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18

Blood Irradiation

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1. Introduction

Transfusion-associated graft-versus-host disease (TA-GVHD) is a possible complication of blood transfusion that occurs when viable donor T-lymphocytes proliferate and engraft in immunodeficient patients after transfusion. Presently, the only method accepted to prevent TA-GVHD is the irradiation of blood and its components before transfusion (Moroff and Luban 1997)). Ionizing irradiation eliminates the functional and proliferative capacities of T-lymphocytes leaving other blood components, especially erythrocytes, granulocytes and platelets, functional and viable. This is possible because T-lymphocytes are more radiosensitive than other blood components (Masterson and Febo, 1992).To carry out the irradiation of blood specially designed commercial irradiators exist, usually localized in blood banks, and dedicated exclusively to this task.

Blood and blood components may be treated with ionizing radiation, such as gamma rays from ^{137}Cs or ^{60}Co sources, and from self-contained X-ray (bremsstrahlung) units and medical linear X-ray (bremsstrahlung) and electron accelerators used primarily for radiotherapy. However, teletherapy machines, such as linear accelerators or ^{60}Co units already available at the hospital, may also be used for the same purpose (Moroff 1997), improving the cost/benefit ratio of the process.

Blood irradiation specifications include a lower limit of absorbed dose, and may include an upper limit or central target dose. For a given application, any of these values may be prescribed by regulations that have been established on the basis of available scientific data.

The absorbed dose range for blood irradiation is typically 15 Gy to 50 Gy. In some jurisdictions, the absorbed dose range for blood irradiation is 25 Gy to 50 Gy. The energy range is typically from approximately 40 keV to 5 MeV for photons, and up to 10 MeV for electrons.

For each blood irradiator, an absorbed-dose rate at a reference position within the canister is measured by the manufacturer as part of acceptance testing using a reference-standard dosimetry system. That reference-standard measurement is used to calculate the timer setting required to deliver the specified absorbed dose to the center of the canister with blood and blood components, or other reference position. Either relative or absolute absorbed dose measurements are performed within the blood or blood-equivalent volume for determining the absorbed-dose distribution. Accurate radiation dosimetry at a reference position which

could be the position of the maximum absorbed dose (Dmax) or minimum absorbed dose (Dmin) offers a quantitative, independent method to monitor the radiation process.
Dosimetry is part of a measurement quality assurance program that is applied to ensure that the radiation process meets predetermined specifications.

2. Blood irradiators

The basic operating principles and configurations of a free-standing irradiator with either ^{137}Cs source or a linear accelerator are shown schematically in Figure 1. With a freestanding ^{137}Cs irradiator, the blood components are contained within a metal canister that is a rotating turntable. Continuous rotation allows for the γ rays, originating from one to four closely positioned pencil sources, to penetrate all portions of the blood component. The number of sources and their placement depend on the instrument and model. The speed of rotation of the turntable also depends on the make or model of the instrument. A lead shield encloses the irradiation chamber. Free standing irradiators employing ^{60} Co as the source of γ rays are comparable except that the canister containing the blood component does not rotate during the irradiation process; rather, tubes of ^{60} Co are placed in a circular array around the entire canister within the lead chamber. When free standing irradiators are used, the rays are attenuated as they pass through air and blood but at different rates. The magnitude of attenuation is greater with ^{137}Cs than with ^{60} Co.
Linear accelerators generate a beam of X-rays over a field of given dimension. Routinely, the field is projected on a table-top structure. The blood component is placed (flat) between two sheets of biocompatible plastic several centimeters thick.The plastic on the top of the blood component (ie,nearer to the radiation source) generates electronic equilibrium of the secondary electrons at the point where they pass through the component container.The plastic sheet on the bottom of the blood component provides for irradiation back-scattering that helps to ensure the homogenous delivery of the x-rays. The blood component is usually left stationary when the entire x-ray dose is being delivered. Alternatively it may be flipped over when one half of the dose has been delivered; this process involves turning off and restarting the linear accelerator during the irradiation procedure. Although it seems as if the practice of flipping is not required,further data are needed.

