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Short Communication

Global availability of dosimetry audits in radiotherapy: The IAEA dosimetry audit networks database

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A B S T R A C T

The International Atomic Energy Agency (IAEA) has established a database describing activities of dosimetry audit networks (DAN) in radiotherapy. Since 2010 the data on different aspects of the dosimetry audit have been collected. This information has allowed for the analysis and comparison of current practices in dosimetry auditing activities worldwide. Overall, 79 organizations in 58 countries confirmed that they offer dosimetry audit services for radiotherapy; however, access of radiotherapy centres to the audit remains insufficient. Increased availability of audits is necessary to improve dosimetry practices, reduce the likelihood of errors and the consequences that would result for patients' health.

1. Introduction

Independent dosimetry audits are an effective way to verify whether the quality of dosimetry practices at a radiotherapy centre are adequate to achieve cancer treatment objectives. This is particularly important as radiotherapy is potentially a high-risk procedure. One of the risks for a patient undergoing radiation treatment is that inadequate clinical dosimetry will have an impact on the local tumour control, treatment morbidity and toxicity and therefore affect patient survival and quality of life [1]. Dosimetry audits assist in identifying problems and provide support in their resolution. Audits have improved the accuracy of dosimetry in many radiotherapy centres over time, and have helped establish and maintain adequate medical physics practices [2]. Audits also help reduce uncertainties and increase consistency of dosimetry between participating centres. All beams used to treat cancer patients should be verified by an independent national, regional or international auditing organization. However, access to dosimetry audits is not easily available to radiotherapy centres in all counties [3]. There is a risk that some, or even many, centres not participating in external quality audit programmes may deliver sub-optimal radiation treatments due to inadequate dosimetry practices.

The objective of this study was to collect information on dosimetry audit programmes operating worldwide and develop a web-based dosimetry audit network (DAN) database [3,4]. The detailed data can be accessed through the DAN website [4]. The purpose of creating the database was to provide benefit both to the auditing organizations, which could compare their activities and exchange experiences, and to the radiotherapy physics community who would have access to information on available dosimetry audit programmes worldwide. This short communication summarizes the current status of information on DAN activities.

2. Material and methods

The process of collecting data related to DAN activities by the International Atomic Energy Agency (IAEA) started in 2010 with the designing of a questionnaire used for DAN surveys. The questionnaire consists of several sections dealing with different aspects of dosimetry audits. It is available at the DAN website [4], under the 'Data collection' tab. Information is requested regarding the reasons for performing an audit, such as regulation by the government, licensing procedure for medical use of radiation by the national regulatory body, requirement for participation in clinical trials, voluntary participation in an independent audit for quality assurance (QA) purposes, and/or the requirement for a radiotherapy centre accreditation or insurance payment. The audit framework and resources deal with information on sources of financial support and institution(s) providing such support. The geographical coverage of audit programmes and the number of participating centres is to be reported. Information on audit frequency is requested as well. Data on QA for the audit system are also requested detailing the Quality Management System (QMS) used, traceability to the international measurements system through standards laboratories,

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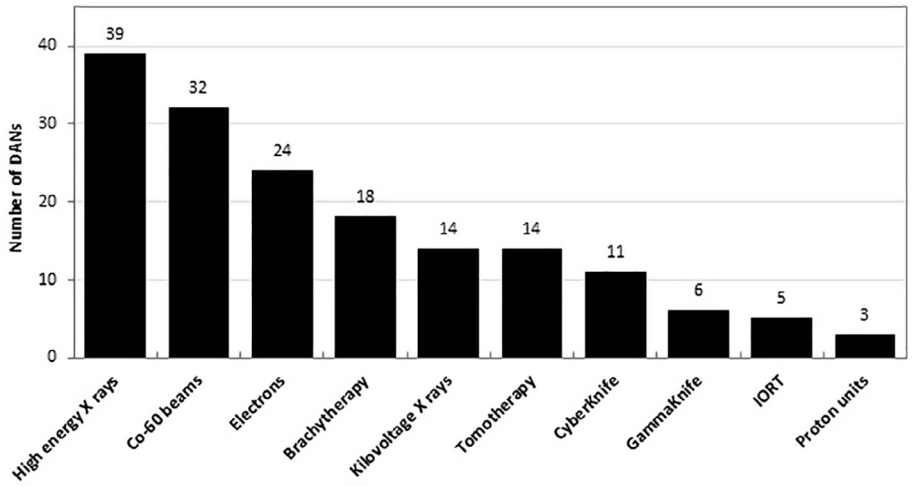

Fig. 1. Scope of audit services by DANs.

and comparisons between DANs. The questionnaire also covers the scope of audit programmes that include Co-60 units, medical linacs, kilovoltage X-ray units, brachytherapy, proton facilities, tomotherapy, CyberKnife, Gamma Knife, intra-operative radiotherapy (IORT) systems and other treatment delivery systems. Separate information sets are requested for different modes of audit operation, i.e. remotely and through on-site visits. Details on the dosimetry systems and phantoms used for basic dosimetry audits in the reference conditions, and audits in non-reference conditions, including complex dosimetry, are included.

