Evaluation of Accuray Tomo ClearRT Imaging As a Substitute for Philips Big Bore CT Simulator

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ABSTRACT

Purpose: To determine image quality performance of Accuray ClearRT as a substitute for Philips Big Bore CT Simulator.

Methods: First, Accuray's image acquisition parameters were compared with Philips' reference and user exam cards for typical protocols. Second, differences between published values and physical measurements were examined for Accuray's $CTDI_{vol,free\ air}$ and Philips' $CTDI_{vol}$. Finally, simulation of hip prosthesis was conducted using a Cheese Phantom with titanium and reference density plugs to represent metal implants and OARs, respectively. To evaluate metal artifacts, Accuray's and Philips' scans were imaged with/without titanium plugs, while reconstructing Philips' scans with/without O-MAR to gauge algorithm's functionality. HU calibration curves were defined for both Accuray and Philips using Gammex's RMI 465 phantom. Scans were imported into Eclipse to contour targets/OARs followed by VMAT planning with Eclipse AAA, copying plan to scans, recalculating dose using same MUs, and comparing DVH values.

Results: Accuray offers longer scan length and higher pitch, but Philips has faster gantry period. Accuray's FOV, kVp, and mAs are protocol specific, whereas Philips allows manual entry. Except for Head protocols, Accuray uses higher mAs, indicating lower image noise. Published $CTDI_{vol}$ are comparable, although Accuray reports lower Head $CTDI_{vol}$ with reduced kVp and mAs. Measured Accuray $CTDI_{vol,free\ air}$ average 25% higher (tolerance=50%/1 cGy), while measured Philips $CTDI_{vol}$ are maximum 4% higher (tolerance=20%). V95% and V100% for GTV and PTV are similar between systems. Mean, max, and D1% doses to targets/OARs are <4% higher for Accuray. Accuray appears less susceptible to metal artifact: 1) PTV min dose reduces 13% for Philips versus 6% for Accuray and 2) PTV V100% reduces by 6% for Philips versus 1% for Accuray.

Conclusion: Accuray ClearRT offers comparable image performance to Philips Big Bore CT Simulator. Notably, both systems deliver imaging dose within specifications and experience similar dose effects from metal artifacts.

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INTRODUCTION

- CT imaging protocols contain unique parameters affecting image quality and patient dose, including:
  - kVp
  - FOV
  - mAs
  - Pitch
- Computed tomography dose index (CTDI) provides standardized comparison of dose output from CT
  - Specifically, **$CTDI_{vol}$ is a useful indicator of exam protocol dose**
- **Accuray ClearRT** claims image fidelity near diagnostic quality
  - Helical kVp CT fan-beam
  - Non-editable anatomy protocol
  - Enhancements versus C-arm CBCT:
    - +10sec shorter scan time
    - +/- 15 HU accuracy
    - 33% improved low contrast at image center
    - 135cm scan length
- **Philips Big Bore CT Simulator**
  - 85cm bore with 70cm FOV
  - Pre-set and editable exam cards
  - **O-MAR algorithm** reduces metal artifact
- **Image acquisition affects**:
  - Image quality for anatomy delineation
  - Imaging dose to patient
  - HU accuracy for TPS dose calculation

➢ **This study evaluates image quality performance of Accuray ClearRT as a substitute for Philips Big Bore CT Simulator**

METHODS AND MATERIALS

➢ **Objectives:**

i. To compare Accuray's and Philips' image acquisition parameters for typical protocols

ii. To compare published and measured values for Accuray's $CTDI_{vol,free\ air}$ and Philips' $CTDI_{vol}$

iii. To assess metal artifact affects on dose distributions for Accuray's and Philip's CT scans

- Published literature obtained from manufacturers for imaging parameters
- Accuray's $CTDI_{vol,free\ air}$ measurements
  - Unable to use IEC formalism since machine is used clinically
    - ➢ Helical free-air measurements only with A1SL ion chamber
- Philips' $CTDI_{vol}$ measurements
  - IEC formalism with PMMA phantoms
- Hip prosthesis simulation to assess dose distributions between imaging systems
  - Scans of Cheese Phantom with/without titanium insert
  - HU curve defined for each system using Gammex's RMI 465 phantom
  - Eclipse AAA VMAT plans created on each scan using same MUs per field

RESULTS

- Table 1 compares published CTDI values between Accuray and Philips
- Tables 2 & 3 provide measured CTDI comparisons for both imaging systems
- Figures 1 – 2 and Table 4 compares dose distribution effects for hip prosthesis simulation scanned on Accuray and Philips

Table 1. CTDI values from Accuray ClearRT and Philips Big Bore CT Simulator for typical imaging procedures. Only Large body protocols are referenced from Accuray ClearRT.

