Quality Assurance

10

Takuji Furukawa and Shinichiro Mori

Abstract

To ensure the quality of treatment, intensive quality assurance (QA) program should be performed. In this chapter, the QA for the ion therapy system with an example of HIMAC facility is briefly introduced.

Keywords

Dosimetry • Imaging system • Positional accuracy • Quality assurance

10.1 Beam Delivery System and Dosimetric QA

In order to ensure the quality of the therapeutic irradiation, periodic QA checks for the beam delivery system are required. Practical implementation of a QA program depends on the detail of the beam delivery. In both deliveries of passive and scanning, the monitor calibration is performed on a daily basis at many facilities. However, the recommended method defers between passive and scanning delivery, as shown in Fig. 10.1. An ionization chamber is set to the isocenter within a phantom. Instead of water, it is useful to use solid water. For monitor calibration, the reference field is irradiated and measured. For the passive delivery, it is recommended to measure in water in the center of an SOBP as the reference condition. On the other hand, for the scanning delivery, measurements in a plastic material in the entrance region of the depth-dose are recommended as a reference. Further, the verification of the beam range is performed on a daily basis at many facilities. Figure 10.2 shows the example of the daily QA for the NIRS scanning system. Additional check of depth and lateral dose profiles is also recommended. On the other hand, weekly and monthly QA should be programmed considering the constancy and configuration of the system.

The beam delivery system and its treatment planning system (TPS) require dosimetric patient-specific QA to check each individual plan and its delivery. The patient-specific QA is usually performed before therapeutic irradiation as the following steps. Schematic of patient-specific QA workflow is shown in Fig. 10.3. After the treatment planning, the dose distribution is measured using ionization chambers set in a water phantom. In the measurement, the irradiation sequence is performed using the same control-point sequence as for the patient treatment. The measured dose profiles are then compared with the dose distribution recalculated by the TPS using a homogeneous medium instead of the patient CT data. In this way, the quality of the field is checked. Such dosimetric verification is important especially for the scanning delivery, considering the fact that the dose conformation is performed by magnetically scanning the raw beam from the accelerator. Furthermore, each treatment plan is individual. Thus, the delivered field should be checked on the basis of the measured dose profiles. On the other hand, in the passive delivery, it is necessary to calibrate dose per monitor unit (Gy/MU) for each irradiation field. Further, the checks of patient-specific devices such as aperture and compensator/bolus are also required in the passive delivery. This check can be performed by measuring each device and comparing with the design.

The following describes the patient-specific QA program for the NIRS scanning delivery. In the patient-specific QA, a

T. Furukawa (✉) • S. Mori
National Institute of Radiological Sciences,
9-1, Anagawa-4, Inage-ku, Chiba 263-8555, Japan
e-mail: t_furu@nirs.go.jp; shinshin@nirs.go.jp

H. Tsujii et al. (eds.), *Carbon-Ion Radiotherapy: Principles, Practices, and Treatment Planning*,
DOI 10.1007/978-4-431-54457-9_10, © Springer Japan 2014

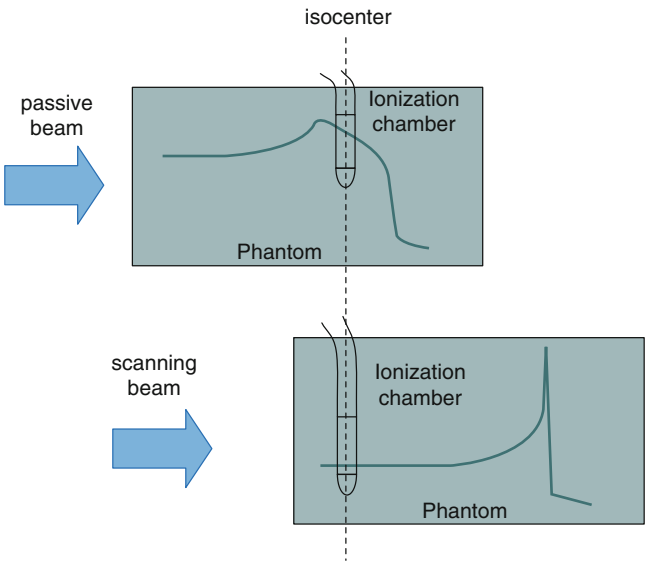

Fig. 10.1 Difference of reference condition for the monitor calibration between passive and scanning delivery

