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# CONSIDERATIONS FOR PATIENT POSITIONING IN STATIC BEAMS FOR BNCT

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## Introduction

Boron neutron capture therapy (BNCT) is a binary treatment modality that may selectively irradiate tumor tissue. BNCT utilizes compounds containing stable isotope of boron, $^{10}B$, to sensitize tumor cells to irradiation by low energy thermal neutrons. The interaction of the $^{10}B$ with a thermal neutron, through capture reaction, causes the boron nucleus to split, releasing an alpha particle and a lithium ion. These high LET particles are very damaging to cells containing $^{10}B$. Thermal neutrons in the brain are derived from the attenuation and moderation of an incident epithermal neutron beam, obtained from filtered neutrons emanating from a nuclear reactor.

Phase I/II clinical trials of BNCT for patients with a highly malignant brain tumor, glioblastoma multiforme, are underway using p-boronophenylalanine - fructose and the epithermal neutron beam of the Brookhaven Medical Research Reactor (BMRR). Since the neutron beam is permanently oriented horizontally with regard to the floor, there is a need to properly position and immobilize the patient for treatment. The objective of this short communication is to provide a guideline for patient positioning, verification and immobilization for BNCT. Although the guideline is based on the experience gained at BMRR it should be applicable to any static beam for BNCT.

## General Conditions

At the BMRR a collimated beam is emitted horizontally from the biological shielding wall into the treatment room. It is this fixed beam into which a patient has to be maneuvered for proper treatment. Because of the rapid loss of neutron intensity at every incremental increase in the distance from the beam port, the head of the patient must be kept contiguous with the beam port, rendering patient positioning difficult. The beam port wall is equipped with three conventional positioning lasers, identical to those used in conventional radiation oncology facilities for triangulation. Three lasers, each with cross hair, are orthogonally mounted so as to project at the isocenter virtually located ten centimeters distal from the beam port. Each of the laser beams intercepts the beam central axis. Typical treatment times of about 40 minutes require that patients be immobilized securely but comfortably.

For patient positioning purposes a mock-up room, identical to the treatment room, was constructed with an opening in a wall simulating the beam port. A cross hair laser, additional to the three orthogonal lasers, was positioned with the axis along the central beam axis shining into the port from the neutron beam direction. The mock-up room is otherwise identical with the treatment room. The opening in the wall allows one to check the patient position from the beam's eye view. A hydraulic table or a chair are employed to provide adjustable patient support during

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BNCT. Another instrument was designed for stereotactic marking of patients prior to the treatment planning MRI scans of the brain. Cardinal to BNCT therapy are three processes, that are closely coupled namely, patient marking, treatment planning and patient positioning. These processes are described in the following sections.

**Patient Marking**

The heads of patients scheduled for BNCT are marked with fiducial marks at anterior, posterior, right lateral, left lateral and vertex points with a surgical pen using the in-house built stereotactic frame. The four other surface marks are located at a plain which is about five centimeters inferior to the vertex. This marking is accomplished by placing the patient (with the stereotactic frame placed on the same surface and around the head) on a flat firm surface so that orthogonal compatibility with that of the positioning lights and patient couch in the MRI scanner is maintained. Vitamin E capsules are placed on the surface marks to provide a MRI image of the fiducial marks that are used during the treatment planning to establish patient coordinates. The four fiducial marks in the cross sectional plane (excluding the one at the vertex) are coplanar. Similarly, anterior, vertex and posterior marks are coplanar in the sagittal plane. Subsequent to surface markings MRI brain scans are carried out, with and without contrast enhancing material. The head is scanned from C4 to the vertex contiguously with 5 mm thick slices.

**Treatment Planning and Patient Positioning**

MRI images are transferred electronically to the treatment planning computer and are used to create a 3D model of the head for isodose calculations employing the MNCP code. In addition the MCNP code provides the coordinates of the beam central axis intercepts of the different regions in the patient's head, e.g., scalp, skull, brain and target. Using this information, the coordinates of the entry and exit points of the beam central axis on patient head are calculated relative to the fiducial marks. In addition the distances from the fiducial marks to the beam port are also calculated. Using these coordinates the entry point and whenever possible the exit point are marked on a patients head.

For the purpose of BNCT simulation, the patient is placed on a table or in a chair in the mock-up room. The table or the chair with the patient are maneuvered until the entry point mark is contiguous with the center of the beam port and the laser lines intercept the exit point. This positioning is confirmed by viewing the patient's head and entry point through the opening in the wall. Once final satisfactory position is achieved, i.e., the beam entry and exit marks on the patient are collinear with the beam central axis as represented by the laser lines, the patient is immobilized using a variety of supporting accessories and materials such as: foams and Velcro strips. These materials are preselected following irradiation in the reactor to assure minimal neutron activation. Final patient position is verified by checking the distances of the fiducial marks from the beam port as calculated by the treatment planning software. At this configuration, laser lines on the patient head are marked with a pen and are used as the final set of marks for patient positioning in the treatment room. In addition the height of the table or chair are measured and the laser lines are marked on all the items used for patient support.

In the treatment room the table or the chair and all the supporting and immobilization items are assembled according to the laser marks. Then patient's position is secured according to

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the laser marks on the head and verified again by measuring the distances of the fiducial marks from the beam port. The outline of the patient head and other features such as the nose are marked on a closed loop video monitor for observing any patient movement. If any movement does occur during treatment the patient is instructed through the audio intercom system to take a corrective action.

## Discussion

As opposed to the conventional radiotherapy where the clinical accelerator moves isocentrically around the patient, for BNCT the reactor provides a fixed beam. Therefore, the patient has to be maneuvered so that the superior, posterior and lateral parts of the head can be placed in contact with the beam port. Due to this unique requirement and because of the need to reduce the distance between the patient and the beam port, no space is left between the beam port and the patient for conventional verification devices e.g., x-ray machine. The procedure described above evolved during our clinical trials of treating patients with glioblastoma multiforme. This procedure has been found to be quite reproducible and verifiable. It is our experience that small errors in positioning of the patient have small effects on the isodose distribution and on the coordinates of the positioning points and on the verification distances. We are conducting systematic analysis on the error propagation in the isodoses and in the coordinates due to errors in fiducial marks and patient positioning.

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