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Evaluation of the Image Quality on Computed Tomography

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Abstract : The purpose of phantom image test is to evaluate the image quality. Therefore, it is investigated that whether several phantoms are available for QC by comparison and measurement of phantoms. In this study, 4 CT scanners were used, light speed VCT (GE healthcare, USA), Brilliance ICT, Brilliance 64 (Philips medical system, Netherlands), Somatom Definition Flash, Somatom Definition AS (Siemens healthcare, Germany), Aquilion 64 (Toshiba medical system, Japan) and 3 phantoms were used, AAPM CT performance phantom (Model 76-140, ACR phantom (Model #438, gammexrmi, USA) and catphan phantom (600, USA). Phantom images were obtained from each CT scanners by axial scan. There was no significant difference in measurement results for 3 phantoms about common evaluation items (slice thickness, uniformity, high contrast resolution, low contrast resolution, CT number evaluation). The intent of study is to allow users to use other phantoms, not AAPM phantom selected as a standard phantom by "The rules on the installation and operation of special medical equipment". It is considered to do quality control with proper phantom depend on necessary quality control items because exceptional phantoms have own characteristic quality control items.

Key words: CT QA and QC, AAPM, ACR, catphan, comparison, purpose, image

INTRODUCTION

As computed tomography has the huge part of frequency of use and importance portion for image medical science it is visualized 2 or 3 dimension to internal organs of human body using.

X-ray and used to widespread for finding various lesions which are difficult diagnosis by general X-ray examination (Hong *et al*., 2013; Richard *et al*., 2012) CT products X-ray and measures the radiation dose after penetrating subject and processed the reconstruction not reflected direct projection result because of the reconstruction equipment with 2 dimension following location information. This reconstructed processing could cause various problems and represent incorrectly to attenuated degree of original subject (Friedman *et al*., 2013; You *et al*., 2015; Bennet *et al*., 2016; Choi *et al*., 2016; McCollough *et al*., 2004; Schneiders and Bushong, 1980).

Literature review: In present, the cases of CT express various organs and vessel structure with small details in human body. To inspect and measure regularly for correct expression of these structures is a matter of course. The quality of CT image depend on how clear and exact represent tiny structure and the important factors of image quality have CT number accuracy expressed material attenuation degree, spatial resolution, low contrast resolution, noise characteristic, artifact and radiation dose. Cody and Mahesh (2007) Hippelinen *et al*., 2008; Zhang *et al*., 2013).

As the evaluation to the decision factors of image quality, phantom image examination purposes to proper evaluation for picture image quality (Brunner and Kyprianou, 2013; Schneiders and Bushong, 1980a, b).

In Korea it is legislated the Ministry of Health and Welfare in Table 5 "The regulation of installation and management for special medical equipment" and controlled quality management and image examination of CT. However, it just use AAPM phantom for measurement that chosen standard phantom when the regulation was legislated.

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MATERIALS AND METHODS

CT scanners for the study are used total 4 equipment with Light Speed VCT (GE healthcare, USA), Brilliance iCT, Brilliance 64 (Philips medical system, netherlands), Somatom Definition Flash, Somatom Definition AS (siemens healthcare, germany) and Aquilion 64 (toshiba medical system, japan) and total 3 phantoms with AAPM CT performance phantom (Model 76-140), ACR phantom (Model #438, gammexrmi, USA) and catphan phantom for the measurement. It is acquired images by axial scanning with all phantoms among manufacture equipment and exposure condition is 120 kVp, 250 mA, scan time 1 sec and 10 mm slice thickness which required the 2013 year article in present "The regulation of installation and management for special medical equipment", excepted C company equipment, 12 mm slice thickness that is the closest to 10 mm slice thickness is used. Scan FOV is 50 cm, display FOV is 25 cm and single slice conventional scan and standard reconstruction algorithm are examined. In each phantom, measurable items are measured and compared. Next are measurement images among phantoms as shown in Fig. 1.

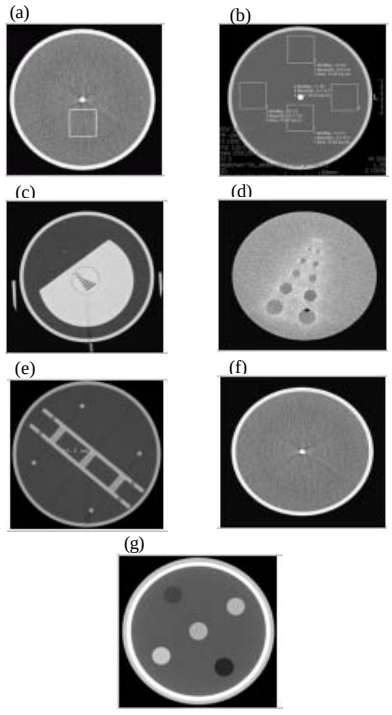

Fig. 1: AAPM quality control images: a) Attenuated coefficient of water, noise measurement; b) Uniformity measurement; c) High contrast resolution; d) Low contrast resolution; e) Slice thickness; f) Artifacts and g) CT number of linearity

RESULTS AND DISCUSSION

To compare the result after the extraction of common articles for measured three different phantoms it could set four common articles. Those are slice thickness, uniformity, spatial resolution and low contrast resolution. For those study it compare and analysis each CT equipment (Fig. 2 and 3).