commercial 2D ionization chamber array (OCTAVIUS Detector 729 XDR, PTW Freiburg, Germany) is employed for the dose distribution measurement cooperating with an accordion-type water phantom. The water-equivalent depth can be changed from 30 to 300 mm. Owing to sealed water tank, this phantom can be used as both horizontal and vertical beams by rotating water tank. Before the QA measurement, the predose of around 5 Gy are applied for warm-up of the detector. In the measurement, the irradiation sequence is performed using the same control-point sequence as for the patient treatment. The measurements of each beam are performed for three different depths, which are predetermined in the treatment planning. The measured dose distributions are then compared with the dose distribution recalculated by the TPS using a homogeneous medium instead of the patient CT data. For the comparison, the gamma index analysis is performed by using the commercial software, Verisoft (PTW Freiburg, Germany). A typical result of comparison between the measured distribution and the recalculated one is shown in Fig. 10.4. In the analysis, distance to agreement of 3 mm and dose difference of 3 % are employed as accepted deviation. This tolerance is widely used at many facilities.

10.2 Patient Support System and Imaging System QA

Patient positioning (geometrical/position accuracy including motion management) is one of the major important factors to improve treatment accuracy as described in Chap. 9 (motion management). To quantify positional accuracy throughout the treatment course, we use an imaging system (X-ray flat panel detector (FPD) (CXDI55C, Canon, Tokyo, Japan, DAR8000f, Shimadzu Cop. Kyoto, Japan, and PaxScan 3030+, Varian Medical Systems, Palo Alto, CA) and computed tomography (CT) (LightSpeed 16-slice QX/i, General Electric Company, Waukesha, WI; Aquilion LB, Toshiba Medical Systems, Otawara, Japan; and Aquilion One Vision, Toshiba Medical Systems, Otawara, Japan) and patient support system (6° of freedom treatment bed (Escort, Toshiba, Tokyo, Japan)) and room laser (LSP-1170A, Takenaka Optonic Co., LTD, Kyoto, Japan)) (Fig. 10.5).

Positional accuracy for the orthogonal X-ray imaging system, CT scanner, treatment bed, and room lasers are confirmed using the QA phantom, which is an acrylic hollow box (220-mm square length, 10 mm thickness) with ten stainless steel beads (2-mm diameter) set on the phantom plane (Fig. 10.7a). Small bead positions are optimized to detect QA phantom pose (position and angle) correctly. Also 0.2-mm-diameter stainless steel wires are embedded in cross on every QA phantom plane. This QA phantom was used for the imaging system, patient support system, and beam delivery system (Fig. 10.6b). By doing so, all treatment systems can adjust their positions to the same reference position (room isocenter).

At the commissioning stage, the QA phantom was placed on the QA stand, and positional accuracy was adjusted to the room coordinate using two transits. Orthogonal FPD positions were also adjusted in the same way. And then, X-ray tube position was adjusted to overlap cross centerline wires on the QA phantom planes along the X-ray direction using FPD images. To do so, X-ray tube and FPDs positions are satisfactorily adjusted to the room coordinate within the 0.2-mm positional accuracy. After commissioning, orthogonal X-ray images for reference images were acquired (Fig. 10.6a).

The QA for the imaging system was done every month using the QA phantom on the QA stand. For the daily QA, in contrast, the QA phantom is placed on the treatment table (Fig. 10.7c), and orthogonal X-ray images are acquired. After these X-ray images are imported into the QA software, the QA phantom pose is calculated by analyzing small bead positions and comparing them to those of the reference images.

For the treatment bed QA, we used FPD imaging system instead of the laser tracker. The treatment bed was moved to predefined positions (monthly QA) and isocenter position only (daily QA) with the QA phantom, which was set on the treatment bed. Orthogonal FPD images are acquired and imported to the QA software; it calculated treatment bed pose. Acceptable level is absolute and relative positional accuracies are within the range of a sphere of 0.5- and 0.3-mm diameter, respectively. We also checked the safety

