ปริมาณรังสีที่ผู้ป่วยเด็กได้รับจากการตรวจ วีซียูจี (VCUG)

นายธวัช สิริวิลาสลักษณ์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต

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RADIATION DOSE IN VOIDING CYSTOURETHROGRAPHY (VCUG) IN CHILDREN

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Field of Study	Medical Imaging
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ธวัช สิริวิลาสลักษณ์ : ปริมาณรังสีที่ผู้ป่วยเด็กได้รับจากการตรวจ วีซียูจี (VCUG) (RADIATION DOSE IN VOIDING CYSTOURETHROGRAPHY (VCUG) IN CHILDREN) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: รศ.ดร. อัญชลี กฤษณจินดา: 75 หน้า.

เนื่องจากเด็กมีความไวในการตอบสนองต่อผลกระทบของรังสีมากกว่าผู้ใหญ่ ดังนั้นต้องให้ความสนใจเป็นพิเศษในการให้ปริมาณรังสีทางคลินิก รังสีส่วนใหญ่ก่อให้เกิดเนื้องอกและไม่ได้ปรากฏให้เห็นผลได้ทันทีจนกว่าเวลาหลายปีหลังจากได้รับรังสีแล้ว ซึ่งผู้ป่วยผู้ใหญ่ที่ได้รับรังสีนั้น อาจจะเสียชีวิตจากสาเหตุอื่นๆ ก่อนที่พวกเขาจะพัฒนากลายเป็นผู้ป่วยมะเร็งหรือเนื้องอกผู้ป่วย เด็กซึ่งคาดหวังว่า จะมีช่วงชีวิตที่ยาวนานกว่า จึงมีโอกาสมากขึ้น ที่จะเป็นโรคมะเร็งได้ ดังนั้น การใช้ปริมาณรังสีให้น้อยที่สุด จึงเป็นปัจจัยที่สำคัญที่สุด วัตถุประสงค์ของการศึกษานี้คือ การตรวจสอบปริมาณรังสีที่ผิว จากขั้นตอนการถ่ายภาพรังสีแบบเรดิโอกราฟฟิค ฟลูออโรสโคปิค ในการตรวจ วีซียูจี ของผู้ป่วยเด็กโดยการบันทึกค่าแดพ

ผู้ป่วยเด็ก 70 ราย ที่ได้รับปริมาณรังสีจากการตรวจ วีซียูจี โดยการใช้หัววัดปริมาณรังสีแบบโปร่งแสง ซึ่งยอมให้รังสีทะลุผ่านได้ เครื่องมือนี้อยู่ติดกับหน้าต่างของหลอดเอกซเรย์ และ มีเครื่องอ่านปริมาณรังสีเชื่อมต่อกับระบบคอมพิวเตอร์สำหรับการเก็บรวบรวมข้อมูล

ผลการศึกษาพบว่า ปริมาณรังสีสำหรับการตรวจ วีซียูจี และข้อมูลพื้นฐานเกี่ยวกับปริมาณรังสีที่ผิว หรือ อีเอสดี, ปริมาณรังสีแบบแดพ และ ปริมาณรังสียังผล เพื่อสร้างระดับปริมาณรังสีระดับอ้างอิงท้องถิ่น ในผู้ป่วยเด็ก พบว่า ปริมาณรังสีอ้างอิงในระดับท้องถิ่น ที่โรงพยาบาลรามาธิบดี ได้ถูกกำหนดขึ้นดังนี้ สำหรับช่วงอายุ 0-1 ปี มีค่า 4 มิลลิเกรย์, 49 เซ็นติเกรย์ตารางเซ็นติเมตร และ 0.10 มิลลิซีเวิร์ต ตามลำดับ สำหรับช่วงอายุ >1-5 ปี มีค่า 10 มิลลิเกรย์, 176 เซ็นติเกรย์ตารางเซ็นติเมตร และ 0.37 มิลลิซีเวิร์ต ตามลำดับ สำหรับช่วงอายุ >5-10 ปี มีค่า 14 มิลลิเกรย์, 393 เซ็นติเกรย์ตารางเซ็นติเมตร และ 0.83 มิลลิซีเวิร์ต ตามลำดับ และ สำหรับช่วงอายุ >10-15 ปี มีค่า 24 มิลลิเกรย์, 708 เซ็นติเกรย์ตารางเซ็นติเมตร และ 1.49 มิลลิซีเวิร์ต ตามลำดับ ควรมีความพยายามที่จะลดปริมาณรังสีที่ได้รับจากการตรวจวินิจฉัยนี้ เนื่องจากผู้ป่วยได้รับปริมาณรังสีสูง มีความเสี่ยงสูงในการก่อให้เกิดการพัฒนาโรคมะเร็ง จากการได้รับรังสีในผู้ป่วยเด็ก

ภาควิชา รังสีวิทยา ลายมือชื่อนิสิต ธวัช สิริวิลาสลักษณ์

สาขาวิชา ฉายาเวชศาสตร์ ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก [signature]

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5374636030: MAJOR MEDICAL IMAGING

KEYWORDS: VOIDING CYSTOURETHROGRAPHY (VCUG) / FLUOROSCOPY, CHILDREN / EFFECTIVE DOSE / DOSE AREA PRODUCT (DAP)

TAWAT SIRIWILADLUK: RADIATION DOSE IN VOIDING CYSTOURETHROGRAPHY (VCUG) IN CHILDREN. THESIS ADVISOR: ASSOC. PROF. ANCHALI KRISANACHINDA, 75 pp.

Children are more sensitive to the effects of ionizing radiation than adults. Special attention must be paid to the amount of radiation in clinical use. Most radiation induced tumors and do not become manifest until many years after exposure, so adult patients may have died of other causes before they develop. Children, because of their longer life expectancy, have a greater chance of being alive long enough for the tumor to present. Therefore, practical aspects on dose savings are the most important factors. The purpose of this study is to determine entrance skin dose (ESD) from radiographic-fluoroscopic procedures in voiding cystourethrography (VCUG) studies of pediatric patients by dose area product (DAP) recordings.

Radiation doses received by 70 pediatric patients undergoing voiding cystourethrography (VCUG) procedures were determined by the transmission ionization chamber (Dose Area Product, DAP Meter, Wellhöfer Dosimetrie GmbH Bahnhofstrasse 5 D-90592 Schwarzenbruck, Germany) directly coupled to the x-ray tube window of machine (Philips Omni Diagnost Eleva) and an electrometer connected to a computer for data collection.

The study revealed the radiation dose for voiding cystourethrography (VCUG) procedure and the baseline data on the entrance skin dose (ESD), dose area product (DAP) and the effective dose (E), to establish local reference dose levels in pediatric patients. The local dose reference level (DRL) at Ramathibodi Hospital, the entrance skin dose (ESD), dose area product (DAP), and effective dose (E), were determined for 0-1 years, 4 mGy, 49 $cGycm^2$, and 0.10 mSv, for >1-5 years, 10 mGy, 176 $cGycm^2$, and 0.37 mSv, for >5-10 years, 14 mGy, 393 $cGycm^2$, and 0.83 mSv, for >10-15 years, 24 mGy, 708 $cGycm^2$, and 1.49 mSv respectively. Attempts could be made to lower the radiation dose received during these procedures due to a higher risk of developing radiation-induced cancer in children.

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LIST OF ABBREVIATIONS

Abbreviation	Terms
AAPM	American Association of Physicists in Medicine
ACR	American College of Radiology
BE	Barium enema
BMI	Body mass index
CI	Confidence interval
DAP	Dose area product
DRLs	Diagnostic (dose) reference levels
E	Effective dose
EAP	Exposure area product
ESD	Entrance skin dose
FID	Focus to image distance
Flu	Fluoroscopy
FOV	Field of views
Gy	Gray
$Gycm^2$	Gray centimeter square
HVL	Half value layer
ICRP	International commission on radiological protection
II	Image intensifier
kVp	Kilo voltage peak
mA	Milliampere
mAs	Milliampere second
MCUG	Micturating cystourethrography
mGy	Milligray

Abbreviation	**Terms**
mGy-cm^2	Milligray centimeter square
mmAl	Millimeter aluminum
mSv	Millisievert
NRDs	National reference doses
NRPB	National radiological protection board
PACS	Picture archiving and communication system
R-cm^2	Roentgen centimeter square
SD	Standard deviation
SID	Source to image distance
TLD	Thermoluminescent dosimeter
UGI	Upper gastrointestinal system
VCUG	Voiding cystourethrography
μGy	Microgray

CHAPTER I

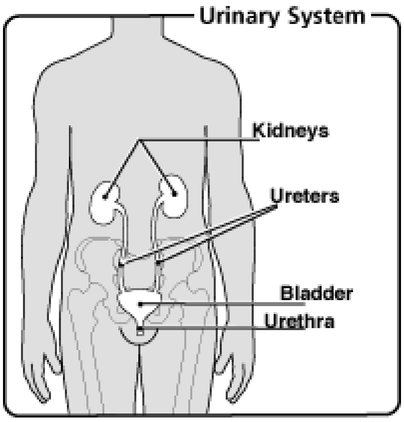
INTRODUCTION

1.1 Background and rationale

The use of radiation in diagnosis of the disease in children is necessary and becomes main modality. General x-ray images show basically anomalies such as plain film of chest, abdomen and the other such as radiographic–fluoroscopic modality shows real-time images such as upper gastrointestinal system (UGI), barium enema (BE), voiding cystourethrography (VCUG) and others. Even though the use of radiation is benefit in diagnosis of disease in children, it is also radiation risk. The risk that may occur from many factors such as not using the immobilization of children during procedure, they may be injured from the special x-ray examination. Therefore, the risk from the use of radiation must be considered.

X-rays is an ionizing radiation which can be benefit and dangerous if given in large doses and unnecessary. The radiation effects in human are both in short and long terms. In short term effect, it can cause red skin rash at the area exposed to radiation. In the long term effects, it can cause cancer, so the amount of radiation the patients received, is very important that we should consider carefully by using the concept of justification, optimization and dose limitation.

Detection of abnormalities in the urinary system of children using radiographic-fluoroscopic procedures should be carefully considered. Because this disorder usually occurs in large number of children and the use of fluoroscopy was 30-50% of all studies [1].



A [7]

B [8]

Figure 1.1 A The diagram of normal urinary tract, **B** The inspection process as voiding cystourethrography (VCUG) using radiographic-fluoroscopic procedure.

Currently, voiding cystourethrography (VCUG) is a specialized radiology procedure that still has an important role. The incidence of diseases or disorders of the urinary tract of children still have quite a lot and the ultrasound examination is still not clear enough images. As a result, this inspection continues to be very popular with pediatric physician who prescribed for any abnormality that occurs using this examination. The amounts of radiation the pediatric patients received from this examination should be an important part for highly consideration.

Children are more sensitive to the damaging effects of ionizing radiation than adults. Special attention must be paid to the amounts of radiation used. Most radiation induced tumors do not become manifest until many years after exposure, so adult patients may have died of other causes before they develop. Children, because of their longer life expectancy, have a greater chance of being alive long enough for the tumor to present. The pediatric patient dose received from the examination is still not available in Thai pediatric patients.

1.2 Research objective

To determine the entrance skin dose (ESD) from fluoroscopic and radiographic procedures in voiding cystourethrography (VCUG) studies of pediatric patients by dose-area product (DAP) recordings.

CHAPTER II

REVIEW OF RELATED LITERATURES

2.1 Theory

2.1.1 Voiding cystourethrography (VCUG) [2]

Voiding cystourethrography is a radiographic and fluoroscopic study of the lower urinary tract. It requires aseptic bladder catheterization, instillation of iodinated contrast media, fluoroscopic observation, and recorded images (film, digital, or video) of the opacified structures. The purpose of the examination is to assess the bladder, urethra, postoperative anatomy, and micturition in order to determine the presence or absence of bladder and urethral abnormalities, including vesicoureteral reflux.

Clinical indications for voiding cystourethrography include, but are not limited to:

- Urinary tract infection.
- Dysuria.
- Dysfunctional voiding.
- Hydronephrosis and/or hydroureter.
- Bladder outlet obstruction.
- Hematuria.
- Trauma.
- Incontinence.
- Neurogenic dysfunction of the bladder, e.g., spinal dysraphism.
- Congenital anomalies of the genitourinary tract.
- Postoperative evaluation of the urinary tract.

There are no absolute contraindications for voiding cystourethrography. Potential benefits must outweigh the minor risks of the procedure. Relative contraindications include prior significant reaction to iodinated contrast media in the setting of the acute stage of a urinary tract infection, and recent urethral surgery or potential urethral trauma.

The request for voiding cystourethrography should provide sufficient information to demonstrate the medical necessity of the examination and allow for its proper performance and interpretation.

Documentation that satisfies medical necessity includes 1) signs and symptoms and/or 2) relevant history (including known diagnoses). Additional information regarding the specific reason for the examination or a provisional diagnosis would be helpful and may at times be needed to allow for the proper performance and interpretation of the examination.

The request for the examination must be originated by a physician or other appropriately licensed health care provider. The accompanying clinical information should be provided by a physician or other appropriately licensed health care provider familiar with the patient’s clinical problem or question and consistent with the state’s scope of practice requirements.

2.1.1.1 Patient Selection and Preparation

The study should be performed only for an appropriate clinical indication. Consultation with referring physicians helps to clarify which children may benefit from voiding cystourethrography.

2.1.1.2 Technique

Sedation is typically not required for voiding cystourethrography. When available, child-life specialists may be useful to facilitate catheterization and the remainder of the examination through use of education, distraction, and relaxation techniques. In circumstances when sedation may be clinically indicated, the child must be monitored during and following the examination, using current guidelines.

If a recent abdominal image is not available, a preliminary abdominal radiograph, fluoroscopic image capture, or digitally acquired spot image may be obtained before instilling contrast media in order to detect opaque calculi or other calcifications and to evaluate anatomy such as skeletal anomalies. Selective use of a lateral image may be useful to evaluate the sacrum if there is a concern for sacral anomalies. A digitally acquired spot image or radiograph may be preferable to fluoroscopic image capture in specific clinical situations needing superior spatial resolution.

Aseptic bladder catheterization of children should be performed by experienced personnel. Latex precautions should be observed especially in those children with known latex allergy or those with a diagnosis of myelomeningocele.

In male, to diminish sensation or pain, aseptic retrograde instillation of a topical anesthetic into the urethra may be performed. The catheter size should be appropriate for the child’s age or urethral caliber. Catheters without balloons are preferred. In premature or extremely small infants, a 5-French catheter is preferred. Above this age, an 8-French catheter is preferred, unless a smaller catheter is appropriate for the urethral anatomy, such as urethral stricture, or if there is inability to catheterize with a larger catheter. A catheter larger than 8-French may be used in adolescents. One should avoid placing loops of catheter in the bladder because they could become knotted, possibly requiring invasive retrieval. In patients with phimosis, the foreskin should not be completely retracted for catheterization.

In female, the catheter may be secured with tape to the adjacent thigh or perineum. In boys, a strip of tape may be placed on the catheter extending longitudinally along the dorsum of the penis to the symphysis. Circumferential placement of tape around the penis is discouraged. After the catheter placement, the bladder should be drained prior to instillation of contrast media, and a sterile urine specimen should be retained for culture if clinically indicated.

Iodinated contrast media (12% to 18% weight/volume solution) should be administered by gravity drip. The expected bladder capacity in children less than one year may be estimated by multiplying the patient’s weight in kilograms times 7, and in children ages 1 through 12 years by multiplying the patient’s age in years plus 2 times 30. If recent bladder surgery has been performed, gravity infusion should be performed with the container of contrast positioned as low as possible above the table height to assure low-pressure filling.

Pulsed fluoroscopy, last image-capture, and video recording of the fluoroscopic examination potentially reduce radiation dose and should be used when available. Fluoroscopy time should be monitored and minimized. The examination should be collimated to the region of interest. Generally, the use of grid available in some equipment increases radiation dose and may not significantly improve image quality. However, in some systems this may not be the case, and grid use may improve image quality. It is the operator’s responsibility to determine what appropriate dosage versus image quality is.

An early-filling last-image capture of the bladder with a small amount of contrast may reveal an intravesical ureterocele or other mass, which might be obscured by larger contrast volume. The bladder should be filled to capacity (as determined by weight-based guidelines) or until the patient voids. Cyclical filling of the bladder (filling to capacity followed by voiding and refilling 2 to 3 times with the catheter in place) may be helpful in infants (1 year of age or younger) who void at low volumes, and to increase detection of reflux in patients with a high pretest probability of reflux. The latter includes patients with prior history of reflux and evidence of pyelonephritis.

Patient positioning for each part of the examination is important. Oblique views of the right and left sides of the full bladder should be obtained to profile each ureterovesical junction. When vesicoureteral reflux occurs, the degree of reflux should be documented by imaging the renal fossae in the frontal projection.

The entire urethra should be demonstrated during the voiding phase. Males should be positioned obliquely during voiding, without superimposition of the hips. In most young children, the entire urethra will be visible on a single voiding image. In adolescent boys, separate images of the posterior and anterior urethra may be necessary. Images without the catheter are preferable, but pertinent pathology may be demonstrated with the catheter in place. The female urethra is generally imaged in the frontal projection, and catheter removal is not necessary. In older males, initiation of voiding may be easier with the fluoroscopic table tilted to 30 to 45 degrees or with the patient standing.

Spot images of the renal fossae immediately after voiding should be obtained to document the presence and grade or absence of reflux. Vesicoureteral reflux should be accurately described and graded (Appendix A), and the maximal degree of reflux should be reported. If reflux is questionable, a lateral view may be helpful to differentiate kidneys from density in overlying bowel.

