The Comparison of the KAPM Dosimetric Protocol (1990) with the TG-21 and C_λ/C_E Method

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The comparison of the KAPM Dosimetric Protocol (1990) with the TG-21 and C_λ/C_E (ICRU-21 and SCRAD protocol) method is studied. The therapetutic range of radiation (photon 4MV-15MV and electron 6 MeV-20MeV) and three kinds of the chambers were used in the water phantom. The results from TG-21 and KAPM protocol did not show much differences (less than 1%) throughout the whole energy range; N_D from KAPM protocol and Ngas from TG-21 showed 0.2% deviation mainly from W/e difference between two protocols. But the results from KAPM protocol (1990) and those from C_λ/C_E Method showed $-1.9\pm0.6\%$ (KAPM protocol is higher) deviation for photom beam and $+3.3\pm1\%$ (KAPM protocol is lower) deviation for electron beams.

Key Words: Dosimetric Protocol, KAPM Dosimetric Protocol, TG-21

INTRODUCTION

During past decade, extensive theoretical and experimental work has been devoted to the studies of dosimetry for high energy photon and electron beams. Dosimetric protocols have written by the American Association of Physicists in Medicine (AAPM)[1,2], International Commission on Radiation Units and Measurements (ICRU)[3], the Hospital Physicists Association (HPA)[4,5], the Nordic Association of Clinical Physicists (NACP)[6] and the International Atomic Energy Agency (IAEA)[7].

Dosimetric protocols such as SCRAD[2], ICRU-21[3] have relied on the cobalt-60 exposure calibration factor, N_x, and C_λ/C_E, the dose conversion factors for photons and electrons. This protocol (generally known as C_λ/C_E method) is a relatively simple and accurate means of dosimetry, and had been used world wide for almost one decade. But C_λ/C_E method does not account for variation in neither beam quality nor composition of the ionization chamber. Recent codes of practice such as NACP[6], AAPM[1], IAEA[7] are based on what can be called the N_D-formalism, initiated by the NACP[6].

Korean Association of Physicists in Medicine (KAPM) has prepared "Standard Radiation Dosimetric Protocol 1990.[8]" and "Revised Standard Radiation Dosimetric Protocol 1991". which was recently published[9]. These are also based on the N_D-formalism. Many institutions in Korea still uses C_λ/C_E method for therapy beam calibration. Even though KAPM recommend the modern dosimetry protocol such as KAPM, IAEA. The purpose of this paper is to provide insight into the origin and magnitude of the dose differences for the cylindrical and the pararell plate chamber. The comparison of the KAPM protocol with the TG-21 (AAPM protocol) and C_λ/C_E has been limited to the condition of the water phantom.

MATERIALS AND METHODS

Three types of ionization chambers (PTW 0.125 cc, PTW Farmer type, Markus pararell plate chambers) are used in the water phantom for comparison. All of these were calibrated from the National Institute of Health which is secondary standard dosimetry laboratory (SSDL). The photon beams (4MV, 6MV, 10MV and 15MV) and the electron beams (6 MeV, 9MeV, 12MeV, 16MeV and 20 MeV) from the CLINAC 1800 and the CLINAC 4/100 (Varian, USA) were used as the radiation source. We followed the KAPM protocol recommendation for the measurement depth and the effective points of measurement (Table 1, Fig. 1). The following formulae were used for the determination of the absorbed dose from the electrometer (Keithley 35617S, USA) reading, M, with three types of the dosimetric protocols:

① C_λ/C_E method

$D_{photon}=C_\lambda\cdot N_x\cdot M\,,$ ································(1)

$D_{El}=C_E\cdot N_x\cdot M\,,$ ································(2)

where, D_{photon} and D_{El} are the absorbed dose of the photom beam and that of the electron beam respectively, N_x is the chamber calibratsion factor.

