CHAPTER 4

RESULTS

Three major studies were performed. First, the patient data collection using routine head protocol, second the study of the performance of the equipment to evaluate the 16-multislice computed tomography system then the water phantom study was performed to create the exposure table, and the third was the assessment of radiation dose and image quality using the exposure table to the second group of patients.

4.1 Patient data and scanning parameters

31 children aged 1-12 years old who were requested non-contrast-enhanced CT brain examinations and assigned to be before study groups. The results were shown in table 4.1

Table 4.1 Patient characteristics and scanning parameters of 31 pediatric CT head.(Pre-Protocol)

Parameters	**Body weight (Kg)**			
	< 10	11-20	21-30	31-40
Number (*n*) of patient	10	10	6	5
Weight (Kg) Average / range	6.3 (1.8-10)	13.7 (10.5-17)	25.3 (21.8-30)	33.8 (31-37)
Height (cm) Average / range	97.7 (70-120)	109.4 (75-130)	124.9 (87-151)	142.4 (124-153)
Head AP diameter (cm) Average / range	13.9 (8.9-17.8)	16.1 (13.8-17.8)	17.5 (17.2-17.7)	18.3 (16.6-19.8)
kVp	120	120	120	120
mAs Average / range	116.2 (96-150)	125.9 (112-144)	209 (114-320)	320
Kernel(algorithm)	c30s	c30s	c30s	H40s
$CTDI_{vol}$ (mGy) Average / range	22.4 (16.8-28.8)	23.7 (21.5-26.9)	25.8 (22.1-28.2)	53.7
DLP (mGy.cm) Average / range	281.4 (178-540)	297 (194-392)	337.9 (317-359)	323
Noise(HU) Average / range	4.5 (3.3-5.6)	3.9 (3.4-4.7)	3.5 (3.2-3.7)	2.3 (2.1-2.5)

4. 2 The water phantom study

The 9.15, 11.15, 13.15, and 15.8 cm actual diameters of water phantom study to mimic pediatric head of 4 groups were related to four groups of patient of different head sizes. In the phantom study, the $CTDI_{vol}$ increased when kVp and mAs increased, but not change with the phantom diameters. The image noise decreased with the increasing kVp and mAs as table 4.2 and figure 4.1 (a), 4.1 (b)

Table 4.2 The effects of increasing kVp and mAs on $CTDI_{vol}$ and noise using 9.15 cm diameter head phantom.

mAs	**80 kVp**		**100 kVp**		**120 kVp**	
	$CTDI_{vol}$ (mGy)	Noise (HU)	$CTDI_{vol}$ (mGy)	Noise (HU)	$CTDI_{vol}$ (mGy)	Noise (HU)
50	3.35	11.5	5.6	8.2	8.4	6.5
100	6.7	8.5	11.2	6.5	16.8	5
150	10.1	4.4	16.8	4.1	25.2	3.6
200	13.4	4.1	22	3.3	33.6	2.6
300	20.1	3.6	33.6	2.2	50.4	2.1

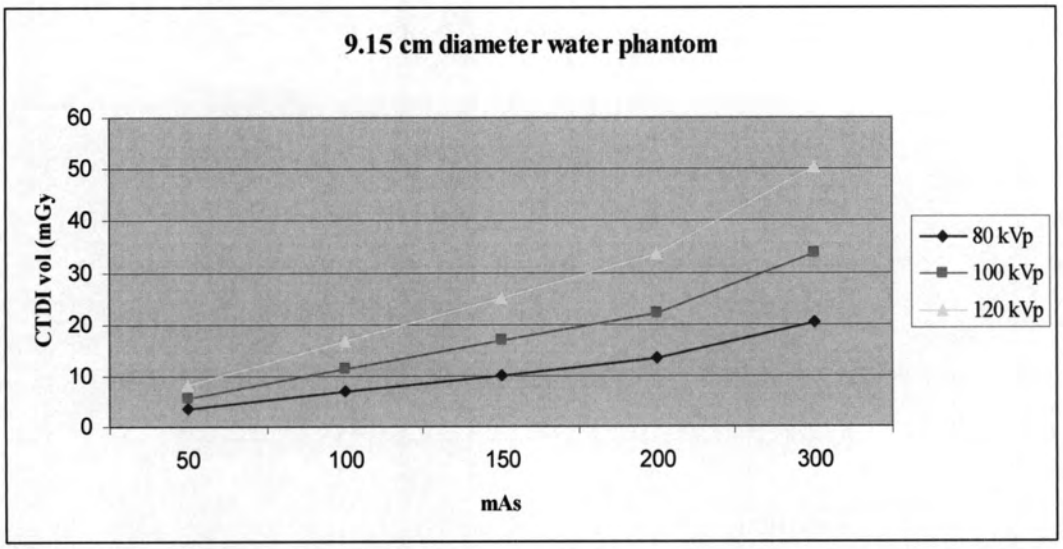

Figure 4.1 (a) The relationship between $CTDI_{vol}$ and mAs on different kVp for 9.15 cm diameter water phantom.

