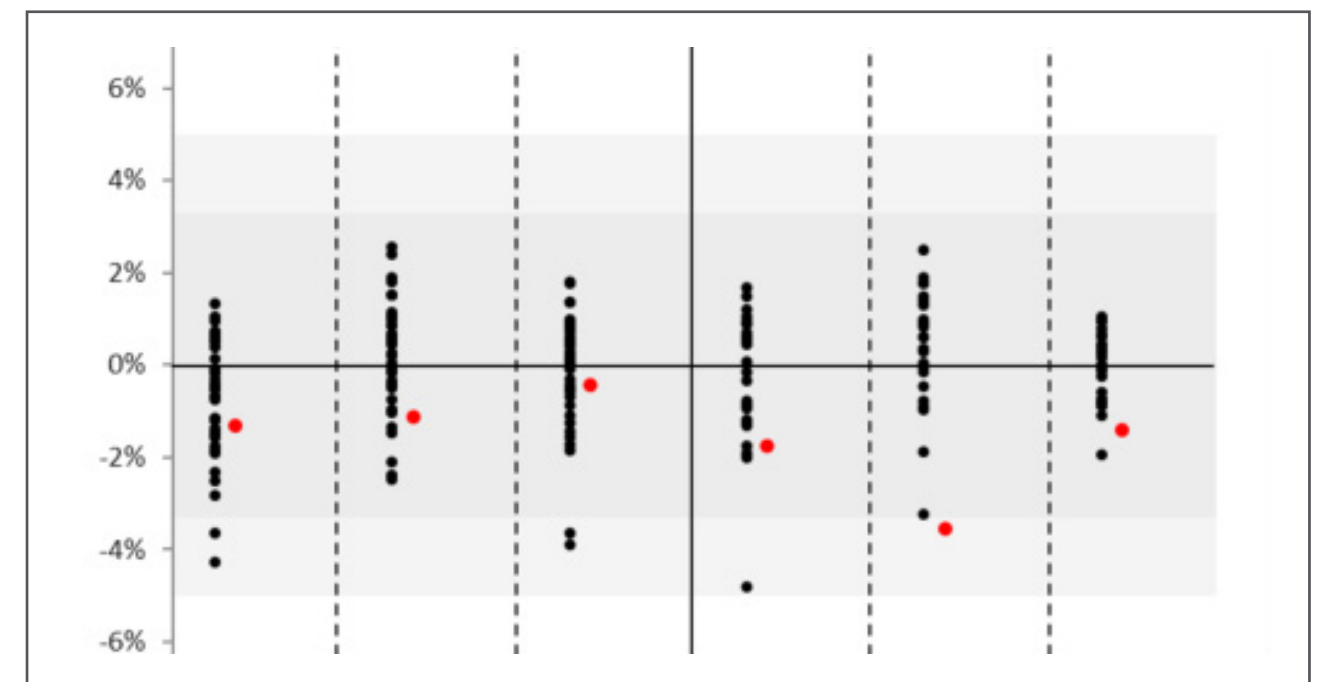


Figure 1: An example benchmarking graphic from an actual ACDS audit report. The red dots indicate the Facility dose difference across multiple audit cases (treatment plans) and the black dots are the dose differences for the same cases at all other audited facilities in Australia and New Zealand.

Improving national dosimetry

Good clinical dosimetry begins fundamentally with ‘reference dosimetry’ i.e. the basic calibration of the treatment delivery system. While accuracy is clearly important, consistency between facilities is equally important i.e. 1 Gray of absorbed dose should be the same, no matter where in Australia or New Zealand it is delivered. As part of further improving this consistency, the ARPANSA Primary Standards Dosimetry Laboratory (PSDL) has offered directly measured k_Q corrections since 2014 (Australas Phys Eng Sci Med. 2014 37(4):753-61) and the ACDS adopted use of PSDL measured k_Q from 2016 for ionisation chamber measurements across all audit levels. The factor k_Q is a necessary correction applied to ionisation chamber measurements and while strictly unique to each individual chamber and beam quality, until 2014, generic corrections were applied based on chamber type. The ACDS has been able to experimentally observe a reduced spread of beam output calibration measurement from the Level 1b audit results.

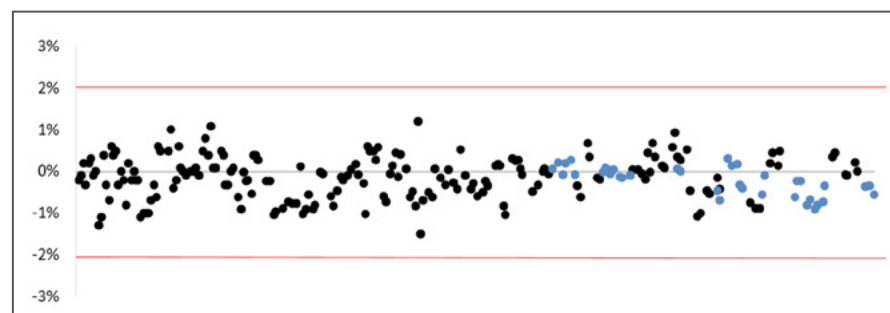
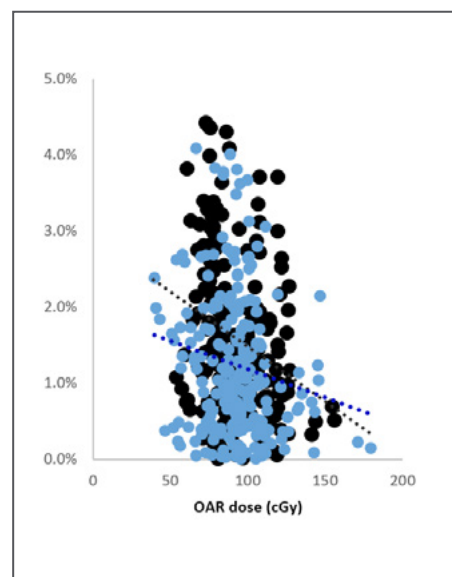