Slice thickness: The measured imagesby each phantom are followed in Fig. 4. As shown in Table 1 each phantom are measured to 10 mm slice thickness all but excepted company case it is resulted 12 mm because 10 mm slice thickness couldn't be measured. Those are measured 12.0, 10.5 and 11.5 mm separately.

Uniformity: The measured images by each phantom are followed in Fig. 5. Uniformity is as shown in Table 2 no correlation because all measurement values are various. It is considered different deviation because measured ROI setting and phantom materials are different. Even, if measurement values are different it is all satisfied with standard of suitability.

High contrast resolution: The measured images by each phantom are followed in Fig. 6. All is included standard of permission it has no difference. However, in case of AAPM it is not possible to compare because hole size express to measurement value in Table 3.

Table 1: Slice thickness measurement results unit: mm

Manufacturer	AAPM	ACR	Catphan
A	10	10.0	10.0
B	10	10.0	10.0
C	12	10.5	11.5
D (64)	10	10.0	10.0
D (128)	10	10.0	10.0

Table 2: Uniformity thickness measurement results unit: <HU

Manufacturer	AAPM	ACR	Catphan	p-valuse
A	0.5	0.7	4.6	0.72
B	0.9	2.7	4.8	0.47
C	0.8	4.5	1.7	0.22
D(64)	3.3	0.9	2.6	0.21
D(128)	1.8	1.4	4.7	0.43
SD	±1.6	±1.8	±1.1	
p	0.67	0.79	0.92	

p = ANOVA test

Table 3: High contrast resolution measurement results unit: line pair/mm

Manufacturer	AAPM (mm)	ACR	Catphan	p-values
A	1	7	6.6	0.03
B	1	7	6.4	0.01
C	1	7	6.2	0.04
D(64)	1	6	6.5	0.01
D(128)	1	6	6.6	0.01
SD	±0.12	±0.38	±0.22	
p**	0.02	0.04	0.02	

p = ANOVA test, between ACR and catphan, p^{**} = ANOVA test

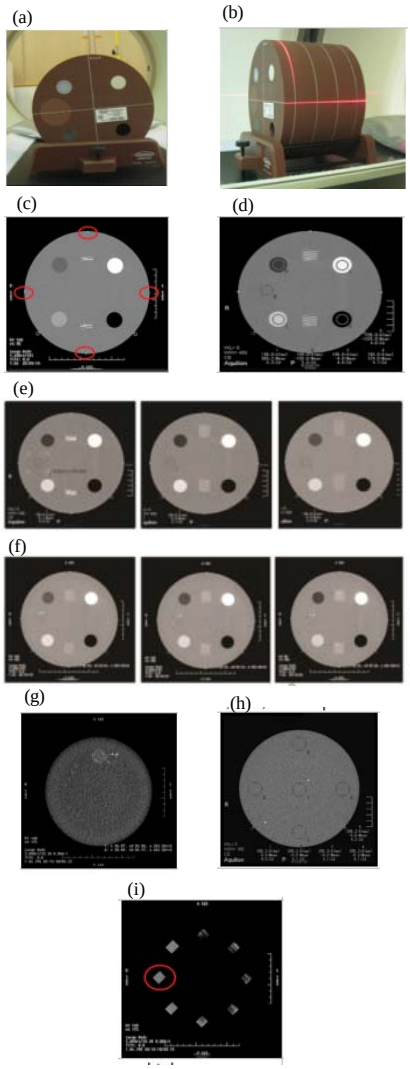

Fig. 2: ACR quality control images: a) Phantom positioning; b) Phantom positioning results; c) CT number calibration; d) Slice thickness 3, 5, 7 mm; e) Slice thickness 80, 100, 120 kVp; f) Low contrast resolution; g) Uniformity and h) High contrast resolution

Low contrast resolution: All is included standard of permission it has no difference. However, in case of catphan it is not possible to compare because it is used to tool of region detectivity measurement as shown Fig. 7 and Table 4.

CT number: The measured images by each phantom are followed in Fig. 8. Because each phantom composition are all different it could not done objective comparison but it could be possible to the measurement following each phantom standard and the results are all appropriated as shown each other (Table 5-7).