System	Anatomy / Protocol	Mode / Resolution	FOV (mm)	kVp	mAs	Max. Scan Length (mm)	Pitch	N x T (mm)	Gantry period / Rotation (Scan time) (s)	$CTDI_{vol}$ (cGy)	$CTDI_{vol,free\ air}$ (cGy)
Accuray ClearRT	Head	Fine	270	100	480	500	0.86	50	8.22	1.04	1.42
			440	100	480	500	0.75	50	8.22	2.09	3.86
		Normal	270	100	384	500	1.00	100	8.28	0.66	0.90
			440	100	384	500	0.75	100	8.28	1.52	2.81
	Thorax	Fine	440	120	480	451.9	0.75	50	8.22	1.70	5.71
			500	120	480	451.9	0.75	50	8.22	1.44	5.71
		Normal	440	120	384	500	0.75	100	8.28	1.25	4.20
			500	120	384	500	0.75	100	8.28	1.05	4.14
	Pelvis	Fine	440	140	480	382	0.75	50	8.22	2.46	7.93
			500	140	480	382	0.75	50	8.22	2.05	7.78
		Normal	440	140	384	500	0.75	100	8.28	1.78	5.74
			500	140	384	500	0.75	100	8.28	1.49	5.66
	Whole Body	Fine	270	120	375	665.4	0.86	50	8.22	1.03	2.00
			440	120	375	544.3	0.75	50	8.22	1.33	4.58
			500	120	375	544.3	0.75	50	8.22	1.13	4.51
		Normal	270	120	300	1350	1.00	100	8.28	0.65	1.26
			440	120	300	1350	0.75	100	8.28	0.98	3.35
			500	120	300	1350	0.75	100	8.28	0.82	3.29
Philips Big Bore CT Simulator: Reference exam card	Onco Brain	Standard	350	120	595	249	0.313	12 (16 x 0.75)	0.5 (35)	7.07	–
	Onco SRS Brain	High	350	120	590	164	0.438	12 (16 x 0.75)	0.75 (25.6)	7.01	–
	Onco Neck	Standard	500	120	321	300	0.813	24 (16 x 1.5)	1 (17.3)	1.9	–
	Onco Chest	Standard	500	120	256	300	0.813	24 (16 x 1.5)	0.75 (13)	1.82	–
	Onco Abdomen	Standard	500	120	287	300	0.813	24 (16 x 1.5)	0.75 (13)	2.03	–
	Onco Pelvis	Standard	500	120	287	300	0.813	24 (16 x 1.5)	0.75 (13)	1.7	–
Philips Big Bore CT Simulator: User exam card	Onco Brain	Standard	400	120	595	249	0.313	12 (16 x 0.75)	0.5 (35)	7.07	–
	Onco SRS Brain	High	400	120	595	249	0.313	12 (16 x 0.75)	0.5 (35.3)	7.07	–
	Onco Neck	Standard	600	120	116	300	0.808	12 (16 x 0.75)	1 (32.8)	0.77	–
	Onco Chest	Standard	600	120	130	300	0.813	24 (16 x 1.5)	0.75 (13)	0.77	–
	Onco Abdomen	Standard	600	120	182	300	0.813	24 (16 x 1.5)	0.75 (13)	1.29	–
	Onco Pelvis	Standard	600	120	182	300	0.813	24 (16 x 1.5)	0.75 (13)	1.08	–

Table 2. Measured $CTDI_{vol,free\ air}$ for Accuray ClearRT with percent differences versus published values. Only Large body protocols are referenced from Accuray ClearRT.