Figure 2: The black points show the dose difference when both ACDS and the facility are using generic published k_Q , and the blue points show when both the ACDS and facility are using directly measured k_Q . The spread using the generic corrections is 0.52%, while the spread is only 0.33% when using the measured chamber specific correction.

Does plan complexity matter?



As plan complexity is increased, it is expected that there is a chance that dosimetric accuracy will be compromised and there is evidence of this in clinical practice, although some of it is anecdotal. This trend is observed in ACDS audit data when using the OAR dose as a surrogate for plan complexity. Other metrics that we have been investigating (small aperture score, modulation factor, modulation complexity score) have not clearly shown similar trends, although it is difficult to ascertain if more data is required or if the metric is not appropriate for our dataset.

Figure 4: The absolute dose difference in the target between planned and measured as the OAR dose is decreased for IMRT (black points) and VMAT (blue points).

IMRT & VMAT dosimetry data maturing

The ACDS has now measured over 5000 points in IMRT and VMAT delivery in Australia and New Zealand. The results from the end-to-end dosimetry are shown in the graph below. The majority of points fall within $\pm 5\%$, displaying the general high quality of radiotherapy dosimetry in our countries. Some measurements do fall outside of expected tolerance and have required follow up investigations and deeper understanding of the beam modelling for more complex treatment deliveries at these radiotherapy departments.

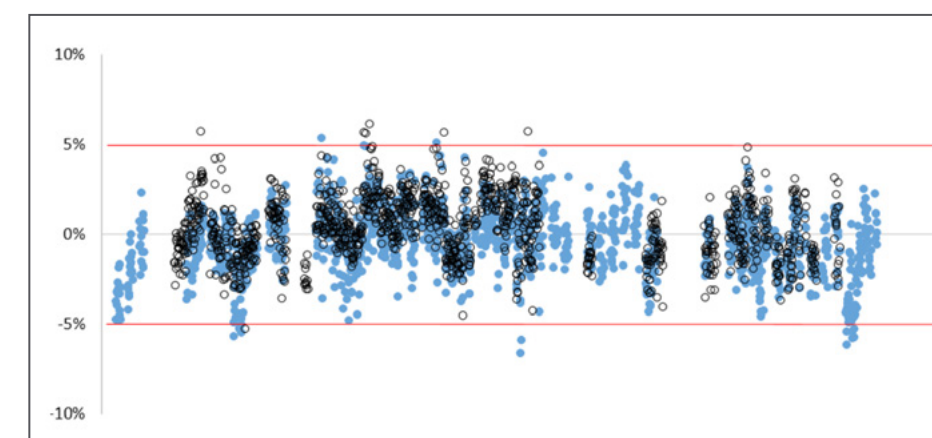
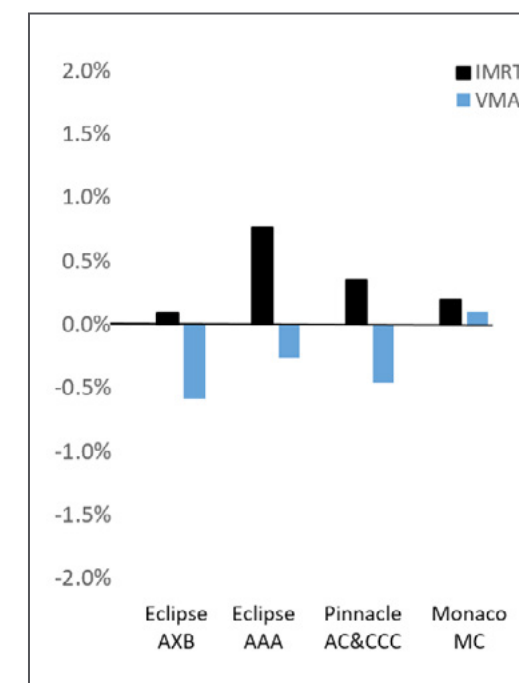


Figure 3: The black points show the difference between planned and measured dose for IMRT deliveries and the blue points show dose differences for VMAT deliveries.

Is IMRT or VMAT more accurate?



Overall neither modality shows significant bias compared to the National Data Set. VMAT does display a slightly tighter spread in dosimetry results with a standard deviation of 1.4%, compared to 1.7% with IMRT deliveries. One trend that is being monitored is the positive dose difference measured by ACDS for IMRT deliveries compared to negative for VMAT. This is observed in both Eclipse and Pinnacle, but not in Monaco Monte Carlo. This supports previously reported results that a compromise in optimal MLC leaf modelling is required to accommodate IMRT and VMAT plans.

Figure 5: The average dose difference across all audit points for different algorithms. A positive difference means the ACDS measures a higher delivered dose than was planned by the facility.

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