Quality Assurance System for Determination of Center Position in X-ray and Proton Irradiation Fields using a Stainless Ball and Imaging Plates in Proton Therapy at PMRC

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ABSTRACT

In the proton therapy using a gantry system, periodical verification of iso-center position is very important to assure precision of patient positioning system at any gantry angles in proton treatment. In the gantry system, there are three different types of iso-center; 1) in a geometrical view, 2) in an X-ray beam's eye view, 3) in a proton beam's eye view. Idealistically, they would be an identical point. They could, however, be different points. It may be a source of errors in patient positioning. At PMRC, we have established a system of verification for iso-center positions using a stainless ball of 2-cm in diameter and an imaging plate. This system provides the relation among a center of a patient target position, a center of proton irradiation field, and/or a center of X-ray field in accuracy of 50□m in the 2) and 3) views, as images of a center of the stainless ball and a center of a 100 mm×100 mm-aperture brass collimator recorded on the imaging plate, which is setup at 1-cm behind the ball. In addition, it provides simultaneously the images of the ball and the collimator on an imaging intensifier (II), which is setup downstream of the proton or X-ray beam. We present a method of quality assurance (QA) for calibration of iso-center position in a rotation gantry system at PMRC and the performance of this system. A proton beam position on the 1st scatterer in the nozzle of the gantry affects less sensitive (reduced by a factor of 1/5) to the results of the iso-center position. The effect is systematically correctable. The effect of the nozzle (or the collimator) position is less than 0.5 mm at the maximum extraction (390 mm).

Keywords: Proton Therapy, Quality Assurance, Gantry, Alignment, Imaging Plate.

1. INTRODUCTION

A rotation gantry used in proton therapy is a very useful system for planning multiple ports in irradiation without a roll of a patient, which may cause an unnecessary shift of organs in a patient body. A selection of the multiple ports in irradiation may increase a chance to spare normal tissues around a tumor target. An iso-center of the gantry system is assumed to be always placed at the center of the target as a stable point in a treatment planning process and in a daily treatment routine. In the daily treatment routine, the target is positioned at a specific gantry angle, where the nozzle of the gantry points a horizontal direction at PMRC, and then the gantry is rotated to the irradiation angle planned for each port in the treatment. No verification is performed at each irradiation angle. Verification of the iso-center position is one of the very important issues in a gantry system in proton therapy. In the proton therapy facilities, various kinds of system has been developed and used for quality assurance of the iso-center positions 1). At PMRC, there are two rotation gantries almost identical. When installed, each gantry is aligned so that a cross of six laser markers is set within 0.5 mm from the iso-center, which was geometrically measured by using transits with a rotation of the gantry2). In the gantry system, there are three different types of iso-center; 1) in a geometrical view, 2) in an X-ray beam's eye view, and 3) in a proton beam's eye view. Idealistically, they would be an identical point. They could be different points. It could be a source of systematic errors in patient positioning procedure. Quality assurance for systematic determination of center position in X-ray and proton irradiation fields makes it available to verify these systematic errors and to keep the positioning procedure convenient with minimum steps of verification. At PMRC, we have established a system of verification for the iso-center position using a stainless ball and imaging plate. We present here the established system and the effect of proton beam and snout positions.

2. MATERIALS AND METHODS

Figure 1 shows a picture of the quality assurance (QA) system for determination of center position in X-ray and proton irradiation fields using a stainless ball of 2-cm in diameter and imaging plates in proton therapy at PMRC. This system provides the relation among a center of a patient target position, a center of proton irradiation field, and/or a center of X-ray field in the X-ray's beam's eye view and the proton beam's eye view, as images of a center of the stainless ball and a center of a 100 mm ×100 mm-aperture brass collimator recorded on the imaging plate, which is set at 1-cm behind the ball. The system is placed on the patient bed, which has four holes to set an extension board, with two pins. The center of the stainless ball, 2-cm in diameter, is set at the cross of laser markers around the iso-center. The 200 mm ×250 mm imaging plate is light-shielded in a black acrylic cassette, which is mounted in an aluminum frame at 1cm behind the stainless ball. The cassette consists of two removable plates pressing the imaging plate inside. The frame is rotated around the ball at a 1 □° step from 0° to 360°. Thus, the imaging plate is kept held with a constant distance of 1 cm at any gantry angles in the step. Figure 2 shows the 5-cm thick collimator which determines the X-ray and proton irradiation fields. The collimator is setup at the place where a patient-dedicated collimator is set in the daily treatment. A pair of screws on the top makes the collimator fixed tightly in the snout and prevents it from shifting even when the gantry is rotated upside down. Figure 3 shows a schematic view of measuring the center positions in X-ray and proton irradiation fields together with the center position of the stainless ball. A pulse of proton beam or X-ray beam is irradiated onto the imaging plate through the collimator and the stainless ball. Their projections are imaged on the imaging plate. The recorded image is analyzed with Bio Imaging Analyzer BAS-2000II of Fuji Photo Film Co. Ltd. using an analysis software , BASTATION.

