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MALAYSIAN PARTICIPATION IN THE IAEA/WHO TLD POSTAL DOSE QUALITY AUDIT SERVICE: DATA ANALYSIS FROM 2011-2015

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ABSTRACT

In this paper, we report the dosimetry methodology used in the IAEA/WHO Thermoluminescent Dosimeter (TLD) Postal Dose Quality Audit Service and the results of 22 Malaysian radiotherapy centres participated in the audit from 2011 to 2015. Each participating centre was provided with a few sets of TLD capsule (two unit of TLD capsules to be irradiated and a control TLD in one set) as requested by the centres. The participating centres were asked to irradiate each TLD capsule at 2 Gy absorbed a dose to water under reference conditions i.e the TLD capsule is positioned at 10 cm depths in water, at central axis with 10 cm x 10 cm field size at 100 cm Source-Surface Distance or 100 cm Source-Axis Distance. In this period, a total of 70 photon beams consist of 43 beams and 27 beams produced by 6 MV and 10 MV photon beams, respectively have been audited. The results demonstrated that all participating centres comply with the acceptance limits of ± 5% as recommended by the International Commission on Radiation Units and Measurements (ICRU) Report 24, except eight photon beams from six centres. However, these centres presented better compliance results after being followed up with a second round of TLD irradiation.

Keywords: Audit, dose, radiotherapy, reference condition, TLD

INTRODUCTION

External beam radiation therapy using megavoltage X-ray beams from medical linear accelerator is the most widely used treatment modality in the cancer treatment. International Commission on Radiation Units and Measurements (ICRU) Report 24 points to a need for accuracy of ± 5% in the delivery of an absorbed dose to a target volume in a patient (ICRU, 1976). Other than routine beam calibration using a calibrated radiotherapy dosemeter performed by the medical physicist, the accuracy of absorbed dose produced from the megavoltage X-ray beams also can be verified by the external bodies such as International Atomic Energy Agency (IAEA) and Secondary Standard Dosimetry Laboratory (SSDL). Through participation in the IAEA/WHO TLD Postal Dose Quality Audit Service, the radiotherapy centres will be able to confirm the accuracy, reliability and precision of their absorbed dose measurements thus gain better improvement in dose delivery to patients.

Being a member state of the IAEA/WHO Network of SSDLs since 1980, the SSDL of Malaysia has been participating in the IAEA/WHO TLD Postal Dose Quality Audit Service since 1985 (Samat et al., 2009). In 2011, the SSDL of Malaysia was designated by the IAEA in coordinating the IAEA/WHO TLD Postal Dose Quality Audit Service for radiotherapy centres in Malaysia. The role of SSDL of Malaysia is to organise the service at national level by being a moderator between radiotherapy centres and the IAEA.

In the IAEA/WHO TLD Postal Dose Quality Audit Service, the accuracy of beam output produced from megavoltage X-rays teletherapy unit will be evaluated using powder form of lithium fluoride (LiF) thermoluminescent dosimeter (TLD) which are encapsulated in a watertight polyethylene 3 mm x 20 mm cylindrical capsule. The radiotherapy centres are supplied with a set of TLD (three capsules in each set), TLD holder with instruction sheets and forms as guidance for irradiating the TLDs. The radiotherapy centres are requested to irradiate the TLD capsules at 2 Gy absorbed dose to water under reference conditions i.e the TLD capsule is positioned at 10 cm depth in water, at central axis with 10 cm x 10 cm field size at 100 cm Source-Surface Distance or 100 cm Source-Axis Distance (IAEA, 2000). The irradiated TLDs are returned to the IAEA Dosimetry Laboratory for analysis and results are reported to the participating centres as well as the SSDL. Agreement within ± 5% between users stated dose and IAEA mean dose is considered satisfactory (Izewska and Andreo, 2000).

Over recent years, the IAEA is encouraging the SSDLs to develop national audits programme. Some countries that have established their national dose audit are Algeria, Australia, Brazil, Czech Republic and Japan (Kroutilikova et al., 2003; Da Rosa et al., 2008; Mizuno et al., 2008; Arib et al., 2009; Davies et al., 2013). In order to ensure unbroken link of the dosimetry chain, these countries were assisted in the standardisation of TLD methodology and were provided with technical back up by the IAEA (Izewska et al., 2002). In addition, guidelines for the preparation of a quality manual for external audit groups on dosimetry in radiotherapy also were provided (Izewska, 2002).