The initial IAEA questionnaire was sent in 2010 to over 80 organizations, mostly members of the IAEA/WHO Network of Secondary Standards Dosimetry Laboratories (SSDLs) and other organizations known for having run dosimetry audits for radiotherapy in their countries or internationally. Since 2010, data have been collected through regular surveys. Subsequently, the DAN database was created [4] and its web version was launched in 2017. The database structure largely follows that of the DAN questionnaire.

3. Results

In response to the IAEA DAN surveys, 79 organizations in 58 countries confirmed they offered some level of dosimetry audit service for radiotherapy in 2010–2016, including one-time auditing initiatives. In the last reporting period, data have been updated by 45 organizations in 39 countries offering audits to radiotherapy centres. A map with all DAN locations is available at the DAN website [4] and it is reproduced in the Supplementary Fig. 1. Mostly, audits are conducted nationally with eight organizations providing audit services internationally. A few DANs provide audits within the geographical region or to neighbouring countries. Four organizations, the IAEA jointly with the World Health Organization (WHO), the Imaging and Radiation Oncology Core (IROC) Houston QA Centre (former Radiological Physics Centre) together with the Radiation Dosimetry Service (RDS) also based in Houston, USA, and the EQUAL-ESTRO, Villejuif, France, reported extending their services to an inter-continental level where annually, the IAEA delivers audits to radiotherapy centres in 60–70 countries, IROC-Houston and RDS to about 60 countries, and EQUAL-ESTRO to about 40 countries.

The audit coverage by a DAN extends from a single radiotherapy centre audited per year to over 2000 centres, with seven organizations auditing more than 100 different radiotherapy centres per year, each. The largest audits coverage, for over 2000 centres per year, are by the IROC Houston QA Centre [5] followed by the RDS-Houston with over 1000 centres participating. Annually, the IAEA/WHO carry out audits in approximately 300–400 centres, with Japanese DAN and EQUAL-ESTRO to 150–200 centres each. In terms of number of beam checks per year, IROC-Houston and RDS check together over 31,000 beams per year, followed by the Japanese DAN (over 800), EQUAL-ESTRO (over 700) and the IAEA/WHO (600–700).

Audits are performed in response to regulations by the government in 21/39 countries. The participation in audits is voluntary for a radiotherapy centre in 20 of 39 countries. Ten DANs provide audits for clinical trial programmes and these are associated with respective clinical trial groups.

Over 50% of DANs work within a QMS framework; approximately 75% of those follow the ISO/IEC 17025 [6] or ISO 9001 standard [7]. Almost all take part in inter-laboratory comparisons to verify the reliability of dosimetry systems they use in audits. Since 2004 the IAEA Dosimetry Laboratory has offered reference irradiations of DANs' dosimeters for QA of their dosimetry systems. Twenty-one different DANs use the IAEA services on a regular basis.

On most occasions, radiotherapy centres are offered an audit regularly, every 1–2 years, with the frequency depending on local arrangements, however, some DANs run audits less frequently, and a few only by request.

Fig. 1 presents the scope of audits offered by DANs as reported in 2010–2016. Most DANs provide audits for high energy photon and electron beams. Several DANs extend the audit scope to brachytherapy, kilovoltage X-rays, Tomotherapy and radiosurgery including CyberKnife and GammaKnife. Some DANs also offer the audit of IORT and proton beams.

All DANs provide basic dosimetry audits in the reference conditions. Audits are also conducted for non-reference conditions; some focus on TPS calculations for more complex beam geometries such as those used in 3D conformal techniques or intensity modulated radiotherapy (IMRT). Specialized audits are designed for clinical trial credentialing, as required for specific trials. A few newer audits are performed virtually by remotely checking the quality of treatment planning calculations or dose delivery systems on linacs. Virtual audits are performed without physical dosimeters and phantoms but they use specialized software tools.

Overall 36/45 DANs reported performing audits through on-site visits, 36 DANs reported remote audits and some reported both. On-site audits typically use ionization chambers, occasionally complemented by passive dosimeters. For remote audits, mostly passive dosimeters are used, such as thermoluminescent dosimeters (TLD), optically stimulated luminescence dosimeters (OSLD), alanine and radiophotoluminescence dosimeters (RPLD), and films. The most common passive dosimeter currently in use for audits is TLD. Typical measurement uncertainties reported by DANs for passive dosimeters are 1%–3% ($k = 1$). For non-reference conditions most DANs use ionization

chambers and films followed by other types of dosimeters such as TLD, alanine, diode, diamond and dosimeter arrays. Measurements in water/solid water phantoms are mostly done with ionization chamber for auditing dosimetric parameters such as field size dependence, depth doses, profile symmetry, off-axis factors, wedge transmission, and tray factors. Films and dosimeter arrays are used for both simple checks such as radiation/light field congruence and for more complex dosimetry e.g., IMRT dose distribution in anthropomorphic/semi anthropomorphic phantoms.

