

BLOOD COMPOUNDS IRRADIATION PROCESS: ASSESSMENT OF ABSORBED DOSE USING FRICKE AND THERMOLUMINESCENT DOSIMETRIC SYSTEMS

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ABSTRACT

The assessment of gamma absorbed doses in irradiation facilities allows the quality assurance and control of the irradiation process. The liability of dose measurements is assigned to the metrological procedures adopted including the uncertainty evaluation. Fricke and TLD 800 dosimetric systems were used to measure absorbed dose in the blood compounds using the methodology presented in this paper. The measured absorbed doses were used for evaluating the effectiveness of the irradiation procedure and the gamma dose absorption inside the irradiation room of a gamma irradiation facility. The radiation eliminates the functional and proliferative capacities of donor T-lymphocytes, preventing Transfusion associated graft-versus-host disease (TA-GVHD), a possible complication of blood transfusions. The results show the applicability of such dosimetric systems in quality assurance programs, assessment of absorbed doses in blood compounds and dose uniformity assigned to the blood compounds irradiation process by dose measurements in a range between 25 Gy and 100 Gy.

1. INTRODUCTION

Transfusion associated graft-versus-host disease (TA-GVHD) is a possible and usually fatal complication of blood transfusion that affects mainly immunocompromised patients. It occurs when donor T-lymphocytes proliferate and attack recipient organs and tissues, rejecting the host due to immunologic differences [1, 2].

There is no effective treatment of TA-GVHD and the mortality rate is extremely high (80-90%) [3]. In the light of the absence of any effective treatment, the prevention of this condition is essential.

A successful prevention of TA-GVHD depends on physical removal of donor lymphocytes or on destruction of their proliferative capacity. Current filtration technology cannot effectively remove the quantity of lymphocytes required. Therefore, the only method presently accepted is gamma irradiation [4].

Ionizing radiation eliminates the functional and proliferative capacities of T-lymphocytes maintaining other blood components functional and viable, especially erythrocytes,

granulocytes and platelets [5]. The recommended central absorbed dose for blood irradiation is typically 25 Gy, with a minimum of 15 Gy at any point in the container. In some jurisdictions, the absorbed dose range for blood irradiation is 25 Gy to 50 Gy [6].

As the dose of gamma radiation can vary from the centre to the periphery of the container being irradiated, it is necessary to establish a quality control procedure to verify the delivered dose to the blood bags. There are several dosimetric systems already employed to the quality control of the radiation dose in the process of blood irradiation, and in this practice, Fricke and thermoluminescent dosimeters were used.

The Fricke dosimetry system provides a reliable method for measurement of absorbed dose in water, based on a process of oxidation of ferrous ions to ferric ions in acid aqueous solution by ionizing radiation. The dosimeter is a solution of ferrous ammonium sulfate ($1,0 \text{ mol.L}^{-1}$) and the absorbed dose is determined by a change in the absorbance at a specified wavelength (303 nm). It is considered a reference-standard dosimetry system in the absorbed dose range of 40 to 400 Gy [7].

Thermoluminescent dosimeters (TLD) are extensively used for quantitative dose measurements. This dosimetry system consists on small crystals whose structure is altered by irradiation. The application of heat repairs the crystal, causing it to emit light in proportion to the initial level of radiation and allowing it to be used as a method of dosimetry [8]. The TLD-800 ($\text{Li}_2\text{B}_4\text{O}_7:\text{Mn}$), used in this practice, is able to measure the absorbed range of $\mu \text{ Gy}$ to 10^5 Gy .

The assessment of gamma absorbed doses in irradiation facilities allows the quality assurance and control of the irradiation process. The liability of dose measurements is assign to the metrological procedures adopted including the uncertainty evaluation. Fricke and TLD 800 dosimetric systems were used to measure absorbed dose in the blood compounds using a methodology presented in this paper. The measured absorbed doses were used for evaluating the effectiveness of the irradiation procedure and the gamma dose absorption inside the irradiation room of a gamma irradiation facility.

2. EXPERIMENTAL PROCEDURE

A blood irradiation was simulated using blood bags filled with saline solution and several samples of TLD and Fricke dosimeters inside a box. The irradiation took place in a facility equipped with a multipurpose panoramic irradiator category II (dry storage), model IR-214, fabricated by MDS Nordion, with a Cobalt-60 source (half-life of 5.27 years) [9].

The Fricke dosimetric solution was prepared dissolving 0.392 g of ferrous ammonium sulfate, $(\text{NH}_4)_2\text{Fe}(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$, and 0.058 g of sodium chloride, NaCl, in 12.5 mL of 0.4 mol.L^{-1} sulfuric acid, H_2SO_4 and then diluting it to 1000 mL in a volumetric flask with 0.4 mol.L^{-1} sulfuric acid.

The solution was used inside two bags, one on the box boundary, side S2, and the other one between two saline bags, point M. Additionally, 8 tubes were also used, 6 located on the box boundaries, side S1 and side S2 and 2 between the bags, point M. The TLDs were located on the box boundaries, sides S1 and S2, 17 dosimeters in each position (Fig. 1).