Table 1. Reference Depth and Effective Point of Measurement of the Ionization Chamber

Radiation	Beam Quality	Reference depth	Effective point of measurement
Cobalt–60		5 cm	0.5 r**
Photon	$TPR^{20}_{10} \leqslant 0.7$	5 cm	0.75 r
	$TPR^{20}_{10} \geqslant 0.7$	10 cm	0.75 r
Electron	Eo < 5 MeV	D_{max}	0.5 r
	5 ⩽ Eo < 10	D_{max} or 1* cm	0.5 r
	10 ⩽ Eo < 20	D_{max} or 2* cm	0.5 r
	20 ⩽ Eo < 50	D_{max} or 3* cm	0.5 r

* large depth should always be chosen. ** radius of ionization chamber (confer Fig. 1.)

This method does not account for the beam quality and the chamber characteristics.

② TG-21 protocol

$$D_{photon} = N_{gas}\ M\ (L/\rho)^{water}_{air}\ P_{wall}\ P_{ion}\ P_{repl}\ , \cdots\cdots(3)$$

$$D_{EI} = N_{gas}\ M\ (L/\rho)^{water}_{air}\ P_{ion}\ P_{repl}\ , \cdots\cdots\cdots\cdots\cdots\cdots(4)$$

where, N_{gas} is cavity-gas calibration factor for ionization chambers as dose to the gas in the chamber divided by the electrometer reading, corrected for the temperature, pressure, and ionization collection efficiency. The meaning of various parameters given in eq. (3), (4) are described detail in the protocol. This protocol is based on N_D-formalism (N_D has same meaning as N_{gas}).

③ KAPM protocol

$$D_{photom} = N_D \cdot M \cdot S_{w.\ air} \cdot P_{u.}\ \cdots\cdots\cdots\cdots\cdots\cdots(5)$$

$$D_{EI} = N_D \cdot M \cdot S_{w.\ air} \cdot P_{u.} \cdots\cdots\cdots\cdots\cdots\cdots\cdots(6)$$

The meaning of various parameters given in equation (5), (6) are described detail in the protocol.

RESULTS

KAPM recommends the effective points of measurement for cylindrical ionization chamber as shown in Table. 1 and Fig. 1., while TG-21 requires gradient corrections, P_{repl}, instead of applying the effective points of measurement. Table 2. shows the differences between two protocols from the different recomendation of the effective, point of measurement and gradient corrections for Farmer type chamber.

As shown in Table 2, the final result does not show a significant difference. For example, the percent depth dose change for 4MV x-ray between depth 5 cm+0.75r and 5 cm (0.75r is 2 mm for Farmer type chamber) is-0.8% (the electrometer reading is 0.8% lower than TG-21 recommendation), while one needs not apply the gradient correction when using KAPM protocol. But one should consider the gradient correction 0.8% (ie, 0.992) in TG-21 instead of considering the deeper measurement point. The final result is exactly same. We could not find any significant differences between two protocols for electron beams, because the dose gradient zero region.

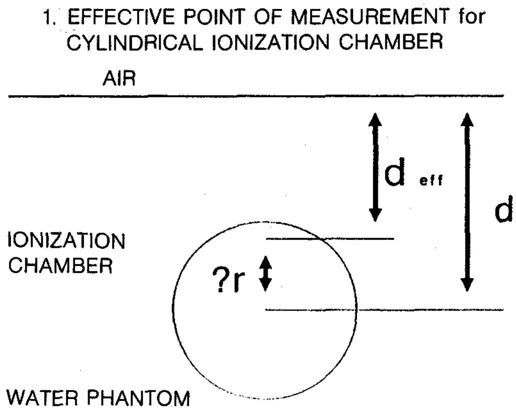

Fig. 1. The effective point of measurement for cylindrical ionization chamber. d_{eff} differs from d.

Table 3 and 4 show the evaluated absorbed dose with three kinds of potocols for photon beams. The result from KAPM and that from TG-21 are nearly same (within 1%), but that from C_λ method is maximum 2.7% and average 1.9±0.6% lower than from KAPM. It means that it is possible that the patient is overtreated about 2%, if we follow C_λ method.

Table 5, 6 and 7 show evaluated absorbed dose with three kinds of protocols for electron beams. The result from KAPM and that from TG-21 are nearly same (within 1%), but that from C_E method is maximum 4.5% and average 3.3±1% higher than from KAPM.

