Patient radiation dose from computed tomography angiography and digital subtraction angiography of the brain

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Abstract. The 64-row multidetector computed tomography angiography (64-MDCTA) provides vascular image quality of the brain similar to digital subtraction angiography (DSA), but the effective dose of CTA is lower than DSA studied in phantom. The purpose of this study is to evaluate the effective dose from 64-MDCTA and DSA. Effective dose (according to ICRP 103) from 64-MDCTA and DSA flat panel detector for cerebral vessels examination of the brain using standard protocols as recommended by the manufacturer was calculated for 30 cases of MDCTA (15 male and 15 female).The mean patient age was 49.5 (23–89) yrs. 30 cases of DSA (14 male and 16 female), the mean patient age was 46.8 (21–81) yrs. For CTA, the mean effective dose was 3.7 (2.82- 5.19) mSv. For DSA, the mean effective dose was 5.78 (3.3-10.06) mSv. The effective dose of CTA depends on the scanning protocol and scan length. Low tube current can reduce patient dose whereas the number of exposures and number of series in 3D rotational angiography (3D RA) resulted in increasing effective dose in DSA patients.

1. Introduction

Cerebrovascular disorders can create the clinical problem to the brain. The most common types are Stroke, Aneurysm and Arteriovenous malformations (AVMs). Computed Tomographic Angiography (CTA), Magnetic Resonance Angiography (MRA) and Digital Subtraction Angiography (DSA) are procedures used to diagnose the diseases.

MDCT provides similar diagnostic information of cervicocranial vasculature as compared to DSA. The DSA should be considered primarily when peripheral vessels or ICA segments close to the skull base [1]. However, the previous study showed that effective dose in phantom with CTA examinations for the cerebral vessels yields 5 times lower than the same examination performed by DSA [2].

Biological effects of radiation can be grouped as stochastic and deterministic effects. The stochastic effect depends on the probability rather than its severity and it increases with dose. Radiation-induced cancer and genetic effects are stochastic [3].

The effective dose, absorbed and organ doses are important for the procedures that either involve high doses or include sensitive tissues in the primary radiation beam. Effective dose provides an approximate indicator of potential detriment from ionizing radiation and should be used as one parameter in evaluating the appropriateness of examinations involving ionizing radiation [4].

The purpose of this study is to evaluate the patient effective dose from CTA and DSA performed in the cerebrovascular region of the brain.

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2. Materials and methods

2.1. Imaging equipment and protocols
CTA was performed by using a 64-row MDCT (Somatom Definition 64; Siemens, Erlangen, Germany). For DSA, a biplane angiography equipment (Axiom Artis Flat panel biplane; Siemens, Erlangen, Germany) was used. The optimized protocols of the CTA and DSA for cerebral vessels had been employed in our department as a routine procedure. Table 1 and 2 provide the parameters of the protocol for CTA and DSA examinations, respectively.

Table 1. Parameters for CTA examination.

Scanning parameters	kVp	mAs	pitch
Topogram	120	35	
Control scan	120	381/450	
Non-Contrast	120	332/450	0.55
Pre-monitoring	120	20	
Monitoring	120	20	
Head Angiogram	100	125/175	1.4
Post contrast	100	125/175	1.4
Rotation time (sec)	1.0 s		
Slice Acquisition (mm)	64×0.6		
Slice collimation (mm)	0.6		

Note: CTA of the brain scan from Common carotid artery bifurcation (C-4) to the vertex.

Table 2. Parameters for DSA examination.

Parameters	2D mode	3D RA mode
kVp	77	70
Pulse width (ms)	40	12.5
kVp filter	81	OFF
kVp mask	96	
Dose (μGy/pulse)	3.6	0.36
Phase 1	4F/s	4s
Phase2	1F/s	16s
Mask	30F/s	5s
Fill	30F/s	5s
Washout	0.5F/s	2s

2.2. Patient population
Thirty cases (15 male, 15 female) at the mean age of 49.5 (23–89) yrs. were studied by the 64-row MDCTA and thirty cases (14 male, 16 female) at the mean age of 46.8 (21–81) yrs. were studied by the DSA flat panel detector for cerebral vessels of the brain from October 2014 to June 2015 at Prasat Neurological Institute, Bangkok, Thailand.

