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# Estimation of pediatric radiation doses in intravenous urography

**Badreldin M.A Elhag**[1], **Hiba Omer**[2], **Abdelmoneim Sulieman***[1]

[1]Sudan University of Science and Technology, College of Medical Radiologic Science, Khartoum, Sudan.
[2]Ahfad University for Women School of Medicine,Omdurman, Sudan

## Abstract

**Objectives:** The current study intends to measure entrance surface dose (ESD) and Effective Dose (ED) and estimate the radiation risks for pediatric patients undergoing IVU procedures.

**Methods:** A survey of radiation doses to 21 pediatric patients during intravenous procedures was carried out in this study. Entrance surface doses (ESDs) were calculated from patient exposure parameters using DosCal software. Effective doses (E) were calculated using published conversion factors and methods recommended by the national Radiological Protection Board (NRPB).

**Results:** The mean and the range of age of the patients were 6.0±4.40 (6 to 13.8) years. The mean patient dose in this study was 4.9 mGy±2.1 in a range of 2.4 to 10.4 mGy. The mean number of films was 12.8±3.8.

**Conclusions:** All the investigations were performed in the same department. The measured ESD in this study was higher than the previous reported studies in the literature. This can be attributed to the use of low kV, short SSD, small filtration and low speed films. An optimisation technique is required in the light of the current practice in order to reduce the unnecessary exposure.

**Key Words**: Measure entrance surface dose, Effective doses, Pediatric radiation doses, Intravenous urography, DosCal software.

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## INTRODUCTION

Children have a higher risk of developing cancer from the irradiation than adults. The rapidly growing tissue of the child is up to eight times more sensitive to ionizing radiation than adult tissue. In addition, the life expectancy of a child is naturally greater than that of an adult, and hence, radiation-induced tumors occur more frequently [1]. Thus, unlike the situation with adults, the 80 % reduction in patient dose cannot be regarded sufficient for children. Intravenous urography (IVU) is a radiographic study of the urinary system disorders. It is useful in the detection of renal and ureteral calculi. IVU has been a major and first-choice method for diagnosing urinary system disease, since its emergence in the medical field in 1923 [2]. It provides structural as well as functional information of the urinary tract. Despite the widespread use of advanced imaging modalities (e.g. ultrasonography, nuclear medicine, CT and MRI), IVU examination still has a leading role in imaging the urinary tract disorders especially in the developing countries. However, during the procedure, patients are exposed to a significant radiation dose [3]. Although, IVU procedures are frequently carried out on pediatric departments, there is little information on doses to children from these procedures. Thus, measurements of patient doses are crucial. This study intended to assess the patient radiation doses during intravenous urography in some hospitals in Sudan, and to estimate the effective doses and the radiation risks during the pediatric examinations.

## MATERIALS AND METHODS

A total of 21 patients with a mean age of 6.0 ±4.4 years were examined as illustrated in Table 1 below.

**Table 1: Patient age and range during IVU procedure**

| Gender | Number of patient | Patient age (year) |
|---|---|---|
| Males | 14 | 5.9±4.2<br>(0.6-11.8) |
| Females | 7 | 6.3±5.4<br>(0.6-13.8) |
| Total | 21 | 6.0±4.4<br>(0.6-13.8) |

### Entrance surface doses (ESDs)

Entrance surface doses (ESDs) in this study were calculated using Dose Cal software developed by the radiological protection centre of Saint George's Hospital, London and this software is extensively used to calculate patient dose in diagnostic radiology[3].For dose measurement the relationship between X-ray unit current

**Address for correspondence***
**Abdelmoneim Sulieman**
College of Medical Radiologic Science,Sudan University of Science and Technology, Khartoum, Sudan
Email: abdelmoneim_a@yahoo.com

time product (mAs) and the air kerma f was established at a reference point of 100 cm from tube focus for the range of tube potentials encountered in clinical practice. The X- ray tube out put was measured in (mGy/mAs) using Unfors Xi Dosimeter (Unfors Inc., Billdal, Sweden) with accuracy better than 5%. ESD was calculated according to the following formula:

$$ESD = OPx \left(\frac{kV}{80}\right)^2 xmAsx \left(\frac{100}{FSD}\right)^2 xBSF$$

where; (OP) is the output in mGy/ (mAs) of the X-ray tube; (kV) is the tube potential; (mAs) is the product of the tube current (in mA) and the exposure time(in s); (FSD) the focus-to-skin distance (in cm) and (BSF) the backscatter factor. It is important to note that the output was obtained at 80 kV at a focus distance of 1 m normalized to 10 mAs. This normalization was used as the potentials across the X-ray tube and the tube current are highly stabilized at this point. BSF is calculated automatically by the Dose Cal software after all input data were entered manually in the software. The tube output, the patient anthropometrical data and the radiographic parameters (kVp, mA s, FSD and filtration) are initially installed in the software.

