Sains Malaysiana 38(2)(2009): 203–207

Variation of Beam Quality Correction Factor with Time: Cases for Ne2571 and Ne2581 Chambers in the 6 and 10 Mv X-Rays Beams

(Perubahan Faktor Pembetulan Kualiti dengan Masa: Kes untuk Kebuk NE 2571 dan NE 2581 dalam Alur Sinar-X 6 dan 10 MV)

S. B. Samat, S. X. Too, T. Kadni & M.T. Dolah

ABSTRACT

The values of beam quality correction factor k_Q that were experimentally determined from year 2002 to 2008 were analysed. As k_Q is the function of ionization chamber and beam quality, the analysis were based on three cases namely (a) k_Q(NE2571, 6 MV x-rays) that were determined from 17 measurements in the duration of 69 months at 6 radiotherapy centres, (b) k_Q(NE2571, 10 MV x-rays) from 7 measurements in the duration of 12 months at one radiotherapy centre, and (c) k_Q(NE2581, 6 MV x-rays) from 5 measurements in the duration of 5 months also at one radiotherapy centre. The purpose is to examine, in each case, the variation k_Q for all the measurements. In other words, to see the variation of k_Q with time. Results obtained are 0.993(NE2571, 6 MV), 0.986(NE2571, 10 MV) and 0.986(NE2581, 6 MV). This shows that in each case, despite the difference in the experimental data in getting k_Q for all measurement, k_Q remains constant with time. Reasons for this are explained.

Keywords: Variation of k_Q; ionization chamber; NE2571; NE2581; 6 MV x-rays; 10 MV x-rays

ABSTRAK

Nilai faktor pembetulan kualiti k_Q yang ditentukan secara eksperimen dari tahun 2002 hingga 2008 dianalisis. Disebabkan k_Q adalah fungsi kepada kebuk pengionan dan kualiti alur, analisis dijalankan berdasarkan tiga kes berikut: (a) k_Q(NE2571, sinar-x 6 MV) yang ditentukan dari 17 pengukuran dalam tempoh 69 bulan di 6 pusat radioterapi, (b) k_Q(NE2571, sinar-x 10 MV) dari 7 pengukuran dalam tempoh 12 bulan di satu pusat radioterapi, dan (c) k_Q(NE2581, sinar-x 6 MV) dari 5 pengukuran dalam tempoh 5 bulan juga di satu pusat radioterapi. Tujuan adalah untuk memeriksa, dalam setiap kes, perubahan bagi k_Q untuk semua pengukuran. Dengan perkatan lain, untuk melihat perubahan k_Q dengan masa. Keputusan yang diperoleh ialah 0.993(NE2571, 6 MV), 0.986(NE2571, 10 MV) dan 0.986(NE2581, 6 MV). Ini menunjukkan dalam setiap kes, walaupun perbezaan dalam data eksperimen k_Q bagi semua pengukuran, k_Q tetap mempunyai nilai malar dengan masa. Sebab untuk ini dijelaskan.

Kata kunci: Perubahan k_Q; kebuk pengionan; NE 2571; NE 2581; sinar-x 6 MV; sinar-x 10MV

Introduction

If $M_{Co\text{-}60}$ is the dosimeter reading from a Co-60 beam corrected for influence factors, $N_{D,w,\,Co\text{-}60}$ is the calibration factor of the NE2571 ionization chamber obtained from the Co-60 beam, the absorbed dose to water in the Co-60 beam at reference depth $D_w(z_{ref})_{Co\text{-}60}$ is calculated from

$$D_w(z_{ref})_{Co\text{-}60} = M_{Co\text{-}60} \times N_{D,w,\,Co\text{-}60}. \qquad (1)$$