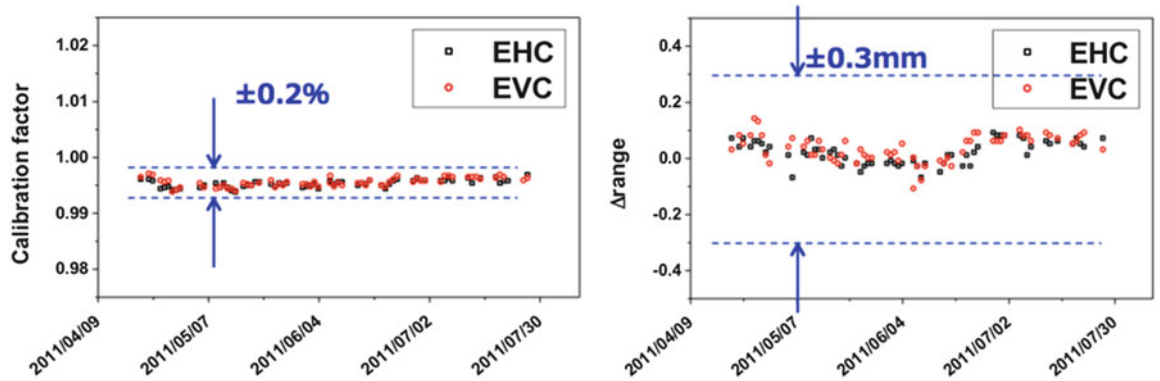

Fig. 10.2 Example of the daily QA for the NIRS scanning system

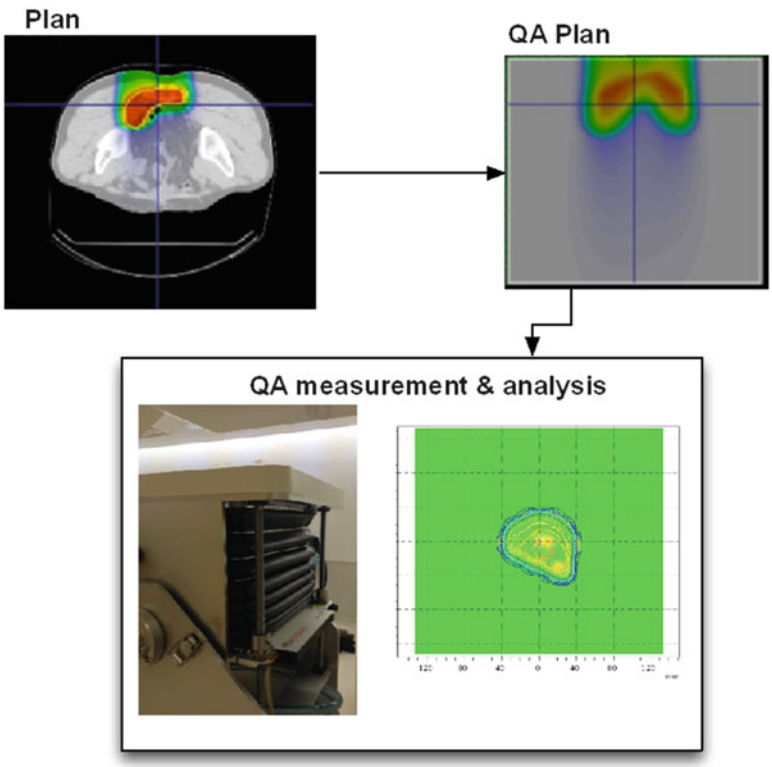

Fig. 10.3 Schematic of patient-specific QA workflow

function every month to void conflicting to the room wall or medical staff.

With regard to the CT, image quality and positional accuracy were evaluated. Image quality metrics were image noise, CT-number uniformity, and CT-number accuracy using the water phantom including several materials, which is provided from CT manufacture. Positional accuracy metric was scan position accuracy using the QA phantom, especially in the CT on rail that we used. All CT-QA items were analyzed by QA software automatically (Fig. 10.8).

For laser equipment (room laser and CT laser), several lasers are installed within the wall and provide lighting through laser slits. Positional accuracy is checked by observing the laser position and QA phantom cross centerlines on the phantom plates (Fig. 10.9).

