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Evaluation of Changes in Dose Estimation on Abdomen CT Scan with Automatic Tube Current Modulation Using In-House Phantom

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ABSTRACT

This study evaluates the effect of the Automatic Tube Current Modulation (ATCM) technique on pitch and effective diameter variation in estimating dose values and noise levels for abdominal examination on Philips Ingenuity CT scan machine using in-house Phantoms. The in-house phantoms are oval in shape with three effective diameter sizes, namely 23.2 cm, 28.3 cm, and 33.3 cm to represent abdominal region. The three size Phantoms were scanned using an Ingenuity 128 Philips CT scan with the abdominal protocol exposure parameters of 120 kVp tube voltage, Dose Right Index (DRI) variations of 10,11,12,13, and 14, and pitch variations of 0.6; 0.8; 1.0; 1.2; and 1.49. The changes in mAs, CTDIvol, and noise to the Philips reference value were then verified (i.e. an addition of one DRI value increases mAs by 12 %). For evaluation, a metric to express the change in DRI is defined as Δ_{DRI}. The study demonstrates that noise level is influenced by object size; size information of the object could be useful to predict the change of tube current and pitch due to ATCM with respect to selected DRI. The DRI value is proportional to the tube current, thus selecting the DRI at a certain pitch will directly determine tube current. The Δ_{DRI} in general, according to Philips specifications, is verified to be approximately 10 % to 13 %, except for DRI 10 to 11 which is relatively high on average 15 % to 17 %. Increasing DRI increases the $CTDI_{vol}$. The CTDI/mAs constantly ranges of 0.06 to 0.07. The value could serve as a characteristic parameter for quality assurance. The ATCM specifications of the Ingenuity 128 CT Scanner is according to Philips regulations.

INTRODUCTION

Abdominal CT scan in the radiology cluster of Kencana Pavillion, Cipto Mangunkusumo National Central General Hospital (RSCM Kencana) is among the most routine examinations performed, alongside brain and thorax CT scan. In 2022, abdominal CT scans were most frequently performed, with 332 examinations (23.2 %) out of 1,430 examinations from 18 typical examinations.

The high number and magnitude of exposure poses the need for dose and image quality optimization [1]. In CT scans, optimization can be done with features such as automatic exposure control (AEC), where the tube current is adjusted according to the patients thickness [2], so that the radiation dose the patient receives depends on the radiation output and the patient size [13]. CT scan with the AEC-like features, i.e. the Automatic Tube Current Modulation (ATCM), automatically adjusts the tube current to the patients thickness to produce a certain level of image quality based on the mapping from the Scan Projection Radiograph (SPR) [3,12,10].

On the Philips Ingenuity 128 CT scanner, the longitudinal ATCM technique is known as Z-Dom, while the angular ATCM is known as D-Dom. A Dose Right Index (DRI) is used as modulation degree metric [2]. The DRI will affect the percentage of mAs and noise values that subsequently affect image quality. Every additional

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one DRI value will increase the mAs value by 12 % and reduce noise by 6 %, while reducing one DRI value will reduce mAs by 12 % and increase noise by 6 % [4].

The designation of DRI in clinical settings, especially during abdominal CT scans at RSCM Kencana, needs to be done carefully [6]. Therefore, it is necessary to carry out a preliminary study by verifying the tube current modulation based on differences in the effective diameter of the in-house phantom.

The aim of this study is to verify the tube current modulation characterizatics using an in-house phantom object. CT dose index (CTDI) is a standardized measure of radiation dose output of a CT scan, which allows the user to compare radiation output of different CT scan [11]. This ($CTDI_{vol}$) with DRI and pitch variations as selectable parameters on the Philips Ingenuity 128 CT Scan was evaluated by evaluating changes in tube current, $CTDI_{vol}$, and noise level to represent image quality with Dose Right Index (DRI) variations based on the abdominal CT scan protocol.

METHODOLOGY

The in-house phantoms are constructed of PMMA or acrylic in an oval shape as a representation of adult human abdomen with three effective diameter sizes; 23.2 cm, 28.3 cm, and 33.3 cm. All phantoms will be referred to as first (phantom 1), second (phantom 2), and third phantom (phantom 3), respectively [8].

Image quality testing was done using a performance Phantom system before in-house phantom scanning. Measurements were made on CT of Ingenuity 128 Philips in the radiology cluster of the Hospital Dr. Cipto Mangunkusumo. The DRI exposure parameters and pitch used for routine abdominal CT protocols are shown in Table 1. The DRI function automatically provides mAs recommendations for each object size based on an program using topogram image (Surview).

Table 1. Exposure parameters of CT Abdomen protocol with ATCM technique.

