Verification of Periodical Calibration for Iso-center Positions using Quality Assurance System for Irradiation Equipment Position Established at PMRC

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ABSTRACT

We present the results on the calibration of iso-center positions using the quality assurance system established at PMRC for determination of center position in X-ray and proton irradiation fields. Details on the system are presented in another presentation in this session. The equipment in the system is mounted on a patient treatment bed in each proton exposure room, G1 or G2. A center of a stainless ball on the equipment is set at a cross of laser markers located around the iso-center and fixed on the room and on the snout in the gantry. A proton beam or an X-ray beam is exposed onto the ball through a brass collimator of 100 mm ×100 mm and projected onto the imaging plate set at 1 cm behind the ball. On the axis perpendicular to the thrust axis of the gantry on the imaging plate, a distance between a center of the collimator image and a center of the ball image varies as a cosine function of gantry angles unless the ball is set on the iso-center. An amplitude of the cosine curve shows the distance between the ball and the iso-center, an offset the offset of the collimator, and a phase shift at a zero crossing point the ball direction viewed from the iso-center. We present the relation among the iso-center position, the laser maker position, and the center of proton and X-ray irradiation fields. Its stability and its reproducibility are discussed.

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

1. INTRODUCTION

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]. In another presentation in this session, we have presented that at PMRC we established the quality assurance system of verification for an iso-center position using a stainless ball of 2-cm in diameter and an imaging plate [2] . This system easily provides the relation among a center of a patient target (the stainless ball) position, a center of proton irradiation field, and/or a center of X-ray field in accuracy of 50μm in an X-ray beam's eye view and in a proton beam's eye view. We may apply this system to calibration of the iso-center position and irradiation equipment positions in the snout of the gantry by taking data with a rotation of the gantry at a necessary step of angles. The calibration is very useful to verify systematic errors caused in patient positioning procedure when the gantry is rotated to each irradiation angle with no verification of the patient position in the X-ray irradiation fields at this angle. We present the results on the calibration of the iso-center position. The relation among the iso-center position, the laser marker position, and the center of proton and X-ray irradiation fields. Its stability and its reproducibility are discussed.

2. MATERIALS AND METHODS

The equipment in the system [1] is mounted on a patient treatment bed in each proton exposure room, G1 or G2, at PMRC. A center of a stainless ball on the equipment is visually set at first at a cross of six laser markers located around the iso-center. Three of the laser markers are fixed on the room (two horizontal and one vertical), two on the snout in the gantry (one horizontal and one vertical), and one on the rotation cage (vertical). A proton beam or an X-ray beam is exposed onto the ball through a brass collimator of 100 mm ×100 mm and projected onto the imaging plate set at 1 cm behind the ball. On the first two imaging plates placed vertically for horizontal beam and horizontally for vertical beam, the laser markers are switched on for 20 seconds after proton or X-ray irradiation on them in order to record the laser marker images together on the imaging plates. It is an application of their eraser (de-excitation) function to the irradiated (excited) plates[3) 4)]. Thus misalignment of the ball is precisely measurable and correctable. On the axis perpendicular to the thrust axis of the gantry on the imaging plate, a distance between a center of the collimator image and a center of the ball image (y_{BEV}: deviation in BEV) varies as a scalar product of the unit vector $\mathbf{n}_{G+90}$ pointing the gantry angle+90-degree direction and the stainless ball vector pointing the center of the ball from the iso-center point, $y_{BEV} = \mathbf{n}_{G+90} \cdot \mathbf{D}_{SB} + y_0 = D_{SB} \cdot \cos(\theta_G+90 - \theta_0) + y_0$, if the ball is offset from the iso-center. Figure 1 shows a) a schematic view of the relation among the stainless ball, the collimator, the laser markers, and the iso-center, and b) an illustration of y_{BEV} variations as a function of the gantry angles when y_0 =0.1 mm, D_{SB} = 1.0 mm, and θ_0 = 50 degrees The amplitude D_{SB} shows the distance between the ball center and the iso-center, the offset y_0 the offset of the collimator, and the phase shift θ_0 the ball direction viewed from the iso-center. In this case, the laser markers are displayed as aligned on the center of the ball.

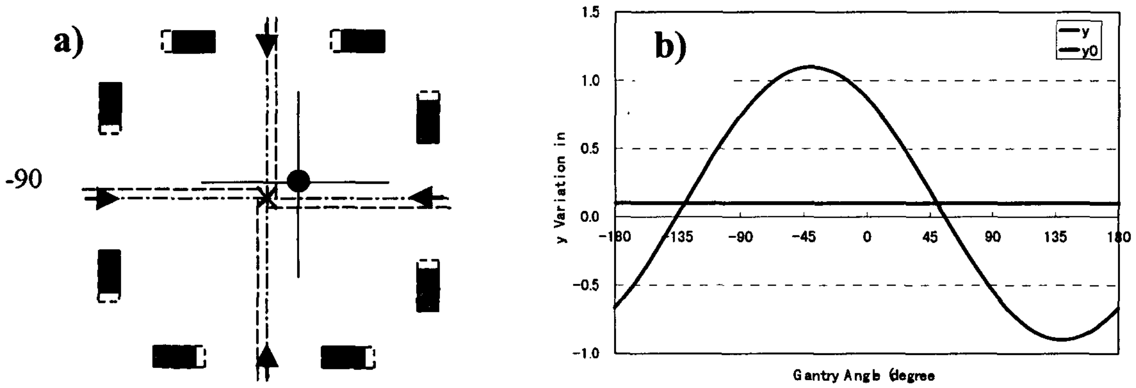

Fig. 1 a) A schematic view of the relation among the stainless ball (circle), the collimator (square), the laser markers (long cross), and the iso-center (short cross), and b) an illustration of y_{BEV} variations as a function of the gantry angles when y_0 =0.1 mm, D_{SB} = 1.0 mm, and θ_0 = 50 degrees.