Let us now consider another beam instead of Co-60, say for example 6 MV x-rays. The same NE2571 chamber is to be used to determine the absorbed dose to water in this beam at reference depth $D_w(z_{ref})_{6MV}$. The formula to calculate $D_w(z_{ref})_{6MV}$ is certainly different from equation (1). Besides the dosimeter reading now becomes M_{6MV}, another factor namely $k_{6MV,Co\text{-}60}$ has to be added. This is the factor that corrects for the effects of the difference between the reference beam quality Co-60 and the actual quality 6 MV x-rays (IAEA 2000). For this case, the equation becomes

$$D_w(z_{ref})_{6MV} = M_{6MV} \times N_{D,w,\,Co\text{-}60} \times k_{6MV,Co\text{-}60}. \qquad (2)$$

If now 6MV and Co-60 are respectively replaced by the general terms Q and Q_o, equation (2) now becomes

$$D_w(z_{ref})_Q = M_Q \times N_{D,w,\,Qo} \times k_{Q,Qo}. \qquad (3)$$

If we now have more than one chamber, and for all these chambers' $N_{D,w}$ were determined in the same Q_o, the subscript Q_o in equation (3) can then be omitted. This then becomes

$$D_w(z_{ref})_Q = M_Q \times N_{D,w} \times k_Q. \qquad (4)$$

At this stage it is clear that k_Q is the function of chamber and beam quality, i.e. k_Q(chamber, beam quality).

The value of k_Q is typically experimentally determined. From year 2002 to year 2008, we have carried-out 29 experiments to detemine k_Q. The present work analyses three cases of k_Q namely (a) k_Q(NE2571, 6 MV x-rays) that were determined from 17 measurements in the duration of 69 months at 6 radiotherapy centres, (b) k_Q(NE2571, 10 MV x-rays) from 7 measurements in the duration of 12 months at one radiotherapy centre, and (c) k_Q(NE2581, 6 MV x-rays) from 5 measurements in the duration of 5 months also at one radiotherapy centre. The dates of the measurements for cases (1), (2) and (3) are respectively given in Table 2, 3 and 4.

For example consider the case of (a) i.e. determination k_Q for chamber NE2571 in the 6 MV x-rays beam. The facts that: (1) the k_Q measurements are repeated for 17 times, (2) each 17 measurements has different k_Q experimental data, (3) measurement were done in the period of 69 months, and (4) measurements were carried out at 6 radiotherapy centres; it would be interesting to see (a) whether the 17 individual values of k_Q are different, (b) the average value of k_Q when the average of the 17 repetition measurements are taken, (c) the reasons behind it (if k_Q varies or k_Q remains constant). These are the aims of the present work.

MATERIALS AND METHOD

Table 1 describes the equipments used in this work. The 6 MV and 10 MV x-rays beams are obtained from the LINAC machines belonging to the radiotherapy centres.

The method for getting k_Q has been described (IAEA 2000). It involves the various steps that need to be followed in order, namely (1) the beam quality type, (2) the chamber type, (3) the corrected dosimeter reading at 20 cm depth D_{20}, (4) the corrected dosimeter reading at 10 cm depth D_{10}, (5) the percentage depth dose $PDD_{20,10}$, tissue to phantom ratio $TPR_{20,10}$, and (6) the use of a table $TPR_{20,10}$-chamber-k_Q, of which the inputs of $TPR_{20,10}$ and chamber type will give the output value of k_Q. For simplicity purposes, in the present work we put all together these six steps in Figure 1. This will enable us to see the relationships of the six parameters. Caption of this figure described two examples of the measurements (no. 6 of Table 2, and no. 1 of Table 3) to get k_Q.

