Radiation Dose Assessment and Risk Estimation During Extracorporeal Shock Wave Lithotripsy

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ABSTRACT

Extracorporeal shockwave lithotripsy (ESWL) is considered the gold standard for calculi fragmentation. The aims of this study are to measure the entrance surface dose (ESD) using thermo-luminescence dosimeter (TLDs) and to estimate the probability of carcinogenesis during ESWL procedure.
The study was carried out at two centers (Group *A*, 50 patients) and (Group *B*, 25 patients). The mean ESD and effective doses were 36 mGy and 34 mSv.
The results show that the probability of carcinogenesis is a tiny value 100 per million patients) but the main biological effect is occurring due to the accumulative impact of radiation.

Key Words: *Lithotripsy/ TLD/ Radiation Dosimetry/ Patient Exposure.*

INTRODUCTION

Extracorporeal shock wave lithotripsy (ESWL), which was first conducted in Germany during 1980, is noninvasive treatment of renal stone disintegration by shock waves, with a high success rate and approximately 90% (1).The mechanism dependend on the destruction the stone in small pieces to become easy to bass out side the body by ureter in renal stone or by common bile duct in gall stone (1).

ESWL involves considerable radiation dose to patients, which addressed as an important issue that must be taken into consideration. Moreover, a part of those patients are subjected to the repetition of the procedure due to stone recurrence.

Fluoroscopy is used for guidance, image formation and localization of kidney calculi in ESWL. Since the ESWL procedures are derived using X-ray fluoroscopy which poses a potential health risk to the patient. Radiation doses to the patient depend greatly on the size of the patient as well as length of the procedure, with typical skin dose rates quoted as 20-50 mGy/min. Exposure time vary depending on the procedure which being performed, but some procedures are extended up to 25 minutes.

During the procedure, X- ray beam is usually moved over different areas of the body during a procedure, there are two very different aspects that must be considered. One is the irradiated area which results in the highest absorbed dose to that specific part of the skin and to specific organs. The other is the total radiation energy imparted to the patient's body. an area of the skin for a long time that can result in radiation injuries in cases of very high doses (2).

The risk associated with a radiological examination· However, any added dose, no matter how small, is unacceptable if it does not benefit the patient. In general, the basic principles of radiation protection (justification and optimization of a procedure), ALARA as low as reasonable achievable principles and the radiation reference level of examination dose need to be respected. time open surgery was the only available treatment process for this problem. In addition to that, few data are available regarding patient exposure during ESWL [(3-6)]. As far as we know, only one study has been performed in Sudan. Therefore, there is a crucial need to quantify the radiation dose and to assess the radiation risk.

This study intended to: (i) measure and evaluate patient's radiation dose during ESWL procedure in Sudan, (ii) estimate the radiation risk when we repeat procedure and (iii) compare the radiation dose between two lithotripsy departments.

MATERIALS AND METHODS

Detector

Patient dose measurements during lithotripsy were made using cylindrical (GR200A) TLD chips manufactured by FIMEL, France. TLD were calibrated under reproducible reference condition using general purpose X- ray machine model DRX-1603B, manufactured by Toshiba Company, Japan in 2005, according to international protocols for the range of energies used in the study ([7,8]).

A set of measurements were performed using (PTW -CONNY II) ionization chamber with dimensions of 180 x 100 x 45 mm, applicable to Cardiology, Radiology, Mammography, and Surgery. After completing the calibration process, any chips that exceeded the 5% error were excluded from the study.

The irradiated chips were read out using automatic TLD reader FIMEL PCL3 (France). The read out was at a 55 ^{0}C preheat temperature and the signal was acquired from 55 ^{0}C to 260 ^{0}C with heating rate of 11 ^{0}C/s. All TLDs were annealed in annealing oven (TLDO, PTW, Freiburg, Germany) at 240ºc for 10 min, followed by fast cooling by opening the oven door.

A total of 50 TLD chips were packed in plastic bags in three numbered positions. These plastic bags were attached with cello-tape to the centre of the field at the surface of entry of radiation for the patients.

Figure 1: TLD in transparent envelopes

Patient dose measurements

A total of 75 consecutive procedures were evaluated. The Ethics and research committee approved the study and a written consent was obtained from all patients prior to the procedure. Three envelopes were used to measure ESD. During the procedure the TLDs were kept in the required positions and were stuck in place with adhesive tape. The envelopes were positioned accordingly at the center of the field in the case where patient positions had to be changed, especially in the case of post-procedure supine view.

