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Australian Radiation Protection and Nuclear Safety Agency

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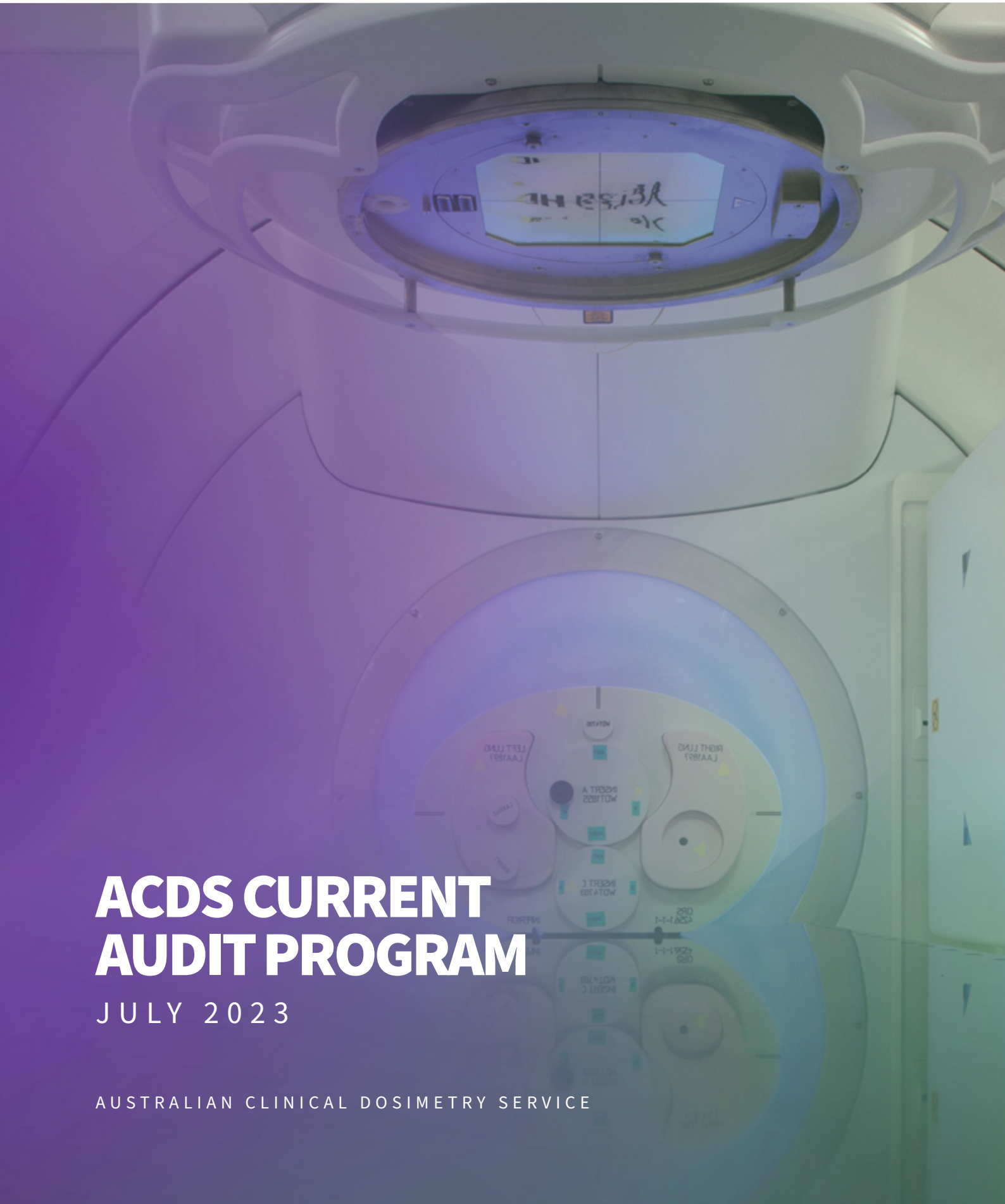


ACDS CURRENT AUDIT PROGRAM

JULY 2023

AUSTRALIAN CLINICAL DOSIMETRY SERVICE

ACDS audit program

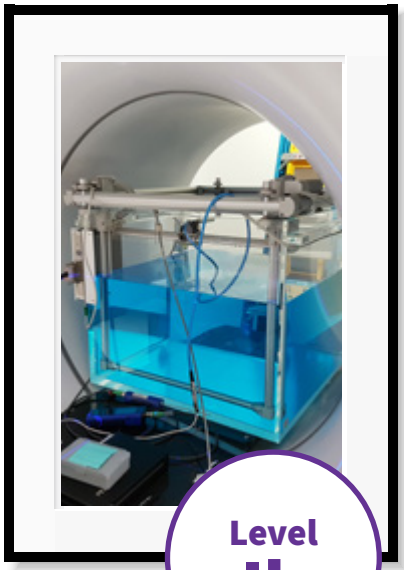
The **ACDS audit suite** comprises a range of remote and onsite audits with various levels of complexity. The audit level structure is described in the table below with more details on each audit level in the following pages.

