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Contents

From the Editor

This issue of the SSDL Newsletter (No. 66) is the first one published only in electronic form. This change in format will open new possibilities by allowing us to use more interactive materials in the future. We would like also to increase the interaction between the members of the IAEA/WHO SSDL Network and thus invite all members to send new ideas and articles for the Newsletter.

One of our services is to organize comparisons for members of the IAEA/WHO SSDL Network. We provide comparison services for standards used for radiation therapy, diagnostic radiology and radiation protection calibrations. To be able to provide these services, we also have to take part in comparisons to support our calibration and measurement capabilities. The first article of this newsletter is one example of this kind of comparison and provides comparison results of the radiation therapy level standards of the National Research Council of Canada (NRC) and the IAEA.

In this newsletter, we have included several reports from different meetings and courses. The article starting from page 9 provides a comprehensive information package for countries establishing and developing dosimetry audit centres. The article that follows introduces a new publication in progress for establishing an SSDL. Training courses about radiation protection calibrations and preparing a quality management system for SSDLs were both organized under IAEA technical cooperation. The uncertainty workshop organised in April by DMRP had more than 80 participants and, in addition to the guidance on uncertainty estimations, it provided the participants a good opportunity to meet other dosimetry experts.

There have been some changes in the DMRP staff. Ahmed Meghzifene, Section Head, retired from his position. Luckily he is currently working as a consultant in the Division of Human Health; so we can still benefit from his expertise and experience. István Csete retired but is temporarily holding the position until the new colleague takes over. Our section provides also opportunities for internship. Mirja Kemppi has been working as an SSDL Network intern since December. A short story describing the experiences of another intern can be found in Intern's corner.

Participants of a regional training course (see page 20)

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Services provided by the IAEA in DMRP Section

The IAEA's Dosimetry and Medical Radiation Physics Section focuses on services provided to Member States through the IAEA/WHO SSDL Network and on a system of dose quality audits. The measurement standards of Member States are calibrated, free of charge, at the IAEA's Dosimetry Laboratory. The audits are performed through the IAEA/WHO postal dose assurance service for SSDLs and radiotherapy centres by using radiophotoluminescence and optically stimulated luminescence dosimeters (RPLDs and OSLDs).

The Dosimetry Laboratory's Quality Management System has been reviewed and accepted by the Joint Committee of the Regional Metrology Organizations and the BIPM (JCRB). The IAEA Calibration and Measurement Capabilities (CMCs) have been reviewed and published in Appendix C of Comité International des Poids et Mesures (CIPM), Mutual Recognition Arrangement (MRA).

The IAEA CMCs can be found at the following web site: http://kcdb.bipm.org/AppendixC/search.asp?met=RI

The range of services is listed below.

Services	*Radiation quality*
Calibration of ionization chambers (radiation therapy, diagnostic radiology including mammography, and radiation protection including environmental dose level)	X rays (10–300kV) and γ rays from ^{137}Cs and ^{60}Co
Comparison of radiation therapy, radiation protection and diagnostic level ionization chamber calibrations coefficients for SSDLs*	γ rays from ^{60}Co and ^{137}Cs and X rays
Dosimetry audits (RPLD) for external radiation therapy beams for SSDLs and hospitals**	γ rays from ^{60}Co and high energy X ray beams
Dosimetry audits (OSLD) for radiation protection for SSDLs	γ rays from ^{137}Cs
Reference irradiations to dosimeters for radiation protection	X rays (40–300 kV) and γ rays from ^{137}Cs and ^{60}Co beams

* Technical protocols for comparisons have been updated and published. Please find more information from the information note 2/2016 http://www-naweb.iaea.org/nahu/dmrp/SSDL/noticeboard.asp

**Thermoluminescence dosimeters (TLDs) were replaced by RPLDs in 2017.

Member States interested in these services should contact the IAEA/WHO SSDL Network Secretariat, for further details, at the address provided below. Additional information is also available at the web site:

https://ssdl.iaea.org

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Note to SSDLs using IAEA calibration and audit services:

1. To ensure continuous improvement in IAEA calibration and audit services, SSDLs are encouraged to submit suggestions for improvements to the Dosimetry Contact Point.

2. Complaints on IAEA services can be addressed to the Dosimetry Contact Point.

Comparison of the Standards of Air Kerma and Absorbed Dose to Water of the NRC and the IAEA for Therapy Level ^{60}Co Gamma Radiation

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Abstract

An indirect comparison of the standards for absorbed dose to water and air kerma of the National Research Council of Canada (NRC) and of the International Atomic Energy Agency (IAEA) was carried out in the ^{60}Co radiation beam of the NRC in August 2016. Both comparison results were calculated based on the calibration coefficients for two transfer standards and expressed as the ratios of the IAEA and the NRC standards. The comparison results for absorbed dose to water and air kerma were 0.9997 (u_c=0.66%) and 0.9963 (u_c=0.47%) respectively.

1. Introduction

The Dosimetry Laboratory of the International Atomic Energy Agency (IAEA), Seibersdorf, Austria, calibrates reference standards in ^{60}Co gamma beams for IAEA/WHO SSDL Network members (more than 80 laboratories worldwide) free of charge. As a signatory of the Mutual Recognition Arrangement (CIPM MRA), a Quality Management System (QMS) complying with ISO 17025 is maintained in the IAEA laboratory and dosimetry calibration and measurement capabilities (CMCs) are published in Appendix C of the CIPM MRA key comparison database (KCDB). To maintain the validity of CMCs, updated “supporting evidence” for the measuring capabilities is required periodically in addition to the traceability of the measured quantities.

An indirect (i.e. using transfer ionization chambers) comparison of the standards for absorbed dose to water and air kerma of the National Research Council of Canada (NRC) and of the IAEA was performed in the ^{60}Co radiation beam of the NRC. The measurements were carried out in June and September 2016 at the IAEA and in August 2016 at the NRC.

2. Materials and Methods

2.1 Determination of reference values

Determination of the absorbed dose to water at the NRC

The absorbed dose to water, determined at the NRC, is based upon measurements made directly in water using the primary standard sealed water calorimeter. This is a Domen type water calorimeter [1] with modifications as described by Seuntjens *et al* [2] and was the basis for the NRC key comparisons with the Bureau International des Poids et Mesures (BIPM) in Co-60 [3]. The measured absorbed dose to water rate was around 0.75 Gy/min.

Determination of the air kerma rate at the NRC

The air kerma standard of the NRC for ^{60}Co is a graphite-walled cylindrical cavity ionization chamber (designated 3C) with a volume of approximately 3 cm^3, constructed at the NRC in 1958 as described by Shortt and Ross [4]. It was used in the most recent comparison of the NRC and BIPM standards in 2009 [5]. The measured air kerma rate was around 0.84 Gy/min.

Determination of the absorbed dose to water at the IAEA

At the IAEA a secondary standard ionization chamber NE2611 calibrated at the BIPM is used to determine the absorbed dose rate to water using the relation

$$\dot{D} = I \cdot N_{D,w,BIPM} \prod_i k_i$$

where I is the current measured with the IAEA standard, $N_{D,w,BIPM}$ is the calibration coefficient of the standard determined at the BIPM and k_i is the product of the correction factors to be applied to the measured current (pressure and temperature correction). The measured

absorbed dose to water rate was around 0.4 Gy/min. The secondary standard is periodically calibrated at the BIPM every 3 years. The most recent calibration was in October 2013.

Determination of the air kerma rate at the IAEA

At the IAEA a secondary standard ionization chamber NE2611 calibrated at the BIPM is used to determine the air-kerma rate using the relation

$$\dot{K} = I \cdot N_{K,BIPM} \prod_i k_i$$

where I is the current measured with the IAEA standard, $N_{K,BIPM}$ is the calibration coefficient of the standard determined at the BIPM and k_i is the product of the correction factors to be applied to the measured current (pressure and temperature correction). The measured air kerma rate was around 0.4 Gy/min. The secondary standard is periodically calibrated at the BIPM every 3 years, the most recent calibration being in October 2013.

2.2 Transfer chambers

The comparison was undertaken using two ionization chambers of the IAEA as transfer standards. The chambers are the FC65-G, manufactured by IBA Dosimetry and NE2571, originally manufactured by N.E. Technology[1]. The physical description of each chamber is provided in Table 1; they are thimble-type, fully guarded chambers made of graphite and they both have an aluminium central electrode.

Table 1. Physical description of the IAEA transfer chambers.

Chamber Model	Serial Number	Sensitive Volume (nominal, cm^3)	Thimble Diameter (mm)	Central Electrode Material	Chamber Voltage (V)
FC65-G	#1552	0.6	7.0	Al	300
NE2571	#3204	0.6	7.0	Al	300

The reference point of each chamber is the geometrical centre of the volume. The signal connection of each chamber is a triaxial BNC plug.