Information	Value
Protocol name	Abdomen
kVp	120
Scout view/sureview	Frontal
TCM: Image Quality	DRI: 10,11,12,13,14
Beam collimation	64 x 0,625
Tube rotation time (s)	0,4
Pitch	0.6, 0.8, 1, 1.2, 1.49
Slice width	1 mm
Reconstruction kernel	Standar
Image matrix	506 x506

The DRI algorithm converts mAs by doubling the mAs value for each increase in object size by 6 cm from the reference size and reducing the mAs value by half for each decrease in object size by 8 cm from the reference size as found in Table 2 [4].

Tabel 2. Body reference size.

Age range	Weight (kg)	Body reference size
Infant	< 10	16
Pediatric	10-20	18
	20-30	20
	30-40	22
	40-50	24
	50-60	26
	60-70	27
	70-90	29
Adult	50-90	29
	90-120	33
	>120	37

The quantity of noise level (Fig. 1) is calculated by Eq. (1) [9].

$$\text{Noise level} = \frac{\sigma}{1000} \times 100\ \% \tag{1}$$

with σ being the standard deviation of HU in the ROI area.

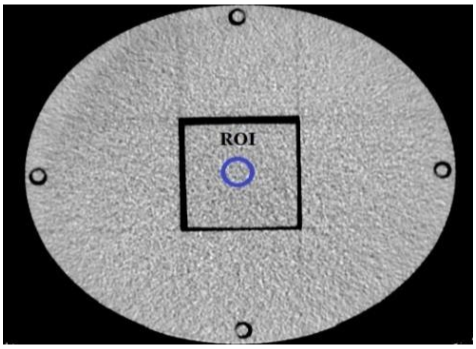

Fig. 1. Measurement of noise level with a region of interest (ROI) in in-house phantom medical imaging.

After the first, second, and third were scanned with the abdominal protocol and ATCM technique, the effect of exposure parameter variations on mAs values, estimated doses, and noise levels at the center of the phantom axis were evaluated. The percentage increase in mAs values and noise level values with the addition of DRI values were then analyzed and compared with Philips provisions. The percentage increase in mAs value for every addition of one DRI value is calculated by the Eq. (2).

$$\Delta_{DRI} = \{((mAs_{n+1})-(mAs_n))/mAs_n\} \times 100\ \% \tag{2}$$

with Δ_{DRI} being the percentage of tube current change after one step increase of DRI. The mAs_{n+1} is the tube current on one step of DRI above the used DRI. Meanwhile, the mAs_n is the tube current on the used DRI.

Determining the pitch value in the CT examination exposure parameter means determining the scan time in the examination. For each pitch selection, the scan time will be constant. The DRI value is proportional to the mAs value, thus selecting the DRI at a certain pitch will determine the current selection automatically.

RESULTS AND DISCUSSION

Table 3 shows the automatic mA selection at the first phantom with a certain pitch, and DRI variations with a fixed scan time. The tube current increases with increasing DRI values. An increase of the DRI value results in an increases of the mAs value, as DRI increasing with constant pitch causes an increase of the mA automatically.

Table 3. Automatic mA, s, and mAs modulation in phantom 1 (23.2 cm effective diameter), using 120 kVp tube voltage.

Pitch	DRI	mA	Scan time (s)	mAs	Δ_{DRI} (%)
0,60	10	43,3 ± 1.2	0,69	29,3 ± 0,6	
	11	48,3 ± 1.2	0,70	33,7 ± 0,6	15,0
	12	54,3 ± 1.7	0,70	37,3 ± 1,2	10,7
	13	60,3 ± 2.3	0,70	42,0 ± 0,0	12,6
	14	68,3 ± 2.9	0,70	47,3 ± 1,2	12,6
0,80	10	56,7 ± 1.2	0,52	29,3 ± 0,6	
	11	64,3 ± 1.2	0,52	33,7 ± 0,6	15,0
	12	72,3 ± 1.7	0,52	37,7 ± 0,6	11,9
	13	81,3 ± 1.7	0,53	42,3 ± 1,2	12,2
	14	91,7 ± 2.3	0,53	47,3 ± 1,2	11,8
1,00	10	71,0 ± 1,2	0,41	29,7 ± 1,2	
	11	81,0 ± 1,2	0,42	33,7 ± 0,6	13,5
	12	90,7 ± 1,5	0,42	37,7 ± 0,6	11,9
	13	101,7 ± 2,1	0,42	41,7 ± 0,6	10,6
	14	113,7 ± 1,7	0,42	47,3 ± 0,6	13,4
1,20	10	85,3 ± 0,6	0,35	29,3 ± 0,6	
	11	97,0 ± 1,2	0,35	33,7 ± 0,6	15,0
	12	109,3 ± 1,5	0,35	37,7 ± 0,6	11,9
	13	122,3 ± 2,1	0,35	42,7 ± 0,6	13,3
	14	136,7 ± 2,1	0,35	47,7 ± 0,6	11,7
1,49	10	105,7 ± 1,2	0,28	29,3 ± 0,6	
	11	120,7 ± 2,3	0,28	33,7 ± 0,6	15,0
	12	135,0 ± 1,5	0,28	37,7 ± 0,6	11,9
	13	151,3 ± 2,3	0,28	42,3 ± 0,6	12,2
	14	169,3 ± 2,9	0,28	47,3 ± 1,2	11,8