### IVU procedure

An injection of x-ray contrast medium is given to a patient via a needle or cannula into the vein, typically in the arm. The contrast is excreted or removed from the bloodstream via the kidneys, and the contrast media becomes visible on x-rays almost immediately after injection. X-rays are taken at specific time intervals (immediate film after injection, 5 minutes, 10 min and 15 min) to capture the contrast as it travels through the different parts of the urinary system. This gives a comprehensive view of the patient's anatomy and some information on the functioning of the renal system.

### Organ dose estimation

In practice, direct measurement of the organ doses is not possible. Therefore, software from National Radiological Protection Board (NRPB 279) based on Monte Carlo calculations were used in order to calculate doses to the radiosensitive organs in pediatric patients [4]. Organ doses and the effective dose were calculated and related to the practical dose measurements routinely made outside the patient (ESD). The data are provided for 50 kV peak applied potential and 2.5 mm A1 total beam filtration. The organ doses are obtained subsequently by multiplying by an appropriate dose conversion factor (DCF).

### Cancer risks estimation

Radiation risk estimates are based on the doses in various organs and tissues of the body. The cancer probability in sensitive organs following IVU examination was estimated by multiplying the mean organ equivalent dose with the risk coefficients obtained from ICRP 60 [5].

$$Cp=Dm \times Rf$$

Where, Cp: cancer probability.
Dm: mean organ equivalent dose.
R: risk factor.

## RESULTS AND DISCUSSION

In this study radiation dose was measured for 21 patients (7 females and 14 Males) undergoing IVU procedure. The main and unique clinical indication was renal stone. The mean age of the patients was 6.0±4.4 and the range was 0.6 to 13.8 years. The mean age for male and female were comparable as illustrated in Table 2. The mean tube voltage used in this study was 63.5kVp while the mean tube current was 10.2 mAs. The mean number of films was 12.8 in a range of 5 to 21. A correlation was found between the ESD (mGy) and tube current; ($R^2$=0.45) and number of films; ($R^2$=0.42). These exposure parameters were comparable with other paediatric examinations performed in children. It is important to note that the number of films in this study was very high and an urgent intervention is required to order optimise the practice.

The mean patient dose in this study was 4.9±2.1 mGy and the range from 2.4 to 10.4mGy. All the investigations were performed in the same department. The high exposure in this study was attributed to the fact that the procedures were performed by fellows (trainees). This point should be urgently discussed regarding the optimisation of the procedure. 61% of the doses were from radiographic examinations while 39% were from fluoroscopic exposure. Therefore, fluoroscopic time and number of X ray images can be a good indicator of dose. Controlling one of these factors is expected to reduce drastically the patient dose.

Intravenous urography (IVU) is the examination of the urinary tract that involves up to 20 radiographs (mean of 8.2) . For this reason, even if the IVU frequency is only about 1.3% of the total number of examinations, its contribution to the collective dose is relatively high, about 11% of the total collective doses from all medical procedures [6]. Thus, ESD measurements are easy to perform, provided that appropriate dosimeters are available. Computed tomography urography (CTU) on the other hand, is a relatively new diagnostic imaging examination that provides comprehensive evaluation of the upper and lower urinary tract. Multi detector CT (MDCT) enables isotropic or near-isotropic high-quality multi planar image reconstruction. As MDCT has become more widely available, CTU is starting to replace other imaging techniques, especially intravenous urography (IVU). In Sudan, IVU still plays a vital role in diagnosis of the diseases of the billiary system due to the small number of CT scans compared to the number of population and the relatively high cost of CTU procedures.

