Physica Medica 36 (2017) 119–125

Contents lists available at ScienceDirect

Physica Medica

journal homepage: http://www.physicamedica.com

Original paper

The evaluation of the neutron dose equivalent in the two-bend maze

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ARTICLE INFO

Article history:
Received 10 August 2016
Received in Revised form 13 February 2017
Accepted 20 March 2017
Available online 4 April 2017

Keywords:
Neutron dose
Two-bend maze
Tenth-value distance

ABSTRACT

The purpose of this study was to explore the effect of the second bend of the maze, on the neutron dose equivalent, in the 15 MV linear accelerator vault, with two bend maze. These two bends of the maze were covered by 32 points where the neutron dose equivalent was measured. There is one available method for estimation of the neutron dose equivalent at the entrance door of the two bend maze which was tested using the results of the measurements. The results of this study show that the neutron equivalent dose at the door of the two bend maze was reduced almost three orders of magnitude. The measured TVD in the first bend (closer to the inner maze entrance) is about 5 m. The measured TVD result is close to the TVD values usually used in the proposed models for estimation of neutron dose equivalent at the entrance door of the single bend maze. The results also determined that the TVD in the second bend (next to the maze entrance door) is significantly lower than the TVD values found in the first maze bend.

1. Introduction

Medical therapy accelerators working at energies higher than energy threshold for (γ, n) nuclear reaction of some materials irradiated by the photon beam, produce measurable number of neutrons. Lead is one of the materials commonly used in accelerator heads, and energy threshold for (γ, n) reaction for isotope ^{208}Pb (52.4% in natural lead) is 6.7 MeV. To protect staff at radiotherapy departments, maze designed bunkers having thick primary and secondary shielding walls, massive shielding doors and wall covers which are good neutron moderators (plastic, paraffin) are usually applied as a cost-effective solution. Neutron dose at the entrance door of one bend maze is considered in a number of publications [1–5], but two bend maze publications are quite rare [6,7]. Recommendations for the design of the entrance maze door which can provide proper shielding for both photon and neutron radiation can be found in NCRP protocol [8]. Two methods for the estimation of the neutron dose equivalent at the place of the door are generally accepted: Kersey's and Wu and McGinley's [8,9]. Both these methods provide neutron dose equivalent estimation for standard one bend maze geometry of the linac's vault. The IAEA publication [10] provides methodology for the estimation of neutron dose equivalent in the two bend maze. According to this document, neutron dose in the second bend decreases following the exponential trend. For a proper estimation of the dose at the maze door, it is acceptable to use total length of the corridor – a sum of lengths of two maze bends and reduce this number by a factor of 1/3.

The objective of this work is to present detailed measurements of the neutron dose equivalent in the two bend maze. These measurements can be used to establish accurate values of the tenth value distance (TVD) in the first bend of the maze and compare it with values predicted by models [9]. TVD for the second maze bend can be different from TVD in the first bend, since the mean energy of neutrons should be significantly lower due to the large number of scatterings. One of the goals of this work is to estimate TVD in both bends of the maze. The neutron source strength or the neutron dose equivalent at the reference point cannot be found, unfortunately in relevant literature for new Elekta Versa HD linear accelerator. Only one available neutron source strength data [11] for accelerators is related to the neutrons created in the regime in which an electron beam is used. In this regime, the accelerator produces two orders of magnitude lower number of neutrons than in the regime when the photon beam is used. To overcome this problem, the neutron source strength for the Elekta Versa HD accelerator was estimated using a technique similar to that described in the reference Followill et al. [12]. By a simple comparison of activity induced in activation detectors made from natural Indium, which were exposed under the same conditions in the vicinity of a Versa HD or a Varian 2100 C accelerator the neutron source strength was estimated. This led to the usage of the proposed methods for the neutron dose calculation and to the comparison

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http://dx.doi.org/10.1016/j.ejmp.2017.03.017
1120-1797/