Lithotripter machines

The two centers are equipped with Siemens (Lithostar multilines, Al-neelain diagnostic center) and Dorneir compact Delta lithotripter, in Khartoum Advance Diagnostic Center

Estimation of absorbed organ doses and effective doses

ESD was used to estimate the organ equivalent dose (*H*) using software provided by the National Radiological Protection Board (NRPB-SR262) [(9)].
However, as specific projections were not available for ERCP, organ doses were obtained from the average value of the conversion factors for the most similar PA kidney, stomach and oblique duodenum views.
The organ equivalent dose *(mSv)* is given by:

$$H_T = \sum_R w_R \cdot D_{T,R} \qquad (1)$$

where $D_{T,R}$ is the mean absorbed dose to tissue (T) from radiation (R) and w_R is the radiation-weighting factor (10).

Effective dose (*E,mSv*) is a quantity that has been introduced to give an indication of risk from partial or non-uniform exposure in terms of the equivalent whole body exposure which gives the same risk (10):

$$E = \sum_T w_T \cdot H_T \qquad (2)$$

where H_T is the equivalent dose to tissue *T*.

Cancer risk estimation

The risk (R_T) of developing cancer in a particular organ (T) following ERCP after irradiation was estimated by multiplying the mean organ equivalent (H_T) dose with the risk coefficients (f_T) obtained from ICRP [(10,11)].

$$R_T = H_T \cdot f_T \qquad (3)$$

The overall lifetime mortality risk (*R*) per procedure resulting from cancer/heritable was determined by multiplying the effective dose (*E*) by the risk factor (*f*).

$$R = E \cdot f = \sum R_T \qquad (4)$$

The risk of genetic effects in future generations was obtained by multiplying the mean dose to the ovaries by the risk factor [10,11].

RESULTS

The patient body characteristic data (age, height, weight and BMI) Table 1 were comparable to the mean values reported in the literature [3-7]. In this study the patient age ranged from 18 to 82 years, the mean height, weight and BMI were 162 cm, 75 Kg and 29.5 Kg/m^2 , respectively. The exposure factors (kVp, mA) for all patients were comparable to exposure factors reported in previous studies [12] as shown in Table 2. In general, high kVp increases the scatter radiation thus also the patients' dose, while decreasing the contrast of the image. The quality of the radiation depends on the tube voltage and the total filtration of the X-ray beam.
The mean ESD and effective dose resulting from ESWL procedure has been estimated to be 0.36 mGy and 0.01 mSv, respectively for the total patient population as presented in Table 3.
The probability of cancer due to radiation dose depends on organ dose, age and tissue weighting factor, which represent the relative contribution of that organ or tissue to these effects. Radiation organ doses are shown in Figure 2.

Table 1: Patient body characteristics (age, Height, BMI and weight).

Center	n	Age (year)	Height (cm)	Weight (Kg)	BMI (kg/m²)
A	50	50 (18-82)	162.6	72.9	27.6
B	25	45 (29-70)	160.5	77.7	31.5
All	75	46.5	161.55	75.3	29.55

Table 2: Exposure factors and parameters for fluoroscopy in ESWL in two centers.

Center	kV	mAs
A	100.7(85-108.3)	4.2(4-4.8)
B	89(69.3-102)	3.6(3.3-4)
All	94.85	3.9

Table 3: Patient radiation dose in ESWL (*mGy*) and Effective dose mSv.

Center	Mean±Sd	Minimum	Median	Maximum	Effective dose (mSv)
A	37±0.1	19	36	197	1.22
B	34±0.3	10	33	55	1.18
All	36±0.2	10	35	179	1.20

