Is Ultraviolet Radiation Safe for Blood Irradiation?

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Abstract— Ultraviolet irradiation has been shown to be effective for TAGVHD prevention. However, ionizing irradiation has not yet been replaced by ultraviolet irradiation for blood irradiation at the blood banks, since there are still questions about the safety of this technique. The samples were irradiated with 4 J/cm2 of UV which is the minimum dose shown to be effective for TAGVHD prevention according to literature available. The data was analyzed with SPSS software. The results showed that UV irradiation does not change the blood potassium level. Furthermore, the hematological tests showed no hematological change after ultraviolet exposure. Moreover, the morphology of RBCs and PLTs after ultraviolet irradiation was normal. According to the results, the ultraviolet irradiation is a suitable way for red blood cell irradiation and a new way for TAGVHD prevention in blood component preparation.

Keywords—Ultraviolet light, Blood irradiation, TAGVHD.

I. INTRODUCTION

The need of blood transfusion has been well known. There are some specific diseases like Thalassemia, Hemophilia and other chronic diseases that the patient is in need of continuous blood transfusion. On the other hand, blood transfusion from a donor to a patient in some cases has many risks such as infection and TAGVHD (Transfusion associated graft versus host disease). TAGVHD happens by transfusion of untreated blood to immunocompromised recipients or when the blood of the donor is homozygous and the recipient is heterozygous for an HLA (human leukocyte antigen) haplotype. The clinical manifestations of TAGVHD are similar to that of GVHD but due to involvement of bone marrow lymphoid tissue it is associated with a higher mortality (80-90%).

Currently, the blood products that are produced in the transfusion department of the hospitals are, whole blood, fresh frozen plasma (FFP), platelet rich plasma, cryoprecipitate, cryosupernatant, red blood cells (PRBC) in the form of packed cells or red cell concentrate, and platelet concentrate.

Transfusion associated graft versus host disease (TAGVHD) is caused by replication-competent donor lymphocytes in cellular blood products that engraft and lead to immune-mediated destruction of host tissues. The development of TAGVHD reflects the inability of the recipient’s immune system to reject the transfused, and thus foreign, lymphocytes.

Blood recipients with acquired or congenital immunodeficiencies, leukemia, lymphoma, aplastic anaemia, solid organ transplants, allogeneic and autologous hematopoietic progenitor cell transplantation, pregnant women, Hodgkin’s disease, immature immune systems, or those receiving closely HLA-matched platelet transfusions especially from first-degree family members are at risk of developing TAGVHD. There is no effective treatment for TAGVHD and its mortality rate is greater than 90% with blood transfusion in these cases. Hence, its prevention is of great importance. TAGVHD causes severe problems such as fever, rash, diarrhea and liver injury; it also results in severe marrow aplasia, with bleeding due to thrombocytopenia and infection due to neutropenia.

Currently, TAGVHD is prevented by ionizing radiation e.g. gamma irradiation or x-ray irradiation. TAGVHD is effectively prevented by exposing blood components to a minimum of 25 Gy of gamma or x-ray radiation prior to transfusion to at risk patients. However, this technique has some side effects on the blood product irradiated[1].

TAGVHD is more common in immunocompromised patients, immunosuppressant, immunodeficient patients e.g. getting treated with chemotherapy or immunosuppressive drugs (for diseases such as multiple sclerosis or rheumatoid arthritis, myasthenia gravis, systemic lupus erythematosus, focal segmental glomerulosclerosis, Crohn’s disease, Behcet’s disease, pemphigus, and ulcerative colitis), low-birth-weight neonates, intrauterine transfusions, bone marrow transplant patients, patients with congenital immunodeficiency syndromes, patients with Hodgkin’s or non-Hodgkin’s lymphoma, patients undergoing intensive treatment, patients being treated for acute leukemia and units donated by a blood relative.

Ionizing irradiation prevents the occurrence of TAGVHD by altering the DNA in the WBCs such that they cannot divide and therefore cannot engraft in the recipient’s blood. The ionizing irradiated blood products are advised for more at risk patients with probability of TAGVHD because of the side effects of ionizing irradiation. For example, ionizing irradiation increases blood potassium, hence ionizing irradiated blood products are not transfused to patient with high potassium levels. Another problem caused by ionizing irradiation is the decrease in the pH of blood. In addition, platelets are more damaged by ionizing irradiation and hence irradiation must be done after storage. Therefore, storage is a problem for ionizing irradiated blood products. Moreover, there is the dose homogeneity and error problem.