TABLE 1. Equipments used

Equipments	Model (series)	Manufacturer	Remarks
LINAC machine	Siemens Digita MevatronKD2 (#2648)	Siemens Medical Systems, Inc. Group, USA	Belongs to HUKM to provide 6 & 10 MV x-ray
	Siemens Oncor Impression (#4176)	Siemens Medical Systems, Inc. Oncology Care Systems Group, USA	Belongs to WIMC to provide 6 MV x-ray
	Siemens Primus (#M2975)	Siemens Medical Systems, Inc. Oncology Care Systems Group, USA	Belongs to AGOC to provide 6 MV x-ray
	Elekta Synergy (#1538)	Elekta Medical Systems, Inc Oncology Products Support Center, UK	Belongs to PMC to provide 6 MV x-ray
	Clinac 600C (#518)	Varian Medical Systems, Inc. Costumer Support Headquarters, USA	Belongs to NCI to provide 6 MV x-ray
Co-60 machine	Eldorado 8 (#104)	Theratronics International Limited, Ontario, Canada	1.25 MeV gamma-ray to get $N_{D,w.}$ Machine belongs to the NMA.
Ionization chamber	NE 2571 (#3171)	Nuclear Enterprises Technology Ltd. Reading England	0.6 cm^3 cylindrical type, non waterproof, acts as a reference standard chamber for $N_{D,w}$ calibration work
	NE 2571 (#3002)	Nuclear Enterprises Technology Ltd. Reading England	0.6 cm^3 cylindrical type, non waterproof, acts as a working standard to get $D_w(zr_{ef})$
	NE 2581 (#334)	Nuclear Enterprises Technology Ltd. Reading England	0.6 cm^3 cylindrical type, non waterproof, acts as a working standard to get $D_w(z_{ref})$
Electrometer	PTW-Unidos 10005 (#50013)	Physikalisch Technische Werkstatten, German	Digital type Minimum scale: 0.001 nC Associated with reference standard chamber in calibration work
Electrometer	PTW-Unidos 10002 (#20494)	Physikalisch Technische Werkstatten, German	Digital type Minimum scale: 0.001 nC
Water phantom	-	IAEA Vienna, Austria	Material: PPMA
Barometer	Prazision Comprensiert (#92084)	G. Lufft, German	Analog type
Thermometer	Digi Thermo (#3468)	Taiwan	Digital type

