Improving precision and safety in the use of beam modifying devices in radiation therapy

R. W. Miller and J. van de Geijn
Radiation Oncology Branch, National Cancer Institute, Bethesda, Maryland 20892

B. A. Fraass
Department of Radiation Oncology, University of Michigan, Ann Arbor, Michigan 48109

(Received 28 December 1989; accepted for publication 7 June 1990)

Reliable and safe implementation of beam modifying devices such as wedges and block trays requires careful design and construction. Inappropriate design may pose problems ranging from user-hostile operation to hard-to-track, but significant variations in actual position in a beam. This may cause variation in actual wedge output factors, or variation in the position of a block tray. In case of simple mechanical failure or personnel mistake, design related mechanical conditions may result in injury to either a patient or a staff member. This paper is based on experience with linear accelerators from one manufacturer, but similar conditions are likely to exist with other radiation machines. A simple technical modification is offered which improves both accuracy and reproducibility in the placement of wedge-type filters. For our machines the solution also provides improved safety in the use of both wedge trays and block trays.

Key words: accelerator, radiotherapy, wedges, x ray, safety, precision

Beam intensity modifying devices, such as wedges and field shaping blocks, are used routinely with most patients undergoing external beam therapy. The essential design requirement is to ensure that any prescribed beam modifying device be mounted easily, accurately, and safely in the intended position; that is, at the proper distance from the source and at the proper position and orientation relative to the center of the beam. In practice, this should mean positioning within set tolerances, supervised by some monitoring system.

Many manufacturers of radiation machines provide wedges mounted on trays that can be slid and locked into place on a rail system attached to the face of the collimator assembly. The system usually includes means to identify the wedge and its orientation, and report this information to the treatment console. Additional information may be provided to a fault logic system designed to prevent treatment using improper combinations of wedge and field size. Variation in the placement of a wedge in the direction of its slope causes variation in the "wedge transmission factor" ("wedge factor") and therefore variable errors in dose delivered. Such variation may be caused by play in the locking mechanism. Play, beyond the built-in tolerance, may increase by wear associated with normal clinical use, or by accidental abuse. This can result in positional variations of the wedge position along the wedge slope of up to 5 mm. Unless this longitudinal play is checked routinely and frequently, uncertainty of this magnitude can go unnoticed for long periods of time, resulting in an unknown error in the absorbed dose delivered to patients of up to 8%, depending on the wedge angle. Although frequently the error may be random, there is a possibility of systematic, gravity-induced error with gantry positions other than vertical.

The positioning and locking mechanism also plays an important role in terms of safety: wedges and other heavier treatment accessories must be secured against falling off the machine at any time. The wedges provided with our linear accelerators[1] were originally mounted with their slopes in the direction of the guide rails. The "zero" position of the rails, in the collimator "neutral" position (the center of the collimator's rotational span), is parallel to the axis of rotation. However, in most clinical situations a wedge is used in the transverse plane, a direction parallel to the plane of rotation (i.e., perpendicular to the axis rotation). Thus, positioning a wedge in the correct plane involves turning the collimator by 90°. On some accelerators, the position control and locking systems used for wedges is highly susceptible to damage. This can result in progressive and variable play which may go unnoticed unless frequent checks on this detail are part of the quality assurance program. Moreover, with the rails thus pointing in the plane of rotation, mechanical failure, or inadvertent incomplete locking during setup, can result in a wedge, block tray or even the entire accessory mount tray sliding out as the gantry is rotated out of the vertical position. This can cause damage to equipment or serious harm to the patient or attending personnel. Incidents of this nature have been reported to the Problem Reporting Program for Radiation Therapy Devices, CDRH.[2] A straightforward and simple solution is to reorient the wedges on their slides so that they project in the transverse direction. This also places the rails of other beam modifying devices, such as blocks, parallel to the axis of gantry rotation under normal conditions.

This modification solves a number of problems:

(i) It minimizes variation in the accelerator "wedge factors" due to "play" in the wedge locating mechanism. It also minimizes the play in block positioning in the lateral direction of the patient, which is usually the more critical one.

(ii) It reduces the set-up time by reducing the amount of collimator rotation necessary for some frequently used treatment configurations.

(iii) It improves the margin of safety by keeping the acces-

 0094-2405/90/050929-02$01.20

sory rails in the general direction of the axis of gantry rotation; thus minimizing the potential for accidental slippage of accessory trays while moving the gantry.

When reorienting each wedge of a pair on its mounting plate, one must pay close attention to proper alignment and centering. Both wedges of a corresponding pair must yield the same wedge factor, that is, have the same thickness at the center of the beam. In practice, remounting requires locating the position of and drilling new holes in the mounting plate to accept the wedge mounting screws. It is important that the position of these holes be referenced to the beam axis rather than to the edges of the plate. This may be facilitated by temporarily covering the cutout in the base plate and marking the location of the center using collimator's rotational axis as the reference point. Once the mounting holes have been drilled, tapped and countersunk, the cutout itself must be enlarged in the new direction, as shown in Fig. 1, to eliminate extra attenuation at the edges of large fields. In addition, some accelerators, in particular the Varian Clinac® -18/20 series, require an additional hardware modification so that the new wedge configuration is properly recognized by the fault logic circuits. Detailed instructions for performing this modification are available upon request from the authors. As a note of caution, one should consult with the appropriate factory service representative before attempting this, or any other modification to an accelerator. Failure to do so may void existing warranties and/or service agreements.

In an operational respect, the insertion of heavy blocks in the longitudinal direction, directly over the patient, may be difficult and somewhat risky. Depending on the location of the target in the body, one can use either of two techniques, after the usual positioning of the patient. The first is to shift the coach top longitudinally to move the patient out of the way, insert the blocks and return the coach to the original position. An accurate scale or digital readout of couch position is then of great assistance. One can also rotate the collimator temporarily, insert the tray from the side and then return the collimator to its original position.

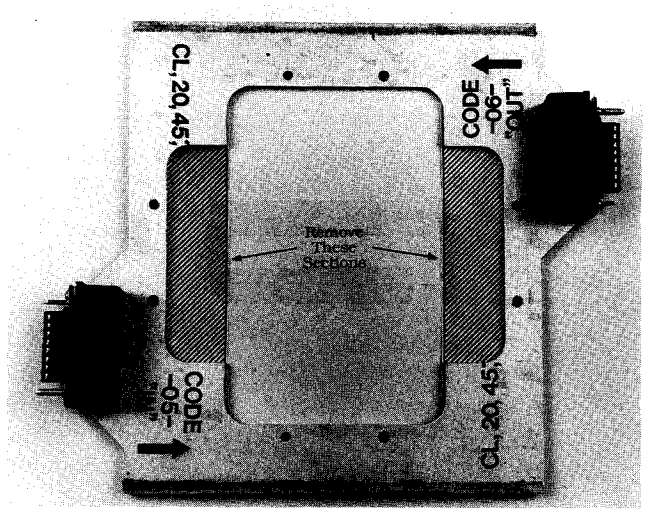

FIG. 1. Wedge mounting plate showing additional areas to be removed when reorienting wedges.

Recently, the same manufacturers have begun to provide sagittally mounted wedges as an optional accessory. However, for those units in the field which have the older, sagittally oriented wedges, this modification is easy to implement. The mechanical part of the modification itself is simple, although close attention must be given to symmetry.

[1]Varian Associates, Radiation Division, Palo Alto, CA.

[2]C. D. Evans, Summary of Reports received from July 1986 to June 1989, Problem Reporting Program for Radiation Therapy Devices, Center for Devices and Radiological Health, U.S. Public Health Service, DHHS, Rockville, MD.