3. Blood components

The risk of GVHD for patients, all components that might contain viable T lymphocytes should be irradiated. These include units of whole blood and cellular components (red cells, platelets, granulocytes),whether prepared from whole blood or by apheresis. All types of red cells should be irradiated, whether they are suspended in citrated plasma or in an additive solution. There are recent data supporting the retention of the quality of irradiated red cells after freezing and thawing.If frozen thawed units are intended for GVHD-susceptible individuals and have not been previously irradiated,they should be irradiated because it is known that such components contain viable T lymphocytes.Filtered red cell products should also be irradiated.Extensive leucoreduction through filtration may decrease the potential for GVHD and serve as an alternative to irradiation in the future when questions about the minimum level of viable T lymphocytes that can lead to GVHD are resolved. There are reports of TA-GVHD in patients who received leucodepleted (filtered) red cells; however,the extent of leucoreduction of the components was not uniformly

quantified in such reports. In addition, investigators have suggested that the number of T lymphocytes present in a product that causes GVHD may depend on the extent of patient immunocompetence at the time of transfusion . It is likely that the greater the degree of immunosuppression, the fewer the viable T lymphocytes that will be required to produce GVHD in susceptible patients. In a recent review, it was suggested that cytotoxic T lymphocytes, or interleukin-2-secreting precursors of helper T lymphocytes,may be more predictive of GVHD than the number of proliferating T cells alone. Accordingly,this suggests that until further data are available to confirm adequate removal of these T-cell subtypes by leucoreduction, irradiation should be used for blood products destined for patients at risk for GVHD. Irradiated red cells undergo an enhanced efflux of potassium during storage at 1^0 to 6^0 C.Comparable levels of potassium leakage occur with or without prestorage leucoreduction. Washing units of red cells before transfusion to reduce the supernatant potassium load does not seem to be warranted for most red cell transfusions because posfinfusion dilution prevents the increase in plasma potassium. On the other hand, when irradiated red cells are used for neonatal exchange transfusion or the equivalent of a whole blood exchange is anticipated, red cell washing should be considered to prevent the possible adverse effects caused by hyperkalemia associated with irradiation and storage. Blood components given to recipients, whether immunocompromised or immunocompetent, that contain lymphocytes that are homozygous for an HLA haplotype that is shared with the recipient, pose a specific risk for TA-GVHD. This circumstance occurs when first and second degree relatives serve as directed donors s-ll and when HLA matched platelet components donated by related or unrelated individuals are being transfused. Irradiation of blood components has been recommended in these situations.

Platelet components that have low levels of leucocytes because of the apheresis process and/or leucofiltration should also be irradiated if intended for transfusion to susceptible patients. This is because the minimum number of T lymphocytes that induces TA-GVHD has not yet been delineated.

Fresh frozen plasma does not need to be irradiated routinely because it is generally accepted that the freezing and thawing processes destroy the T lymphocytes that are present in such plasma.

During the past 2 years, there have been two brief articles suggesting that immunocompetent progenitor cells may be present in frozen-thawed plasma; the authors therefore suggested that frozen-thawed plasma may need to be irradiated. Further studies are needed to validate these findings and to assess whether the number of immunocompetent cells, that may be present in thawed fresh frozen plasma, is sufficient to induce GVHD. In rare instances, when nonfrozen plasma (termed *fresh plasma)* is transfused, it should be irradiated because of the presence of a sizable number of viable lymphocytes, approximately 1 x10^7 cells in a component prepared from a unit of whole blood.

4. Quality assurance guidelines

Various dosimetry techniques have been used to measure the dose to blood products. These include thermoluminescent dosimeters (TLD); alanine, ferrous sulphate, red perspex, metaloxide semiconductor field effect transistors (MOSFETs) and chloroform /dithoizone/parafin mixture (Hillyer *et al* 1993). Recently radiochromic film was shown to be an adequate dosimeter for blood irradiation (Butson *et al* 1999). The most prevalent method relies on TLDs and tries to ascertain the causes and variations in delivered *in vitro*

dose across an 'active' treatment volume in a dedicated blood box for standard x-ray beams.

Most dosimeters have significant energy dependence at photon and electron energies less than 100 keV, so great care must be exercised when measuring absorbed dose in that energy range.

