

Variation in Dosimeter Calibration Factor (N_{DW}) Over a Period of 20 Years

Manoj Kumar Semwal, Harishchandra Gupta¹, Sakshi Singhal¹, Ashok Kumar, Aruna Kaushik¹

Department of Radiation Oncology, Army Hospital Research and Referral, ¹Division of Clinical PET, Institute of Nuclear Medicine and Allied Sciences, Delhi, India

Abstract

Long delays in renewal of calibration of secondary standards radiation dosimeters in radiation oncology centers due to the COVID19 pandemic have aroused concerns regarding accuracy in dose delivery to patients. The concerns are mainly due to the uncertainty in the absorbed dose to water calibration factor (N_{DW}) over a period of time. In this study, the N_{DW} factor for two ion chambers, thimble type (Farmer) and parallel plate type (Markus), used in most of the radiotherapy centers, were retrospectively reviewed for 20 years. The calibration on all occasions except once was carried out at the Secondary Standards Dosimetry Laboratory, Bhabha Atomic Research Centre, Mumbai. The change in the N_{DW} factor over this period was $< \pm 3\%$. We, therefore, believe that a dosimeter with no history of repairs showed reasonable stability in the N_{DW} factor over a long period.

Keywords: Calibration factors, farmer chamber, Markus chamber, secondary standards dosimeter

Received on: 19-03-2021

Review completed on: 17-04-2021

Accepted on: 23-04-2021

Published on: 07-08-2021

INTRODUCTION

The absorbed dose to water calibration factor, N_{DW} , is a crucial link for the accurate determination of dose delivered to patients during radiotherapy treatment.^[1-3] Unknown variation in N_{DW} value with time may lead to unacceptable uncertainties in the delivered dose. Thus, renewal of calibration factor has to be done every 2 or 3 years as per the regulatory norms of a country.^[4] As it is known to all of us working in radiotherapy clinics in India, the prevailing COVID 19 pandemic has resulted in long delays in the renewal of calibration of clinical dosimeters in many radiotherapy centers. This happened mainly because there is only one accredited calibration laboratory for clinical dosimeters in India namely the Secondary Standards Dosimetry Laboratory (SSDL), at Bhabha Atomic Research Centre (BARC), Mumbai.^[5] The delays have created unprecedented challenges and concerns for the clinical medical physicists as well as for the regulators. The concerns primarily arise from the unknown variations that may occur in the calibration factors in the absence of timely renewal of calibration.

In this retrospective analysis, the values of absorbed dose to water calibration factors (N_{DW}) for a secondary standard

dosimeter (SSD) comprising two ion-chambers have been reviewed over a period of 20 years involving seven cycles of calibration from 2001 to 2021. The dosimeter has been extensively used in the clinic over these years. The intention of submitting this article for publication is to apprise other clinical medical physicists and physicians of the variations in N_{DW} factors over a long period. This can help them in taking an informed decision whether to use or not to use the dosimeter, whose calibration has got delayed, for dose measurements in these unprecedented times.

MATERIALS AND METHODS

A cylindrical Farmer-type ion-chamber (model 30006), a parallel plate ion-chamber (model Markus 23343) and an electrometer (model UnidosE) - all three from Physikalisch-Technische Werkstätten (PTW), Freiburg, Germany- were used in this study on five of the seven calibration occasions.

Address for correspondence: Dr. Manoj Kumar Semwal, Department of Radiation Oncology, Army Hospital Research and Referral, Subroto Park, Dhaura Kuan, Delhi - 110 010, India. E-mail: manojsemwal@yahoo.co.in

Access this article online

Quick Response Code:



Website:
www.jmp.org.in

DOI:
10.4103/jmp.JMP_42_21

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: WKHLRPMedknow_reprints@wolterskluwer.com

How to cite this article: Semwal MK, Gupta H, Singhal S, Kumar A, Kaushik A. Variation in dosimeter calibration factor (N_{DW}) over a period of 20 years. J Med Phys 2021;46:125-7.

