CHARACTERISTICS OF A 62MEV PROTON THERAPY BEAM

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This paper describes the 62MeV proton therapy beam at the MRC Cyclotron Unit at the Clatterbridge Hospital. The characteristics of the beam are reported in terms of range, beam penumbra, the variation in output with field area, and beam shaping.

Introduction

The 62MeV proton beam produced by the Scanditronix MC60 cyclotron at the Clatterbridge Hospital has been used in the treatment of eye tumours (ocular melanoma) since June 1989, and to date a total of 73 patients have been treated. The beam line is shown in figure 1 and consists of a double scattering foil system incorporating a central stopper, parallel plate ionisation chambers, range shifter and beam modulator together with anti-scatter collimators. The scattering foil system is used to provide uniform beam profiles over an area of 30mm in diameter. The foils are made of tungsten and are separated by a distance of 300mm. The first foil is 0.017mm thick and the second 0.027mm thick and the central stopper has a 3.05mm radius. These parameters were calculated using the method described by Gottschalk (1986). The overall length of the beam line is 1.8m and the distance from the final collimator to the isocentre is 70mm. Both range shifters and beam modulators are constructed from Perspex (Lucite). The range shifters define the maximum penetration of the beam for a given patient treatment. The modulators are stepped vanes which rotate in the beam to produce a uniform dose distribution across the target volume from the proton Bragg peak (Koehler et al 1975).

The purpose of this paper is to report the characteristics of this beam line in terms of range, beam penumbra, the variation of output with field area and beam shaping.

Range

The beam line was designed to minimise energy losses in order to treat all possible sites within the eye. The advantage of this system over a single foil system is illustrated in table 1. The distance of the double foil system is measured from the first foil to the point of measurement. In the case of the single foil this distance was increased until the flatness of the two beam lines was comparable. The depth of penetration is measured to the distal 90% isodose line using a small silicon photo-diode (type BPW34). It can be seen that the double foil system gives an extra 1.4mm of range compared with the single foil. The maximum beam range required so far has been 28.7mm of eye tissue compared with a final measured maximum range for the beam line of 30.4±0.2mm. The maximum required range is in good agreement with the value of 28.6mm (eye tissue) for 99% of the patients treated at the Harvard cyclotron (Goitein et al 1983).

Beam Penumbra

In order to achieve maximum range the modulator and range shifter were placed 600mm from the final collimator to maximise the length of the beam line in vacuum. Measurements of beam penumbra have been made in a water phantom using a small diode (BAS11) and a three dimensional scanner. For the current position the penumbra measured between 90% and 10% isodose lines varied from 2.3±0.1mm to 3.6±0.1mm as the effective thickness of Perspex (i.e. thickness of range shifter + ½ thickness of modulator) was increased from 7.5 to 23.8mm. If, however, the modulator and range shifter were placed further upstream, that is just after the scattering foils then the penumbra was virtually independent of the thickness of Perspex and measured 1.9±0.2mm. In order to achieve this position the amount of beam line in vacuum was shortened and consequently the maximum range was reduced to 29.7±0.2mm. This would still be adequate to treat all patients seen to date. The improvement in penumbra can easily be understood in terms of geometrical considerations. An improved penumbra would reduce the required safety margin. This latter quantity is calculated as the 90% - 50% penumbra + 1.5mm to allow for microscopic spread of disease and positioning error.

Variation in Output with Field Area

The treatment of ocular melanoma incorporates the use of irregular shaped collimators, each milled from a design produced by the planning program (Goitein & Miller 1983). Calibration of the beam is normally carried out using a 25mm diameter collimator and a 0.1cc thimble ionisation chamber (Far West Technology type IC-18). The variation in output with field size was investigated using a small diode and a selection of patient collimators. The output was normalised to the 25mm collimator and the results shown in figure 2 both for a modulated and unmodulated (full energy) beam. The modulated beam is the normal condition and the variation with field area is <1% for a representative range of patient collimators, therefore no output corrections are made to the chamber calibration. A much larger variation was seen in the case of the unmodulated beam indicating that the scattering out of the beam is much more dominant in this case.

Beam Shaping

The planning program incorporates the facility for shaping the beam with the use of aluminium wedges. These are placed 40mm downstream from the collimator to minimise perturbations of the beam relative to the target volume (Egger private communication). Figure 3 shows a set of isodose curves measured in a water phantom for a wedge with a nominal angle of 25° in eye tissue and compares with a measured angle of 22°.