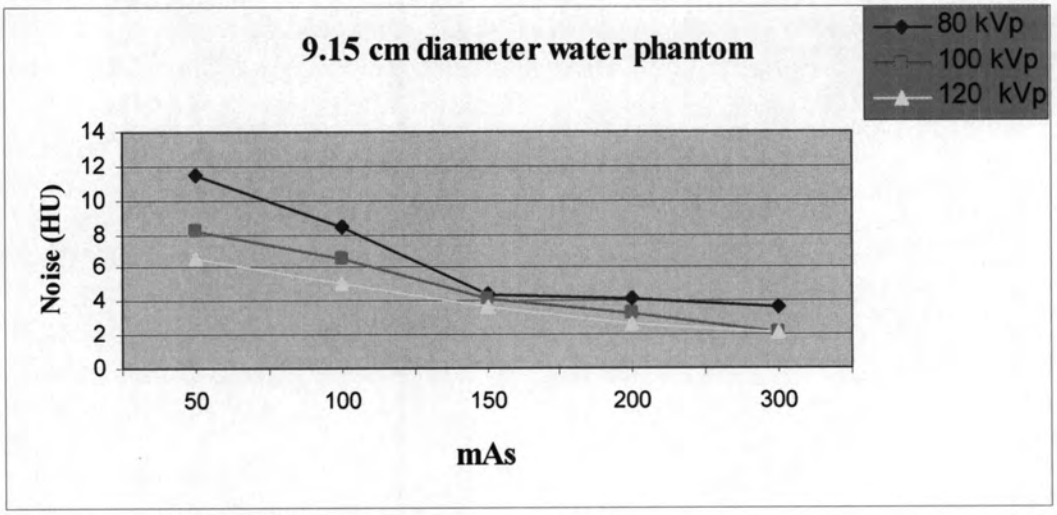

Figure 4.1(b) The relationship between noise and mAs on different kVp for 9.15 cm diameter water phantom.

Table 4.3 The effects of increasing kVp and mAs on CTDI $_{vol}$ and noise using 11.15 cm diameter head phantom.

mAs	80 kVp		100 kVp		120 kVp	
	CTDI $_{vol}$ (mGy)	Noise (HU)	CTDI $_{vol}$ (mGy)	Noise (HU)	CTDI $_{vol}$ (mGy)	Noise (HU)
50	3.35	3.5	5.6	2.5	8.4	2.1
100	6.7	2.4	11.2	1.9	16.8	1.6
150	10.03	2.2	16.8	1.5	25.2	1.5
200	13.4	1.9	22.4	1.3	33.6	1.2
300	20.1	1.5	33.6	1.2	50.4	1

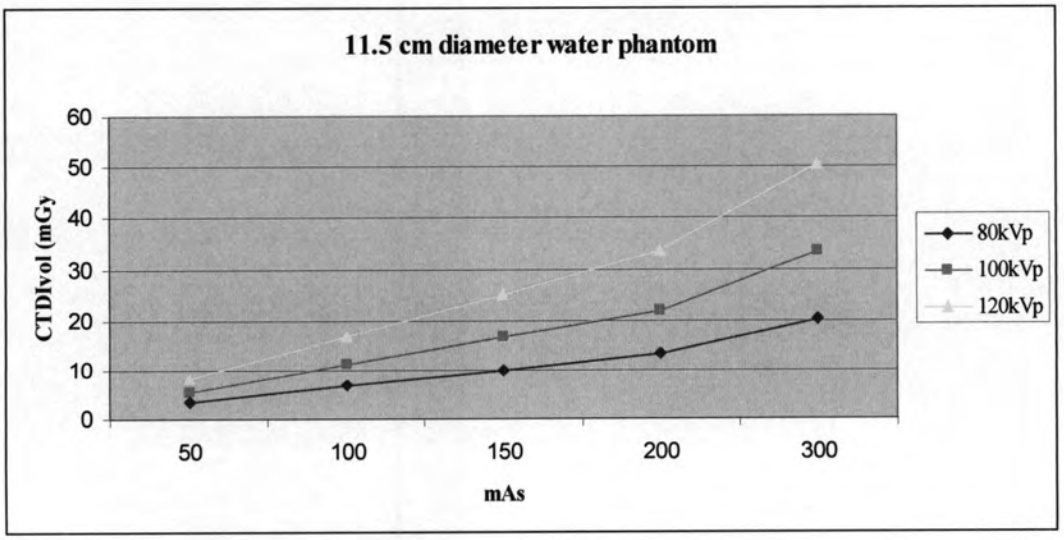

Figure 4.2 (a) The relationship between CTDI$_{vol}$ and mAs on different kVp for 11.15 cm diameter water phantom.