In Malaysia, the first national TLD postal dose quality audit was co-ordinated by the University of Malaya Medical Centre (UMMC) in collaboration with the Radiation Calibration Laboratory (UWRCL) in the University of Wisconsin (Rassiah et al., 2004). The dose measurements were carried out on three units of Co-60 teletherapy and nine units of linac using TLD chips as the transfer detector and the IAEA's Technical Report Series No. 277 as the standard irradiation protocol. To date, a number of studies towards the development of radiotherapy audit in Malaysia have been carried out, including establishing a national audit using the IAEA's Technical Report Series No. 398 and introducing fabricated silica fibre as an alternative detector to use in radiotherapy dosimetry (Fadzil et al., 2014; Noor et al., 2014; Norhayati et al., 2016).

MATERIALS AND METHODS

An invitation letter for participating in the IAEA/WHO TLD Postal Dose Quality Audit Service was delivered by the IAEA via e-mail through the SSDL of Malaysia. Radiotherapy centres having new installations of medical linear accelerator (linac) and the last participations in many years were given a priority in the selection. The invitation letter with an application form and the principles of operation statement were sent to all selected radiotherapy centres. Radiotherapy centres which are interested to participate in the audit were asked to complete the application form and returned to the IAEA Dosimetry Laboratory through e-mail within a certain period.

Every participant was provided with instruction and data sheets, a number of TLD set as requested by the centres (three capsules of TLD in one set where two capsules to be irradiated and a control TLD) and the IAEA standard TLD holder. The control TLD labelled with a white sticker uses to monitor background radiation, undesirable accidental irradiation and unexpected fading. The participants were asked to irradiate the TLDs with an absorbed dose to water of 200 cGy at 10 cm depth in water, at central axis with 10 cm x 10 cm field size at 100 cm Source-Surface Distance

(SSD) or 100 cm Source-Axis Distance (SAD) (Figure 1). The water phantom with a minimum dimension of 30 cm x 30 cm should be used. The participant who irradiated the TLD capsules with a different measurement set-up was asked to report the irradiating procedure in the data sheets. The irradiated TLDs were returned to the IAEA Dosimetry Laboratory with the completed data sheets after irradiation through SSDL of Malaysia. At the IAEA Dosimetry Laboratory, the irradiated TLDs were then heated at two-step heating cycles which are preheating at 130^{o}C and the heating at 300^{o}C, with integration time of 25 s for obtaining the TL signals (Izewska et al., 2008).

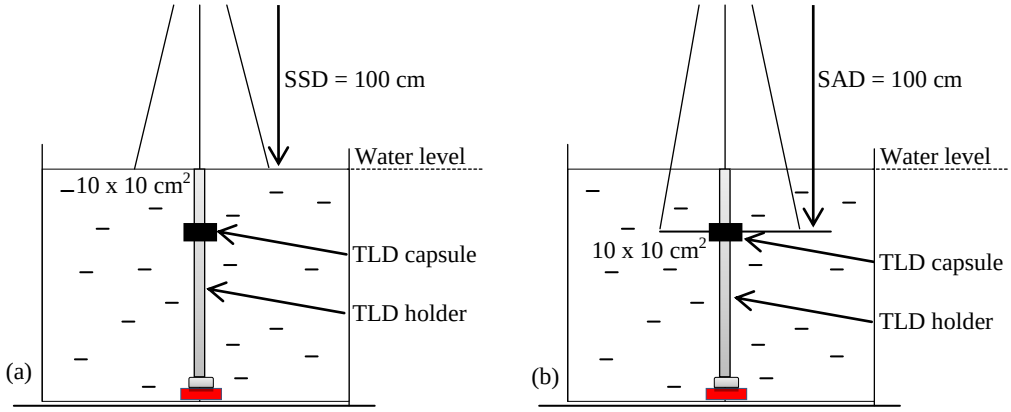

Figure 1: Two alternative geometry set-ups for irradiating the TLD capsules. A minimum dimension of water phantom is 30 cm x 30 cm. (a) The TLD capsule is placed at 10 cm depth, field size of 10 cm x 10 cm at surface and 100 cm Source-Surface Distance (SSD). (b) The TLD capsule is placed at 10 cm depth, field size of 10 cm x 10 cm at axis and 100 cm Source-Axis Distance (SAD)

Result of TLD audit was described in the form of the percentage relative deviation between the user stated dose and the measured absorbed dose where the acceptance limit of ± 5% should be complied. This value was calculated using equation 1.

$$Percentage\ deviation, \Delta\% = \left(\frac{D_{stat} - D_{TLD}}{D_{TLD}} \right) x\, 100\% \qquad \text{(Equation 1)}$$

Where the D_{TLD} is an average absorbed dose determined by the IAEA Dosimetry Laboratory from the readings of the TLDs irradiated by the participant and D_{stat} is the dose stated by the participating centre.

