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50 Years of the IAEA/WHO postal dose audit programme for radiotherapy: what can we learn from 13756 results?

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ABSTRACT

Background: The IAEA/WHO postal dose audit programme has been operating since 1969 with the aim of improving the accuracy and consistency of dosimetry in radiotherapy in low-income and middle-income countries worldwide. This study summarises the 50 years’ experience of audits and explores the quality of reference dosimetry in participating radiotherapy centres throughout the years.

Material and methods: During the IAEA/WHO postal audits the dose determined from the mailed dosimeter is compared with that stated by the participant. Agreement to within ±5% is regarded acceptable whilst deviations outside ±5% limits trigger follow-up actions. Of particular interest in this study was the dependence of clinical dosimetry quality on factors related to the centre infrastructure and expertise in dosimetry of its staff.

Results: The IAEA/WHO dose audit programme noted great increase in the overall percentage of acceptable results from about 50% in its early years to 99% at present, although there is some variability of results amongst participating countries. Whereas results for younger radiotherapy machines show the agreement rate between the measured and the stated doses well above 90%, for those over 20 years old the rate dropped to <80%. Linac dosimetry was always better than 60Co dosimetry and multi-machine centres generally performed better than single machine centres equipped with cobalt alone. Second and subsequent participation in audits showed higher quality dosimetry than the first participation. The implementation of modern dosimetry protocols resulted in more accurate dosimetry than the use of the older protocols.

Conclusions: Over the 50 years that the IAEA has accumulated dosimetry audit data, practices in radiotherapy centres have significantly improved. Higher quality dosimetry confirmed in audits is generally associated with better infrastructure and adequate dosimetry expertise of medical physicists in participating centres.

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Introduction

For 50 years the International Atomic Energy Agency (IAEA) jointly with the World Health Organisation (WHO) have operated the postal dose audit programme aiming at improving the accuracy and consistency of reference dosimetry in radiotherapy centres across the globe. The IAEA is responsible for technical aspects of the programme including preparing, mailing out and reading the irradiated dosimeters, following up on errant results, gathering data on the capital and human resources of participating centres, and maintaining a database containing audit results and other pertinent information. WHO, together with the Pan American Health Organisation (PAHO), helps to raise awareness of the programme, promotes it and assists with dosimeter distribution, particularly in Latin America and the Caribbean.

Following the very first pilot audit runs organised by the IAEA in 1966 – 1967, a panel of experts in medical radiation dosimetry provided recommendations to the IAEA for the operation of dosimetry audits for radiotherapy centres on a permanent basis. WHO joined the IAEA dose audits in 1968. The project received its first official name ‘Joint IAEA/WHO Dose Inter-comparison Service for Radiotherapy’ which evolved to ‘the IAEA/WHO postal dose audit service for radiotherapy’ that is currently used. In 1969 the dosimeter batch #1 of the new postal dose audit service was distributed to centres as documented by the IAEA [1,2]. For 48 years the IAEA/WHO dose audits utilised thermoluminescence dosimeters (TLDs) and in 2017, the IAEA phased out its aging TLD readers and upgraded the laboratory equipment by acquiring new radiophotoluminescence dosimetry (RPLD) systems using glass dosimeters [3]. Initially the audits were performed for 60Co beams and in 1991 they were extended to high energy X-ray beams from linear accelerators [4]. In 1996 – 1998, the IAEA introduced substantial modifications in the technical and operational aspects of its
audits, including the organisation of a computerised database containing a comprehensive set of audit related information. Initially developed for storing the information, the current version of the database became an invaluable instrument for planning, organising, processing, evaluating, analysing and archiving all received and generated data including items describing the infrastructure of centres and their dosimetry practices.

The purpose of this study is to review the status of dosimetry practices in radiotherapy in low-income and middle-income countries (LMI) participating in the IAEA/WHO audits throughout the 50 years period and to mine the vast data the IAEA has collected in order to identify those factors that have the greatest impact on the quality of clinical dosimetry. By comparison with earlier studies [4–6], changes in dosimetry practices can be tracked. Furnished with this information the global radiotherapy community can develop strategies necessary to improve dosimetry practices, which is an important aspect of the quality of care for cancer patients in different geographical regions and countries of the world.