2.3 Calibration procedures

The comparison of the NRC and IAEA standards was made indirectly using the calibration coefficients $N_{D,w}$ and N_K for two transfer chambers given by

$$N_{D,w,lab} = \dot{D}_{w,lab} / I_{lab}$$

$$N_{K,lab} = \dot{K}_{lab} / I_{lab}$$

where $\dot{D}_{w,lab}$ and $\dot{K}_{lab}$ are the absorbed dose rate to water and air kerma rate at each lab, respectively, and I_{lab} is the corrected ionization current of a transfer chamber measured at the NRC or IAEA.

Positioning – absorbed dose to water

At each laboratory, the chambers were positioned with the stem perpendicular to the beam direction and with the appropriate marking on the stem (engraved lines) facing the source. A 30 cm × 30 cm × 30 cm water phantom was positioned with its front face at a distance of 1 m from the source (uncertainty parallel to the beam axis = 0.1 mm). The chambers were set in the centre of beam (uncertainty perpendicular to the beam axis = 0.5 mm) at a water-equivalent depth of 5.3 cm (uncertainty in depth in-water = 0.1 mm). The field size was set to be 10 cm × 10 cm at the surface of the phantom.

Positioning – air kerma

At each laboratory, the chambers were positioned with the stem perpendicular to the beam direction and with the appropriate marking on the stem (engraved lines) facing the source. The chambers were set in the centre of the beam at 1 m distance from the source. The chambers were set in the centre of beam (uncertainty perpendicular to the beam axis = 0.5 mm) with the centre of the chamber at a distance of 1 m from the source (uncertainty parallel to the beam axis = 0.1 mm). The field size was set to be 10 cm × 10 cm at the reference position.

Applied voltage and polarity

At both laboratories, a collecting voltage of 300 V (both polarities) was applied to the central electrode of each chamber at least 30 min before any measurements were made. The corresponding calibration coefficients were determined for both polarities.

Volume recombination

For these chambers and applied polarizing voltages, the volume recombination is negligible at an air kerma or absorbed dose to water rate used in the two laboratories. The initial recombination loss will be the same and, consequently, no correction for recombination was applied.

Charge and leakage measurements

The charge collected by each transfer chamber was measured using a Keithley electrometer, model 6517 at the

[1] Currently manufactured by Phoenix Dosimetry Ltd.

IAEA. The source is operational during the entire exposure series and the charge is collected for the appropriate, electronically controlled, time interval. As a test of the electrometer, the charge collected was also measured at the NRC with a Keithley model 35617 electrometer. At both laboratories the chambers were pre-irradiated for at least 15 min (≈ 10 Gy).

The ionization current measured from each transfer standard was corrected for the leakage current at both the IAEA and the NRC. This correction was less than 1×10^{-4} in relative value at each laboratory.

Ambient conditions

During a series of measurements, the water temperature is measured for each chamber measurement and it was stable to better than 0.05 °C at the IAEA and 0.7 °C at the NRC. The measurements are normalized to 293.15 K and 295.15 K at the IAEA and the NRC, respectively, and normalized to 101.325 kPa at both laboratories. For the comparison, the NRC calibration coefficients were multiplied by 0.9932 to account for the difference in the reference temperature. Relative humidity is controlled at (50 ± 5) % at the IAEA and (40 ± 20) % at the NRC. Consequently, no correction for humidity is applied to the ionization current measured.

Radial non-uniformity

No correction is applied to the ionization current for the radial non-uniformity of the beam over the cross-section of the transfer chambers as the beam non-uniformity is better than 0.1 % over the central 4 cm at both laboratories.

The calibration of each chamber was repeated with repositioning several times at the IAEA before sending the chambers to the NRC. At the NRC, the calibration was carried out twice with repositioning. The calibrations were repeated again at the IAEA after the chambers returned from the NRC.

3. Comparison results

The results of the comparison, $R_{D,w}$ and R_K, are given in terms of the mean ratio of the calibration coefficients of the transfer chambers determined at the two laboratories under the same reference conditions, in which the average value of the measurements made at the IAEA is compared with the measurements made at the NRC:

$$R_{D,w} = N_{D,w,IAEA} / N_{D,w,NRC}$$
$$R_K = N_{K,IAEA} / N_{K,NRC}$$

The relevant values of $N_{D,w}$ and N_K for each chamber and the reference conditions are provided in Table 2 and Table 3, respectively. The ratios, R, are calculated using the overall mean of the measurements performed at the IAEA (before and after the measurements at the NRC) and the measurements performed at the NRC. The comparison result is calculated as the unweighted mean of the ratios calculated from the two transfer chambers at the two polarities. The comparison results are $R_{D,w}$ = (0.9997 ± 0.0066) for absorbed dose to water and R_K = (0.9963± 0.0047) for air kerma.

3.1 Uncertainties

The estimated relative uncertainties of absorbed dose rate to water and air kerma rate, the calibration coefficients of the transfer chambers and their ratio were calculated according to the ISO Guide to the Expression of Uncertainty in Measurement (GUM), using the NRC key comparison reports [3, 5] and the Tables III and IV of the appendix of the IAEA therapy level calibration certificate. The calculated uncertainty components for absorbed dose to water and air kerma are summarized in Table 4 and Table 5, respectively. The expanded relative uncertainty of the comparison result for absorbed dose to water ($R_{D,w}$) is 1.32 % and for air kerma (R_K) is 0.94 %.

Table 2. Relevant values of $N_{D,w}$ for each chamber and stated reference conditions. All $N_{D,w}$ values are expressed in mGy/nC.

Chamber	Polarity Voltage (V)	$N_{D,w,\mathrm{IAEA}}$ before NRC	$N_{D,w,\mathrm{IAEA}}$ after NRC	$N_{D,w,\mathrm{IAEA}}$ overall mean	$N_{D,w,\mathrm{NRC}}$	$R_{D,w}$
FC65-G (#1552)	+300	48.0079	48.0475	48.0277	48.0384	0.9998
	-300	47.9287	47.9607	47.9447	48.0018	0.9988
NE2571 (#3204)	+300	45.2159	45.2404	45.2282	45.2258	1.0001
	-300	45.1561	45.1753	45.1657	45.1571	1.0002
Average						**0.9997**

Table 3. Relevant values of N_K for each chamber and stated reference conditions. All N_K values are expressed in mGy/nC.

Chamber	Polarity Voltage (V)	$N_{K,\mathrm{IAEA}}$ before NRC	$N_{K,\mathrm{IAEA}}$ after NRC	$N_{K,\mathrm{IAEA}}$ overall mean	$N_{K,\mathrm{NRC}}$	R_K
FC65-G (#1552)	+300	44.0340	44.0407	44.0374	44.2064	0.9962
	-300	43.9901	43.9996	43.9949	44.1667	0.9961
NE2571 (#3204)	+300	41.4610	41.4830	41.4720	41.6182	0.9965
	-300	41.4493	41.4144	41.4319	41.5743	0.9966
Average						**0.9963**

Table 4. Estimated relative standard uncertainties of the calibration coefficient $N_{D,w,lab}$, of the transfer chambers and of the comparison result, $R_{D,w}$

Relative Standard Uncertainty	**NRC**		**IAEA**	
	100 s_i	**100 u_i**	**100 s_i**	**100 u_i**
Absorbed dose rate to water	0.21	0.35	0.06	0.40
Ionization current of transfer chamber	0.03	0.07	0.05	0.20
Distance	-	-	-	-
Depth in water	-	0.02		0.02
Correction *T*,*P*	0.05	0.10	0.03	0.10
$\boldsymbol{N_{D,w,\mathrm{lab}}}$				
Quadratic summation	0.22	0.37	0.08	0.47
Combined uncertainty	0.43		0.50	
$\boldsymbol{R_{D,w}}$				
Stability of transfer chamber	0.04			
Dependence on transfer chamber type	0.06			
Relative standard uncertainty	0.66			
Expanded uncertainty (k = 2)	1.32			

Table 5. Estimated relative standard uncertainties of the calibration coefficient $N_{K,lab}$, of the transfer chambers and of the comparison result, R_K

Relative Standard Uncertainty	**NRC**		**IAEA**	
	100 s_i	**100 u_i**	**100 s_i**	**100 u_i**
Air kerma rate	0.07	0.27	0.09	0.32
Ionization current of transfer chamber	0.03	0.07	0.05	0.20
Distance	0.02	0.02		0.01
Correction *T*,*P*	0.05	0.10	0.03	0.10
$\boldsymbol{N_{K,\mathrm{lab}}}$				
Quadratic summation	0.10	0.30	0.08	0.39
Combined uncertainty	0.32		0.40	
$\boldsymbol{R_K}$				
[1]Stability of transfer chamber	0.03			
Dependence on transfer chamber type	0.03			
Quadratic summation	0.53			
[2]Relative standard uncertainty	0.47			
Expanded uncertainty (k = 2)	0.94			

[1] Stability of the transfer chambers during the comparison period was estimated with the standard deviation of the mean of all measurement performed at the IAEA.