Participants were informed that no further investigation is required for the results within ± 5%, unless the dose recalculated by the IAEA differs from the dose stated by the participant. Participants with results exceeding the acceptance limits of ± 5% will be contacted. Participants were encouraged to review their dosimetry procedures and analyse the previous data of their TLD irradiations to identify the origin of discrepancy. The second TLD irradiations were proposed to all photon beams in the linacs to find out if the observed deviation is accidental or systematic. Participants were requested to perform second round TLD irradiations with the shortest possible

delay. If the repeat audit does not resolve the discrepancy, the IAEA experts visit to the radiotherapy centre will be carried out.

RESULTS AND DISCUSSION

A total number of 29 Malaysian participations in the IAEA/WHO TLD Postal Dose Quality Audit Service were recorded during 2011 to 2015 as presented in Table 1. Twenty two (22) participations were from private medical centres (76%) and 7 participations were from government hospitals (24%). It is also noted that not more than ten radiotherapy centres were audited every year. This number of participation is relatively small (37%) as compared with a current number of 36 radiotherapy centres having 56 units of medical linear accelerators (linac) and 4 units of tomotherapy in Malaysia (AELB, 2015).

Table 1: Number of the participating centres in the IAEA/WHO TLD Postal Dose Audit Service from 2011 to 2015

Year	Government Hospital	Private Medical Centre	Total
2011	2	5	7
2012	1	9	10
2013	0	2	2
2014	1	4	5
2015	2	3	5
Total	**7**	**22**	**29**

From 2011 to 2015, 22 radiotherapy centres in Malaysia were participated in the IAEA/WHO TLD Postal Dose Quality Audit Service. Five radiotherapy centres were took part in the programme twice, one centre with three times participation and 16 centres with once participation as shown in Table 2. A total of 70 photon beams consists of 43 beams and 27 beams produced by 6 MV and 10 MV photon beams, respectively were assessed throughout these years. Out of 29 participations, most of the centre were participate for 2 photon beams (59%) followed by 3 photon beams (17%), 1 and 4 photon beams (10% each) and 6 photon beams (4%).

Figure 2 illustrated number of photon beam that was evaluated in the IAEA/WHO TLD Postal Dose Quality Audit Service during 2011 to 2015. Results show that the numbers of photon beam that have been evaluated were reduced almost 42% (10 photon beams) in 2013 and 25% (6 photon beams) in 2014 as compared in 2012 (24 photons beams). This result might be due to: (i) limited invitation for participating in this audit by the IAEA. Priority was given to the centres having new installations, had major repairs and urgent needs due to any unusual clinical considerations. Audit was also not eligible for the audited linac in the subsequent year; and (ii) the invited radiotherapy centres were not willing to participate in the audit programme. A lack of technical staff, time constraints and fully utilised of linac might also be the reasons.

Table 2: Summary of the participating centres in the IAEA/WHO TLD Postal Dose Quality Audit Service from 2011 to 2015

Centre	**Year of Participation**	**Photon Beam**		**No. of Beam**
		6 MV	**10 MV**	
A	2011	3	3	6
	2014	2	2	4
B	2011	1	1	2
	2015	1	1	2
C	2011	1	1	2
D	2011	2	1	3
E	2011	2		2
F	2011	1	1	2
	2014	1	1	2
G	2011	4		4
H	2012	1	1	2
I	2012	1	1	2
	2015	1	1	2
J	2012	1	1	2
K	2012	1	1	2
L	2012	2	1	3
	2014	2	2	4
	2015	2	0	2
M	2012	2	1	3
N	2012	1	1	2
O	2012	1		1
P	2012	1	1	2
	2015	1	1	2
Q	2012	1		1
R	2013	2	1	3
S	2013	2	1	3
T	2014	1	1	2
U	2014	1	1	2
V	2015	1	0	1
Total		**43**	**27**	**70**

