

Comprehensive Clinical Implementation of Brilliance Big Bore 16 Slice CT Simulator in a Radiation Oncology Department

1. Introduction:

CT images have become the standard basis for radiation treatment planning¹⁻⁷. Traditional diagnostic CT scanners have 70-cm bore size which has some limitations for radiation oncology purposes. Some patients need specific positions for their treatments, therefore the simulation position should also be exact the same for reproduction purpose. Also large size patients require the big bore simulators to get the undistorted images. Some patients need specific immobilization devices. Therefore, big-bore CT simulators are required for radiation treatment planning. Recently, a Philips Brilliance Big Bore CT has been installed in our department. This paper presents a comprehensive study of the performance evaluation of this CT simulator through the acceptance testing and commissioning process and outlines a quality assurance program consistent with TG-66 criteria⁸. Several phantoms were used in this study. Image quality parameters were compared to those of manufacturer-specific parameters and published data. The results are used to demonstrate that this CT simulator can provide high quality images for use in treatment planning. The acceptance testing and commissioning process provide baseline values for QA purposes. These exceed TG-66 recommendation and appear to be achievable in practice.

2. Material and methods:

2.1 Philips Brilliance Big Bore CT (85-cm bore)

The Brilliance Big Bore CT simulator is a "modified" third-generation scanner. It has scanning field of view ranging from 50 to 600 mm. This facility designed for CT imaging for radiation treatment planning can afford patient positioning flexibility. Slice thickness, as small as 0.75 mm, is achievable for precision delineation of the tumor volume using the small focal spot. Three kVp settings are available: 90, 120, and 140 kVp. Exposure techniques range is from 20 to 400 mA with six rotation times for sequential scanning and six reconstruction algorithms. The manufacturer-specific spatial resolution is 16 line pairs/cm at 0% MTF for both axial and spiral scanning modules. Low-contrast resolution is 3.5 mm at 0.35% contrast.

2.2 Phantoms used for acceptance testing and commissioning for clinical use of the Brilliance Big Bore CT simulator

In this study, several different phantoms were used for the acceptance testing and commissioning for clinical use of the Brilliance Big Bore CT simulator: ACR phantom; CDTI phantom; Philips phantom; CATPHAN 504 and RMI phantom.

2.3 CT Simulator acceptance testing and commissioning using ACR phantom

ACR phantom was used to evaluate the image quality for CT acceptance test and clinical commissioning⁹. The acceptance testing includes: slice thickness, field uniformity, low contrast resolution, and high contrast resolution. The accuracy of slice thickness is defined as the full width at half-maximum CT number, which was evaluated by setting slice thickness as 1.5, 3.0 and 6.0 mm in ACR phantom. Field uniformity is used to evaluate the CT image noise and artifacts. CT numbers from ROIs at the center image and four peripheral areas are measured and compared to the manufacturer-specific values.

2.4 Radiation Safety and CT dose

Scanner provides shielding for primary radiation. Scatter is the main source of radiation outside the scan plane. CTDI (CT Dose Index) is a measurement of dose delivered during scan. The measurement followed the protocol of AAPM Report 31¹⁰ and CTDI preliminary report¹¹. Head and Body parts of the CTDI phantoms were used for the measurements with diameters of 16 cm and 32 cm respectively. Measured results were compared with the manufacturer-specific values, as well as the data from publications of Washington University Group for the CT simulator dose and facility radiation safety evaluation⁴.

2.5 Daily Image Quality QA

Vendor phantom was used to for daily Quality Assurance (QA): daily image Quality and CT number test. Philips phantom includes two parts: head phantom, and body phantom. Due to its simple design, this phantom is used for quick daily image quality QA performed by the radiation therapists. The daily image quality QA includes: Quick Image Quality test (CT number, CT uniformity, CT noise and low contrast resolution), which is automatically performed by Vendor software using the head phantom; detailed CT number test using both the head and body phantoms. Quickly daily image quality QA scan is for weekly QA in our clinic.

2.6 Monthly QA using CATPHAN 504

CATPHAN 504 was used for image quality monthly QA due to its comprehensive modular design. Evaluation of image quality parameters includes: 1) field uniformity; 2) CT number linearity; 3) slice thickness; 4) low contrast resolution; 5) high spatial contrast resolution. The application of these parameters are the same as those used with ACR Phantom except the low contrast resolution, which was defined as the minimum resolvable diameter of an object embedded in a uniform medium that differs in density from its background using the CATPHAN phantom. IRIS software was used to perform the analysis of image quality parameters automatically. In order to compare to the published data, we set similar parameters.

2.7 CT number accuracy and linearity evaluation using RMI phantom

RMI Phantom was used to evaluate CT number accuracy and linearity with material physical density and electron density due to its wide density range. There are 17 materials with density range between 0.279 g/cm³ (lung 300) and 4.14 g/cm³ (Titanium). Three data sets were derived with different kVp (90, 120 and 140) for use in treatment planning systems employed in the department. For different kVp, the CT number vs. electron density curves analyzed. For each kVp, two separate trendlines are evaluated with CT number range larger than 100 HU and smaller than 100 HU, respectively.¹²

3. Results:

3.1 Computed tomography dose index

For the CT acceptance testing requirement, the Adult Head CTDI should be less than 75 mGy and the Adult Body CTDI should be less than 25 mGy. In our measurements, these values are 58.9 mGy and 22.8 mGy respectively, which meet the requirement. Table 1 shows the dose results from our big bore CT and AcQsim CT from published data using the Head CTDI⁴. In our CT simulator, the doses in the center and surface are 3.1 cGy and 3.49 cGy respectively. And in AcQsim CT, these values are 4.8 cGy and 4.9-5.9 cGy respectively. Table 1 also shows the dose results comparison using the Body CTDI. In our CT simulator, the doses in the center and surface are 1.09 cGy and 2.66 cGy respectively. In AcQsim CT, those values are 1.2 cGy and 2.6-3.3 cGy respectively. Our dose values are lower.