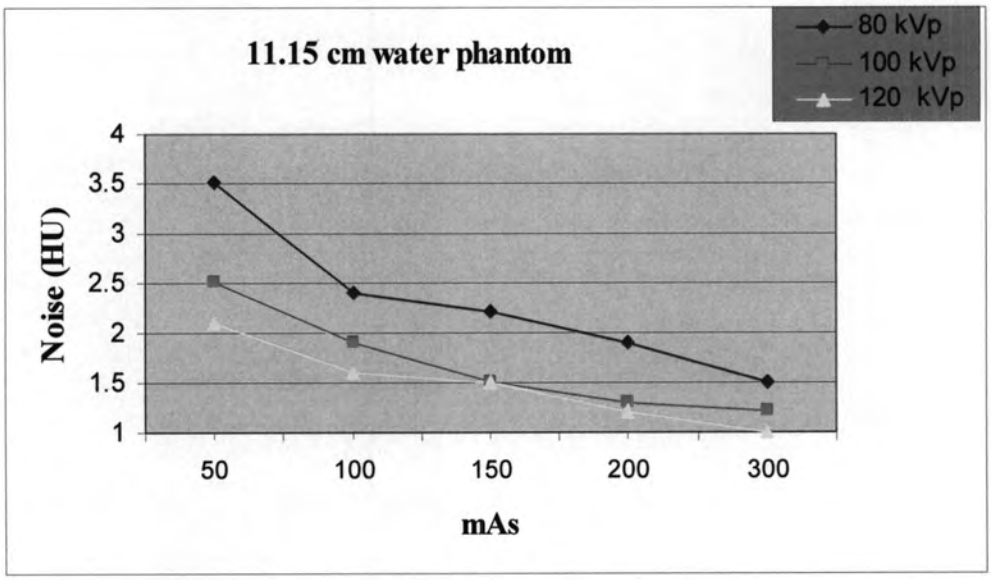

Figure 4.2 (b) The relationship between noise and mAs on different kVp for 11.15 cm diameter water phantom.

Table 4.4 The effects of kVp and mAs on $CTDI_{vol}$ and noise using 13.15 cm diameter head phantom

mAs	**80 kVp**		**100 kVp**		**120 kVp**	
	$CTDI_{vol}$ (mGy)	Noise (HU)	$CTDI_{vol}$ (mGy)	Noise (HU)	$CTDI_{vol}$ (mGy)	Noise (HU)
50	3.35	5.2	5.6	3.5	8.4	3.2
100	6.7	3.7	11.2	2.6	16.6	2.3
150	10.05	3.3	16.8	2.2	25.2	2
200	13.4	2.8	22.4	2	33.6	1.7
300	20.1	2.2	33.6	1.8	50.4	1.4

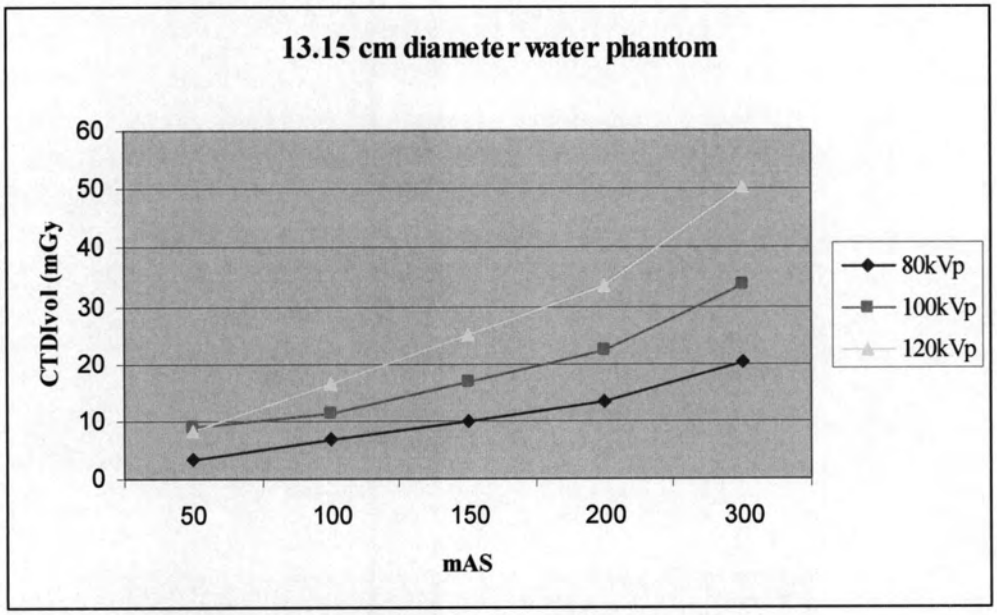

Figure 4. 3 (a) The relationship between CTDI $_{vol}$ and mAs on different kVp for 13.15 cm diameter water phantom.

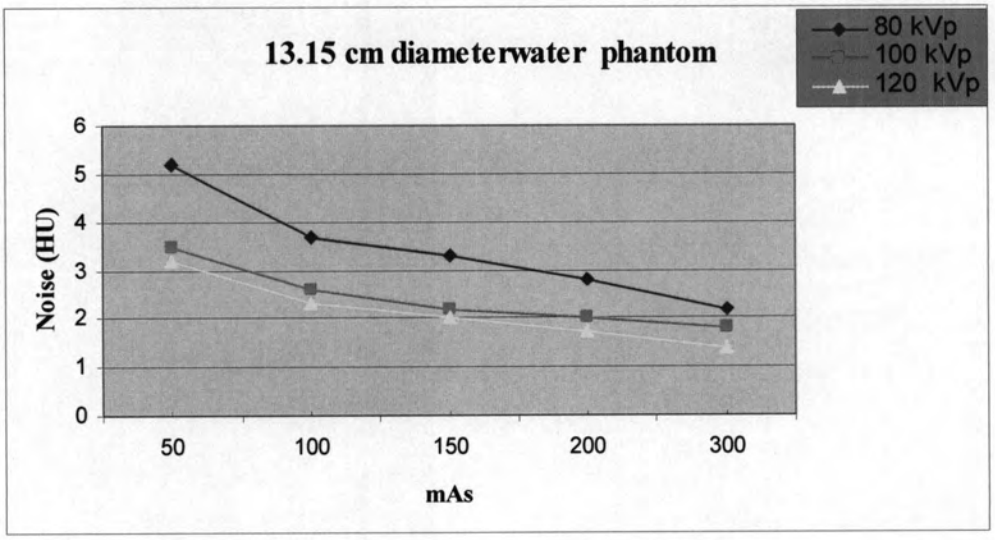

Figure 4.3 (b) The relationship between noise and mAs on different kVp for13.15 cm diameter water phantom.