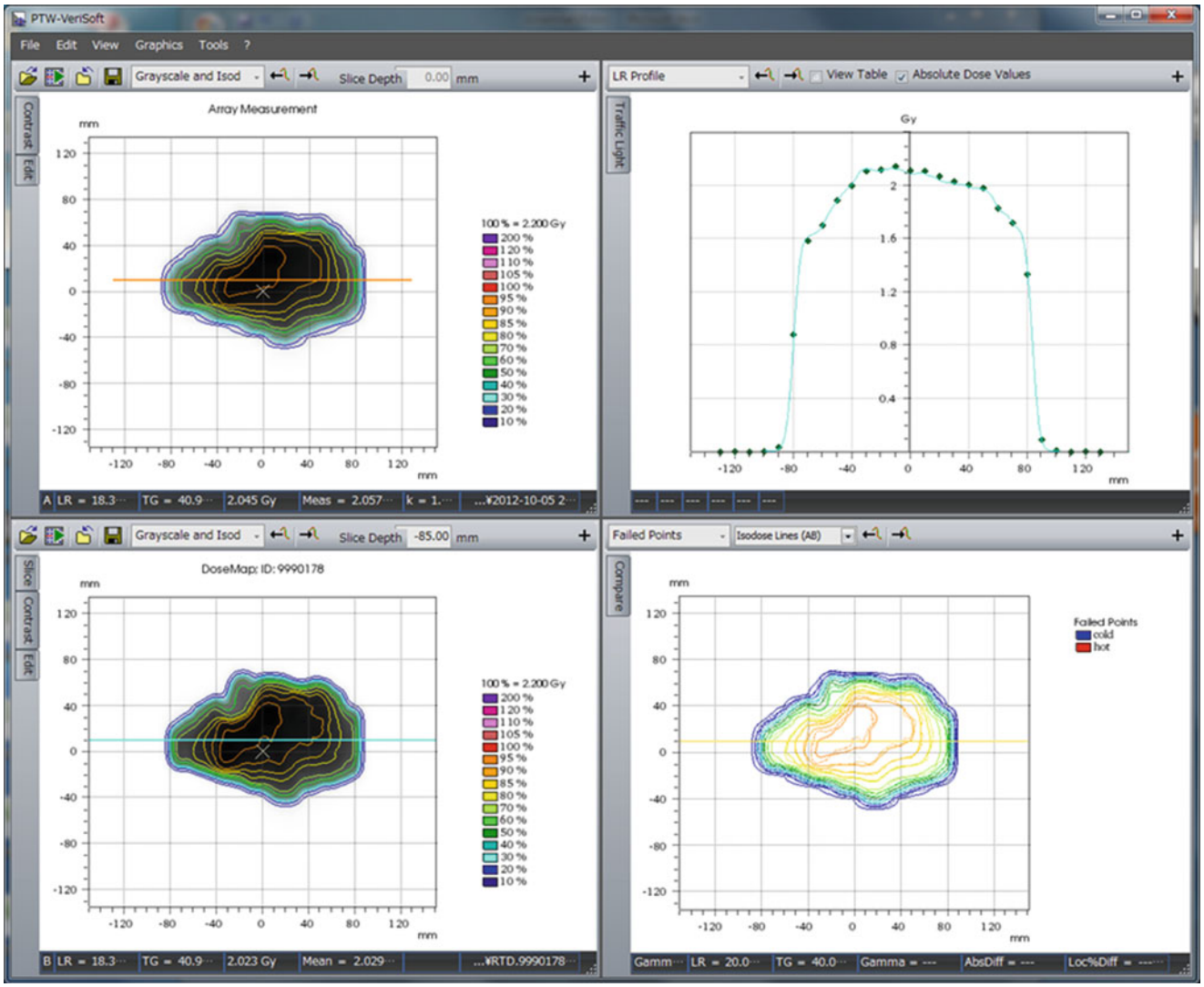

Fig. 10.4 Example of comparison between QA plan and measurement

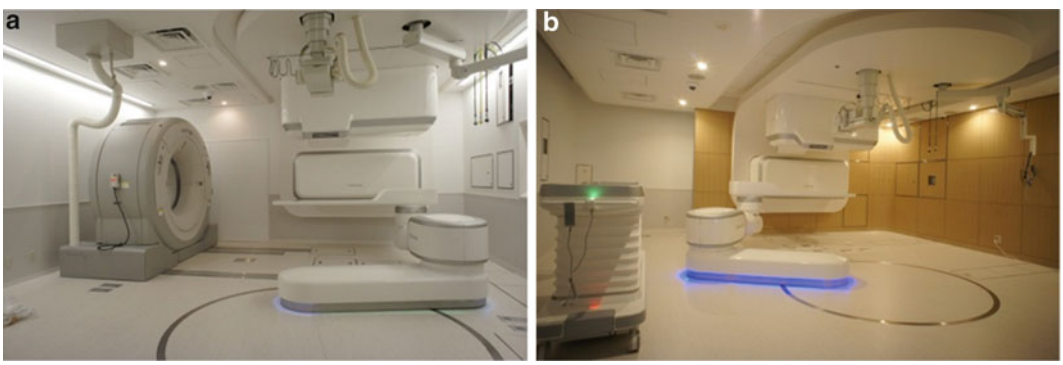

Fig. 10.5 (**a**) Simulation room. (**b**) Treatment room

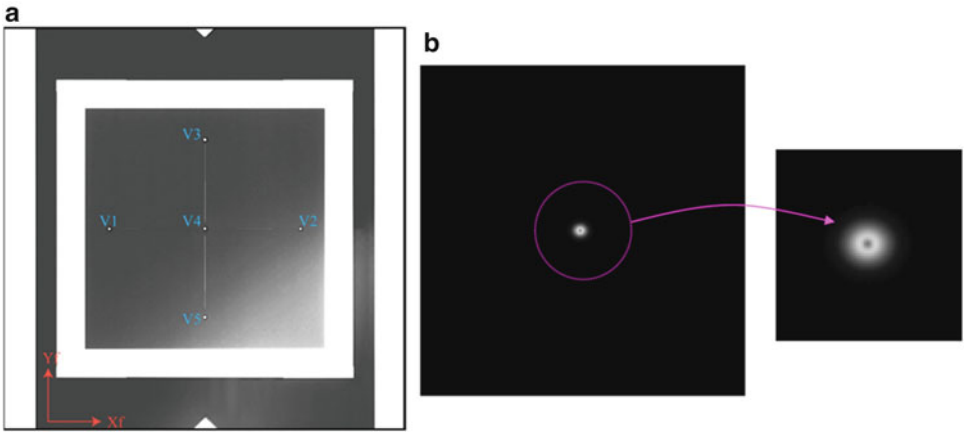

Fig. 10.6 (**a**) QA phantom X-ray image in the vertical direction. *Blue points* (V1–V5) are small beads positioned on