TREATMENT OPTIMIZATION OF A BRAIN TUMOR IN BNCT BY MONTE CARLO METHOD

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Abstract

Brain cancers are one of the most important diseases. BNCT (Boron Neutron Capture Therapy) is used to brain tumor treatment. In this method the $^{10}B\ (n,\alpha)^{7}Li$ reaction is used. The purpose of this study is absorbed dose evaluation of tumoral and healthy parts of brain. To achieve this aim the brain was simulated by a cylindrical phantom with the dimensions of 20 cm in diameter and height. In BNCT treatment the BSH ($Na_2B_{12}H_{11}SH$) is injected to the human body and absorbed in the healthy and tumoral parts by the ratios of 18 and 65 ppm respectively. So in this research the absorption of BSH in tumoral and healthy parts of brain was considered as the mentioned ratio. Then the neutron with the energy range of 50 eV - 10 keV was exposed to the brain and maximum absorbed dose in healthy and tumoral parts of brain were calculated for a cylindrical tumor with the thickness of about 1 cm which was considered in 5.5 cm depth of brain. This research showed the suitable energy to treat this tumor by BNCT is interval 4 keV- 6keV. The average of dose which is met with healthy and tumor tissue was gained for 6 keV energy of brain 1.18×10^{-12} cGy/n and 5.98×10^{-12}cGy/n respectively. Maximum of dose which is met with healthy tissue was 4.3 Gy which is much less than standard amount 12.6 Gy. Therefore BNCT method is known as an effective way in the therapy of this kind of tumor.

Introduction

Neutron therapy by boron was submitted by locher in the 1936 by use of thermal neutron at first. In some cases neutrons didn't have enough energy to react with boron because of the deepness of tumor. So, Hiroshi Hatanaka suggested epithermal neutrons usage. In this method when epithermal neutrons pass along brain tissue, they lose energy and get to thermal range (E<10 eV). Nowadays many countries use this way to treatment the tumors. At present time

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many clinical research are done at countries such as Japan, Netherlands, England, Australia , Finland and etc in this way.

Fast neutrons are made in core of reactor which is used for BNCT. Then they pass through heavy water tank and reach to epithermal area. Besides epithermal neutrons, there are thermal neutrons and gamma in the outlet. The most appropriate beam along with the least pollution is made by use of bismuth shield and cadmium shutter in the outlet (Figure1).

Epithermal neutron are absorbed less in the frontal area of brain, until they tend to be absorbed more by passing along brain and losing energy. So they arrive in the thermal area at 5 cm of brain deepness where the tumor place is visualized. Therefore they become appropriate to $^{10}B\ (n,\alpha)^{7}Li$ reaction which ensures to make helium particles and lithium ions and they are along with 487 keV gamma radiation in 94 percent of reactions. They can collapse DNA structure of tumor cells and they don't damage surrounded healthy cells because of their short range (Figure2). The deep distributed dose in healthy and cancerous tissue of brain for mono-energy neutron means 35 eV and 4 keV with GEANT code has been simulated for a tumor with 1cm thickness at 5 cm deepness in brain and brain was simulated by a 1 m^3 dimension cubic phantom. This was done at the year 2000 because of particularization neutron energy for deep tumor brain therapy in BNCT way by Biscelgie. Now in this research brain was simulated by a 20cm×20cm cylindrical phantom and a tumor inside the cylinder with the dimensions of 3 cm in diameter and 1 cm in thickness at 5.5 cm depth of brain. The results of this research work were compared with Biscelgie work.

Materials and methods

There are many elements in the human brain such as hydrogen and nitrogen which each one react with various neutron energy include $H(n,n')H$,$^{1}H(n,\gamma)^{2}H$,$^{14}N(n,p)^{14}C$ and $^{10}B\ (n,\alpha)^{7}Li$ as the most important reaction among others. These reactions are considered in the simulation with MCNPX code. Dose in the healthy and cancerous brain tissues is calculated by below formula:

$$D\ (\text{Gy-eq}) = W_B D_B + W_\gamma D_\gamma + W_N (D_H + D_N) \qquad (1)$$

Each W coefficient shows different biological effects of beams which relate to weight factors. W_B 1.3 and 3.8 for healthy and cancerous tissue respectively, W_N=3.2 and W_B=1 as well. D_B dose which is made by neutron absorption and boron fission that is led to make He ion with

1.47 MeV energy and lithium ion with 0.48 MeV energy and it is along with 487 KeV gamma radiation in 94 percent of reactions. D_H is dose which relates to hydrogen rejection which ensures proton shooting from atom or molecule and releases energy very much. This reaction usually occurs with high neutron energy. D_N is dose which is arised from neutron absorption in the ^{14}N which ensures (n,p) reaction. D_γ relates to $^{1}H(n,\gamma)^{2}H$ reaction which produces 10.83 MeV gamma energy. In this simulation the human brain was simulated by a 20×20 cm^2 cylindrical phantom. The cylinder was made of plexi-glass material. BSH drug in 18:65 ppm concentration was distributed in the healthy and tumor tissues respectively. Cells in 3 cm diameter and 0.5 cm thickness were arranged in the direction of phantom center of axis and energy which releases in their mass unit was calculated. Tumor was set as cylindrical form in 3 cm diameter and 1 cm thickness in the 5.5 cm deepness of brain surface (Figure 3).