This practice outlines irradiator installation qualification, operational qualification, performance qualification, and routine product processing dosimetric procedures to be followed in the irradiation of blood and blood components by the blood-banking community. If followed, these procedures will help to ensure that the products processed with ionizing radiation from gamma, X-rays (bremsstrahlung), or electron sources receive absorbed doses within a predetermined range.

One must document that the instrument being used for irradiation is operating appropriately and confirm that blood components had been irradiated.To assure that the irradiation process is being conducted correctly, specific procedures are recommended for free-standing irradiators and linear accelerators, which are summarized in Tables 1 and 2. The procedures to be used with free-standing irradiators are an update to the guidelines provided several years ago by Anderson. Included are current recommendations from the FDA.

Measure	Frequency
Isotop decay factor	Annually for ^{137}Cs ;montly for ^{60}Co
Dose map	Annualy for ^{137}Cs; annually for ^{60}Co
Radiation leakage	daily
Timer accuracy	montly
Turntable	daily

Table 1. Recommended Quality Assurance Measures to be Used with Free-Standing Gamma Irradiators.

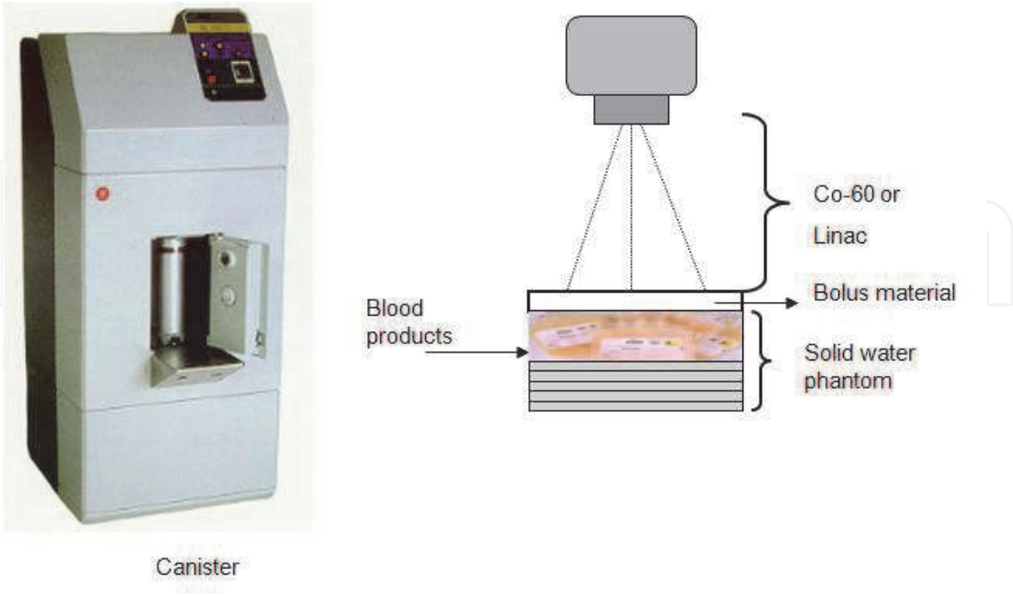

Fig. 1. With a freestanding ^{137}Cs irradiator, the blood components are contained within a metal canister that is positioned on a rotating turntable.

Dose mapping measures the delivery of radiation within a simulated blood component or over an area in which a blood component is placed. This applies to an irradiation field when a linear accelerator is used or to the canister of a free-standing irradiator. Dose mapping is the primary means of ensuring that the irradiation process is being conducted correctly. It documents that the intended dose of irradiation is being delivered at a specific location (such as the central midplane of a canister), and it describes how the delivered irradiation dose varies within a simulated component or over a given area. This allows conclusions to be drawn about the maximum and minimum doses being delivered. Dose mapping should be performed with sensitive dosimetry techniques. A number of commercially available systems have been developed in recent years. Other quality assurance measures that need to be done include the routine confirmation that the turntable is operating correctly (for ^{137}Cs rradiators), measurements to ensure that the timing device is accurate, and the periodic lengthening of the irradiation time to correct for source decay. With linear accelerators, it is necessary to measure the characteristics of the x-ray beam to ensure consistency of delivery. Confirming that a blood component has, in actuality, been irradiated is also an important part of a quality assurance program. At least one commercial firm has developed an indicator label for this purpose.