Level I

Reference dosimetry for megavoltage photons and electrons with passive detectors

Modalities audited
Photons, Photons FFF, Electrons

Detectors used
OSLD



Level Ib

Reference dosimetry for megavoltage photons and electrons, and photon small field output factors

Modalities audited
Photons, Photons FFF, Electrons, Small field output factors

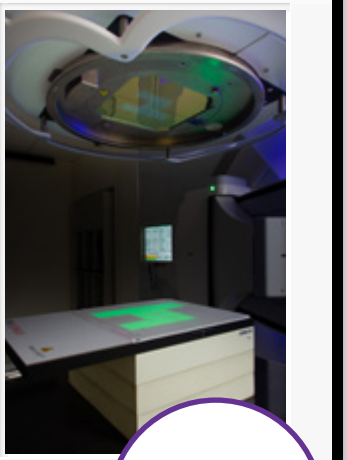
Detectors used
Ionisation chamber (reference dosimetry), microDiamond (small fields output factors)

Level Ib kV

Reference dosimetry for therapeutic kilovoltage x-ray beams

Modalities audited
kV photons

Detectors used
Ionisation chamber

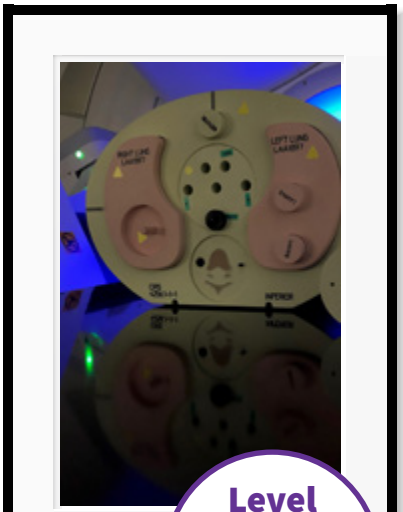


Level II

Array measurements in a slab phantom geometry to test TPS performance

Modalities audited
3DCRT, 3DCRT FFF, IMRT, IMRT FFF, VMAT, VMAT FFF

Detectors used
Ionisation chamber array detector



Level III (including SABR)

End to end tests with an anthropomorphic thorax/ abdomen phantom

Modalities audited
3DCRT, 3DCRT FFF, IMRT, IMRT FFF, VMAT, VMAT FFF SABR Soft Tissue, SABR Spine, SABR Lung, Online Adaptive

Detectors used
Ionisation chamber (3DCRT, IMRT, VMAT), Radiochromic film and microDiamond (SABR)