Several studies have been done on the suitability of ultraviolet radiation on platelet concentrates both for
disinfection [2-6] and TAGVHD prevention [7-14]. On the other hand, in some other studies it has been mentioned that the platelets are activated upon UV irradiation [15, 16]. Hence, the controversy remains as to choose non-ionizing UV radiation as a replacement for ionizing radiation or not. Besides, the suitability and safety of ultraviolet radiation on PRBC and whole blood cells for TAGVHD prevention still needs to be investigated. In this study, the suitability of blood products by non ionizing ultraviolet irradiation has been investigated for TAGVHD prevention.

II. METHODS AND MATERIALS

In this study, the samples were irradiated with 4 J/cm2 of UV light which is the minimum dose shown to be effective for TAGVHD prevention according to literature available. The test tubes used for this purpose were vacuum plastic test tubes which the absorbance of UV for these test tubes were analyzed with a spectrometer. The transparency of these plastic test tubes to UV light was insured.

A 0.6 ml of blood sample was separated in to each vacuum plastic test tube and exposed to UV. A total of 30 blood samples were irradiated with 4 J/cm2 of UV light and 30 samples were kept as control. These blood samples were then analyzed with Olympus AU640 biochemistry analyzer before and after irradiation for blood potassium level.

Another 30 blood samples with different anticoagulant were considered as is the lowest amount that can statistically give significant results. 1 ml of blood with EDTA anticoagulant was separated in to each vacuum plastic test tube and exposed to UV radiation and 1 ml kept as control. These blood samples were analyzed with a Sysmex Hematoanalyzer before and after irradiation. The blood cell counts, blood cell volumes, hematocrit and hemoglobin difference were analyzed. Furthermore, the statistical calculations were done with SPSS software using student t test.

In addition, blood slides were prepared using blood smear technique for microscope investigation prepared from a single blood drop before and after UV irradiation. The red blood cells and platelets morphologies were investigated with a microscope equipped with a CCD to acquire photos.

III. RESULTS

Using SPSS software it was concluded that statistically the potassium level after UV irradiation is similar to the potassium level before UV irradiation. Hence, UV irradiation does not change the blood potassium level.

The results of 30 blood samples showed no statistical difference between the values of RBC, HGB, HCT, MCH, MCHC, MCV and PLT before and after UV irradiation. In addition, the difference in MPV values before and after UV irradiation was statistically negligible. On the other hand, the value of WBC after UV irradiation was statistically different and was less than the values before UV irradiation just as was expected and desirable.

Out of the 30 samples studied, 5 samples were chosen for further investigations. These 5 blood samples were stored for two consecutive day at 4-6°C and analyzed each day for hematological changes. There was negligible difference after the first and second day of storage in RBC related hematological parameters. In addition, there was improvement in platelet counts after just one day storage.

Furthermore, UV irradiation has no impact on red blood cells or platelet morphology as was checked in the blood slides prepared under the microscope. No abnormal red blood cells (e.g. spherical, sickle shaped, etc) or abnormal platelets (large platelets, etc) were observed after the irradiation.

IV. CONCLUSION

The fact that UV irradiation does not increase the potassium concentration of human blood is the main issue that makes UV irradiation of red blood cells a better option for TAGVHD prevention in comparison to ionizing X-ray or gamma-ray blood irradiation techniques. Hence, UV irradiation may be a better method for TAGVHD prevention of RBC collected either by apheresis technique or donated routinely in the blood banks. UV irradiation does not change the number of RBC and platelet counts and decreases the number of WBC count as it is desired in blood irradiation. In addition, UV irradiation does not change blood HGB, HCT, MCH and MCHC values. Moreover, UV irradiation does not change blood cell volumes. In other words, MCV do not change and there is no change in the volume of RBCs and they do not undergo any deformability. This is an advantage in comparison to ionizing radiation blood irradiation. Hence, UV irradiation of red blood cells is a better option for TAGVHD prevention in comparison to ionizing X-ray or gamma-ray blood irradiation techniques. In addition, this advantage increases the transfusion option for more patients at risk of TAGVHD like neonates. Besides, storage has no side effect on the quality of blood products and unlike ionizing blood irradiation, irradiation before storage is safe and has no health impacts. In conclusion, the ultraviolet irradiation is a suitable way for red blood cell irradiation and may be a new method for TAVGHD prevention in blood component preparation.

ACKNOWLEDGEMENTS

This work is supported by the Universiti Sains Malaysia. The authors have no conflict of interest.

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