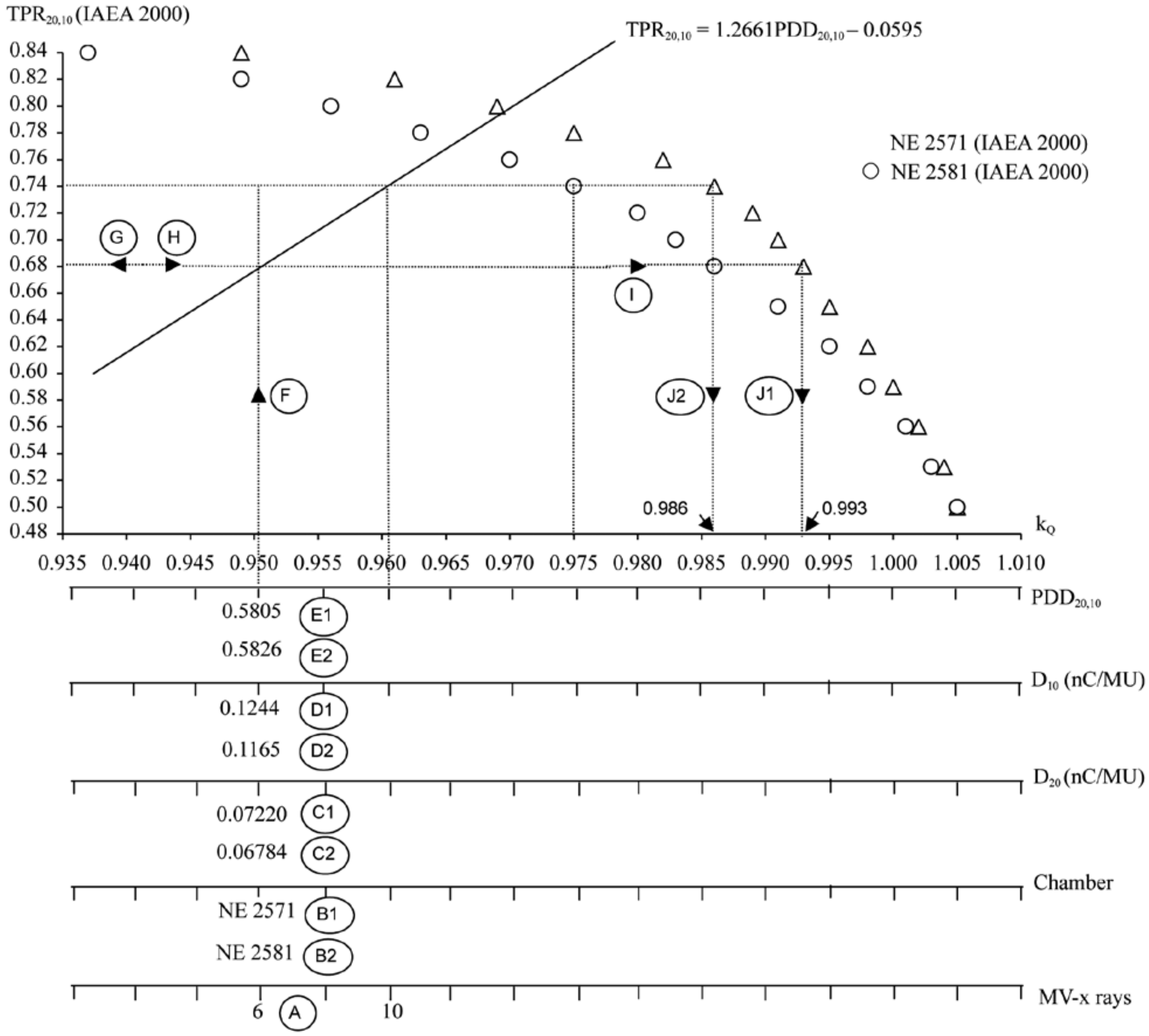

FIGURE 1. Relationships between linac beam quality, chamber, D10, D20, PDD20,10, TPR20,10 and quality beam correction factor. Examples: For 6 MV x-ray, to get kQ for (a) NE 2571, follow steps A, B1, C1, D1, E1 to I, JI. This is shown in Table 2, measurement no. 6. (b) NE 2581, follow steps A, B2, C2, E2 to I, J2. This is shown in Table 3, measurement no. 1

RESULTS AND DISCUSSION

The results of k_Q for cases (a), (b) and (c) are given in Table 2, 3 and 4, respectively. They are 0.993(NE2571, 6 MV), 0.986(NE2571, 10 MV) and 0.986(NE2581, 6 MV). It can be seen in each table that k_Q remains the same with time. The reasons for the constant k_Q in each cases might be explained by examining the experimental data and the steps for getting k_Q. Table 2, 3 and 4 show the experimental data of D_{20} and D_{10} for the purpose of getting k_Q for three respective cases. It can be seen that in each case, the values of D_{20} and D_{10} are all different. When these D_{20} and D_{10} are used to calculate $PDD_{20,10}$, in each case we can see that all values of $PDD_{20,10}$ are almost the same, only differ in the third decimal points. When this $PDD_{20,10}$ is inserted the IAEA (2000) formula to get $TPR_{20,10}$, in each case we can see that the $TPR_{20,10}$ (exact values) are almost the same, only differ in the second decimal points. As the IAEA (2000) $TPR_{20,10}$-chamber-k_Q table only take a two-decimal point of $TPR_{20,10}$, the $TPR_{20,10}$(exact value) need to rounded off to $TPR_{20,10}$(to nearest value). This will end up with the same value of k_Q. Notice also that in all Table 2, 3 and 4, the average value of $PDD_{20,10}$ together with their lower and upper limits yield the same value of k_Q.

CONCLUSION

It is interesting to note that despite the IAEA (2000) procedures, which require us to determine of k_Q each time when the $D_w(z_{ref})_Q$ is to be determined (as in equation 4), the present work yields that this may not be necessary as k_Q remains constant with time.