If the patient is unable to void during the fluoroscopic portion of the examination, after adequate bladder distension and after a reasonable amount of time and coaxing, he or she may be allowed to void in the restroom. Immediately after voiding, images should be obtained over the renal fossae and bladder to document the presence or absence of reflux and degree of bladder emptying. This limitation of the voiding portion of the examination must be documented.

If there is concern for coexistent obstruction, the rate of contrast drainage from the pyelocalyceal system and ureter may be estimated by obtaining a delayed image.

Assessment of the study should include the following:

- Presence or absence of reflux.
- Grade of reflux and at what point in the examination it occurred.
- Intrarenal reflux should be noted, if present.
- Appearance of the entire urethra.
- Site of insertion of ureter(s) when visualized by reflux.
- Bladder contour, location, capacity, and residual volume.
- Bladder lumen and filling defects, such as ureteroceles, clot, or other masses.
- Appearance of the spine and pelvic bones.
- Presence or absence of opaque calculi, calcifications, or other foreign bodies.

• Presence or absence of extravasation or evidence of fistula.

The findings of the voiding cystourethrogram should be reported in accordance with the ACR Practice Guideline for Communication of Diagnostic Imaging Findings.

2.1.2 Dose-Area Product (DAP) [3]

Some fluoroscopic and radiographic systems are equipped with dose-area product (DAP) meters. DAP meters measure the radiation dose in 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 dose to exposure. EAP is expressed in roentgen-cm^2(R-cm^2) and DAP is expressed in gray-cm^2 (Gycm^2).

2.1.2.1 DAP measurement

An ionization chamber of rectangular size larger than the area of the x-ray beam is placed just beyond the x-ray collimator. The DAP intercepts the entire x-ray field for an accurate reading, one proportional to the EAP. 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. If the chamber area is larger than that of the collimators, as the collimators are opened or closed the charge collected will also increase or decrease in proportion to the area of the field. For example, a 5 x 5 cm^2 x-ray field with an entrance dose of 1 mGy will yield a 25 mGycm^2 DAP value. If the field is increased to 10 x 10 cm^2, with the same entrance dose of 1 mGy the DAP increases to 100 mGy-cm^2, which is 4 times the DAP for the 5 x 5 cm^2 field.

DAP meters have been around for many years, and were actually used in the 1964 and 1970 U.S. X-ray Exposure Studies. Advocates of DAP meters contend that the DAP is a better indicator of risk than entrance dose alone, since DAP incorporates the entrance dose and field size. DAP has been shown to correlate well with the total energy imparted to the patient, which is related to the effective dose and therefore to overall cancer risk.

There are several problems with the use of the DAP value. The configuration of the DAP meter may introduce a bias to the DAP value. For example, if any material is placed between the meter and patient, the patient will receive less than what is implied by the displayed DAP value. For an under table fluoroscopy system this can be the tabletop and pad.

Consequently, the use of DAP to estimate skin entrance exposure or skin dose is complex and should only be attempted by a qualified medical physicist. This is particularly true for fluoroscopic procedures where multiple beam directions, source-skin distances, and field sizes may be used.

DAP meters must be calibrated and maintained. Large changes in the DAP meter response can occur over time, particularly if meters are adjusted for couch transmission factors. Calibration should be done in the field after any changes that might alter the DAP and at least annually.

DAP meters are valuable quality control tools for monitoring changes in equipment and procedures. DAP does not represent radiation dose per second, and use of a DAP meter to determine patient dose should only be attempted by a qualified medical physicist.

2.2 Review of related literatures

Travassos, et al. [4] used DAP meter to measure the entrance skin dose (ESD) in 37 pediatric patients .This study showed the mean values for voltage (kV) and tube current (mAs) obtained in the examinations of 72 and 6.1 , respectively.

The number of exposures ranged between 6 and 18, the average fluoroscopy time was 516 seconds, corresponding, on average, to 85% of total dose. Total DAP ranged from 154 to 1,865 cGycm^2 and total ESD ranged from 17 to 321 mGy.

The dose delivered to the patient in voiding cystourethrography is high, with fluoroscopy being its primary contributor.

Sulieman A and Theodorou K, et al. [1] used thermoluminescent dosimeter (TLD) to measure entrance surface dose (ESD), organ dose and estimate the level of risk in micturating cystourethrography (MCUG) in 52 pediatric patients.

The mean organ equivalent dose assessed from ESD using NRPB software, thyroid, ovaries, and testes was 0.006 mSv, 0.44 mSv and 0.33 mSv, respectively. The risk of developing cancer in a particular organ following MCUG, or genetic effects in future generations after irradiation was estimated by multiplying the mean organ equivalent dose with the risk coefficients obtained from ICRP 60. (Table 2.1)

Table 2.1 Risk estimation for gonads and thyroid. The risk of radiation-induced fatal cancer and hereditary effects was taken for the whole population for each organ from ICRP 60

Organ	Organ equivalent dose (mSv)	Risk factor $10^{-2}Sv^{-1}$	Risk of malignancy $\times 10^{-7}$	Genetic effect* $\times 10^{-7}$
Thyroid	0.006	0.08	0.04	-
Ovaries	0.44	0.1	4.4	44
Testes	0.33	0.1	3.3	33

*Probability for genetic effects = $1.0 \times 10^{-2}Sv^{-1}$ (ICRP 60)

Fluoroscopy-captured image technique can reduce the radiation dose by approximately 50% while still obtaining the necessary diagnostic information.

The radiation surface doses to the thyroid and testes are relatively low, whereas the radiation dose to the co-patient is negligible. The risks associated with MCUG for patients and co-patients are negligible.

Smans K, et al. [5] collected data from DAP measurements in VCUG from centres to specify whether the reported values were mean or median values. The data were collected from at least five centres with a representative sample. The diagnostic reference levels (DRLs) were calculated (Table 2.2).

Table 2.2. DAP values ($cGycm^2$) for voiding cystourethrography (VCUG) procedure.

	<1 y	1-2 y	2-3 y	3-8 y	8-12 y	>12 y	Reported value
Center 1	5 (10)	14 (19.2)	11 (15.5)	14.2 (22)	26.5 (36.5)	68 (87)	Median (75^{th} perc.)
Center 2	6.8 (16.7)	43.2 (46.9)	16.1 (18.2)	8.5 (9.2)	8.8 (22)	15.0 (32.7)	Median (75^{th} perc.)
Center 4	30		90				Median
Center 12	12.2		24.2		86.5	346.2	Mean (stdev)
Center 13							
a) Male	20 (19.6)	36.9 (19.9)	42.2 (6.7)	82.5 (27.7)	132.2 (58.9)	280.6	Mean (stdev)
b) Female	14.9 (5.7)	38.5 (7.2)	57.0 (10.6)	81.7 (48.3)	141.9 (19.0)	316.5	
DRL	**18.7**		**53.3**		**132.2**	**316.5**	

A DRL was calculated if data from at least five centers were available (75 th percentile; stdev; standard deviation).

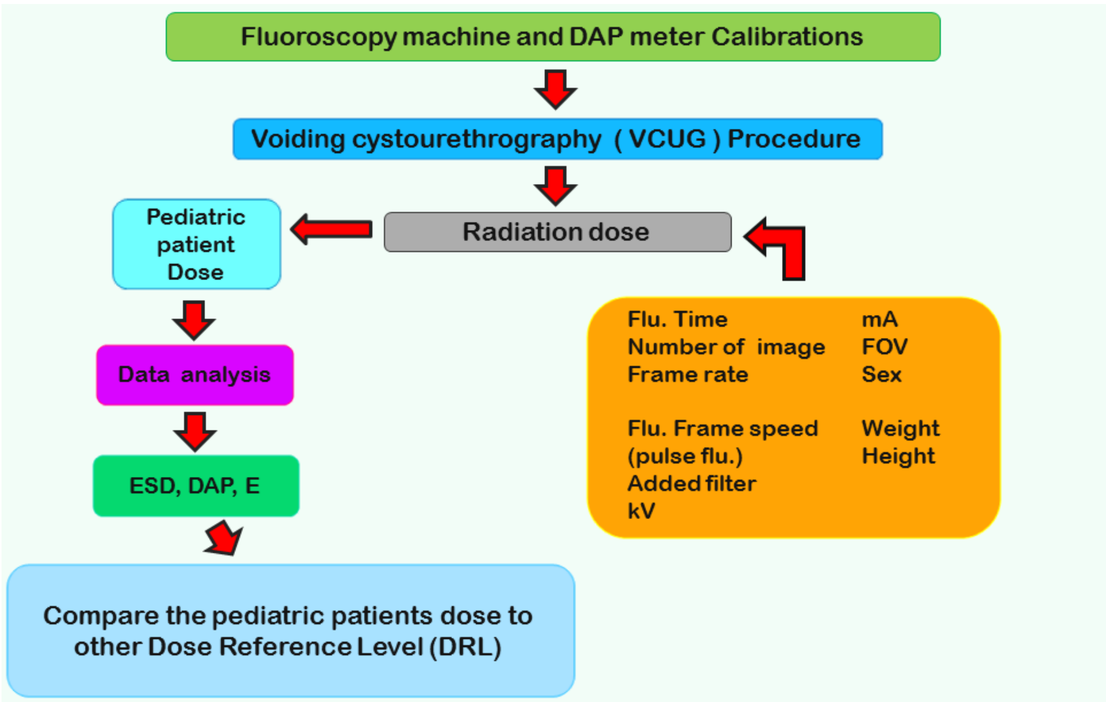
CHAPTER III

RESEARCH METHODOLOGY

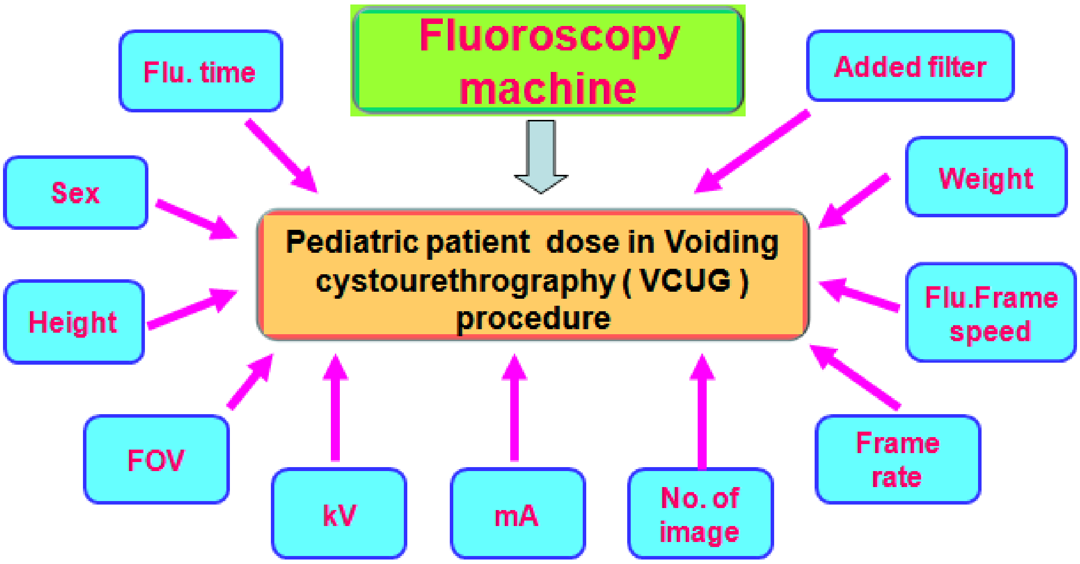
3.1 Research design

The study is an observational descriptive design.

3.2 Research design model



3.3 Conceptual framework



3.4 Key words

Voiding cystourethrography (VCUG)
Entrance skin dose (ESD)
Effective dose (E)
Fluoroscopy
Children
Radiation dose

3.5 Research questions

What are pediatric patient dose in voiding cystourethrography (VCUG) using DAP meter?

3.6 The sample

3.6.1 Target population

The pediatric patients in voiding cystourethrography (VCUG) procedure at room 16 fluoroscopy unit, Department of Radiology, Faculty of Medicine, Ramathibodi Hospital on Monday to Friday from May to December 2011.

3.6.2 Sample population

The pediatric patients who underwent voiding cystourethrography (VCUG) procedure at room 16 fluoroscopy unit, Department of Radiology, Faculty of Medicine, Ramathibodi Hospital.

3.6.3 Sample size determination

Sample size for this study is calculated from continuous data estimating the population mean based on the formula and construct 95% confidence interval (CI).

$Z_{\alpha/2}$ = 1.96 (two tail)
σ = Standard deviation (SD)
σ^2 = Variance of data
d^2 = Value of variation data (error at 10%)

$$\mathbf{n = (Z_{\alpha/2})^2 \sigma^2 / d^2}$$

$$n = (1.96)^2 (1866.65)^2 / (439.20)^2$$
$$n = 70 \text{ cases}$$

3.7 Materials

3.7.1 Radiographic-fluoroscopic system

The radiographic-fluoroscopic system: manufacturer Philips, model OmniDiagnost Eleva was installed at room 16 fluoroscopy unit, Department of Radiology, Faculty of Medicine, Ramathibodi Hospital was used in VCUG procedure. The machine is single plane with 2 x-ray tubes. One tube is ceiling suspension x-ray tube which is used for general radiographic image, the other one is over couch x-ray tube which is used for both of fluoroscopic and radiographic procedures. In this study, we used only over couch x-ray tube for VCUG procedure, as shown in figure 3.1

Figure 3.1 Radiographic-fluoroscopic system: Philips, OmniDiagnost Eleva.

The specification of radiographic-fluoroscopic system Philips model OmniDiagnost Eleva [9] is as followings:

3.7.1.1 X-ray generator

The x-ray generator is Model Velara with 50, 65, 80 or 100 kW power generator. The main standard features are following:

- Automatic x-ray tube load monitoring
- Automatic exposure control (AEC)
- Eleva programming for x-ray (EPX)
- Fluoroscopy
- In-pulse controlled exposure (IQX)

Optional features

- Pulsed controlled fluoroscopy (PCF)
- Grid controlled fluoroscopy (GCF)
- Dose calculation or measurement

3.7.1.2 X-ray tube and Collimator

The kilo voltage is ranging from 40 to 150 kVp. Tube focus is double focus: 1.2 mm. large size, 0.6 mm. in small size. Anode heat storage capacity is more than 300,000 H.U. (Heat Unit). The automatic collimator is equipped with field illumination, an iris diaphragm that automatically adjusts the x-ray field to the selected image intensifier field size and a filter changer.

3.7.1.3 Image chain

A large field of view or field size of image intensifier is adjustable to 14×17 cm^2 in rectangular area. The image intensifier -TV chain of the OmniDiagnost Eleva offers various circular diameters as the followings:

- 38 cm
- 31 cm
- 25 cm
- 20 cm
- 17 cm

The parameters that display on the monitor of operator console:

- Cumulative skin dose
- Cumulative DAP
- Fluoroscopy time

The DAP meter calibrated by manufacturer is mounted on window of x-ray tube. The data is sent to the PACS workstation

3.7.2 Radiation dose meter system

The radiation dose meter system manufactured by Unfors, model XI is a solid state detector used to calibrate DAP meter, the radiography-fluoroscopic system for kVp, dose, dose rate, half value layer (HVL), dose/frame, time and waveforms. The Unfors model XI was used for the measurement of entrance skin air kerma (ESAK) and the equipment quality control, as shown in figure 3.2.

Figure 3.2 Solid state detector systems, Unfors model XI [10, 11].

3.7.3 Dose area product meter (DAP)

The DAP meter (The KermaX plus model 120-131P) is supplied by the manufacturer: Wellhöfer Dosimetrie GmbH Bahnhofstrasse 5 D-90592 Schwarzenbruck, Germany. It is used to measure the dose in air (μGy), times the area of the x-ray field (m^2). DAP is expressed in μGy- m^2.

For recording the dose-area product, the flat transparent ionization chamber is mounted on window of x-ray tube. This chamber is light-transparent, thus not affect the routine use of the x-ray equipment as shown in figure 3.3.

Figure 3.3 DAP meter placed on an x ray tube with the readout value on display monitor**.**

3.7.4 The patients

Seventy data parameter of pediatric patients who underwent the radiographic-fluoroscopic system of the VCUG procedure include radiation dose the pediatric patients received from VCUG procedure at room 16 fluoroscopy radiology unit, Department of Radiology, Faculty of Medicine, Ramathibodi Hospital.

3.7.5 The patient data record in data recording (Appendix B).

3.8 Methods

3.8.1 The quality control of Radiographic-Fluoroscopic System [12]

The quality control of radiographic-fluoroscopic system was performed for the following topics:

- Dose assessment
- Automatic brightness control test
- Maximum dose rate assessment
- Half value layer (HVL) assessment
- Image quality assessment

The result of quality control of radiographic-fluoroscopic system is reviewed using the tolerance values recommended by AAPM.

3.8.2 DAP meter calibration [13-15]

DAP meter mounted on x-ray tube of the radiographic-fluoroscopic system was calibrated.

The calibration factor N (M_{PKA}/P_{KA}) can be calculated by dividing the readings on the calibrated dose meter with the multiplication of the area exposed, M_{PKA} by the DAP meter P_{KA}.

3.8.3 Collect and record data parameters

The parameters of pediatric patients such as gender, age, height, weight, kVp, mAs, SID, field of view of image intensifier format, focal spot size, frame rate, fluoroscopy frame speed, added filter, fluoroscopic time, cumulative skin dose, cumulative DAP and number of image were recorded from work station system in case record form.

3.8.4 Analyze data

Effective dose will be calculated by using conversion factor from literature review [6].