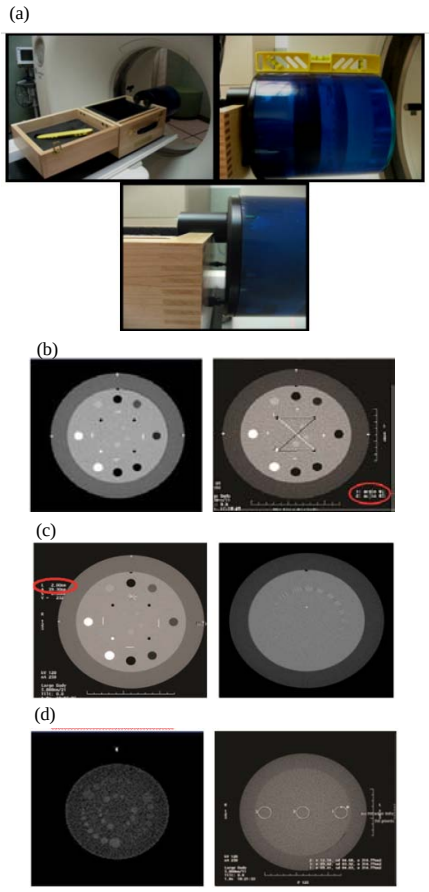

Fig. 3: Catphan quality control images: a) Positioning; b) Correct positioning image; c) Circular symmetry and spatial linearity of pixel size verification; d) Scan incrementation; e) High contrast resolution; f) Low contrast resolution and g) Image uniformity

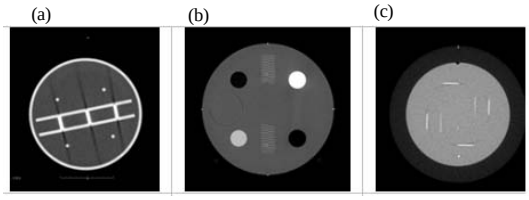

Fig. 4: Slice thickness; a) AAPM; b) ACR and c) Catphan

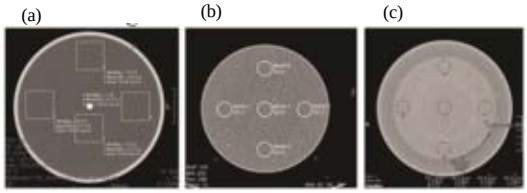

Fig. 5: Uniformity: a) AAPM; b) ACR and c) Catphan

Table 4: Low contrast resolution measurement results unit: mm

Manufacturer	AAPM	ACR	Catphan	p-values
A	6.4	4	-	0.01
B	6.4	5	-	0.03
C	6.4	6	-	0.00
D(64)	6.4	4	-	0.03
D(128)	6.4	4	-	0.03
SD	±0.0	±1.3		
p**	0.01	0.04		

p = ANOVA test, between AAPM and ACR, p** = ANOVA test

Table 5: AAPM CT number measurement results unit: HU

Variables	Polystyrene	Polyethylene	Nylon	Polycarbonate	Acrylic
A	-26.2	-63.7	91.7	102.8	126.5
B	-20.4	-55.7	97.6	105.8	129.7
C	-32.3	-72.8	91.5	98.7	127.2
D(64)	-39.3	-41.61	90.69	90.28	116.83
D(128)	-38.38	-38.65	97	99.63	124.7
SD	±7.43	±17.27	±4.71	±2.82	±3.19
P	0.04	0.07	0.03	0.04	0.03

p = ANOVA test

Table 6: ACR CT number measurement results unit: HU

Variables	Air	Polyethylene	Water	Acrylic	Bone
A	-984.98	-88.91	0.71	123.47	870.24
B	-1008.9	-97.1	-2.1	126.36	917.63
C	-1028.19	-103.32	-3.33	119.24	954.17
D(64)	-983.53	-91.59	3.32	122.36	910.87
D(128)	-984.36	-91.14	3.32	123.75	916.02
SD	± 21.69	± 11.91	± 4.58	± 3.52	± 30.06
P	0.04	0.02	0.03	0.04	0.07