Level III SRS

End to end tests with a head phantom including MRI registration

Modalities audited
Single PTV, MR Multiple PTVs, Complex multiple PTVs

Detectors used
Radiochromic film and microDiamond

Onsite Remote

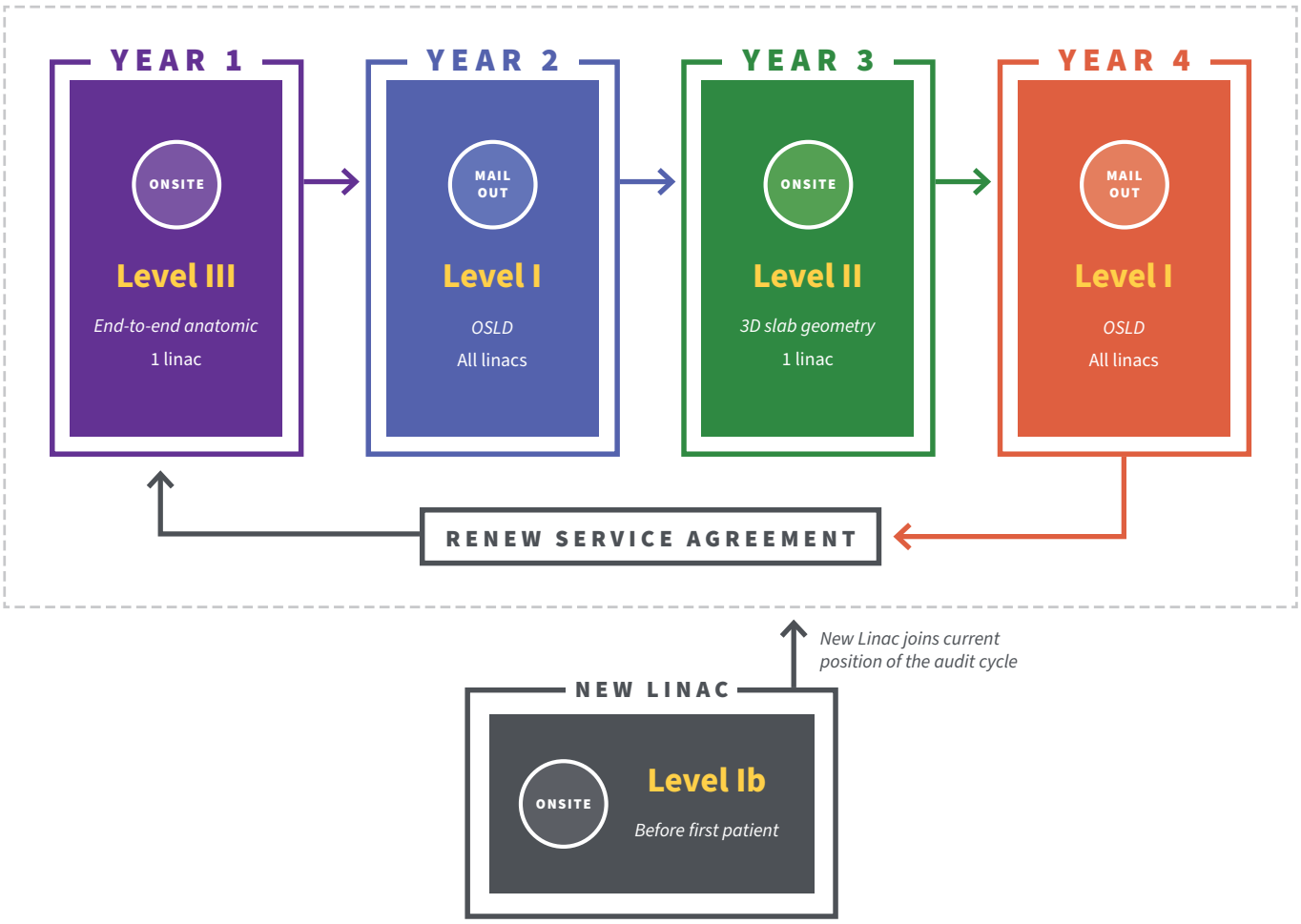
ACDS schedule

ACDS engages with radiotherapy facilities through a **four-year service level agreement** which includes a schedule of one audit per financial year. The four year schedule includes two onsite audits and two remote OSLD audits in alternate years of the cycle.

Specific points related to ACDS schedules and exclusions include:

- an audit schedule for specialty equipment can be included in the service level agreement. Specialty equipment includes Varian Halcyon®/Ethos™, Elekta Unity, Accuray Tomotherapy®, Accuray CyberKnife® and Elekta Gamma Knife®
- post audit follow up measurements or calculations by ACDS are included in the service level agreement cost
- participation in field trial audits is at no cost to subscribing facilities
- Level Ib audits are intended for new linear accelerator (linac) installations, are not included in the schedule, and are at separate cost
- Level III SRS audits and Level Ib kV audits are not included in the schedule and are arranged at separate cost upon request
- a desktop review of facility reference dosimetry calculations for all linacs at the facility (in years 1 and 3 of the schedule).

The subscriber audit cycle



Field trials
Additional, no fee

Level III SRS
Separate cost

Level Ib kV
Separate cost

The current audit program capability

The current audit program includes Level I, Level Ib, Level II and Level III audits. Each Level II and III audit consists of various cases representing standard tests and clinical cases that sample a limited yet challenging set of complex treatment scenarios.

A live audit is scored, and audits still in field trial, whether emergent or mature, are reported but not scored against the overall audit outcome. Mature field trials are reported with indicative outcomes. Other audit results that are reported but not scored include any deliveries which are restricted for clinical use, repeated measurements, alternative audit metrics, and supporting measurements.

ACDS audits, either live or in field trial, are accepted by ROHPG, TROG and state regulators.

The status of the ACDS audit program as of July 2023 is given in the following table.

