

# Radiation Doses to Paediatric Patients Undergoing Voiding Cystourethrography (VCUG) at Siriraj Hospital

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## ABSTRACT

**Objective:** The aims were to quantify and evaluate the radiation doses and to estimate the radiation risk for the paediatric patients undergoing VCUG according to the protocol used in Siriraj Hospital.

**Methods:** Among 93 children of the age of 0-15 years who underwent VCUG at Siriraj Hospital, we reported the patient's data, the radiation doses determined by a DAP meter and the baseline data including the entrance skin dose (ESD), dose area product (DAP) and the effective dose according to the patient's age.

**Results:** The mean ESD, DAP and effective doses of 93 paediatric patients were 3.63 mGy, 92.9 cGy $\cdot$ cm<sup>2</sup> and 0.20 mSv, respectively. The initial local DRLs of DAP for VCUG examination at Siriraj Hospital were 37, 77 and 105 cGy $\cdot$ cm<sup>2</sup> in the age range of 0-1, >1-5, and >5-10 years, respectively. The ESD, DAP and effective doses were in ranges of 0.36-81.96 mGy, 1.37-1506.90 cGy $\cdot$ cm<sup>2</sup> and 0.003-3.16 mSv, respectively.

**Conclusion:** The initial local DRLs of DAP for VCUG examinations at Siriraj Hospital were less than in NRPB and Siriwiladluk T, et al in the age range of 0-1, >1-5, and >5-10 years. Due to the small number of patients at the age of >10-15 years (n=4), it was inconclusive of the dose level in this age group. The lifetime risk of radiation induced cancer was approximately calculated to be 2.6 per 100,000.

**Keywords:** Voiding cystourethrography (VCUG), radiation dose, dose area product (DAP), dose reference levels (DRLs), paediatric patient

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## INTRODUCTION

Radiation exposure from diagnostic radiology gives the greatest collective absorbed dose to the population when compared with other human activities using ionizing radiation.<sup>1</sup> In 2006, the National Council on Radiation Protection and Measurements (NCRP) reported that 36%

of human-made radiation comes from Diagnostic Radiation, including 5% from general X-rays and fluoroscopy.<sup>2</sup> There has been a growing concern regarding the risks of radiation exposure from diagnostic X-ray examinations.<sup>3</sup> At Siriraj Hospital, voiding cystourethrography (VCUG) is the most frequent fluoroscopic examination and accounts for 48.5% of all fluoroscopic examinations performed in children.

In children, the radiologic examinations cause higher risks than adults for developing radiation-induced cancer, hereditary effects or other serious disorders by two to three times. The International

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Commission on Radiation Protection (ICRP) estimated that the risk coefficient for the average population is 5% per Sv, whereas for children is 13% per Sv for stochastic effects. Attention to radiation risk for children has increased in recent years and several studies have been performed in the field of dose calculation and related risk.<sup>4</sup>

The diagnostic reference levels (DRLs) is the 75<sup>th</sup> percentile (third quartile) of the doses of common protocols from a national survey of imaging practices. It is recommended by international organizations for standard X-ray examinations to monitor and optimize the radiation dose and to improve the techniques without affecting the diagnostic value. The National Radiation Protection Board (NRPB 2000, Public Health England) reported DRLs using DAP value for paediatric VCUG are 90, 110, 210 and 470 cGy.cm<sup>2</sup> for 0-1, >1-5, >5-10, and >10-15 years of age, respectively.<sup>5</sup> The dose levels for VCUG examination in children at Siriraj Hospital is still not available.

Radiation doses imparted to patients are measured using a DAP meter.<sup>6</sup> A number of investigators have utilized the DAP values to assess radiation risk from fluoroscopic studies. The DAP is a better indicator of risk, compared to the entrance surface dose (ESD), due to the fact that DAP is a product of entrance dose and field size.<sup>2</sup> The effective dose can be estimated by combining measurements of DAP and calculated dose conversion factors.<sup>6</sup>

The aims of this study are (i) to quantify and evaluate the radiation doses for paediatric patients undergoing VCUG according to the protocol used at the radiology department in Siriraj Hospital and (ii) to estimate the radiation risk to the paediatric patients.