5. Dose mapping with free-standing irradiators

For free-standing irradiators, a dose-mapping procedure will measure the delivered dose throughout the circular canister in which the blood component is placed. To establish a two-dimensional map, a dosimetry system is placed in a canister that is completely filled with a blood/tissue-compatible phantom composed of water or an appropriate plastic such as polystyrene. The dosimetry material is placed within the phantom in a predetermined way. This approach provides data that describe the minimum levels of irradiation that would be absorbed by a blood component placed in the canister and recognizes that maximum attenuation will occur when the canister is completely filled with a blood-compatible material. Relevantly, it was shown recently that the absorbed dose at the central midplane of a canister (ie, at the center point) decreased by approximately 25% (from 3100 to 2500 cGy) in a ^{137}Cs irradiator (JL Shepherd and Associates, San Francisco, CA) when the loading of the canister was changed from 0% (air) to 100% (with blood components). An irradiationsensitive film dosimetry system (International Speciality Products) that will be described later in this report was used for this purpose. A linear relationship was observed between the amount of fill and the measured central dose. With 1 and 2 units of blood components, the central dose relative to air was 0.98 and 0.93. The minimum and maximum levels were influenced in the same manner as the central dose on decreasing the proportion of the canister that contained air. Other studies have shown that the extent of variability in the dose delivered to the interior of simulated blood units (water or saline in plastic blood storage containers) depended on the model of the ^{137}Cs free-standing irradiator. An immobilized grid of thennoluminescent dosimeters in a plastic sheet were placed within the simulated blood units to measure dose delivery. See the section on dosimetry systems in use. It was also shown that a spacer into the bottom of the canister increases the minimum level of radiation within the simulated blood units as expected from the results of full-canister dose mapping involving a phantom.The extent of variability with ^{137}Cs irradiations is influenced by a number of factors, including the number of sources, turntable speed, and the presence of a spacer at the bottom of the canister.These studies underscore the need for

consistency in loading the canister.Attenuation of the irradiation dose delivered is a function of physical density, electronic density, and atomic number with three major processes: photoelectric, Compton, and pair production. In practical terms, attenuation is caused when the irradiation enters a liquid, such as water or blood. The extent of attenuation depends on a number of factors,including the dimensions of the canister. In a fully filled canister, as is used for dose mapping, the attenuation will increase as the irradiation transverses to the center point. The dose map that is generated describes the dose distribution. As depicted in the theoretical dose map shown in Figure 2, the edges of the canister are exposed to a greater dose of irradiation compared with the center line because the attenuation is less in the periphery. The attenuation with ^{60}Co is less than that seen with ^{137}Cs.

When an irradiator is purchased, the distributor will provide a central dose level that is determined in a blood-compatible environment. In the 1970s and 1980s manufacturers provided a central dose that was determined in air, resulting in the use of timer settings that provided for a dose level that was somewhat less than what was expected. Subsequent to the issuing of the FDA guidelines in July 1993 and the use of dose mapping, it has been necessary to readjust irradiation times with some instruments because the attenuation effect had not been considered previously.

A theoretical two-dimensional dose map describing the irradiation dose distribution through a fully filled canister of a free-standing ^{137}Cs irradiator is shown in Figure 2. To obtain this dose map,dosimeters would have been positioned in the central axis and the edge of circular canister from the top to the bottom of the canister. The y dimension of the map depicts the top to bottom axis of the canister, whereas the x dimension depicts the cross-sectional axis. For the theoretical situation described in Figure 2, the central midplane dose is 2560 cGy, slightly above the minimum standard of 2500 cGy, and the minimum dose is 1750 cGy. In this irradiation dose map, the minimum dose is at the central bottom of the canister, a common finding in actual practice.

The dose map can also be used to assess whether the turntable of a ^{137}Cs irradiator is rotating in an appropriate manner. The occurrence of comparable readings at the two edges of the two-dimensional map, as depicted in the theoretical dose map, indicates that the canister is rotating evenly in front of the ^{137}Cs source. If the turntable were not rotating, the dose levels at the edge of the map closest to the source would be much higher than that found on the opposite edge, ie, the side located distant to the source. According to the 1993 recommendations from the FDA, dose mapping should be performed routinely on an annual basis and after a major repair, especially one involving the sample handling apparatus such as the turntable.

