White Paper

The Richardson Healthcare ALTA750G CT Tube as an alternative to the Varian tube in Toshiba/Canon Aquilion CT scanners: A comparison.

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1. Introduction

This project was undertaken to evaluate the validity of replacing the OEM CT tube used in Toshiba/Canon Aquilion Prime scanners with the new Richardson Healthcare ALTA750G tube.

2. Materials and methods

In July of 2021, an Aquilion Prime S CT scanner was used to characterize both tubes at the Richardson Healthcare facility in Fort Mill, South Carolina. The OEM Varian tube (Model MCS-7178A; S/N 31670-R5; 0.9 x 0.8 and 1.6 x 1.4 mm focal spots) was evaluated first. This tube was then replaced with the Richardson Electronics ALTA750G tube (S/N BEH002H; 0.9 x 0.8 and 1.6 x 1.4 mm focal spots). After installation, calibration and seasoning, a process which took 1.5 days, the same tests were repeated on the same scanner with the new tube. These tests are described below.

2.1. Radiation Dose Measurements

The standard CTDI cylindrical acrylic phantoms consisting of a 16-cm diameter head and a 32-cm diameter abdomen were used for all dosimetry measurement along with a Fluke/RaySafe X2 dosimetry system (last calibrated on 4/7/2021). For $CTDI_{vol}$ calculations, two measurement each were made in the center of the phantom and in the periphery (12 o'clock position). As scanner output is dependent on various scan parameters, testing was done to compare how the two tubes compare when certain parameters are changed, specifically: kVp, mAs and detector configuration. For this part of the comparison, two $CTDI_{100}$ measurements were obtained with the pencil chamber in the body phantom center position. In addition, Gafchromic film was used to measure beam widths.

2.2. Image Quality Measurements

The Gammex 464 phantom (ACR phantom) was used to investigate any differences in image quality between the two tubes. To provide data relatable to most readers, the testing follows that required for ACR CT submissions; namely: Contrast to noise ratio, CT number accuracy, uniformity, spatial resolution, and beam width measurements.

3. Results

3.1. Radiation Dose

Table 1 shows how the measured $CTDI_{vol}$ values compared with those displayed by the scanner for the following scan parameters: 120 kVp, 4 x 4 detector configuration, 100 mA and 1 second rotation time.

	$CTDI_{vol}$ (mGy)		
Phantom	**Varian Tube**	**ALTA750G tube**	**Scanner Displayed**
Head	22.7	22.1	22.1
Body	9.8	9.9	10.1

Table 1. Agreement between measured and displayed $CTDI_{vol}$.

CONCLUSION 1: Both Varian and Richardson tubes deliver $CTDI_{vol}$ values within ±3% of those displayed by the CT scanner.

Table 2 shows how the two tubes responded to variations in kVp while keeping all other parameters fixed: 4 x 4 detector configuration, 100 mA and 1 second rotation time.

kVp	**Varian Tube**	**ALTA750G tube**
80	0.27	0.26
100	0.59	0.6
120	1.0	1.0
130	1.36	1.37

Table 2. Measured kVp dose adjustment factors.

CONCLUSION 2: Dependence of $CTDI_{100}$ on kVp variation is practically identical for both Varian and Richardson tubes.

Table 3 shows how the two tubes responded to variations in mA while keeping all other parameters fixed: 120 kVp, 4 x 4 detector configuration, and 1 second rotation time.

mA	Varian Tube	ALTA750G tube
50	0.51	0.5
100	1.0	1.0
200	1.99	2.01
300	2.97	3.01
400	4.24	4.34
500	5.3	5.42

Table 3. Measured mA dose adjustment factors.

CONCLUSION 3: Dependence of $CTDI_{100}$ on mA variation is very similar for both Varian and Richardson tubes.

Table 4 shows how the two tubes responded to variations in detector configuration while keeping all other parameters fixed: 120 kVp, 100 mA and 1 second rotation time.

Detector Configuration (mm)	Varian Tube	ALTA750G tube
0.5 x 4	2.87	2.77
1 x 4	1.81	1.76
2 x 4	1.27	1.26
3 x 4	1.09	1.09
4 x 4	1.00	1.00
5 x 4	1.02	1.02
8 x 4	0.85	0.86
10 x 4	0.84	0.86

Table 4. Measured detector configuration dose adjustment factors.

CONCLUSION 4: Dependence of $CTDI_{100}$ on z-collimator aperture is comparable for both Varian and Richardson tubes.

3.2. Image Quality

Table 5 shows the scan parameters used for the ACR testing for a typical Aquilion Prime S scanner.