3.9 Data collection

The parameters of patient collected from work station display system were recorded in case record form as following:

- Gender
- Age
- Height
- Weight
- Number of image
- Image intensifier format
- SID, kVp, mAs
- Focal spot size
- Frame rate
- Fluoroscopy frame speed
- Added filter
- Patient dose collected from DAP meter

3.10 Data analysis

3.10.1 Statistical analysis

This study is observational descriptive statistics for continuous data to determine:

- Mean
- Range (minimum-maximum)
- Median
- 3^{rd} quartile
- Standard deviations (SD)
- 95% confidence interval (CI)

This determination was analyzed using Microsoft Excel for windows evaluation version.

3.10.2 Outcome

- The entrance surface dose (ESD).
- The effective dose.

3.10.3 Outcome measurement

The measurement of this study consists in two types of variables:

- Dependent variable: patient dose.
- Independent variables: kVp, mAs, number of images, patient weight, patient height, fluoroscopy time.

3.11 Data presentation

The table and bar chart are presented.

3.12 Ethical considerations

The prospective patient data was collected after the approval of the ethics committee of Faculty of Medicine, Chulalongkorn University and Mahidol University. The ethical principle in research involving human subjects was considered. Selection of subjects for this research has obviously inclusion and exclusion criteria, non bias. The ethics was approved by ethics committee of Faculty of Medicine, Chulalongkorn University and Mahidol University.

3.13. Expected benefits

3.13.1. Pediatric patient dose received from voiding cystourethrography (VCUG) procedure at Ramathibodi hospital.

3.13.2. The awareness of the radiation dose from voiding cystourethrography (VCUG) procedure.

3.14. Limitation

The number of children at the age range more than 5 years old is less than at the lower age range.

CHAPTER IV

RESULTS

4.1 The quality control of DAP meter

4.1.1 DAP meter calibration

The results of DAP meter calibration (Appendix C).

4.2 The quality control of Radiographic-Fluoroscopic system

4.2.1 The Radiographic-Fluoroscopic system performance test

The Performance of the Radiographic-Fluoroscopic system was studied for the following topics.

- Dose assessment
- Automatic brightness control test
- Maximum dose rate assessment
- Image size assessment
- Half value layer (HVL)
- Image quality assessment

The results of quality control of Radiographic-Fluoroscopic system were within acceptable range of AAPM protocol (Appendix D).

4.3 The data of patient studies

4.3.1 The patient data parameters

The parameters of seventy pediatric patients who underwent the radiographic-fluoroscopic voiding cystourethrography (VCUG) procedure were shown in table 4.1 Among 70 patients there were 45 males and 25 females.

Table 4.1 The patient data parameters from seventy pediatric patients who underwent radiographic-fluoroscopic voiding cystourethrography (VCUG) procedure.

Case No.	Gender (M/F)	Age	Height (cm)	Weight (kg)	BMI (kg/m^2)
1	M	5m	66.00	6.74	15.47
2	M	23d	54.50	3.54	11.91

d, day; m, month; y, year; BMI, body mass index

Table 4.1 The patient data parameters from seventy pediatric patients who underwent radiographic-fluoroscopic of voiding cystourethrography (VCUG) procedure (cont.).

Case No.	Gender (M/F)	Age	Height (cm)	Weight (kg)	BMI (kg/m2)
3	F	3y	83.40	11.80	16.96
4	M	3y	92.00	13.10	15.47
5	F	7y	126.00	33.80	21.28
6	M	2m	51.70	2.95	11.01
7	F	15d	47.60	2.68	11.80
8	M	9m	78.00	11.50	18.90
9	M	2y	93.00	18.10	20.92
10	F	1y	70.20	8.60	17.45
11	M	14d	52.00	3.67	13.57
12	F	9y	113.60	20.50	15.88
13	M	20d	56.50	4.90	15.34
14	M	15y	148.50	37.30	16.91
15	F	8y	133.00	34.20	19.33
16	M	1m	58.20	5.86	17.28
17	F	7y	118.00	21.00	15.08
18	F	2y	89.00	10.90	13.76
19	F	1m	56.00	4.74	15.10
20	M	5m	62.00	7.09	18.43
21	M	4m	64.00	6.81	16.62
22	M	3y	99.60	13.60	13.70
23	M	2m	53.00	4.24	15.08
24	F	6m	65.00	7.20	17.04
25	F	10y	132.00	57.10	32.77
26	M	2y	86.00	12.60	17.03
27	M	6m	75.00	7.87	13.99
28	M	6m	71.70	7.98	15.52
29	M	5y	104.00	15.10	13.96
30	F	5y	108.60	21.00	17.80
31	M	4m	72.00	7.60	14.66
32	M	5y	107.00	16.20	14.14
33	M	2m	52.50	4.40	15.96
34	M	1m	57.00	5.71	17.56
35	F	9y	134.50	37.30	20.61
36	M	6y	114.00	19.60	15.08
37	M	4m	63.00	6.64	16.72
38	F	1y	64.00	7.30	17.82
39	F	4y	104.00	16.50	15.25
40	M	7m	69.60	7.95	16.41
41	F	1y	78.00	9.00	14.79
42	F	3y	95.00	19.25	21.32

d, day; m, month; y, year; BMI, body mass index

Table 4.1 The patient data parameters from seventy pediatric patients who underwent radiographic-fluoroscopic of voiding cystourethrography (VCUG) procedure (cont.).

Case No.	Gender (M/F)	Age	Height (cm)	Weight (kg)	BMI (kg/m^2)
43	M	1y	74.00	8.00	14.60
44	M	4m	61.00	6.06	16.27
45	M	10y	131.00	23.90	13.92
46	M	13y	145.00	34.50	16.40
47	M	5m	74.00	8.18	14.93
48	M	23d	52.00	3.60	13.31
49	M	2m	66.50	5.80	13.11
50	M	4m	63.50	6.78	16.81
51	F	10y	152.00	40.20	17.39
52	F	7m	67.25	7.80	17.24
53	M	52d	52.00	4.50	16.64
54	M	5y	108.00	18.40	15.78
55	M	2y	92.00	12.70	15.00
56	M	2y	92.00	13.70	16.18
57	M	2y	110.00	16.30	13.47
58	M	4m	66.50	7.77	17.55
59	M	5m	67.00	7.90	17.59
60	M	3m	54.50	5.66	19.03
61	F	8y	127.50	25.50	15.68
62	M	3y	97.00	14.00	14.87
63	F	1y	74.50	9.50	17.11
64	F	10y	138.00	33.00	17.32
65	F	8m	70.00	8.30	16.93
66	F	7y	122.00	23.50	15.78
67	M	1y	75.50	10.30	18.06
68	M	1y	74.00	9.70	17.71
69	M	1y	74.00	9.80	17.89
70	F	8m	71.00	8.40	16.66
Mean	-	2.83y	85.29	13.68	16.41
Min.	-	14d	47.60	2.68	11.01
Max.	-	15y	152.00	57.10	32.77
Median	-	1y	74.25	9.25	16.34
SD	-	3.62y	28.29	10.79	2.89
3rd Quartile	-	4.75y	106.25	17.70	17.44

d, day; m, month; y, year; BMI, body mass index

The mean age of patient was 2.83 years with the range from14 day to 15 years, mean height of patient was 85.29 cm with the range from 47.60 to 152 cm, mean weight of patient was 13.68 kg with the range from 2.68 to 57.10 kg, and mean body mass index (BMI) of patient was 16.41 kg/m^2 with the range from 11.01 to 32.77 kg/m^2 respectively.

4.3.2 The data parameterin in male

The data parameter in male (n=45) was shown in table 4.2.

Table 4.2 The patient data parameters in male (n=45) for the radiographic-fluoroscopic voiding cystourethrography (VCUG) procedure.

Case No.	Gender (M/F)	Age	Height (cm)	Weight (kg)	BMI (kg/m^2)
1	M	5m	66.00	6.74	15.47
2	M	23d	54.50	3.54	11.91
4	M	3y	92.00	13.10	15.47
6	M	2m	51.70	2.95	11.01
8	M	9m	78.00	11.50	18.90
9	M	2y	93.00	18.10	20.92
11	M	14d	52.00	3.67	13.57
13	M	20d	56.50	4.90	15.34
14	M	15y	148.50	37.30	16.91
16	M	1m	58.20	5.86	17.28
20	M	5m	62.00	7.09	18.43
21	M	4m	64.00	6.81	16.62
22	M	3y	99.60	13.60	13.70
23	M	2m	53.00	4.24	15.08
26	M	2y	86.00	12.60	17.03
27	M	6m	75.00	7.87	13.99
28	M	6m	71.70	7.98	15.52
29	M	5y	104.00	15.10	13.96
31	M	4m	72.00	7.60	14.66
32	M	5y	107.00	16.20	14.14
33	M	2m	52.50	4.40	15.96
34	M	1m	57.00	5.71	17.56
36	M	6y	114.00	19.60	15.08
37	M	4m	63.00	6.64	16.72
40	M	7m	69.60	7.95	16.41
43	M	1y	74.00	8.00	14.60
44	M	4m	61.00	6.06	16.27
45	M	10y	131.00	23.90	13.92
46	M	13y	145.00	34.50	16.40
47	M	5m	74.00	8.18	14.93
48	M	23d	52.00	3.60	13.31
49	M	2m	66.50	5.80	13.11
50	M	4m	63.50	6.78	16.81
53	M	52d	52.00	4.50	16.64
54	M	5y	108.00	18.40	15.78
55	M	2y	92.00	12.70	15.00

d, day; m, month; y, year; BMI, body mass index

Table 4.2 The patient data parameters in male (n=45) during the radiographic-fluoroscopic of voiding cystourethrography (VCUG) procedure (cont.)

Case No.	Gender (M/F)	Age	Height (cm)	Weight (kg)	BMI (kg/m2)
56	M	2y	92.00	13.70	16.18
57	M	2y	110.00	16.30	13.47
58	M	4m	66.50	7.77	17.55
59	M	5m	67.00	7.90	17.59
60	M	3m	54.50	5.66	19.03
62	M	3y	97.00	14.00	14.87
67	M	1y	75.50	10.30	18.06
68	M	1y	74.00	9.70	17.71
69	M	1y	74.00	9.80	17.89
Mean	-	1.99 y	78.45	10.63	15.79
Min.	-	14d	51.70	2.95	11.01
Max.	-	15y	148.50	37.30	20.92
Median	-	6m	72.00	7.95	15.78
SD	-	3.31y	24.78	7.37	1.97
3rdQuartile	-	2y	92.00	13.60	17.03

d, day; m, month; y, year; BMI, body mass index

The summarized patient data parameters recorded in male (n=45) from voiding cystourethrography (VCUG) procedure were the mean age was 1.99 years with the range from 14 days to 15 years, mean height was 78.45 cm with the range from 51.70 to 148.50 cm, mean weight was 10.63 kg with the range from 2.95 to 37.30 kg, and mean body mass index (BMI) was 15.79 kg/m^2 with the range from 11.01 to 20.92 kg/m^{2}respectively.

4.3.3 The data parameter in female

The data parameter in female (n=25) was shown in table 4.3.

Table 4.3 The patient data parameters in female (n=25) during the radiographic-fluoroscopic of voiding cystourethrography (VCUG) procedure.

Case No.	Gender (M/F)	Age	Height (cm)	Weight (kg)	BMI (kg/m^2)
3	F	3y	83.40	11.80	16.96
5	F	7y	126.00	33.80	21.28
7	F	15d	47.60	2.68	11.80
10	F	1y	70.20	8.60	17.45
12	F	9y	113.60	20.50	15.88
15	F	8y	133.00	34.20	19.33
17	F	7y	118.00	21.00	15.08
18	F	2y	89.00	10.90	13.76

d, day; m, month; y, year; BMI, body mass index

Table 4.3 The patient data parameters in female (n=25) during the radiographic-fluoroscopic of voiding cystourethrography (VCUG) procedure (cont.)

Case No.	Gender (M/F)	Age	Height (cm)	Weight (kg)	BMI (kg/m^2)
19	F	1m	56.00	4.74	15.10
24	F	6m	65.00	7.20	17.04
25	F	10y	132.00	57.10	32.77
30	F	5y	108.60	21.00	17.80
35	F	9y	134.50	37.30	20.61
38	F	1y	64.00	7.30	17.82
39	F	4y	104.00	16.50	15.25
41	F	1y	78.00	9.00	14.79
42	F	3y	95.00	19.25	21.32
51	F	10y	152.00	40.20	17.39
52	F	7m	67.25	7.80	17.24
61	F	8y	127.50	25.50	15.68
63	F	1y	74.50	9.50	17.11
64	F	10y	138.00	33.00	17.32
65	F	8m	70.00	8.30	16.93
66	F	7y	122.00	23.50	15.78
70	F	8m	71.00	8.40	16.66
Mean	-	4.34y	97.61	19.16	17.53
Min.	-	15d	47.60	2.68	11.80
Max.	-	10y	152.00	57.10	32.77
Median	-	3y	95.00	16.50	17.04
SD	-	3.73y	30.47	13.65	3.85
3rd Quartile	-	8y	126.00	25.50	17.80

d, day; m, month; y, year; BMI, body mass index

The summarized patient data parameters recorded in female (n=25) from voiding cystourethrography (VCUG) procedure were the mean age of 4.34 years with the range from 15 days to 10 years, mean height 97.61 cm with the range from 47.60 to 152.00 cm, mean weight 19.16 kg with the range from 2.68 to 57.10 kg, and mean body mass index (BMI) of patient 17.53 kg/m^2 with the range from 11.80 to 32.77 kg/m^2 respectively.

4.3.4 The data parameter of pediatric patient were divided by age range

The data parameter of pediatric patient were divided by age range as shown in tables 4.4, 4.5 and 4.6

Table 4.4 The height of pediatric patient (n=70) was divided by age range

Age range (years)	No. of patient	Height (cm)					
		Mean	Minimum	Maximum	Median	SD	3rd Quartile
0-1	32	62.20	47.60	78.00	63.25	8.22	67.84
>1-5	20	85.86	64.00	110.00	87.50	12.42	93.50
>5-10	12	118.02	104.00	134.50	116.00	10.48	126.38
>10-15	6	141.08	131.00	152.00	141.50	8.75	147.63

Table 4.5 The weight of pediatric patient (n=70) was divided by age range

Age range (years)	No. of patient	Weight (kg)					
		Mean	Minimum	Maximum	Median	SD	3rd Quartile
0-1	32	6.27	2.68	11.50	6.69	1.97	7.82
>1-5	20	12.24	7.30	19.25	12.20	3.39	13.78
>5-10	12	23.84	15.10	37.30	21.00	7.39	27.58
>10-15	6	37.67	23.90	57.10	35.90	11.00	39.48

Table 4.6 The body mass index (BMI) of pediatric patient (n=70) was divided by age range

Age range (years)	No. of patient	Body mass index (BMI) (kg/m^2)					
		Mean	Minimum	Maximum	Median	SD	3rd Quartile
0-1	32	15.76	11.01	19.03	16.34	2.03	17.09
>1-5	20	16.47	13.47	21.32	16.57	2.19	17.74
>5-10	12	16.70	13.96	21.28	15.78	2.47	18.18
>10-15	6	19.12	13.92	32.77	17.12	6.81	17.37

In age range 0-1 years (n=32), mean height was 62.20 cm with the range from 47.60 to 78.00 cm, mean weight of patient was 6.27 kg with the range from 2.68 to 11.50 kg, and mean body mass index (BMI) of patient was 15.76 kg /m^2 with the range from 11.01 to 19.03 kg /m^2 respectively.

In age range >1-5 years (n=20), mean height was 85.86 cm with the range from 64.00 to 110.00 cm, mean weight was 12.24 kg with the range from 7.30 to 19.25 kg, and mean body mass index (BMI) was 16.47 kg /m^2 with the range from 13.47 to 21.32 kg /m^2 respectively.

In age range >5-10 years (n=12), mean height was 118.02 cm with the range from 104.00 to 134.50 cm, mean weight was 23.84 kg with the range from 15.10 to 37.30 kg, and mean body mass index (BMI) was 16.70 kg /m^2 with the range from 13.96 to 21.28 kg /m^2 respectively.

In age range >10-15 years (n=6), mean height was 141.08 cm with the range from 131.00 to 152.00 cm, mean weight was 37.67 kg with the range from 23.90 to 57.10 kg, and mean body mass index (BMI) of patient was 19.12 kg /m^2 with the range from 13.92 to 32.77 kg /m^2 respectively.

4.4 The data parameters of exposure technique and pediatric patient dose recorded from pediatric patient underwent the radiographic-fluoroscopic of voiding cystourethrography (VCUG) procedure.

4.4.1 The data parameters of exposure technique and pediatric patient dose recorded in all patients.

The data parameters of exposure technique and pediatric patient dose recorded from pediatric patient who underwent the radiographic-fluoroscopic voiding cystourethrography (VCUG) procedure performed by radiographic-fluoroscopic system manufacturer Philips model Omni Diagnost Eleva such as fluoroscopic time, number of exposures, frame rate, mean image intensifier (II) format, mean tube voltage (kVp), mean tube current-time (mAs), cumulative skin dose and cumulative dose area product (DAP) were shown in table 4.7.

Table 4.7 The data parameters of exposure technique and pediatric patient dose recorded from pediatric patient who underwent the radiographic-fluoroscopic voiding cystourethrography (VCUG) procedure.