Table 4.5 The effects of kVp and mAs on $CTDI_{vol}$ and noise using 15.8 cm diameter head phantom.

mAs	80 kVp		100 kVp		120 kVp	
	$CTDI_{vol}$ (mGy)	Noise (HU)	$CTDI_{vol}$ (mGy)	Noise (HU)	$CTDI_{vol}$ (mGy)	Noise (HU)
50	3.35	3.6	5.6	2.6	8.4	2.1
100	6.7	2.8	11.2	2.2	16.8	1.8
150	10.1	2.2	16.8	1.6	25.2	1.4
200	13.4	2	22	1.4	33.6	1.2
300	20.1	1.7	33.6	1.3	50.4	1

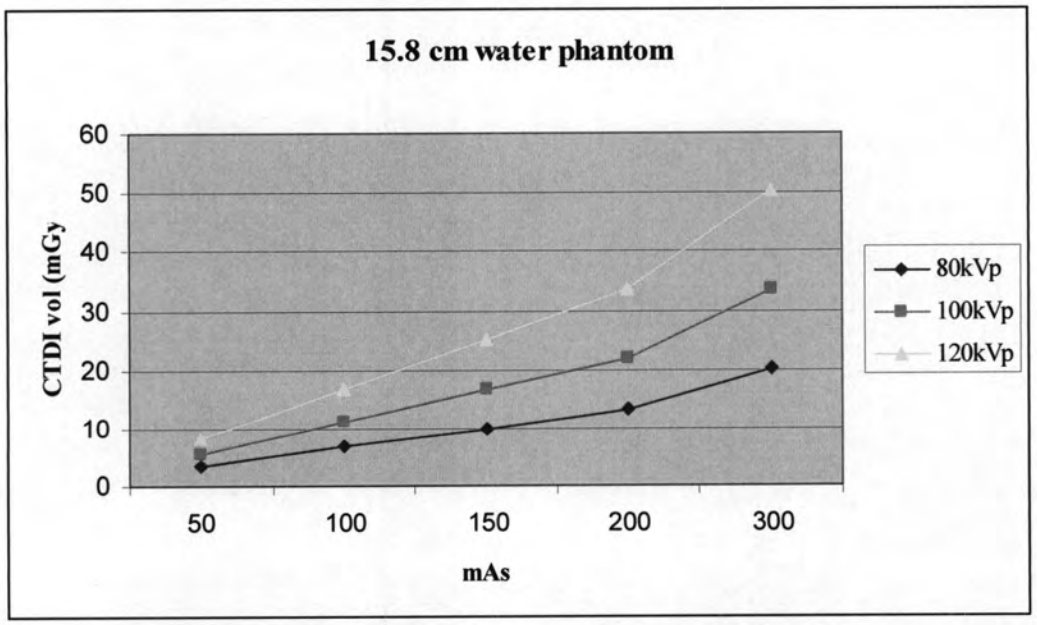

Figure 4.4 (a) The relationship between $CTDI_{vol}$ and mAs on different kVp for 15.8 cm diameter water phantom.

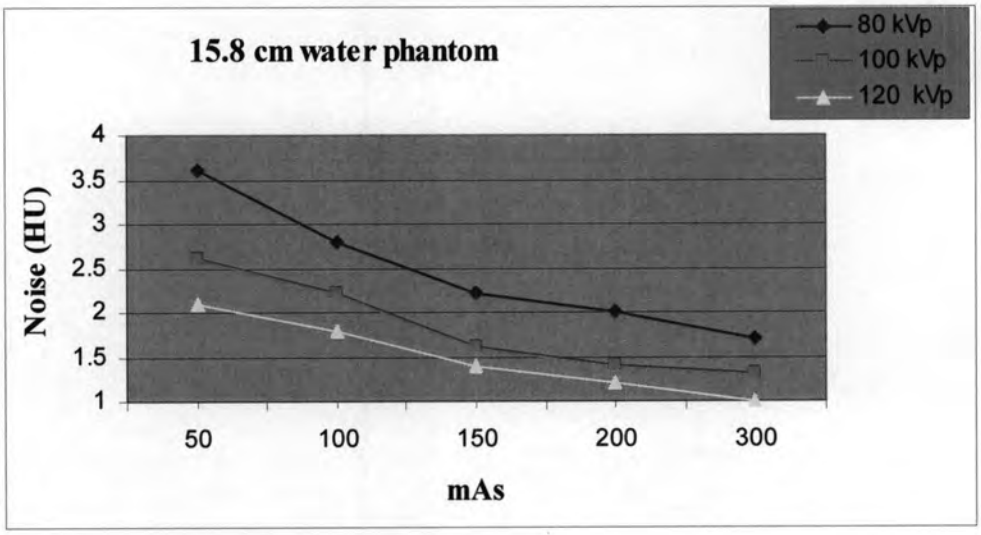

Figure 4.4 (b) The relationship between noise and mAs on different kVp for 15.8 cm diameter water phantom.