		Conventional (photons)	Conventional (electrons)	Halcyon®, Ethos™	MR-Linac	Tomotherapy®	CyberKnife®	Superficial/orthovoltage	Gamma Knife®	Protons
Level 1	Reference fields	✓	✓	✓	✓	✓	✓	✓	★	★
Level Ib	Reference fields	✓	✓	✓	✓	✓	✓	✓	✓	★
	Small fields	✓		✓	✓	✓	✓		✓	
Level II	3DCRT	✓		N/A	N/A	N/A	N/A		N/A	
	IMRT/VMAT	✓		✓	●				N/A	
Level III	3DCRT	✓		N/A	N/A	N/A	N/A		N/A	●
	IMRT/VMAT	✓		✓	✓	✓		N/A	N/A	●
	Online Adaptive	✓		✓	✓			N/A	N/A	●
	Motion Adaptive	★	N/A	★	★	★	★	N/A	N/A	●
	SABR soft tissue	✓	N/A	✓	★	✓	✓	N/A	N/A	●
	SABR lung	✓	N/A	✓	▲	✓	✓	N/A	N/A	●
	SABR spine	✓	N/A	✓	▲	✓	✓	N/A	N/A	●
	SRS cranial	✓	N/A	✓	▲	✓	✓	N/A	✓	●

✓ Live ✓ Mature field trial ▲ Emergent field trial ★ In development ● Future

Current audit program

Level I

The Level I audit determines absorbed dose to water per monitor unit for megavoltage photon and electron beams under reference conditions. Optically Stimulated Luminescence Dosimeters (OSLD) are sent by post to the Radiation Oncology Facility (facility). The OSLDs are irradiated by the facility medical physicists and returned to the ACDS for processing. All clinical linacs in a facility are tested.

The audit results are determined by the percentage deviation of the facility stated dose output from the ACDS determined dose output, for each clinical beam. All beams on each linac are tested unless the facility states that a beam is not clinical.

An overall audit outcome for each linac is determined, which is equal to the poorest result of any individual beam. Outcome thresholds are given in the following table.

Result	**Level**	**% Deviation** (Facility stated dose / ACDS measured dose)		**mm Deviation** (Facility – ACDS)
		Photons	**Electrons R_{100}**	**Electrons R_{50}** (6-16 MeV)
Pass	Optimal	≤ 2.6	≤ 3.4	≤ 2.4
	Action	> 2.6 and ≤ 3.9	> 3.4 and ≤ 5.1	> 2.4 and ≤ 3.6
Out of tolerance		> 3.9	> 5.1	> 3.6

Current audit program

Level Ib

The Level Ib audit is conducted onsite by ACDS representatives and is offered for new linear accelerator installations or performed in response to a Level I audit result. To ensure independence from the facility, the ACDS provides external equipment and measurements whenever practicable. This audit is designed to measure static beams on a conventional linac, Halcyon® including Ethos™, MR-Linac, TomoTherapy® and CyberKnife® systems and determines absorbed dose to water per monitor unit, for mega voltage photon and electron beams, under the facility's reference conditions. Reference class electrometers and ionisation chambers are used with a water phantom. The absorbed dose determination is made using the IAEA TRS 398 and TRS 483 Codes of Practice. The ACDS uses ionisation chamber calibration factors provided by the ARPANSA PSDL. The energy dependent correction, k_Q, is determined in megavoltage beams at the ARPANSA linac, which are similar in quality to facility beams. ACDS also measures small field output factors during the Level Ib audit. Measurements are performed in the facility's water phantom with a microDiamond detector using the methodology and correction factors of the IAEA TRS 483 Code of Practice.

For Level Ib audits of kilovoltage X-ray therapy units, reference dose determination is made using the AAPM TG 61 protocol and ionisation chambers are calibrated in terms of air kerma by the ARPANSA PSDL. Consistent with AAPM TG 61, ACDS audits kV beams in the range 40 kV to 300 kV.

Audit results for reference dosimetry are determined by the percentage deviation of the facility stated dose output from the ACDS determined dose output, for each clinical beam. An overall audit outcome is determined, which is equal to the poorest result of any individual beam. Outcome thresholds for megavoltage beams from conventional linacs are given in the following table.

Level Ib

Result	Level	% Deviation (Facility stated dose / ACDS measured dose)	
		Photons	Electrons R_{100}
Pass	Optimal	≤ 1.4	≤ 2.2
	Action	> 1.4 and ≤ 2.1	> 2.2 and ≤ 3.3
Out of tolerance		> 2.1	> 3.3

Outcome thresholds for the small field output factors (Facility stated OF / ACDS measured OF) are given in the following table.

Result	Level	Field size (cm)				
		4	3	2	1	0.5 RNS
Pass	Optimal	≤ 1.1%	≤ 1.2%	≤ 1.7%	≤ 2.4%	≤ 5.0%
	Action	> 1.1% to ≤ 1.7%	> 1.2% to ≤ 1.9%	> 1.7% to ≤ 2.5%	> 2.4% to ≤ 3.7%	> 5.0% to ≤ 7.5%
Out of tolerance		>1.7%	>1.9%	>2.5%	>3.7%	>7.5%

Outcome thresholds for kilovoltage X-ray beams are given in the following table.

