INTERCOMPARISON PROGRAMME OF DOSE CALIBRATOR USED IN NUCLEAR MEDICINE CENTRE IN MALAYSIA

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Abstract

Calibration of dose calibrator is significant in order to ensure that the equipment operates optimally and provides accurate and reliable measurements of the total activity of radiopharmaceuticals before being administered into the patients. Through this work, the response between the secondary standard dose calibrator and user's radioactivity measurement are obtained by using standard sources such as ^{57}Co, ^{133}Ba, ^{137}Cs *and* ^{60}Co. *The calibration procedure is in accordance with the NPL's (National Physical Laboratory, United Kingdom) document; Guide No. 93[1] and the IAEA's (International Atomic Energy Agency) Technical Report Series No. 454[2] is used as a reference for maintaining secondary standard dose calibrator. A total of 21 units of dose calibrator from eight nuclear medicine departments comprising five hospitals, two medical centres and one production laboratory were calibrated. The measurement results were intercompared with the national standard equipment and a baseline data was established for future comparison as well as dose optimization purposes. Results showed that the overall response of all dose calibrators are within NPL's tolerance limit of ± 10% except for 5 units which exceed the tolerance limit for radionuclide* ^{133}Ba *and* ^{57}Co.

Abstrak

Tentukuran penentukur dos adalah sangat penting bagi memastikan alat ini dapat beroperasi secara optimum dan memberikan bacaan aktiviti bahan radiofarmaseutikal yang tepat dan boleh dipercayai sebelum diberikan kepada pesakit. Dalam kajian ini, respons antara keputusan bacaan radioaktiviti penentukur dos piawai sekunder dan penentukur dos pengguna telah diperolehi dengan menggunakan punca-punca radioaktif piawai iaitu ^{57}Co, ^{133}Ba, ^{137}Cs *dan* ^{60}Co. *Prosedur tentukuran ini adalah berdasarkan dokumen oleh NPL iaitu Guide No. 93[1] dan dokumen Technical Report Series No. 454 [2] IAEA diguna sebagai rujukan untuk penyelenggaraan penentukur dos piawai sekunder. Sebanyak 21 unit penentukur dos yang dimiliki oleh 8 jabatan perubatan nuklear yang terdiri daripada 5 hospital, 2 pusat perubatan dan 1 makmal pengeluaran telah ditentukur. Keputusan pengukuran telah dibandingkan dengan peralatan piawai kebangsaan dan data asas telah diwujudkan bertujuan untuk perbandingan pada masa depan dan juga pengoptimum dos. Keputusan menunjukkan bahawa hampir kesemua penentukur dos memberikan respons yang memenuhi had toleransi ± 10% seperti yang disarankan oleh NPL kecuali 5 unit penentukur dos yang mencatatkan bacaan melebihi had toleransi yang dibenarkan iaitu bagi radionuklid* ^{133}Ba *dan* ^{57}Co.

Keywords: Intercomparison programme, nuclear medicine, dose calibrator

RESEARCH BACKGROUND

The diagnostic and therapeutic radiopharmaceutical dosages to patient should be measured accurately and administered optimally to ensure desired results. The administration of appropriate quantity of radiopharmaceutical into the patient depends on the accuracy of the dose calibrator used which is verified through its calibration by the national standard laboratory. It is the aim of the Medical Physics Group, as a national standard laboratory in this field, to provide calibration services in ensuring reliability and accuracy of the measurements made by these nuclear medicine equipments. The need for high level of accuracy in measurement of total activity of radio pharmaceutical led to the Medical Physics to establish the calibration procedures for dose calibrators. In addition, it is important to make sure that the dose calibrators used in every nuclear medicine department provides readings that are traceable to the national standard measurement system. Ideally, the dose calibrators should be calibrated within an interval of not exceeding one year to ensure correct operation and that overall characteristics of the instrument are within acceptable limits.