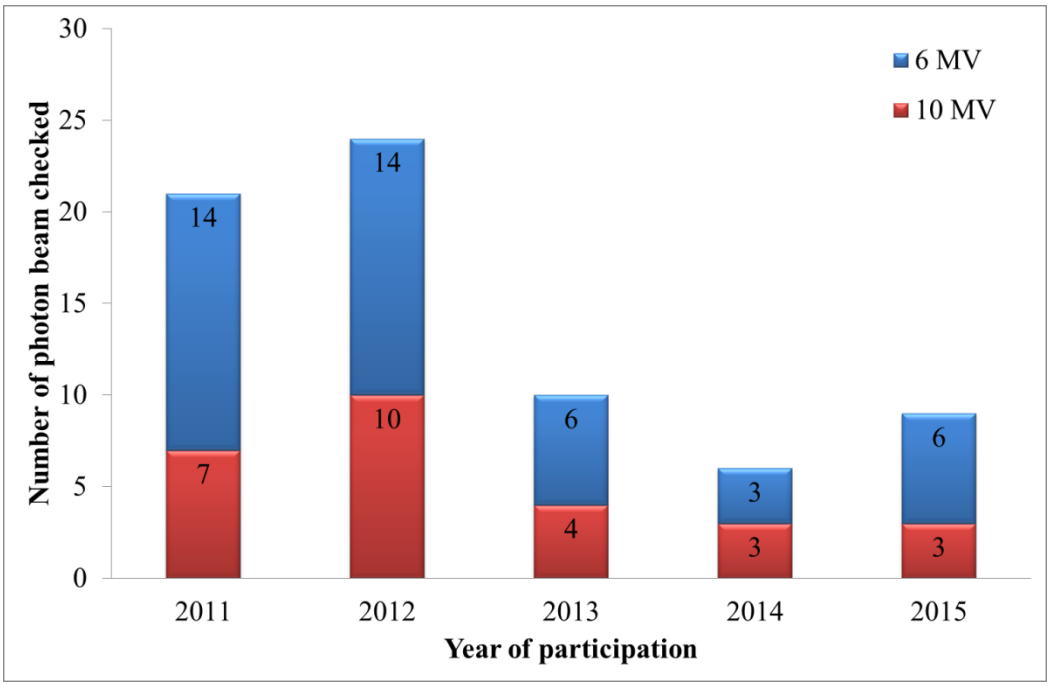

Figure 2: Number of photon beam evaluated in the IAEA/WHO TLD Postal Dose Quality Audit Service during 2011-2015. A total of 70 photon beams consists of 43 beams and 27 beams produced by 6 MV and 10 MV photon beams, respectively

Results of the IAEA/WHO TLD Postal Dose Quality Audit Service during 2011 to 2015 in Figure 3 shows that 89% (62 beams) were within the IAEA acceptance limits of ± 5%, whereas 11% (8 beams) had discrepancies more than ± 5%. All results outside the ± 5% acceptance limit which are six 6 MV photon beams and two 10 MV photon beams from six radiotherapy centres were requested to repeat the TLDs irradiation and perform investigation to find the sources of error. Half of the incompliance results were occurred in 2011 followed by two errors in 2012 and 2015. The sources of error were identified due to: (i) mistake in absorbed dose calculation; (ii) mistake in reporting the absorbed dose in data sheets; and (ii) medical physicists were unclear with the TLD irradiation procedure given in the instruction sheets especially for the first timer. In 2015, the latter was improved by providing the TLD irradiation procedure in form of video in compact disk (CD) as an additional guidance to all participating centres. After repeating irradiation, all participants improved their results as shown in Table 3.