The scan time decreases with increasing pitch value and is relatively constant at DRI variations with a fixed pitch. In general, pitch variations on a certain DRI do not result in significant changes of the mAs values. The Δ_{DRI} value for the first phantom for pitch and DRI variations ranged from 10.6-13.4 %, except for the increase of DRI from 10-11 which gives 15 % in average. For the second phantom, it is relatively the same as the first phantom with a constant increase of pitch and DRI, so the scan time will decrease since mAs will be constant.

An increase of the DRI value is followed by an increase of the mAs value, with a constant scan time as the DRI increases causing a change to the increase of mA automatically. The lowest current (DRI 10) is 73.3 ± 1.5 mA and the highest (DRI 14) is 304.3 ± 4.6 mA as shown in Table 4. The Δ_{DRI} value for the second phantom for pitch and DRI variations ranged from 10.9-13 %, except for the increase of DRI from 10-11 (ranging from 15.2-15.6 %). The second phantom has a larger effective diameter than the first phantom, resulting in higher mA and mAs values at the same pitch and DRI variations. The scan times on the first and second phantoms have the same value for the same pitch and DRI.

Table 4. Automatic mA, s, and mAs modulation in the second phantom (28,3 cm effective diameter), using 120 kVp tube voltage.

Pitch	DRI	mA	Scan time (s)	mAs	Δ_{DRI} (%)
0,60	10	73,7 ± 1,5	0,70	51,3 ± 1,2	
	11	84,7 ± 1,5	0,70	59,3 ± 1,2	15,6
	12	92,7 ± 1,5	0,71	66,0 ± 1,0	11,0
	13	105,3 ± 2,1	0,70	73,7 ± 1,5	12,0
	14	118,0 ± 2,0	0,70	82,7± 1,5	12,0
0,80	10	101,7 ± 1,5	0,52	52,7 ± 0,6	
	11	116,7 ± 1,5	0,52	60,7 ± 0,6	15,2
	12	129,7 ± 1,5	0,52	67, 3 ± 0,6	10,9
	13	143,0 ± 2,0	0,53	75,7 ± 0,6	12,5
	14	159,7 ± 1,5	0,53	84,7 ± 0,6	11,9
1,00	10	124,7 ± 1,2	0,42	52,3 ± 0,6	
	11	143,7 ± 1,2	0,42	60,3 ± 0,6	15,3
	12	159,7 ± 1,5	0,42	67,0 ± 1,0	11,1
	13	180,0 ± 1,7	0,42	75,7 ± 0,6	13,0
	14	202,0 ± 1,7	0,42	84,7 ± 0,6	11,9
1,20	10	149,3 ± 0,6	0,35	52,0 ± 0,0	
	11	172,0 ± 0,0	0,35	60,0 ± 0,0	15,4
	12	190,7 ± 0,6	0,35	66,7 ± 0,6	11,2
	13	214,7 ± 0,6	0,35	75, 0 ± 0,0	12,4
	14	239,7 ± 0,6	0,35	84,0 ± 0,0	12,0
1,49	10	188,3 ± 1,2	0,28	52,7 ± 0,6	
	11	217,0 ± 1,2	0,28	60,7 ± 0,6	15,2
	12	241,0 ± 1,7	0,28	67,7 ± 0,6	11,5
	13	270,7 ± 2,3	0,28	75,7 ± 0,6	11,8
	14	304,3 ± 4,6	0,28	85,3 ± 1,2	12,7

Table 5 shows the automatic change in tube current for the third phantom with an effective diameter of 33.3 cm, exposure conditions of 120 kVp, and pitch and DRI variations. The pitch and DRI values used are the same as for the first and second phantoms. DRI selection at a certain pitch determines the change in mA value automatically. With a larger effective diameter compared to the first and second phantoms, the mA value in the third phantom is larger than that of the first and second phantoms. The Δ_{DRI} value in the third phantom for pitch and DRI variations ranges from 10.1-13.8 %, except for an increase of DRI from 10-11 ranging from 13.6-17.5 %. In general, the Δ_{DRI} values of the first, second, and third phantoms follow Philips specifications, approximately 10-to 13 %, except for DRI 10-11, which is relatively high, on average of 15 %.