On the last two occasions, the electrometer was changed to model Max 4000 from Standard Imaging, Middleton (WI), USA. The calibration laboratory was SSDL-BARC, Mumbai on 06 out of 07 occasions and PTW, Freiburg, Germany's accredited laboratory on one occasion. The calibration of the SSD was carried out in a Co-60 beam in a water phantom and the calibration laboratories provided N_{DW} (absorbed dose to water) calibration factors for both the chambers. Reference temperature and pressure conditions for the determination of N_{DW} values were 20°C and 1013.2 mbar for BARC and 22°C and 1013.2 mbar for PTW laboratory, respectively.

It is to be noted that no major repairs were carried out either on the chambers or the electrometers in the study period. The signal cable, however, was changed once during the calibration process when the calibration laboratory had to use its own signal cable (2021).

RESULTS

Table 1 provides the N_{DW} values for each calibration cycle for the Farmer and the Markus chambers along with other relevant details. The slight reduction in N_{DW} values was observed with a reduction in polarizing voltage for the Farmer chamber. Table 2 displays the percentage deviation between consecutive N_{DW} values (provided at an interval of 3 to 4 years) over a period of 20 years for both the chambers. The maximum deviation of 2.72% in N_{DW} was obtained for the calibrations done in October 2001 and July 2004 in respect of the Farmer chamber at PTW Germany and SSDL, BARC, respectively. The average percentage deviation in consecutive N_{DW} values was found to be 0.87% with a deviation of 1.73% at the upper 95% confidence level for the Farmer chamber. For calibrations done at SSDL, BARC, the average percentage deviations in the consecutive N_{DW} values was 0.49% with a deviation of 0.91% at the upper 95% confidence level for the Farmer chamber. For the Markus chamber, the average percentage deviation between consecutive N_{DW} values was found to be 0.59% with a deviation of 1% at the upper 95% confidence level.

Table 3 displays variation in N_{DW} values with respect to a fixed initial N_{DW} value. The maximum deviation noticed was 3.74% for the Farmer chamber at 20 years. Interestingly, if the initial reference N_{DW} value for calculation of subsequent variations is taken as the first SSDL-BARC value, the maximum deviations

noticed were 1.05% and 0.91% for Farmer and Markus chambers, respectively.

DISCUSSION

As per International Commission on Radiation Unit and Measurements recommendations, the accuracy of the physical dosimetry has to be within $\pm 3\%$ to ensure overall $\pm 5\%$ accuracy in the dose delivery to a patient.^[4] In the present pandemic scenario renewal of calibration of absolute dosimeters for many radiotherapy centers has been delayed by about a year beyond the stipulated 3-year period. Hence the change in N_{DW} factor between two consecutive cycles (3-year) is the most relevant deviation to be looked for. The maximum deviation in consecutive N_{DW} values is 1.1% for six cycles of calibration involving SSDL- BARC. Only in one instance when there was a change of calibration laboratory from PTW Germany (2001) to SSDL-BARC (2004) did we observe a deviation of 2.70%. Ideally, such a difference due to a change of laboratories should not exist. We have no firm explanation for this difference except for speculating that the reason could be related to differences in primary/reference standards to which these calibration laboratories trace their secondary standards.^[6] In the case of SSDL-BARC, the reference standard was NPL, UK whereas in the case of PTW it was the German National Standards Laboratory (PTB, Braunschweig). From the data, it was evident that the Markus parallel plate chamber is more stable as compared to the thimble chamber. We also observed that with decrease in polarizing voltage from 400 V to 300 V for the Farmer chamber (March 2017 and February 2021) there was a slight decrease in N_{DW} value for the Farmer chamber. This could be related to decrease in ion collection efficiency with polarizing voltage. Karzmark reported accuracy of $\pm 2\%$ in ionization chamber measurements taken over a period of 14 years and even calling off the need of calibration every 2 years.^[7]

CONCLUSION

Overall, we observed that the performance of the ion-chamber-based dosimeter was quite stable over 20 years in a clinical environment. We believe that this stability should be applicable to all quality SSDs of different makes available in the market. Therefore, in the absence of timely renewal of calibration due to unforeseen and extraordinary situations such as the present