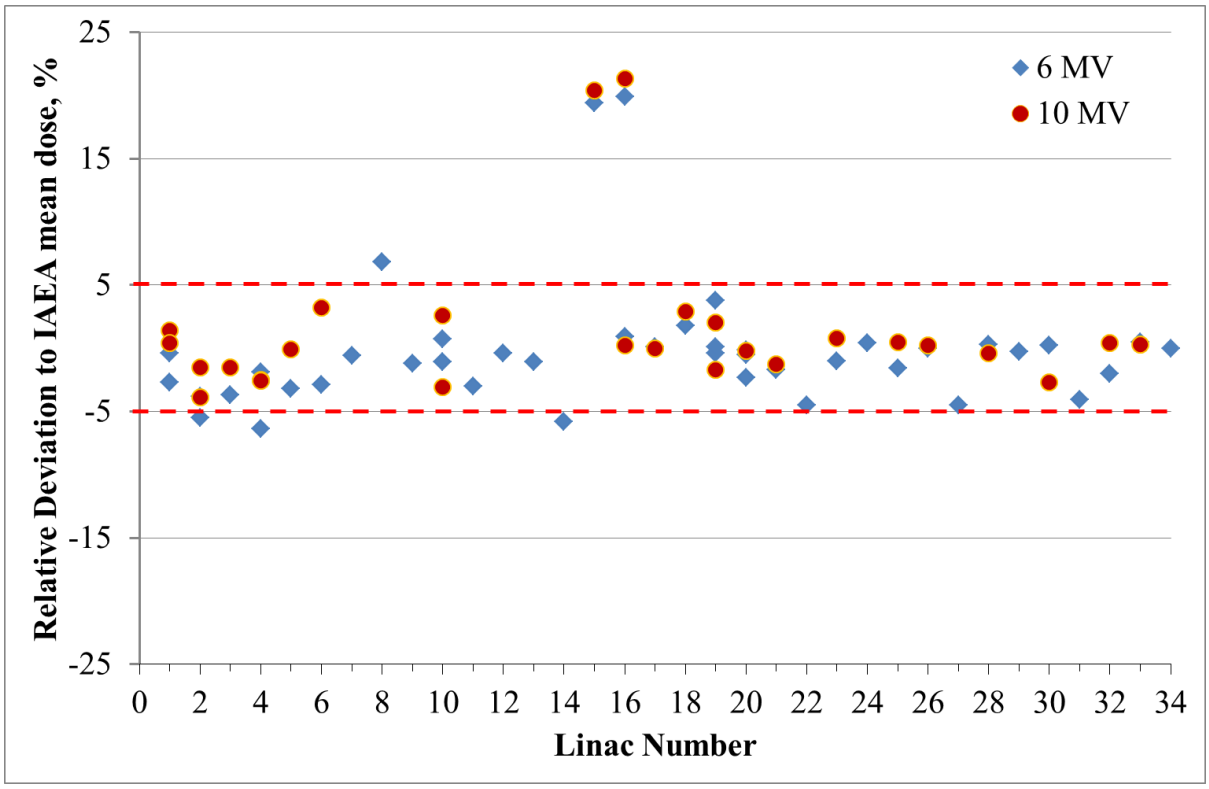

Figure 3: Summary of the results of the IAEA/WHO TLD Postal Dose Quality Audit Service during 2011 to 2015. Data points represent the percentage relative deviation between user stated dose, D_{stat} and IAEA mean dose, D_{TLD}. The IAEA considers a TLD result within ± 5% to be satisfactory. The results for 6 MV photon beam distributed within the mean of -0.864% and the standard deviation is 1.874%. The deviations vary between a minimum percentage relative deviation of -4.500% and a maximum of 3.800%. For 10 MV photon beam, the mean of the distribution is -0.170% and the standard deviation is 1.873%. The results vary between a minimum percentage relative deviation of -3.900% and a maximum percentage relative deviation of 3.200%. The uncertainty of each data is 1.8% (1 standard deviation)

Table 3: Results of repeated TLDs irradiation

Centre	Year of Participation	Linac Machine	Photon Beam	Percentage Deviation Relative to IAEA Mean Dose	
				1st Irradiation	2nd Irradiation
A	2011	2	6 MV	-5.5	0.7
B	2011	4	6 MV	-6.4	0.5
E	2011	8	6 MV	6.8	-0.5
G	2011	14	6 MV	-5.8	0.9
H	2012	15	6 MV	19.4	3.0
H	2012	15	10 MV	20.4	2.2
I	2015	16	10 MV	21.3	-0.2
I	2015	16	6 MV	19.9	-0.1

Figure 4 presents the distribution of the results of the IAEA/WHO TLD Postal Dose Quality Audit Service during 2011 to 2015. The results are expressed as percentage relative deviation between user stated dose, D_{stat} and IAEA mean dose, D_{TLD}. The mean of the distribution is -0.596% and the standard deviation is 1.874%. The deviations vary between a minimum percentage relative deviation of -4.5% and a maximum of 3.8%. Out of 70 photon beams, 41 photon beams (59%) given negative relative deviation to IAEA mean dose. This negative sign indicates that the user estimates lower dose than what is measured.