In this study, the author designed a protocol in order to optimise the radiation dose for patients. This protocol was based on reduction of number of images. Three patients were examined using this protocol. The number of images was reduced to 3.3 per procedure. The mean dose was reduced to 1.6 mGy per procedure. A reduction of 72% was achieved by controlling the number of radiographic images

In the literature, few studies were reported regarding the patient doses in similar procedures. Results reported by Eikefjord et al [7], Nawfel et al[8] and Entisar [9] are illustrated in Table 3 Table 4 compares the results of this study with the previous dose values to adults in the literature. The dose value in this study was lower than previous studies due to the sample variation in weight, exposure factors and patient parameters. The number of images acquired and technique factors also contribute to the variation in effective dose. Yakoumakis et al [10] report a mean effective dose for conventional urography of 3.0 mSv with an average of 9.3 images acquired, and Muller et al [11] reported an average of 3.7 images acquired at conventional urography. Liu et al [12] reported a conventional urography protocol consisting of acquisition of one postero-anterior image and four antero-posterior images. Each exposure was performed with a constant technique: 70 kVp and 64 mAs. In our study, the tube current–time product for the same projection was lower than the previous studies due to the variation in patient thickness. During IVU procedure the abdomen and pelvic organs experience a multiple exposure. Therefore, estimation of organ doses and its related cancer risk will be a suitable descriptor of the radiation carcinogenesis. Table 4 present the organ dose and cancer risks from the entire procedures. The bladder has the highest organ dose because it always lies in the primary radiation field while the thyroid has the lowest dose value. The radiation risk for IVU was estimated to be 1 cancer incidence per million procedures. The nominal cancer risks ranged between 1 per million for testes, uterus and breast, to 40 per million for skin cancer per procedure.

The radiation dose for conventional urography would be decreased substantially if fewer images were acquired, as is done at some institutions (Liu et al [10]). Moreover, doses can be reduced by carefully selecting technical factors (tube potential, tube current–time

**Table 2 patient exposure parameter during IVU procedure**

| Imaging mode | ESD (mGy) |
|---|---|
| Fluoroscopy | 1.9±0.7<br>(0.8-4.0) |
| Radiography | 3.0±1.5<br>(1.3-7.3) |
| Total | 4.9±2.1<br>(2.4-10.4) |

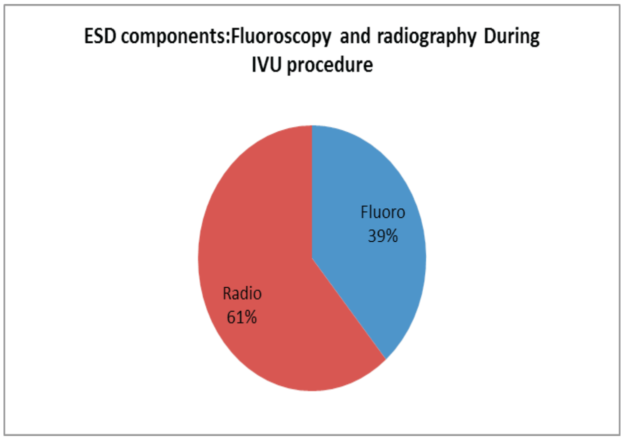

**Figure 1: ESD components**

**Table 3 Patient dose during IVU procedure**

| Gender | Tube voltage (kVp) | Tube current (mAs) | Time (s) | No of films |
|---|---|---|---|---|
| **Males** | 63.2±1.3<br>(60-65.8) | 10.7±3.1<br>(6.9-18.1) | 19.5±5.5<br>(8-31.2) | 13.4±4.1<br>(5-21) |
| **Females** | 64.1±1.2<br>(63-65.8) | 9.1±5.4<br>(4.9-19.4) | 18.2±11<br>(9.9-39.6) | 11.3±2.5<br>(8-15) |
| **Total** | 63.5±1.3<br>(60-65.8) | 10.2±3.8<br>(4.9-19.4) | 19.1±7<br>(6-39.6) | 12.8±3.8<br>(5-21) |

**Table 4 Organ dose estimation during IVU and cancer risk estimation**

| Organ | Organ equivalent dose (mSv) | Nominal risk coefficient x$10^{-4}$$Sv^{-1}$ | Radiation induced cancer probability x $10^{-6}$ |
|---|---|---|---|
| Skin | 0.4 | 1000 | 40 |
| Testes | 0.3 | 20 | 0.6 |
| Urinary bladder | 2.1 | 39 | 8 |
| Thyroid | 0.003 | 20 | 0.006 |
| Ovaries | 1.0 | 16 | 1.6 |
| Uterus | 1.6 | 6.3 | 1.0 |
| Breast | 0.1 | 116 | 1.2 |
| Effective dose | 1.0 | 13 | 1.3 |