Anatomy	Mode	FOV (mm)	Measurements (pC) 1	2	3	Avg. charge (pC)	Meas. $CTDI_{vol,free\ air}$ (cGy)	Pitch	Meas. $CTDI_{vol,free\ air}$ (cGy)	Publ. $CTDI_{vol,free\ air}$ (cGy)	% diff.
Head	Fine	270	24.8	26.8	27.2	26.3	1.4	0.86	1.6	1.42	13
		440	70.8	71.7	71.4	71.3	3.8	0.75	5.0	3.86	30
	Normal	270	16.8	16.8	16.8	16.8	0.9	1.00	0.9	0.90	0
		440	51.7	51.0	52.2	51.7	2.7	0.75	3.7	2.81	32
Thorax	Fine	440	104.5	104.2	106.5	105.0	5.6	0.75	7.4	5.71	30
		500	105.0	103.2	104.9	104.3	5.5	0.75	7.4	5.71	30
	Normal	440	76.6	78.4	76.7	77.2	4.1	0.75	5.5	4.20	31
		500	76.3	77.9	75.8	76.7	4.1	0.75	5.4	4.14	30
Pelvis	Fine	440	144.4	146.1	147.2	145.9	7.7	0.75	10.3	7.93	30
		500	143.2	146.7	141.7	143.9	7.6	0.75	10.2	7.78	31
	Normal	440	104.1	105.5	107.3	105.6	5.6	0.75	7.5	5.74	31
		500	106.0	104.4	104.4	104.9	5.6	0.75	7.4	5.66	31
Whole Body	Fine	270	38.3	38.2	36.9	37.8	2.0	0.86	2.3	2.00	15
		440	81.1	83.2	81.9	82.1	4.4	0.75	5.8	4.58	27
		500	83.2	82.1	81.5	82.3	4.4	0.75	5.8	4.51	29
	Normal	270	23.5	23.3	23.5	23.5	1.2	1.00	1.2	1.26	-4.8
		440	60.9	59.9	60.1	60.3	3.2	0.75	4.3	3.35	28
		500	59.9	60.5	60.5	60.3	3.2	0.75	4.3	3.29	31

DISCUSSION

- Image acquisition parameters
  - Accuray offers longer scan length and higher pitch values
  - Philips offers manual entry for FOV, kVp, and mAs
  - Accuray uses higher mAs (except Head protocols) ➡ Lower image noise
- Published $CTDI_{vol}$ are comparable between imaging systems
  - Accuray reports lower Head $CTDI_{vol}$ with reduced kVp and mAs
- Metal artifact influence on dose delivery
  - V95% and V100% for GTV and PTV are similar between systems
  - Mean, max, and D1% to targets/OARs are < 4% higher for Accuray
  - Accuray may be less susceptible to metal artifact:
    - PTV min reduces 6% versus 13% for Philips
    - PTV V100% reduces 1% versus 6% for Philips

CONCLUSIONS

- Accuray and Philips offer comparable image performance for the metrics measured in this project (particularly anatomy delineation)
  - ➢ Future study to provide in-depth analysis of image quality metrics
- Accuray's and Philips' measured $CTDI_{vol}$ meet manufacturer specifications
- Both system's CT scans experience similar metal artifact effects

Table 3. Measured $CTDI_{vol}$ for Philips Big Bore CT Simulator with percent differences versus console scanner values.

Image acquisition parameter		Protocol: Onco Brain	Protocol: Onco Pelvis
kVp		120	120
mA		373	350
Time per rot. (s)		0.5	0.75
mAs		186	263
Effective mAs		594	323
FOV (mm)		500	500
Resolution		Standard	Standard
Delivery		Helical	Helical
N x T (mm)		24 (16 x 1.5)	24 (16 x 1.5)
Table increment, I (mm/rot.)		7.51	19.51
Pitch [I / (N x T)]		0.313	0.813
Recon. image width (mm)		3	3
Recon. image interval (mm)		3	3
Center CTDI measurements	1 (mR)	521.0	250.2
	2 (mR)	517.4	247.9
	3 (mR)	522.3	247.1
	Average (mR)	520.2	248.4
	Center $CTDI_{100}$ (mGy)	18.9	9.0
Peripheral CTDI measurements	1 (mR)	648.6	542.0
	2 (mR)	643.4	537.5
	3 (mR)	649.1	546.5
	Average (mR)	647.0	542.0
	Peripheral $CTDI_{100}$ (mGy)	23.5	19.6
Measured $CTDI_w$ (mGy)		21.9	16.1
Measured $CTDI_{vol}$ (cGy)		70.0	19.8
Scanner reported $CTDI_{vol}$ (cGy)		70.7	19.1
% difference		0.9	3.7