The reduction of the tube-current (mAs)

The result of 9.15, 11.15, 13.15, and 15.8 cm diameter water phantom study using 120 kVp, 1sec, 10 mm slice thickness, and reduced mAs 10%(135 mAs),20% (120 mAs), 30%(105 mAs) and 40% (90mAs) from routine pediatric brain protocol (150 mAs) was shown in Table 4.6 The image noise was found to increase from 7-30% for 9.15 cm diameter phantom, 6.6-33.3% for 11.15 cm phantom, 12.5-50% for 13.15 cm diameter phantom and 8.6-39.1% for 15.8 cm diameter phantom (in figure 4.5) in each actual AP diameter water head phantom. The result are illustrated in table 4.6 The $CTDI_{vol}$ decreased from 10.3-40.1% and DLP decreased from 9.9 – 40.1% for all phantom sizes. At 20 % mAs reduction, $CTDI_{vol}$ was about 19.8% reduction. This relationship was used for small children of less than 10 years old.

Table 4.6 The effect of mAs reduction of 10, 20, 30 and 40% from routine protocol for $CTDI_{vol}$, DLP and noise.

mAs	water head phantom diameter (cm)											
	9.15			11.15			13.15			15.8		
	$CTDI_{vol}$ (mGy)	DLP (mGy.cm)	Noise (HU)	$CTDI_{vol}$ (mGy)	DLP (mGy.cm)	Noise (HU)	$CTDI_{vol}$ (mGy)	DLP mGy.cm	Noise (HU)	$CTDI_{vol}$ (mGy)	DLP mGy.cm	Noise (HU)
150	25.2	252	1.3	25.2	252	1.5	25.2	252	1.6	25.2	252	2.3
135 (-10%)	22.6 -10.35%	227 (9.9 %)	1.4 (7.7%)	22.6	227	1.6 6.6%	22.6	227	1.8 12.5%	22.6	227	2.5 8.69%
120 (-20%)	20.8 -17.46%	202 (19.8 %)	1.5 (15.4%)	20.8	202	1.7 13.3%	20.8	202	2.0 25%	20.8	202	2.7 17.4%
105 (-30%)	17.6 -30.16%	176 (30.15 %)	1.6 (23.1%)	17.6	176	1.8 25%	17.6	176	2.2 37.5%	17.6	176	2.9 26.1%
90 (-40%)	15.1 (-40 %)	151 (40.1 %)	1.7 30.76%	15.1	151	2.0 33.3%	15.1	151	2.4 50%	15.1	151	3.2 39.1%

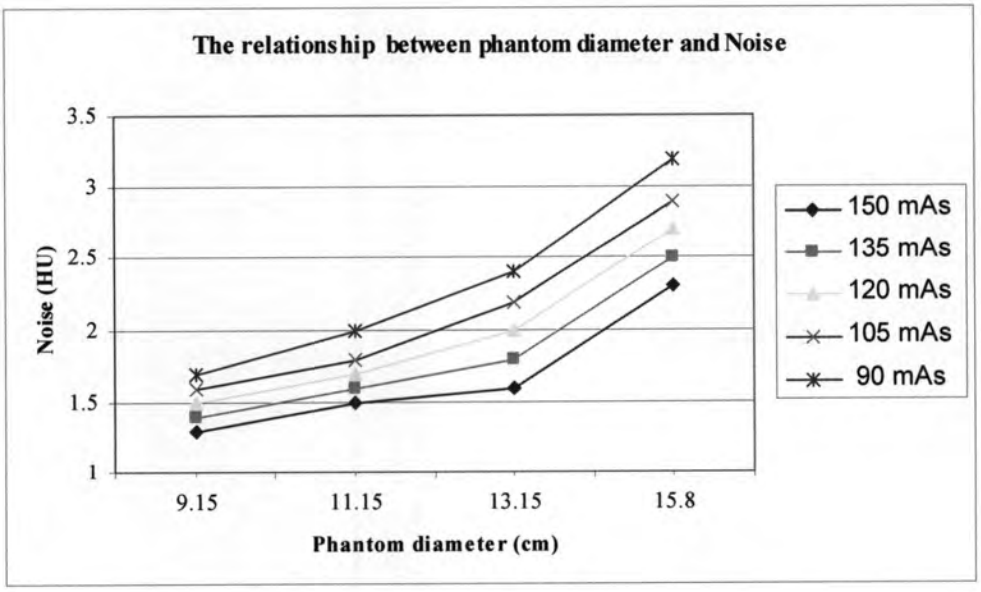

Figure 4.5 The relationship between noise and phantom diameter on reduced mAs 10% (135 mAs), 20% (120 mAs), 30% (105 mAs), and 40%(90 mAs) from routine head protocol

Table 4.7 New Exposure Table

Body weight (Kg)	Average AP diameter (cm)	kVp	Old mAs	New mAs	Percentage Change %
<10	14	120	115	90	-21
11-20	16.1	120	125	100	-20
21-30	17.5	120	210	140	-33
31-40	18.3	120	250	160	-36

4.3 16-Multislice Computed Tomography calibration

The calibration of 16-Multislice Computed Tomography (MSCT) is important for accurate signal response as all acquired images. The QC results were in the acceptable range (Shown in Appendix B)