6. Dosimetry systems

The delivered irradiation dose can be measured by a variety of dosimetry systems. In recent years, several commercial interests have developed complete systems for use with free-standing irradiators; each system consists of a phantom that fills the canister and a sensitive dosimetry system. Three main types of dosimetry measurement systems are available (Table 3).

These dosimeters are referred to as routine dosimeters. They are calibrated against standard systems, usually at national reference laboratories such as the National Institute of Standards and Technology in the United States. The routine dosimeter measurement systems were initially developed for use with ^{137}Cs irradiators because this is the

predominant irradiation source for blood. More recently, they have been developed also for use with ^{60}Co irradiators. Thermolumeniscent dosimeters (TLD chips) are one type of routine dosimeter. TLD chips are small plastic chips with millimeter dimensions having a crystal lattice that absorbs ionizing radiation. Specialized equipment is used to release and measure the energy absorbed by the TLD chip at the time of the test irradiation. In one commercially available system, chips are placed at nine different locations within a polystyrene phantom that fits into the canister of the IBL 437C irradiator (CIS US, Inc,Bedford, MA). The timer setting used routinely for an instrument is used in the test procedure.

Method	Measurement type
Thermoluminescent Dosimetry	Emission of light
Radiochromic(GafChromic) film	Optic density
Mosfet(metal –oxide field effect transistors)	Voltage detection
Alanine/ESR	ESR signal-Magnetic field

Table 3. Dosimetric systems in different clinics.

There are two systems that use radiochromic film. On exposure to irradiation, the film darkens, resulting in an increase in optical density. The optical density, determined at various locations on the film, is linearly proportional to the absorbed irradiation dose. Standard films that are irradiated at a given dose level with a calibrated source at a national reference laboratory provide the means to assess the absolute level of absorbed irradiation.This type of dosimeter is basically an x-ray film comparable with that used in clinical practice. With this device, the map that is developed identifies the absorbed irradiation dose that is measured at a large number of locations. In one system, a film contained in a thin water-tight casement is placed into the canister (International Specialty Products,Wayne, NJ), This approach is being used with a variety of irradiators. The canister is filled completely with water before the irradiation procedure.This system provides a direct readout of the dose that is delivered throughout the canister. The timer setting used routinely is employed for the test procedure. In a second system, a film having different radiation sensitive characteristics is embedded between two halves of a circular-fitting polystyrene plastic phantom (Nordion Internation, Canada, Ontario). Irradiation of specialized films is performed with a number of timer settings, each being larger than that used routinely. The map produced is normalized for a central midplane dose of 2500 cGy. The time to produce the 2500 cGy will have been predetermined with a different dosimeter system, the Fricke system, in which absorbed radiation causes a change in the state of a iron salt that can be assessed spectrophotometrically. Another approach to irradiation dose mapping employs a solid-state electronic dosimeter that is technically referred to as a *metal-oxide silicon field effect transistor* (MOSFET). A board contains a number of small transistors in an arrangement that provides data for a dose map. This board is placed between two halves of a circular polystyrene phantom that fits into the canister. This dosimeter absorbs and stores the radiation dose imparted to it electronically . The radiation causes the formation of holes in the metal-oxide layer that becomes trapped within the transistor. The magnitude of the holes is evaluated by measuring the voltage across the transistor with a voltmeter. The voltages measured are converted to absorbed dose. With each dosimetry system, measurements are used to express the absorbed irradiation dose of cGrays. All dosimetry

measurements are associated with a degree of uncertainty or possible error. The magnitude of the uncertainty depends on the kind of dosimeter used. For most dosimeters, the level is 5% of the measured value. For a central absorbed dose level of 2560 cGy (see theoretical dose map in Fig 2) the value could be as high as 2788 cGy or as low as 2432 cGy. Correspondingly, a measured value of 2400 cGy could be as high as 2520 cGy or as low as 2380 cGy. Because the measured value could in actuality meet the 2500 cGy standard, it is appropriate to accept a value of 2400 cGy as meeting the current standard. The same approach should be used when evaluating the minimum value on a dose map. Albeit arbitrary and cautious, the actual minimum on an irradiation dose map should not be below 1500 cGy.