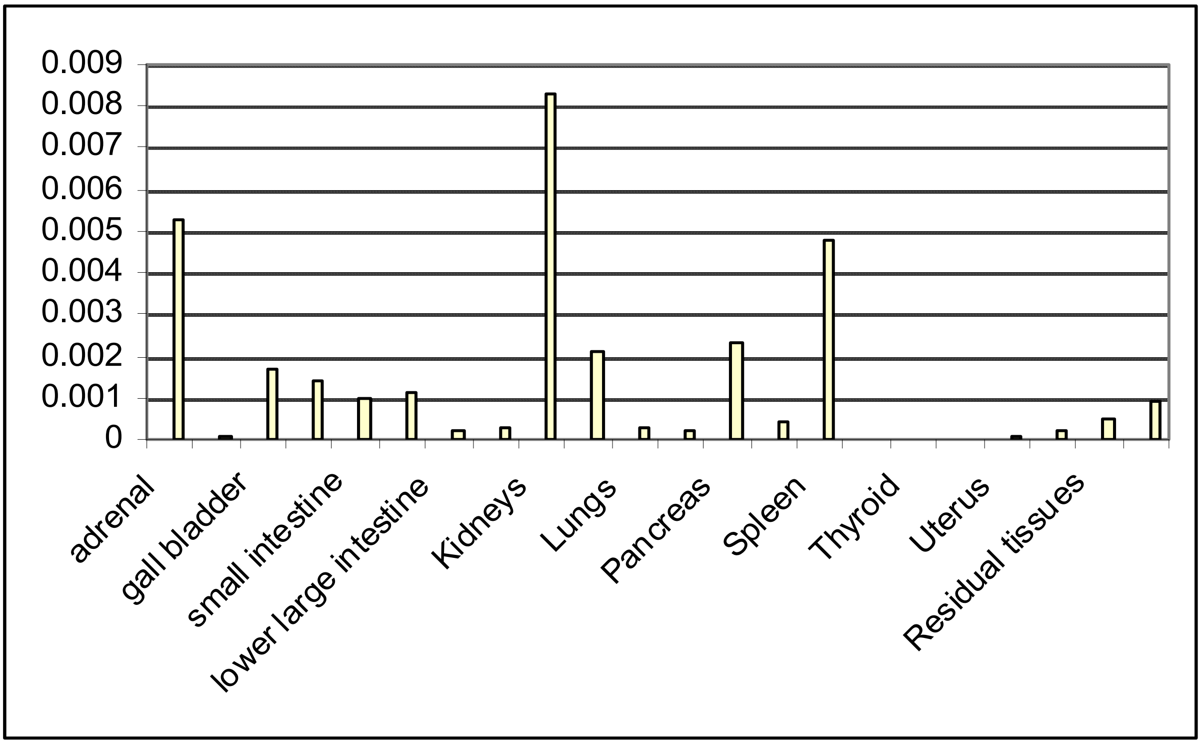

Figure 2: patient's organ dose during lithotripsy procedures (Gy).

DISCUSSIONS

Estimation the impact of radiation dose and its related effects during extra corporeal shock waves lithotripsy procedures is vital in order to improve patient radiation protection.

Adult patients were divided into two Groups; the first Group was submitted to Siemens (lithostar multilines) lithotripter and the second to Dorneir compact Delta lithotripter. The most common indications were renal stones and uretric stones, 51% and 37% for Group *A* and *B* respectively. From the results of measurements the mean entrance surface dose for Group *A* is 37 mGy (17-197) and the mean entrance surface dose for Group *B* is 34 mGy (10- 55), as it observed Group *A* was irradiated to higher dose than Group *B* that's because of the X-ray fluoroscopy equipment in the first Group *A* has no ability to change the orientation of the machine without exposing the patient the reason which extending the irradiation duration then increasing the entrance surface dose. This values is lower than 1.2 mGy which is measured by McNamara and others. This result disagreed with to our results where Group *A* showed a weak correlation between the measured dose and weight (R^2 =0.036) while in Group *B* showed strong correlation (R^2=0.94).

Table 4 present the results of the current study compared to previous studies. These variations in patient doses could be attributed to the X-ray machine characteristics and to projections used to derive the effective dose from ESD. However, it offers a good and simple indicator of effective dose estimation.

It's believed that there is a notice possibility for carcinogenesis due to irradiation by ionizing radiation; this study shows that a small amount of radiation reaching the internal organs such as stomach, lungs and thyroid with compared with skin dose; these organs doses are shown in chapter four in details; then probability of carcinogenesis due to these small amount of radiation is considered a tiny odd too. Although, the obtained results were consent to previous study done by J.Talati and others aimed to reducing the radiation exposure to patient following ESWL. In addition to that much concern should be taken for skin (40% and 30% for Group *A* and *B* respectively. The mean ESD and effective dose values measured in this study are lower to but smaller than the values reported in the literature for ESWL

Table 4: patient radiation dose during lithotripsy procedures in the literature

Author	No of patients	ESD (mGy)	Effective dose (mSv)
Present study	75	38	1.2
Sandilos et al [6]	50	76.5	1.63
Wei-Chuan Chen et al [14]	89	30.1	NR
Perisinakis et al [13]	124	NR	1.82
Bushara et al [12]	41	34	1.13
Talati et al [5]	78	5.78	NR

NR: Not Reported

CONCLUSION

The mean entrance surface dose is 37 mGy and 34 mGy for the both of centers, these values are considered an acceptable values if compared with previous studies. Although the measured doses were infinitesimal, ESWL can not consider a safe treatment procedure because of the accumulative effect due to repetition of procedures in addition to the exposures from pre and post-examination.

Based on the results we recommended the technologist should undergo to intensive training courses because the experience of technologist in lithotripsy field is the key of patients protection. Also we recommended establishing strong and regular quality assurance program to optimize ESWL procedure.

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