Result	Level	% Deviation (Facility stated dose / ACDS measured dose)
Pass	Optimal	≤ 3.5
	Action	> 3.5 and ≤ 5.0

Current audit program

Level II

The Level II audit determines absorbed dose delivered to selected points and planes within a slab geometry phantom. This is an audit of the beam model within a treatment planning system, where the phantom CT data set is supplied to the facility for treatment planning and delivery. It includes several modalities, each with additional options and the facility can choose to complete as many options in the audit as deemed necessary.

Multiple cases are planned for all modalities of the audit. Fields are fully prescribed by the ACDS and link directly to the ACDS Level III Audit. Dosimetry measurements are made in a custom phantom of CIRS plastic water, using a 2D ionisation chamber array as a primary detector. The 2D array is calibrated against a Farmer type ionisation chamber, which is traceable to the primary standard at ARPANSA. All clinical beam models (6X, 10X, 18X, 6FFF, 10FFF) can be tested using the Level II audit.

Modality	Conventional Linac	Halycon®/Ethos™
3DCRT	6X, 10X, 18X, 6FFF, 10FFF	6FFF
IMRT	6X, 10X, 6FFF, 10FFF	6FFF
VMAT	6X, 10X, 6FFF, 10FFF	6FFF

Level II

The audit outcome for an individual case is determined using the measured 2D dose map. An overall audit outcome for each modality is determined, which is equal to the worst case outcome for each modality.

For 3DCRT, audit results are determined for each case using the dose variation between the facility stated dose (planned dose) and the ACDS measured dose. For IMRT/VMAT, gamma criteria of 3%/3mm relative to 2 Gy, with dose <20% suppressed, are assessed across the entire measurement plane for each case. Local dose variation and gamma pass rate outcome thresholds are given in the following table.

Modality	**Metric**	**Pass** (Optimal)	**Pass** (Action)	**Out of tolerance**
3DCRT	Local dose variation	≤ 3.3%	> 3.3% and ≤ 5.0%	> 5.0%
IMRT & VMAT	Gamma Criteria	$\gamma \leq 1$ at 3%/3mm^{+} for ≥95% points	$\gamma \leq 1$ at 3%/3mm for ≥90% and <95% points	$\gamma \leq 1$ at 3%/3mm <90% points

Current audit program

Level III

The Level III audit investigates the accuracy with which a Radiation Oncology Facility delivers dose to a simulated patient. An anthropomorphic phantom undergoes all steps which a patient would experience for treatment with radical intent. Dosimetry measurements are made with ionisation chambers, microDiamond detectors and Gafchromic™ film in an anthropomorphic phantom.

The audit comprises multiple modalities and energies, which can be performed on a conventional linac, Halcyon®, Ethos™, MR-Linac, TomoTherapy®, CyberKnife® or Gamma Knife®. Specialist (non-conventional) linacs follow the general audit procedure.

The SABR technique is audited within the Level III audit.

Adaptive modalities are in field trial and results are reported but not scored.

Modality	Conventional Linac	Varian Halcyon®	Varian Ethos™	Elekta MR-Linac	Accuray TomoTherapy®	Accuray CyberKnife®
3DCRT	6X, 10X, 18X, 6FFF, 10FFF	6FFF*		7FFF*	6FFF*	6FFF*
IMRT	6X, 10X, 6FFF, 10FFF	6FFF		7FFF	6FFF	
VMAT	6X, 10X, 6FFF, 10FFF	6FFF		7FFF	6FFF	
SABR	6X, 10X, 6FFF, 10FFF	6FFF		7FFF	6FFF	6FFF
Adaptive			6FFF	7FFF		

**3DCRT fields are measured as reference as needed.*

Level III

Audit results are provided for each modality the facility chooses to include in the audit, from the audit suite that is offered. Outcome thresholds for all available audits are outlined in the following table.

Modality	Metric	Criteria	**Pass** (Optimal)	**Pass** (Action)	**Out of Tolerance**
3DCRT	Local dose variation	100% points	≤ 3.3%	> 3.3% and ≤ 5%	> 5%
IMRT and VMAT	Local dose variation	94% points*			
SABR	Gamma Criteria all cases	5%/2 mm	≥ 95%	< 95% and ≥ 90%	< 90%
	Soft Tissue 1D profile DTA	Mean DTA @ 70% isodose (L-R) and (A-P)			> 3 mm
	Spine 1D profile DTA	Mean DTA @ 70% isodose (L-R). DTA at PTV-Spinal Cord PRV interface @70%			> 2 mm
	Lung 1D profile DTA	Mean DTA @ 70% isodose (S-I)			> 3 mm
	Local dose variation all cases	100% points			> 8%

**An Out of Tolerance outcome will be given if a single point returns > 8% local dose variation.*

Current audit program

SRS

The SRS audit is a Level III audit that investigates the accuracy with which a Radiation Oncology Facility delivers dose for a simulated cranial treatment. Dosimetry measurements are made with microDiamond detectors and Gafchromic™ film in an anthropomorphic head phantom. Audit results are provided for each modality the facility chooses to include in the audit, from the audit suite that is offered.