4.4 Correlation between patient body weight and mAs

In routine study of the head scan, the mAs was chosen according to the body weight(kg). There is a significant correlation (r^2 = 0.69) between body weight and tube current time. However, there is a large variation in individual technician operator, for patients from 30 to 40 kg body weight. (as shown in figure 4.6)

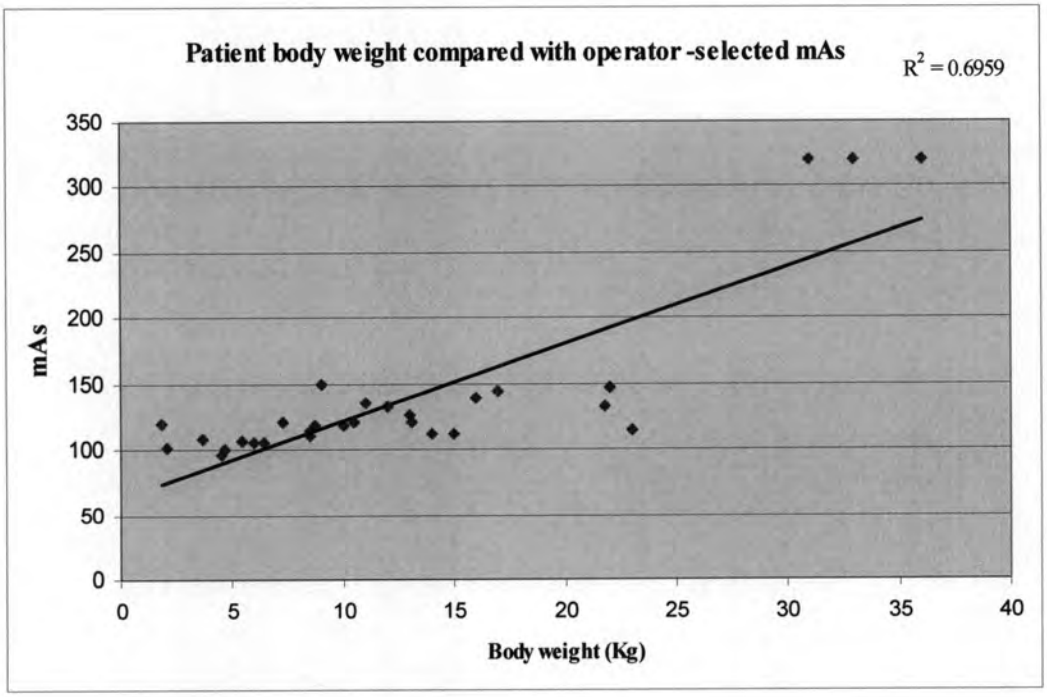

Figure 4.6 Patient body weight and mAs

In order to get the patient dose reduction and the acceptable image noise the exposure table is set up according to the body weight in relation to the head AP diameter (cm). The tube current was reduced from 20-36% and the noise increase from 20–46.9% as in table 4.8

Table 4.8 The result on the application of new exposure table according to reduced mAs in comparison to the result from routine protocol.

Body weight (Kg)	mAs			$CTDI_{vol}$ (mGy)			DLP (mGy.cm)			Noise (HU)		
	Routine	New protocol	% Difference	Routine	New protocol	% Difference	Routine	New protocol	% Difference	Routine	New protocol	% Difference
<10	115	90	-21.7	22.4	10.4	-53.7	281	187	-33	4.2	5.2	20.9
11-20	125	100	-20	23.7	18.7	-21	297	218	-26	4	4.8	20
21-30	210	140	-33.3	25.8	22.05	-14.5	337	224	-33	3.8	5.1	34.2
31-40	250	160	-36	53.7	23.2	-56.7	323	245	-24	3.2	4.7	46.9

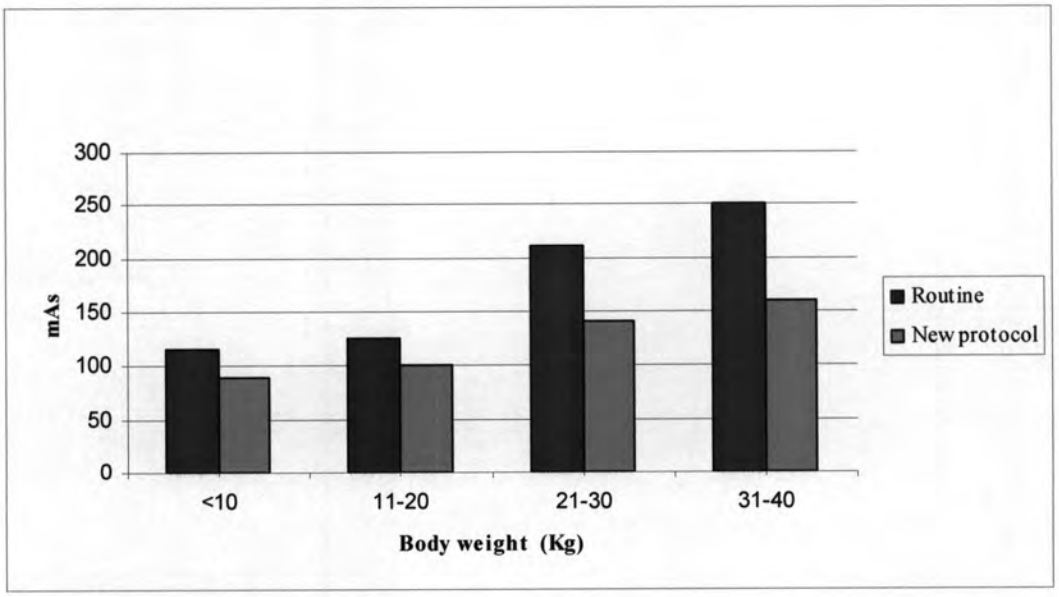

Figure 4.7 Correlation between mAs and body weight routine and after application of exposure table