Material and methods

The IAEA/WHO dosimetry audit operations have been extensively described elsewhere [1–8] and only a brief summary is presented here. The audit cheque beam output in the reference conditions for high energy photon beams. Participants are requested to calculate the dose to the IAEA dosimeter the same way as they would do for a patient to ensure the audit results correspond to clinical dosimetry practices. It should be noted, however, that checking the performance of treatment planning systems in participating centres is outside the audit scope. As a separate step, participants are asked to determine the dose from ion chamber measurements following the dosimetry code of practice (protocol) used.

Through the efforts of the IAEA/WHO and national audit coordinators, the availability of audits is brought to the attention of radiotherapy centres in LMI countries. Audits are coordinated with national networks operating in some of these countries [9,10]. Participation is entirely voluntary. IAEA dosimeters are mailed to participants, irradiated and returned to the IAEA Dosimetry Laboratory for readout and evaluation. When the dosimeter confirms the participant stated dose to within 5% (the acceptance limit established historically [1,2] and confirmed in further analyses [3,4,7,8]), the participant is informed of the result, and no further action is taken. If agreement between the participant and the IAEA doses falls outside the 5% acceptance limit, a new set of dosimeters (TLDs before 2017, RPLDs afterwards) is sent out for re-irradiation. Reasons for discrepancies are discussed with participants by the IAEA staff remotely. When necessary, contacts with local experts in radiotherapy physics are made, or international experts are recruited to assist in resolving discrepancies at the centres with poor audit results.

In parallel with the provision of the IAEA dosimeters, participants are requested to supply key information about their centre, such as the details of machines/beams available, dosimetry systems used for the beam calibration and the dosimetry protocol they followed, including relevant coefficients and factors for the protocol application.

A subset of the larger data set, acquired since the development of the IAEA audit database in 1998, has allowed analysis of the audit results in the context of indicators such as the age of the radiotherapy machine, the dosimetry associated with $^{60}$Co units versus linear accelerators, number of machines in the centre and whether the audit results are the first or a subsequent participation which is used as an indicator of the dosimetry experience of staff in participating centres. This study further explores the impact of dosimetry protocol on the quality of reference dosimetry. It is acknowledged however, that there are gaps in the database where participants have not supplied the required information, in particular on dosimetry equipment and the details of the centre procedure for the dose determination from ionisation chamber measurements. The implications of not reporting dosimetry data are also discussed below.

Results

Overall audit results

By the end of 2018, 2364 radiotherapy centres in 136 countries world-wide have been audited by the IAEA/WHO; 4427 machines and 5790 beams were encompassed by the audit programme. The results of 13,756 individual TLD/RPLD sets irradiated over a period of 50 years form the basis of this study.

The audits were performed in LMI countries of six geographical regions: Africa (AF), Latin America/Caribbean (AM), Eastern Mediterranean (EM), Eastern, South-Eastern Europe and Northern Asia (EU), South-East Asia (SE) and Western Pacific (WP). Table 1 shows these regions along with pertinent statistics.

The distribution of audit results presented as ratios $D_m/D_s$ of the IAEA’s measured dose ($D_m$) to the dose stated by the centre ($D_s$) for 1969 – 2018 is shown in Figure 1(a). The

### Table 1. Statistics of the regional participation in 1969–2018.

<table>
<thead>
<tr>
<th>Region</th>
<th>#Countries</th>
<th>#Participating centres</th>
<th>#Co-60 units</th>
<th>#Linacs</th>
<th>#Beams</th>
<th>#Audits</th>
<th>%Results within 5% limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa (AF)</td>
<td>22 (16%)</td>
<td>90 (4%)</td>
<td>61 (3%)</td>
<td>134 (6%)</td>
<td>317 (6%)</td>
<td>785 (6%)</td>
<td>93</td>
</tr>
<tr>
<td>Latin America/Caribbean (AM)</td>
<td>30 (22%)</td>
<td>464 (19%)</td>
<td>451 (23%)</td>
<td>452 (18%)</td>
<td>1116 (19%)</td>
<td>4110 (30%)</td>
<td>85</td>
</tr>
<tr>
<td>Eastern Mediterranean (EM)</td>
<td>19 (14%)</td>
<td>138 (6%)</td>
<td>107 (5%)</td>
<td>213 (9%)</td>
<td>520 (9%)</td>
<td>1351 (10%)</td>
<td>89</td>
</tr>
<tr>
<td>Eastern, South-Eastern Europe and Northern Asia (EU)</td>
<td>41 (30%)</td>
<td>537 (23%)</td>
<td>709 (35%)</td>
<td>637 (26%)</td>
<td>1807 (31%)</td>
<td>3832 (28%)</td>
<td>88</td>
</tr>
<tr>
<td>South-East Asia (SE)</td>
<td>11 (8%)</td>
<td>380 (16%)</td>
<td>293 (15%)</td>
<td>296 (12%)</td>
<td>796 (14%)</td>
<td>1581 (11%)</td>
<td>84</td>
</tr>
<tr>
<td>Western Pacific (WP)</td>
<td>13 (10%)</td>
<td>755 (32%)</td>
<td>379 (19%)</td>
<td>715 (29%)</td>
<td>1234 (21%)</td>
<td>2097 (15%)</td>
<td>85</td>
</tr>
<tr>
<td>ALL REGIONS</td>
<td>136 (100%)</td>
<td>2364 (100%)</td>
<td>2000 (100%)</td>
<td>2427 (100%)</td>
<td>5790 (100%)</td>
<td>13,756 (100%)</td>
<td>86</td>
</tr>
</tbody>
</table>
median of the distribution is 1.005 and the interquartile range (IQR) containing the middle 50% results is 0.032. Recent results obtained in 2016–2018 show the median of 1.002 and the IQR of 0.022.