[2] Taking into account the correlated uncertainty components (physical constants and air humidity) of the BIPM primary air kerma standard, where the IAEA secondary standard is traceable, and NRC primary standards [5]

4. Conclusion

An indirect comparison of the standards for absorbed dose to water and air kerma of the NRC and of the IAEA was carried out in the ^{60}Co radiation beam of the NRC in August 2016. The comparison results were calculated based on the calibration coefficients for two transfer standards and expressed as the ratio of the IAEA and the NRC standards. The comparison result for absorbed dose to water was 0.9997 with a combined relative standard uncertainty of 0.0066. The comparison result for air kerma was 0.9963 with a combined relative standard uncertainty of 0.0047. These results support the IAEA CMCs in the KCDB for air kerma and absorbed dose to water of Co-60 radiation having 0.8% and 1% expanded uncertainties.

Both results are consistent with the existing IAEA Degree of Equivalence (DoE) values. (K_{IAEA}/K_{BIPM} = 0.9984, u_c = 0.0034 and D_{IAEA}/D_{BIPM} = 0.9978, u_c = 0.0038) taking into account the NRC DoE values (K_{NRC}/K_{BIPM} = 1.0032, u_c = 0.028 and D_{NRC}/D_{BIPM} 0.9980, u_c =0.0052) available in the Key Comparison Data Base.

5. References

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Setting up a Dosimetry Audit Centre: Infrastructure and Resources

Report of a Consultants' Meeting 28 November – 2 December 2016, IAEA, Vienna

Joanna Izewska, Dosimetry and Medical Radiation Physics Section, IAEA

***Consultants*:** David Followill (USA), Costas Hourdakis (Greece), Petri Sipilä (Finland), Ivan Williams (Australia)

Scientific Secretary: Joanna Izewska (IAEA)

1. Introduction

It is estimated that at most only 2/3 of radiotherapy facilities world-wide have participated in some level of dose quality audit [1] by an independent dosimetry audit centre (DAC). Some, or even many, facilities not involved in external quality programmes may deliver inferior radiotherapy treatment due to inadequate dosimetry practices. One of the greatest risks for a patient undergoing radiotherapy treatment is that inaccurate dose delivery has implications for tumour control, treatment morbidity and toxicity impacting upon patient survival and quality of life in the immediate and longer terms [2]. The primary objective of an external quality audit programme as administered by a DAC is to ensure the accurate dose delivery to radiotherapy patients. Variation between the dose prescribed to that delivered can have direct impact on the treatment outcomes. It is recognized internationally [3-4] that an effective quality management programme involve an independent dose assessment. An ongoing quality audit programme enables measurements to be repeated over time, providing added assurance that local radiotherapy centres maintain accurate and stable dosimetric conditions. Every radiotherapy centre should have access to an independent dosimetry audit, thus the need to have a guidance document to establish a DAC.

2. Aims of a Dosimetry Audit Centre

The aims of a DAC are to perform radiotherapy dosimetry audits, to ensure quality radiotherapy treatments to patients at local radiotherapy centres by increasing the accuracy and reducing uncertainty in the dosimetry of clinical radiotherapy beams, and to improve patient safety. Accomplishing these aims will increase the likelihood of detecting any patient dose delivery errors.

To gain wide acceptance and full collaboration from the local radiotherapy centres, it is essential that a DAC obtain the approval and endorsement by the national radiation oncology and medical physics community. DACs should also be recognized to provide dosimetry audits in radiotherapy by the national competent authority or other relevant governmental body (e.g. Ministry of Health). With the endorsement from such organizations, it is essential that funding be made available that will ensure that the audit activities are sustained and proper resources are allocated to support this audit programme.

3. DAC Infrastructure

A Dosimetry Audit Centre exists within a Dosimetry Audit Network (DAN) which consists of several components. These components include the local radiotherapy centres to be audited, a Clinical Medical Physics Group (MPG), a Measuring Centre (MC), and the Standards Dosimetry Laboratory (SSDL or, in some instances, PSDL). Depending on the existing national quality audit resources/facilities, the relationship with an SSDL, and country-specific conditions, the DAC infrastructure within a DAN can be organized into one of the two structures shown in Figure 1.

The first type of a possible DAC structure (Figure 1a) includes the SSDL as a primary component of the DAC where the MC is located. Additionally, a close relationship with a clinical MPG exists. The alternate structure is shown in Figure 1b. In this structure, the primary component of the DAC is composed of the MPG, and the MC is co-located within the same organization. In this second structure, the DAC must have a close collaboration with a standards dosimetry laboratory. Regardless of the DAC structure within a DAN (see Figure 1a and b), a DAC is to have connections to radiation oncologists of other DACs

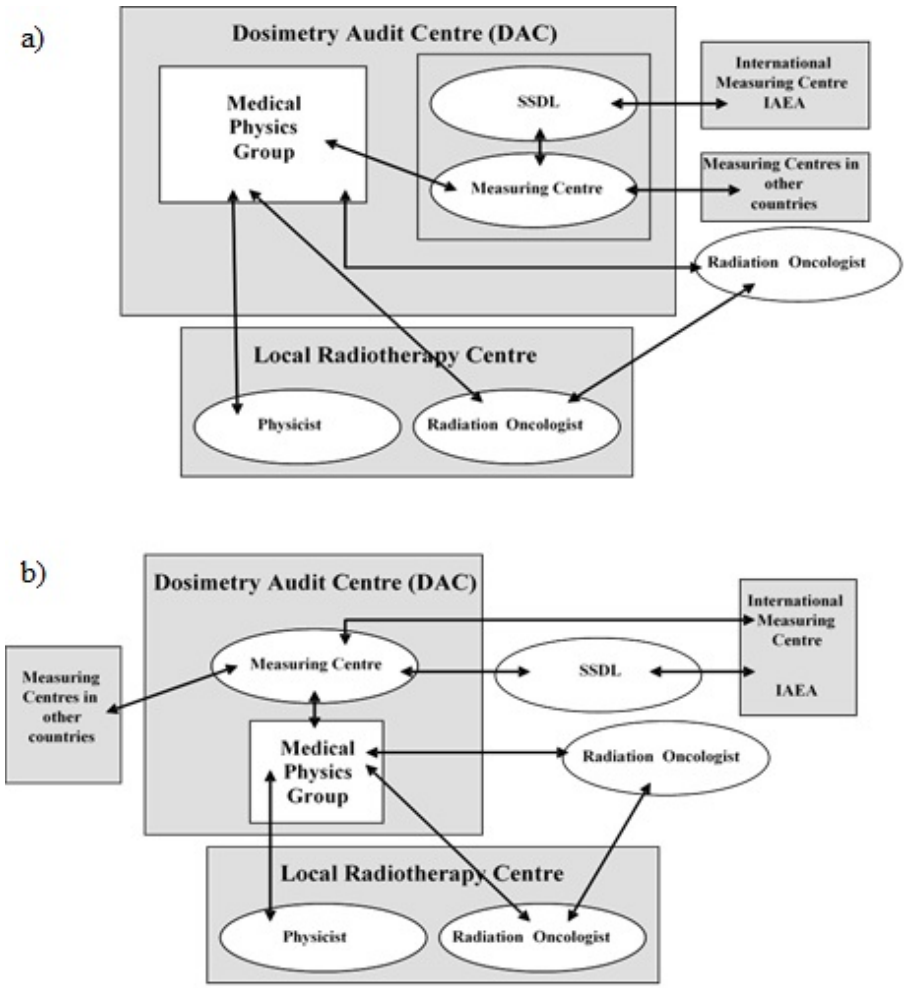

Figure 1. Examples of the two DAC organizational structures a) and b) within a DAN

and local radiotherapy centres. Each of the DAN components is defined below.

a) The clinical Medical Physics Group (MPG) should be formed by one or several medical physicists with extensive experience in clinical dosimetry from working in a radiotherapy department.

b) The Measuring Centre (MC) is responsible for providing reliable and accurate measurements that are traceable to primary standards using the up-to-date codes of practice for photon and electron dosimetry, implementing specific audits, maintaining the dosimetry equipment used for remote and on-site audits, and exchanging information with other DAN groups. The MC can be a part of the SSDL, affiliated with the SSDL, or a part of the clinical MPG at a radiotherapy department.

c) The Standards Dosimetry Laboratory (SSDL or, in some instances, PSDL), may or may not be a part of the DAC. It provides traceability to primary dose standards and interacts with other SSDLs, International Measuring Centres, and in particular with the IAEA. A close collaboration and cooperation between the SSDL and other DAN groups is an essential prerequisite for the successful operation of a DAC and the implementation of the dosimetry audits.

d) The Local Radiotherapy Centre (LC) within a DAN can be any medical radiotherapy centre where a radiotherapy treatment unit is used for clinical practice.

e) The Clinical Advisory Group (CAG) is comprised of members of the radiotherapy community (radiation oncologists, medical physicists, etc.) with the purpose of providing advice to the DAC in terms of development and execution of the audit programme and clinical impacts of audits. At the discretion of the DAC director and upon request by the LC, a radiation

oncologist member of the CAG may be asked to interact with the LC.