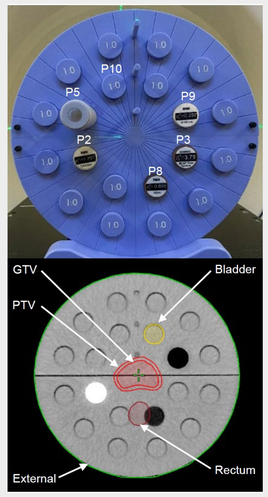

Figure 1. (Top-Bottom)
1) Cheese Phantom setup for prostate hip prosthesis. Titanium plugs in positions P3 and P5. Reference materials in positions: bone – P2, adipose – P8, lung – P9, and tissue – P10.
2) Cheese Phantom contours for hip prosthesis showing External, GTV, PTV, Bladder, and Rectum contours.

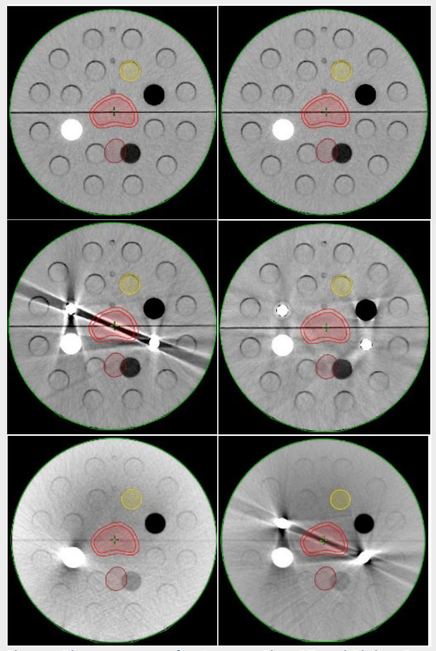

Figure 2. Cheese Phantom scans for Accuray ClearRT and Philips Big Bore CT Simulator with plan name in parentheses. (L-R, T-B)
1) Philips: ref. mtls. only *w/out* O-MAR (**CT Ref NoOMAR**)
2) Philips: ref. mtls. only *w/* O-MAR (**CT Ref OMAR**)
3) Philips: ref. mtls. *plus titanium w/out* O-MAR (**CT Met NoOMAR**)
4) Philips: ref. mtls. *plus titanium w/* O-MAR (**CT Metal OMAR**)
5) Accuray: ref. mtls. only (**TomoRfMt Th S**)
6) Accuray: ref. mtls. *plus titanium* (**Tomo Met Th S**)

Table 4. DVH values from 2-arc VMAT Eclipse plan for Accuray ClearRT and Philips Big Bore CT Simulator scans. See Figure 2 for image set to plan name conversion.

Plan name	Structure	Min. Dose (cGy)	Mean Dose (cGy)	Max. Dose (cGy)	D1% (cGy)	V95% (%)	V100% (%)
CT Ref NoOMAR	GTV	499	513	526	521	100	100
	PTV	433	512	531	522	99.6	97.2
	Bladder	17	132	227	214	0	0
	Rectum	32	141	255	221	0	0
CT Ref OMAR	GTV	499	513	526	521	100	100
	PTV	433	512	531	522	99.6	97.2
	Bladder	17	132	227	214	0	0
	Rectum	32	141	255	221	0	0
CT Met NoOMAR	GTV	493	508	522	517	100	98.5
	PTV	375	507	534	521	98.9	91.0
	Bladder	17	134	226	213	0	0
	Rectum	37	144	252	221	0	0
CT Metal OMAR	GTV	493	509	523	517	100	98.8
	PTV	375	508	534	521	98.9	91.3
	Bladder	17	134	226	213	0	0
	Rectum	37	144	252	221	0	0
TomoRfMt Th S	GTV	506	524	542	534	100	100
	PTV	407	524	546	537	99.5	98
	Bladder	17	134	232	219	0	0
	Rectum	33	144	264	226	0	0
Tomo Met Th S	GTV	502	523	542	533	100	100
	PTV	382	521	544	536	98.9	97.0
	Bladder	18	136	229	218	0	0
	Rectum	34	145	261	226	0	0

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