Table 5. Automatic mA, s, and mAs modulation in the third phantom (33,3 cm effective diameter), using 120 kVp tube voltage.

Pitch	DRI	mA	Scan time (s)	mAs	Δ_{DRI} (%)
0.6	10	125 ± 1,0	0,70	86,0 ± 1,7	
	11	142 ± 1,5	0,70	98,7 ± 2,1	14,8
	12	157 ± 2,1	0,71	109,3 ± 2,9	10,7
	13	177 ± 0,6	0,70	124,0 ± 1,0	13,4
	14	199 ± 2,5	0,70	138,0 ± 3,6	11,3
0.8	10	167 ± 2,1	0,53	86,3 ± 1,5	
	11	189 ± 3,1	0,53	98,7 ± 2,1	14,4
	12	212 ± 4,4	0,53	110,0 ± 2,6	11,4
	13	236 ± 2,5	0,53	123,0 ± 1,0	11,8
	14	265 ± 5,0	0,53	138,3 ± 3,1	12,4
1.0	10	207 ± 1,2	0,42	84,0 ± 3,6	
	11	236 ± 1,5	0,42	98,7 ± 2,1	17,5
	12	264 ± 2,0	0,42	110,0 ± 2,6	11,4
	13	295 ± 2,3	0,42	123,0 ± 1,0	11,8
	14	333 ± 3,8	0,42	138,7 ± 3,5	12,8
1.2	10	249 ± 0,6	0,35	86,3 ± 1,5	
	11	284 ± 0,6	0,35	98,3 ± 1,5	13,9
	12	317 ± 1,5	0,35	109,3 ± 2,9	11,2
	13	354 ± 1,5	0,35	123,3 ± 1,2	12,8
	14	398 ± 1,5	0,35	138,7 ± 3,2	12,5
1.49	10	297 ± 2,5	0,28	86,3 ± 1,5	
	11	335 ± 2,5	0,28	98,0 ± 1,7	13,6
	12	377 ± 4,0	0,28	110,3 ± 2,9	12,2
	13	418 ± 5,3	0,28	123,3 ± 0,6	11,8
	14	469 ± 5,5	0,28	135,7 ± 6,8	10,1

The mAs value increases with the increase of the DRI value for every pitch value. The larger the effective phantom diameter, the greater the mAs value at the same pitch and DRI. The lowest mAs value occurs in the first phantom with a DRI value of 10, and the highest mAs value occurs in the third phantom with a DRI value of 14.

Figure 2 shows the curve of the DRI value against the current value of the mAs tube. The Figure shows that an increase of the DRI value causes an increase of the mAs value. All phantoms show a linear curves. The phantom with a larger effective diameter will give a higher mAs value for the same DRI value. In every DRI, the mAs value is smallest for the first phantom and largest for the third phantom. For different pitch values, the mAs value is relatively constant for the same DRI.

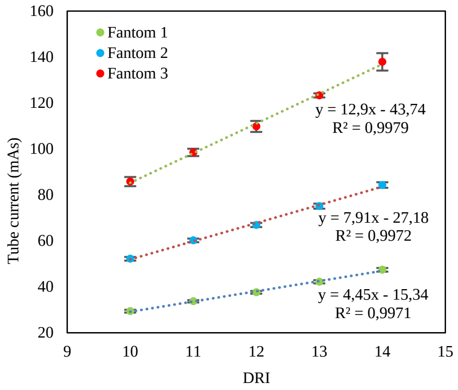

Fig. 2. DRI vs mAs for the first, second, and third phantoms with an exposure factor of 120 kVp for pitches of 0.6;0.8;1;1.2; and 1.49.

Table 6 shows that for a certain pitch and DRI, the second phantom has a higher mAs value than the first phantom, and the third phantom is higher than the second phantom. Changes of the pitch value for a certain DRI do not change the mAs value for each phantom size. The difference of the effective diameter of the second phantom to the first phantom is 5.1 cm, and the difference of the effective diameter between the third and second phantom is 5 cm. Based on the Philips reference, for each additional 6 cm effective diameter, the mAs value will increase 2 fold. For the same pitch and DRI, the different value of the mAs is 2.1 for the second phantom compared to the first phantom and 3.2 for the third phantom compared to the second phantom.