The detailed structure of the DAC (MPG, MC and SSDL) shall be described in the DAC Quality Manual with corresponding organisational flow charts. The interaction between the members shall be clearly stated. In addition, it is warranted that the DAC develop a national DAN database that includes demographic information on radiotherapy centres including treatment equipment and beams to be audited. Audit results and some clinical data, as needed, should be included. The DAN infrastructure database should be continuously updated by the DAC. By tracking the trends in the database, reasonable predictions on the evolution of the radiotherapy infrastructure and dosimetry audit programme can be made in order to ensure that future needs are met accordingly.

The roles and responsibilities of each DAC staff member should be clearly defined within the DAC Quality Manual. The position of each staff member and the relations between the individuals should be indicated in the organizational chart of the DAC. It is critical that the senior leadership of the DAC not only have the appropriate training and experience, but that they have demonstrable managerial and communication skills to interact with the local radiotherapy centres. Examples of DAC staff are given below; they may include but not be limited to the positions and responsibilities listed below.

a) DAC Director (Chief Medical Physicist, PhD), typically a senior level medical physicist, is responsible for the internal organisation and operation of the DAC; interacts with external organizations and CAG; manages and supervises DAC operations, etc.
b) Medical Physicist(s), with experience in clinical dosimetry, is (are) responsible for audit developments, analysis of results, interactions with LC physicists, resolution of discrepancies, etc.
c) Scientific and technical staff (e.g. physicists, dosimetrists, engineer, IT support, etc.) is responsible for the maintenance of the dosimetry systems, implementation of audits, dosimeter readouts and analyses, audit database, and IT support, etc.
d) Administrative staff is responsible for audit logistics, mailing dosimetry audit equipment and documents, and any other administrative activities as needed for DAC operations.

4. DAC development and operations

The tasks listed below and shown in Table 1 need to be performed during the initial starting up of the DAC, developing an audit, and during day to day operation of the DAC. The relative amount of effort by DAC staff required for each task is also presented in Table 1. This list of tasks is not exhaustive and should be adapted to the specific situation in each DAN.

4.1 Audit development

Audit development includes all the tasks required to consider, consult, review, design, model, test, pilot test, and develop an audit to its initial clinical implementation. Each individual audit level should fit within the scope of the DAC as defined in its Quality Manual.

Table 1. Tasks required for establishing and maintaining a DAC: Start-up (S), Developing (D) and Operational (O) Phases

Tasks	L0	LI		LII		LIII		LIV	
	S	D	O	D	O	D	O	D	O
Recruitment	✓✓✓	✓	✓	✓	✓	✓	✓		
Audit on-going improvement		✓✓	✓	✓	✓	✓	✓		
Audit development	✓✓	✓✓✓	✓	✓	✓✓	✓	✓✓		✓
Administrative tasks	✓✓	✓	✓	✓	✓	✓	✓	✓	✓
Training	✓	✓✓	✓	✓	✓	✓	✓		✓
Logistics	✓✓✓	✓		✓		✓			✓
Equipment purchase & commissioning	✓✓	✓✓✓		✓	✓✓	✓	✓✓		
Audit		✓✓✓	✓✓	✓	✓✓	✓	✓✓		✓
Audit follow-up		✓	✓✓	✓	✓✓	✓	✓✓		

L0 Development of DAC infrastructure.
LI Audit of beam output in reference conditions.
LII Audit of beam parameters in non-reference conditions.
LIII Audit of beam parameters for complex treatment modalities.
LIV End-to-end audit for advanced dose delivery techniques.

Consultation with the CAG during the development phase is important to ensure that the audits are relevant to clinical demand of the local radiotherapy centres. Additionally, this interaction with the CAG will assist engagement with professional societies.

Audit development is an iterative process with feedback between all component parts. As the first part of the

process, the audit's role and its impact on improving the quality and safety of patient treatments must be identified and defined. In developing each audit level, dosimetry equipment and QA tools suitable for the audit aims, logistical overhead requirements, expertise, and training requirements should be considered.

4.2 Audit on-going improvement

On-going improvement begins as soon as an audit is clinically implemented and the audit results are reported to the local radiotherapy centre. Improvement will be driven by internal and external inputs. External inputs will include feedback from audited centres and the CAG, and informal feedback during audits. These inputs may result from misunderstandings of the documentation, time requirements to perform an audit and potential requests for audit modifications.

Internal and external efficiency drivers will encourage DAC staff to assign efforts appropriately to develop the next audit level while maintaining daily DAC tasks required for implementing audits. This effort allocation will require on-going oversight. An important part of the on-going improvement programme is likely to be automation of internal processes. The software, ideally, will be developed to ensure a consistency of internal process for all audits and to reduce manual data entry.

4.3 Training

The DAC will ensure that it has enough trained staff to implement the planned audit schedule. The DAC will maintain a training register listing each staff member and the level to which they are trained for each component of each audit. Examples can be seen in the ISO 17025 standard [5]. The staff register is used for ensuring that the staff members assigned to specific audits are competent to perform the audit.

4.4 Logistics

Logistics encompasses communication with the audited local radiotherapy centres prior, during and post audit to ensure that the local radiotherapy centre equipment, personnel, address, agreement to audit, and all other pertinent details have been collected by the DAC. The logistics team within the DAC is also responsible for any packaging, shipping and receiving of all audit equipment and documentation. The logistics team, if appropriately trained, may also participate in the readout of the passive dosimeters returned from audits.

Logistics also encompasses any overarching software (e.g. database) and IT support which stores the radiotherapy centre demographic information, audit measurements and audit reports in a structured manner. It is recommended that databases containing this information set be developed during the DAC start-up phase.

4.5 Equipment

The primary equipment needs of a DAC include the dosimeters, readout devices and dedicated software used to perform audits. Potential level specific dosimetry equipment sets are listed in Table 2 for each audit level.

4.6 Audits

An audit is defined as the dosimetry measurement performed by the DAC at a local radiotherapy centre. There are up to four different audit levels proposed within this guidance document, each requiring significant effort by the DAC staff.

4.7 Audit follow-up

After the audit results have been formally reported to the participating local radiotherapy centre, follow-up communication may be required to resolve discrepancies or other unresolved issues.

An audit whose result is not within the acceptance limits must be investigated and brought to the DAC Director's attention as soon as the result has been finalized. The Director and the audit team will review the audit and attempt to identify the reason for the discrepancy. The Director may communicate with the CAG for expert advice on clinical implications and/or assistance with determining the reason for the discrepancy.

4.8 Staff recruitment

In the start-up phase of a DAC, one of the most important tasks for the Director to accomplish is to ensure that the DAC has the appropriate staffing complement capable of implementing a comprehensive quality audit programme within budgetary constraints. Recruiting expert medical physicists may require advertising and a considerable amount of time to complete.

5. DAC audits and required resources

There are currently two different methods used by DACs to audit local radiotherapy centres: remote and on-site audits. A remote audit is defined as the process of providing specific dosimetry audit tools to a local radiotherapy centre to collect dosimetry data and assess the centre's accuracy in delivering a radiation dose, all without the need for DAC to be physically present at the centre. Conversely, the on-site audit consists of auditing a centre's radiation dosimetry

accuracy by DAC staff physically travelling to the local radiotherapy centre with dosimetry equipment and audit tools to perform the audit. A DAC may employ both types of audits depending on the audit level it implements. Regardless of the type of audit used, both will result in a report to the local radiotherapy centre detailing the results of the audit.

This guidance document identifies a minimum of two audit levels and potentially up to a total of five audit levels that a DAC can implement within the DAN. The audit levels increase in complexity and should be implemented in the order of increasing complexity from level 0 to level 4 without skipping any of the steps. It is acknowledged that if a DAC has the appropriate resources and funding, it may develop multiple audit levels at the same time. The following list briefly describes each audit level.

Level 0: This level includes the time and effort required to receive the endorsement of the sponsoring organization, identify and recruit the DAC Director (a senior level medical physicist). The Director will then begin the recruitment of additional DAC staff to assist in the development of the desired initial audits to be implemented by the DAC.

Level 1: This audit level includes the verification of the megavoltage photon and electron beam output under reference conditions for clinical radiotherapy machines at local radiotherapy centres.

Level 2: This audit level includes the verification of the megavoltage photon and electron beam's relative dosimetry parameters under non-reference conditions, on- and off-central axis for clinical radiotherapy machines at local radiotherapy centres.

Level 3: This audit level includes the verification of individual dosimetry parameters within advanced treatment modality paths by comparing treatment planning system calculations with DAC measurements.