7. Precautions with free-standing irradiators

It is important periodically to lengthen the time of irradiation to correct for decay of the isotopic source that emits the gamma irradiation. Until recently, this was the only major quality assurance measure that was performed routinely. With the half-life for ^{137}Cs being 30 years, annual lengthening of the timer setting is appropriate.On the other hand, with the half-life of ^{60}Co being only 5,27 years, the time of irradiation should be increased on a quarterly basis. The additional seconds of irradiation that are needed can be calculated using formulae that can be found in any physics text. Alternatively, distributors of irradiators provide a chart that specifies the appropriate setting as a function of calendar time.

7.1 Turntable rotation

For ^{137}Cs irradiators, it is essential that the turntable operates at a constant speed in a circular pattern to ensure that each part of a blood component is exposed equally to the source. Daily verification of turntable rotation is an appropriate quality assurance measure. With some free-standing irradiator models rotation of the turntable can be observed before the door of the compartment in which the canister is positioned is closed. In other models, this can be done only indirectly by ensuring that an indicator light is operating appropriately. With some older models, there have been occasional reports that the turntable failed to rotate because of mechanical problems. Such problems should not be encountered with the newer models because of changes in the turntable mechanisms. In any event, daily verification of turntable rotation is a prudent quality assurance measure.

7.2 Radioactivity leakage

Irradiators are constructed so that the isotopic sources are contained in a chamber heavily lined with a protective lead shield to prevent leakage of radioactivity. Accordingly, gamma irradiators are considered to be very safe instruments. Although there have been no reports of source leakage of radioactivity, periodic measurements are warranted to ensure that this is the case. Attaching a film badge to the outside of the irradiator, using a Geiger counter periodically, and performing a wipe test of the inside of the chamber where the canister is positioned at least semiannually are measures that are being used.

8. Dose mapping with linear accelerators

Linear accelerators that are used therapeutically to provide radiation therapy are carefully monitored to ensure appropriateness of dose to an irradiation field. When blood components

are treated with x-rays, the instrument settings are very different than those used to treat oncology patients. Hence, additional periodic quality control measures, primarily to assess the dose delivered to blood components, are needed to ensure that linear accelerators are being operated appropriately when used for blood irradiation. Currently, there are no commercially available systems for assessing the dose delivered throughout the area of an irradiation field in which blood components are placed for treatment with x-rays. An ideal dosimeter for this purpose would be made of a tissue-compatible plastic phantom, containing appropriate dosimeter material and a covering that could be placed at the appropriate distance from the source. An alternative approach might involve the use of a blood bag filled with water (simulating a blood unit) containing TLD chips, as described earlier. In comparative studies using such simulated blood units, it was determined that radiation delivery was more uniform with linear accelerators than with ^{137}Cs free-standing irradiators. This reflects the relative homogeneity of x-ray beams. In the absence of an available system modified for the irradiation of blood bags, the dose delivered throughout an irradiation field should be mapped with the dosimetric measuring system known as an *ionization chamber.* The ionization chamber is used to calibrate linear accelerators for patient use. In addition, on a yearly basis, dose mapping should be performed using a tissue-compatible phantom.

In view of the widely divergent conditions that are used during the operation of linear accelerators, other parameters pertaining to the x-ray beam should be evaluated on at least a quarterly basis to provide assurance that the instrument is being used appropriately for the irradiation of blood components. The goal is to ensure that the instrument is being set in a consistent fashion. When setting a linear accelerator for blood component irradiation, the following should be measured: the distance between the x-ray source and the position where the blood components are to be placed; consistency in the strength of the x-ray beam; and (3) the intensity of the x-ray beam. The distance between the source and position on the table where blood components will be placed (referred to as the *target)* can be evaluated easily with a calibrated measuring device. This is a simple task that can be performed on a routine basis. The consistency of beam output can be evaluated by measuring the beam current. Beam intensity can be evaluated by measuring the ionization current in a monitoring ionization chamber array that can be expressed in terms of the number of photons delivered per square centimeter. These parameters should be assessed routinely as part of quality control programs used by radiation physicists. A code of practice was published in 1994 by the Radiation Therapy Committee of the American Association of Physicists in Medicine for the quality control of radiotherapy accelerators. The described practices are used routinely by radiation physicists. It would he prudent to ensure that an institution using a linear accelerator for blood irradiation follow these quality assurance guidelines and recommendations.