Currently, there is no specific legal requirement by the national authority on the possession, use, calibration and check of dose calibrators. However, all nuclear medicine facilities are encouraged to possess a dose calibrator and use it to measure the amount of activity administered to each patient. In Malaysia, there are about 14 nuclear medicine departments and more than 30 units of dose calibrators in used. Upon installation, and thereafter at a regular interval, each dose calibrator should be calibrated for accuracy, scale linearity and geometry dependence of the reading by assaying radioactive sources. The unit should be adjusted, repaired or replaced as appropriate if reading deviates by more than 10% as compared to the national standard. In addition, the unit should be checked for constancy with a dedicated standard check source at the beginning of each day of use.

Equipment with prolonged exposure to uncontrolled environmental condition, poor maintenance and aging may affect the overall performance of the dose calibrator leading to administration of inaccurate or wrong dosage. In addition, continued usage of poorly maintained and old equipment, without a proper calibration create more doubt on the accuracy and reliability of radioactivity measurement. Currently, maintenance and calibration of dose calibrator is not a mandatory requirement.

It is of our interest to investigate the compliance of all dose calibrators used throughout the country is within the national tolerance limit. This can be achieved by making intercomparison measurement with the national standard instrument by using travelling standard radioactive sources. In this particular study, the four travelling standard radioactive sources i.e. ^{57}Co, ^{133}Ba, ^{137}Cs and ^{60}Co were used for calibrating the dose calibrator and these sources were chosen because of the similarity in terms of gamma energy as compared to the widely used radiopharmaceuticals namely ^{99m}Tc, ^{131}I and ^{18}F. The measurement results obtained in this study are treated as a baseline data for future comparison and could be used for dose optimization purposes.

MATERIAL AND METHOD

The IAEA's Technical Report Series No. 454 is adhered for maintaining the consistency of secondary standard radionuclide calibrator. Meanwhile, the calibration procedure for dose calibrator was in accordance with the recommendation of the NPL's document, Guide No. 93. Ideally, as in other calibration works, the dose calibrator should be calibrated against a standard instrument in a laboratory under standard controlled conditions. Variation of climatic conditions such as humidity, temperature and pressure on site may result to undesirable effects on instrument reading. On the contrary, rough handling and vibration as well as possibility of exposure to abnormal atmospheric conditions during transportation from nuclear medicine facilities to the calibration laboratory may also introduce an adverse effect on the reading of this sensitive equipment. Based on a professional judgment and irrespective of logistic, most users prefer to calibrate their equipment on site for a lesser risk of malfunction and also to maintain the similar environmental condition during calibration and clinical measurement. Therefore, an on site calibration procedure using the travelling standard radioactive sources i.e. ^{57}Co, ^{133}Ba, ^{137}Cs and ^{60}Co taking into account the requirement of the above standard protocols has been established for this study.

From observation, all calibrators in nuclear medicine facility were located in stable room temperature within the range of 20-30^{o}C with the atmospheric pressure of between 992-1006 mbar and maximum relative humidity of 70%. The system was also ensured to operate at minimum level of background radiation and as constant as possible. These conditions are significant to avoid any interference to the ionization chamber and electronic systems that may lead to unfavorable measurement results.

A calibrated Fidelis Secondary Standard Dose Calibrator together with a few radioactive sources such as ^{57}Co, ^{133}Ba, ^{137}Cs and ^{60}Co which is traceable to National Physical laboratory (NPL), UK is used as the national standard instrument. System consistency is maintained through a monthly check by using all the radioactive sources which are also used as travelling standard radioactive sources. The standard dose calibrator shows long term system stability of ± 2% and complies with the requirement set by the IAEA for such a measuring system. Even though, the activities of standard radioactive sources were most unlikely to change during transportation but the readings were verified before and after the site visit to ensure the activities remained unchanged. Based on two years experience, the activities before and after the site visit were found to vary by approximately ± 2% which may be mainly due to changes in geometrical set-up for the measurement.