TABLE 2. The value of kQ for NE 2571 in the 6 MV x-ray beam

	Measurement		D_{20}/D_{10}	$PDD_{20,10}$ [b]	$TPR_{20,10}$ [c]		kQ	References
RC [a]	Date	no.			EV [d]	TNV [e]		
HUKM	Aug 2002	1	0.08722 / 0.1491	0.5850	0.681	0.68	0.993	Abdul Rani 2005
	Oct 2002	2	0.08737 / 0.1501	0.5819	0.677	0.68	0.993	Abdul Rani 2005
	Jan 2003	3	0.08641 / 0.1487	0.5812	0.676	0.68	0.993	Abdul Rani 2005
	Feb 2003	4	0.08615 / 0.1480	0.5822	0.678	0.68	0.993	Abdul Rani 2005
	Mar 2003	5	0.08624 / 0.1484	0.5813	0.676	0.68	0.993	Abdul Rani 2005
	Feb 2006	6	0.07220 / 0.1244	0.5805	0.675	0.68	0.993	Amat 2007
	Mar 2006	7	0.07236 / 0.1246	0.5806	0.676	0.68	0.993	Amat 2007
	Apr 2006	8	0.07219 / 0.1243	0.5807	0.676	0.68	0.993	Amat 2007
	Jun 2006	9	0.07254 / 0.1250	0.5804	0.675	0.68	0.993	Amat 2007
	Jul 2006	10	0.07249 / 0.1244	0.5825	0.678	0.68	0.993	Amat 2007
WIMC	Oct 2007	11	0.08792 / 0.1508	0.5830	0.679	0.68	0.993	Present work
	Nov 2007	12	0.08761 / 0.1507	0.5814	0.677	0.68	0.993	Present work
AGOC	Dec 2007	13	0.08587 / 0.1481	0.5798	0.675	0.68	0.993	Present work
	Jan 2008	14	0.08615 / 0.1482	0.5813	0.676	0.68	0.993	Present work
PMC	Feb 2008	15	0.08780 / 0.1498	0.5861	0.683	0.68	0.993	Present work
NCI	Apr 2008	16	0.08709 / 0.1494	0.5829	0.679	0.68	0.993	Present work
PMC	May 2008	17	0.08770 / 0.1498	0.5854	0.682	0.68	0.993	Present work
	Duration: 69 months			Average: 0.5821±0.0004				
				0.5817 [f]	0.677	0.68	0.993	
				0.5821	0.677	0.68	0.993	
				0.5825 [g]	0.678	0.68	0.993	

[a]Radiotherapy centre
[b]Experimental set-up of 20 cm and 10 cm depth, 10 × 10 cm^2 of FS, 100 cm of SSD
[c]Calculation from $TPR_{20,10} = 1.2661PDD_{20,10} - 0.0595$ (IAEA 2000)
[d]Exact value
[e]To nearest value
[f,g]Lower and upper limit of the average

TABLE 3. The value of kQ for NE 2571 in the 10 MV x-ray beam

	Measurement		D_{20}/D_{10}	$PDD_{20,10}$ [b]	$TPR_{20,10}$ [c]		kQ	References
RC [a]	Date	no.			EV [d]	TNV [e]		
HUKM	Aug 2002	1	0.1056 / 0.1644	0.6345	0.744	0.74	0.986	Pan 2005, Ibrahim 2005
	Oct 2002	2	0.1051 / 0.1661	0.6326	0.741	0.74	0.986	Pan 2005, Ibrahim 2005
	Jan 2003	3	0.1046 / 0.1651	0.6336	0.743	0.74	0.986	Pan 2005, Ibrahim 2005
	Feb 2003	4	0.1043 / 0.1645	0.6343	0.744	0.74	0.986	Pan 2005, Ibrahim 2005
	Mar 2003	5	0.1060 / 0.1677	0.6318	0.740	0.74	0.986	Pan 2005, Ibrahim 2005
	Jul 2003	6	0.1084 / 0.1708	0.6346	0.744	0.74	0.986	Pan 2005
	Aug 2003	7	0.1081 / 0.1703	0.6345	0.744	0.74	0.986	Pan 2005
	Duration: 12 months			Average: 0.6337±0.0004				
				0.6333 [f]	0.742	0.74	0.986	
				0.6337	0.743	0.74	0.986	
				0.6341 [g]	0.743	0.74	0.986	