the QA phantom vertical planes. (**b**) QA phantom image acquired bead number 4 by carbon-ion pencil beam

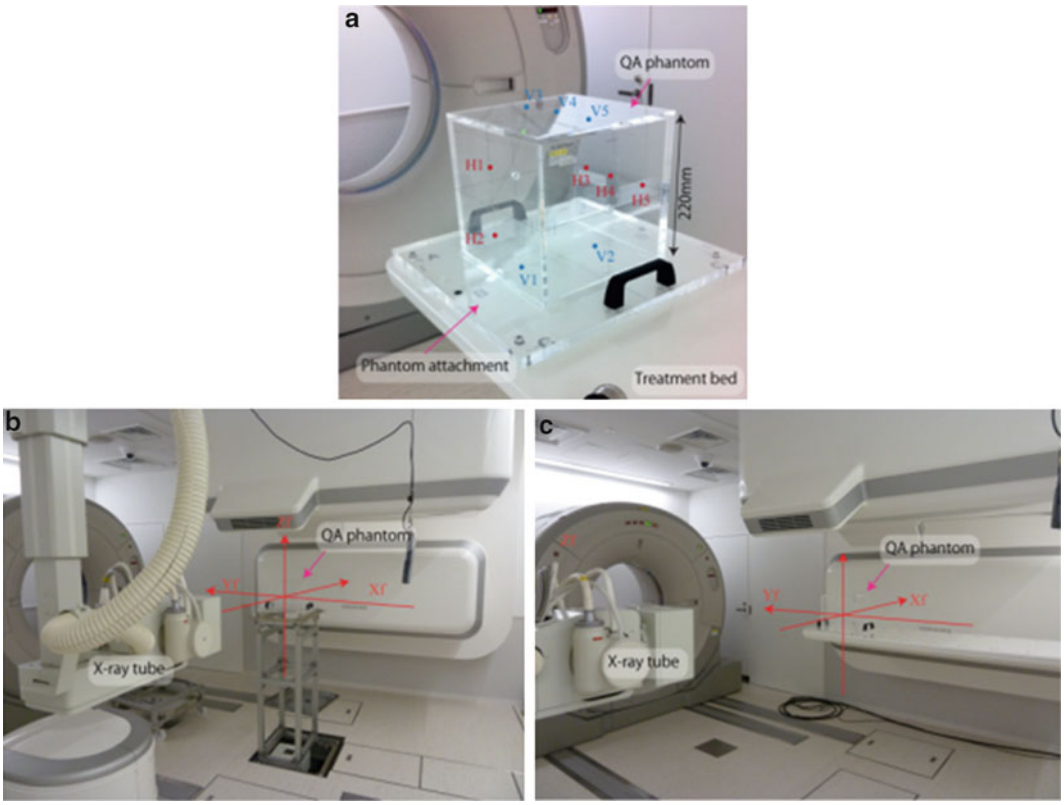

Fig. 10.7 (**a**) QA phantom and phantom attachment. The *blue* (V1–V5) and *red points* (H1–H5) are small beads on the vertical and horizontal planes. (**b**) QA phantom on the QA stand and (**c**) on the treatment bed