Table 6. Comparison of $\Delta mAs_{2,1}$ dan $\Delta mAs_{3,2}$ values with pitch and DRI variables for 120 kVp.

Pitch	DRI	Tube current (mAs)				
		Phantom 1 d = 23.2 cm	Phantom 2 d = 28.3 cm	Phantom 3 d = 33.3 cm	$\Delta mAs_{2,1}$	$\Delta mAs_{3,2}$
0.6	10	29,3 ± 0,6	51,3 ± 1,2	86,0 ± 1,7	1,75	1,68
	11	33,7 ± 0,6	59,3 ± 1,2	98,7 ± 2,1	1,76	1,67
	12	37,3 ± 1,2	66,0 ± 1,0	109,3 ± 2,9	1,77	1,65
	13	42,0 ± 0,0	73,7 ± 1,5	124,0 ± 1,0	1,75	1,68
	14	47,3 ± 1,2	82,7± 1,5	138,0 ± 3,6	1,75	1,67
0.8	10	29,3 ± 0,6	52,7 ± 0,6	86,3 ± 1,5	1,80	1,63
	11	33,7 ± 0,6	60,7 ± 0,6	98,7 ± 2,1	1,80	1,63
	12	37,7 ± 0,6	67, 3 ± 0,6	110,0 ± 2,6	1,79	1,63
	13	42,3 ± 1,2	75,7 ± 0,6	123,0 ± 1,0	1,79	1,62
	14	47,3 ± 1,2	84,7 ± 0,6	138,3 ± 3,1	1,79	1,63
1.0	10	29,7 ± 1,2	52,3 ±0,6	84,0 ± 3,6	1,76	1,61
	11	33,7 ± 0,6	60,3 ± 0,6	98,7 ± 2,1	1,79	1,64
	12	37,7 ± 0,6	67,0 ± 1,0	110,0 ± 2,6	1,78	1,64
	13	41,7 ± 1,2	75,7 ± 0,6	123,0 ± 1,0	1,82	1,62
	14	47,3 ± 1,2	84,7 ± 0,6	138,7 ± 3,5	1,79	1,64
1.2	10	29,3 ± 0,6	52,0 ± 0,0	86,3 ± 1,5	1,77	1,65
	11	33,7 ± 0,6	60,0 ± 0,0	98,3 ± 1,5	1,78	1,63
	12	37,7 ± 0,6	66,7 ± 0,6	109,3 ± 2,9	1,77	1,63
	13	42,7 ± 0,6	75, 0 ± 0,0	123,3 ± 1,2	1,76	1,64
	14	47,7 ± 0,6	84,0 ± 0,0	138,7 ± 3,2	1,76	1,65
1.49	10	29,3 ± 0,6	52,7 ± 0,6	86,3 ± 1,5	1,80	1,63
	11	33,7 ± 0,6	60,7 ± 0,6	98,0 ± 1,7	1,80	1,61
	12	37,7 ± 0,6	67,7 ± 0,6	110,3 ± 2,9	1,80	1,62
	13	42,3 ± 0,6	75,7 ± 0,6	123,3 ± 0,6	1,79	1,62
	14	47,3 ± 1,2	85,3 ± 1,2	135,7 ± 6,8	1,80	1,59

Addition of the mAs value of the second phantom increased 1.7 fold of the first phantom, and the addition of the mAs value of the third phantom increased 1.67 fold of the second phantom. Table 6 shows an increase of the mAs value of the second phantom compared to first phantom ranged from 1.75-1.8 fold, and the increase of mAs value of the third phantom compared to the second phantom ranged from 1.6-1.68 fold.

Changes of the $CTDI_{vol}$ values in the first, second, and third phantoms as shown in Table 7 indicate that an increase of DRI will increase the $CTDI_{vol}$ value for all phantoms.

The $CTDI_{vol}$ value does not depend on the pitch value, it only depends on the DRI or mAs value. Increasing the phantom size will increase the $CTDI_{vol}$ value. With a larger size, it will increase the mAs value as well so that it will increase of the $CTDI_{vol}$ value [7]. The $CTDI_{vol}$/mAs value, which are found to be constant in the range of 0.06-0.07, is proven as physical characteristics of a CT scanner which is a subject only to object size. Figure 3 shows that the increase of DRI will be followed by an increase of $CTDI_{vol}$. A larger effective diameter of the phantom has a greater $CTDI_{vol}$ value for the same DRI value. For different pitch values and the same DRI, the $CTDI_{vol}$ value is relatively constant. The $CTDI_{vol}$ values in the first phantom ranged from 1.9-3.1 mGy, the second phantom ranged from 3.2-5.4 mGy, and the third phantom ranged from 5.5-9.1 mGy.

