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Analysis on the photoneutron according to the varying factors and treatment planning in LINAC

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ABSTRACT

As the use of high-energy photon by Linac is recently generalized, there are studies conducted actively on the generation of photoneutron. However, existing studies are lack verification of reliability, and focus only on fragmentary evaluation. Therefore, in this study, evaluation was performed not only on the photoneutron according to the energy, the field size, the dose, the doserate and the distance, but also on the photoneutron on the conventional plan, 3D CRT plan, and the VMAT plan. As a result, the photon energy and the radiation field were proportional in the photoneutron generation rate, and the distance showed inverse proportion. The treatment planning was proportional according to the sophistication, and the occurrence rate of the photoneutron dose exceeded the tolerance of 5% with 8% when the quality factor was applied. Therefore, the conversion factor value proposed in this study must be applied in the treatment planning.

1. Introduction

Due to the development of LINAC, high-energy electron beam and high-energy photon are used on the radiotherapy for the cancer treatment [1–3]. As the high-energy photon is used in LINAC, the concerns on the occurrence of photoneutron began from the 1990′s. In the past, the photon energy of LINAC was low-energy to have no contribution in the occurrence of photoneutron, but due to the technical development from the advance in science, the use of high-energy photon over 10 MV was generalized. Therefore, there was great interest also in the occurrence of photoneutron on using high-energy photon of LINAC. The mechanism of photoneutron occurrence is shown in Fig. 1a, and the interaction formula on the occurrence of photoneutron is shown from Formula A. 1 to Formula A. 3 [4–8].

Formula A. 1 is the equation on the nuclear reaction process on the occurrence of photoneutron, and Formula A. 2–A. 3 are the equations on the nuclear reaction process of secondary occurrence by various radiations during the process of nuclear reaction. Also, Formula A. 4 is the complex process formula on the occurrence of photoneutron on the LINAC head, and Formula A. 5 shows the equation on the capture of photoneutron colliding and scattering by the concrete within the treatment room [9,10].

$$n = l \times \sigma \times N \tag{A.1}$$

n: Number of nuclear reactions at unit time

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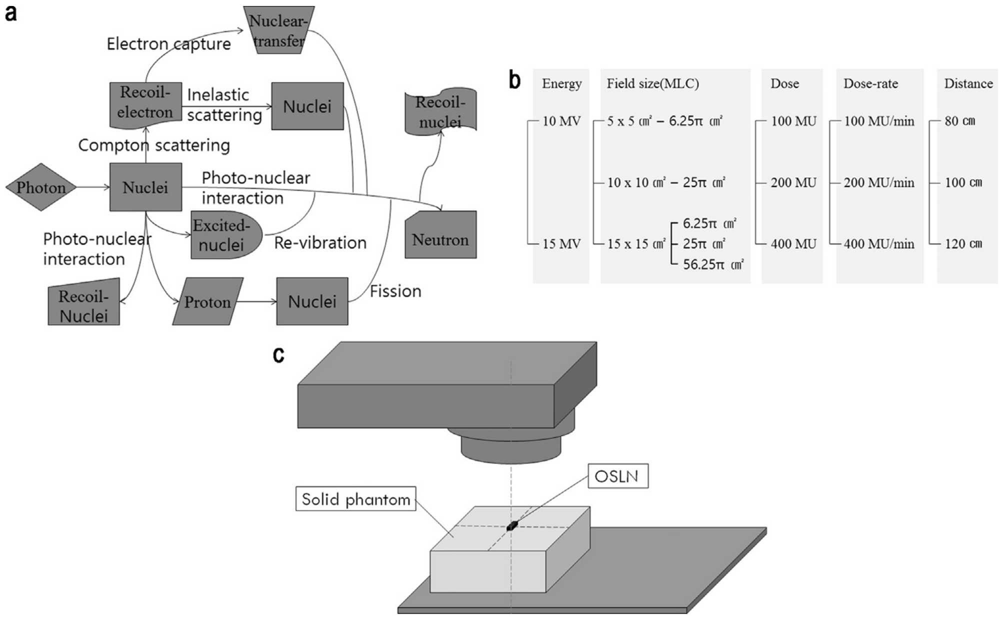

Fig. 1. 1 Mechanism of the photoneutron. Various radiations are generated by the high-energy photon. Among them, the generation mechanism of the photon is as follows: it is generated by the photonuclear reaction with the photon, the recoil electron generated by Compton scattering shows nuclear reaction with the nucleon, and proton generated by inelastic scattering and photonuclear reaction of the recoil electron is generated by the interaction with the nucleon. Also, it is generated by the neutron emission. Fig. A 2 Classification of variation factors. The conditions of the photon can be largely classified into energy, radiation field, dose, dose rate and distance. As for the energy, it is divided into 10 MV and 15 MV, and the radiation field is classified into the radiation field by collimator and the radiation field by multi-leaf collimator. Also, the collimator is divided into the square collimator with the diameter of 5 cm, 10 cm and 15 cm. And the multileaf collimator is divided into the circle collimator with the diameter of 5 cm, 10 cm and 15 cm. The dose is divided into 100 MU, 200 MU, and 400 MU. Then the doserate is divided into 150 MU/min, 300 MU/min, and 600 MU/min. The distance is divided into 80 cm, 100 cm and 120 cm. Fig. A 3 OSLN setup. The location of the optically stimulated luminescent dosieter is in the center of the solid phantom surface, and is set to correspond with the central axis of the flux.

l: Number of particle passing through a unit area at unit time
σ: Cross section
N: Number of atoms of the target nucleus in the irradiated part

$$\sigma(\gamma, xn) = \sigma(\gamma, n) + 2\sigma(\gamma, 2n) + 3\sigma(\gamma, 3n) + \sigma(\gamma, np) + \ldots \tag{A.2}$$

$$Y_{m,Ep} = N_m \int_{Eth}^{Eo} \sigma_m(r, xn)\varphi_{Ep}(E)dE \tag{A.3}$$

$Y_{m,Ep}$: Photoneutron yield
N_m: Atomic density of m
Eth: Tolerance energy of (r,xn) reaction
Eo: Bremsstrahlung end point energy
$\varphi_{Ep}(E)$: Fluence spectrum of the bremsstrahlung beam
$\sigma_m(r,xn)$: Representative photoneutron cross-section of m

$$\phi_{tot} = \phi_{dir} + \phi_{sc} + \phi_{th} = \frac{aQ_n}{4\pi d^2} + \frac{5.4aQ_n}{S} + \frac{1.26aQ_n}{S} \tag{A.4}$$

$$F = \frac{\phi_{sc}}{\phi} = \frac{1}{1 + \frac{S}{\delta.4\times 4\pi^2}} \tag{A.5}$$

φ_{tot}: photoneutron production per unit x ray dose
φ_{dir}: direct neutron fluence
φ_{sc}: scatter neutron fluence
φ_{th}: thermal neutron fluence
Q_n: neutron source strength per Gy-x of linac
a: transmission factor for linac head
d: distance (cm) between measured point and target
S: area of treatment room
F: Photoneutron impact scattering surface area of concrete structures