Table 1 Head central and surface doses and Body central and surface doses

Simulator	Center Dose (cGy) (Head)	Surface Dose (cGy) (Head)	Center Dose (cGy) (Body)	Surface Dose (cGy) (Body)
Brilliant Big Bore	3.1	3.49	1.09	2.66
AcQSim (Wash U)	4.8	4.9-5.9	1.2	2.6-3.3

3.2 Daily Image Quality QA

Table 2 shows the Quick Image Quality check. The tolerance values (manufacture recommendations) of CT number, CT uniformity, CT noise, low contrast are 0±4 HU, 0±4 HU, 3.7±0.4 HU, 4.5±1.2 HU, respectively.

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Table 2 Quick Image Quality test: row 2 shows measured values, row 3 gives the results if this test passes or not based on the tolerance values.

CT Number (Ave.)	CT Uniformity (Ave.)	CT Noise (Ave.)	Low Contrast (Ave.)
2.3	0.3	3.7	4.8
Pass	Pass	Pass	Pass

3.3 Monthly QA using CATPHAN 504

CATPHAN 504 together with IRIS software was used for comprehensive monthly QA purpose. In this study, we set slice thickness as 3.00 mm. IRIS software reported that the average slice width is 2.82 mm, which matched the expected value well. Published data shows that the acceptable criteria CT number value for air and water are -1000 ± 3 HU and 0 ± 2 HU respectively¹⁴. However, due to the measurement condition difference, the CT number can change up by 20 HU, even for water. Therefore, some clinics use this value as tolerance for low density materials⁴.

3.4 Image quality evaluation using ACR phantom

3.4.1 High Contrast Resolution

The highest spatial frequency for two part of the ACR phantoms: abdomen and chest. 8 and 9 lp/cm were visible respectively. These exceed the acceptance testing requirement by manufacturer-specific recommendation value of 5 lp/cm.

3.4.2 Imaging field uniformity

The imaging field uniformity data includes the mean CT number from the field center and the four edges (3, 6, 9, and 12 o'clock). The CT acceptance testing requirement is that the water CT number should be 0 ± 5 HU and $|\text{Center-Edge}| \leq 5$. The results in this study exceed these recommended values.

3.4.3 Low Contrast resolution

The CT acceptance testing requirement from ACR is that the 6 mm rod should be visible and the contrast should be around 6 ± 0.5 HU. The measured contrast values in this study are 5.9HU and 6.4 HU using abdomen and head phantoms respectively, within the recommended value.

3.4.4 Geometric accuracy: slice thickness

The CT acceptance testing requirement from ACR is that the measured slice width should be ≤ 1.5 mm of prescribed width. The water CT number should be 0 ± 5 HU. In our evaluation, the maximum slice thickness difference is from the 6.0mm thickness test, which is 1.25mm. The results in this study meet those recommended values.

3.5 CT number linearity

Figure 1 shows the HU vs. Electron Density results relationship, two different trend lines were generated using dividing point (HU=100)¹². Three different kVp parameters were used in this study. For lower electron density materials (corresponding HU number less than 100), the HU numbers are the same from all three kVp settings. However, for the higher electron density materials (corresponding HU number larger than 100), the HU numbers have great differences due to different kVp settings, which can be derived from the linear equations in figure 1. Same conclusion was derived from M.D. Anderson Cancer Center⁶. These results are used in treatment measuring system QA.

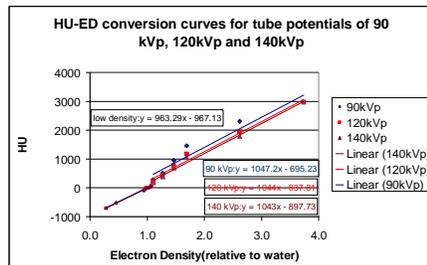


Figure 1 HU-ED curve from three different kVp.

3.6 Image quality analysis between Philips, CATPHAN 504 and ACR phantom

In this study, ACR phantom was used for acceptance testing and clinical commissioning and CATPHAN 504 phantom was used for comprehensive monthly QA. For the similar measurement, the results were compared, for example CT number comparison in Table 3.

Table 3 CT number accuracy and linearity.

	Expected HU	CATPHAN 504 (HU)	ACR (HU)	Philips (HU)
Air	-1000	-971.3	-985.6	n/a
Water	0	n/a	0.0	0.7
Acrylic	120	124.3	121.7	n/a
Teflon	990	921.2	-68.8	918.5

4. Conclusion:

Philips Brilliance Big Bore CT simulator has been installed in our radiation oncology department. Several phantoms were used in this study for CT simulator acceptance testing, clinical commissioning and comprehensive quality assurance. The measured data demonstrate this big bore CT simulator meets the clinical requirements. Compared to the published data using big bore CT in radiation oncology department, our simulator shows similar or more restricted measured values. It can be well used in radiation oncology settings.

5. References:

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