## MATERIALS AND METHODS

### *I. Radiography-Fluoroscopy system and quality control (QC)*

The hospital's scientific committee had approved the dosimetry protocol. The evaluation of radiation dose was carried out at the radiology department of Siriraj Hospital. The VCUG procedures were performed using digital fluoroscopy-radiography unit (Philips Eleva V.4.0). The QC

of these x-ray units was performed and calibration of DAP meter for ensuring the reliability and reproducibility of technical parameters.

### *II. Voiding cystourethrographic (VCUG) procedure*

The standard routine VCUG was performed by training radiologists under supervision of paediatric radiologists which started with urethral catheterization under strict aseptic conditions. Intermittent fluoroscopy and radiographic images used automatically selected kV and mA exposure parameters.

The first radiographic image was obtained before contrast media administration. Under intermittent fluoroscopy, diluted iodinated contrast medium was administered through the catheter and then radiographic images in both oblique views were taken during early filling of the bladder and full bladder. Additional radiographic images were taken to clearly detect the abnormality and grading of vesicoureteric reflux (VUR) During voiding under fluoroscopy, the radiographic images were taken with antero-posterior radiographs in girls, and oblique or lateral views in boys. After the voiding was completed, an anteroposterior abdominal radiography was performed.

### *III. Patient data collection*

The ethical approval was granted by Siriraj Hospital ethical committee (COA Si.664/2011). Data of a total 93 paediatric patients who underwent VCUG at Siriraj Hospital, were recorded from December 2011 to December 2012. The patient's population was subdivided into 4 groups based on age of patients: 0-1 year, >1-5 years, >5-10 years, and >10-15 years.

For each patient, all the following parameters were recorded including radiographic data (kV, mAs, number of images), fluoroscopic data (kV, mA and total screening time) and patient's data (sex, age, weight, height, clinical indication, result of examination) and radiation dose (DAP, ESD).

### *IV. Dose-area product*

The fluoroscopic-radiographic system used in this study was equipped with the dose-area product (DAP) meter. The DAP meter measures the radiation dose to air, times the area of the

x-ray field. The relationship between DAP and exposure-area product (EAP) is essentially a single conversion factor that relates the dose to the exposure.

The reading from a DAP meter can be changed by altering the x-ray technique factors (kVp, mA, or time), varying the area of the field, or both. Therefore, DAP is appropriate to estimate radiation dose in fluoroscopic procedure.

#### V. Effective dose and risk estimation

The effective dose could be calculated from DAP value multiplied by the conversion coefficient of 0.21mSv/Gy.cm<sup>2</sup> for VCUG procedure.<sup>7</sup>

The risk of developing cancer in a particular organ following VCUG, or genetic effects in future generations after irradiation was estimated by multiplying the effective dose with the risk coefficients. The attributable lifetime risk for cancer per absorbed dose is 13% per Sv for paediatric exposure as given by ICRP.<sup>4,6,8</sup>

## RESULTS

### I. Patient and examination data

A total of 93 children (61 boys and 32 girls) were examined at Siriraj Hospital with mean age of 3.4 years (1 day-14 years). The children were divided into 4 groups based on age of patients: 0-1 year (32 patients), >1-5 years (33 patients), >5-10 years (24 patients), and >10-15 years (4 patients).

The clinical indications for VCUG examinations were urinary tract infection (34.4%), VUR

(32.2%), hydronephrosis (16.1%), congenital anomaly (9.7%) and other indications (7.5%) including neurogenic bladder, acute kidney injury, urinary incontinence and pelvicaliectasis. 33.3% (31/93) of the patients were positively diagnosed with VUR.

The data parameter technique of patients who underwent VCUG, were shown in Table 1. The mean values for kV and mAs obtained in the fluoroscopic examinations were 70.8 kV and 0.25 mAs, respectively. The number of images ranged from 6 to 30 and the average fluoroscopic time was 2.3 minutes.

### II. Radiation dose

Dose data from 93 patients who underwent VCUG procedures, were shown in Table 1. The radiation dose to the patients were divided by age range and gender as shown in Table 2. Our results showed total DAP ranged from 1.37 to 1506.9 cGy.cm<sup>2</sup> and entrance surface dose (ESD) ranged from 0.36 to 81.96 mGy, respectively.

We have compared the DRLs of DAP values obtained with this study to those reported by other authors<sup>9,10,15</sup> and NRPB 2000<sup>5,8,11</sup> in Table 3.