Case No.	FT (min)	No. of exposure	Frame rate (f/s)	Mean II format (cm)	Mean kVp	Mean mAs	Cumulative skin dose (mGy)	Cumulative DAP ($cGycm^2$)
1	2.07	45	3	20.63	67.00	1.67	3	34.75
2	4.22	88	3	20.91	65.36	1.00	4	40.80
3	2.23	52	3	32.40	70.53	1.72	4	107.80
4	1.90	23	3	32.40	70.33	1.90	2	57.00
5	1.90	43	3	31.00	80.00	9.78	23	546.02
6	6.52	21	3	20.00	65.13	0.89	4	36.57
7	3.40	99	3	18.71	66.00	1.15	5	41.23
8	1.80	69	3	30.07	67.00	2.72	9	152.54
9	2.75	42	3	32.09	68.09	3.10	5	169.85
10	1.38	14	3	28.71	67.00	2.40	2	37.25
11	1.72	45	3	21.00	66.77	2.17	3	59.71
12	3.25	11	3	25.00	79.64	4.23	8	143.80
13	1.03	28	3	22.29	67.00	1.39	2	21.02
14	2.55	51	3	32.40	78.27	7.27	15	240.26
15	2.77	19	3	29.67	80.00	8.03	13	339.20
16	2.62	13	3	20.57	66.75	1.84	2	26.02
17	2.12	18	3	20.94	78.61	5.75	10	161.73
18	2.63	13	3	21.62	70.69	3.29	4	47.70
19	2.45	24	3	17.46	67.00	1.82	3	24.10
20	2.78	19	3	19.00	67.00	3.05	4	35.04

FT, fluoroscopy time; II, image intensifier; DAP, dose area product

Table 4.7 The data parameters of exposure technique and pediatric patient dose recorded from pediatric patient who underwent the radiographic-fluoroscopic voiding cystourethrography (VCUG) procedure (cont.).

Case No.	FT (min)	No. of exposure	Frame rate (f/s)	Mean II format (cm)	Mean kVp	Mean mAs	Cumulative skin dose (mGy)	Cumulative DAP (cGycm^2)
21	2.78	33	3	21.31	67.00	2.24	4	42.72
22	7.65	63	3	27.93	70.68	2.68	15	258.70
23	2.63	18	3	22.00	66.13	1.08	2	22.85
24	2.02	35	3	25.10	67.00	1.16	2	34.08
25	4.88	18	3	31.23	84.92	16.53	42	1110.54
26	7.70	22	3	29.08	71.00	2.47	11	206.30
27	3.73	23	3	20.36	67.00	2.14	4	45.98
28	3.22	32	3	21.60	67.00	1.88	3	30.53
29	3.88	15	3	35.40	71.00	2.12	3	88.90
30	4.73	75	3	36.53	71.16	4.27	16	498.00
31	3.13	25	3	22.59	67.00	3.75	4	100.61
32	2.20	30	3	25.86	71.29	4.67	10	141.40
33	3.38	60	3	21.06	66.75	1.79	5	66.34
34	1.03	28	3	23.38	65.63	1.05	2	24.32
35	3.40	33	3	31.77	80.00	5.96	22	506.37
36	1.73	21	3	24.00	71.78	4.66	10	115.74
37	2.28	40	3	19.62	67.00	2.07	8	65.57
38	2.43	68	3	20.62	66.69	2.98	15	160.70
39	2.10	43	3	28.56	71.78	5.32	9	195.90
40	1.45	16	3	23.29	67.43	3.41	3	42.72
41	1.98	28	3	23.27	67.09	3.20	6	76.42
42	2.83	25	3	27.67	71.50	5.45	12	198.94
43	2.02	27	3	23.22	67.00	2.96	5	61.92
44	1.52	32	3	22.30	66.50	1.64	2	27.46
45	3.18	49	3	33.55	72.82	2.79	12	275.58
46	2.65	28	3	34.50	78.13	4.77	10	283.97
47	2.30	37	3	28.82	66.91	0.95	2	29.47
48	3.32	24	3	25.60	65.30	0.92	1	21.15
49	1.45	25	3	26.71	77.00	2.09	2	60.63
50	2.13	30	3	25.75	76.00	0.90	2	27.55
51	6.92	55	3	38.00	78.50	4.91	26	765.95
52	2.08	20	3	28.10	66.90	2.10	2	39.36
53	3.12	70	3	26.38	63.77	0.79	3	37.08
54	2.05	26	3	27.00	71.00	4.83	6	118.10
55	2.73	25	3	22.90	71.00	2.93	6	84.70
56	3.05	22	3	24.09	70.55	3.01	5	88.70
57	2.58	28	3	22.77	70.31	3.72	5	90.90

FT, fluoroscopy time; II, image intensifier; DAP, dose area product

Table 4.7 The data parameters of exposure technique and pediatric patient dose recorded from pediatric patient who underwent the radiographic-fluoroscopic voiding cystourethrography (VCUG) procedure (cont.).

Case No.	FT (min)	No. of exposure	Frame rate (f/s)	Mean II format (cm)	Mean kVp	Mean mAs	Cumulative skin dose (mGy)	Cumulative DAP ($cGycm^2$)
58	2.50	52	3	20.42	66.92	2.04	7	62.69
59	4.07	15	3	20.64	66.56	1.35	6	75.94
60	2.48	25	3	23.20	67.00	1.20	3	34.37
61	2.08	44	3	35.00	72.78	4.46	9	327.71
62	4.15	79	3	22.25	71.17	3.93	16	220.70
63	2.68	18	3	20.89	67.00	2.10	4	44.45
64	6.15	76	3	35.50	71.81	3.39	18	534.69
65	0.73	29	3	25.75	66.75	1.09	1	22.27
66	5.30	33	3	38.00	72.20	2.54	11	358.39
67	2.73	47	3	33.00	67.00	1.77	4	90.82
68	1.63	24	3	27.25	67.00	2.89	4	54.82
69	0.87	15	3	19.22	66.44	1.78	2	19.87
70	2.08	20	3	28.10	66.90	2.10	2	39.36
Mean	2.88	35.	3	25.97	69.95	3.09	7.27	146.49
Min.	0.73	11.00	3	17.46	63.77	0.79	1.00	19.87
Max.	7.70	99.00	3	38.00	84.92	16.53	42.00	1110.54
Median	2.60	28.00	3	25.05	67.00	2.44	4.50	65.95
SD	1.47	19.82	-	5.33	4.63	2.41	7.00	190.93
3rd Quartile	3.24	45.	3	29.52	71.45	3.74	10.00	167.82

FT, fluoroscopy time; II, image intensifier; DAP, dose area product

The mean fluoroscopy time was 2.88 min with the range from 0.73 to 7.70 min, mean number of exposure was 35.19 exposures with the range from 11 to 99 exposures, mean image intensifier (II) format was 25.97 cm with the range from 17.46 to 38.00 cm, mean tube voltage (kVp) was 69.95 with the range from 63.77 to 84.92, mean tube current-time (mAs) was 3.09 with the range from 0.79 to 16.53, mean cumulative skin dose was 7.27 mGy with the range from1.00 to 42.00 mGy, and mean cumulative dose area product (DAP) was 146.49 $cGycm^2$ with the rang from 19.87 to 1110.54 $cGycm^2$

4.4.2 The data parameters of exposure technique and pediatric patient dose recorded in male

The pediatric patient data parameters of exposure technique and pediatric patient dose recorded in male (n=45) who underwent the radiographic-fluoroscopic Voiding cystourethrography (VCUG) procedure such as fluoroscopic time, number of exposure, mean image intensifier (II) format, mean tube voltage (kVp), mean tube current-time (mAs), cumulative skin dose, and cumulative dose-area product (DAP) were shown in table 4.8.

Table 4.8 The data parameters of exposure technique and pediatric patient dose that was recorded in male (n=45) who underwent the radiographic-fluoroscopic of voiding cystourethrogrphy (VCUG) procedure.

Case No.	FT (min)	No. of exposure	Frame rate (f/s)	Mean II format (cm)	Mean kVp	Mean mAs	Cumulative skin dose (mGy)	Cumulative DAP ($cGycm^2$)
1	2.07	45	3	20.63	67.00	1.67	3	34.75
2	4.22	88	3	20.91	65.36	1.00	4	40.80
4	1.90	23	3	32.40	70.33	1.90	2	57.00
6	6.52	21	3	20.00	65.13	0.89	4	36.57
8	1.80	69	3	30.07	67.00	2.72	9	152.54
9	2.75	42	3	32.09	68.09	3.10	5	169.85
11	1.72	45	3	21.00	66.77	2.17	3	59.71
13	1.03	28	3	22.29	67.00	1.39	2	21.02
14	2.55	51	3	32.40	78.27	7.27	15	240.26
16	2.62	13	3	20.57	66.75	1.84	2	26.02
20	2.78	19	3	19.00	67.00	3.05	4	35.04
21	2.78	33	3	21.31	67.00	2.24	4	42.72
22	7.65	63	3	27.93	70.68	2.68	15	258.70
23	2.63	18	3	22.00	66.13	1.08	2	22.85
26	7.70	22	3	29.08	71.00	2.47	11	206.30
27	3.73	23	3	20.36	67.00	2.14	4	45.98
28	3.22	32	3	21.60	67.00	1.88	3	30.53
29	3.88	15	3	35.40	71.00	2.12	3	88.90
31	3.13	25	3	22.59	67.00	3.75	4	100.61
32	2.20	30	3	25.86	71.29	4.67	10	141.40
33	3.38	60	3	21.06	66.75	1.79	5	66.34
34	1.03	28	3	23.38	65.63	1.05	2	24.32
36	1.73	21	3	24.00	71.78	4.66	10	115.74
37	2.28	40	3	19.62	67.00	2.07	8	65.57
40	1.45	16	3	23.29	67.43	3.41	3	42.72
43	2.02	27	3	23.22	67.00	2.96	5	61.92
44	1.52	32	3	22.30	66.50	1.64	2	27.46
45	3.18	49	3	33.55	72.82	2.79	12	275.58
46	2.65	28	3	34.50	78.13	4.77	10	283.97
47	2.30	37	3	28.82	66.91	0.95	2	29.47
48	3.32	24	3	25.60	65.30	0.92	1	21.15
49	1.45	25	3	26.71	77.00	2.09	2	60.63
50	2.13	30	3	25.75	76.00	0.90	2	27.55
53	3.12	70	3	26.38	63.77	0.79	3	37.08
54	2.05	26	3	27.00	71.00	4.83	6	118.10
55	2.73	25	3	22.90	71.00	2.93	6	84.70
56	3.05	22	3	24.09	70.55	3.01	5	88.70
57	2.58	28	3	22.77	70.31	3.72	5	90.90

FT, fluoroscopy time; II, image intensifier; DAP, dose area product

Table 4.8 The data parameters of exposure technique and pediatric patient dose that was recorded in male (n=45) who underwent the radiographic-fluoroscopic of voiding cystourethrogrphy (VCUG) procedure (cont.).

Case No.	FT (min)	No. of exposure	Frame rate (f/s)	Mean II format (cm)	Mean kVp	Mean mAs	Cumulative skin dose (mGy)	Cumulative DAP (cGycm^2)
58	2.50	52	3	20.42	66.92	2.04	7	62.69
59	4.07	15	3	20.64	66.56	1.35	6	75.94
60	2.48	25	3	23.20	67.00	1.20	3	34.37
62	4.15	79	3	22.25	71.17	3.93	16	220.70
67	2.73	47	3	33.00	67.00	1.77	4	90.82
68	1.63	24	3	27.25	67.00	2.89	4	54.82
69	0.87	15	3	19.22	66.44	1.78	2	19.87
Mean	2.83	34.	3	24.85	68.75	2.45	5.33	86.50
Min.	0.87	13.00	3	19.00	63.77	0.79	1.00	19.87
Max.	7.70	88.00	3	35.40	78.27	7.27	16.00	283.97
Median	2.62	28.00	3	23.22	67.00	2.12	4.00	60.63
SD	1.46	18.	-	4.60	3.45	1.34	3.84	73.96
3rd Quartile	3.18	45.00	3	27.25	71.00	3.01	6.00	100.61

FT, fluoroscopy time; II, image intensifier; DAP, dose area product

The summarized patient data parameters recorded in male (n=45) from voiding cystourethrography (VCUG) procedure. The mean fluoroscopy time was 2.83 min with the range from 0.87 to 7.70 min, mean number of exposure was 34.44 with the range from 13.00 to 88.00 , mean image intensifier (II) format was 24.85 cm with the range from 19.00 to 35.40 cm, mean n tube voltage (kVp) was 68.75 with the range from 63.77 to 78.27, mean tube current-time (mAs) was 2.45 with the range from 0.79 to 7.27, mean cumulative skin dose was 5.33 mGy with the range from 1.00 to 16.00 mGy, and mean cumulative dose area product (DAP) was 86.50 cGycm^2 with the range from 19.87 to 283.97 cGycm^2.

4.4.3 The data parameters of exposure technique and pediatric patient dose recorded in female.

The data parameters of exposure technique and pediatric patient dose recorded in female (n=25) such as fluoroscopic time, number of exposure, mean image intensifier (II) format, mean tube voltage (kVp), mean tube current-time (mAs), cumulative skin dose, and cumulative dose area product (DAP) were shown in table 4.9.

Table 4.9 The data parameters of exposure technique and pediatric patient dose recorded in <u>female</u> (n=25) who underwent the radiographic-fluoroscopic of voiding cystourethrogrphy (VCUG) procedure.

Case No.	FT (min)	No. of exposure	Frame rate (f/s)	Mean II format (cm)	Mean kVp	Mean mAs	Cumulative skin dose (mGy)	Cumulative DAP (cGycm^2)
3	2.23	52	3	32.40	70.53	1.72	4	107.80
5	1.90	43	3	31.00	80.00	9.78	23	546.02
7	3.40	99	3	18.71	66.00	1.15	5	41.66
10	1.38	14	3	28.71	67.00	2.40	2	37.25
12	3.25	11	3	25.00	79.64	4.23	8	143.80
15	2.77	19	3	29.67	80.00	8.03	13	339.20
17	2.12	18	3	20.94	78.61	5.75	10	161.73
18	2.63	13	3	21.62	70.69	3.29	4	47.70
19	2.45	24	3	17.46	67.00	1.82	3	24.10
24	2.02	35	3	25.10	67.00	1.16	2	34.08
25	4.88	18	3	31.23	84.92	16.53	42	1110.54
30	4.73	75	3	36.53	71.16	4.27	16	498.00
35	3.40	33	3	31.77	80.00	5.96	22	506.37
38	2.43	68	3	20.62	66.69	2.98	15	160.70
39	2.10	43	3	28.56	71.78	5.32	9	195.90
41	1.98	28	3	23.27	67.09	3.20	6	76.42
42	2.83	25	3	27.67	71.50	5.45	12	198.94
51	6.92	55	3	38.00	78.50	4.91	26	765.95
52	2.08	20	3	28.10	66.90	2.10	2	39.36
61	2.08	44	3	35.00	72.78	4.46	9	327.71
63	2.68	18	3	20.89	67.00	2.10	4	44.45
64	6.15	76	3	35.50	71.81	3.39	18	534.69
65	0.73	29	3	25.75	66.75	1.09	1	22.27
66	5.30	33	3	38.00	72.20	2.54	11	358.39
70	2.08	20	3	28.10	66.90	2.10	2	39.36
Mean	2.98	36.52	3	27.98	72.10	4.23	10.76	254.50
Min	0.73	11.00	3	17.46	66.00	1.09	1.00	22.27
Max	6.92	99.00	3	38.00	84.92	16.53	42.00	1110.54
Median	2.45	29.00	3	28.10	71.16	3.29	9.00	160.70
SD	1.50	23.00	-	6.03	5.69	3.35	9.70	275.45
3rd Quartile	3.40	44.00	3	31.77	78.50	5.32	15.00	358.39

FT, fluoroscopy time; II, image intensifier; DAP, dose-area product

The summarized patient data parameters recorded in female (n=25) from voiding cystourethrography (VCUG) procedure were the mean fluoroscopy time at 2.98 min with the range from 0.73 to 6.92 min, mean number of exposure was 36.52 exposures with the range from 11.00 to 99.00 exposures, mean image intensifier (II) format was 27.98 cm with the range from 17.46 to 38.00 cm, mean tube voltage (kVp) was 72.10 with the range from 66.00 to 84.92, mean tube current-time (mAs) was 4.23 with the range from 1.09 to 16.53, mean cumulative skin dose was 10.76 mGy with the range from 1.00 to 42.00 mGy, and mean cumulative dose-area product (DAP) was 254.50 cGycm^2 with the range from 22.27 to 1110.54 cGycm^2.

4.4.4 The data parameters of exposure technique and dose recorded in pediatric patient who underwent the radiographic-fluoroscopic of voiding cystorethrography (VCUG) procedure were divided by age range.

The data parameters of exposure technique and pediatric patient dose recorded in pediatric patient who underwent the radiographic-fluoroscopic of voiding cystorethrography (VCUG) procedure were divided into age range as shown in table 4.10 to 4.16.

Table 4.10 The fluoroscopy time of pediatric patient (n=70) who underwent the radiographic-fluoroscopic of voiding cystourethrogrphy (VCUG) procedure in various age range.

Age range (years)	No. of patient	Fluoroscopy time (min)					
		Mean	Minimum	Maximum	Median	SD	3rd Quartile
0-1	32	2.56	0.73	6.52	2.47	1.13	3.15
>1-5	20	2.90	0.87	7.70	2.61	1.77	2.77
>5-10	12	2.95	1.73	5.30	2.48	1.18	3.52
>10-15	6	4.39	2.55	6.92	4.03	1.88	5.83

Table 4.11 The number of exposure of pediatric patient (n=70) who underwent the radiographic-fluoroscopic of voiding cystourethrogrphy (VCUG) procedure in various age range.

