OPTIMIZING NEUTRON IRRADIATION DIRECTION FOR ESOPHAGEAL CANCER IN BORON NEUTRON CAPTURE THERAPY (BNCT) USING PARTICLE AND HEAVY ION TRANSPORT SYSTEM (PHITS)

BACHELOR'S THESIS

FITDHIA AL AYUNANDA
2110441026

DEPARTMENT OF PHYSICS
FACULTY OF MATHEMATICS AND NATURAL SCIENCE
UNIVERSITAS ANDALAS
PADANG

2025

OPTIMIZING NEUTRON IRRADIATION DIRECTION FOR ESOPHAGEAL CANCER IN BORON NEUTRON CAPTURE THERAPY (BNCT) USING PARTICLE AND HEAVY ION TRANSPORT SYSTEM (PHITS)

BACHELOR'S THESIS

A bachelor's thesis submitted in partial fulfilment of the requirements for the degree of Bachelor of Science at Andalas University

FITDHIA AL AYUNANDA
2110441026

DEPARTMENT OF PHYSICS
FACULTY OF MATHEMATICS AND NATURAL SCIENCE
UNIVERSITAS ANDALAS
PADANG

2025

OPTIMASI ARAH IRADIASI NEUTRON PADA KANKER ESOFAGUS DENGAN *BORON NEUTRON CAPTURE THERAPY* (BNCT) MENGGUNAKAN *PARTICLE AND HEAVY ION TRANSPORT SYSTEM* (PHITS)

ABSTRAK

Kanker esofagus merupakan salah satu jenis kanker paling mematikan, menempati peringkat ketiga dalam risiko kematian secara global maupun di Asia, dengan angka kematian mencapai 87%, sedangkan di Indonesia mencapai 96,27%. Radioterapi merupakan metode yang umum digunakan untuk mengobati kanker esofagus, namun radioterapi konvensional masih kurang efektif karena rendahnya selektivitas terhadap jaringan sehat. Oleh karena itu, penelitian ini menggunakan BNCT, jenis radioterapi yang lebih selektif, tidak memerlukan fraksionasi, serta menggunakan boron yang aman dan tidak toksik bagi tubuh. Pendekatan stokastik dengan metode Monte Carlo digunakan untuk menghitung dosis radiasi secara akurat pada BNCT karena reaksi nuklirnya bersifat probabilistik, menggunakan perangkat lunak seperti *Monte Carlo N-Particle* (MCNP), *Fluktuierende Kaskade* (FLUKA), *Geometry and Tracking* versi 4 (GEANT4), dan *Particle and Heavy Ion Transport code System* (PHITS). PHITS dipilih karena mampu menghitung energi hingga 1 TeV, yang memungkinkan simulasi lebih akurat dan waktu komputasi yang lebih singkat. Penelitian ini merupakan simulasi komputer menggunakan program PHITS versi 3.34.1 untuk menentukan arah iradiasi optimal yang aman bagi organ sehat di sekitar kanker esofagus pada area *middle thoratic*, serta menghitung waktu iradiasi. Model fantom yang digunakan adalah fantom pria dewasa dari *Oak Ridge National Laboratory* (ORNL), dengan *gross tumor volume* (GTV) sebesar 25,88 cm^3 dan tipe kanker *squamous cell carcinoma*. Sumber neutron yang digunakan berasal dari akselerator siklotron berenergi 30 MeV dengan arus 1 mA. Konsentrasi boron yang digunakan adalah 150 ppm. Variasi sudut arah iradiasi yang digunakan yaitu 0°, 30°, 45°, 60°, dan 90°. Hasil penelitian menunjukkan bahwa: waktu iradiasi tercepat adalah 32 menit 36 detik; evaluasi dosis ekuivalen dan efektif menunjukkan bahwa seluruh *organs at risk* (OARs) menerima dosis radiasi di bawah batas dosis yang ditentukan; dan sudut iradiasi neutron yang menghasilkan dosis optimal pada kanker yang diteliti dan tetap aman bagi OARs dicapai pada sudut 90° dengan posisi lateral kanan pasien.

Kata kunci: *Boron Neutron Capture Therapy*, dosis radiasi, kanker esofagus, *Particle and Heavy Ion Transport code System*

OPTIMIZING NEUTRON IRRADIATION DIRECTION FOR ESOPHAGEAL CANCER IN BORON NEUTRON CAPTURE THERAPY (BNCT) USING PARTICLE AND HEAVY ION TRANSPORT SYSTEM (PHITS)

ABSTRACT

Esophageal cancer is among the most dangerous types of cancer, ranking third in mortality risk globally and in Asia, with a mortality rate of 87%, while in Indonesia, the rate reaches 96.27%. Radiotherapy is a common method used to treat esophageal cancer; however, conventional radiotherapy remains less effective due to its low selectivity for healthy tissues. Therefore, this study employs BNCT, a more selective type of radiotherapy that does not require fractionation and uses boron, which is safe and non-toxic to the body. A stochastic approach using the Monte Carlo method is employed to accurately calculate radiation doses in BNCT, as its nuclear reactions are probabilistic, utilizing software such as Monte Carlo N-Particle (MCNP), Fluktuierende Kaskade (FLUKA), Geometry and Tracking version 4 (GEANT4), and Particle and Heavy Ion Transport code System (PHITS). PHITS was chosen because of its advantage to calculate up to 1 TeV energy, which ensures higher accuracy and shorter simulation time. This study is a computer simulation using the PHITS version 3.34.1 program to determine the optimal irradiation direction that is safe for healthy organs surrounding the esophageal cancer in the middle thoracic area, as well as to calculate the irradiation time. The phantom model used is an adult male phantom from Oak Ridge National Laboratory (ORNL), with a gross tumor volume (GTV) of 25.88 cm^3 and a cancer type of squamous cell carcinoma. The neutron source was a 30 MeV cyclotron accelerator with 1mA current. The boron concentration used was 150 ppm. The variation of irradiation angle direction was 0^o, 30^o, 45^o, 60^o, and 90^o. The results showed: the shortest irradiation time obtained is 32 minutes 36 seconds; both equivalent and effective dose evaluation results show that all organ at risk (OAR) received radiation doses below their respective dose constraints; and the neutron irradiation angle that produces the optimal dose to this cancer and is safe for organs at risk (OARs) is achieved at a variation of 90^o with the patient's right lateral position.

Keywords: Boron Neutron Capture Therapy, radiation dose, esophageal cancer, Particle and Heavy Ion Transport code System