A7－5

Experimental Verification of Pencil Beam Algorithm by Measurements of Proton Dose Distributions of Heterogeneous Phantoms

Ryosuke Kohno, Yoshihisa Takada, Akihiro Nohtomi,
Takeji Sakae[1], Kiyoshi Yasuoka[2], Toshiyuki Terunuma[3], Keiji Matsumoto

Institute of Applied Physics, University of Tsukuba
[1]Institute of Clinical Medicine, University of Tsukuba
[2]Institute of Basic Medical Sciences, University of Tsukuba
[3]Proton Medical Research Center,University of Tsukuba

INTRODUCTION

Broad beam algorithm (abbreviated as BBA hereafter) has been widely used proton dose calculations for treatment planning because of its simplicity and short calculation time. However, discrepancies between dose calculations and measurements were observed for phantoms with large heterogeneity. Therefore we developed a method of dose calculation based on the pencil-beam algorithm (PBA) to improve the precision of dose calculation. In order to verify the predicability of dose distributions by the PBA, proton dose distributions of heterogeneous phantoms were measured using a silicon semiconductor detector (SSD) and an imaging plate (IP) in water. Comparisons between measurements and calculations by PBA are presented. We found that the IP can be used for a 2-dimensional detector of dose distribution if correction for LET dependence is applied.

METHOD

1. Pencil beam algorithm

Since the BBA does not take into account the angular distribution of incident proton beam and the scattering in the target directly, discrepancies occur for cases where there is an abrupt change of distal boundary of target and for heterogeneous targets. We developed a method of dose calculation based on the PBA developed by Hong and et al. We modified the Hong's method by considering the change of depth-dose curve of broad beam depending on the energy and by characterizing the open beam by the phase space parameters at the effective source point instead of the source size only. We developed a method of obtaining a depth-dose distribution of any depth in water of broad beam using fitted function obtained by measurements of several sampled depth-dose distributions. We showed a method of calculating the position of the effective source when scattering materials are inserted in the beam line.

2. Measurements of dose distributions

We manufactured heterogeneous phantoms with the cross sectional view shown in figure 1. They are made from Mixed-DP, tissue equivalent material for X-ray developed in Japan. Experimental arrangement is shown in figure 1 for the case where the IP is used. The IP sheet is put into a special bag which is suspended in the lucite holder in water. For finding reference positions in the horizontal and vertical directions on the IP sheet, two perpendicular thin wires was attached on the surface of lucite box and carefully aligned on the beam line. When the SSD was used, the lucite holder was replaced by SSD. We used a proton beam of horizontal beam line of Proton Medical Research Center, University of Tsukuba. The residual range of protons were set at about 20 cm by adjusting the fine degrader. We measured lateral dose distributions at different depths by SSD and the IPs and depth-dose distributions by SSD on the beam line. Since IP has a LET dependence, calibration was made by measuring a depth-dose curve by SSD and IP without phantom.

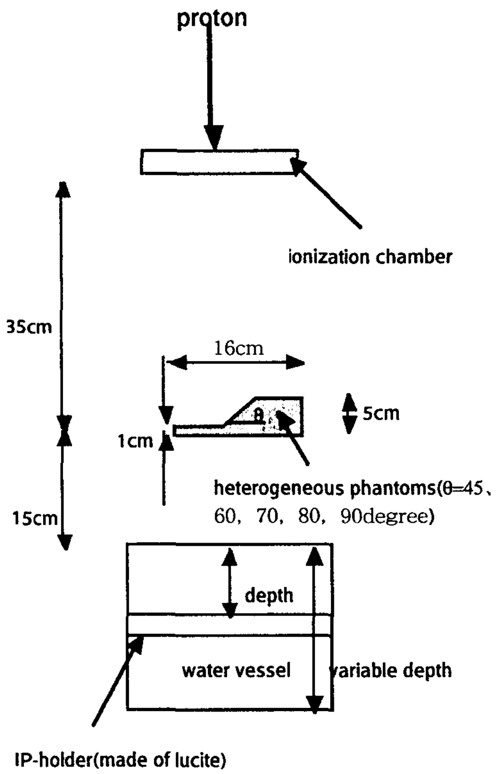

Figure1. Experimental setup(top view) for dose distribution measurement using IP

RESULTS

We found that measured depth-dose distributions of heterogeneous phantoms can be reproduced well by the PBA and that x-z (or y-z) equi-dose lines produced by the measurements by IPs at sampled depths are well reproduced by the PBA. Since IP response has LET dependence, knowledge of average LET are required at measured points for the correction. In order to obtain the LET corrections on IP response, the PBA was used to predict the average LET.

CONCLUSION

We verified that the PBA can make a more precise prediction of dose distributions of heterogeneous phantoms compared with the BBA. We found that The IP can be used as a useful 2-dimensional dose detector if LET corrections are applied appropriately.