Age range (years)	No. of patient	Number of exposure (exposure)					
		Mean	Minimum	Maximum	Median	SD	3rd Quartile
0-1	32	35.63	13.00	99.00	28.50	21.04	41.25
>1-5	20	33.90	13.00	79.00	26.00	19.07	44.00
>5-10	12	30.67	11.00	75.00	28.00	17.45	35.50
>10-15	6	46.17	18.00	76.00	50.00	20.61	54.00

Table 4.12 The mean image intensifier (II) format of pediatric patient (n=70) who underwent the radiographic-fluoroscopic of voiding cystourethrogrphy (VCUG) procedure in various age range.

Age range (years)	No. of patient	Mean image intensifier (II) format (cm)					
		Mean	Minimum	Maximum	Median	SD	3rd Quartile
0-1	32	22.90	17.46	30.07	22.15	3.23	25.64
>1-5	20	26.00	19.22	33.00	25.67	4.43	28.80
>5-10	12	30.01	20.94	38.00	30.34	5.51	35.10
>10-15	6	34.20	31.23	38.00	34.03	2.40	35.25

Table 4.13 The mean kVp of pediatric patient (n=70) who underwent the radiographic-fluoroscopic of voiding cystourethrogrphy (VCUG) procedure in various age range.

Age range (years)	No. of patient	Mean kVp					
		Mean	Minimum	Maximum	Median	SD	3rd Quartile
0-1	32	67.17	63.77	77.00	66.92	2.57	67.00
>1-5	20	69.14	66.44	71.78	70.32	2.01	70.77
>5-10	12	74.96	71.00	80.00	72.49	4.19	79.73
>10-15	6	77.41	71.81	84.92	78.20	4.72	78.44

Table 4.14 The mean mAs of pediatric patient (n=70) who underwent the radiographic-fluoroscopic of voiding cystourethrogrphy (VCUG) procedure in various age range.

Age range (years)	No. of patient	Mean mAs					
		Mean	Minimum	Maximum	Median	SD	3rd Quartile
0-1	32	1.73	0.79	3.75	1.73	0.75	2.10
>1-5	20	2.98	1.72	5.45	2.95	1.03	3.22
>5-10	12	5.11	2.12	9.78	4.67	2.12	5.80
>10-15	6	6.61	2.79	16.53	4.84	5.10	6.68

Table 4.15 The cumulative skin dose of pediatric patient (n=70) who underwent the radiographic-fluoroscopic of voiding cystourethrogrphy (VCUG) procedure in various age range.

Age range (years)	No. of patient	Cumulative skin dose (mGy)					
		Mean	Minimum	Maximum	Median	SD	3rd Quartile
0-1	32	3.41	1.00	9.00	3.00	1.92	4.00
>1-5	20	6.80	2.00	16.00	5.00	4.54	9.50
>5-10	12	11.75	3.00	23.00	10.00	5.97	13.75
>10-15	6	20.50	10.00	42.00	16.50	11.93	24.00

Table 4.16 The cumulative DAP of pediatric patient (n=70) who underwent the radiographic-fluoroscopic of voiding cystourethrogrphy (VCUG) procedure in various age range.

Age range (years)	No. of patient	Cumulative DAP ($cGycm^2$)					
		Mean	Minimum	Maximum	Median	SD	3rd Quartile
0-1	32	44.54	21.02	152.54	36.82	26.86	49.42
>1-5	20	113.67	19.87	258.70	89.76	71.65	176.36
>5-10	12	278.78	88.90	546.02	244.72	171.33	393.29
>10-15	6	535.17	240.26	1110.54	409.33	346.92	708.13

In age range 0-1 years (n=32), mean fluoroscopy time was 2.56 min with the range from 0.73 to 6.52 min, mean number of exposure was 35.63 exposures with the range from 13.00 to 99.00 exposures, mean of mean image intensifier (II) format was 22.90 cm with the range from 17.46 to 30.07 cm, mean kVp was 67.17 with the range from 63.77 to 77.00, mean mAs was 1.73 with the range from 0.79 to 3.75, mean cumulative skin dose was 3.41 mGy with the range from 1.00 to 9.00 mGy, and mean cumulative DAP was 44.54 $cGycm^2$ with the range from 21.02 to 152.54 $cGycm^2$ respectively.

In age range >1-5 years (n=20), mean fluoroscopy time was 2.90 min with the range from 0.87 to 7.70 min, mean number of exposure was 33.90 exposures with the range from 13.00 to 79.00 exposures, mean of mean image intensifier (II) format was 26.00 cm with the range from 19.22 to 33.00 cm, mean kVp was 69.14 with the range from 66.44 to 71.78, mean mAs was 2.98 with the range from 1.72 to 5.45, mean cumulative skin dose was 6.80 mGy with the rang from 2.00 to 16.00 mGy, and mean cumulative DAP was 113.67 $cGycm^2$ with the range from 19.87 to 258.70 $cGycm^2$ respectively.

In age range >5-10 years (n=12), mean fluoroscopy time was 2.95 min with the range from 1.73 to 5.30 min, mean number of exposure was 30.67 exposures with the range from 11.00 to 75.00 exposures, mean image intensifier (II) format was 30.01 cm with the range from 20.94 to 38.00 cm, mean kVp was 74.96 with the range from 71.00 to 80.00, mean mAs was 5.11 with the range from 2.12 to 9.78, mean cumulative skin dose was 11.75 mGy with the range from 3.00 to 23.00 mGy, and mean cumulative DAP was 278.78 $cGycm^2$ with the range from 88.90 to 546.02 $cGycm^2$ respectively.

In age range >10-15 years (n=6), mean fluoroscopy time was 4.39 min with the range from 2.55 to 6.92 min, mean number of exposure was 46.17 exposures with the range from 18.00 to 76.00 exposures, mean image intensifier (II) format was 34.20 cm with the range from 31.23 to 38.00 cm, mean kVp was 77.41 with the range from 71.81 to 84.92, mean mAs was 6.61 with the range from 2.79 to 16.53, mean cumulative skin dose was 20.50 mGy with the rang from 10.00 to 42.00 mGy, and mean cumulative DAP was 535.17 $cGycm^2$ with the range from 240.26 to 1110.54 $cGycm^2$ respectively.

4.5 The effective dose (E) the pediatric patient received from the radiographic-fluoroscopic of voiding cystourethrography (VCUG) procedure.

The effective dose (E) that pediatric patient received from the radiographic-fluoroscopic voiding cystourethrography (VCUG) procedure was calculated from the conversion coefficient of 0.21 mSv per $Gycm^2$ [6] multiplied by dose area product (DAP) as shown in table 4.17.

Table 4.17 The radiation dose of pediatric patient (n=70) who underwent the radiographic-fluoroscopic of voiding cystourethrogrphy (VCUG) procedure.

Case no.	Radiation dose	
	Dose-area product (DAP) ($cGycm^2$)	Effective dose (E) (mSv)
1	34.75	0.07
2	40.80	0.09
3	107.80	0.23
4	57.00	0.12
5	546.02	1.15
6	36.57	0.08
7	41.23	0.09
8	152.54	0.32
9	169.85	0.36
10	37.25	0.08
11	59.71	0.13
12	143.80	0.30
13	21.02	0.04
14	240.26	0.50
15	339.20	0.71
16	26.02	0.05
17	161.73	0.34
18	47.70	0.10
19	24.10	0.05
20	35.04	0.07
21	42.72	0.09
22	258.70	0.54
23	22.85	0.05
24	34.08	0.07
25	1110.54	2.33
26	206.30	0.43
27	45.98	0.10
28	30.53	0.06
29	88.90	0.19
30	498.00	1.05

Table 4.17 The radiation dose of pediatric patient (n=70) who underwent the radiographic-fluoroscopic of voiding cystourethrogrphy (VCUG) procedure (cont.).

Case no.	Radiation dose	
	Dose-area product (DAP) ($cGycm^2$)	Effective dose (E) (mSv)
31	100.61	0.21
32	141.40	0.30
33	66.34	0.14
34	24.32	0.05
35	506.37	1.06
36	115.74	0.24
37	65.57	0.14
38	160.70	0.34
39	195.90	0.41
40	42.72	0.09
41	76.42	0.16
42	198.94	0.42
43	61.92	0.13
44	27.46	0.06
45	275.58	0.58
46	283.97	0.60
47	29.47	0.06
48	21.15	0.04
49	60.63	0.13
50	27.55	0.06
51	765.95	1.61
52	39.36	0.08
53	37.08	0.08
54	118.10	0.25
55	84.70	0.18
56	88.70	0.19
57	90.90	0.19
58	62.69	0.13
59	75.94	0.16
60	34.37	0.07
61	327.71	0.69
62	220.70	0.46
63	44.45	0.09
64	534.69	1.12
65	22.27	0.05
66	358.39	0.75
67	90.82	0.19
68	54.82	0.12
69	19.87	0.04
70	39.36	0.08

Table 4.17 The radiation dose of pediatric patient (n=70) who underwent the radiographic-fluoroscopic of voiding cystourethrogrphy (VCUG) procedure (cont.).

Case no.	Radiation dose	
	Dose-area product (DAP) ($cGycm^2$)	Effective dose (E) (mSv)
Mean	146.49	0.31
Min	19.87	0.04
Max	1110.54	2.33
Median	65.95	0.14
SD	190.93	0.40
3rd Quartile	167.82	0.35

The mean effective dose of pediatric patient that was calculated was 0.31 mSv with the range from 0.04 to 2.33 mSv.

The effective dose in male pediatric patients were shown in table 4.18

Table 4.18 The radiation dose of male pediatric patient (n=45) who underwent the radiographic-fluoroscopic of voiding cystourethrogrphy (VCUG) procedure.

Case no.	Radiation dose	
	Dose-area product (DAP) ($cGycm^2$)	Effective dose (E) (mSv)
1	34.75	0.07
2	40.80	0.09
4	57.00	0.12
6	36.57	0.08
8	152.54	0.32
9	169.85	0.36
11	59.71	0.13
13	21.02	0.04
14	240.26	0.50
16	26.02	0.05
20	35.04	0.07
21	42.72	0.09
22	258.70	0.54
23	22.85	0.05
26	206.30	0.43
27	45.98	0.10
28	30.53	0.06
29	88.90	0.19
31	100.61	0.21
32	141.40	0.30
33	66.34	0.14
34	24.32	0.05

Table 4.18 The radiation dose of male pediatric patient (n=45) who underwent the radiographic-fluoroscopic of voiding cystourethrography (VCUG) procedure (cont.).

Case no.	Radiation dose	
	Dose-area product (DAP) ($cGycm^2$)	Effective dose (E) (mSv)
36	115.74	0.24
37	65.57	0.14
40	42.72	0.09
43	61.92	0.13
44	27.46	0.06
45	275.58	0.58
46	283.97	0.60
47	29.47	0.06
48	21.15	0.04
49	60.63	0.13
50	27.55	0.06
53	37.08	0.08
54	118.10	0.25
55	84.70	0.18
56	88.70	0.19
57	90.90	0.19
58	62.69	0.13
59	75.94	0.16
60	34.37	0.07
62	220.70	0.46
67	90.82	0.19
68	54.82	0.12
69	19.87	0.04
Mean	86.50	0.18
Min	19.87	0.04
Max	283.97	0.60
Median	60.63	0.13
SD	73.96	0.16
3rd Quartile	100.61	0.21

The mean effective dose of male pediatric patient that was calculated was 0.18 mSv with the range from 0.04 to 0.60 mSv.

The effective dose in female pediatric patients were shown in table 4.19

Table 4.19 The radiation dose of female pediatric patient (n=25) who underwent the radiographic-fluoroscopic of voiding cystourethrogrphy (VCUG) procedure.

Case no.	Radiation dose	
	Dose-area product (DAP) ($cGycm^2$)	Effective dose (E) (mSv)
3	107.80	0.23
5	546.02	1.15
7	41.66	0.09
10	37.25	0.08
12	143.80	0.30
15	339.20	0.71
17	161.73	0.34
18	47.70	0.10
19	24.10	0.05
24	34.08	0.07
25	1110.54	2.33
30	498.00	1.05
35	506.37	1.06
38	160.70	0.34
39	195.90	0.41
41	76.42	0.16
42	198.94	0.42
51	765.95	1.61
52	39.36	0.08
61	327.71	0.69
63	44.45	0.09
64	534.69	1.12
65	22.27	0.05
66	358.39	0.75
70	39.36	0.08
Mean	254.50	0.53
Min	22.27	0.05
Max	1110.54	2.33
Median	160.70	0.34
SD	275.45	0.58
3rd Quartile	358.39	0.75

The mean effective dose of female pediatric patient that was calculated was 0.53 mSv with the range from 0.05 to 2.33 mSv.

The effective dose of pediatric patient underwent the radiographic-fluoroscopic of voiding cystourethography (VCUG) procedure divided by age range were shown in table 4.20

Table 4.20 The radiation dose of pediatric patient (n=70) who underwent the radiographic-fluoroscopic of voiding cystourethrogrphy (VCUG) procedure were divided by age rang.

Age range (years)	No. of patient	Effective dose (mSv)					
		Mean	Minimum	Maximum	Median	SD	3rd Quartile
0-1	32	0.09	0.04	0.32	0.08	0.06	0.10
>1-5	20	0.24	0.04	0.54	0.19	0.15	0.37
>5-10	12	0.59	0.19	1.15	0.51	0.36	0.83
>10-15	6	1.12	0.50	2.33	0.86	0.73	1.49

The mean effective dose of pediatric patient in age range 0-1 years was 0.09 mSv with the range 0.04 to 0.32 mSv, in age range >1-5 years was 0.24 mSv with the range 0.04 to 0.54 mSv, in age range >5-10 years was 0.59 mSv with the range 0.19 to 1.15 mSv, and in age range >10-15 years was 1.12 mSv with the rang 0.50 to 2.33 mSv respectively.

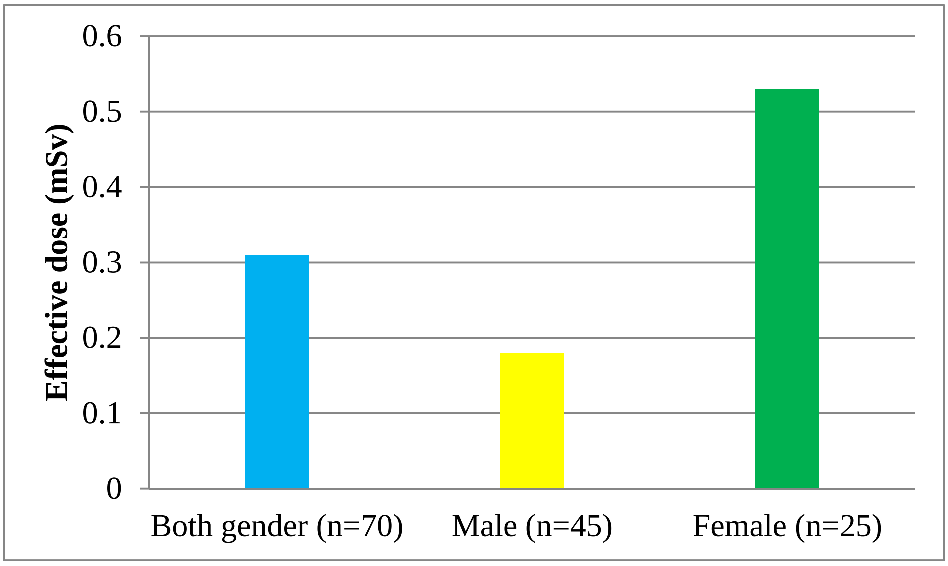


Figure 4.1 The mean effective dose between both gender (n=70), male (n=45) and female (n=25).

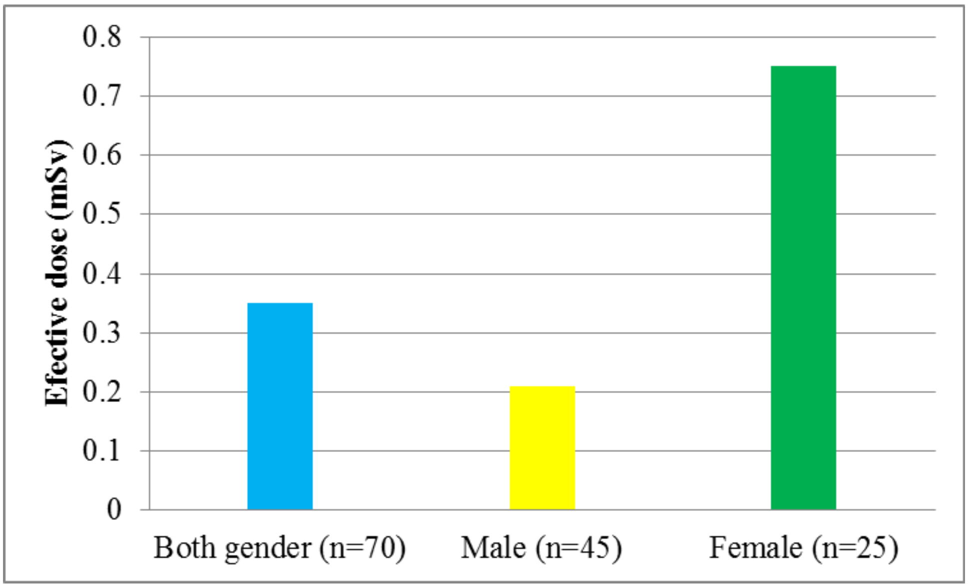


Figure 4.2 The 3rd quartile of effective dose between both gender (n=70), male (n=45) and female (n=25).