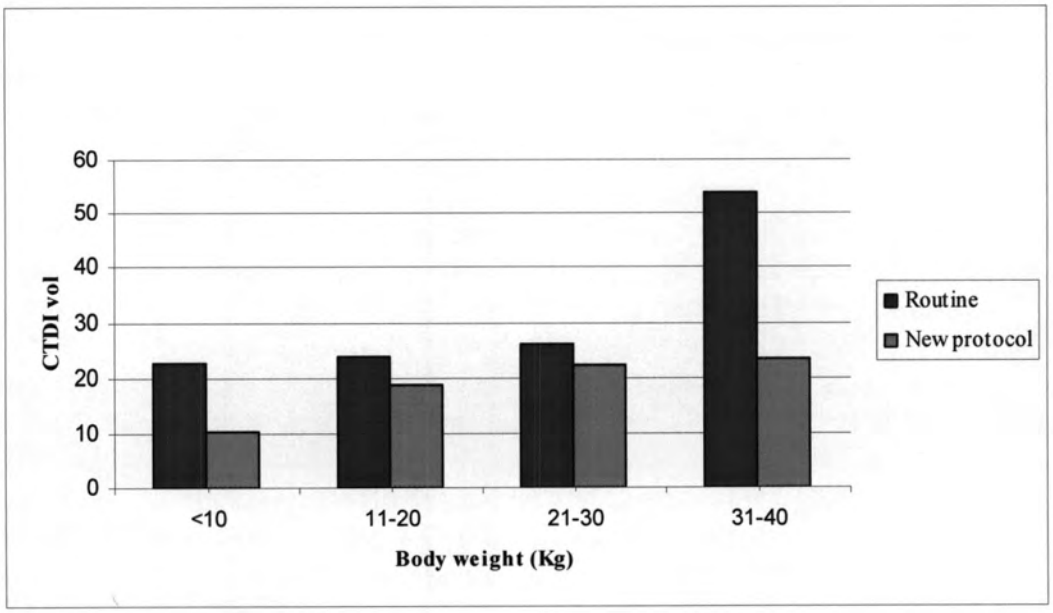

Figure 4.8 Correlation between $CTDI_{vol}$ and body weight for routine and after application exposure table

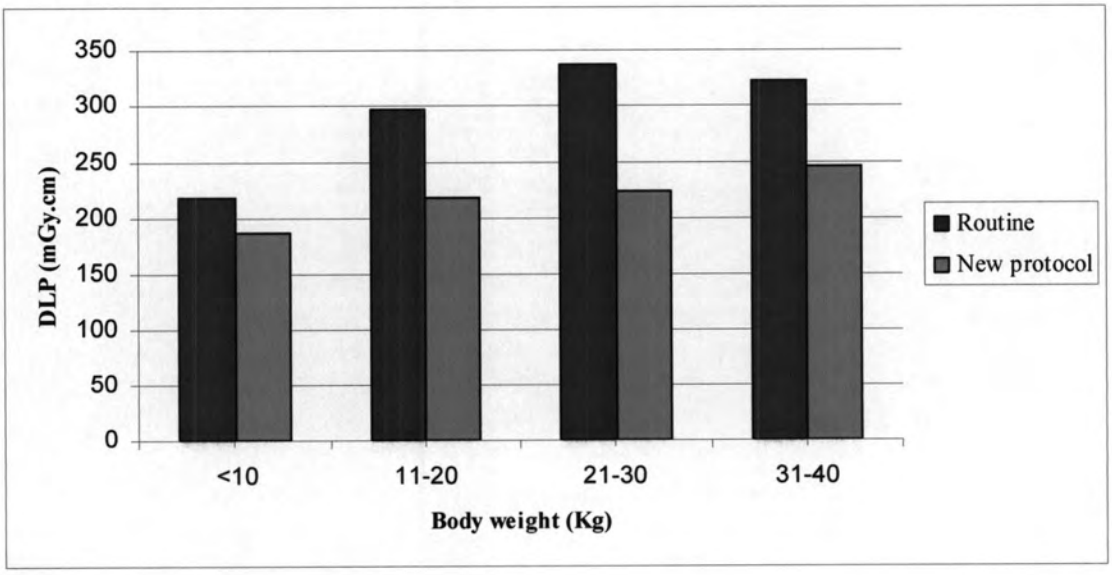

Figure 4.9 Correlation between DLP and body weight routine and after application of exposure table