3. RESULTS AND DISCUSSION

We have performed the calibration of the iso-center positions using the quality assurance system of verification established for the iso-center measurement. A pulse of proton beam or X-ray beam is irradiated on the imaging plate with images of the collimator and the stainless ball at the gantry angles, every 45 degrees from -180 to +180 and reversed from +180 to -180 degrees every 90 degrees. Figure 2 shows the results on behavior of y_{BEV} by protons at the gantry angles of G2 measured. The amplitude D_{SB} is 1.1+/-0.1mm, the phase shift $\square_0$ is -170+/-5 degrees, and the offset y_0 is 0.3+/-0.1 mm, on the average of clockwise and counterclockwise directions in the plane perpendicular to the thrust axis of the gantry. The offset y_0 is 0.2 mm different between both scanning directions. The vector pointing the cross of the laser markers from the center of the ball is (0.5,2.5). Thus the cross of the laser markers locates at the point vector D_{LM} = (0.3,1.5), which is consistent with the results of geometrical survey, in the iso-center coordinate system. The shift from the iso-center is corrected to zero approximate ly by moving the laser marker positions after measurements. Figure 3 shows the results on behavior of y_{BEV} by X-rays as well. In

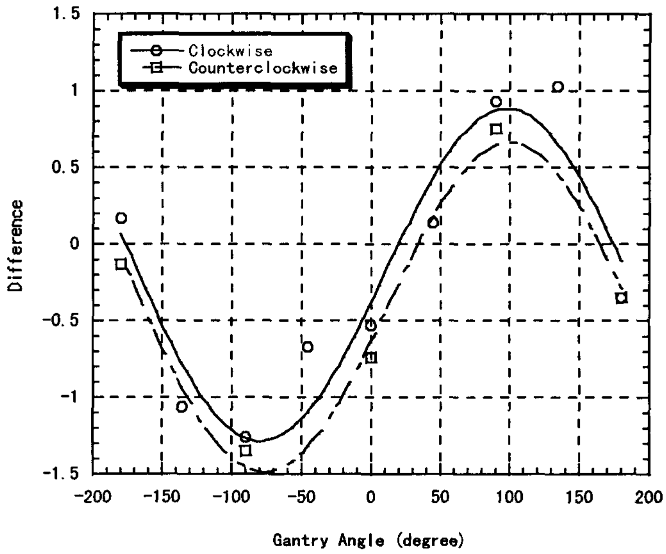

Fig. 2 The results on behavior of y_{BEV} by protons at the gantr angles of G2 measured.

convenience the patient bed is shifted down by 1 cm to record a wider image of the collimator on the imaging plate. Similar results are obtained for the laser marker positions relative to the iso-center. In this method, no imaging plate positions are required to perform precise measurements. Therefore, it is very easy to setup imaging plates. It takes about 1.5 hours, which is much shorter than consumed time in the geometrical survey, about one day. Thus we may perform it periodically in a short term, once or twice a month for example for maintenance. We will continue to measure the relation between the iso-center and the laser marker positions periodically and study their reproducibility and stability by proton and X-ray beams at both gantries G1 and G2 for the quality assurance in the patient positioning system.

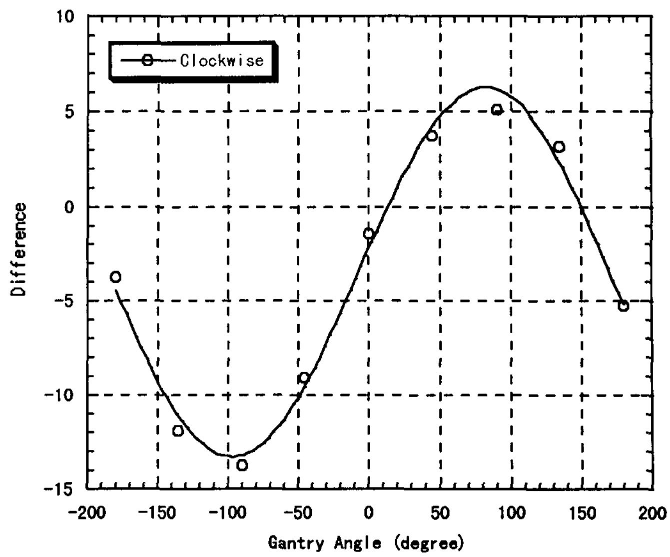

Fig. 3 The results on behavior of y_{BEV} by X-rays at the gantr angles of G2 measured.

4. CONCLUSIONS

The calibration of the iso-center positions has been performed by using the quality assurance system of verification established at PMRC. The laser marker positions are verified in the iso-center coordinate system, which is obtained from the results on the behavior of difference between the collimator center and the stainless ball center, which are recorded on the imaging plates, as a function of the gantry angles. The iso-center position relative to the laser markers is consistent with the results of the geometrical survey. This method may easily and precisely provide periodical verification of the iso-center position relative to the laser markers used in the patient positioning system.

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