Level 4: This audit level includes the verification of advanced treatment modalities, for example intensity modulated radiation therapy (IMRT), stereotactic radiosurgery (SRS) and stereotactic body radiation therapy (SBRT), using an end-to-end anthropomorphic phantom that approximates patient treatment, including targets, organs at risk and heterogeneities.

The implementation of any of the audit levels described above and using the dosimetry resources shown in Table 2 require that the DAC have appropriate funding, resources, and personnel who have been trained to conduct the audits to achieve a high level of accuracy with minimal achievable uncertainty.

Table 2. Potential dosimetry equipment for each audit level for remote (R) and on-site (O) audits.

Applicable dosimetry Equipment	Level 1 Ref. condi-tions		Level 2 Non-ref. condi-tions		Level 3 Complex		Level 4 Ad-vanced	
	R	O	R	O	R	O	R	O
Dosimeters*								
TLD	✓	✓	✓	✓	✓	✓	✓	✓
OSLD	✓	✓	✓	✓	✓	✓	✓	✓
RPLD	✓	✓	✓	✓	✓	✓	✓	✓
Alanine	✓	✓	✓	✓	✓	✓	✓	✓
Ion chamber	✓	✓	✓	✓	✓	✓	✓	✓
Film			✓	✓	✓	✓	✓	✓
Diode			✓	✓	✓	✓	✓	✓
2D array				✓	✓	✓		✓
3D array				✓	✓	✓		✓
3D dosimetry (gel)							✓	✓
Phantoms								
Water	✓	✓	✓	✓	✓	✓		
Geometric /solid	✓	✓	✓	✓	✓	✓		
Semi-anthropomor-phic or anthropomor-phic					✓	✓	✓	✓

* require appropriate dosimeter readout device

Audit level 0: Engaging professional societies and stakeholders to support the DAC, development of the DAC infrastructure, and recruitment of the DAC Director and staff.

Level 0 refers to the period of time and activities that ensure that the key local stakeholders are positively engaged to endorse the development of a DAC, i.e. the point at which the authority for the DAC is given, and the initial engagement of the Director and funding is secured. These key stakeholders may include, for example, governmental bodies (health, regulatory, etc.), professional societies (radiation oncology, medical physics, etc.), hospital administration, patient advocacy groups, etc.

Once the DAC Director is selected and recruited, the Director must continue the engagement with the professional societies to request nominees to form the CAG. The CAG should consist of experienced clinical radiotherapy representatives nominated by the professional societies. The CAG main task is to advise the Director, upon request, on audit development plans, documentation, and clinical requirements to perform the planned audits.

During this start-up phase of the DAC, the Director will plan the audit development and auditing schedule for the first few years' operations, develop risk assessment and contingency plans, and engage in a hiring process required to staff the DAC appropriately.

Audit level 1: Verification of megavoltage photon and electron beam outputs under reference conditions for clinical radiotherapy machines.

One of the IAEA recommendations is that all therapy beam outputs under reference conditions should be verified on a regular basis. Historically, this specific audit has been the most common audit offered by established DACs. The IAEA/WHO, the Imaging and Radiation Oncology Core Houston QA Centre (IROC H; formerly the Radiological Physics Centre) [6] and Radiation Dosimetry Services (RDS), Houston, USA, are examples of DACs that have offered level 1 audits annually to more than 3000 radiotherapy centres worldwide for over 40 years. The primary remote audit passive dosimeters currently in use are thermoluminescence dosimeters (TLD), optically stimulated luminescence dosimeters (OSLD) and radiophotoluminescence dosimeters (RPLD).

Verification of the beam output can also be accomplished during on-site audits using ion chamber/electrometer dosimetry or passive dosimetry systems. The preferable ion chambers used for photon and electron beam calibrations are of a 0.6 cc Farmer type and/or parallel plate ion chambers, respectively, as indicated in the code of practice used. There is a variety of waterproof chamber models and electrometer models by different manufacturers to choose from. On-site audits of photon and electron beam outputs under reference conditions using ion chambers should follow the recommendations detailed in the $N_{D,w}$ based codes of practice, such as IAEA's TRS 398 [7] or the AAPM's TG-51 [8].

Regardless of the specific dosimeter to be used in the audits, they all require commissioning by properly trained medical physicists to ensure that they yield accurate audit results with minimum achievable uncertainty. Networking and collaboration with current active DACs utilizing the desired passive dosimeter or ion chamber dosimetry system provide an excellent opportunity to gain the required training and methodologies to perform this specific level 1 audit. In addition to the DAC Medical Physicist, other DAC personnel such as technicians, dosimetrists, etc., may be employed to perform certain components of this audit. Software should be developed to calculate the dose from the dosimeter readings, to assist in the logistics of packaging, shipping and receiving of the dosimeters, and for reporting and archiving the results. This software should include capacity to track the characteristics of ion chambers or passive dosimetry systems. The number of staff required to implement this level 1 remote audit depends on the number of radiotherapy centres/machines/megavoltage beams to be audited and on any national/regional circumstances that might influence the radiotherapy centres' access to this audit.

The following list specifies the equipment, the consumables and the services that may be required for the DAC to implement the level 1 audit:

1. Passive dosimeters
2. Readout device
3. Precision balance if using TLD
4. Bar code reader if using OSLD or RPLD
5. Nitrogen gas cylinders if using TLD
6. Computer with dedicated software connected to readout device
7. UV light annealing cabinet and wavelength specific light fixtures for OSLD
8. Annealing oven for TLD and RPLD and a sieving system for TLD powder
9. Dosimeter mini-phantoms or holders for dosimeter irradiations
10. Water phantom with ion chamber positioning device
11. SSDL calibrated ion chambers and electrometers, cables, connectors
12. Calibrated barometers and thermometers
13. Shipping containers for passive dosimeter audit devices
14. Miscellaneous shipping materials (tape, bubble wrap, etc.)
15. On-site dosimetry system transport container if this audit technique is used
16. Miscellaneous dosimeter handling tools
17. Reader planchettes if using TLD readers
18. Computer, printer, office supplies, etc.
19. Shipping, travel and postal costs
20. Personnel radiation monitoring services.

The implementation of level 1 remote and on-site audits also requires that the DAC have access to a ^{60}Co unit with calibration traceability to a primary radiation dose standard for irradiation of reference and control dosimeters as well as a linear accelerator with multiple photon and electron energies for dosimeter commissioning purposes. The ^{60}Co unit can be used to verify the stability of the on-site dosimetry system prior to and after conducting the on-site audit trip. A calibrated barometer and thermometer should be available to verify the on-site visit barometer and thermometer devices prior to each trip.

Audit level 2: Verification of megavoltage photon and electron beam relative dosimetry parameters under non-reference conditions on the central beam axis and off-axis for clinical radiotherapy machines.

Generally the same equipment used for level 1 can be used also for level 2. Appropriate size phantoms are required for this audit to accommodate level 2 audit beam geometries. During on-site visits a water phantom with manual or automatic movements of the ion chamber with 2D or 3D motion will ease and hasten the measurement process.

Verification of the beam outputs in non-reference conditions can also be accomplished using passive dosimeter systems or ion chamber/electrometer dosimetry systems. The preferable ion chamber used for photon beam audits is a 0.6 cc Farmer type chamber. Ideally, a parallel plate ion chamber is used for electron beam audits when the field size is greater than 5 × 5 cm^2. For smaller field sizes a suitable small volume ion chamber can be used. There is a variety of waterproof chamber models and electrometer models by different manufacturers to choose from.

The level 2 audit measurement schedule at the local radiotherapy centre should reflect the time required to perform the audit measurements. The schedule should verify the dosimetry for all photon and selected electron energies used clinically at the local radiotherapy centre as agreed between DAC and the local centre. An example of level 2 audit dosimetry parameters to be verified can include multiple field sizes at different depths, including symmetric, asymmetric, and MLC shaped beams, wedged beams, various off-axis distances at isocentric and fixed SSD conditions. Additional mechanical checks can be performed to verify the treatment machine integrity.

As stated in the description of level 1 audit, all dosimetry equipment require commissioning to ensure that they yield accurate audit results with minimum achievable uncertainty. The effort required to implement this level 2 audit will be greater than that of level 1 audit.

All of the remote and on-site dosimetry equipment, consumables and services listed above in level 1 audit may also be required for a level 2 audit. Additionally, the DAC may need the following equipment, consumables and services to implement level 2 audits:

1. Appropriate sized water phantom with chamber positioning device, holders for passive dosimeters and/or appropriate solid phantom
2. Film dosimeters
3. Film densitometer/scanner
4. 2D array including cable extensions
5. Diodes
6. Small volume ion chambers
7. Hardware and software for operating the dosimetry systems above.

Audit level 3: Verification of dosimetry parameters by comparing treatment planning system calculations with DAC measurements.