Results

It is tried to maximize the absorbed dose to tumor and minimize it to healthy tissues. As it has been shown in Figure4, this goal was achieved in this research until the average absorbed dose to tumor was calculated 5.98×10^{-12} cGy/n and to healthy tissue 1.8×10^{-12} cGy/n. Nuisance reaction releases such as hydrogen rejection because of increasing of energy. Because it causes to increase dose in the healthy tissue near tumor, hydrogen rejection is known as a limited factor in the energy selection. Results comparison is shown reasonable concordance of this simulation results and results of other´s. The difference is seen in these two figures is because of the difference in the used geometrical figure and materials. In the reference article a tumor in 1 cm thickness was simulated in the 5 cm deepness and brain was considered as a cubic phantom in 1 m^3 dimensions. Real elements of brain in natural percentage are used in material card.

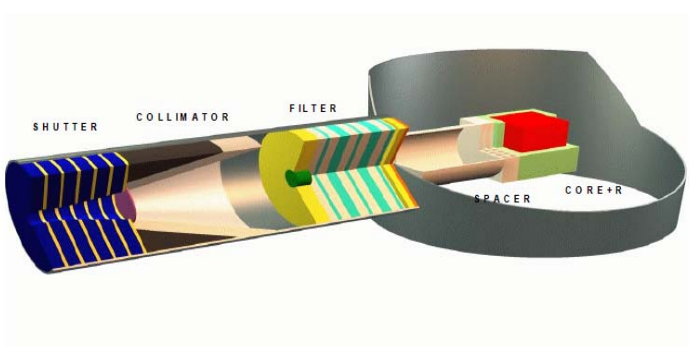


Figure 1. Epithermal neutron spectrum formation [5].

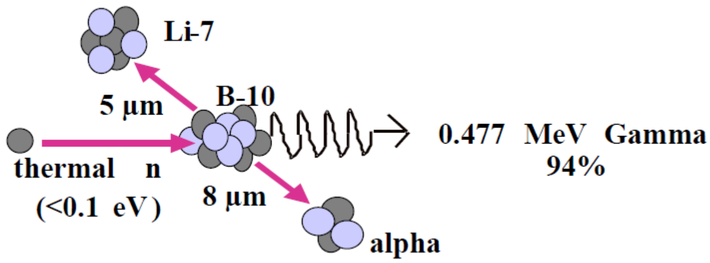


Figure 2. Boron 10 nucleus is split because of epithermal neutron absorption and is made alpha particles and lithium ion which has a range about cell diameter [5].

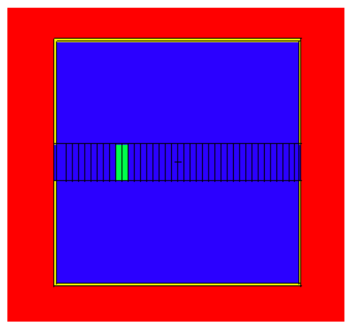
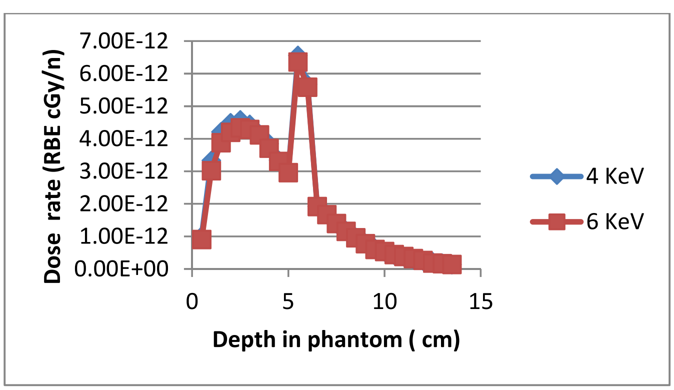
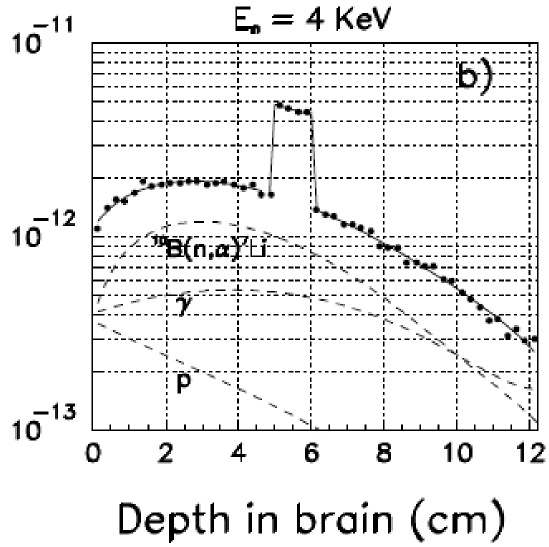


Figure 3. The 20 × 20 cm^2 cylindrical brain phantom with 0.5 cm plexi-glass material thickness (red colored). This image is like that at the direction of any axis . Tumor has the dimensions of 1 cm in thickness and 3 cm in diameter at 5 cm in depth of brain. To calculate the absorbed dose, Cells with the dimensions of 0.5 cm in thickness and 3 cm in diameter were considered at direction of center axis.



(a)

Figure 4. a. Absorbed dose of healthy and tumoral tissues at direction of phantom axis. Dose has maximized in the tumor place (5.5 cm depth).



(b)

Figure 4. b. Reference of depth dose for a tumor in 1 cm thickness at 5 cm depth from a cubic phantom in 1 m^3 dimensions [1].

Conclusion

As it shown in the results, the best interval energy is 4-6 KeV for the therapy of a tumor with 1 cm thickness which is at 5.5 cm of depth from brain surface. Absorbed dose of tumor is maximized by this energy. Energy can't be more than this range because, proton rejection is considered as limited factor of radiating neutron energy. It can't happen because nuisance dose increases in the healthy tissue. In the future work the results will be compared with clinical research.

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