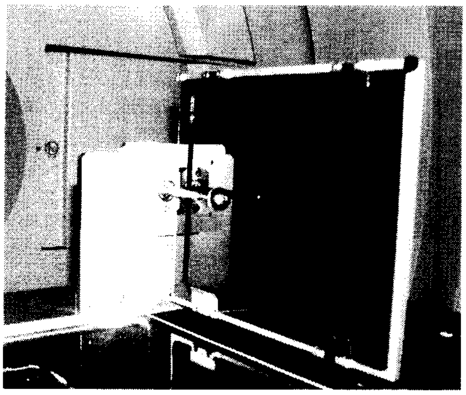

Fig. 1 The QA system for determination of center position in X-ray and proton irradiation fields using a stainless ball and an imaging plate at PMRC

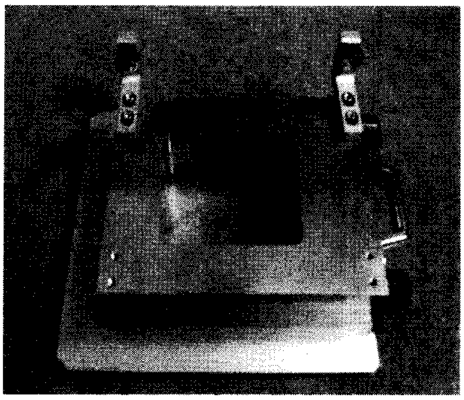

Fig. 2 The brass collimator with 100 mm × 100 mm aperture used in the QA system.

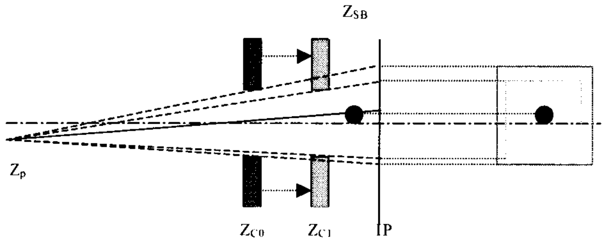

Fig. 3 A schematic view of the QA system for determination of irradiation fields and the iso-center.

3. RESULTS AND DISCUSSION

Figure 4 shows a) an image of the stainless ball and the collimator projected on the imaging plate by protons, and b) a profile of the projected images along the line in a). The profile of the ball is enhanced from a flat-top of the collimator profile, which has a width of 125.9 mm. Since the collimator surface is 49.7 cm upstream from the ball center, the effective proton-source position along the beam direction locates 242 cm upstream from the ball. A scattering at the edge of the ball generates a pair of hot spot and cold spot at the both side of the ball profile. The effective X-ray-source position locates 98.1 cm upstream from the ball. Figure 5 shows the effect of the proton beam positions on the position difference between the ball center and the collimator center. The proton beam position on the 1st scatterer in the nozzle of the gantry affects less sensitive (reduced by a factor of 1/5) to the results of the iso-center position. The effect is systematically correctable at each measurement. The effect of the nozzle (collimator) position is less than 0.5 mm at the maximum extraction (390 mm).

4. CONCLUSIONS

We have established a system of verification for iso-center positions using a stainless ball of 2-cm in diameter and an imaging plate. This system easily provides the relation among a center of a patient target position, a center of proton irradiation field, and/or a center of X-ray field in accuracy of 50μm. A proton beam position on the 1st scatterer in the nozzle of the gantry affects less sensitive (reduced by a factor of 1/5) to the results of the iso-center position. The effect is systematically correctable. The effect of the nozzle (collimator) position is less than 0.5 mm at the maximum extraction (390 mm).

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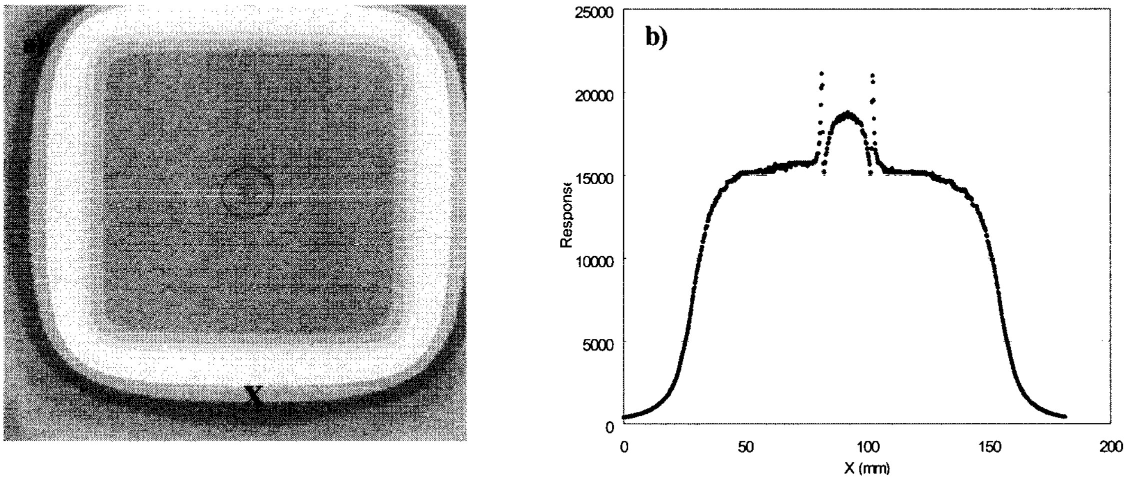

Fig. 4 a) An image of the stainless ball and the collimator projected on the imaging plate, b) A profile of the projected image along the line in a).

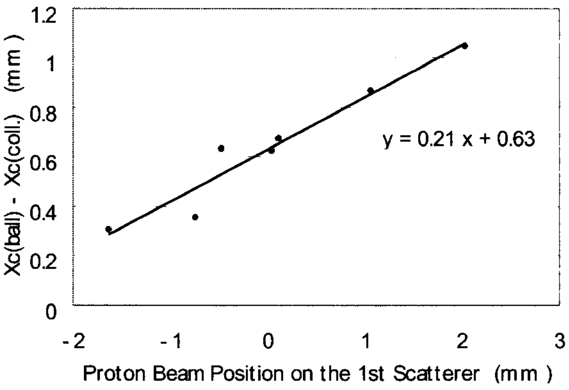

Fig. 5 Effect of the proton beam positions on position difference between the ball center and the collimator center.