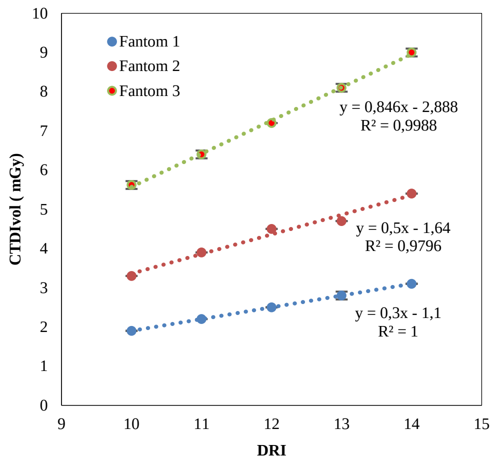

Fig. 3. DRI vs $CTDI_{vol}$ at phantoms 1, 2, and 3 with an exposure factor of 120 kVp at pitches 0.6;0.8;1;1.2; and 1.49.

Table 7. $CTDI_{vol}$/mAs values and phantom noise levels 1, 2, and 3 with variations in pitch and DRI on 120 kVp.

Pitch	DRI	$CTDI_{vol}$ (mGy)			mAs			$CTDI_{vol}$/mAs		
		Phantom 1	Phantom 2	Phantom 3	Phantom 1	Phantom 2	Phantom 3	Phantom 1	Phantom 2	Phantom 3
0.6	10	1,9 ± 0	3,2 ± 0,2	5,6 ± 0	29,3 ± 0,6	51,3 ± 1,2	86,0 ± 1,7	0,06	0,06	0,06
	11	2,2 ± 0	3,8 ± 0,2	6,4 ± 0,2	33,7 ± 0,6	59,3 ± 1,2	98,7 ± 2,1	0,07	0,06	0,07
	12	2,5 ± 0,1	4,5 ± 0,2	7,2 ± 0,2	37,3 ± 1,2	66,0 ± 1,0	109,3 ± 2,9	0,07	0,07	0,06
	13	2,7 ± 0,1	4,7 ± 0,3	8,1 ± 0,1	42,0 ± 0,0	73,7 ± 1,5	124,0 ± 1,0	0,06	0,06	0,06
	14	3,1 ± 0,1	5,3 ± 0,2	9 ± 0,3	47,3 ± 1,2	82,7± 1,5	138,0 ± 3,6	0,07	0,06	0,06
0.8	10	1,9 ± 0,1	3,3 ± 0,2	5,7 ± 0,2	29,3 ± 0,6	52,7 ± 0,6	86,3 ± 1,5	0,06	0,06	0,06
	11	2,2 ± 0,1	3,9 ± 0,1	6,5 ± 0,2	33,7 ± 0,6	60,7 ± 0,6	98,7 ± 2,1	0,07	0,06	0,07
	12	2,4 ± 0,1	4,5 ± 0,1	7,2 ± 0,2	37,7 ± 0,6	67, 3 ± 0,6	110,0 ± 2,6	0,06	0,07	0,06
	13	2,8 ± 0,1	4,7 ± 0,4	8,1 ± 0,1	42,3 ± 1,2	75,7 ± 0,6	123,0 ± 1,0	0,07	0,06	0,06
	14	3,1 ± 0,1	5,3 ± 0,2	9 ± 0,2	47,3 ± 1,2	84,7 ± 0,6	138,3 ± 3,1	0,07	0,06	0,06
1.0	10	1,9 ± 0,1	3,3 ± 0,1	5,5 ± 0,3	29,7 ± 1,2	52,3 ± 0,6	84,0 ± 3,6	0,06	0,06	0,06
	11	2,2 ± 0,1	3,9 ± 0,1	6,5 ± 0,2	33,7 ± 0,6	60,3 ± 0,6	98,7 ± 2,1	0,07	0,06	0,07
	12	2,4 ± 0,1	4,5 ± 0,2	7,2 ± 0,3	37,7 ± 0,6	67,0 ± 1,0	110,0 ± 2,6	0,06	0,07	0,06
	13	2,8 ± 0,1	4,7 ± 0,3	8 ± 0,2	41,7 ± 1,2	75,7 ± 0,6	123,0 ± 1,0	0,07	0,06	0,06
	14	3,1 ± 0,1	5,3 ± 0,2	9 ± 0,2	47,3 ± 1,2	84,7 ± 0,6	138,7 ± 3,5	0,07	0,06	0,06
1.2	10	1,9 ± 0,1	3,3 ± 0,1	5,7 ± 0,1	29,3 ± 0,6	52,0 ± 0,0	86,3 ± 1,5	0,06	0,06	0,06
	11	2,2 ± 0	3,9 ± 0,2	6,4 ± 0,2	33,7 ± 0,6	60,0 ± 0,0	98,3 ± 1,5	0,07	0,07	0,07
	12	2,5 ± 0,1	4,5 ± 0,1	7,2 ± 0,1	37,7 ± 0,6	66,7 ± 0,6	109,3 ± 2,9	0,07	0,07	0,06
	13	2,8 ± 0,1	4,7 ± 0,4	8 ± 0,1	42,7 ± 0,6	75, 0 ± 0,0	123,3 ± 1,2	0,07	0,06	0,06
	14	3,1 ± 0,1	5,3 ± 0,2	9,1 ± 0,2	47,7 ± 0,6	84,0 ± 0,0	138,7 ± 3,2	0,06	0,06	0,06
1.49	10	1,9 ± 0	3,3 ± 0,2	5,6 ± 0,1	29,3 ± 0,6	52,7 ± 0,6	86,3 ± 1,5	0,06	0,06	0,06
	11	2,2 ± 0	3,9 ± 0,1	6,3 ± 0,3	33,7 ± 0,6	60,7 ± 0,6	98,0 ± 1,7	0,07	0,06	0,07
	12	2,5 ± 0	4,5 ± 0,2	7,3 ± 0,2	37,7 ± 0,6	67,7 ± 0,6	110,3 ± 2,9	0,07	0,07	0,06
	13	2,7 ± 0	4,7 ± 0,4	8,1 ± 0,1	42,3 ± 0,6	75,7 ± 0,6	123,3 ± 0,6	0,06	0,06	0,06
	14	3,1 ± 0,1	5,4 ± 0,3	8,9 ± 0,4	47,3 ± 1,2	85,3 ± 1,2	135,7 ± 6,8	0,07	0,06	0,06