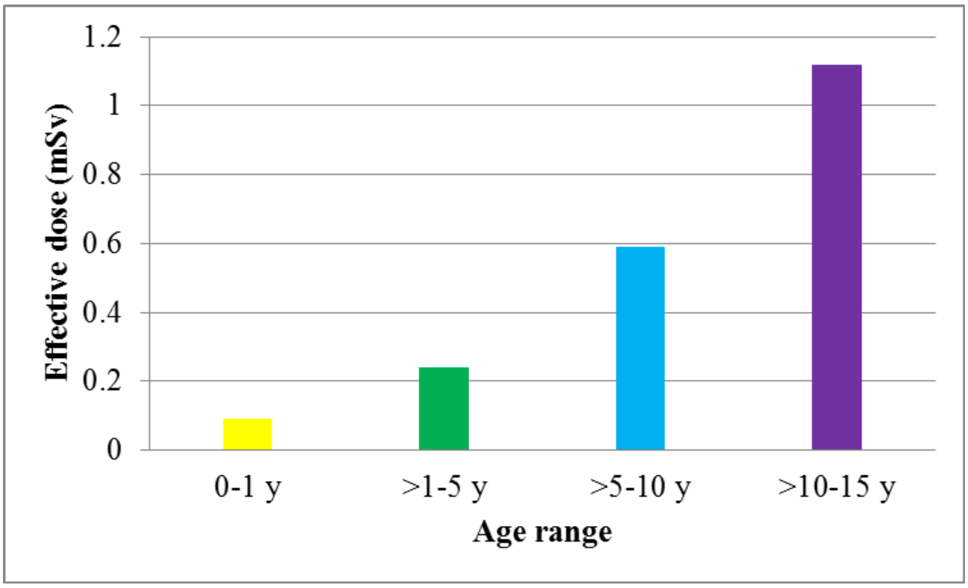


Figure 4.3 The mean effective dose of 5 groups of different age range.

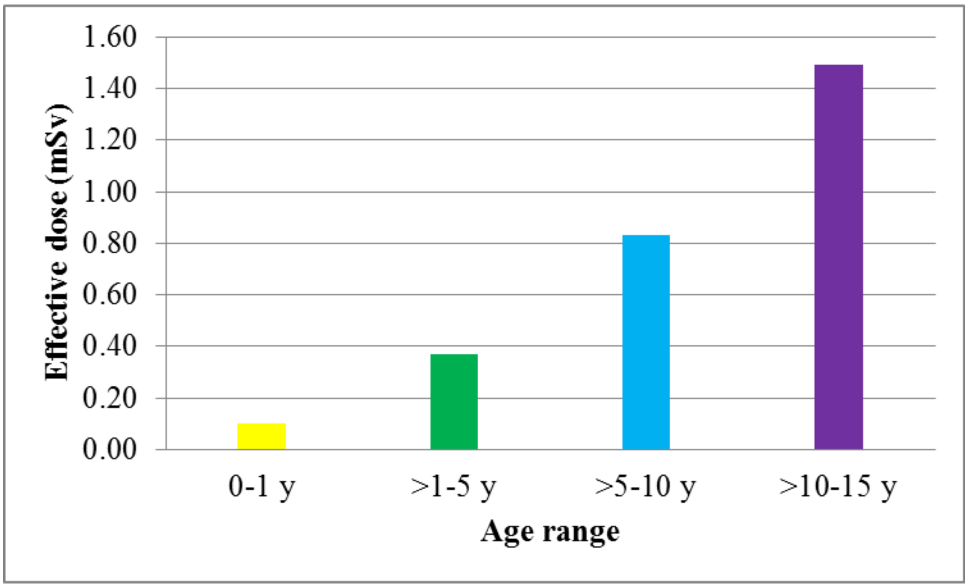


Figure 4.4 The 3rd quartile of effective dose of 5 groups of different age range.

4.6 The relationship between the factors affecting during the radiographic-fluoroscopic of voiding cystourethrography (VCUG) procedure.

4.6.1 The relation between the dose area product (cGycm^2) and body mass index (kg/m^2) underwent the radiographic-fluoroscopic of the voiding cystourethrography (VCUG) procedure is show in figure 4.5

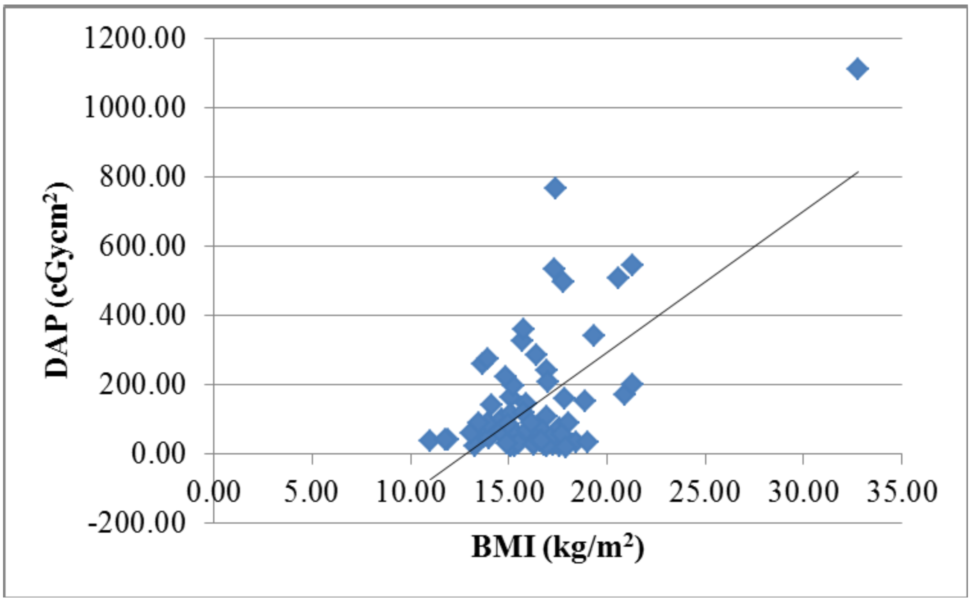


Figure 4.5 The relations between the dose area product (cGycm^2) and body mass index (kg/m^2) with r = 0.382. Line on graphs indicates linear regressions.

The relation between the dose area product (cGycm^2) and body mass index (kg/m^2) is shown in figure 4.5. The regression line showed linearity with r = 0.382.

4.6.2 The relation between the dose area product ($cGycm^2$) and fluoroscopy time (min) underwent the radiographic-fluoroscopic of the voiding cystourethrography (VCUG) procedure is show in figure 4.6

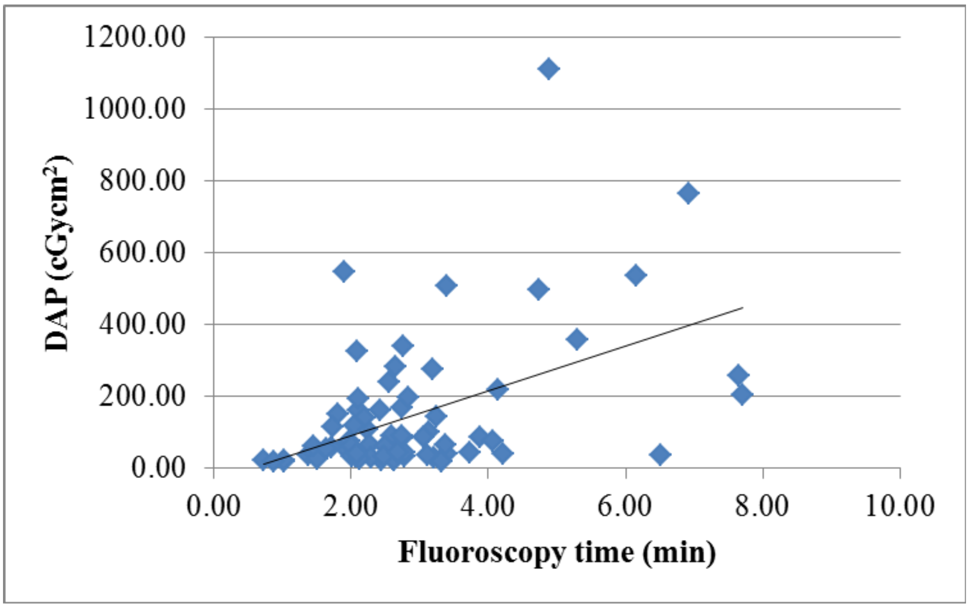


Figure 4.6 The relations between the dose area product ($cGycm^2$) and fluoroscopy time (min) with r = 0.230. Line on graphs indicates linear regressions.

The relation between the dose area product ($cGycm^2$) and fluoroscopy time (min) is shown in figure 4.6. The regression line showed linearity with r = 0.230.

4.6.3 The relation between the dose area product ($cGycm^2$) and number of exposures underwent the radiographic-fluoroscopic of the voiding cystourethrography (VCUG) procedure is show in figure 4.7

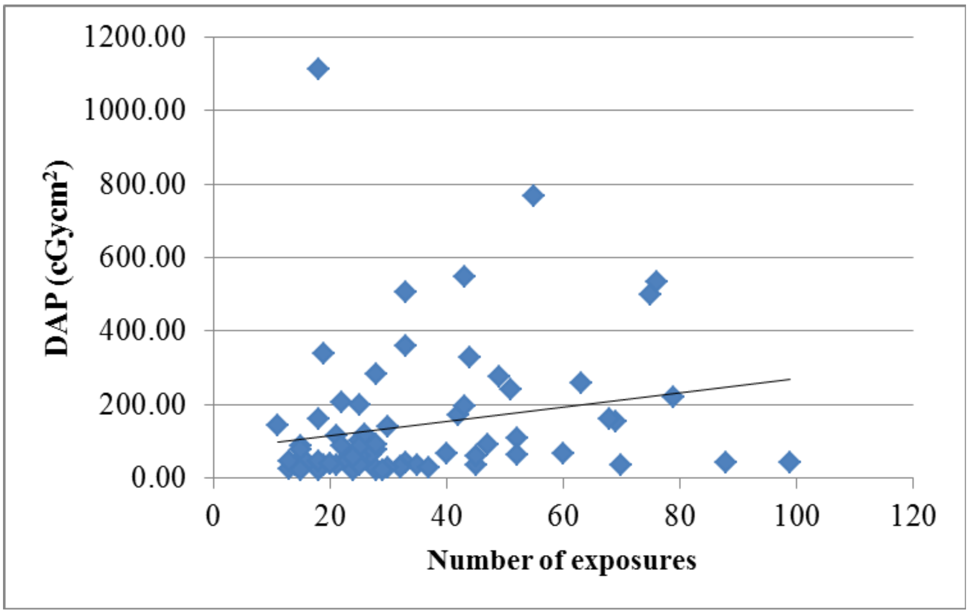


Figure 4.7 The relations between the dose area product ($cGycm^2$) and number of exposures with r = 0.040. Line on graphs indicates linear regressions.

The relation between the dose area product ($cGycm^2$) and fluoroscopy time (min) is shown in figure 4.7. The regression line showed linearity with r = 0.040.

4.6.4 The relation between the dose area product (cGycm^2) and mean image intensifier format (cm) underwent the radiographic-fluoroscopic of the voiding cystourethrography (VCUG) procedure is show in figure 4.8

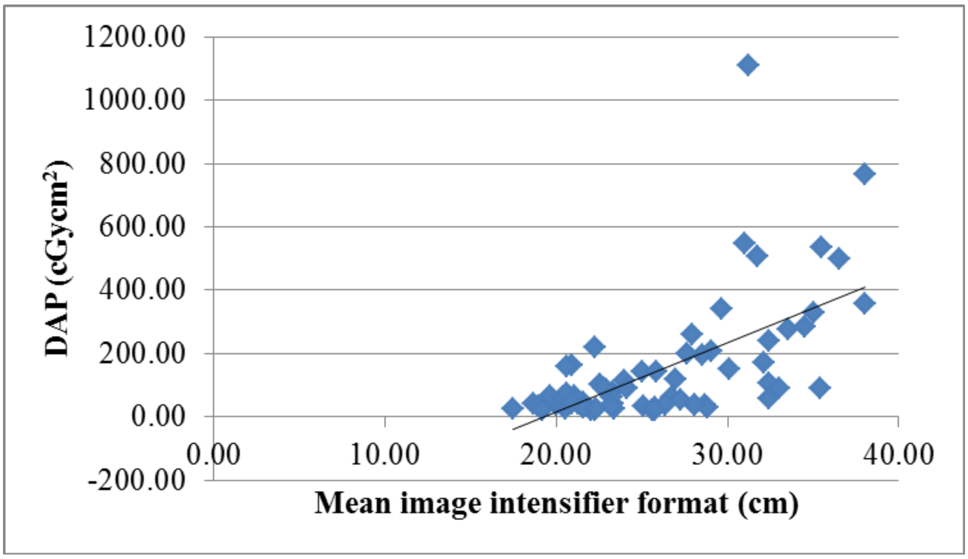


Figure 4.8 The relations between the dose area product (cGycm^2) and mean image intensifier format (cm) with r = 0.377. Line on graphs indicates linear regressions.

The relation between the dose area product (cGycm^2) and mean image intensifier format (cm) is shown in figure 4.8. The regression line showed linearity with r = 0.377.

4.6.5 The relation between the dose area product (cGycm^2) and mean killo voltage peak (kVp) underwent the radiographic-fluoroscopic of the voiding cystourethrography (VCUG) procedure is show in figure 4.9

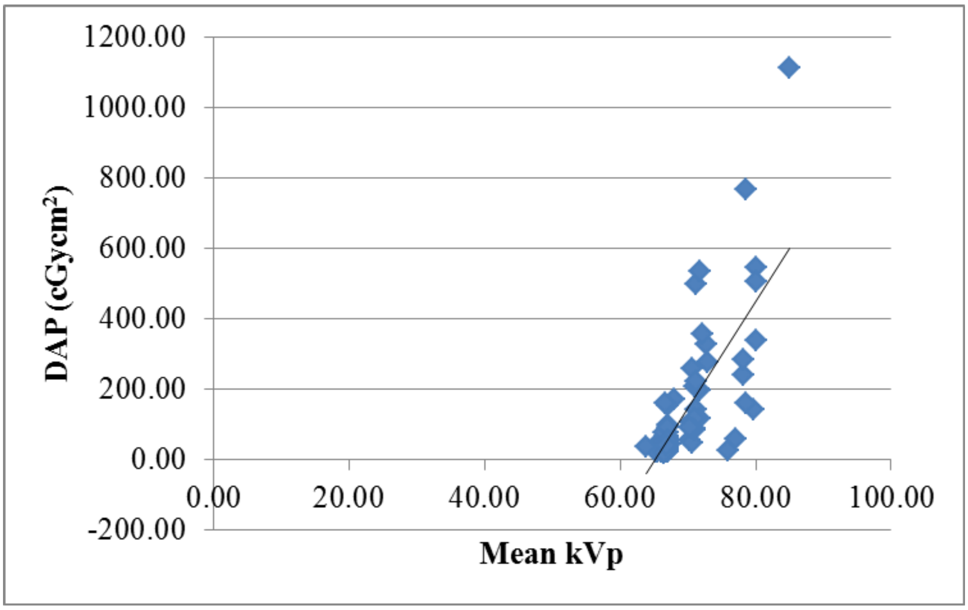


Figure 4.9 The relations between the dose area product (cGycm^2) and mean kilo voltage peak (kVp) with r = 0.541. Line on graphs indicates linear regressions.

The relation between the dose area product (cGycm^2) and mean kilo voltage peak (kVp) is shown in figure 4.9. The regression line showed linearity with r = 0.541.

4.6.5 The relation between the dose area product (cGycm^2) and mean milli ampere second (mAs) underwent the radiographic-fluoroscopic of the voiding cystourethrography (VCUG) procedure is show in figure 4.10

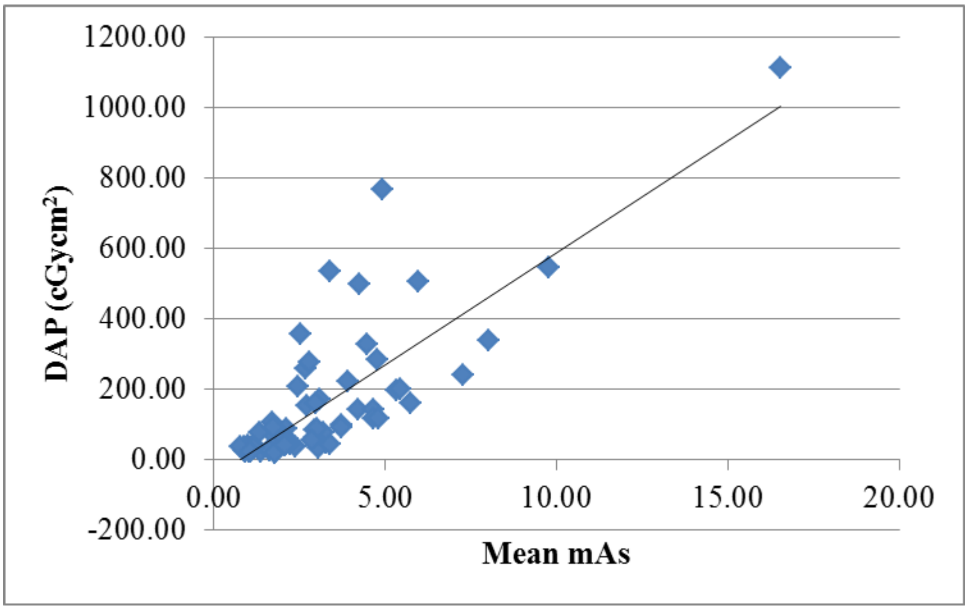


Figure 4.10 The relations between the dose area product (cGycm^2) and mean milli ampere second (mAs) with r = 0.647. Line on graphs indicates linear regressions.

