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Original research article

Assessment and evaluation of MV image guidance system performance in radiotherapy

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ABSTRACT

Background and aim: The clinical use of imaging system in image guided radiotherapy (IGRT) necessitates performing periodic quality assurance of the system to be confident in applying corrections for patient set-up errors. We aim to develop and implement a quality assurance (QA) programme for megavoltage (MV) based image guidance system and assess its long term performance for a period of 3 years.

Materials and methods: Periodic QA tests were performed for the MV planar and cone beam computed tomography (CBCT) imaging system to assess the system safety, mechanical and geometrical accuracy, image quality and dose. The tests were performed using the equipment supplied by the manufacturer along with the image guidance system and using simple methods developed in-house. The test results were compared with expected or baseline values established during commissioning.

Results: The safety system was found to be functional. The results of mechanical and geometrical tests were in good agreement with the expected results. The system mechanical positioning was stable and reproducible within ±2 mm accuracy. The image quality and the imaging dose of the planar and CBCT imaging were found to agree with the baseline values and the manufacturer specifications.

Discussion: Throughout the three-year period, all the QA tests were within the specification. The mechanical and geometrical tests are most crucial as they directly affect the patient positioning accuracy.

Conclusion: We conclude that the MV image guidance system is efficient to perform IGRT and insist to perform periodic QA tests and calibration for the system.

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1. Background and aim

With the advances in in-room imaging system, image guided treatment has become routine in radiotherapy centres. Image guided radiotherapy (IGRT) offers benefits in monitoring the patient treatment positional accuracy, set-up uncertainties and inter-fraction anatomy changes.[1–4] The clinical use of the image guidance system necessitates implementing a quality assurance (QA) programme to monitor and maintain its performance characteristics. Several guidelines have been published for the QA programme to verify the safety, functionality and quality of the imaging system.[5–7] In our centre, safe and accurate patient positioning is our requirement to achieve with the image guidance (IG) system. Thus, the IG system safety, mechanical and geometrical accuracy, image quality and imaging dose to patient need to be assessed periodically. Therefore we implemented a QA programme to evaluate all these criteria. In this work, we share our experience in developing and implementing the QA programme for a long term of 3 years for image guidance system based on manufacturer provided test methods[8] and published guidelines.

2. Materials and methods

2.1. Medical linear accelerator and imaging system

The Medical high energy linear accelerator, Siemens Oncor Expression™ equipped with the imaging guidance (IG) system, (OPTIVUE 1000ST™, Siemens Medical solutions Inc., Concord, CA) used for megavoltage planar and cone beam computed tomography (MV CBCT) imaging, is attached to the gantry at the counter-part of the head of the linear accelerator, as shown in Fig. 1. The IG system consists of flat panel detectors which have sensors of amorphous silicon (a-Si) photo diodes that are deposited on a glass substrate with a scintillator coating. The pixels have a pitch of 400 μm and there are 1024 × 1024 pixels covering a 40 × 40 cm^2 area. The entire imaging system operates under SYNGO™ based COHERENCE™ therapist workspace which communicates with the control console, the linear accelerator, and a local patient database. The workspace contains applications allowing the automatic acquisition of projection images, image reconstruction, CT-to-CBCT image registration, and couch position adjustment. Each projection of the CBCT acquisition is corrected for defective pixels, as well as for pixel-to-pixel offset and gain variations before 3D reconstruction. The imager uses 6 MV low dose rate 50 MU/min beam to acquire MV planar images. MV CBCT images are acquired in a cone beam mode, where the 6 MV, low dose rate beam is rotated 200° from 270° to 110° and 200 projection images are acquired on the flat panel in 1° steps. The cone beam has lower dose per radiation pulse and higher radiation pulse repetition frequency when compared to regular 6 MV treatment beam. The IG system imager calibration, image acquisition, reconstruction procedure and clinical use are mentioned elsewhere.[1,8–11]

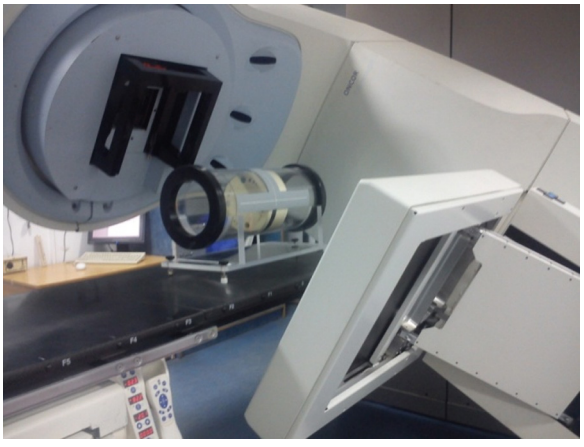

Fig. 1 – The Siemens Oncor Expression linear accelerator equipped with OPTIVUE imaging system.

2.2. Equipment for QA

X-ray reticule: The X-ray reticule (named 'X-RETIC') consists of two orthogonal radio-opaque tungsten wires, shown in Fig. 2, which can be inserted in an accessory slot in the gantry head. It is calibrated such that the intersection of the two wires corresponds exactly to the mechanical isocentre and is used to align the phantoms at the isocentre and to determine the coincidence between the accelerator isocentre and the imaging centre of the flat panel imager.

QC 3V phantom: The QC-3V phantom (Standard Imaging, Inc. USA), as shown in Fig. 2, consists of a series of bar patterns, used for measuring spatial resolution and contrast-to-noise ratio. Four large numbers engraved in the corners provide a crude visual feedback but are not used for analysis. Lines are inscribed on the front and sides for easy alignment with field lights and lasers. Planar images are acquired with the flat panel imager and analysed with the portal image processing programme.

Image quality phantom: The image quality phantom (Siemens Medical Solutions, Concord, CA), as shown in Fig. 2, is a cylindrical acrylic shell of diameter 20 cm with four solid water sections positioned axially within the shell. Section 1 is purely made of solid water of thickness 4 cm without any inserts and used to check image uniformity, noise and artefacts. Sections 2 and 4 consists of 5 circular inserts of 8 different density materials with diameter 2, 1, 0.7, 0.5 and 0.3 cm used to check low and high contrast resolution. Section 3 contains 11 bar groups and each bar group contains 5 air bars to evaluate spatial resolution. The sections 2, 3, and 4 are of thickness 2 cm each. In the outer shell, three axial planes (at the centre, head and foot of the phantom) have four tungsten beads arranged at 12, 3, 6 and 9 o'clock positions to determine the geometric positional accuracy of the CBCT image.

2.3. Imaging system QA programme

To assess and evaluate the performance of the imaging system, a periodic quality assurance programme was developed. The QA tests, frequencies and tolerances are given in Table 1. In this study, these tests were performed for a period of 3 years and the results were evaluated for its accuracy and consistency. The baseline values of these tests were defined