Increasing the pitch value at a fixed DRI will increase the noise value. Automatic current modulation determines noise [15]. The noise level value in the first phantom is in the range of 2.1-3.1, the noise level in the second phantom is in the range of 3.2-4.1, and the noise level in the third phantom is in the range of 3.7-5. The noise level with the automatic current selection in each phantom is relatively constant according to Philips conditions as shown in Table 8.

The relationship between noise level and phantom size in Fig. 4 shows that phantom size affects noise level. The larger the phantom size, the higher the noise level value [14]. Increasing the DRI value for each phantom will decrease the noise level value. The average value of noise level in the first phantom is 2.6 %, the second phantom is 3.6 %, and the third phantom is 4.3 %.

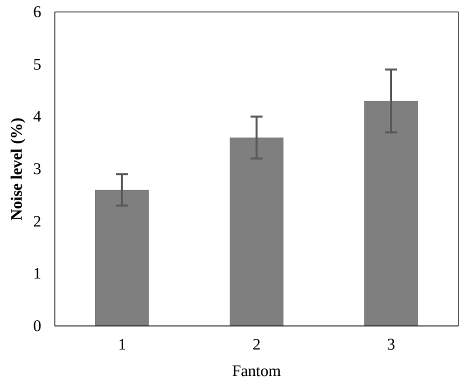

Fig. 4. Noise level (%) vs phantom sizes 1, 2, and 3, at an exposure factor of 120 kVp

Previous research by Papadakis et al. [5] was a study using standard phantom dosimetry to assess the characterization of the function of the ATCM technique using two configurations of phantom. The standard CTDI phantom is used by medical physicists to evaluate the performance of TCM operasional characteristics.

Table 8. $CTDI_{vol}$ values and phantom noise levels 1, 2, and 3 with variations in pitch and DRI on 120 kVp tube voltage.