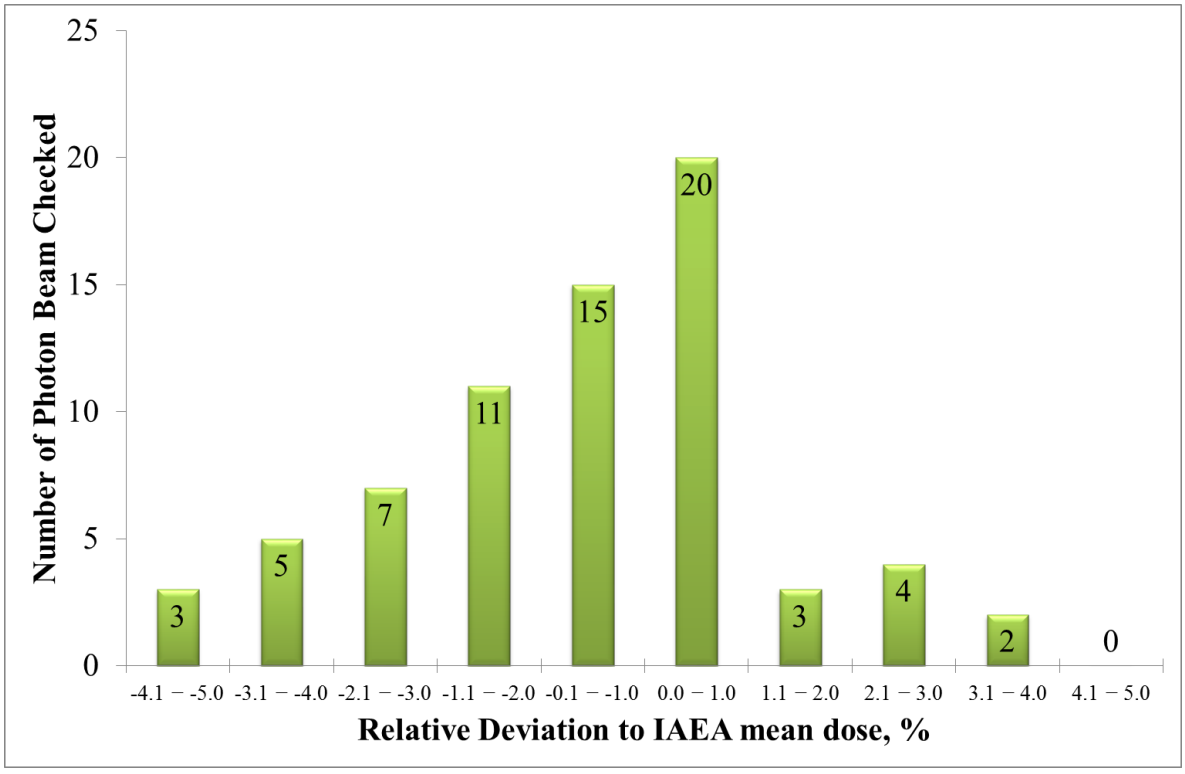

Figure 4: Distribution of the results for 43 beams of 6 MV photon and 27 beams of 10 MV photon evaluated in the IAEA/WHO TLD Postal Dose Quality Audit Service during 2011–2015. The mean of the distribution is -0.596% and the standard deviation is 1.874%.

CONCLUSIONS

The IAEA/WHO TLD Postal Dose Quality Audit Service for radiotherapy centres has been carried out to check the accuracy of photon beam produced from megavoltage X-ray teletherapy unit in Malaysia. The results obtained from 2011 to 2015 demonstrate that all photon beams comply with the acceptance limits of ± 5% except eight photon beams. The centres with the results exceeding ± 5% were followed up with second rounds of TLD irradiation which brought to a better compliance and identification of causes of errors. These audit results provide evidence that the SSDL of Malaysia having a capability to properly calibrate the radiotherapy dosemeters in compliance with the IAEA standard dosimetry protocols thus contributes to the improvement of status of radiotherapy in Malaysia. From this experience, we suggest to all radiotherapy centres in Malaysia to participate in the dosimetry audit services that are carried out by the external laboratories such as IAEA and SSDL in order to validate the performance of their megavoltage X-ray teletherapy units.

For future works, the current radiotherapy audit will be extended to include the more complex methodologies as proposed by the IAEA such as radiotherapy audit under non-reference condition for both photon and electron beams.

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