9. Confirming that irradiation occurred

It is important to have positive confirmation that the irradiation process has taken place. This is to identify whether an operator fails to initiate the electronically controlled irradiation process or when the irradiation process is not performed because of instrumentation malfunction. A radiation-sensitive indicator label has been developed specifically for this purpose by International Speciality Products,Wayne, NJ. The label containing a radiationsensitive film strip is placed on the external surface of the blood

component. Irradiation causes distinct visually observable changes: The appearance changes from clear red to opaque with obliteration of the word "NOT." When the label is placed on a blood component, there is a visual record that the irradiation process took place. The reliability of this type of indicator was documented recently in a multisite study.
Two versions of the indicator label have been manufactured. The difference is the range of radiation needed to cause a change in the radiationsensitive film. The ratings for these indicators are 1500 cGy or 2500 cGy. The ratings serve as an approximate guideline for the amount of absorbed radiation that will be needed to completely change the window from reddish to opaque with complete obliteration of the word "NOT." Because the indicator labels are designed for and are used to confirm that the irradiation process has occurred, we have concluded that the 1500 cGy label is the most appropriate tool to perform this quality control measure. This is based on the routinely observed pattern of dose distribution to a blood component in a canister of a free-standing irradiator. Despite a targeted central dose of 2500 cGy, there will be spots at which the dose will be less. If the theoretical dose map presented in Figure 2 is used as an example, there will be a spot that will receive only 1800 cGy. If the 2500 cGy-rated label were to be located on the external surface of a component, there may be minimal changes in the appearance of the radiation-sensitive film window.This would result in a judgment that the blood component was not irradiated, when in actuality it was treated satisfactorily.

Dose	
Linear accelerators	*Free standing irradiators*
2500 cGy to the center of an irradiation field with a minumum of 1500 cGy elsewhere.	2500 cGy to the central midplane of a canister with a minumum of 1500 cGy elsewhere.
Dose mapping	
Linear accelerators	*Free Standing irradiators*
Yearly dose mapping with an ionization chamber and a water phantom.More frequent evaluation of instrument conditions to ensure consistency of x-rays.	Routinely,once a year Cs-137 or twice a year Co-60 and after major repairs;the irradiation procedure should be tested using a fully filled canister with a dosimetry system to map the distrubition of the absorbed dose.
Correction for radioisotopic decay	
Cs-137; annually	Co-60; every 3 month
Turntable rotation(Free standing Cs-137 irradiators)	
Daily should be checked.	
Storage time (after irradiation)	
Red cells	*Platelets*
For up to 28 days;total storage time cannot exceed maximum stroga time for unirradiated red cells	No change due to the irradiation.

Table 4. Guidelines for irradiating blood components.

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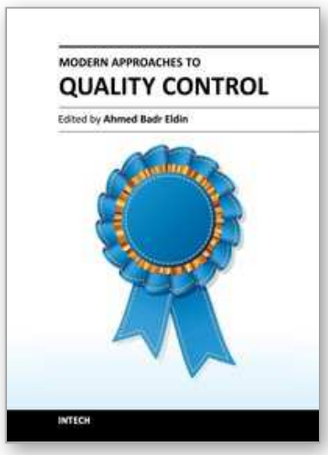

Modern Approaches To Quality Control

Edited by Dr. Ahmed Badr Eldin

ISBN 978-953-307-971-4
Hard cover, 538 pages
Publisher InTech
Published online 09, November, 2011
Published in print edition November, 2011

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How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Sezer Saglam (2011). Blood Irradiation, Modern Approaches To Quality Control, Dr. Ahmed Badr Eldin (Ed.), ISBN: 978-953-307-971-4, InTech, Available from: http://www.intechopen.com/books/modern-approaches-to-quality-control/blood-irradiation

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