The relation between the dose area product (cGycm^2) and mean milli ampere second (mAs) is shown in figure 4.10. The regression line showed linearity with r = 0.647.

From the relation between dose area product (DAP) and all parameters that affect to pediatric patient dose that we used regression line with r value for indication. The parameters influenced the radiation that pediatric patient be received were tube current (mAs) with r = 0.647, tube voltage (kVp) with r = 0.541, body mass index (BMI) with r = 0.382, image intensifier format (cm) or field of view size (FOV) with r = 0.377, fluoroscopy time with r = 0.230, and number of exposures with r = 0.040 respectively.

CHAPTER V

DISCUSSION AND CONCLUSION

5.1 Discussion

The dose reference levels (DRLs) for Thai pediatric patients underwent voiding cystourethrography (VCUG) procedure should be established for different age group to optimize patient dose, compared with other study and reviewed regularly.

The dose reference levels (DRLs) [16-21] is the 75th percentile (3rd quartile) of the spread of the median doses of common protocols from a national survey of imaging practices. So, our DRL is defined as the 75th percentile (3rd quartile) of the spread of doses for common protocols surveyed at the local radiology practice.

The application of the dose reference levels (DRLs) that follow:

- improve local, regional, or national distributions of observed doses for a general medical imaging task, by reducing the frequency of unjustified high or low dose values
- promote a narrower range of doses that represent good practice for a more specific medical imaging task
- promote an optimum range of doses for a specified medical imaging protocol
- provide a common dose metric for the comparison of local DRL between practices, protocols and modalities
- assess the dose impact of the introduction of new protocols
- provide compliance with the relevant state and territory regulatory requirements

From this study, we established our dose reference level (DRL) for voiding cystourethrography (VCUG) procedure as shown in table 5.1

Table 5.1 Our dose reference level (DRL) for voiding cystourethrography (VCUG) procedure.

Age range (years)	No. of patient	3rd quartile of radiation dose		
		ESD (mGy)	DAP ($cGycm^2$)	Effective dose (mSv)
0-1	32	4	49	0.10
>1-5	20	10	176	0.37
>5-10	12	14	393	0.83
>10-15	6	24	708	1.49

ESD, entrance skin dose; DAP, dose area product

In fluoroscopy procedure use DAP value to determine dose reference level (DRL), so we use dose reference level (DRL) of DAP of this study compare to other reference that shown in table 5.2

Table 5.2 Comparison of the dose reference level (DRL) of DAP of this study to dose reference level (DRL) of NRDs (UK) [22] and ICRP (2011) [23] for voiding cystourethrography (VCUG) procedure.

Age range (years)	No. of patient	Dose reference level of DAP ($cGycm^2$)		
		This study ($cGycm^2$)	NRDs (UK)	ICRP (2011)
0-1	32	49	90	81
>1-5	20	176	110	94
>5-10	12	393	210	164
>10-15	6	708	470	341

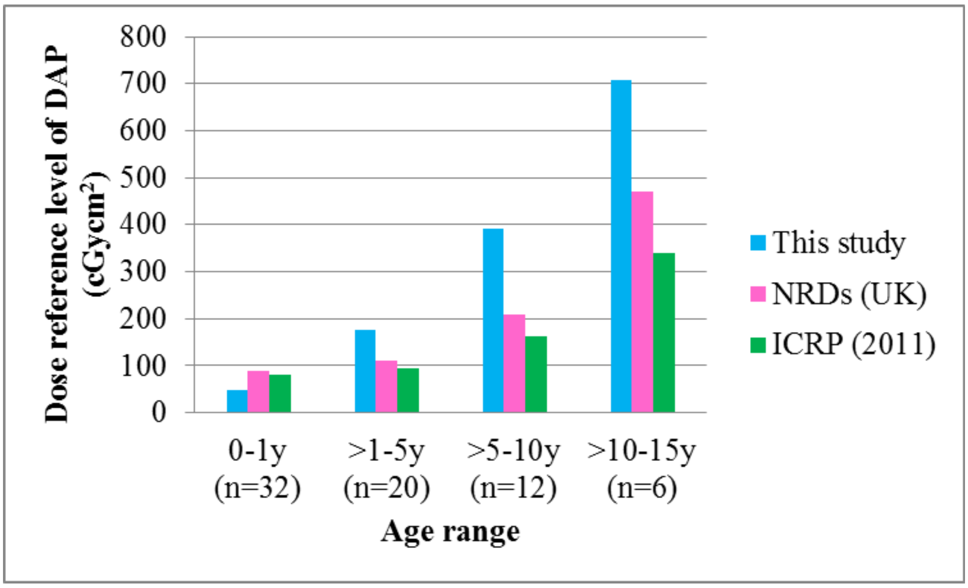


Figure 5.1 Comparison of the dose reference level (DRL) of DAP of this study to dose reference level (DRL) of NRDs (UK) and ICRP (2011) for voiding cystourethrography (VCUG) procedure.

Figure 5.1 show that the dose area product (DAP) of this study, in age range >1-5 years (n=20), age range >5-10 years (n=12), and age rang (n=6) are higher than dose reference level (DRL) of DAP of NRDs (UK) and ICRP (2011). As the number of patients in this study is limited and the nature of disorder of lower urinary tract often occur in children patient in age range 0-1 years.

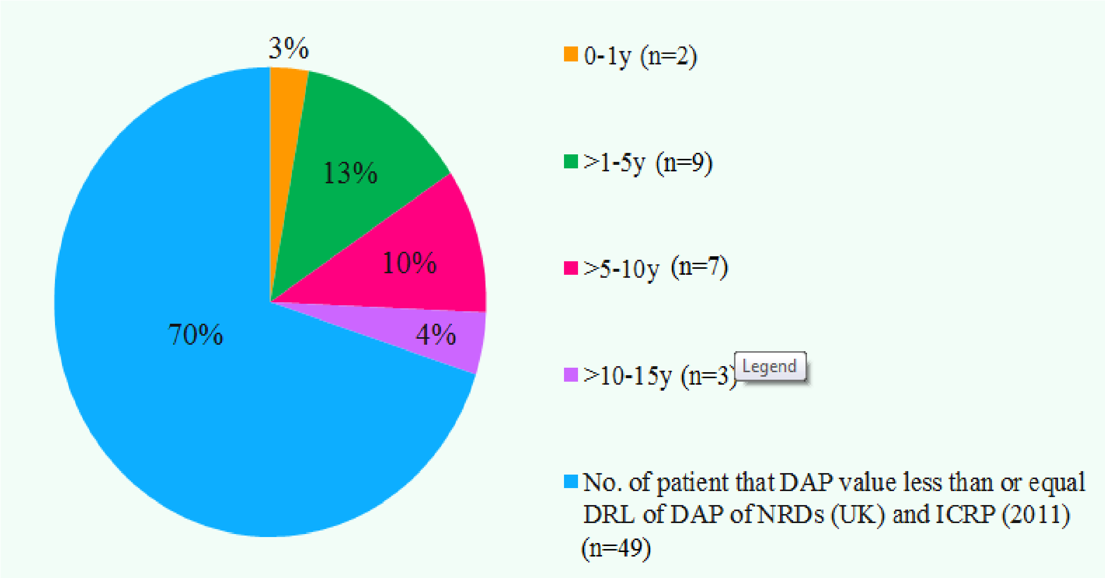


Figure 5.2 Distribution of percentage of number of patients that DAP value is less than, equal to and greater than DRL of DAP of NRDs (UK) and ICRP (2011).

From figure 5.2, we found that 30% of all patients in this study were patient who received radiation dose greater than dose reference level (DRL).It is still larger number. The cause of higher dose is from the unawareness of radiation dose delivered to patient. The application of the concept of justification to these procedures is not fulfilled yet.

The number of exposures per voiding cystourethrography (VCUG) procedure was ranged from 11 to 99 exposures, which is higher than previous study, 6 to 18 exposures [4].

Repetition radiographyaccording to the immobilization is not appropriate and cannot display radiograph while patient voiding. This affects the radiation dose the pediatric patientreceived.

In this study, the effective dose was calculated by using conversion coefficient, 0.21 $mSv.Gy^{-1}cm^{-2}$, multiplied DAP value. From figure 5.3, red line show the effective dose tends to increase with age range. In higher age range, pediatric patients are at larger size than younger pediatric patient. In addition, the dose reference level (DRL) of effective dose of this study when compared to the effective dose reported by ICRP (2011), 0.80 to 4.60 mSv. The results show in age rang 0-1 years (n=32) with DRL of effective dose 0.10 mSv, age range >1-5 years (n=20) with DRL of effective dose 0.37 mSv. They are lower than range of the effective dose reported by ICRP (2011). In age range >5-10 years (n=12) with DRL of effective dose 0.83 mSv, age range >10-15 years (n=6) with DRL of effective dose 1.49 mSv. They are in range of the effective dose that reported by ICRP (2011).

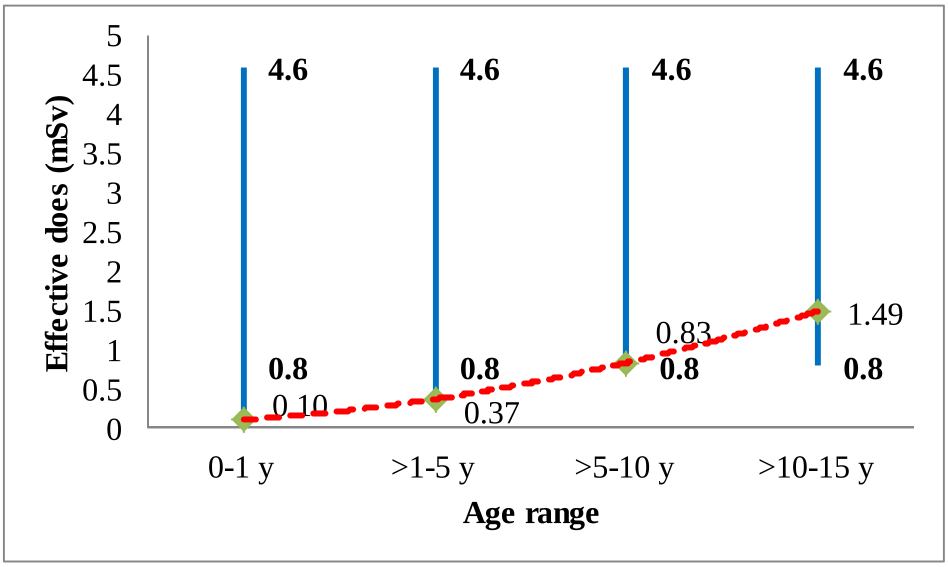


Figure 5.3 Comparison of the dose reference level (DRL) of effective dose of this study to ICRP (2011) for the voiding cystourethrography (VCUG) procedure.

Age range classification influence to determine of dose reference level (DRL) of radiation dose that patients received. The example of the result is shown in table 5.3 and 5.4.

Table 5.3 The dose reference level (DRL) of dose area product (DAP) [5].

Age range (years)	**DRL of DAP ($cGycm^2$)** K Sman et al.(2008)
<1	18.70
1-2	-
2-3	53.30
3-8	-
8-12	132.20
>12	316.50

DRL, dose reference level; DAP, dose area product

Table 5.4 The dose reference level (DRL) of dose area product (DAP) [6].

Age range (years)	**DRL of DAP ($cGycm^2$)** M P Heron et al.(2006)
0-1	4.90
1-7	10.00
8+	41.60

DRL, dose reference level; DAP, dose area product

The example of table 5.3 and 5.4 show that dose reference level (DRL) changes when age classification changes.

After that we try to establish dose reference level (DRL) of dose area product (DAP) of this study follow age range of previous study and compare it to previous study that shown in table 5.5 and 5.6.

Table 5.5 Comparison of the dose reference level (DRL) of dose area product (DAP) of this study to previous study [5].

Age range (years)	DRL of DAP ($cGycm^2$)	
	This study	**K Sman et al.(2008)**
<1	49	18.70
1-2	91	-
2-3	131	53.30
3-8	309	-
8-12	597	132.20
>12	273	316.50

DRL, dose reference level; DAP, dose area product

Table 5.6 Comparison of the dose reference level (DRL) of dose area product (DAP) of this study to previous study [6].

Age range (years)	DRL of DAP ($cGycm^2$)	
	This study	**M P Heron et al.(2006)**
0-1	49	4.90
1-7	197	10.00
8+	528	41.60

DRL, dose reference level; DAP, dose area product

From table 5.5 and 5.6, we found that our dose reference level (DRL) of dose area product (DAP) is still higher than dose reference level (DRL) of dose area product (DAP) of previous study.

5.2 Conclusion

The range of the entrance skin dose (ESD) of this study was 1.00 to 42.00 mGy, the dose area product (DAP) was 19.87 to 1110.54 cGycm^2, and the effective dose (E) was 0.04 to 2.33 mSv respectively.

The dose delivered to the patient in voiding cystourethrography (VCUG) is high when compared to the dose reference level (DRL) of other references.

The results provide the baseline data to establish dose reference levels (DRL) for voiding cystourethrography (VCUG) procedure in children patients.

The recommendations for low dose as following:

- Quality control (QC) of the radiographic-fluoroscopic system should be performed by qualified medical physicists. Test results should be reviewed and compared with tolerance levels of AAPM protocol
- Verify DAP meter to find the calibration factor
- Dose reference level (DRL) should be established for different age group to optimize patient dose
- Reduce the spot image to 8 to 10 images per voiding cystourethrography (VCUG) procedure
- Reduce fluoroscopy time to 5 to10 min per voiding cystourethrography (VCUG) procedure
- Use last image hold (freeze frame) for observation
- Low-dose mode: reduce about 40-50% of dose of normal fluoroscopy
- All operators must be trained to perform fluoroscopy
- Review includes patient description, part of anatomy involved before start procedure
- If entrance skin dose (ESD) exceeds 2 mGy, note in patient record and inform parent of patient for the awareness of the skin reaction. [24]

In future study, to provide a better statistic distribution in higher age range, the data of patients in larger number should be collected. Design protocol standard for determine conversion factor in each age range should be prepared.

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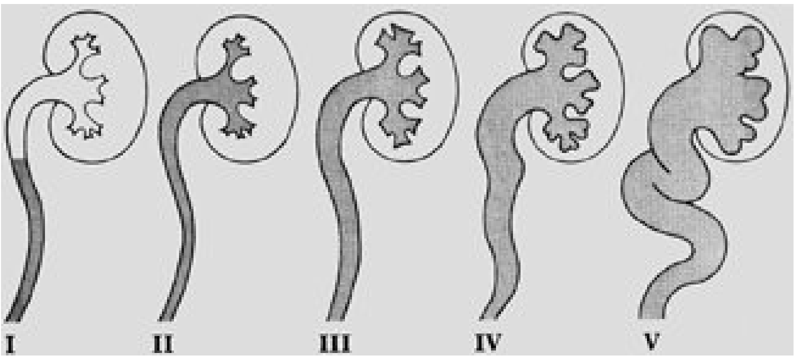
APPENDICES

APPENDIX A

Grading System of the International Reflux Study of 1985

I. Reflux only into the ureter.
II. Reflux into the entire ureter and pelvicalyceal system, no dilatation.
III. Mild pelvic or ureteral dilatation, with mild or no blunting of the fornices.
IV. Moderate dilatation of the pelvis and ureter, with moderate dilation of the calyces.
V. Massive ureteral or pyelocalyceal dilatation.