For the overall system accuracy measurement, the standard radioactive sources were assayed in the dose calibrator under test. Response of radioactivity measurement for ^{57}Co, ^{133}Ba, ^{137}Cs and ^{60}Co was obtained by making the comparison between the reading of reference instrument and user's dose calibrator. The response values for the above sources should fall within the tolerance limit of ±10% as quoted in the calibration certificate given by NPL as well as MGPG No.93. In addition, as described in the above protocols, the dose calibrators were also checked for system stability, dipper and well liner contamination, constancy, linearity and also geometry dependence.

System was checked on zero setting, background radiation and system voltage before making any measurement to ensure that the system is in stable and optimum condition during calibration. The contamination for dipper and well liner is ensured to be less than 3μCi otherwise they need to be cleaned or replaced. Using ^{137}Cs source, the reproducibility of the activity values over a period of time was determined. Record shows that the maximum deviation of reproducibility for all dose calibrators in this study is ± 2.5%. The linearity test was carried out in order to confirm that the same setting could be used to indicate the correct activity of radionuclide over the entire measurement range of the dose calibrator. The test could be done using decay method or shield method depending on the system suitability. Shield method is more practical to be used due to its immediate reading and will take only six minutes to obtain measurements to the tenth half live compared to the decay method that may need 3 days to complete the same process. For ^{99}Tc of 200 mCi with a complete set of lineator, activities ranging down to 0.2 mCi of initial activities may be expected and this is sufficient for this purpose. Geometry test identifies the variation of readings for different positions within the ionization chamber using ^{57}Co. From the observation, the indicated readings of activity for linearity and geometry tests was varied within ± 9.5% and ± 9.3% (within the position of 10cm from the bottom) respectively and these comply with the acceptable limit of ± 10%.

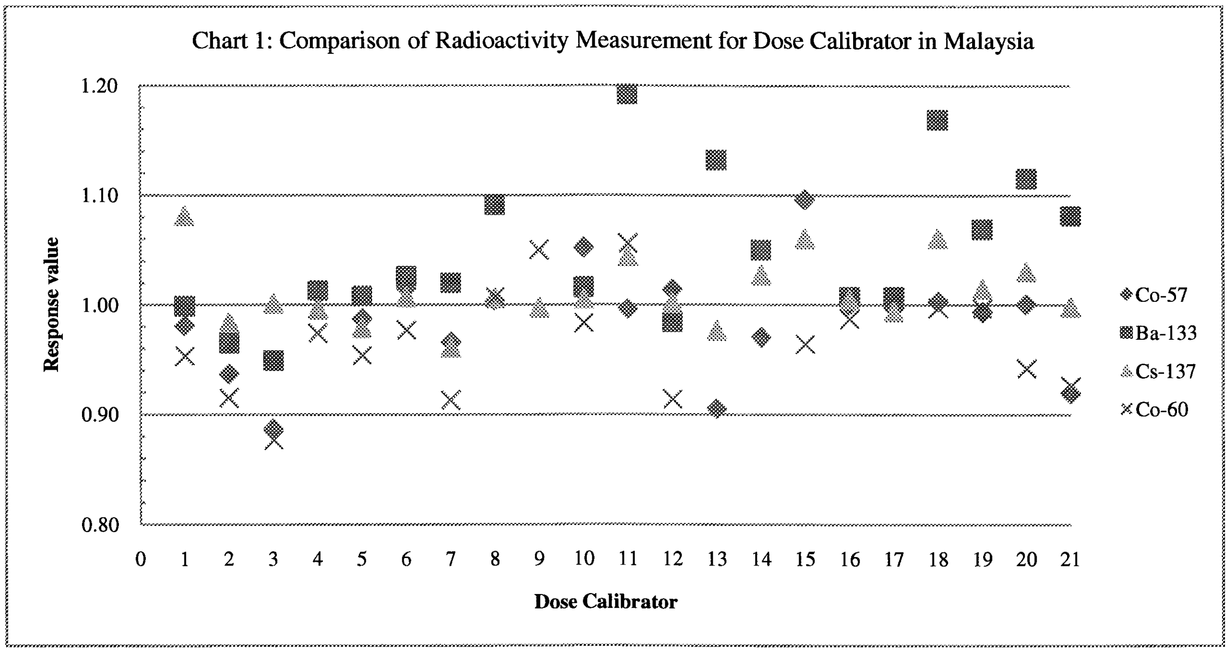
Since the past two and half years, a total of 21 radioactivity dose calibrators of various products and design from eight nuclear medicine facilities were calibrated on site and in the Medical Physics laboratory. Details of equipment are shown in Table 1.