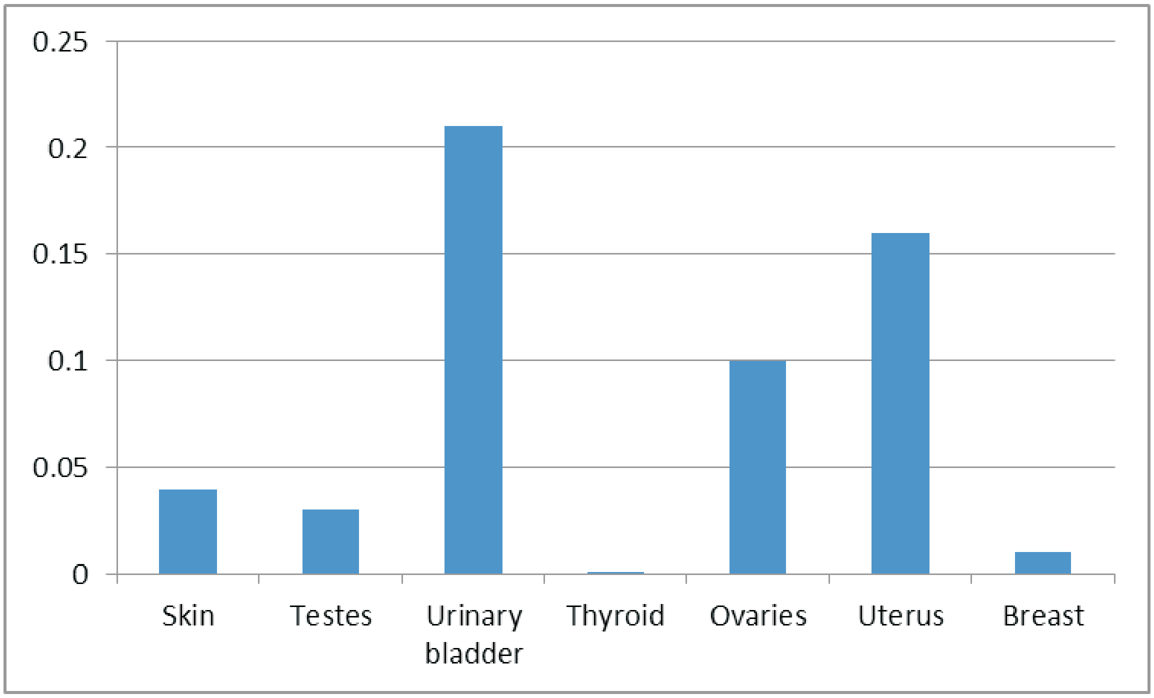

**Figure 2 Patient organ doses (mSv) during IVU procedure**

In general, the incidence of urinary stone disease in the paediatric populations is less than in adults [13]. While renal colic is the main finding in adults, it is observed in only 15% of children [14]. While childhood stone disease is continuing to decrease in developed countries, it remains endemic in some parts of the world [14]. Radiological imaging has a very important role in the evaluation of stone patients. Therefore, IVU is expected to be a part of routine practice in the developing countries. Sjöholm et al [15] reported that patient doses could be reduced by a factor of 4 using flat panel detectors with no significant difference in image quality. Therefore digital imaging techniques is highly recommended.

**Table 5: Show the previous studies results during IVU procedure**

| Author | No of patients | effective dose (mSv) |
|---|---|---|
| Eikefjord et al, [7] | 119 | 3.63 |
| Nawfel et al, [8] | 11 | 9.7± 3.0 |
| Present study | 20 | 1.0 |
| Entisar, [9 | 25 | 1.79 |
| Yakoumakis et al, [10] | 25 | 3.0 |
| Muller et al [11] | 205 | 3.7 |

## CONCLUSION

The measured ESD in this study was higher than the previous reported studies in the literature. This can be attributed to the use of low kV, short SSD, small filtration and low speed films. An optimisation technique is required in the light of the current practice in order to reduce the unnecessary exposure.

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