2.3. Radiation dose determination
The effective dose of CTA was calculated by using DLP (mGy.cm) × k-factor (mSv/mGy.cm) [5]. For CTA brain, k-factor was 0.0019 mSv/mGycm [6, 7] and DSA used DAP (mGy.cm^2) × Dose conversion coefficient (mSv/mGy.cm^2) [5]. The dose conversion coefficient for cerebral angiogram was 0.087 mSv/mGy.cm^2 [8]. The results were shown in section 3.1

3. Results

3.1. Comparison of the effective dose from CTA and DSA

The mean effective dose related to patient characteristic is 3.7 (2.82 - 5.19) mSv for CTA and 5.78 (3.3 – 10.06) mSv for DSA as shown in table 3.

Table 3. Effective dose and patient characteristics for CTA and DSA.

	CTA	DSA	p value
Effective dose (Mean±SD)	3.70 ±0.66	5.78 ±1.53	<.001
Gender (% male)	15 (50%)	14 (46.67%)	.800
Age (Mean±SD)	49.53 ±17.3	46.8 ±16.12	.529
BMI (Mean±SD)	24.02 ±4.01	22.82± 4.27	.265

After adjusting for gender, age and BMI differences in our sample, we demonstrate the effective dose, on average was significant (Mean difference adjust = 2.193, p<0.001).The effective dose comparing between procedures by box plots is shown in figure 1.

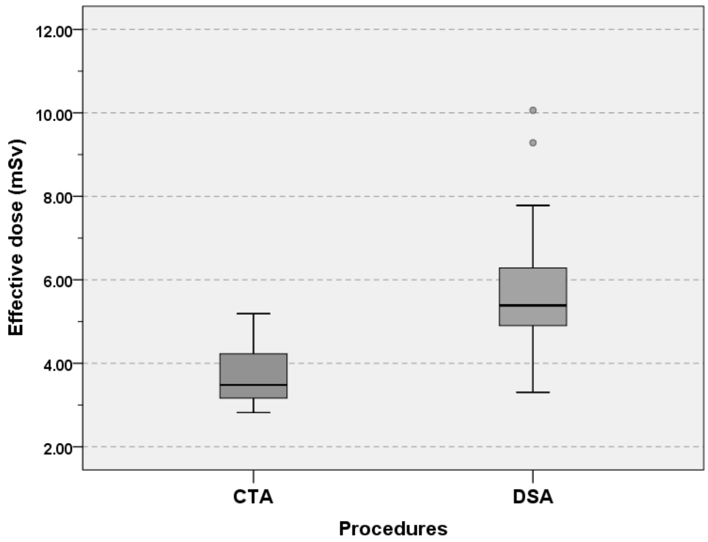

Figure 1. Box plots show the distribution of effective dose for the CTA and DSA procedures.
The effective dose for CTA, Mean = 3.7, Min = 2.82, Max = 5.19, Mod = 2.82, Median = 3.48, Range = 2.37, SD = 0.66, Percentiles; 25^{th} = 3.16, 75^{th} = 4.23 mSv, respectively.
The effective dose for DSA, Mean = 5.78, Min = 3.3, Max = 10.06, Mod = 3.3, Median = 5.39, Range = 6.76, SD = 1.53, Percentiles; 25 = 4.86, 75 = 6.34 mSv, respectively.

*Outliers are the maximum effective dose over the third quartiles.

3.2. Correlations between effective dose and patient characteristics of CTA

When we investigated the correlation between effective dose and patient characteristics for CTA procedure, the results show a moderately strong linear relationship between the effective dose and body weight (r=0.642, p<0.001), BMI (r=0.552, p=0.002) and fair linear relationship between the effective dose and height (r=0.445, p=0.014), respectively. Table 4 shows Spearman correlation.