Table 1: Radioactivity dose calibrators of various products and design installed at eight nuclear medicine facilities.

No.	Nuclear Medicine Center	Manufacturer	Dose Calibrator Model	Identification No.	Usage	Age (year)
1.	NM-1	Biodex	Atomlab 200	1	^{99m}Tc, ^{131}I, FDG	>10
			Atomlab 200	2	^{99m}Tc, ^{131}I, FDG	>10
			Atomlab 200	3	^{99m}Tc, ^{131}I, FDG	>10
			Atomlab 300	4	^{99m}Tc, ^{131}I, FDG	< 5
			Atomlab 300	5	^{99m}Tc, ^{131}I, FDG	< 5
			Atomlab 300	6	^{99m}Tc, ^{131}I, FDG	< 5
2.	NM-2	Biodex	Atomlab 300	7	FDG	< 5
			Atomlab 300	8	FDG	< 5
			Atomlab 300	9	FDG	< 5
3.	NM-3	Biodex	Atomlab 100	10	^{99m}Tc, ^{131}I	< 5
		Capintec	CRC-12R	11	^{99m}Tc, ^{131}I	> 25
4.	NM-4	Biodex	Atomlab 200	12	^{99m}Tc	> 5
		PTW	Curiementor 3	13	^{99m}Tc	< 5
5.	NM-5	Capintec	CRC-15B	14	^{99m}Tc	< 5
6.	NM-6	PTW	Curiementor 3	15	^{99m}Tc, FDG	< 5
7.	NM-7	Capintec	CRC-15PET	16	FDG	< 5
8.	NM-8	Biodex	Atomlab 200	17	^{99m}Tc, ^{99}Mo	< 5
		Capintec	CRC-12R	18	^{99m}Tc, ^{99}Mo	> 10
			CRC-127R	19	^{99m}Tc, ^{99}Mo	> 5
			CRC-127R	20	^{99m}Tc, ^{99}Mo	> 25
			CRC-712MH	21	^{99m}Tc, ^{99}Mo	< 5

RESULT AND DISCUSSION

Chart 1 summarizes the result for intercomparison programme of radioactivity measurement for dose calibrator in Malaysia. Apparently, there are 5 calibrators numbered 3, 11, 13, 18 and 20 which exceeded the tolerance limit while the others were gave results within the tolerance limit of ± 10% for all standard sources. Dose calibrators 11, 13, 18 and 20 showed deviation of response for radionuclide ^{133}Ba of 19.2%, 13.2%, 16.9% and 11.5% respectively while dose calibrator 3 deviate by 11.3% for radionuclide ^{57}Co and 12.3% for radionuclide ^{60}Co.



Response value of dose calibrator 3 to ^{57}Co and ^{60}Co source was found to exceed the stipulated limit. Measurement results confirmed that the system was in stable condition with consistent readings with sufficient high voltage supplied to the ionization chamber and no contamination of the dipper and well liner. It was suspected that electrical fault may contribute to the system performance due to high background radiation level displayed compared to the other dose calibrator at the same location. Even though, the calibrator gave a higher reading for radionuclide ^{60}Co but it was no significance since currently in the country, the highest energy of radionuclide used in nuclear medicine is 511 keV for Fludeoxyglucose (^{18}F-FDG). The manufacturer claimed that the equipment can be operated at wide energy range, from 25 keV to 3 MeV but poor maintenance might contribute to failure of the energy response dependence for the system for low and high gamma energy.