Pitch	DRI	$CTDI_{vol}$			Noise level		
		Phantom 1 d =23.2 cm	Phantom 2 d = 28.3 cm	Phantom 3 d = 33.3 cm	Phantom 1 d =23.2 cm	Phantom 2 d = 28.3 cm	Phantom 3 d = 33.3 cm
0.6	10	1,9 ± 0,0	3,2 ± 0,2	5,6 ± 0,0	2,7 ± 0,2	3,5 ± 0,3	4,0 ± 0,8
	11	2,2 ± 0,0	3,7 ± 0,2	6,4 ± 0,2	2,6 ± 0,1	3,4 ± 0,6	4,0 ± 0,4
	12	2,5 ± 0,1	4,1 ± 0,2	7,2 ± 0,2	2,5 ± 0,1	3,2 ± 0,3	3,9 ± 0,3
	13	2,7 ± 0,1	4,6 ± 0,3	8,1 ± 0,1	2,4 ± 0,1	3,3 ± 0,2	4,0 ± 0,6
	14	3,1 ± 0,1	5,1 ± 0,2	9,0 ± 0,3	2,2 ± 0,1	3,3 ± 0,5	3,7 ± 0,6
0.8	10	1,9 ± 0,1	3,3 ± 0,2	5,7 ± 0,2	2,8 ± 0,1	3,5 ± 0,5	4,3 ± 0,8
	11	2,2 ± 0,1	3,8 ± 0,1	6,5 ± 0,2	2,7 ± 0,1	3,7 ± 0,4	4,2 ± 0,7
	12	2,4 ± 0,1	4,2 ± 0,1	7,2 ± 0,2	2,6 ± 0,1	3,6 ± 0,2	4,5 ± 0,5
	13	2,8 ± 0,1	4,7 ± 0,4	8,1 ± 0,1	2,4 ± 0,1	3,5 ± 0,2	4,0 ± 0,3
	14	3,1 ± 0,1	5,3 ± 0,2	9,0 ± 0,2	2,3 ± 0,1	3,2 ± 0,7	3,7 ± 0,4
1.0	10	1,9 ± 0,1	3,2 ± 0,1	5,5 ± 0,3	2,9 ± 0, 0	4,1 ± 0,2	4,4 ± 0,8
	11	2,2 ± 0,1	3,7 ± 0,1	6,5 ± 0,2	2,8 ± 0,1	3,7 ± 0,6	4,6 ± 0,2
	12	2,4 ± 0,1	4,1 ± 0,2	7,2 ± 0,3	2,6 ± 0,1	3,6 ± 0,3	4,8 ± 0,6
	13	2,8 ± 0,1	4,6 ± 0,3	8,0 ± 0,2	2,4 ± 0,0	4,0 ± 0,4	4,3 ± 0,4
	14	3,1 ± 0,1	5,2 ± 0,2	9,0 ± 0,2	2,3 ± 0,2	3,4 ± 0,3	4,1 ± 0,7
1.2	10	1,9 ± 0,1	3,3 ± 0,1	5,7 ± 0,1	3,1 ± 0,2	3,9 ± 0,6	4,7 ± 0,6
	11	2,2 ± 0,0	3,8 ± 0,2	6,4 ± 0,2	2,8 ± 0,1	3,5 ± 0,5	4,5 ± 0,3
	12	2,5 ± 0,1	4,2 ± 0,1	7,2 ± 0,1	2,5 ± 0,1	3,8 ± 0,6	5,0 ± 0,9
	13	2,8 ± 0,1	4,7 ± 0,4	8,0 ± 0,1	2,4 ± 0,1	3,8 ± 0,3	4,3 ± 0,6
	14	3,1 ± 0,1	5,3 ± 0,2	9,1 ± 0,2	2,4 ± 0,1	3,2 ± 0,7	3,9 ± 0,2
1.49	10	1,9 ± 0,0	3,2 ± 0,2	5,6 ± 0,1	2,9 ± 0,1	3,9 ± 0,6	4,7 ± 0,8
	11	2,2 ± 0,0	3,7 ± 0,1	6,3 ± 0,3	2,8 ± 0,2	3,6 ± 0,7	4,4 ± 0,8
	12	2,5 ± 0,0	4,1 ± 0,2	7,3 ± 0,2	2,6 ± 0,0	3,6 ± 0,2	4,7 ± 0,6
	13	2,7 ± 0,0	4,6 ± 0,4	8,1 ± 0,1	2,4 ± 0,1	3,7 ± 0,4	4,4 ± 0,5
	14	3,1 ± 0,1	5,2 ± 0,3	8,9 ± 0,4	2,1 ± 0,1	3,4 ± 0,1	4,1 ± 0,5

CONCLUSION

This study demonstrates that noise level is influenced by object size. Therefore, size information of the object could be useful to predict the change of tube current and pitch due to ATCM with respect to selected DRI. The information stated by the manufacturer has been validated with the exception of DRI change from 10-11 which yielded relatively higher tube current change. The $CTDI_{vol}$/mAs depends only on phantom size. For Ingenuity 128 Philips used in this study, the $CTDI_{vol}$/mAs constantly ranges between 0,06-0,07. The value could serve as a characteristic parameter for quality assurance. The ATCM specifications of the Ingenuity 128 CT scanner is according to Philips regulations.

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AUTHOR CONTRIBUTION

A. Taopik is the main contributor of this paper and work. L. E. Lubis, D. S. K. Sihono, and D. S. Soejoko performed scientific and substantial review on the manuscript prior to submission. All authors read and approved the final version of the paper.

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