On average, 86% audit results were within the 5% acceptance limit in 1969–2018 (Table 1), but the IAEA records show a systematic increase in acceptable results from approximately 50% in the first years of the audit programme, 65–70% in early 1990’s, to 97% in 2016–2018 (see grey area in Figure 1(b)). After the follow-up of poor results (initiated in 1996 and conducted regularly since), the fraction of acceptable results increased further to approximately 99% at present (see blue area Figure 1(b)).

As the amount of information about the infrastructure of the participating centres has increased markedly since 1998, it was possible to perform more detailed analysis of the audit results given below. The overall percentage of acceptable results derived from 10,809 audits conducted in 1998–2018 was 92% before and 98% after follow-up of discrepancies.

Audit results by country
Fraction of audit results within 5% acceptance by country is given in Figure 2 for 95 countries who participated in the IAEA/WHO audits with ≥10 beams in 1998–2018. The results are shown for the initial check and after the follow-up of discrepancies through the repeated dosimeter irradiation.

Pass rates (after the follow-up of initial discrepancies) range from 78% to 100% with 93% (88/95) countries having >95% acceptable results including 55% (52/95) countries having 100% of acceptable results. Seven countries have <95% of acceptable results.

Audit results versus infrastructure of radiotherapy centres
In 1998–2018 audits were conducted for 7304 linac and 3505 cobalt beams. It was observed that in general, the rate of successful results was related to the treatment machine age

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Figure 1. Results of the IAEA/WHO postal dose audits of radiotherapy centres. (a) Ratios $D_m/D_s$ of the IAEA’s measured dose ($D_m$) to the dose stated by the centre ($D_s$); data collected in 1969–2018. (b) Fraction of results within 5% acceptance limit in 1990–2018, grey – initial check, blue – after follow-up of discrepancies.
Figure 2. Fraction of results within 5% acceptance limit for 95 countries participating with more than 10 beams in 1998–2018; black – initial check, blue – after follow-up of discrepancies.

Figure 3. The IAEA/WHO postal dose audit results in 1998–2018. (a) Percentage of results within the acceptance limits of 5% as a function of machine age, grey – initial check, blue – after follow-up of discrepancies. (b) Results of cobalt units (blue) and linacs (green) by geographical region. Results of the initial check are marked in light blue/green and these after follow-up of discrepancies in dark blue/green, respectively.
that was calculated from the date of irradiation of the IAEA dosimeters and the year of installation of the machine. Figure 3(a) shows the percentage of results within the 5% limit versus machine age. Acceptable results range from 93–94% for machines younger than 10 years, drop to 84% for machines older than 20 years and further drop to 78% for machines older than 30 years. After the follow-up of poor results, 7–13% of them remained uncorrected in the machine age group of 20–30 years or more, whereas for the machines 10 years old or less, the rate of unresolved discrepancies was about 1–2%.

Moreover, it was found that the dosimetry of linac beams was better than that of 60Co beams in all world regions (Figure 3(b)). In 1998–2018, the average of acceptable results before follow-up was 95% for linacs and 85% for 60Co units.

In particular, 60Co dosimetry in EU and WP yielded lower pass rates than other regions, i.e., 79% and 84%, respectively, triggering substantial follow-up actions. It is worth mentioning that the situation has changed throughout the years. More recently, in 2016–2018, the statistics for initial cheques averaged over all regions improved to 98% acceptable results for linacs and 93% for 60Co beams; the average age of 60Co units was 14 years at the time of audit compared to the average of 6 years for linacs.