Although dose calibrators 11, 18 and 20 indicated measurement results of inadequate accuracy in exceeding the optimum standard but were still acceptable as the requirement of correction for ^{133}Ba activity is estimated to be about ± 10% for that brand of calibrator (as specified by manufacturer's specification). User should add 10% to the meter reading if the ^{133}Ba is in a glass vial or subtract 10% if it is in a plastic vial. This meant that we need to minus the measurement reading because the standard sources that were used in the measurement were in plastic container, thus the final result were accurate to within the tolerance limit. In addition, aging factor is also a valid reason for not being satisfactory in performance considering that these calibrators had been in operation for almost 25 years. Although the manufacturer's specification claimed the system accuracy should fall within ± 3% but it is an accepted fact that performance will certainly deteriorate with age of the instrument. The electronic systems changed with time especially under prolonged exposure to uncontrolled environmental conditions.

Calibrator 13 has not been serviced or re-calibrated by the supplier for sometime and hence showed higher value of response for radionuclide ^{133}Ba. This is may be due to the function key for ^{133}Ba was preset based on the initial back-dated activity measured by the manufacturer. Unfortunately, there is no operating manual available to enable renewing or re-adjusting the setting of the function key. As a result, the reading for standard ^{133}Ba is over-estimated as expected and remained out of tolerance limit. For continued service of this equipment, the reading has to be corrected as appropriate and effort should be geared towards a properly scheduled maintenance program. The sensitivity of most ionization chambers may be brought back to unity by simple adjustment which is normally accessible by calibrating laboratory personnel.

As granted by the instrument's manufacturer, dose calibrator is a long lasting instrument that could be useful for more than 30 years. As can be seen in Table 1, dose calibrator 1 and 2 are still in good condition although they have been used for more than 10 years. However, aging factor might be a reason contributing to the inaccuracy of the calibrator. Dose calibrator 3, was in use for more than 10 years and dose calibrators 11, 18 and 20 have been in operation for more than 25 years. Without proper routine maintenance such as regular daily system check and constancy check, long term system stability could not be maintained. In addition, system storage and operational environment should be controlled to the room temperature in the range of 0-30^{o}C with 910-1050 mbar of atmospheric pressure and maximum relative humidity of 80%. The calibrator should also be avoided to be located in areas with high change of background radiation place e.g. in a hot lab or in a cyclotron room that will affect activity measurement. Although, the chamber is shielded however, the radiation from external sources will easily penetrate the shield and affect the activity measurement.

CONCLUSION

As a conclusion, except for 5 units of dose calibrators, the dose calibrators used in nuclear medicine departments in Malaysia generally gave accurate result to within ± 10%. This complies with the recommendations of NPL. Data presented in this paper only covers a small number of dose calibrators in Malaysia but it is very important to be used as a baseline data for future reference. Further research should be continued to cover all dose calibrators used in nuclear medicine facilities in Malaysia.

Proper routine maintenance such as regular daily system check and constancy check should be performed by the user to ensure long term system stability can be maintained. In addition, system should be stored and operated within controlled environment of constant room temperature, atmospheric pressure and relative humidity (as specified in manufacturer's specification). The calibrator should also be avoided to be located in areas with high change of background radiation that will affect activity measurement. If the chamber is to be located in a high-activity area, additional shield would be necessary.

Calibration service locally should also be provided to encourage the nuclear medicine centre to recalibrate their dose calibrator annually for optimization of dose to patient purposes. Previously, the dose calibrator had to be sent abroad for recalibration and the cost is about RM 15,000 per unit. Besides the cost, users have to consider the time factor they will be without their dose calibrators if sent abroad for recalibration which might affect the medical service to patients. Therefore, Nuclear Malaysia as a national calibration laboratory in this field is ready to take the responsibility to provide the calibration service.

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