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FRICKE DOSIMETRY FOR BLOOD IRRADIATORS

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Irradiation of blood and blood components is practiced with the main purpose of preventing graft versus host disease in immunodeficient patients. Transfusion-associated graft-versus-host disease (TA-GVHD) is a possible transfusion reaction and can often be a fatal complication occurring in patients receiving cellular blood components. Inactivation of transfused lymphocytes by the use of ionizing irradiation of blood components remains the most efficient method for inhibiting lymphocyte blast transformation and mitotic activity, hence preventing TA-GVHD. Chemical dosimetry using a standard FeSO4 solution, Fricke solution, has shown potential in being a reliable standard of absorbed dose for blood irradiation and other applications. The linearity for this dosimeter and reproducibility tests have been investigated by this group. Thus, considering all these issues, we propose the use of a Fricke dosimeter to perform blood irradiation dosimetry, for this we have provided the dose distribution in the irradiator container.

The use of an equivalent water phantom and the control of organic and inorganic impurities in the Fricke solution are important factors to ensure that less correction is necessary for the measurements of radiation dose inside the blood irradiator. For this purpose, a specific phantom was constructed and patented by the Radiological Sciences Laboratory to perform the measurements. The phantom created by the authors consists of a cylindrical container made in a 3D printer using acrylonitrile butadiene styrene (ABS) with a density (ρ = 1.03 g.cm-3) close to that of water. It has a design suitable for the Fricke solution to be placed in small polyethylene bags of approximately 4 x 4 x 0.2 cm3. The phantom has 19 cavities with dimensions of 4 x 4 x 0.4 cm3, to accommodate the polyethylene bags filled with Fricke solution, that are spatially homogeneous distributed throughout the cylindrical volume.

All measurements were performed under normal irradiation conditions for blood bags, including rotation of the canister and a current time for irradiation. Five bags were used as the control solution and submitted to the same conditions but were not irradiated. The absorbance was read using a Varian Cary 50 Bio spectrophotometer for the control and the irradiated solutions maintained at a temperature of 25 ℃. All measurements were performed in a Gammacell 3000 Elan (Best Theratronics) blood irradiator located at the Hemocenter in Rio de Janeiro, Brazil, which uses two 137Cs sources for irradiation. The measurements were performed as a routine irradiation procedure, of 5 minutes and 49 seconds, with an expected dose of 25.7 ± 1.5 Gy in the centre of the cylinder.

The cavities of the phantom can be grouped into three regions: the center, the top and the bottom. Five sets of measurements using 19 bags each were performed. The mean doses were calculated and were as follows: 29.28 Gy with a type A uncertainty of 1.06% for the bottom part, 30.40 Gy with a type A uncertainty of 1.10% for the central part, and 26.39 Gy with a type A uncertainty of 1.15% for the top part. The upper doses were lower than the bottom doses, and the center of the canister received the highest dose. Type A uncertainties were calculated as the standard deviation of the absorbed dose to water obtained for each group of bags, bottom, central and top, separately. Figure 1 shows the mean values for all measurements for each individual cavity. It is important to note that the nonuniformity of the source causes this high standard deviation. The increasing tendency shown in Figure 1 is due to the position within the cylinder. The dose is higher in the external part of the cylinder (C) due to its proximity to the source.

Fig 1. Average doses and standard deviation for all 19 cavities. The dashed dotted line indicates the expected dose (25.7 Gy) and the short dashed line indicates the standard deviation of average doses.

Fricke dosimetry provided a volumetric dose distribution evaluation with a final uncertainty of 2.07% (k=1). The obtained results showed that the setup, the Fricke dosimeter and the phantom, is able to perform dosimetry for blood irradiators. Using the Fricke system reduces the uncertainty of the dose in the centre of the mid plane of the canister by about a factor of 4 compared to that achievable using EBT film. The mean value of Fricke solution resulted in 28.7 Gy, which is about 12% greater than the expected value of 25.7 Gy, but this is not statistically significant since the 2 sigma uncertainty using EBT film is about 12%.

We intend to implement a standard for absorbed dose to water based on Fricke chemical dosimetry and supply the need for hemocenters, hospitals and clinics to perform annual dosimetry for the irradiation of blood components as required by the Brazilian Health Regulatory Agency (ANVISA), American Association of Blood Bank (AABB) and the Brazilian National Commission of Nuclear Energy (CNEN).

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