Modality	Conven-tional Linac	Varian Halcyon®	Varian Ethos™	Elekta MR-Linac	Accuray TomoTherapy®	Accuray CyberKnife®	Elekta Gamma Knife®
SRS	6X, 10X, 6FFF, 10FFF	6FFF		7FFF	6FFF	6FFF	Co-60

Outcome thresholds for all available audits are outlined in the following table.

Modality	Metric	Criteria	Pass (Optimal)	Pass (Action)	Out of Tolerance
SRS	Gamma Criteria	5%/1 mm	≥ 95%	< 95% and ≥ 90%	< 90%
	1D DTA	Mean DTA @ 90% Isodose (L-R) (A-P) and (S-I)	≤ 1 mm	> 1 mm and ≤ 1.5 mm	> 1.5 mm
	Local dose variation	100% points			> 8%

Field trials

A field trial is a preclinical developmental stage of an audit. Data gathered informs decision making on phantom design, detector use, correction factors and analysis techniques. Uncertainty budgets and the setting of tolerances are refined as predicted tolerances are compared to measurements taken at participating facilities.

Audit development moves through three phases. From an emergent field trial, through to a mature field trial and then a live audit. An emergent field trial audit is when the technology required for performing the audit is explored in the clinical setting. Results have not been validated at this stage and tolerances are not set. An audit matures when the procedure for delivering the audit, analysing results, and producing the report in a timely manner, has been refined and indicative outcomes are provided. However, an overall audit score is not returned. A field trial becomes live when there is enough data collected and experience gained such that there is confidence in the uncertainty budgets and final results are then scored.

The Clinical Advisory Group review the results of the field trials and contributes to the decision making that determines when an audit is ready to become live.

Current field trials include:

- Level I audits for specialty linacs and kV x-ray therapy units
- Level III audits for MR-linacs
- Level III motion management/adaptive audits for conventional linacs and specialty linacs (in development).

ACDS audit report and certificate

ACDS generates an **audit report and certificate** for each completed audit. The certificate is a one-page summary intended for display.

The comprehensive audit report includes the following:

- a summary of audit outcomes for each modality audited (refer to the next section for more detail)
- ACDS recommendations and comments (refer to the next section for more detail)
- a tabulated summary of audit results
- facility location, audit date and technologies audited
- audit methodology and facility supplied data
- detailed audit results
- graphs comparing audit results to the ACDS's ANZ national dataset.

ACDS outcome levels

Audit outcomes are fundamentally binary, either Pass or Out of Tolerance (OT). The threshold is nominally derived from the calculated uncertainty budget, where the distribution of expected results is described in terms of standard deviation (σ). The OT threshold (>3 σ) makes it statistically unlikely the result occurred purely due to measurement uncertainty. A Pass outcome is further classified as Pass-Optimal Level (if within 2 σ) or Pass-Action Level (2-3 σ). The thresholds for each of the audits are outlined in this document.

Pass-Action levels and how they are used

Action level audit outcomes are used to draw attention to outcomes that are unlikely to represent a significant error but may benefit from closer scrutiny and are viewed as an opportunity for improvement. It provides both facilities and the ACDS a level of informed discretion when determining appropriate follow up.

A Pass–Action level outcome is still a pass for the audit. The potential to mitigate risk or improve quality must be balanced against unwarranted investigations that would draw time away from clinical needs. An appropriate action can be as simple as additional facility scrutiny of the audit. The decision to proceed and the scope of any facility follow up to a Pass-Action Level outcome remains at the discretion of the organisation's medical physics team, as they are ultimately responsible for the dosimetric accuracy within a clinical treating facility.