Table 8 shows the comparison of the measured

Table 2. Differences Between Two Protocols (TG–21 and KAPM) from the Different Recommendation of the Effective Point of Measurement and the Gradient Corrections for Farmer Type Chamber (Unit %)

Energy / Factor	Photon 4 MV	Photon 6 MV	Photon 10 MV	Photon 15 MV	Electron
0.75r or 0.5r (KAPM)	–0.8	–0.7	–0.7	–0.6	Not significant
Gradient Correction (TG–21)	+0.8	+0.8	+0.6	+0.6	N.A.
Total	0	+0.1	+0.1	0	0

For electron beams, the variation of effective point of measurement does not affect the result because of the plateau region of dose gradient around the depth maximum.

Table 3. PTW 23333 Cylindrical Chamber Results for Photon Beams

Energy / Protocol	4MV	6MV	10MV	15MV
KAPM	100	100	100	100
TG–21	100.5	100.1	101.1	100.9
C_λ/C_E	97.9	98.6	98.8	97.7

Table 4. PTW 23364 Chamber Results for Photon Beams

Energy / Protocol	4MV	6MV	10MV	15MV
KAPM	100	100	100	100
TG–21	99.9	100.3	100.6	100.6
C_λ/C_E	97.6	98.3	98.6	97.3

Table 5. PTW 23333 Results for Electron Beams

Energy / Protocol	6 MeV	9 MeV	12 MeV	16 MeV	20 MeV
KAPM	100	100	100	100	100
TG–21	100.3	100.2	100.4	100.5	100.1
C_λ/C_E	104.2	104.0	104.5	103.1	101.6

Table 6. PTW 233643 Results for Electron Beams

Energy / Protocol	6 MeV	9 MeV	12 MeV	16 MeV	20 MeV
KAPM	100	100	100	100	100
TG–21	99.8	99.7	100	99.9	99.6
C_λ/C_E	103.6	103.3	104	103.3	101.2

and evaluated absorbed dose from various type of ionization chambers. The evaluated absorbed doses from different type of ionization chambers show good agreement within average 1% deviation.

Table 7. PTW 23343 (Pararell Plate) Results for Electron Beams

Energy Protocol	6 MeV	9 MeV	12 MeV	16 MeV	20 MeV
KAPM	100	100	100	100	100
TG–21	100.2	100.2	100.1	100.2	100
$C\lambda/C_E$	100.5	101.5	101.5	101	101.5

Table 8. Comparison of the Measured and Evaluated Results from Various Type of Ionization Chambers

Energy Chamber	4X	6X	10X	15X	6E	12E	20E
Farmer Type	100	100	100	100	100	100	100
0.125 cc	99.8	99.8	100	100.2	100.9	100.8	100.8
Markus (Pararell Plate)					101.3	101.1	100.0

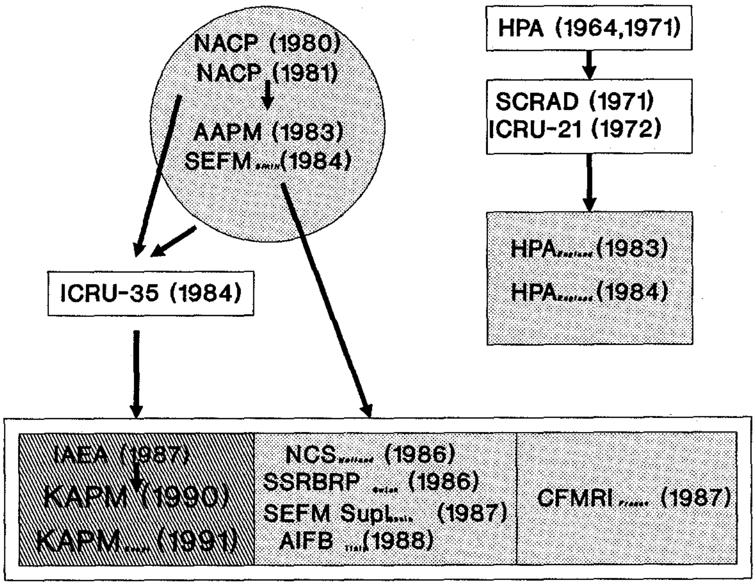

Fig. 2. An overview of the history and the relationships of the dosimetric protocols. The protocols in shadow area are modern protocols.