[a–g]The same as in Table 1

TABLE 4. The value of kQ for NE 2581 in the 6 MV x-ray beam

Measurement			D_{20}/D_{10}	$PDD_{20,10}$ (b	$TPR_{20,10}$ (c		kQ	References
RC(a	Date	no.			EV(d	TNV(e		
HUKM	Feb 2006	1	0.06784 / 0.1165	0.5826	0.678	0.68	0.986	Amat 2007
	Mar 2006	2	0.06770 / 0.1167	0.5803	0.675	0.68	0.986	Amat 2007
	Apr 2006	3	0.06791 / 0.1168	0.5814	0.677	0.68	0.986	Amat 2007
	Jun 2006	4	0.06877 / 0.1177	0.5843	0.680	0.68	0.986	Amat 2007
	Jul 2006	5	0.06794 / 0.1170	0.5807	0.676	0.68	0.986	Amat 2007
	Duration: 5 months			Average: 0.5819±0.0007				
				0.5812(f	0.676	0.68	0.986	
				0.5819	0.677	0.68	0.986	
				0.5826(g	0.678	0.68	0.986	

[a-g]The same as in Table 1

ACKNOWLEDGEMENT

We gratefully acknowledge the Ministry of Higher Education for the research grant with project code UKM-ST-01-FRGS0045-2006 and the cooperation of Hospital Universiti Kebangsaan Malaysia (HUKM), Wijaya International Medical Centre (WIMC), Aushealth Gleneagles Oncology Centre (AGOC), Pantai Medical Centre (PMC), Nilai Cancer Institute (NCI) and their medical physicists.

REFERENCES

Abdul Rani, E.M. 2005. Absorbed Dose to Water Values in a 6 MV x-ray Beam Determined by Two IAEA Protocols: Comparison of Accuracy and Precision. MSc Thesis, School of Applied Physics.

Amat, A. 2007. Comparison of Accuracy and Precision of Absorbed Dose to Water Values Determined by IAEA TRS-398 and AAPM TG-51 Protocols in a 6 MV x-ray Beam. MSc Thesis, School of Applied Physics, Universiti Kebangsaan Malaysia.

IAEA. 2000. Absorbed Dose Determination in External Beam Radiotherapy: An International Code of Practice for Dosimetry Based on Standards of Absorbed Dose to Water, TRS-398. Vienna: International Atomic Energy Agency: 68.

Ibrahim, I. 2005. Absorbed Dose to Water Determined by two IAEA Protocols TRS-277 and TRS-398 at x-ray Beam of 10 MV: Comparison of Accuracy and Precision. MSc Thesis, School of Applied Physics, Universiti Kebangsaan Malaysia, 147 pages.

Pan, L.L. 2005. Comparison of Accuracy and Precision of Absorbed Dose to Water values in a 10 MV x-ray Beam Determined by IAEA TRS-398 and AAPM TG-51 Protocols. MSc Thesis, School of Applied Physics, Universiti Kebangsaan Malaysia.

S. B. Samat and S. X. Too
School of Applied Physics
Universiti Kebangsaan Malaysia
43600 UKM Bangi, Selangor D.E.
MALAYSIA

T. Kadni and M.T. Dolah
Secondary Standard Dosimetry Laboratory (SSDL)
Malaysian Nuclear Agency (Nuclear Malaysia)
43000 Kajang, Selangor D.E.
MALAYSIA

Received : 4 June 2008
Accepted : 30 July 2008