Applied Radiation and Isotopes 70 (2012) 2755–2762

Contents lists available at SciVerse ScienceDirect

Applied Radiation and Isotopes

journal homepage: www.elsevier.com/locate/apradiso

Design and optimization of a beam shaping assembly for BNCT based on D–T neutron generator and dose evaluation using a simulated head phantom

Fatemeh S. Rasouli, S. Farhad Masoudi *

Department of Physics, K.N. Toosi University of Technology, P.O. Box 15875-4416, Tehran, Iran

HIGHLIGHTS

- A BSA has been designed based on D–T neutron generators for treating brain tumors in context of BNCT.
- The optimization process has been realized by MCNP for all of the BSA materials and their geometries.
- A simulated head phantom was used to evaluate dose profiles due to the irradiation of designed beam.
- The results show that the designed neutron beam is effective for deep-seated brain tumor treatments.
- Proposed BSA is proper for BNCT treatment even with D–T neutron generator which yields 2.4×10^{12} n/s.

ARTICLE INFO

Article history:
Received 11 June 2012
Received in revised form
1 August 2012
Accepted 13 August 2012
Available online 21 August 2012

Keywords:
BNCT
D–T neutron generator
Neutron multiplier
BSA
In-phantom parameters

ABSTRACT

A feasibility study was conducted to design a beam shaping assembly for BNCT based on D–T neutron generator. The optimization of this configuration has been realized in different steps. This proposed system consists of metallic uranium as neutron multiplier, TiF_3 and Al_2O_3 as moderators, Pb as reflector, Ni as shield and Li-Poly as collimator to guide neutrons toward the patient position. The in-air parameters recommended by IAEA were assessed for this proposed configuration without using any filters which enables us to have a high epithermal neutron flux at the beam port. Also a simulated Snyder head phantom was used to evaluate dose profiles due to the irradiation of designed beam. The dose evaluation results and depth–dose curves show that the neutron beam designed in this work is effective for deep-seated brain tumor treatments even with D–T neutron generator with a neutron yield of 2.4×10^{12} n/s. The Monte Carlo Code MCNP-4C is used in order to perform these calculations.

1. Introduction

Cancer is caused by the out of control growth of cells in a part of the body. Nowadays, millions of people live with cancer or have had cancer. There are different methods such as surgery, radiotherapy, chemotherapy and immunotherapy for treating cancers. Glioblastoma multiforme (GBM) is the most common and the most aggressive type of the brain tumor involving glial cells. As GBM is a deep-seated tumor, it is very difficult to treat it via surgery or other conventional therapies (Smith et al., 1996; Yamamoto et al., 2008; Tahara et al., 2006).

As a therapeutic modality for tumors, Boron Neutron Capture Therapy (BNCT) was suggested by Gordon. L. Locher, four years after the discovery of neutron by Chadwick in 1932 (Yokoyama et al., 2006). BNCT is a very appealing due to its potential for selective cell killing. This method includes two stages: initially the ^{10}B carrier drug, such as BPA (boronophenylalanine) and BSH (sodium borocaptate) (Yamamoto et al., 2008; Zamenhof et al., 1975), is injected into the patient's body. Boron concentration in the tumor zone will be higher than the healthy brain cells owing to the blood–brain function that prevents the entering of toxic substances into the brain. In the second stage of the treatment, the patient is affected locally by the neutron irradiation (Tahara et al., 2006). Two different neutron beams are commonly used in BNCT: the thermal neutron beam that limits the treatment to shallow tumors, and the epithermal neutron beam which reaches to the thermal energy range after passing through head tissues and therefore is able to treat deep tumors. These thermal neutrons are captured by ^{10}B, due to its large absorption cross section for thermal neutrons (3838 barn), and the ^{11}B excited nucleus breaks into two fragments (Barth et al., 2005):

$$^{10}B + n_{th} \rightarrow {}^{4}He(1.47\ MeV) + {}^{7}Li(0.84\ MeV) + \gamma(0.48\ MeV) \quad (93.7\%)$$

$$^{10}B + n_{th} \rightarrow {}^{4}He(1.78\ MeV) + {}^{7}Li(1.01\ MeV) \quad (6.3\%)$$

* Corresponding author.
E-mail address: masoudi@kntu.ac.ir (S.F. Masoudi).

0969-8043/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.apradiso.2012.08.008