APPENDIX B

Case record form

Patient information

Gender	Age	Height (cm)	Weight (kg)

Technique information of radiography

Run No.	No. of image	II format	SID	kV	mAs
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

Technique information of fluoroscopy

Focal spot size	Frame rate	Flu.Frame speed	Added Filter

Dosimeter reading information

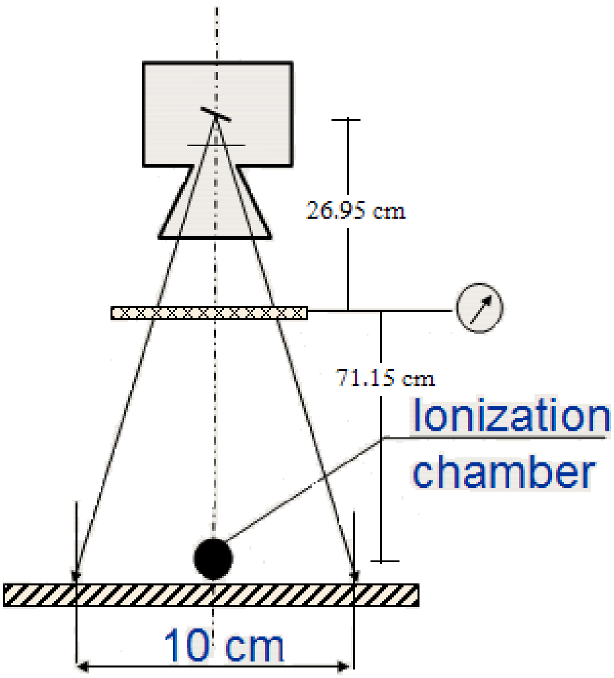
Cumulative skin dose (mGy)	Cumulative DAP ($cGycm^2$)	Fluoroscopy time (sec)

APPENDIX C

DAP meter calibration

Hospital: Ramathibodi hospital
Equipment: OmniDiagnost Eleva (Philips)
Dose Area Product Measurement Device Type: Transmission chamber (PTW)
S/N.: 03G30905

1. Test condition:
    a. Place ion chamber of dosimeter in center of the template and place this on the image intensifier in the center of the beam.
    b. Select 2.5 mmAl dose measurment range at the dosimeter.
    c. Collimate down to 10x10 cm^2.
    d. Reset DAP and dosimeter to 0.
    e. No test tools or other filters in beam.
    f. Normal Mode



2. Test

2.1. Tube voltage	U_a	=	40 kV
Beam field size	F	=	100 cm^2
Mean dose value	K_e	=	31.63 µGy
Dose area product	M_{PKA}	=	3163 µGy*cm^2
Mean displayed value DAP	P_{KA}	=	3333.33 µGy*cm^2
Correction factor	N	=	M_{PKA}/P_{KA}
		=	3163/3333.33
		=	0.95

2.2. Tube voltage	U_a	=	50 kV
Beam field size	F	=	100 cm^2
Mean dose value	K_e	=	16.61 µGy
Dose area product	M_{PKA}	=	1661 µGy*cm^2
Mean displayed value DAP	P_{KA}	=	2000 µGy*cm^2
Correction factor	N	=	M_{PKA}/P_{KA}
		=	1661/2000
		=	0.83

2.3. Tube voltage	U_a	=	60 kV
Beam field size	F	=	100 cm^2
Mean dose value	K_e	=	17.42 µGy
Dose area product	M_{PKA}	=	1742 µGy*cm^2
Mean displayed value DAP	P_{KA}	=	2000 µGy*cm^2
Correction factor	N	=	M_{PKA}/P_{KA}
		=	1742/2000
		=	0.87

2.4. Tube voltage	U_a	=	70 kV
Beam field size	F	=	100 cm^2
Mean dose value	K_e	=	13.38 µGy
Dose area product	M_{PKA}	=	1338 µGy*cm^2
Mean displayed value DAP	P_{KA}	=	1333.33 µGy*cm^2
Correction factor	N	=	M_{PKA}/P_{KA}
		=	1338/1333.33
		=	1.00

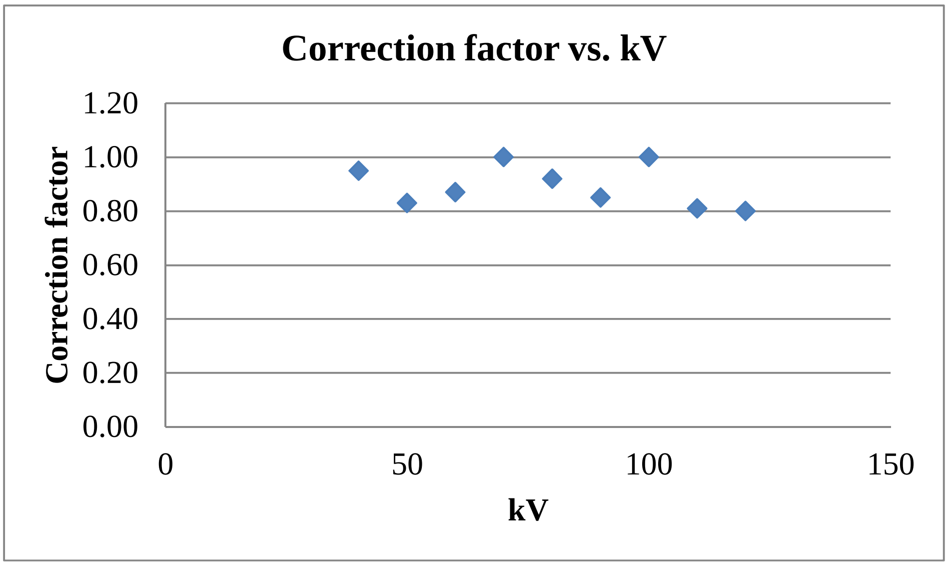
2.5. Tube voltage	U_a	=	80 kV
Beam field size	F	=	100 cm^2
Mean dose value	K_e	=	12.27 µGy
Dose area product	M_{PKA}	=	1227 µGy*cm^2
Mean displayed value DAP	P_{KA}	=	1333.33 µGy*cm^2
Correction factor	N	=	M_{PKA}/P_{KA}
		=	1227/1333.33
		=	0.92

2.6. Tube voltage	U_a	=	90 kV
Beam field size	F	=	100 cm^2
Mean dose value	K_e	=	14.09 µGy
Dose area product	M_{PKA}	=	1409 µGy*cm^2
Mean displayed value DAP	P_{KA}	=	1666.67 µGy*cm^2
Correction factor	N	=	M_{PKA}/P_{KA}
		=	1409/1666.67
		=	0.85

2.7. Tube voltage	U_a	=	100 kV
Beam field size	F	=	100 cm^2
Mean dose value	K_e	=	16.62 µGy
Dose area product	M_{PKA}	=	1662 µGy*cm^2
Mean displayed value DAP	P_{KA}	=	1666.67 µGy*cm^2
Correction factor	N	=	M_{PKA}/P_{KA}
		=	1662/1666.67
		=	1.00

2.8. Tube voltage	U_a	=	110 kV
Beam field size	F	=	100 cm^2
Mean dose value	K_e	=	21.48 µGy
Dose area product	M_{PKA}	=	2148 µGy*cm^2
Mean displayed value DAP	P_{KA}	=	2666.67 µGy*cm^2
Correction factor	N	=	M_{PKA}/P_{KA}
		=	2148/2666.67
		=	0.81

2.9. Tube voltage	U_a	=	120 kV
Beam field size	F	=	100 cm^2
Mean dose value	K_e	=	26.74 µGy
Dose area product	M_{PKA}	=	2674 µGy*cm^2
Mean displayed value DAP	P_{KA}	=	3333.33 µGy*cm^2
Correction factor	N	=	M_{PKA}/P_{KA}
		=	2674/3333.33
		=	0.80

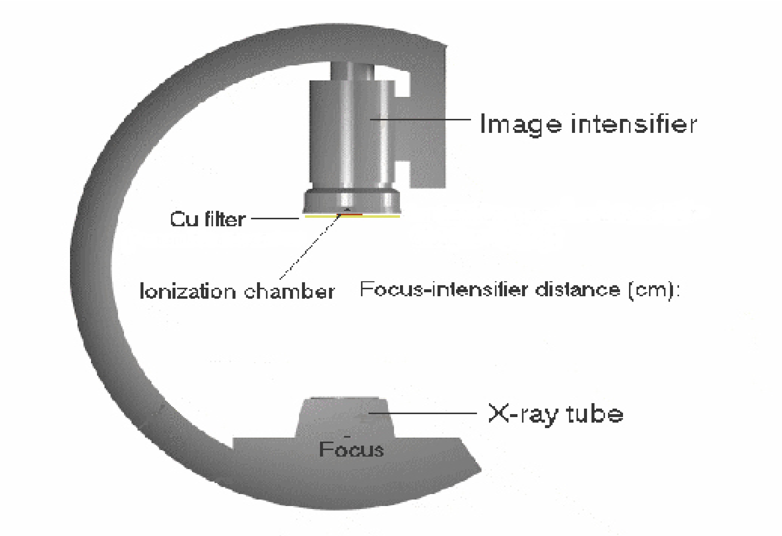


APPENDIX D

EQUIPMENT PERFORMANCE FOR FLUOROSCOPY EQUIPMENT

Hospital :	Ramathibodi Hospital
X-ray unit :	Philips OmniDiagnost Eleva
Room :	16
Report Number :	1
Date :	05 May 2011
Test performed by :	Tawat Siriwiladluk

Single plane
Rotating Anode, Pulse Fluoroscopy 2, 3, 4, cont. p/s
Small focal spot: 0.6 mm, Large focal spot: 0.8 mm
Anode heat storage capacity 300,000 HU
Filter 2.5 mmAl, 0.2, 0.3, 0.4 mmCu
Rectangular Collimator 25 in diagonal
Cesium Iodine Scintilator use Amorphous silicon array max FOV 60x60 cm
Carbon fiber table minimum height adjust 70 cm, minimum weight 200 kg
Table at 0 position, minimum distance from Focus to table 101 cm, focus to detector face 98.50 cm. and to detector 100 cm.



DOSE ASSESSMENT

	set	Measure	Error
Focus –Intensifier d. (cm)	110	109.7	0.27%
Patient dose measurement: Focus-Ion ch. Dist		98.5 cm	
Entrance II dose measurement: II-Ion ch. Dist		11.5 cm	

Mode	Submode/ Image quality	Pulse rate (pulses/s)	Automatic added filtration (mmCu+mmAl)	Field size (cm)	Mean kV	Mean mA	(Patient entrance surface air kerma) Copper filter entrance air kerma (mGy/min)	Image Intensifier entrance air kerma (mGy/min)	Patient entrance surface air kerma (including backscatter 1.35) (mGy/min)	Phantom
Normal	0.5 f/s	2 p/s	0.0+2.5	38	87.40	0.30	1.01	0.81	1.36	2mmCu
				31	89.92	0.30	1.16	0.93	1.56	
				25	90.19	0.40	1.21	0.97	1.63	
				20	91.76	0.40	1.52	1.22	2.05	
				17	95.00	0.50	1.94	1.55	2.61	

DOSE ASSESSMENT

Mode	Submode/ Image quality	Pulse rate (pulses/s)	Automatic added filtration (mmCu+mmAl)	Field size (cm)	Mean kV	Mean mA	(Patient entrance surface air kerma) Copper filter entrance air kerma (mGy/min)	Image Intensifier entrance air kerma (mGy/min)	Patient entrance surface air kerma (including backscatter 1.35) (mGy/min)	Phantom
Low Dose	0.5 f/s	2 p/s	0.0+2.5	38	85.00	0.20	0.48	0.38	0.65	2mmCu
				31	86.00	0.20	0.57	0.46	0.77	
				25	87.00	0.20	0.61	0.49	0.83	
				20	91.12	0.20	0.76	0.61	1.03	
				17	95.66	0.20	0.95	0.76	1.28	
High Quality	0.5 f/s	2 p/s	0.0+2.5	38	87.00	0.40	1.24	1.00	1.68	2mmCu
				31	89.50	0.40	1.49	1.19	2.01	
				25	90.00	0.45	1.60	1.29	2.16	
				20	94.00	0.50	1.93	1.54	2.60	
				17	101.00	0.50	2.36	1.89	3.18	
Single Shot (SPOT)	0.5 f/s	2 p/s	0.0+2.5	38	67.50	125.00	0.21	0.17	0.28	2mmCu
				31	67.50	125.00	0.21	0.17	0.28	
				25	67.60	125.00	0.21	0.17	0.28	
				20	67.57	125.00	0.21	0.17	0.28	
				17	67.27	125.00	0.21	0.17	0.28	

AUTOMATIC BRIGHTNESS CONTROL TEST

FID 110 cm

<table>
<tr><th>Mode</th><th>Submode/
Image quality</th><th>Pulse rate
(pulses/s)</th><th>Automatic added
filtration
(mmCu+mmAl)</th><th>Field size
(cm)</th><th>Dose rate
(µGy/s)</th><th>kV</th><th>mA</th><th>Phantom</th></tr>
<tr><td rowspan="3">Normal</td><td rowspan="3">0.5 f/s</td><td rowspan="3">2 p/s</td><td rowspan="3">0.0+2.5</td><td>25</td><td>13.82</td><td>83.00</td><td>0.30</td><td>1.5mm Cu</td></tr>
<tr><td>25</td><td>27.60</td><td>91.00</td><td>0.40</td><td>2.5 mm Cu</td></tr>
<tr><td>25</td><td>38.74</td><td>103.40</td><td>0.50</td><td>3.5 mm Cu</td></tr>
</table>

***Only one mode and field size is checked (about 25 cm)**

MAXIMUM DOSERATE ASSESSMENT

SID 110 cm 3.0 mmAl, Chamber to focus distance 50 cm

**Measure dose rate for all modes and FOVs, dosimeter on the table and table at the lowest position Absorber: 2 mm of lead on the image intensifier (or equivalent attenuation with a folded lead apron)

Mode	Submode/ Image quality	Pulse rate (pulses/s)	Automatic added filtration (mmCu+mmAl)	Field size (cm)	Mean kV	Mean mA	Doserate (μGy/s)	Phantom
Normal	0.5 f/s	2 p/s	0.0+2.5	38	95.00	0.50	113.60	1.6mmPb
				31	97.50	0.50	125.90	
				25	97.50	0.50	139.35	
				20	104.30	0.50	163.40	
				17	109.20	0.60	204.00	
Low Dose	0.5 f/s	2 p/s	0.0+2.5	38	94.70	0.20	55.67	1.6mmPb
				31	96.50	0.20	64.55	
				25	99.10	0.20	68.40	
				20	101.60	0.30	88.30	
				17	104.50	0.40	120.55	
High Quality	0.5 f/s	2 p/s	0.0+2.5	38	100.50	0.50	133.25	1.6mmPb
				31	100.90	0.50	152.90	
				25	104.40	0.50	165.45	
				20	112.50	0.60	203.75	
				17	111.00	0.80	288.30	

IMAGE QUALITY ASSESSMENT

Resolution should be assessed in the usual illumination conditions and from the operator's position. Leeds Test placed on Image-Intensifier detector entrance surface with grid .All modes (fluoroscopy and image acquisition) and image qualities and FOVs.

Monitor Focus-Image-Insifier detector 110 cm

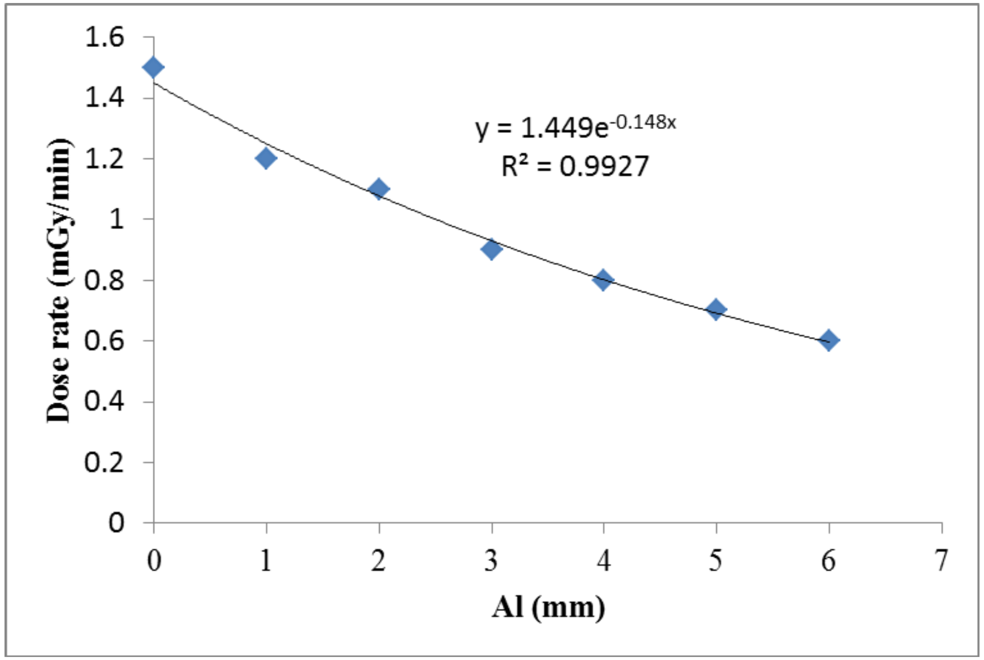
Mode	Submode/ Image quality	Focus S/L	Automatic added filtration (mmCu)	Field size (cm)	kV	mA	Phantom (Group)	High contrast resolution(lp/mm)	Phantom (Group)	Low contrast (% contrast)
Normal	0.5 fps	L	0.0+2.5 mmAl	38	78	0.20	8	1.12	3	12.80
				31	79	0.20	9	1.25	4	10.90
				25	80	0.20	10	1.40	6	7.50
				20	82	0.30	15	2.50	5	8.80
				17	85	0.30	16	2.80	6	7.50
Low Dose	0.5 fps	L	0.0+2.5 mmAl	38	77	0.10	6	0.90	2	14.80
				31	79	0.10	7	1.00	3	12.80
				25	80	0.10	7	1.00	3	12.80
				20	82	0.20	9	1.25	3	12.80
				17	85	0.20	11	1.60	3	12.80
High Quality	0.5 fps	L	0.0+2.5 mmAl	38	80	0.20	8	1.12	3	12.80
				31	81	0.20	9	1.25	4	10.90
				25	82	0.30	9	1.25	4	10.90
				20	85	0.30	13	2.00	6	7.50
				17	88	0.40	15	2.50	5	8.80

IMAGE QUALITY ASSESSMENT

Mode	Submode/ Image quality	Focus S/L	Automatic added filtration (mmCu)	Field size (cm)	kV	mA	Phantom (Group)	High contrast resolution(lp/mm)	Phantom (Group)	Low contrast (% contrast)
Single Shot No filter (10 ms)	0.5 fps	L	0.0+2.5 mmAl	38	67	125.00	12	1.80	9	4.50
				31	67	125.00	12	1.80	9	4.50
				25	67	125.00	12	1.80	9	4.50
				20	67	125.00	15	2.50	9	4.50
				17	67	125.00	16	2.80	9	4.50

HALF VALUE LAYER ASSESSMENT

Al attenuator (mm)	Submode/ Image quality	Doserate (mGy/min)	HVL (mmAl)
0.0	0.5 f/s Normal	1.5	4.45
1.0		1.2	
2.0		1.1	
3.0		0.9	
4.0		0.8	
5.0		0.7	
6.0		0.6	



Make measurement in fluoroscopy mode; add attenuator (copper sheets) on II to drive kV to 80 kV

VITAE

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