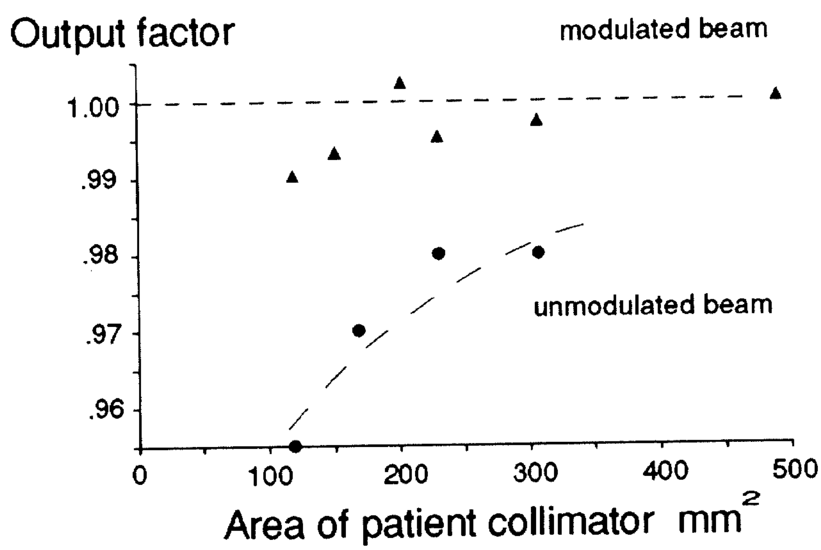

Figure 2: The variation of output in terms of dose with respect to collimator area (modulated beam, unmodulated beam)

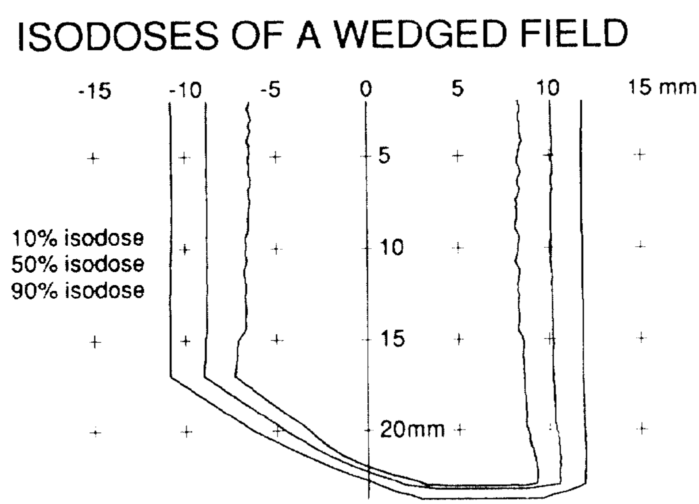

Figure 3: The isodose dsitriution for a field half covered by an aluminium wedge giving an effective wedge anle of 22° in eye tissue

Conclusions

The current beam line design has been able to treat all cases of coular melanoma that have been presented to date. Improvements in the penumbra can be made with an acceptable loss of penetration. It has also been shown that there is a negligible variation of output with field area and that shaping of the beam can be adequately achieved by the use of aluminium wedges.

References

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Table 1

A comparison of single and double tungsten foil scattering systems for a 62 MeV proton beam

Condition	Distance (mm)	Flatness (90%/50%)	Depth in Eye Tissue (mm)
No foil	--	--	31.0 ±0.4
Single W foil (0.15mm)	2200	93±1	29.3 ±0.4
Double W foil (0.044mm)	1500	94±1	30.7 ±0.4

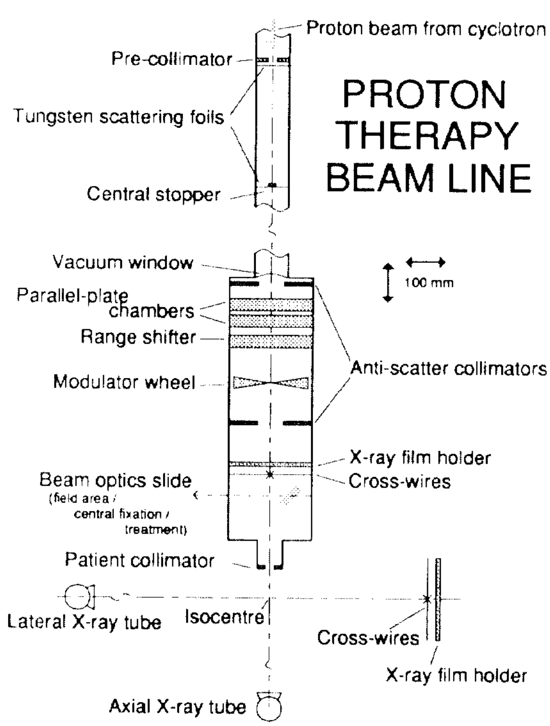

Figure 1: The proton therapy beam line at Clatterbridge