

## THE DESIGN OF NEUTRON BEAMS FOR NEUTRON CAPTURE THERAPY

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Improved Federal support for neutron capture therapy in recent years has brought about a resurgence of activity in this field by researchers in various disciplines. Furthermore, encouraging clinical results from Japan in the treatment of glioblastoma multiforme and melanoma by neutron capture therapy has resulted in renewed enthusiasm for mounting a clinical trial of this treatment modality in the U.S. One area of intense activity world wide is the development of optimal neutron beams for neutron capture therapy for both shallow and deeply seated tumors. In this paper we will review the physical basis for the interaction of neutrons with tissue and the principles underlying the development of neutron beams for neutron capture therapy. In particular, the greater availability of sealed, high-activity  $^{252}\text{Cf}$  sources from US government laboratories has prompted a reappraisal of their suitability for neutron capture therapy.

### INTRODUCTION

Neutron capture therapy (NCT) is a binary form of radiation therapy originally conceived in 1936. It relies on initial targeting of tumor cells by an appropriate drug tagged with the stable isotope  $^{10}\text{B}$ , followed by irradiation of the local tumor site with low energy neutrons. When  $^{10}\text{B}$  absorbs a low energy neutron it ejects an energetic, short-range alpha particle which deposits most of its energy within the cell containing the original  $^{10}\text{B}$  atom. Therefore, if a higher concentration of  $^{10}\text{B}$  exists in tumor cells relative to other normal tissues, a selectively higher dose will be delivered to tumor cells during neutron irradiation.

In addition to the development of  $^{10}\text{B}$  labelled drugs for NCT, an important area of research in the field of NCT over the past years has been the optimization of "thermal" and "epithermal" neutron beams.<sup>1,2,3</sup> Thermal neutron beams (0-0.1 eV) are the original type of neutron beams that were used unsuccessfully in clinical trials of NCT for high-grade astrocytomas in the US in the 1950's and 1960's, and also are currently being used in the Japanese NCT clinical trials for high-grade astrocytomas and melanomas. These more recent clinical trials appear to be demonstrating a more favorable outcome than the earlier US ones.<sup>4</sup>

Unlike the familiar dose distribution pattern in tissue produced by conventional high energy X-ray beams, thermal neutron beams exhibit very rapid fall-off with depth in tissue, with a half-value thickness of approximately 1-1.5 cm, and negligible skin-sparing at the tissue surface. Consequently, the successful use of thermal neutron beams for neutron capture therapy of intracranial tumors generally requires that the tumor be relatively superficial and that normal radiosensitive superficial structures, such as scalp, skull and dura be surgically reflected during treatment. This essentially makes this type of NCT an intraoperative form of radiation therapy. More recently, it has been shown<sup>5</sup> that if

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