This audit level includes a verification of dosimetry parameters that may be included in simple or complex treatment deliveries. This verification may be performed using a geometric/rectilinear phantom or possibly an anthropomorphic phantom. A level 3 audit will require the dose calculations of the local radiotherapy centre treatment planning system to be compared with audit measurements. Some audits may require the use of CT imaging of phantoms. Additional audits at this level may require 1D and/or 2D dose distribution audit measurements such as needed for picket fence tests using arrays or film to assess multi-leaf collimator performance.

Level 3 auditing is recommended by the IAEA [9] and other organizations to be performed at a local radiotherapy centre for an entirely new clinical department and at regular intervals.

Level 3 audits are presently offered by the most developed DANs, examples being the IROC Houston QA Centre and the Australian Clinical Dosimetry Service (ACDS) which both provide on-site level 3 auditing [10]. The IAEA developed and tested the methodology for the remote and on-site level 3 auditing which is in use by several national dosimetry audit networks [9].

Level 3 auditing is complex and should only be implemented when the level 1 and level 2 audits are mature and stable processes. Level 3 audits should be developed

with the support and engagement of the CAG. The DAC should review existing level 3 audit designs and identify which audit components are most relevant to the existing and proposed clinical practices within the DAN. The set of clinical test cases may cover a range of tests of individual dosimetry parameters including, for example, small field dosimetry, picket fence tests, or similar. Mature level 3 audits may include static gantry IMRT irradiations analysed in a single plane. Audit development will require initial trial runs within the local DAN, ideally at different local radiotherapy centres with the different planning system/linac combinations. The CAG should be engaged to review the trial audit outcomes and to provide advice on possible improvements.

As for all other audit levels, the equipment used for level 3 audits requires trained personnel to use it and maintain. Advice on equipment solutions is summarized in Table 2. The following list includes examples of specific additional equipment (beyond level 1-2 audits) that the DAC may require to implement level 3 audits:

1. Rectilinear or anthropomorphic phantom within inserts to accept the detector(s) of choice. The rectilinear phantom may include the option to include sloped or curved surfaces and heterogeneities.
2. Transport cases with shaped foam packing to protect the equipment.

Audit level 4: Verification of advanced treatment modalities using an end-to-end anthropomorphic QA phantom.

There is an ongoing substantial increase worldwide in the number of radiotherapy machines capable of delivering advanced treatment. These machines can deliver complex beam arrangements such as, but not limited to, those required for IMRT including volumetric arc therapy (VMAT), SRS, and SBRT. It is essential that radiotherapy centres understand these advanced treatment techniques and implement a quality assurance programme to provide accurate treatment and to avoid harming patients. A key component to the QA programme for these advanced treatment modalities should include an independent end-to-end audit. These advanced technologies typically consist of many inter-dependent processes that span from imaging of a patient to treatment planning, and to final dose delivery. The level 4 audit relies on a methodology that verifies whether the components from imaging to treatment delivery produce the prescribed radiation dose and whether this dose is delivered accurately to the intended spatial location.

Currently there are several DANs that offer level 4 audits either as a remote and/or on-site audit. For example, IROC H has been providing independent remote and on-site QA dosimetry audits for complex IMRT, SRS, and SBRT treatments since 2001 [11]. The IAEA has also developed end-to-end IMRT/VMAT audit methodologies for both remote and on-site audits.

Some DANs implement audits of this level remotely, but other DANs, including the RTTQA (UK) and ACDS (Australia), currently perform their level 4 audits using a lung phantom as a part of their on-site audits. Regardless of whether this level 4 audit is implemented as a remote or on-site audit, they both achieve the same result of verifying the complete advanced treatment process.

Implementing level 4 audits is resource intensive, both for the DAC and the local radiotherapy centre being audited. The DAC personnel must have the resources, training and expertise gained from audit levels 1-3 to analyse the results of a level 4 audit accurately since the anthropomorphic phantoms contain dosimeters to measure the dose and 2D or 3D dosimeters to measure dose distributions. In addition, the DAC staff must have a comprehensive understanding of the advanced treatment process to be audited.

This specific audit requires that the medical physicists at the local radiotherapy centre treat the phantom the same way as an actual radiotherapy patient is treated with curative intent. This will require preparation of the phantom, CT simulation of the phantom, development of a treatment plan according to the provided audit instructions, set up on the treatment machine, and delivery of the dose to the anthropomorphic phantom. Depending on the complexity of the treatment modality and skill of the local radiotherapy centre staff, a level 4 audit may require on average 1-2 days of effort from several members of the centre's staff to finish the audit and to return the phantom to the DAC.

This guidance document focuses on audits for SRS, IMRT/VMAT and SBRT advanced treatment processes. Image Guided Radiation Therapy (IGRT) treatment process audits are not addressed in this document.

Each DAC should consider the following guidelines when acquiring equipment to perform a level 4 audit.

- Anthropomorphic phantoms can be purchased from commercial vendors or custom built. The total number of phantoms needed to perform the audit should be considered when deciding whether to purchase or build phantoms. To build customized

phantoms much effort needs to be invested in designing and creating the phantom using a skilled machinist, identifying tissue equivalent materials, as well as in dosimeter placement and in commissioning the phantom. For some DACs, purchasing commercial phantoms will be a more appropriate solution.

- The phantoms can hold different dosimeters such as TLD, RPLD, alanine or ion chambers. OSLDs are not considered optimal dosimeters due to their directional dependence. Radiochromic film is primarily used currently to measure dose distributions. The use of Polymer gel or PRESSAGE 3D dosimeters in phantoms is currently under investigation, but has not yet been widely accepted. Care should be exercised when using an ion chamber since some treatment fields may be very small, thus requiring adequate dosimeters recommended for small beam dosimetry.
- After each audit is performed and the anthropomorphic phantom is returned to the DAC, the phantom integrity should be assessed by inspection prior to shipping it to the next local radiotherapy centre to be audited. If it does not meet the DAC's specifications for integrity and functionality, then the phantom should be repaired or replaced before being shipped again.
- Phantom anatomy decisions should made based on what the DAC believes is the most relevant clinical treatment site for each advanced treatment process to be audited. Advice by CAG will be useful. SRS treatments typically require a head phantom with targets in the brain. IMRT treatments can be delivered to many different anatomic sites, but the head seems to be the most challenging site due to the proximity of organs at risk to the target. This requires a large amount of beam modulation. SBRT treatments can also be delivered to multiple anatomic sites, but a lung phantom can provide an assessment of the dose delivery in a heterogeneous tissue.
- Dosimeter readout and analysis will be the same regardless of the advanced treatment process audited and the resources to perform this have been listed in level 1-3 audits above. Gamma analysis software should be available to perform a comparison of the measured dose distributions with the radiotherapy centre's treatment plan data. If the DAC chooses to develop its own gamma analysis software, this requires programming effort, rigorous tests and effort to benchmark its results with a more established gamma analysis software product.
- Since level 4 audits include CT simulation and dose delivery, there is the possibility that each phantom will receive additional imaging dose that can affect the results of the audit. The DAC medical physicists must have an understanding of CT simulations and on-board imaging devices to ascertain whether the imaging dose will add to the therapeutic dose to affect the results.

Specific additional equipment/resources to implement level 4 audits beyond what is required to implement level 1-3 audits include the following:

1. Anthropomorphic phantoms (purchased or custom built)
2. Shipping cases for the phantoms
3. Miscellaneous shipping materials
4. Machinist effort to repair phantoms and shipping cases
5. Commercial gamma analysis software

A level 4 audit should be performed when a specific advanced treatment process has been commissioned and before the first patient is treated using that treatment process. The results of this audit will provide assurance to the local radiotherapy centre that the new advanced treatment process will deliver a safe and accurate therapeutic dose. Level 4 audits may also be conducted upon request from the local radiotherapy centre, in particular when the treatment procedures have been modified significantly.

If the level 4 audit results do indicate a disagreement between the measurements and the treatment planning system calculations, the task to identify the cause of the disagreement can consume a great deal of effort as there can be many reasons for the poor result. Resolution of any disagreement will require a collaborative effort between the DAC and the local radiotherapy centre.

6. Summary

This document provides a summary of the infrastructure, equipment and resources required to plan a Dosimetry Audit Centre. A DAC can only exist within a Dosimetry Audit Network and thus requires a strong positive engagement with the local radiation oncology and medical physics societies as well as with national authorities and government bodies. These organizations are needed to

support the DAC to ensure secured funding for its operations. Without the secured funding, the DAC cannot exist.

Engaging the right selection of staff for the DAC is vitally important to its success. The Director should be experienced in both medical physics and management. The DAC staff will require expert skills in medical physics as well as human interaction abilities. Indicative equipment lists have been provided for each audit level to guide DACs on resource planning.

When funding is secured and the audits are clinically implemented, the indicator of true success of the DAC is the acceptance by the local radiotherapy centres as they realize the benefits of the independent dosimetry audit programme. It is essential that the centres understand the consequences of the observed discrepancies and how they affect the treatment of patients. The Clinical Advisory Group may be required to explain any important changes in dosimetry practices to the local radiation oncologists, particularly if these changes may have a significant impact on the clinical outcome of patient radiation treatment.