Table 1: Calibration factors (N_{DW}) for PTW Farmer chamber and PTW Markus chamber

Date of calibration	Calibration laboratory	Electrometer used	N_{DW} farmer chamber (Gy/C)	Polarising Voltage (V)	N_{DW} markus chamber (Gy/C)	Polarising Voltage (V)
October-2001	PTW, Germany	UnidosE	5.181E+07	400	-	-
July-2004	SSDL, BARC	UnidosE	5.040E+07	400	5.410E+08	300
November-2007	SSDL, BARC	UnidosE	5.017E+07	400	-	-
October-2010	SSDL, BARC	UnidosE	5.012E+07	400	5.458E+08	300
September-2014	SSDL, BARC	UnidosE	5.048E+07	400	5.459E+08	300
March-2017	SSDL, BARC	Max 4000	4.992E+07	300	5.416E+08	300
February-2021	SSDL, BARC	Max 4000	4.987E+07	300	5.452E+08	300

SSDL: Secondary standards dosimetry laboratory, BARC: Bhabha Atomic Research Centre

Table 2: Percentage deviations between consecutive N_{DW} values obtained for 20 years for the Farmer chamber and the Markus chamber

Date of calibration	Percentage deviation between consecutive readings for Farmer chamber (%)	Percentage deviation between consecutive readings for Markus chamber (%)
October-2001	-	-
July-2004	2.72	-
November-2007	0.456	-
October-2010	0.099	0.887
September-2014	0.718	0.0183
March-2017	1.109	0.787
February-2021	0.100	0.664

Table 3: Percentage deviation of N_{DW} values from the initial calibration values provided by the calibration laboratories

Date	Deviation of N_{DW} values with respect to October 2001 (PTW Germany) value for Farmer chamber (%)	Deviation of N_{DW} values with respect to July 2004 (BARC) value for Farmer chamber (%)	Deviation of N_{DW} values with respect to July 2004 (BARC) value for Markus chamber (%)
July-04	2.72	-	-
November-07	3.165	0.4563	-
October-10	3.262	0.555	0.887
September-14	2.567	0.718	0.906
March-17	3.648	0.952	0.111
February-21	3.744	1.052	0.776

BARC: Bhabha Atomic Research Centre

pandemic, an informed decision can be taken by the treating physicians and medical physicists whether to continue with the existing calibration factors beyond the stipulated recalibration period of 3 years or suspend treatment till the availability of updated calibration factors. However, the long-term stability of the dosimeters depicted in this study does not imply the extension of the calibration period beyond 3 years under normal conditions and calibrations must be renewed within the prescribed duration.

Financial Support and Sponsorship

Nil

Conflict of interest

There are no conflicts of interest.

REFERENCES

- Ravichandran R, Binukumar JP, Davis CA. Estimation of absorbed dose in clinical radiotherapy linear accelerator beams: Effect of ion chamber calibration and long-term stability. *J Med Phys* 2013;38:205-9.
- Minniti R, Shobe J, Stephen M Seltzer, Chen-Mayer HH, Domen SR. Absorbed dose to water calibration of ionization chambers in a ^{60}Co Gamma-Ray Beam. Special Publication (NIST SP) 2006;250:250-74.
- Castro P, García-Vicente F, Mínguez C, Floriano A, Sevillano D, Pérez L, *et al.* Study of the uncertainty in the determination of the absorbed dose to water during external beam radiotherapy calibration. *J Appl Clin Med Phys* 2008;9:70-86.
- IAEA, International Atomic Energy Agency, Absorbed Dose Determination in External Beam Radiotherapy: An International Code of Practice for Dosimetry based on Standards of Absorbed Dose to Water, Technical Reports Series No. 398. Vienna: IAEA; 2001.
- Kulkarni MS. Role of standards in radiation protection. *Radiat Prot Environ* 2018;41:107-9.
- Muir BR. Ion chamber absorbed dose calibration coefficients, NDW, measured at ADCLs: Distribution analysis and stability. *Med Phys* 2015;42:1546-54.
- Karzmark CJ. Concerning radiotherapy standard dose meter calibration. *Med Phys* 1980;7:574-5.