Proton Beam Dosimetry Intercomparison

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ABSTRACT

A new protocol for dosimetry in external beam radiotherapy is published by the Japan Society of Medical Physics (JSMP) in 2002. The protocol deals with proton and heavy ion beams as well as photon and electron beams, in accordance with IAEA Technical Report Series No. 398. To establish inter-institutional uniformity in proton beam dosimetry, an intercomparison program was carried out with the new protocol. The absorbed doses are measured with different cylindrical ionization chambers in a water phantom at a position of 30-mm residual range for a proton beam, that had range of 155 mm and a spread out Bragg peak (SOBP) of 60-mm width. As a result, the intercomparison showed that the use of the new protocol would improve the +/- 1.0 % (one standard deviation) and 2.7 % (maximum discrepancy) differences in absorbed doses stated by the participating institutions to +/- 0.3% and 0.9 %, respectively. The new protocol will be adopted by all of the participants.

Keywords: Proton Beam, dosimetry, intercomparison, dosimetry protocol.

1. INTRODUCTION

Japan Society of Medical Physics (JSMP) is publishing a new code of practice for dosimetry, titled "Standard Dosimetry of Absorbed Dose in External Beam Radiotherapy (Standard Dosimetry 01)" [1]. The principal purposes for the revision are to adopt the absorbed-dose-to-water based formalism, to update physical data, to harmonize with international protocols, to note narrow beam dosimetry and to deal with proton and carbon beams. Recently, the number of proton and carbon beam therapy facilities has increased in Japan[2]. International organizations, such as ICRU, recommend periodic dosimetry intercomparison to verify inter-institutional uniformity of proton beam dosimetry[3-4]. Although the some of the authors had attended international dosimetry intercomparisons for proton and carbon beams[5-6], the domestic intercomparison involving new facilities had not been carried out in Japan. Then, using the new dosimetry protocol, the first nationwide proton dosimetry intercomparison was held at Proton Medical Research Center (PMRC) of University of Tsukuba, with the participation of National Institute of Radiological Sciences (NIRS), PMRC, National Cancer Center East (NCC), Hyogo Ion Beam Medical Center (HIBMC) and Wakasa Wan Energy Research Center (WERC) personnel. The aims of the intercomparison were to evaluate the differences in absorbed dose determined at different proton therapy facilities in Japan and to establish consistency in absorbed dose to water for proton beams with the new protocol.

2. MATERIAL AND METHODS

2.1 . The new Japanese dosimetry protocol

The new Japanese dosimetry protocol mostly follows IAEA Technical reports series No. 398[7], titled "Absorbed Dose Determination in External Beam Radiotherapy: An International Code of Practice for Dosimetry Based on Standards of Absorbed Dose to Water", which is based on N_{D,w,Q_0}, i.e., the calibration factor in terms of absorbed dose to water for a dosimeter at a reference beam quality Q_0. According to the protocols, absorbed dose is given by

$$D_{w,Q} = M_Q N_{D,w,Q_0} k_{Q,Q_0} \qquad (1)$$

where

$D_{w,Q}$ is the absorbed dose to water at the reference depth in a water phantom irradiated by a beam of quality Q
M_Q is the reading of a dosimeter at quality Q, corrected for influence quantities other than beam quality,

and k_{QQ_0} is the factor to correct for the difference between the response of an ionization chamber in the reference beam quality Q_0 used for calibrating the chamber and in the actual user beam quality Q.

However, N_{D,wQ_0} has not been supplied by the primary standard dosimetry laboratory in Japan. The new Japanese protocol alternatively gives the calculated values of $N_{D,wQ_0}/N_{XQ_0}$, which depend upon ionization chambers. The value of N_{XQ_0} is the calibration factor in terms of exposure for a dosimeter at a reference beam quality Q_0, which is supplied by the Japanese standard dosimetry laboratories.

2.2 . Proton beam irradiation

The proton beam used for the intercomparison had range of 155 mm and spread out Bragg peak (SOBP) of 60-mm width in water. The field size of the proton beam was 15 cm× 15 cm. Each cylindrical ionization chamber was inserted in a water phantom with a 1-mm thick PMMA sleeve for waterproof. The center of the chamber was set at the middle of the SOBP and the field. Each chamber was irradiated with preset proton beam for which a given signal was recorded by the upstream beam monitor. Participants separately determined the absorbed dose to water per monitor unit (Gy/MU) from the ionization chamber measurements, using both their respective dosimetry procedures and the new protocol. Before the proton beam irradiation, exposure measurements in a ^{60}Co γ-ray field with all ionization chambers were also carried out for comparison.

3. RESULTS AND DISCUSSION

Table I summarizes the results of the intercomparison. The "Old" column shows the absorbed dose to water per monitor unit (Gy/MU) which was determined with the procedure routinely used at each institute. The "New" column shows the values determined by the new Japanese protocol. In "Old" column, a maximum discrepancy of 2.7% exists and a standard deviation of 1% is shown. In this case, participants calculated the absorbed dose with different dosimetric parameters, i.e., w-value for proton beam, proton stopping power ratio etc., according to the respective dosimetry procedures. The lack of unity in dosimetry procedures among the participants resulted in the observed significant discrepancies.

Table I. The results from the proton dosimetry intercomparison

Institution	Ionization Chamber	Cobalt 60	Proton/Absorbed Dose to Water		Ratio
		Exposure(C/kg)	Old (Gy/MU)	New (Gy/MU)	New/Old
NIRS	PTW30001(ICT2)	0.00902	0.1121	0.1125	1.004
	PTW30001(ICS0)	0.00899	0.1119	0.1124	1.004
PMRC	C-110(0.6ml)#823	● 0.00898	0.1132	0.1125	0.994
	C-110(0.2ml)#944	0.00898	0.1124	0.1116	0.993
NCC	C-110(0.6ml)#754	0.00895	0.1140	0.1121	0.983
	C-110(0.6ml)#967	0.00901	0.1149	0.1129	0.983
HIBMC	PTW30001	0.00895	0.1144	0.1129	0.987
	PTW31003	0.00902	0.1145	0.1133	0.989
WERC	PTW30001	0.00894	0.1131	0.1123	0.993
Mean		0.00898	0.1134	0.1125	0.992
Standard Deviation/Mean (%)		0.3	1.0	0.3	0.8

On the other hand, a maximum discrepancy of 1.0% and a standard deviation of 0.3% is shown in the "New" column. The standard deviation is equal to that of exposure measurements in a ^{60}Co γ-ray field. This means that the obtained consistency of proton beam dosimetry is nearly identical to the consistency obtained in the case of ^{60}Co γ-rays. As a result, it is shown that the use of the new protocol improves the differences in absorbed doses stated by the participants.

4. CONCLUSION

To establish inter-institutional uniformity in proton beam dosimetry, an intercomparison program was carried out using the new Japanese dosimetry protocol. The dose measurements using different cylindrical ionization chambers were carried out in a water phantom at a position of 30-mm residual range for a proton beam which had a range of 155 mm and spread out Bragg peak (SOBP) of 60 mm width. As a result, the use of the new protocol improved the +/- 1.0 % (one standard deviation) and 2.7 % (maximum discrepancy) differences in absorbed doses stated by the participating facilities to +/- 0.3% and 0.9 %, respectively. The new protocol follows IAEA Technical Report Series No. 398, especially in selecting the dosimetric parameter for proton beam. The new Japanese protocol will be adopted by the all of the participants. The consistency of the absorbed dose will be essential to compare clinical results.

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