p = ANOVA test

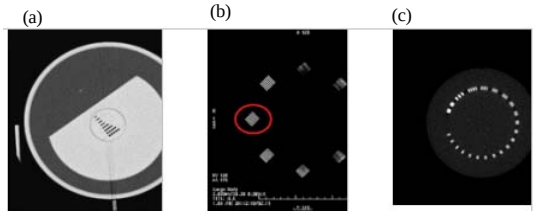

Fig. 6: High contrast resolution: a) AAPM; b) ACR and c) Catphan

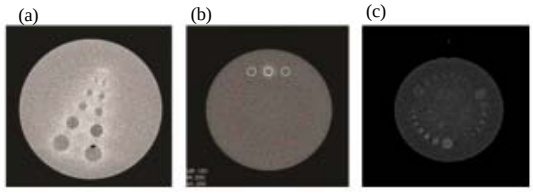

Fig. 7: Low contrast resolution: a) AAPM; b) ACR and c) Catphan

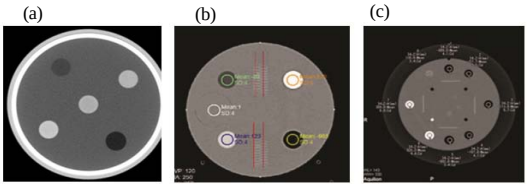

Fig. 8: CT number: a) AAPM; b) ACR and c) Catphan

The measurement articles and many others: The measured each other values by phantoms are followed in Table 8 and 9. In present, diagnosis equipment for human body are a wide variety those are often used in medical fields. For the correct examination of diagnosis equipment it must be expected to quality management for equipment characteristic. Specially, the quality management of CT which is important to image examination must be expected to regular quality control. In Korea, even though it has the regulation and been the management by medical institutions, most of them have no private quality control program and put it to other inspection company for the charge practically. This kind of act is far from the purpose that fields do quality control and adjust image quality directly and management steadily.

As this study, even if measured by using AAPM, ACR and catphan phantoms it has no difference to main study such as slice thickness, uniformity, spatial resolution, low contrast resolution and CT number evaluation. It is considered to have meaning to strength the basis to use phantoms except in AAPM phantom which is decided to standard by "The regulation of installation and management for special medical equipment" in Korea.

CT has status very important portion of image examination in modern medical science. It is very important issue to correct reconstruction of detector. It is very meaningful research to perform quality control to check proper reconstruction with regular measurement. In Korea it had been managed as set the Ministry of Health and Welfare "the regulation of safety management of diagnosis radiation production equipment" and then has been managed to image quality control in earnest by "The regulation of installation and management for special medical equipment" in 2003. However, it had wistfulness because used phantom was just designated AAPM phantom from trial initial to 2013 in present. Therefore, in this study it is considered the usefulness of the image quality evaluation with various phantoms compared typical phantom performance of CT.

In slice thickness evaluation it is measured 10 mm of all 5 sorts CT of AAPM, ACR and catphan and confirmed no measurement difference of 12 mm scanned image of one CT. In uniformity it could be known that all equipment within ±5HU status under measurement error range. In spatial resolution, the case of AAPM could not be the comparison with other phantoms because hole size is shown measurement value but it is confirmed no difference of measured values by other phantom separately. In low contrast, the case of AAPM is

Table 7: Catphan CT number measurement results unit: HU

Variables	Air (6CW)	Air (0CW)	PMP	LDPE	Polystyrene	Acrylic	Delrin	Teflon
	-1000	-1000	-200	-100	-35	120.0	340.0	990.0
A	-983.8	-979	-200	-100	-35	120.0	340.0	906.3
B	-986.7	-951.1	-179.6	-86.7	-31.4	128.0	287.0	871.3
C	-992.6	-989	-187.8	-113.9	-57.7	116.9	309.9	920.3
D(64)	-987.1	-985.5	-187.9	-98.1	-43	114.2	332.0	925.5
D(128)	-989.8	-988	-186.3	-96.7	-40.8	118.5	353.2	971.0

p = ANOVA test

Table 8: AAPM measurement results

Variables	CT no. of water (HU)	Distance (mm)	Angle (o)	Noise(HU)
A	-1.2	0.05	0	3.9
B	0.6	-1.1	-2	4
C	-1.6	-0.3	0.9	4.4
D(64)	-1.56	-1	1	4.13
D(128)	0.08	-1	0	4.43
SD	±1.62	±0.83	±0.21	±0.39
P	0.04	0.04	0.03	0.04

p = ANOVA test

Table 9: Catphan measurement results

Variables	FWHA (mm)	Alignment	Circular symmetry	Angle symmetry
A	2.55	good	good	good
B	2.42	good	good	good
C	3.0	good	good	good
D (64)	2.2	good	good	good
D (128)	5.5	good	good	good

macroscopic evaluation for ACR it is the result using software and catphan case could not be compared in accordance with a little bit different evaluation items but if it set standard differently for each phantom it is consider that to perform quality control management has no problem. For the evaluation of CT number it could not be compared one by one for different material of phantom but it has no problem with measurement using any phantoms because measured values are all under allowable error.

CONCLUSION

It is considered to do quality control with proper phantom depend on necessary quality control items because exceptional phantoms have own characteristic quality control items. In the future it should be use various phantoms for the measurement phantom images of special medical equipment in Korea and it should do wide range quality control with proper selection for each phantom standard level.

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