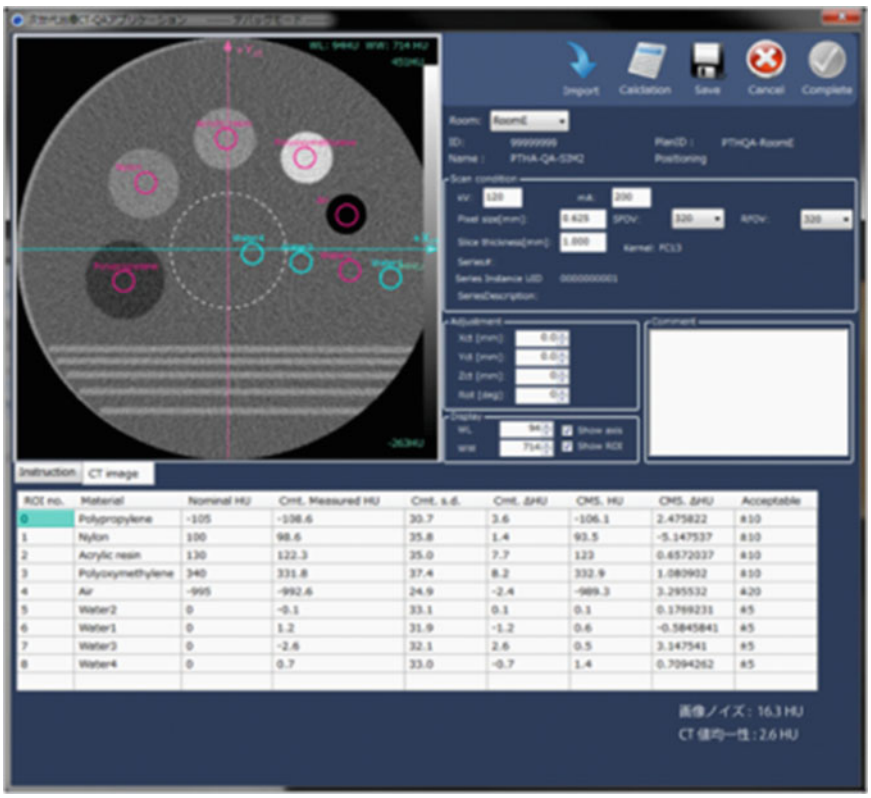

Fig. 10.8 QA software for CT image quality. After importing CT images, the CT-QA software automatically evaluates CT image quality

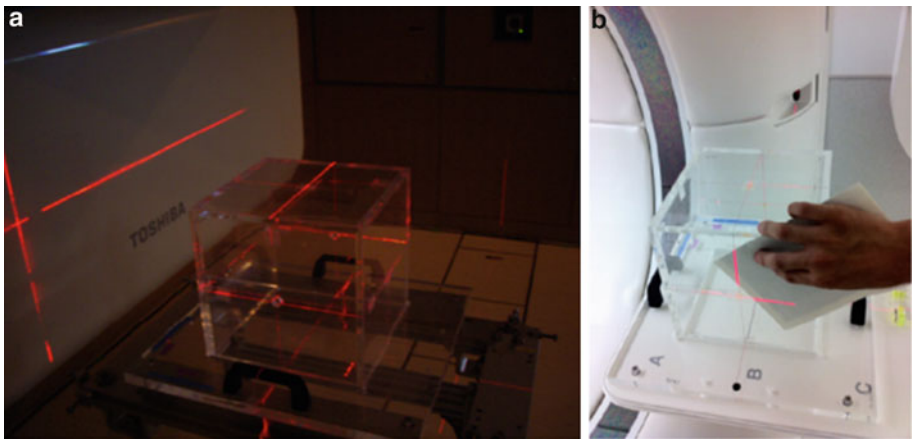

Fig. 10.9 (**a**) Room laser QA. The QA phantom was set on the QA stand. (**b**) CT laser QA. The QA phantom was set on the treatment bed