DISCUSSION

An overview of the history and the relationships of the dosimetric protocols is illustrated in Fig. 2., where shadow area is the modern dosimetry protocols.

As C_λ and C_E are very dependent on the size, the shape and construction of an ionization chamber, HPA (1983) protocol[4] keeps to the original simple procedure using the conversion factor C_λ, and provides values of C_λ specifically for the NE 2561 chamber, which is accessible to all radiotherapy deparment in England. The chamber should be calibrated against a secondary standard chamber in the x-ray beams in which it is to be used, while the KAPM or the TG-21 require in the Co-60 beams.

The Farmer NE 2571 graphite-wall cylindrical chamber and the Vinten Model 631 thin window flat chamber have been designated for the electron beam dosimetry in the HPA (1985) protocol[5].

Values of conversion factor, now given a new symbol Ce, have different unit (SI unit) than old protocol[3]. If one try to keep to the C_λ/C_E method, one should follow above. But the most department in Korea have various types of ionization chambers which are calibrated in the Co-60 beams. That is why one should use the KAPM protoco or otherN_D formalism based dosimetric protocols. Attix[10] pointed out that the equation for N_{gas} in the TG-21 protocol is incorrect. And it contains wrong W/e data. But those errors cancell out each other within 0.5% error, so AAPM recommended that the AAPM protocol should be used in it's original forms as presented in 1983[11].

The KAPM Protocol uses correct values and revised parameters such as stopping power ratio. The effect of the central electrode on the response of an ion chamber is incorporated by the KAPM, while TG-21 not. The response of the ion chamber increases by 0.8% for a Farmer type chamber with on aluminum central electrode, in the electron beams. Hunt *et al*[12] compared the dose differences for thimble ionization chamber with TG-21 and C_λ/C_E method. They reported 5% differences between two protocols. Huq[13] compared the IAEA 1987 and TG-21. For photon beams, the IAEA results are 0.6% smaller than the AAPM results while discrepancies between two are in the range of −0.4%∼−1.2%. The IAEA results are −0.3∼1.1% smaller than the AAPM results for electron beams.

KAPM and TG-21 do not give the practical explanation for the determination the N_D (or N_{gas}) of the pararell plate chamber. Mattson's[14] recommendation was used for calculating the N_D (or N_{gas}) of the pararrell plate chamber.

CONCLUSION

The KAPM dosimetric protocol, the TG-21 and the C_λ/C_E protocols are compared. The KAPM and the TG-21 consider the characteristics of the ionization chambers while C_λ/C_E not. The KAPM protocol uses more accurate and new factors than TG-21.

The KAPM and the TG-21 show good agreement within 1% deviation. But C_λ/C_E method shows 1.9% (for photon) or 3.3% (for electron) differencies than KAPM. The determined absorbed doses with various ionization chamber showed good agreement within 1% for KAPM protocol. Authors recommend to use KAPM 1990 protocol for the calibration of the radiation therapy machine.

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= 국문초록 =

방사선 선량의 표준 측정법(한국의학물리학회 1990) 및 TG-21, C_λ/C_E 방법의 비교

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방사선 선량의 표준측정법(한국의학 물리학회 1990) 및 TG-21, C_λ/C_E 방법을 비교 연구하였다.

방사선 치료에서 사용되는 광자선과(4MV-15MV) 전자선(6 MeV-20 MeV)을 세 종류의 전리함으로 물팬톰속에서 측정, 평가한 결과를 비교하였다. TG-21과 방사선 선량의 표준 측정법 비교에서는 1% 이내의 작은 차이만을 보여주었으며 그 차이는 주로 N_D-N_{gas}차이에서 나오는 것으로 평가되었다. 그러나 C_λ/C_E 방법과의 비교에서는 광자선의 경우 −1.9±0.6%(방사선 선량의 표준 측정에 의한 결과가 높게 나옴)전자선의 경우 3.3±1%(방사선 선량의 표준 측정법에 의한 결과가 낮게 나옴)의 차이를 보였다