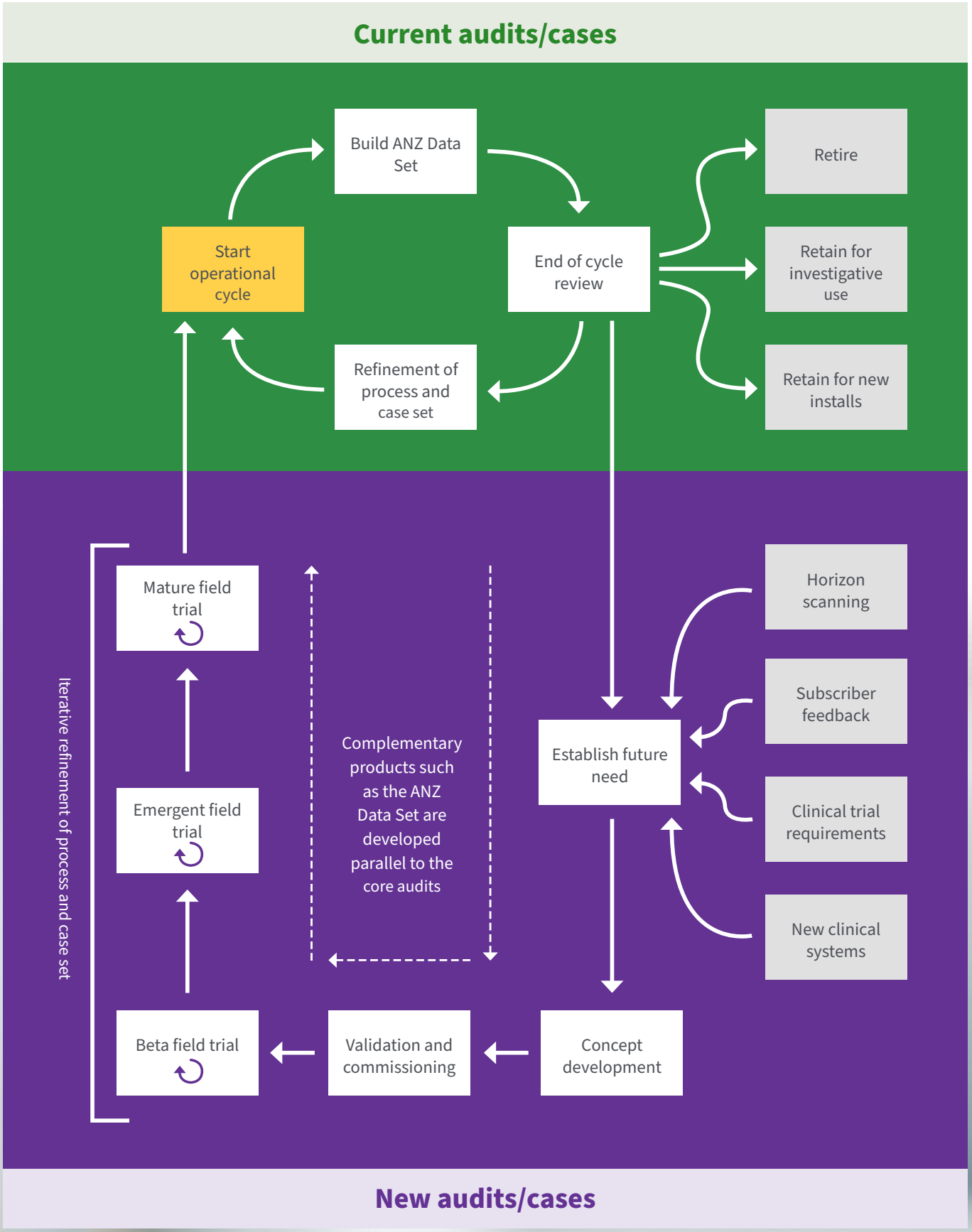
Recommendations and comments

The ACDS report includes explanatory comments and recommendations for follow up, which are made after consideration of all measurement outcomes within the audit, the ANZ dataset benchmarks, and detailed knowledge of the audit design. Any well-established behaviours will be identified and typically no further immediate follow up is requested. Less clear-cut cases may be discussed with the facility medical physics team, additional information may be requested and a follow up ACDS measurement may be offered.

All Out of Tolerance findings are reviewed by the ACDS's Clinical Advisory Group (CAG). In practice, in almost all cases, OT results have been due to demonstrable dosimetric or procedural errors rather than measurement uncertainties. Follow up of OT outcomes is determined by the severity and scope of the findings, where an outcome can fall into one of 3 categories; resolvable immediately, requires timely follow up or an event where the OT finding indicates the potential for significant clinical impact and a requirement for immediate intervention. This would be the case if the CAG recommends a facility cease or restrict patient treatment after reviewing the audit results.

The ACDS team are available for further discussion and will provide support and assistance however, it is necessary to note that the ACDS is not a regulator and has no regulatory role. An ACDS protocol is used to determine the levels of communication regarding audit results which may include the Chief Medical Physicist, Medical Director/Head of Radiation Oncology, ARPANSA CEO and State regulators. The ACDS will continuously engage and consult closely with the team involved in the audit if this situation were to arise.

The audit cycle review



Feedback and review

Feedback from subscribers and stakeholders is essential to the cycle of audit review and development and the ACDS continues to actively seek feedback on both their products and their service delivery. Feedback is welcomed and encouraged.