## DISCUSSION

The data of 93 paediatric patients under going VCUG procedures were collected for a duration of a year at Siriraj Hospital. We found that the applied voltages and fluoroscopic times of this study were comparable with the values reported in literature.

**TABLE 1.** The data parameter technique and radiation dose of 93 patients underwent VCUG.

Data	Mean	SD	Min	Max	Median	3 <sup>rd</sup> Quartile
Radiographic (kV)	70.2	5.3	57.5	91.5	71.0	72.0
Radiographic (mAs)	1.2	0.8	0.1	5.3	1.1	1.5
Fluoroscopic (kV)	70.	4.9	53.5	82.5	71.0	73.5
Fluoroscopic (mA)	0.3	0.2	0.1	1.4	0.2	0.3
II format (cm)	26.6	5.9	17.0	38.0	25.0	31.0
No. of images	12.9	4.0	6.0	30.0	13.0	15.05
Fluoroscopic times (min)	2.3	1.5	0.33	7.9	1.9	2.8
FFD (cm)	89.7	6.7	75.0	103.0	92.0	95.0
ESD (mGy)	3.634	8.75	0.36	81.96	1.75	3.37
DAP (cGy.cm <sup>2</sup> )	92.90	193.99	1.37	1506.90	43.59	79.20
Effective dose (mSv)	0.20	0.41	0.003	3.16	0.09	0.17

**TABLE 2.** The mean radiation doses to patients divided by age range and gender

Age range (years)	Entrance skin dose (ESD) (mGy)		Dose area product (DAP) (cGy.cm <sup>2</sup> )		Effective dose (mSv)	
	This study	Siriwiladluk	This study	Siriwiladluk	This study	Siriwiladluk
0-1 (n=32)	1.35	3.41	27.85	46.58	0.08	0.10
>1-5 (n=33)	4.79	6.80	103.10	115.48	0.16	0.24
>5-10 (n=24)	3.91	11.75	116.42	292.28	0.22	0.61
>10-15 (n=4)	10.70	20.50	388.03	575.98	1.25	1.21
Male (n=61)	3.95	5.33	97.24	89.01	0.20	0.19
Female (n=32)	3.02	10.76	84.63	270.30	0.18	0.57

**TABLE 3.** Comparison of the diagnostic reference levels (DRLs) of dose area product (DAP) values in this study to those reported by other authors and NRPB divided by age range.

Age range (years)	This study (cGy.cm <sup>2</sup> )	Chappel (cGy.cm <sup>2</sup> )	Ruiz (cGy.cm <sup>2</sup> )	NRPB (cGy.cm <sup>2</sup> )	Siriwiladluk (cGy.cm <sup>2</sup> )
0-1 (n=32)	37	168	192	90	46.58
>1-5 (n=33)	77	262	381	110	115.48
>5-10 (n=24)	105	433	845	210	292.28
>10-15 (n=4)	595	N/A	1353	470	575.98

In this study, the radiographic exposure factors ranged from 57.5 to 91.5 kV and from 0.1 to 5.3 mAs during the examination, and the fluoroscopic applied voltage ranged from 53.5 to 82.5 kV and from 0.1 to 1.35 mA during image acquisition (Table 1). Ruiz et al<sup>10</sup> reported radiographic exposure factors ranged from 50 to 90 kV with 5 to 75 mAs and fluoroscopic applied voltage ranged from 55 to 90 kV with 0.2 to 3.4 mA. The European Commission suggested 65 to 90 kV for paediatric VCUg examination.<sup>1</sup>

Chapple et al<sup>9</sup>, Ruiz et al<sup>10</sup>, Travassos et al<sup>7</sup> and Siriwiladluk T, et al.<sup>15</sup> reported fluoroscopic times of 0.2-20.4 minutes, 0.1-4.9 minutes, 1.3-20.6 minutes, and 0.7-7.7 minutes, respectively. The fluoroscopic times in this study were recorded for 0.3-7.9 minutes, within the range of most reports. In this study, the number of images acquired in the VCUg procedure (Table 1) ranged from 6 to 30 which was higher than those reported by

Chapple et al<sup>9</sup>, Travassos et al<sup>7</sup> and Ruiz et al<sup>10</sup>. For the reduction of the radiation dose in Siriraj Hospital, we should attempt to limit the number of unnecessary images and fluoroscopic time.

