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NOTE

Blood irradiation with accelerator produced electron beams

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Abstract. Blood and blood products are irradiated with gamma rays to reduce the risk of graft versus host disease (GVHD). A simple technique using electron beams produced by a medical linear accelerator has been studied to evaluate irradiation of blood and blood products. Variations in applied doses for a single field 20 MeV electron beam are measured in a phantom study. Doses have been verified with ionization chambers and commercial diode detectors. Results show that the blood product volume can be given a relatively homogeneous dose to within 6% using 20 MeV electrons without the need to rotate the blood bags or the beam entry point. The irradiation process takes approximately 6.5 minutes for 30 Gy applied dose to complete as opposed to 12 minutes for a dual field x-ray field irradiation at our centre. Electron beams can be used to satisfactorily irradiate blood and blood products in a minimal amount of time.

1. Introduction

Blood products are irradiated to diminish the risk of transfusion associated graft versus host disease (TA-GVHD). The desired effect of irradiating the blood is to inhibit lymphocyte function and therefore to prevent GVHD while not causing damage to platelets or other blood fractions. Guidelines based on the work of Pelszynski *et al* (1994) and Luban and DePalma (1996) state that at least 2500 cGy provides a 5log depletion of T cells in a T cell collagen assay and thus sufficient for elimination of GVHD.

Blood and blood products are normally irradiated using gamma rays from a dedicated canister (Moroff and Luban 1997) or using linear accelerator dual field x-ray beam irradiations (Butson *et al* 1999). The dual field treatment requires the use of a 'blood box' with build-up and scatter material around the blood for equilibrium condition to apply. Usually 10 cm of scatter material around the blood is taken, which is more than sufficient. The blood is normally irradiated isocentrically from two parallel opposed directions. Thus the blood is normally located at a depth of approximately 10 cm. This means that half way through the treatment, the machine or the blood box must be physically rotated by 180 degrees. An easier method, which utilizes a single beam, can be performed with a 20 MeV electron beam produced by a linear accelerator. Two types of blood product are normally irradiated. These are blood itself, usually contained in a blood bag which is approximately 1 cm to 3 cm thick, and platelets, which are contained in a bag which is approximately 3 to 5 mm thick. This note quantifies

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the dose distributions achievable with this technique and analyses the time efficiency of the technique. For analysis of dosimetry, phantom blood bags were used instead of actual blood products. The phantom material used was a mixture of water and organic matter to produce a relative density of approximately 1.1, similar to blood (Woodard and White 1986) inside the blood bags of equivalent volumes to platelets and blood. Future references to blood products will mean phantom blood products.

2. Materials and methods

Blood products are irradiated in a 25 cm × 25 cm × 10 cm (inner dimensions) Perspex 'blood box' which is filled with the blood to be irradiated and spaces packed with bags containing rice during irradiation. A 0.6 cm Perspex lid is placed on the blood box as build-up material. Tests are performed using a 20 MeV electron beam produced by a Varian 2100C medical linear accelerator. The 20 MeV electron beam treatment requires the blood to be placed in the active volume located from 0 cm to 5 cm depth. The blood is irradiated to 30 Gy. The largest clinical field size achievable with an electron cone is 25 cm × 25 cm. 10 cm thick rice filled bags are placed around the blood box to provide sufficient lateral scatter material. The blood products irradiated range in thickness with platelet bags being approximately 3–5 mm and blood bags being approximately 1–3 cm. With this configuration up to 12 layers of platelets or two layers of blood (depending on thickness) can be irradiated at once. The dose at depth characteristics for a 20 MeV electron beam in water for comparison was measured using a thimble ionization chamber. Doses throughout the active volume in the blood box were measured using a thimble type ionization chamber and a Scanditronix photon diode in absolute dose mode (Rikner 1985). These detectors were placed in between the blood or platelet bags during irradiations and their absolute dose measured. These detectors are calibrated against measurements taken in standard conditions and irradiated to 30 Gy applied dose.