Table 4. Correlations between effective dose and patient characteristics of CTA.

	r	p value
Age	-.353	.056
Weight	$.642^{**}$	<.001
Height	$.445^{*}$	.014
BMI	$.552^{**}$	.002

Spearman's Correlation is significant at the 0.01 level (2-tailed) **, or 0.05 level (2-tailed).*

3.3. Correlations between effective dose and patient characteristics of DSA
For DSA, we found poor linear relationship no significant between the effective dose and patient characteristics as Table 5 for Spearman correlation coefficient.

Table 5. Correlations between effective dose and patient characteristics of DSA.

	r	p value
Age	.243	.196
Weight	.203	.283
Height	.109	.556
BMI	.172	.362

Spearman's Correlation is significant at the 0.01 level (2-tailed) **, or 0.05 level (2-tailed).*

3.4. Correlations between effective dose and factors of DSA
We also investigated other factors that might be associated with effective dose for DSA. Table 6 gives Spearman correlation coefficient for several potential predictors of effective dose in the DSA procedure.

Table 6. Correlations between effective dose and factors of DSA.

	r	p value
Number of exposures	.755**	<.001
Fluoroscopic time	.330	.075
Number of Vessels selection	.282	.130
Number of 3D RA	.406*	.026
Experience of Radiologist	.337	.362

Spearman's Correlation is significant at the 0.01 level (2-tailed) **, or 0.05 level (2-tailed).*

We found a moderately strong correlation between the effective dose and number of exposures ($r=0.775$, $p<0.01$) and a fair correlation between the effective dose and number of 3D rotational angiography ($r=0.406$, $p<0.05$), respectively.

4. Discussion
The purpose of this study was to evaluate the effective dose from 64-row MDCTA and diagnostic DSA of the brain. Cohnen M *et al.* [9] measured the average effective dose in comprehensive CT of the brain in acute stroke at 3.6 mSv. Our study, the mean effective dose was 3.7 mSv.The key factors that affecting to high dose in CT were scan length, tube voltage, and effective mAs.

The reduction of scan length can significantly result in patient dose reduction in CT. However, in case of scan length reduction is impossible, using of low tube voltage should be considered [10, 11]. CTA of the brain obtained by using 80 kVp not only reduces patient radiation exposure by approximately 40% lower than 120 kVp but also give superior in higher contrast and contrast-to-noise ratio [12] [13]. Optimization in the acquisition parameters such as gantry rotation time, tube current, pitch and dose modulation can also reduce effective dose.

Manninen A L *et al.* [2] compared radiation exposure between diagnostic CTA and DSA examinations of brain and neck vessels by exposed anthropomorphic phantom. The effective dose for DSA of cerebral vessels was approximately 5 times of the CTA (0.67 mSv for CTA and 2.71 mSv for DSA). Our study, the mean effective dose of DSA was 1.5 times of the CTA. The number of exposures and number of 3D RA were the major factors affecting effective dose in DSA. Patients received a higher dose from 2D mode rather than 3D mode due to the differences in imaging parameters, higher frame rates in 2D mode result in high radiation dose during procedure.

For DSA, using lower pulse rates during fluoroscopy and frame rates are techniques to reduce the radiation dose to the patient from cerebral angiography procedures.

According to our study, CTA procedure should be primarily considered in order to reduce radiation dose to the patient.

5. Conclusion

Our study shows, the effective doses for CTA ranged from 2.82 - 5.19 mSv and the average of 3.7 mSv. Whereas, for DSA, the average effective dose was 5.78 mSv and doses ranged from 3.3 – 10.06 mSv, respectively. The key factors that affecting to high dose in CTA were effective mAs, kVp and scan length. Increasing patient height, weight and BMI result in increasing effective dose from CTA examination.

For DSA, the number of exposures and a number of 3D RA were the factors affecting the effective dose. Most of the dose is high as a result of a number of radiographic DSA exposures. The patient dose increases with a number of 3D RA of the procedure.

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