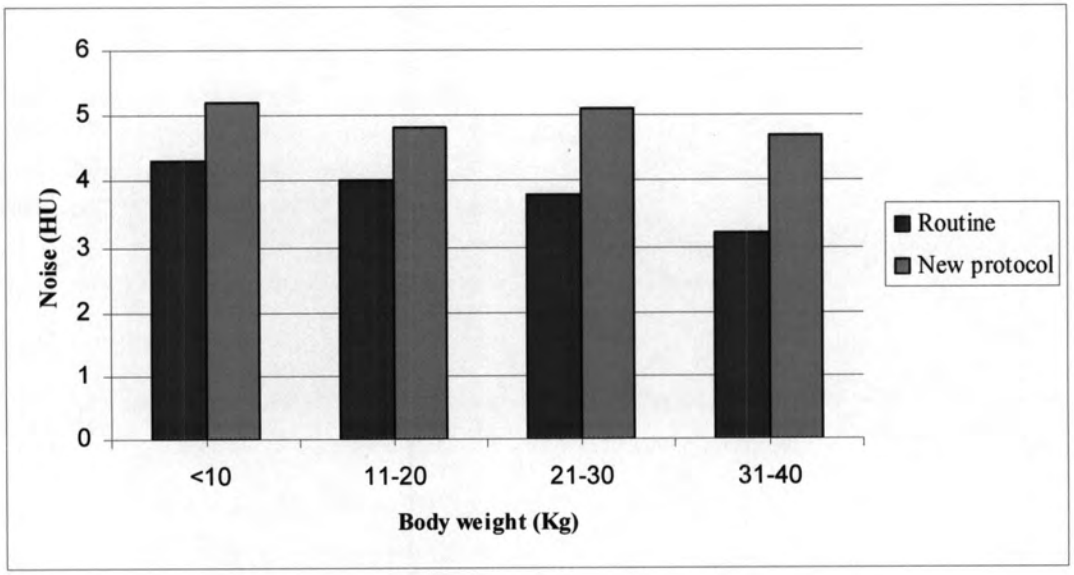

Figure 4.10 Correlation between noise and body weight for routine and application of exposure table

4.5 The results of patient dose and image quality

Evaluation the image quality by radiologists using the European Commissioning (EC) image quality criteria guideline as shown in table 4.9 and result is shown in table 4.10

Table 4.9 Scoring criteria

Score	Overall quality
1	Non-acceptable
2	Poor
3	Acceptable
4	Good
5	Excellent

Table 4.10 Grading of image quality by 2 radiologists according to table 4.9 for 2 groups of 62 patients

Score on Image quality	Radiologist No. 1		Radiologist No. 2	
	Pre protocol group ($n = 31$)	Post protocol group ($n = 31$)	Pre protocol group ($n = 31$)	Post protocol group ($n = 31$)
1	0	0	0	0
2	0	0	0	0
3	4	15	1	13
4	22	12	21	13
5	5	4	9	5
Mean score	4.03	3.64	4.25	3.74

Table 4.11 Result of grading of image quality according to table 4.10 for 2 groups of 62 patient.

	Radiologist No. 1		Radiologist No. 2	
	Pre protocol	Post protocol	Pre protocol	Post protocol
	Lower	Upper	Lower	Upper
95% CI of the difference	0.6490	0.70929	.19492	.83734
P-value using *t* - test	0.002		0.19	

4.6 Agreement Test

31 Pediatric patients were scored by 2 senior pediatric radiologist to compare the agreement between pre-protocol group and control or study group, using agreement test - weighted Kappa-test. The result of agreement of image quality was fair (Kappa coefficient = 0.305), good (Kappa coefficient = 0.611) for pre protocol group and study group. (Shown in table 4.13 – 4.16)

Agreement is quantified by the Kappa statistic (Cohen, 1960)
K = 1, when there is perfect agreement between the classification system.
K = 0, when there is no agreement better than chance.

Table 4.12 The Kappa – test value (K) and the strength of agreement.

Value of K	Strength of agreement
< 0.20	Poor
0.21 - 0.40	Fair
0.41 – 0.60	Moderate
0.61 – 0.80	Good
0.81 – 1.00	Excellent

Table 4.13 Cross tabulation of image quality for pediatric brain MSCT routine group.

		Radiologist No. 1					Total
		Non acceptable	Poor	Acceptable	Good	Excellent	
Radiologist No. 2	Non acceptable	0	0	0	0	0	0
	Poor	0	0	0	0	0	0
	Acceptable	0	0	1	3	0	4
	Good	0	0	0	16	6	22
	Excellent	0	0	0	2	3	5
	Total	0	0	1	21	9	31

Table 4.14 Agreement of Radiologist No.1 and Radiologist No. 2 for brain MSCT image quality of routine group.

	Weighted Kappa	Level of agreement
Image quality	0.305	Fair

Table 4.15 Cross tabulation of image quality for pediatric brain MSCT study group.

		Radiologist No. 1					Total
		Non acceptable	Poor	Acceptable	Good	Excellent	
Radiologist No. 2	Non acceptable	0	0	0	0	0	0
	Poor	0	0	0	0	0	0
	Acceptable	0	0	11	4	0	15
	Good	0	0	2	8	2	12
	Excellent	0	0	0	1	3	4
	Total	0	0	13	13	5	31

Table 4.16 Agreement of Radiologist No.1 and Radiologist No. 2 for brain MSCT image quality of study group.

	Weighted Kappa	Level of agreement
Image quality	0.611	Good