3. Results and discussion

Figure 1 shows the measured dose for a 20 MeV electron beam in water and the dose variation through the 'active' region and beyond in the blood box for the 20 MeV treatment. Errors shown are one standard deviation of the mean for all measurements taken. Variation in applied dose for the active volume with 30 Gy given to maximum dose position for 20 MeV electrons was 6% with the maximum dose recorded at 2.8 cm depth. As shown in the figure, the measured results using the blood bags show a slightly decreased dose compared to the water depth dose as depth increases. This is expected due to the higher density of the phantom blood products, which simulate the density of blood being closer to 1.1. These measurements at each depth were repeated ten times and measured results showed a variation in measured dose of approximately ±4%. Measurements were also performed in a lateral position to analyse the effect of off axis dose. Results showed that there was no dose reduction seen off axis, thus an adequate level of scatter material was present to provide dose homogeneity off axis. The time required to provide this dose at a dose rate of 400 monitor units per minute is approximately 6.5 minutes per treatment. This is the fastest clinical dose rate used in our centre. This can be compared to the dual field 6 MV x-ray treatment, which requires the blood to be set up with the x-ray beam from two directions at 400 monitor units per minute. Thus a physical movement of the machine from 0 degrees to 180 degrees is required, which adds approximately 4 minutes time to the irradiation procedure. As the blood is treated at depth, a larger monitor unit exposure is required to deliver the same dose as with the electron beam. Overall this treatment takes

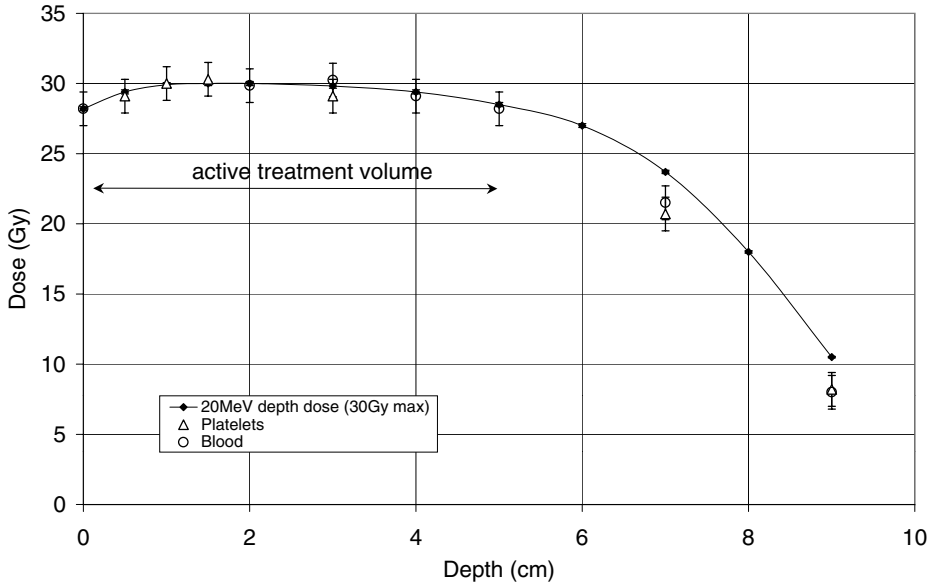

Figure 1. Radiation dose characteristics of a 20 MeV single field electron beam technique and measured values within the blood products using various dosimeters. The active treatment volume is shown, which could accommodate up to 12 layers of platelet bags or two layers of blood bags.

approximately 13 minutes to complete. Thus a single field 20 MeV electron beam effectively produces a 100% increase in time efficiency. In a busy radiotherapy department this reduction in time can provide an enhancement in the quantity of service provided for blood irradiation. As the electron beam has a definite range, the margin for set-up error is smaller. This however should not be a deterrent from its use as due care will always eliminate these errors. Platelet bags are only 3–5 mm thick and thus pose no dosimetry problems in set-up for a 20 MeV beam. The blood bags are 1–3 cm thick. Thus for conservative treatment set-up to alleviate any risk of the blood bag being outside the active treatment volume, one layer of blood bags could be irradiated using the 20 MeV electron beam; however up to two layers can be performed. The irradiation of one layer of blood bags is the normal procedure in our department using x-rays.

4. Conclusion

An irradiation technique using 20 MeV electrons can provide adequate irradiation techniques for blood irradiation with an increase in time efficiency, which could be beneficial in a busy radiotherapy department.

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