Australian Government
Australian Radiation Protection and Nuclear Safety Agency

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Australian Clinical Dosimetry Service

Level Ib Audit Fact Sheet and Instructions

Definition

The ACDS Level Ib Audit determines absorbed dose to water per monitor unit, for mega-voltage photon and electron beams, under the Radiation Oncology Facility's (Facility) reference conditions. Dosimetry measurements are made with a reference class electrometer with ionisation chambers for photon outputs (Farmer-type PTW 30013) and electron outputs (PTW 34001 Roos), and a microdiamond detector (PTW 60019) for small field output factors. All measurements are made in the facility water tank. The determination is made using the IAEA TRS-398[1] and TRS-483[2] Codes of Practice. For measurements on MRI-Linacs, the correction factors for the magnetic field effects on the response of the dosimeters are taken from Begg et al. 2023[3]. The ACDS uses ionisation chamber calibration coefficients determined in high-energy photon beams of similar quality (referred to as "Directly measured"), as recommended by TRS-398. This audit is conducted by ACDS representatives, on-site at the Facility. The audit will require 5-7 hours of Linac time on the day of the audit.

The Level Ib audit consists of the following modalities:

- Reference beams (photons)
- Reference beams (photons FFF)
- Reference beams (electrons)
- Small field beams (photons and photons FFF)

Audit Coverage

The Level Ib audit is typically offered for new linear accelerator installations. This audit is designed to measure static beams on Conventional Linac, Halcyon™ including Ethos™, MRI-Linac, TomoTherapy®, Gamma Knife® and CyberKnife® systems.

Audit Scope

The ACDS aims to ensure a high degree of independence from the Facility by providing external equipment and measurements whenever practicable. The ACDS will however assume that:

- The Linac has been accepted from the supplier by the Facility
- The Linac has been commissioned by a certified ROMP (or equivalent) and performance (Mechanical and Radiation) is within Facility tolerance on the day of measurement

The ACDS will typically perform independent measurements of:

- Ionisation chamber charge collected per monitor unit under Facility reference conditions
- Ionisation chamber specific corrections for polarity (k_{POL}) and recombination (k_S)
- Water phantom temperature
- Ambient air pressure and relative humidity
- Water phantom depth positioning accuracy – at selected points over the range of interest

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For small field beams, the ACDS will typically perform independent measurements of:

- Small field lateral profiles for field centre and width
- Small field output factors at 10 cm depth
- Small fields will only be measured for a selection of:
  - Conventional Linac, Halcyon, MRI-Linac, TomoTherapy and CyberKnife systems,
  - 6 MV, 10 MV, 6FFF, 7FFF and 10FFF photon beams,
  - square or circular fields with a size of 0.5, 1, 2, 3 or 4 cm,
  - the most clinically relevant collimation method (jaws, MLC, cone, iris).
- The ACDS calculates the output factors relative to the machine-specific reference field (10 cm square field for conventional linacs).
- The ACDS output factors are compared to a set of Facility-stated output factors determined using either a single detector or using an average of several detectors.

Please note that this audit does not include independent measurement of:

- Beam Quality Index ($D_{20,10}$, $TPR_{20,10}$ or $R_{50,dose}$)
- Percentage Depth Doses or Tissue Phantom Ratios
- Output Factors or Applicator Factors for Non-Reference fields other than small fields

CPD

Radiation Oncology Medical Physicists participating in the audit may claim 5 ACPSEM CPD points and 1 Optional Reflective point.

ACPSEM CPD Endorsed Activity

Certificates will be issued with the audit report.

Audit Outcome

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. Result Levels are given in Table 1 for conventional linacs. Note that different outcome thresholds apply for non-conventional linacs and Gamma Knife.

Each modality (photons, photons FFF, electrons, small fields) is assigned an outcome which is equal to the worst result recorded for a clinical beam.