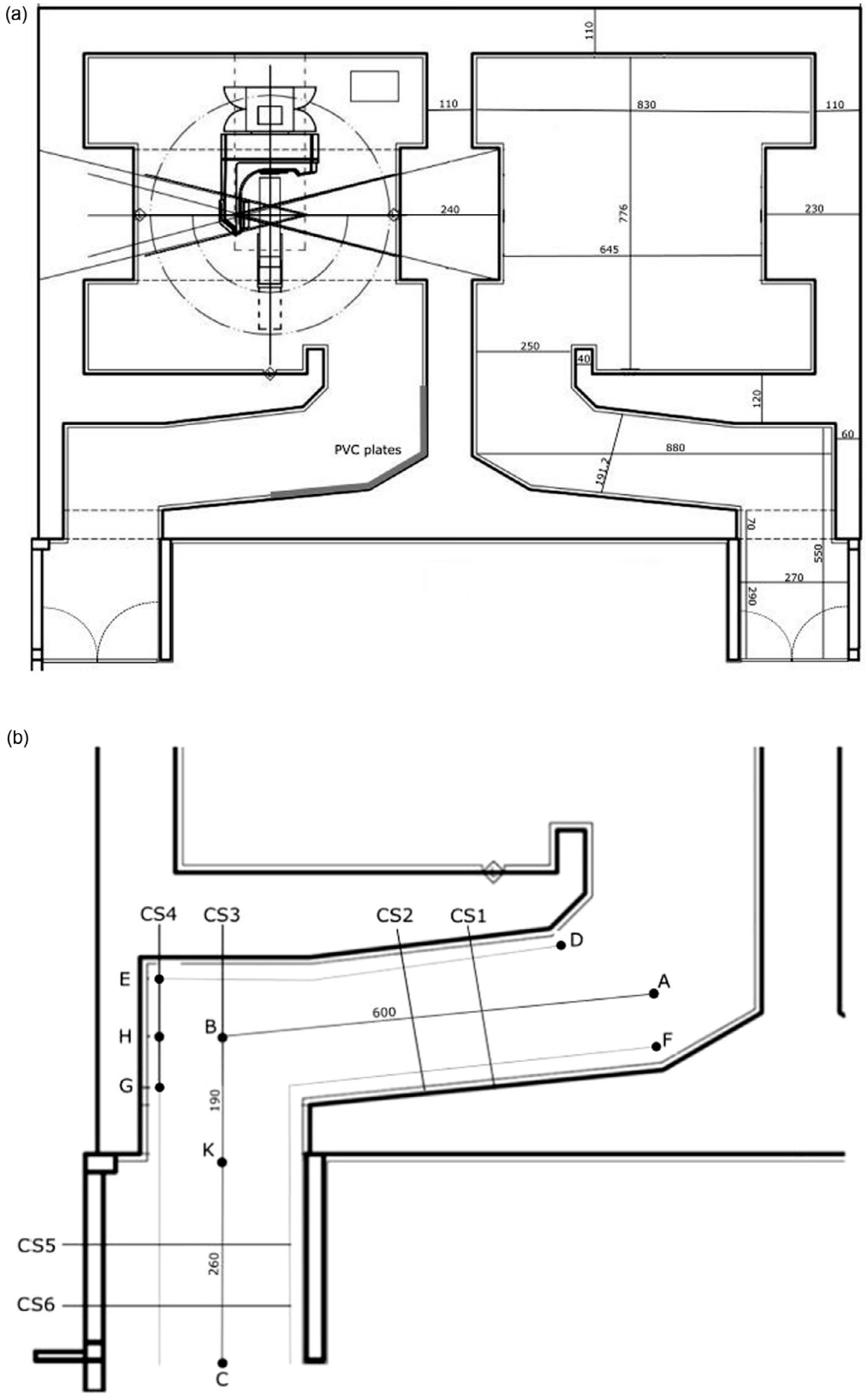

Fig. 1. a) Scheme of therapy vault. b) Magnified maze area. Lines represent directions of activation detectors alignments.

of the obtained results with the measurements. One of the most important objectives of this work is to verify the trends of the neutron dose equivalent decrease along the both bends of the maze corridors. Special attention was paid to the comparison of the neutron dose equivalent measured in the second maze bend and the results of the model given in IAEA report [10].