The on-going success of an established DAC will rely upon continually improving the initial audit programme and developing higher level audits, in response to requests by the DAN members. Such audits may be developed by reviewing the most recent audit advances, discussing with CAG and/or consulting DACs in other countries.

Importantly, the Dosimetry Audit Network programme should always focus on developing and maintaining audit techniques to verify that radiotherapy patient dose delivery is accurate and safe.

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Guide on Establishing an SSDL

Report of Consultants' Meeting
December 5 -9, 2016, IAEA, Vienna, Austria

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Establishing a Secondary Standards Dosimetry Laboratory (SSDL) is a challenging process and requires very specific type of expertise. IAEA's technical cooperation programme offers the Member States assistance and guidance in establishing and upgrading their SSDLs. Some of the information about establishing an SSDL can be found in various IAEA publications, but so far a comprehensive guide has not been available. The lack of an all-encompassing document has acted as the main motivation for writing a detailed guide on establishing an SSDL. This was also a recommendation (R4) of the 17th SSC (SSDL Newsletter No. 65.).

This new publication will provide Member States with information about planning, establishing and upgrading their SSDLs as well as about the requirements for an SSDL. First and foremost, it presents a detailed overview of the process of establishing an SSDL. It is a concise guide for both decision makers and technical staff. In addition to the useful information about the costs and the time frame, which can be used for estimating the SSDL project budget and schedule, it also contains comprehensive technical information about the requirements related to the structure of the facilities and to equipment. The guide can be used for training new SSDL staff members and as supporting documentation for the technical assistance provided by the IAEA.

All of the invited consultants have a long experience in SSDL work and in establishing SSDLs. Their contribution to this guide is crucial. Without it, it would be impossible to compile a document of this magnitude and importance.

The purpose of the meeting was to prepare the first version of the publication "Establishment of an SSDL". This immense task was approached by first reviewing and restructuring the existing preliminary draft. Then the content of each individual section was discussed in detail after which the sections were divided between the experts based on their own preferences and expertise.

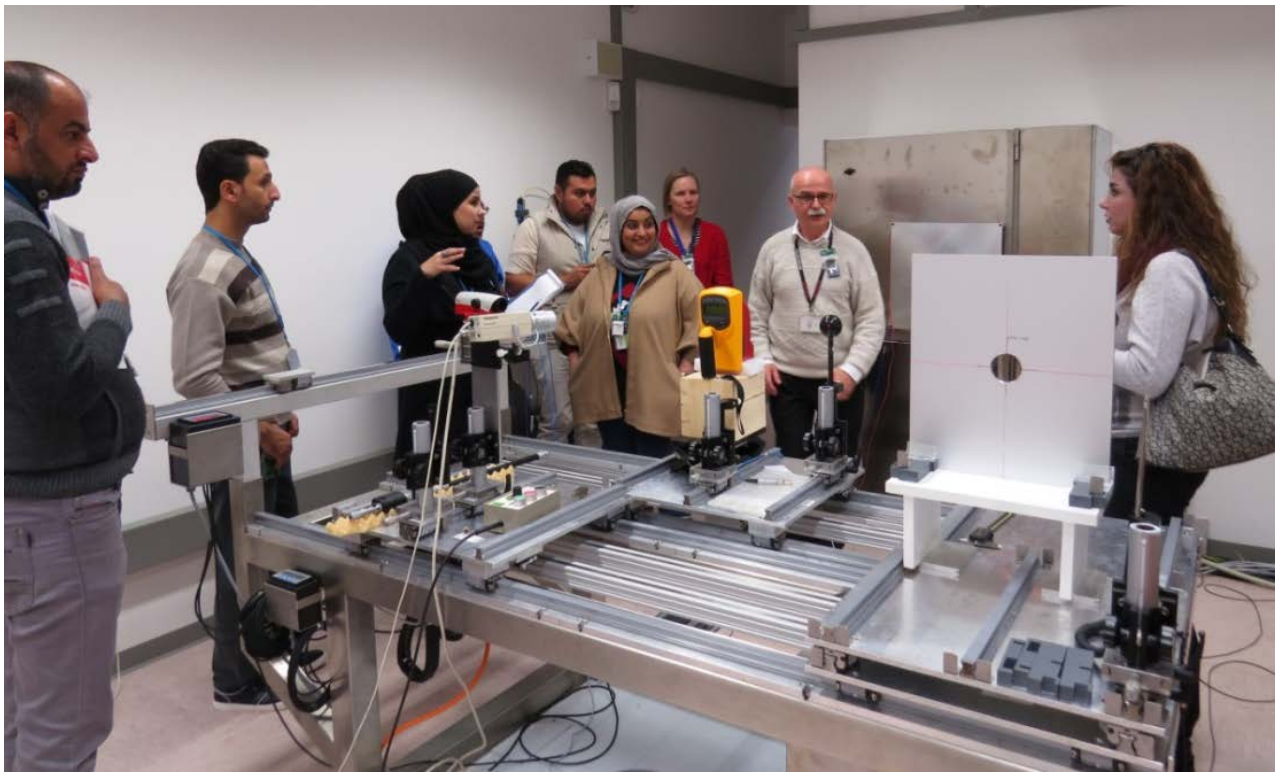
The guide consists of two parts. The first part, including Sections 1 – 4, is aimed at decision makers and contains basic information about SSDLs including the time frame and costs related to the establishment of an SSDL as well as the requirements for SSDL staff. The second part, i.e. Sections 5 – 9, includes information about the technical details, such as the facilities, infrastructure, equipment, commissioning and future steps, and is mainly intended for expert readership.

At the end of this intensive week, the first version of the guide "Establishment of an SSDL" was well on its way. The goal is to publish it in 2018.

Experts from the left: C. Hourdakis, P. Toroi, Z. Msimang, and M. Arib

Regional Training Course on Protection Level Calibrations Performed at SSDLs

Report of RAS6084 TC Course
November 14 -18, 2016, IAEA, Vienna and Seibersdorf



Experts: Mehenna Arib (KFSHRC, Saudi Arabia), and Jussi Huikari (STUK, Finland)

IAEA Staff: Paula Toroi (Course coordinator), István Csete, Ladislav Czap, and Carina Kraupa (Reporter)

In November 2016, a training course dealing with the topic 'Protection Level Calibrations at SSDLs' took place at the Vienna International Centre (VIC) as well as in Seibersdorf, where the IAEA's SSDL and the corresponding laboratory facilities are located. 20 Participants from ARASIA[2] countries participated in the course to improve their knowledge about radiation protection level calibrations and the related procedures in an SSDL.

The course programme included theoretical lecturers related to the topic, but the main focus was on praxis-oriented exercises at the laboratory. The participants learned, for example, how to determine reference values and how to calibrate survey meters and personal dosimeters, as well as how to measure the half-value layer of an X-ray beam.

Based on the comparison of the entry and exit test results, a noticeable improvement could be detected suggesting that the course was a success and the participants can take all this newly acquired knowledge with them and share it with their colleagues. Read more about the workshop in the story published under IAEA News.

[2] Iraq, Jordan, Lebanon, Saudi Arabia, Oman, Qatar, Syrian Arab Republic, United Arab Emirates, and Yemen

Regional Training Course for Implementation of QMS According to ISO 17025 Requirements

Report of RAS6084 TC Course

December 12 -16, 2016, IAEA, Vienna

WHAT?	A training course on Quality Management System (QMS)
WHERE?	At the IAEA Headquarters in Vienna, Austria
WHEN?	12 – 16 December, 2016
WHOM?	18 participants from ARASIA countries who work at an SSDL and are involved in developing a QMS
WHY?	To train participants in developing their own QMS based on the ISO 17025.
HOW?	Intensive course combining lectures and practical sessions

Experts: Mehenna Arib (KFSHRC, Saudi Arabia) and Roula Bou Khozam (CNRSL, Lebanon)

IAEA staff: Paula Toroi (Course director), Tom Bokulic, Ales Fajgelj, Mirja Kemppi (reporter)

A training course on Quality Management System (hence QMS) was organised by the IAEA in December 2016. This course was mainly aimed at candidates from the ARASIA Member States. All participants currently work at an SSDL as members of the technical staff and are involved in developing the QMS for their laboratory.

The main goals of the course were to train selected participants in developing a QMS and to provide them with information about how to implement the ISO 17025 general requirements in their own QMS. In order to fulfil these goals, the course consisted of both theoretical and practical sessions. During these practical sessions, the participants divided into four groups were to develop their own "baby-QMS" based on the lectures, which they can take home and use as an example in developing their own QMS. The course was structured to present the content of a QMS starting from more quality manual and moving on to more and more technical detailed features.

Based on the evaluation of the entry and exit test results, the course was successful in introducing and conveying the most important information about SSDL quality management systems based on the ISO 17025 standard.