In this study, the maximum ESD was 81.96 mGy (Table 1) which was less than the concerned level for deterministic risk of 2 Gy for all the populations. The mean ESD was 5.59 mGy in patients with positive VUR and was 2.65 mGy in patients with negative VUR (Table 4). The ESD was higher in patients with positive VUR due to higher number of radiographic images and fluoroscopic times (Table 4).

Tables 2 and 3 showed that the mean DAP and the DRLs of DAP values for the complete examination increased with increasing age range, varying from 27.85 to 388.03 cGy.cm<sup>2</sup> and 37 to 595 cGy.cm<sup>2</sup> which were lower as compared with the report of Siriwiladluk T et al.<sup>15</sup> For individual patients within the age range group, the fluctuations

**TABLE 4.** Data parameters in positive and negative vesicoureteric reflux (VUR) groups.

Result of VUR	Number of patient	Mean number of images	Mean fluoroscopic times (sec)	Mean DAP (cGy.cm <sup>2</sup> )	Mean ESD (mGy)
Positive	31	16	155.26	120.66	5.59
Negative	62	12	131.31	79.02	2.65

in DAP may occur due to attributable differences in patient size, patient cooperation and the complexity of the examination. There was no appreciable difference in the mean DAP between males and females in this study but appreciable difference in the report of Siriwiladluk T et al.<sup>15</sup> The DRLs of DAP values reported in this study were lower than those reported by Chapple et al,<sup>9</sup> Ruiz et al,<sup>10</sup> and Siriwiladluk T et al,<sup>15</sup> in all age ranges (Table 3). The DAP values in this study were lower than the DRLs reported by NRPB in ages of 0-1, 1-5 and 5-10 years (Table 3). The limitation in this study was the small number of patients at the higher age of >10-15 years (n=4), so it was inconclusive of the dose level in this age group.

The difference of DAP could be due to several factors, dependent on imaging protocols equipment and examiner. In this study, we selected to apply the digital equipment, low frame rate pulsed fluoroscopy, last frame hold feature, and application of standard protocol under the supervision of paediatric radiologists and technicians for reduction of the radiation dose during fluoroscopic examinations.

The effective dose was calculated to be approximately 0.003 mSv to 3.16 mSv. The mean effective dose was 0.2 mSv with a tendency to increase with increasing age (Table 1,2). While the mean effective dose of chest radiography in paediatric patient was about 0.1-0.2 mSv.<sup>13</sup> The risk of developing cancer in a particular organ following VCUG, or genetic effects in future generations after irradiation, was estimated by multiplying the effective dose with the risk coefficients. The attributable lifetime risk for cancer per absorbed dose is 13% per Sv for paediatric exposure as given by ICRP.<sup>4,6,8</sup> In Soour's study, using 13% per Sv and 0.2 mSv effective dose value, the lifetime risk of radiation induced cancer from this dose was calculated to be 2.6 per 100,000.

However, it is well known that radiation induced cancers cannot be distinguished from those produced by other possible carcinogenic agents, because of the high natural incidence and the long latent period. Therefore, cancer risk estimation depends on the observation of a number of cancers of different kinds that arise in irradiated groups.<sup>4</sup>

## CONCLUSION

This study provided valuable data for establishing dose reference levels of paediatric VCUG examination at Siriraj Hospital. The initial local DRLs of DAP values were established of 37, 77 and 105 cGy.cm<sup>2</sup> in the ages of 0-1, >1-5, and >5-10 years, respectively that are less than those reported in NRPB and Siriwiladluk T et al.<sup>15</sup> The ESD, DAP and effective dose were in ranges of 0.36-81.96 mGy, 1.37-1506.90 cGy.cm<sup>2</sup> and 0.003-3.16 mSv, respectively. Due to the small number of patients at the higher age of >10-15 years (n=4), it was inconclusive of the dose level in this age group.

The risk of radiation induced cancer by paediatric VCUG examination at Siriraj Hospital was calculated to be 2.6 per 100,000. The radiation dose for paediatric VCUG examination at Siriraj Hospital can be reduced more by limiting the number of unnecessary images and fluoroscopic time. However, it is necessary to periodically monitor radiation doses in order to reduce the radiation burden on the patient.

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