	Adult Head	Pediatric Head	Adult Abdomen	Pediatric Abdomen	High Resolution Chest
kV	120	100	120	100	120
mA	220	220	250	150	150
Time per rotation	0.75	0.5	0.5	0.5	0.35
mAs (calculated by the System)	165	110	125	75	52.5
Effective mAs	264	176	152	91	64
Scan FOV (cm)	24	24	40	24	40
Display FOV (cm)	22	20	40	22	36
Reconstruction Algorithm	FC26	FC49	FC18	FC18	FC51
Axial (A) or Helical (H)	H	H	H	H	H
# Data channels used (N)	40	40	40	40	40
Z-axis collimation (T, in mm)	0.5	0.5	0.5	0.5	0.5
Helical Table Speed (mm/rot)	12.5	12.5	16.5	16.5	16.5
Pitch (Pitch = I / N • T)	0.625	0.625	0.825	0.825	0.825
Reconstructed Image Width (mm)	5	5	5	3	1
Reconstructed Image Interval (mm)	5	5	5	3	1
Scanner Displayed CTDI (mGy)	57.5	25.2	15.1	5.6	4.2
Dose Reduction Technique(s) used in routine patient scanning.	AIDR 3D		SureExposure, AIDR 3D		

Table 5. Typical clinical scan parameter for various protocols.

Table 6 shows how the measured $CTDI_{vol}$ compares with that displayed by the scanner.

Protocol	Adult Head	Pediatric Head	Adult Abdomen	Pediatric Abdomen
Displayed $CTDI_{vol}$ (mGy)	57.5	25.2	15.1	5.6
Varian Tube				
Measured $CTDI_{vol}$ (mGy)	61.6	26.2	15.2	5.8
% Difference	7%	4%	1%	4%
Richardson Tube				
Measured $CTDI_{vol}$ (mGy)	61.5	27.2	14.9	5.5
% Difference	7%	8%	1%	1%

Table 6. Agreement between measured and displayed $CTDI_{vol}$.

CONCLUSION 5: Both Varian and Richardson tubes deliver $CTDI_{vol}$ values that are within ±8% of those displayed by the CT scanner.

For the Gammex phantom, Tables 7 through 12 show the various image quality test results as defined by the ACR accreditation requirements: Contrast to noise ratio, uniformity, high contrast spatial resolution, image (slice) thickness, CT number accuracy, and radiation beam width. As an aside, the half-value layers were measured in the "scout" mode for both tubes with essentially the same results (6.92 mm Al for the Varian tube and 6.96 mm Al for the Richardson tube).

Contrast to Noise Ratio (CNR)			
Protocol	**Varian Tube**	**ALTA750G tube**	**ACR CNR Pass Criterion**
Adult Head	1.64	1.56	> 1.0
Adult Abdomen	1.33	1.2	> 1.0
Pediatric Head	0.99	0.96	> 0.7
Pediatric Abdomen	0.62	0.56	> 0.4

Table 7. Measured CNR values for the four ACR clinical protocols and the corresponding performance criteria.

Uniformity			
Difference in CT #s	**Varian Tube**	**ALTA750G tube**	**ACR Pass Criterion**
Center - 12:00	0.9	1.0	< 5
Center - 3:00	0.3	0.5	
Center - 6:00	0.5	0.1	
Center - 9:00	0.9	0.5	

Table 8. Measured uniformity values for the four ACR clinical protocols and the corresponding performance criteria.

High Contrast Spatial Resolution (line pair/cm)			
Protocol	**Varian Tube**	**ALTA750G tube**	**ACR Pass Criterion**
Adult Abdomen	9	9	≥ 6
High Resolution Chest	10	10	≥ 8

Table 9. Measured spatial resolution values for the required ACR clinical protocols and the corresponding performance criteria.

Radiation Beam Width (mm)		
Detector Configuration	**Varian Tube**	**ALTA750G tube**
0.5 x 4	7	7
1 x 4	10	9
2 x 4	13	13
3 x 4	16	16
4 x 4	20	19
5 x 4	26	26
8 x 4	36	36
10 x 4	45	45

Table 10. Measured beam width for all possible detector configurations.

	Varian Tube		**ALTA750G tube**	
Image Thickness (mm)	**Top(mm)**	**Bottom(mm)**	**Top(mm)**	**Bottom(mm)**
0.5	0.5	0.5	0.5	0.5
1.0	1.0	1.0	1.0	1.0
2.0	2.0	2.0	2.0	2.0
3.0	3.0	3.0	3.0	3.0
4.0	4.0	4.0	4.0	4.0
5.0	5.0	5.0	5.0	5.0

Table 11. Measured image thickness for all possible axial values.

	Mean CT # (HU)		ACR Acceptable Range (HU)
Material	**Varian Tube**	**ALTA750G tube**	
Polyethylene	-96.4	-94.3	-107 to -84
Water	1.8	2.1	-7 to 7
Acrylic	119.3	120.2	110 to 135
Bone	942.8	944.5	850 to 970
Air	-992.2	-991.6	-1005 to -970

Table 12. Measured CT number accuracy for the various materials in the Gammex phantom.

CONCLUSION 6: The Aquilion scanner tested would pass the physics portion of ACR accreditation with either tube. The results show no discernible difference between the Varian and Richardson tubes.

4. Global Summery

From the radiation dose and image quality tests performed on the Aquilion CT scanner, it can be concluded that the Richardson ALTA750G x-ray tube is equivalent to the OEM Varian tube. Without prior knowledge, it is practically impossible to deduce which tube is installed in the scanner from the measurements taken.