4. Discussion

The summary of information provided by 45 DANs helped the IAEA to estimate the number of radiotherapy centres with access to dosimetry audits globally. At present there are over 7000 radiotherapy centres worldwide registered in the IAEA Directory of Radiotherapy Centres (DIRAC) [8]. They operate approximately 13,800 radiotherapy machines (11,400 clinical accelerators and 2200 Co-60 units). Capacity is needed in the world to provide dosimetry audits for over 20,000 photon beams and roughly 40,000 electron beams generated by these machines. Current data on DAN activities suggests that, in total, 16,200 audits are delivered for high energy photons and 17,600 for electron beams in approximately 66% (4600/7000) radiotherapy centres registered in DIRAC. This information is consistent with that reported in 2013 [3] that only 2/3 of radiotherapy centres received some level of dosimetry audit at that time.

Several high-income countries such as North America, Japan, Australia and a number of countries of the European region (e.g. Belgium, Czech Republic, Finland, France, Greece, Germany, the Netherlands, Norway, Poland, Slovakia, Switzerland and UK), have adequate audit coverage. There are also some one-time auditing initiatives in Europe focusing mostly on the advanced audit of a specific treatment parameter or technique. However, sustainable and systematic auditing programmes are still needed at national levels in many countries. Currently, less than 50% of radiotherapy centres in Western Europe participate in dosimetry audits.

The costs of audits are mainly covered by the auditing organization or by a governmental body; however, 18 DANs reported that audits are offered against fees by participating centres. On some occasions these fees are partially subsidized by funding organizations. Some DANs operate under the umbrella of more than one governmental agency, for example the Ministry of Health and the regulatory body; a few are supported by professional societies. 34 DANs are linked to standards labs or are located within the standards' labs structures. Some audit systems are supported by clinical trial organizations. In fact clinical trial credentialing provided the starting point for several DANs.

The IAEA/WHO postal dose service provides per year 600–700 audits of high energy photon beams in 300–400 radiotherapy centres of about 60–70 low- and middle-income countries. Centres are eligible to participate on a biennial basis. Currently, no audits for electron beams are offered by the IAEA/WHO. It is estimated that national DANs in these countries cover slightly above 10% of the needs. This is by far insufficient. The IAEA supports national auditing activities by providing guidelines on how to set up an auditing centre and also by providing auditing methodologies tested in multicentre studies which can be adapted on the national level [16]. Also DANs are offered reference irradiations and blind test services in order to check the performance of their dosimetry systems.

In the best possible scenario, all beams used to treat cancer patients should be audited upon installation of new radiotherapy machines and systematically afterwards (preferably on a yearly basis) [1]. Yearly audits are applied in North America and a few high income countries, whereas in other countries the current priority is to ensure that at least high energy photon beams that are used for the majority of radiotherapy treatments, are audited every second year.

Although international recommendations exist [1,9,10], national regulations in several countries do not demand that radiotherapy centres participate in audits, neither to license new facilities nor to renew such licenses. In too few countries audits are organized within the framework of national regulations. Largely, participation is voluntary and is mostly driven by the motivation to perform high-quality radiotherapy supported by reliable clinical dosimetry. Genuine concern exists that dosimetry practices in centres not participating in audits might be sub-optimal, potentially affecting radiation treatments of patients. Many centres have to rely on international audit providers because national DANs do not exist or remit of their activities is insufficient.

Scarce resources constitute an obstacle for establishing new DANs and ensuring availability of sustainable auditing services in several countries. Most audits, whether on-site or remote, require considerable resources including expertise, physical phantoms and dosimeters [11], therefore virtual techniques constitute an interesting alternative as they are less resource intensive. At present they are limited to the auditing of a particular process [12] or a beam parameter [13].

Previous experiences [1,14] suggest that basic audits of the beam output in the reference conditions should be mandatory for all radiotherapy centres to ensure that beams used for patient treatments are correctly calibrated, whereas more advanced audits are usually offered based on needs. To keep pace with the development of new technologies in radiation oncology, new auditing methodologies have been developed [16–20] in response to challenges these technologies present. Currently, demand is increasing for the global availability of advanced audits, in particular end-to-end IMRT audits. In addition, small beam dosimetry requires more attention and the relevant audits are becoming available [13,15].

Although several national dosimetry audit networks exist, the current access of radiotherapy centres across the world to audit opportunities is not sufficient. Many new facilities are being established every year and the demand for dosimetry audits exceeds the current capabilities of DANs. Broader availability of dosimetry audits is needed in order to improve clinical dosimetry in radiotherapy and to ensure adequate safety of cancer patients treated with radiation.

Conflict of interest

Joanna Izewska, Wolfgang Lechner and Paulina Wesolowska have no conflict of interest to declare.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.phro.2017.12.002.

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