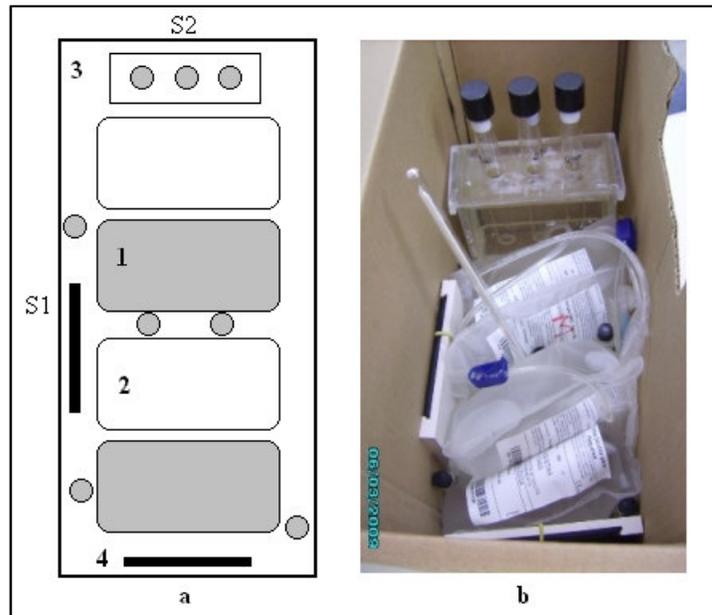


Figure 1. (a) Plan of dosimeters distribution inside the box. (1: Fricke Bag; 2: Saline bag; 3: Fricke Tube; 4: TLD) (b) All material inside the box

The experiment was carried out under the circumstances of a routine blood irradiation in March 6, 2009.

The box was located on a turntable one meter distant to the source, near its mid-height (Fig. 2), and submitted to four irradiation processes of 4 minutes and 38 seconds (time of a 25 Gy exposure at this position according to the dose rate of that day, $324.27 \text{ Gy}\cdot\text{h}^{-1}$). Temperature measures were made before and after the irradiation.



Figure 2. Position of the box inside the irradiation room.

3. RESULTS AND DISCUSSION

The obtained average dose results of each group of samples and respective uncertainties at the 95% confidence level are show in Table 1. Fig. 3 shows the histogram with frequency of all measured doses using both dosimetric systems.

Table 1 – Average dose and respective uncertainty of each sample group

| Sample group | Average Dose (Gy) | Uncertainty (%) |
|---------------------|--------------------------|------------------------|
| Fricke Tubes S1 | 25.4 | 2.6 |
| Fricke Tubes M | 23.2 | 8.4 |
| Fricke Tubes S2 | 27.6 | 7.1 |
| Fricke Bag S2 | 25.3 | 0.4 |
| Fricke Bag M | 23.8 | 0.4 |
| TLD S1 | 21.9 | 2.2 |
| TLD S2 | 21.3 | 3.8 |

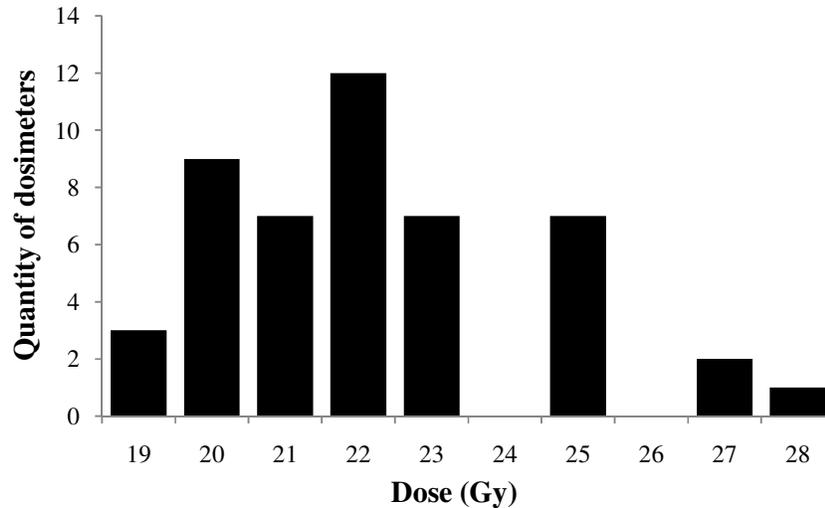


Figure 3. Frequency histogram for the dosimeters used in quality control blood irradiation.

The uncertainty estimation was made based on the guide to the expression of uncertainty in measurement – GUM [10]. As it can be seen, the results have shown no exceed to the limits of the recommended dose. The minimum and maximum dose values obtained were 19.7 Gy and 28.5 Gy, respectively.

4. CONCLUSIONS

The obtained results have shown the applicability of these techniques for evaluation of the absorbed dose on blood compounds to prevent the transfusion associated graft-versus-host disease. In all cases, the absorbed dose was within the limits of recommended dose, from 15 to 50 Gy.

It was also shown that Fricke and TLD 800 dosimetric systems could be used in quality assurance programs to evaluate the absorbed dose on the blood compounds during the irradiation process, once they present low values of uncertainty. The standard uncertainties (95% coverage interval) for Fricke and TLD dosimeters were 8.4 % and 3.8 % respectively.

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