Workshop on Uncertainty Estimations for Radiation Measurements

Report of Workshop

April 3 -7, 2017, IAEA, Vienna, Austria

Experts: Peter Ambrosi (PTB (retired), Germany), Mehenna Arib (KFSHRC, Saudi Arabia), Costas Hourdakis (EEAE, Greece),

IAEA staff: Paula Toroi (Course director), Ladislav Czap, Tom Bokulic, Mirja Kemppi (reporter and course assistant)

The main focus of the workshop was on uncertainty estimations at SSDL calibrations but all dosimetry levels from PSDL to end user measurement were covered. This course was organized not only as a part of a specific technical cooperation project but it was open to all participants, both cost-free and TC-funded. The workshop was attended by more than 80 people from approximately 50 countries around the world.

The aim of the workshop was to present and explain the theory behind uncertainty calculations and to provide the participants with tools for calculating uncertainty budgets for measurements in radiation therapy, diagnostic radiology as well as in radiation protection. The workshop also included practical sessions during which the participants created uncertainty budgets in groups for one specific radiation measurement of their own choice covering the whole traceability chain from the primary and secondary standards dosimetry laboratory to the clinic.

In addition to gaining new knowledge, the workshop and especially the course dinner on Thursday acted as an excellent opportunity to meet and exchange knowledge with colleagues from around the world.

Despite the large amount of participants, the feedback was mostly positive and the results of the exit test suggest that the experts succeeded in dispensing knowledge about uncertainty estimations.

Intern's corner

My experiences as an intern in DMRP

February 2016 – January 2017

Living only a few kilometres away from the IAEA Headquarters, I have frequently driven past the impressing building. When I actually got the opportunity to work for this organization, I was quite excited about the tasks waiting for me inside that building.

During my internship the Directory for Radiotherapy Centres (DIRAC), was my main responsibility. DIRAC was founded already in 1959 and contains information about radiotherapy hospitals and clinical institutions which have radionuclide and high-energy teletherapy machines. My daily tasks included dealing with customer requests and enquiries from the public and from clinical institutions, requesting updates from countries all over the world, reviewing incoming data manually, and performing data filtering and validation of electronic records. I also helped in establishing the new DIRAC webpage. Additionally, I created a new data collection form for DIRAC with JavaScript and was also involved in the DIRAC history project. As a part of my job, I attended weekly database meetings and the biannual section meetings. I was mainly allowed to work independently and I could always contact my supervisors when in need of help and advice.

Apart from working on DIRAC, I contributed to the preparation and reviewing of educational and training material for several courses as well as to the preparation of background material for consultancy and technical meetings. I had the chance to participate in several national and international meetings and events, such as the SSC-16 meeting, the Long Night of Research, and the General Conference in 2016, where the new DIRAC webpage was launched.

During my time at the Agency, I met not only a lot of people, but also many amiable colleagues, and I made new friends. I would like to thank both of my supervisors as well as all the colleagues I had the privilege to work with.

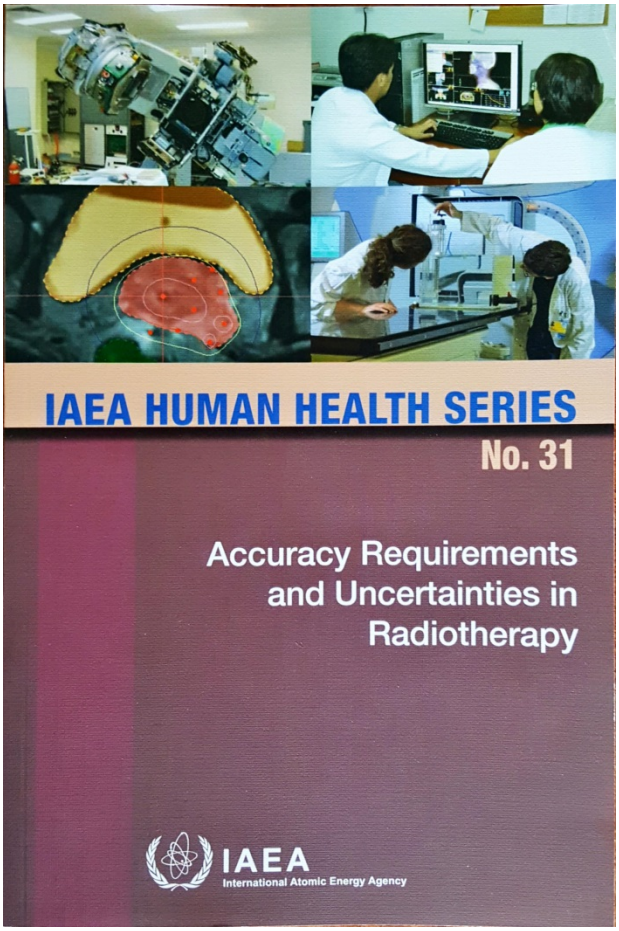
To summarize my year in one sentence: It was an unbelievable journey with so many amazing, wise and bright people from all over the world who welcomed me immediately into their team as a full member and formed the foundation to this unforgettable and awesome experience. Thank you.

Carina Kraupa

New IAEA Publications

Accuracy Requirements and Uncertainties in Radiotherapy

Accuracy requirements in radiation oncology have been defined in multiple publications; however, these have been based on differing radiation technologies. In the meantime, the uncertainties in radiation dosimetry reference standards have been reduced and more detailed patient outcome data are available. No comprehensive literature on accuracy and uncertainties in radiotherapy has been published so far. The IAEA has therefore developed a new international consensus document on accuracy requirements and uncertainties in radiotherapy, to promote safer and more effective patient treatments. This publication addresses accuracy and uncertainty issues related to the vast majority of radiotherapy departments including both external beam radiotherapy and brachytherapy. It covers clinical, radiobiological, dosimetric, technical and physical aspects. (*Information taken from www.pub-iaea.org*)



IAEA Human Health Series No. 31 on "Accuracy Requirements and Uncertainties in Radiotherapy

Upcoming Courses, Meetings and Consultancies in 2017

TC Courses and Workshops related to DMRP activities

- RER6033: Regional Training Course on High Accuracy Radiotherapy: Technical and Physical Requirements, Moscow, Russian Federation, 11–15 September 2017
- RER6033: Radiobiology for Radiation Oncologists and Medical Physicists, Moscow, Russian Federation, Q3, 2017
- RER6033: Regional Training Advanced Course on the Role of Imaging in Clinical Radiotherapy, Moscow, Russian Federation, 7–9 October 2017
- RAF6048: Regional AFRA Training Course on QA for Non-imaging Equipment and Radiation monitoring instrumentation in Nuclear Medicine, 9–13 October 2017, Cape Town, South Africa
- RAS6072: Regional training course on quality audits for intensity modulated radiotherapy, Singapore, 20–24 November 2017
- RER6003: Regional Hands-on Training Course on Image Guided Radiation Therapy (IGRT), Haarlem, Netherlands, Q4, 2017
- RER6033: Training Course on Radiation Safety and Accident Prevention in Radiotherapy, Moscow, Russian Federation, Q4, 2017
- RER6033: Workshop on QUATRO-Physics audits for Advanced Radiotherapy Dose Delivery, 8–12 November 2017

ESTRO Courses

- RER6033: IAEA/ESTRO Advanced treatment planning, Barcelona, Spain, 3–7 September 2017

DMRP Meetings and Consultancies

- International Conference on Advances in Radiation Oncology (ICARO-2), Vienna, Austria, 19–23 June 2017
- Consultants' Meeting on Development of Methodology for 'End-to-End' Audit for Dose Delivery using Intensity Modulated Radiation Therapy through On-Site Visits to Radiotherapy Centres, Vienna, Austria, 10–14 July 2017
- Consultancy Meeting on Drafting of a guidance document on dosimetry in radionuclide therapy, Vienna, Austria, 21–23 August 2017
- Consultants meeting on QA of advanced technology, Vienna, Austria, 4–7 September 2017.
- Consultants meeting on Revision of TRS 398, Vienna, Austria, 9–12 October 2017
- Technical Meeting on Developments and Trends in Secondary Standards Dosimetry Laboratories, Vienna, Austria, 9–13 October
- Combined training course and comparison for HDR Brachytherapy, Seibersdorf, Austria, 13–17 November, 2017
- Consultants' Meeting on Revision of the IAEA Publication "Comprehensive Audits of Radiotherapy Practices: a Tool for Quality Improvement", Vienna, Austria, 4–8 December 2017
- Consultants' Meeting on Review of Methodologies for Quality Audits for Radiotherapy Dosimetry and Further Steps in Audit Developments, Vienna, Austria, 11–15 December 2017


International Conference on
Advances in Radiation Oncology
#ICARO2
Vienna, Austria
20–23 June 2017
Organized by the International Atomic Energy Agency
IAEA-CN-250
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* SSDL Organization

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