Table 1. Conventional linac audit pass criteria

Outcome	% Deviation (Facility-Stated Dose / ACDS-Determined Dose)	
	Photons	Electrons
Pass (Optimal Level)	≤ 1.4	≤ 2.2
Pass (Action Level)	> 1.4 and ≤ 2.1	> 2.2 and ≤ 3.3
Out of Tolerance	> 2.1	> 3.3

Table 2. Small Field audit pass criteria

Outcome	% Deviation (Facility-Stated Dose / ACDS-Determined Dose)				Not Scored
	Field Size (cm)				
	4	3	2	1	0.5
Pass (Optimal Level)	≤1.1%	≤1.2%	≤1.7%	≤2.4%	≤5%
Pass (Action Level)	>1.1% to ≤1.7%	>1.2% to ≤1.9%	>1.7% to ≤2.5%	>2.4% to ≤3.7%	>5% to ≤7.5%
Out of Tolerance	>1.7%	>1.9%	>2.5%	>3.7%	>7.5%

Small field output factors

The ACDS performs small field output factor measurements at 10 cm depth using a PTW 60019 microDiamond. Published field size specific corrections from the 'IAEA/AAPM TRS-483 Dosimetry of Small Static Fields Used in External Beam Radiotherapy' Code of Practice are applied to the ACDS output factor measurements. A scanning water tank is required to measure profiles to determine the true centre and irradiated field size (FWHM) of the small field. If a scanning tank is not available, e.g. MRI-Linac, the nominal field size will be used.

Outcome Reporting

A Level Ib audit report is created for each individual Linac audited. If required by the facility, an ACDS representative will issue preliminary results to the Facility immediately following the audit. The formal audit report will be sent to the Facility within two working weeks of the audit. This timeline will extend if additional information or follow up of non-optimal audit results are required.

Out of Tolerance results are promptly communicated to the Chief Physicist and reviewed by the Clinical Advisory Group. Data collected is held confidentially by the ACDS and its oversight groups. Publicly reported outcomes are randomised and de-identified.

The Australia and New Zealand (ANZ) Dataset is comprised of an extensive number of data points and information collected while developing, executing, and analysing ACDS audits. This comparative data is available for benchmarking the Facility's audit results against measured audit data for all modalities in the Level Ib audit, and will be included in the formal report.

Facility Audit Procedures

- Ensure the dose outputs for photon, photon FFF and electron beams (the absorbed dose per MU at DOSP, under reference conditions) are available for the day of the audit.
    - The dose output should be measured according to the Facility's routine physics output check (NOT Daily QA device).
    - DOSP = Dose Output Specification Point, the point at which the nominal linac dose calibration is specified by the Facility e.g. 1cGy/MU at d_{max}.
- Ensure a medical physics representative is available for the duration of the audit to operate all Facility equipment and provide supplemental information if required
- Please have the scanning water tank set up prior to ACDS arrival. Ensure the tank can measure at varying depths for reference dosimetry and scan profiles for small field measurements. A 1D manual water tank is suitable for MRI-Linac.
- Reference dosimetry measurements may be performed in service mode, with a clinical mode

verification measurement performed once for each reference beam through the R&V system (QA mode is acceptable).

- Ensure each reference field is prepared in the R&V system QA mode

  e.g. *6X beam, Gantry = 0°, Coll = 0°, 10 cm x 10 cm field size, 200 MU*

  9e beam, Gantry = 0°, Coll = 0°, 10 cm x 10 cm Applicator, 200 MU, etc.

- Small field output factors setup preparation:
  - Ensure lateral profiles may be scanned to determine the irradiated field size and place the detector at the radiation field centre. Please create a measurement queue in the water tank driving software for **the smallest** small field to be measured. The following settings are preferred:

    Step-by-Step mode, 0.2 mm step size

    Speed 3mm/sec both during scanning and moving between scans

    Scan width to ± 10 mm beyond the 50% field edge

    Prepare: 2 x inline scans (G→T, T→G) in sequence

    2 x crossline scans (A→B, B→A) in sequence

    These four scans will be used to assess the tank performance, set the final (0,0) position, and choose a preferred scanning direction for the subsequent scans for which the queue will be modified during the audit.
  - For MRI-Linacs and 1D manual water tanks, the nominal field size is used and the detector is centred in the beam using MV imaging.

References

1. International Atomic Energy Agency, Absorbed Dose Determination in External Beam Radiotherapy, Technical Reports Series No. 398, IAEA, Vienna (2000)
2. International Atomic Energy Agency, Dosimetry of Small Static Fields Used in External Beam Radiotherapy, Technical Reports Series No. 483, IAEA, Vienna (2017)
3. Begg J, Jelen U, Moutrie Z, Oliver C, Holloway L, Brown R, ACPSEM position paper: dosimetry for magnetic resonance imaging linear accelerators. Phys Eng Sci Med 46, 1–17 (2023)