Our post audit feedback surveys collect information relative to specific professional clinical groups, allowing us to tailor our changes in practice and ensure that we provide a service reflecting the needs of our consumers. Surveys have been constructed to be as time sensitive as possible.

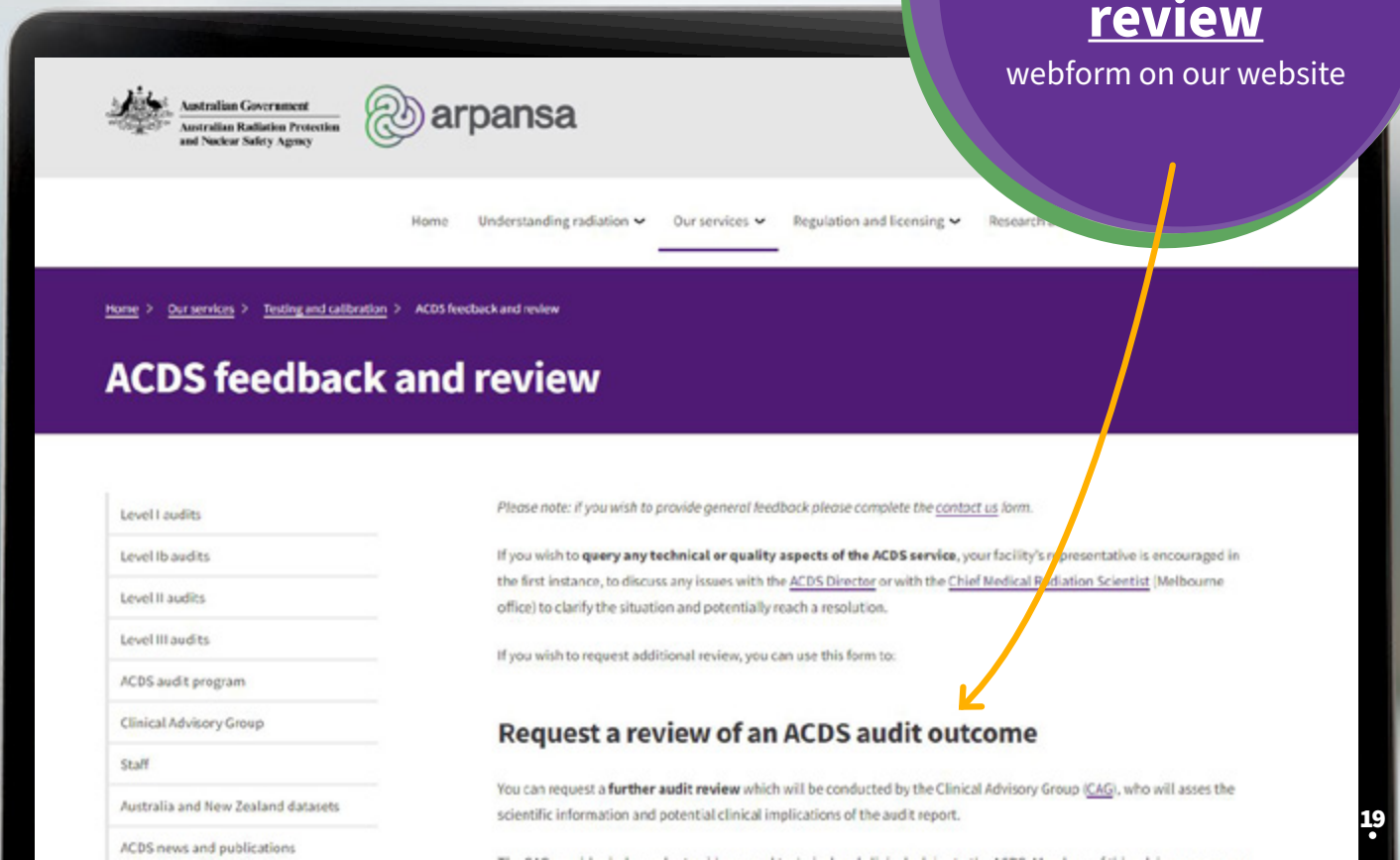
The ACDS also has a formal review process, developed with the assistance of the CAG. This is accessible via ARPANSA's website.

In the first instance, the facility representative is encouraged to discuss any issues or concerns with the director of the ACDS or the chief medical radiation scientist with the aim of a resolution via acds@arpansa.gov.au or +61 3 9433 2220.

Alternatively, or in addition to this, there is the opportunity to either:

- request a further audit review
- dispute a review response by CAG
- provide feedback or a complaint.

Visit the **feedback and review** webform on our website



Australian Clinical Dosimetry Service

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