No significant differences in successful results, confirmed by pairwise comparison of proportions with correction for multiple testing, p > .01, were seen in 1998–2018 between different energies of linac beams; the pass rate ranged between 95% for lower energies of 4–6 MV beams (4640 results), 96% for interim energies (1793 results) and 97% for 18 MV and above (871 results).

Audit related infrastructure data collected in 1998–2018 suggest that single machine centres equipped with a 60Co unit alone had only 84% initial audit results within the 5% acceptance limits whereas this figure increased to 93% for single machine centres equipped with a linac and for larger centres having two machines or more. After the follow-up of discrepancies, the agreement between the measured and the stated doses increased to 94% for single 60Co unit centres and to 97% for other centres.

**Audit results versus dosimetry practices in radiotherapy centres**

About 80 centres per year newly register to the audit programme. The rate of satisfactory results for these new centres is low compared to the results of centres that have regularly participated in the IAEA/WHO audits. For example, in 1998–2018, 84% results of first-time participants were within acceptance limits compared to 95% for regular participants.

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**Table 2. Results with 5% acceptance limit and the dosimetry code of practice in 2000–2018.**

<table>
<thead>
<tr>
<th>Code of practice</th>
<th># Results</th>
<th>% Results</th>
<th>Before follow-up % N (&lt;5%)</th>
<th>After follow-up % N (&lt;5%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N_{D,w}$ based</td>
<td>6704</td>
<td>65.8</td>
<td>96.1</td>
<td>99.0</td>
</tr>
<tr>
<td>$N_k$ based</td>
<td>1390</td>
<td>13.6</td>
<td>92.5</td>
<td>98.5</td>
</tr>
<tr>
<td>$N_x$ based</td>
<td>372</td>
<td>3.7</td>
<td>78.8</td>
<td>94.1</td>
</tr>
<tr>
<td>Unknown</td>
<td>1719</td>
<td>16.9</td>
<td>80.3</td>
<td>92.3</td>
</tr>
</tbody>
</table>

Over the past 50 years, dosimetry protocols have advanced significantly as have the data gathered from participating centres and the IAEA methodology of analysis and recording the data. Absorbed dose to water ($N_{D,w}$ based dosimetry protocols [11,12] have been widely adopted in the last 20 years, replacing the earlier air kerma ($N_k$) and exposure ($N_x$) based protocols [13–15]. Table 2 illustrates the effect the dosimetry protocol can have on the variability of audit results. These data are shown for 2000–2018 starting from the date of publication of the IAEA TRS-398 code of practice [11]. They represent 10,185 audits done on 6475 beams from 4852 radiotherapy machines.

An improvement in dosimetric quality can be seen both as the newer protocols are adopted and on re-irradiation following initial results out of compliance with the IAEA’s 5% acceptance limits. The last row of Table 2 gives the results of the centres that did not supply sufficient information as the newer protocols are adopted and on re-irradiation following initial results out of compliance with the IAEA’s 5% acceptance limits. The last row of Table 2 gives the results of the centres that did not supply sufficient information (16.9%). Most participants not reporting dosimetry protocols were from Eastern Europe and Northern Asia (41%) or Latin America and the Caribbean (37%). In 2016–2018, 90% data sets indicated the use of the $N_{D,w}$-based protocol, mainly the IAEA TRS-398; still 10% datasets did not contain the requested information. Again, they were mostly from EU and LA.

Since 1969, the IAEA/WHO audits identified 1854 discrepancies between the IAEA determined dose and the user stated dose. They were discussed extensively in previous publications [4–6,16]. In 1998–2018, 855 discrepancies were recorded in 10,809 audits. They are grouped below according to the cause of deviation indicating confusion about a specific factor or a parameter:

- Dosimetry setup errors (26%); these involve misunderstandings of the geometry setup, in particular, confusing source to surface distance (SSD) and the isocentric setups, incorrect alignment of dosimeters for irradiation, wrong distance from the source or wrong field size.
- Dose calculation errors (18%); these include various mistakes such as incorrect use of factors required to calculate the dose or omissions in using them, for example, not correcting for percentage depth dose when calculating the irradiation time or monitor units (MU) to deliver the prescribed dose to the dosimeter positioned at depth.
- Incorrect dosimetry and combination of various mistakes (11%); these include incorrect beam output determination, issues with dosimetry equipment, wrong time/MU or wrong energy selected on a machine console when irradiating dosimeters.
- Insufficient data or unconfirmed cause of deviation (45%).

