Dose Estimation of Patient by X-ray Positioning in Particle Cancer Therapy

Masaaki Hirai[a], Kanae Nishizawa[a], Kouichi Shibayama[b], Tatsuaki Kanai[a]

[a]Division of Medical Physics, National Institute of Radiological Sciences, Chiba, 263-8555, Japan
[b]Hospital, National Institute of Radiological Sciences, Chiba, 263-8555, Japan
e-mail:m_hirai@nirs.go.jp

ABSTRACT

The effective dose due to the X-Ray radiography in the patient positioning for the heavy ion radiotherapy was measured on three regions, chest, upper-abdomen and pelvis. All the radiographic systems and the conditions used in the measurements were same as the clinical trial being performed in National Institute of Radiological Sciences, Japan. The organ or tissue for measurements was selected by following ICRP60[1] and the effective dose was calculated from measured organ doses and the surface dose.

Keywords: patient positioning, medical exposure, effective doses, surface doses, TLD measurement

1. INTRODUCTION

In the particle cancer therapy, it should be important that evaluating the risk on healthy tissues caused not only by the penumbra and scattering of therapeutic beams but also by the X-ray radiography in the patient positioning, the X-ray CT for the treatment planning, and neutron and γ-ray radiation from the beam delivery system. In case of the patient positioning X-ray photography, the radiographic conditions are different from conventional diagnostic X-ray radiography in two major points. First, the interests are rather on bones or implanted metals than lesion to confirm the therapy position. Second, the distance from X-ray tube focus to patient surface is very long (about 3 meters). In addition considering from the viewpoint of treatment planning, the risk evaluation of patient positioning X-ray radiography is important for determining the number of fractions in the whole treatment. On the other hand, the measurement and evaluation methods themselves have been well-established. Therefore we decided to measure the patient positioning X-ray radiography as the first part of total risk evaluation.

2. METHODS AND ANALYSIS

Table 1 Typical conditions of X-ray radiography for the patient positioning at NIRS-HIMAC (treatment room B).

	A/P	Lateral		
	All Region	Chest	Upper-Abdomen	Pelvis
Tube Voltage [kV]	70	80	85	120
Half Value Layer [mmAl]	2.95	3.88	4.13	5.30
Effective Energy [keV]	33	36	37	41
Intensity [mAs]	12	27.2	27.2	27.2

The measurements were performed on three regions, chest, upper-abdomen and pelvis, with lateral and anterior-posterior direction. Two identical X-ray tubes are used in each direction but the focus-to-isocenter distances are almost same. The X-ray tube voltages are 70 kV (anterior-posterior), 80 kV, 85 kV and 120 kV (lateral). Other conditions are summarized in Table 1. In the clinical trial in NIRS, typically three or four exposures are occurred in each direction for a fraction, while in rare case around ten each exposures are occurred. In all measurements, the radiation fields were about 25 cm diameters at the skin surface. For patient dose evaluation, an anthropomorphic phantom (Kyoto-Kagaku inc. Japan, 163cm stature and 53kg weight for whole body, no arms or legs though) was used as the model for a Japanese adult. This phantom was made of the bone, tissue and lung substitute and has around 150 small pits for dosimetry in itself. Throughout the measurements of the organ or tissue doses in/on the phantom, two kinds of thermo-luminescence dosimeters (TLDs) encapsulated in glass, UD-170A (BeO) and an UD-110S (CaSO4:Tm) (Panasonic, Japan) were used. They are identical in their size and shape, 12mm length with 2mm diameter cylinder. The physical

characteristics of two kinds of TLD were complementary in sensitivities and energy dependency. Hence the 170A was appropriate for dose measurements within the X-ray beam field, where beam intensity was high. The 110S was better suited for dose measurement outside the beam field. We used 187 TLDs (54 for bone, 93 for soft tissue, 40 for skin surface) in each measurement. The TLDs were calibrated inside and outside of the radiation field on/in a tissue-equivalent (Tough-Water, Kyoto-Kagaku inc.) phantom. In order to neglect the background exposure and the inaccuracy of TLD reader, all the measurements were performed to X-Ray of 1000 mAs. This intensity corresponds to around 90 and 36 exposures for anterior-posterior and lateral direction, respectively. The method of evaluation was basically according to Nishizawa *et al.*[2] The red bone marrow dose and the bone surface dose were assessed based on the following expression:

$$D = \sum m_r d_r / \sum m_r ,$$

Where d_r is the weight and the exposure dose and m_r is the weight of red bone marrow or bone mineral at the measurement position r. We used the bone weights of Japanese adult researched by Miyakawa[3] (for the red bone marrow) and Tanaka *et al.*[4] (for bone mineral). The whole weights are 766.5g and 3700g, respectively. (Note that the phantom we used has no arms or legs so that the weights in the consideration are less than them.)
The effective dose was evaluated by the following formula:

$$E = \sum w_T H_T ,$$

where w_T indicates the recommended weight factors from ICRP60[1] and H_T indicates the equivalent dose on the organ or the tissue T. The sum of w_T is unity. For the red bone marrow and the bone mineral, the equivalent dose calculated in above was used, while the equivalent doses for other organs are calculated from the average of corresponding TLDs. The rectum is assumed as a part of the colon. The measurements were performed with breasts on the phantom and the doses on them are considered on both male and female cases.

3. RESULTS

Table 2 shows the results of preliminary analysis on the effective dose and the equivalent doses on some important organs, for a pair (A-P and lateral) of exposures. Considering that three or four exposures are occurred in a fraction of treatment, the typical effective dose can be calculated as 0.15 – 0.2 mSv per fraction. The comparison of the effective dose on healthy tissues caused by therapeutic beams and this result will be done in near future. We would like to thank the technicians and engineers in the treatment room in NIRS-HIMAC for giving us time to this measurement and their support.

Table 2. The preliminary results of the effective dose, the red bone marrow dose, the surface dose, and th e genital organ doses, caused from a pair (A/P and lateral) of exposures.

		Chest	Upper-Abdomen	Pelvis
Effective Dose [μSv]	Male	49.5	50.1	60.7
	Female	49.2	51.4	73.0
Red Bone Marrow Dose [μGy]		34.4	22.8	71.0
Surface Dose [mGy]	A-P	0.159	0.113	0.133
	lateral	0.32	0.30	0.62
Genital Organ Dose [μGy]	Male	0.05	0.47	66.4
	Female	0.19	9.0	126.1

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