Even with the careful review of the audit datasheets supplied by participants, in 45% cases it was not possible to
determine the specific cause of the discrepancy due to insufficient information provided to the IAEA or communication issues. A significant number of unexplained deviations occurred in under-resourced centres with older equipment; therefore these discrepancies could be associated with poor treatment conditions or issues with dosimetry equipment. Other problems may be due to insufficient training of staff working in radiotherapy.

**Discussion**

Within half a century of operating the dosimetry audit programme, the IAEA/WHO provided 13,756 audits to 136 countries in six geographical regions. The rate of participation corresponded to the number of voluntary requests by centres from these regions; for example, 30% of all audits were done in LA and 28% in EU. Only 6% audits were performed in AF (Table 1) which is a reflection of lower number of radiotherapy centres in Africa compared to other regions. The overall pass rate was 86% (before follow-up) with above average results from AF, EU and EM (last column in Table 1). In particular, the results in Africa were better than in other regions possibly due to targeted regional training in dosimetry provided by the IAEA.

The IAEA/WHO audits recorded significant increase in the fraction of the results within the acceptance limits of 5% from 50% in early years of the programme operation to 99% at present. Concurrently, the global radiotherapy environment has changed throughout the years with more advanced equipment, better trained medical physics staff and superior dosimetry protocols. The overall improvement in dosimetry noted through audits is mainly attributed to the scientific progress and technical developments in dosimetry, increased interest in quality assurance in radiotherapy centres and also because of regular participation in audits. As expected, participation in the IAEA/WHO postal audit programme lead to more accurate dosimetry through the educational experience associated with participation.

The IAEA results for low-income and middle-income countries collected in 2010–2016 were compared with the results obtained by the Imaging and Radiation Oncology Core (IROC), Houston, USA, providing remote beam output audits mostly in USA but also internationally, and the results of the Australian Clinical Dosimetry Services (ACDS) in Australia [16]. The percentage of results outside the acceptance limits was higher for low-income and middle-income countries (1.6%) audited by the IAEA than the results for USA and the countries audited by IROC (0.6%) and for Australia (0%). This is understandable given that several low-income and middle-income countries struggle to obtain sufficient radiotherapy resources.

The snapshot of IAEA/WHO audit results presented in Figure 2 illustrates the variability in dosimetry practices amongst participating countries. Whilst 93% countries had >95% pass rate, including 55% countries with 100% pass rate, seven countries had <95% acceptable results including one country with only 78% pass rate. There were jointly 315 discrepancies (approximately 40% of all discrepancies recorded in 1998–2018) in these seven countries. They have all received follow-up dosimeters for repeat irradiation. Only half of them showed improvement achieving the results within 5% acceptance limits. Unresolved discrepancies were mostly associated with obsolete equipment and/or poorly qualified staff. For example, failing results of country #1 (Figure 2) pertained mostly to obsolete 60Co units that are currently being replaced. With the radiotherapy infrastructure change and adequate staff training, this country may improve dosimetry practices in future. Countries #2–#7 in Figure 2 also struggle with obsolete equipment and staffing problems. Nevertheless, poor dosimetry practices may result in unacceptably large uncertainties in the doses delivered to cancer patients in some centres.

There is a clear trend globally for poorer dosimetry being associated with older machines when looking at the IAEA/WHO audit results (Figure 3(a)). This might be an impression of inadequate maintenance of these older machines. However, younger machines are predominantly linacs, so the effect of age may include the influence of the ratio of linacs to cobalt units over time. In 1998, 40% of audit results were from linac beams and in 2018 this figure reached 86%. Clearly, linac dosimetry was superior to cobalt dosimetry in all periods analysed in this study and in all world regions (Figure 3(b)). However, recent results for cobalt units younger than 10 years are quite comparable to the results of linacs but they become poorer for older 60Co units in contrast with the linac results. It must be emphasised that many old machines have been replaced recently; 53% of linacs and 18% of cobalt units participating in audits in 2016–2018 were younger than 5 years. At the same time, 22% of cobalt units older than 20 years were included in audits in this period. It was seen that poor technical condition of these old 60Co units contributed to increased failure rates in the audits. In an examination of postal dosimetry data acquired during the period 1998–2001 [5] a similar observation was made. Currently, over 40% of 60Co units in EU are older than 20 years as recorded in the IAEA Directory of Radiotherapy Centres [17]. In LA, 56% of 60Co units and 13% of linacs are older than 20 years [17].

It was also noted that single machine centres, equipped solely with cobalt units have a lower rate of successful audits compared to centres equipped with linacs and centres having more machines. This may be an indication of inadequate investment in staffing and education. The physics/dosimetry infrastructure is believed to be more extensive in centres with linacs resulting in higher quality dosimetry compared to the single cobalt centres. Personnel related factors can be expected to play a significant role in the variability of the audit results.

The postal audit data make it possible to chart the uptake of the modern $N_{D,w}$ based dosimetry protocols [11,12]. With a subset of data for which there is information on the dosimetry protocol used there is a clear trend towards less variability with newer protocols. In 2000–2018, approximately 66% audits were on beams with calibrations based on $N_{D,w}$ whereas in 2016–2018 this figure had risen to 90%. The results for centres using $N_{D,w}$ protocols (mostly IAEA TRS-398
and AAPM TG-51 [11,12]) show greater agreement of the IAEA measured to the centre stated doses than the results for the centres that use older dosimetry protocols. The results from the centres that did not supply information on the protocol used show significantly lower pass rate (p < .01, comparison of two proportions test) than the corresponding pass rates of the participants who reported the use of modern protocols. This effect was also apparent in the 1998–2001 data set which has been previously analysed [5]. Educational efforts are still required to increase the expertise in dosimetry, in particular in LA and EU, who supplied most audit datasheets without information on the dosimetry protocol used.

It is important to note that agreement of the participant’s audit result with their calculation of the expected dose depends on some factors beyond the IAEA’s control. These factors are the actual accuracy of the participant’s calibration of their treatment beam using their in-house dosimetry system; compliance with the specified irradiation conditions of the IAEA dosimeters and the calculations used to predict the dose received by the dosimeters. Clearly, this analysis is unable to fully disentangle the individual accuracies attached to each of these factors. However, conclusions from the resolution of discrepancies suggest that mistakes caused by the misunderstandings of the audit instructions and/or setting up the dosimeter irradiation conditions incorrectly as well as errors in the dose calculation contributed significantly to the variability of results. Such mistakes were substantially reduced as of 2016 when the participants were provided with a video-tutorial that was specially developed to aid them in following the specified dosimeter irradiation geometry and dose calculation. This decrease in the number of trivial mistakes improved the effectiveness of the audit services. Indeed, misunderstandings of the IAEA instructions generated poor audit results that were unrelated to clinical dosimetry used for patients’ treatments. However, errors in equipment calibration and discrepancies caused by failures of equipment [16,18–21], including those caused by poorly maintained old radiotherapy machines in some centres, can compromise the quality of dose delivery to many cancer patients treated with these machines. The clinical relevance of discrepancies in dosimetry detected in the IAEA/WHO audit programme was confirmed in several cases [4–6,18], and without participation in independent dose audits such discrepancies may have not been discovered. It is of importance for any radiotherapy centre to be alerted of the dosimetric errors before patients suffer the consequences of undiscovered mistakes.

Conclusions

Over the 50 years of its existence, the IAEA/WHO postal dose audit programme has played an important role in improving the accuracy and consistency of dosimetry in radiation therapy across the globe. The programme has been used by more than 2300 radiotherapy centres in 136 countries and several clinically relevant errors in the calibration of therapy beams were detected and corrected.

Clearly, throughout the 50 years, practice has changed both in centres and in the IAEA postal dosimetry audit system. One of the improvements has been the collection of more and higher quality data from participating centres. The analysis of information stored in the IAEA database allowed identification of a few factors that have the greatest impact on the quality of radiotherapy dosimetry both related to the infrastructure and staff qualifications, and it was possible to draw some general conclusions from the analysis. Higher quality dosimetry was generally associated with younger machines, linacs as opposed to 60Co units, centres equipped with more than one machine, as well as prior experience with the IAEA/WHO’s audit programme, and the use of up-to-date dosimetry protocol. Staff training, their experience and competence in clinical dosimetry as well as the availability of well qualified staff in adequate numbers cannot be overstated. This study suggests that more training of medical physicists is still required, particularly in Eastern Europe and Northern Asia, and in Latin America.

Overall, by providing dose audits, the IAEA/WHO have assisted radiotherapy centres in achieving and maintaining accurate dosimetry for radiotherapy which benefitted many patients. The availability of dosimetry audits should be expanded [22] through the activities of national audit networks, so that more centres and their patients can benefit from accurate dosimetry.

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Disclosure statement

The author(s) report no conflicts of interest.

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