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Measurement Of Radiation Dose During ExtraCorpearal ShockWave Lithotripsy Procedure

Nada AA Bushara[1], Abdelmoneim Sulieman[2,3 *], Mohamed A Halato[1], Ibrahim.I.Suliman[4]

[1]Department of biomedical physics – school of physics and applied physics- faculty of sciences and technology - Al-Nialeen University - Sudan.

[2]Department of Radiology and Medical Imaging, College of Applied Medical Sciences, Salman bin Abdulaziz University, Alkharj,P.O.Box 422, Kingdom of Saudi Arabia.

[3]College of Medical Radiologic Science, Sudan University of Science and Technology, P.O.Box 1908, Khartoum, Sudan

[4]Department of Radiology & Molecular Imaging, Medical Physics Section, College of Medicine & Health Sciences, Sultan Qaboos University, PO 35, Al-Khod 123, Oman

Abstract

Extracorporeal shock wave lithotripsy (ESWL) is considered the gold standard in vivo treatment process for renal, uretric and kidney stones. This procedure is usually followed up by using x-ray fluoroscopy device. Therefore, optimization the absorbed dose of patients is crucial ; the aim of this study is to measure the entrance surface dose, organ dose and the probability of carcinogenesis regarding to x-ray fluoroscopy irradiating during ESWL. The study was performed in Al-Naileen diagnostic center (group A, 33 patient) and in Al-Khartoum advance diagnostic center (group B, 18 patients), the entrance surface doses (ESD) measurements were performed using thermoluminescence dosimeter (TLDs) GR200A LiF. The mean entrance surface dose and mean effective dose were (0.34 mGy & 0.014 mGy) and (0.22mGy & 0.01 mGy) for groupA and B respectively. The estimated organ dose were (0.16 mGy), (0.02) and (0.01) for kidneys, intestines and ovaries in that order. Group A was irradiated to higher dose than group B due to the X ray machine characteristics and techniques. The results show that the probability of carcinogenesis is a tiny value (1 for million patient. In addition the study insures that there is a correlation between the weights, irradiating factors and absorbed doses; as a result guiding charts, training courses for technician and a strong quality assurance program were recommended to optimize the ESD for patients.

Key Words: Lithotripsy, Radiation Dose, Cancer Risk, TLD, Patient Exposure.

INTRODUCTION

Shock waves were discovered in 1980 by German's scientists. Since the shock wave is generated outside the body, the scientific name of lithotripsy procedures is termed by Extracorporeal Shock Wave Lithotripsy (ESWL) where lithotripsy is a Greek word contains of two parts, litho means calculi and tripsy means to break.[1]

One of the well-known shock waves applications in the medical field is ESWL it has for the first time provided a completely non-invasive technique for the management of renal, uretric and bladder calculi and has rapidly gained world wide acceptance as an effective and safe method in adults on the other hand, several studies on a small number of children have demonstrated that ESWL can be used safely in young patients. Although, ESWL is less difficult to perform but there success ranges from 50 to 80 %.[2]

ESWL is not without risks; the shock waves themselves, as well as cavitations bubbles formed by the agitation of the urine medium, can lead to many complication occurring including: Bleeding around the kidney, Infection of the urinary tract, Loss of function then renal failure, Obstruction of the urinary tract by calculi fragments.[3]

Address for correspondence*

Dr. Abdelmoneim Sulieman Department of Radiology and Medical ImagingCollege of Applied Medical Sciences, Salman bin Abdulaziz University, Alkharj,P.O.Box 422, Kingdom of Saudi Arabia .Email: abdelmoneim_a@yahoo.com

However, Lithotripsy requires fluoroscopic and radiographic exposures, which impose radiation risks for patients and examiners as well. Considerable doses are delivered to entire patients groups. Consequently, radiation dosimetry in this context can be concerned by estimation of the entrance surface dose (ESD) during X ray examination to radiosensitive organs and the probability of carcinogenesis due to irradiating to this type of radiation during ESWL. The partial exposures of patient result in heterogeneous dose distribution; therefore the organ dose values are more appropriate descriptors of patient dose and related risks. Moreover, in order to assess the radiation risk for a procedure or particular organs, it is necessary to know effective and organ equivalent doses associated with the procedures, by applying a suitable conversion factor to ESD.

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 times vary depending on the procedure which being performed, some procedures are extended up to 75 minutes just like ESWL and because of the 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 area most exposed by the primary beam 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, however the long length of ESWL procedures, in addition to the biological effects of ionizing radiation- which it will be explained later on - and the absorbed dose to a specific part of the skin and other tissues is of concern in applying the reference radiation levels of x-ray fluoroscopy devises for two reasons: one is the need for minimizing the dose to sensitive organs, such as the thyroid, gonads and breast, the second is the possible incidence of the radiation beam to an area of the skin for a long time that can result in radiation injuries in cases of very high doses.[4]

Justification of Lithotripsy for the patients has already been established but it has to be applied in concordance with optimization of the technique.[5] Optimizing patient radiation dose also provides a direct benefit to the examination team: scattered radiation in the room is directly proportional to the patient dose.[4-6] International Commission on Radiological Protection (ICRP),[5] has recommended dose limits for occupational exposure in order to reduce the probability of the stochastic effects and to prevent the deterministic effects.

There is a lack of information concerning the doses received by radiosensitive organs and related risks during lithotripsy. Advantages of TLDs include their small size, wide dose measuring range, integrative measurement method, no attached cables, tissue equivalence (at least for some materials) and high spatial resolution.[7-9]

Because risks associated with radiation exposure may be related to the cumulative number of x-ray examinations and/or treatments over a long period of time, our study is aimed to determine the dose fractions which reaching different parts of the patient body through an ESWL procedure derived by x-ray fluoroscopic devices in Sudan. The average effective dose calculated in a given procedure, as well as the number of lithotripsy procedures performed for an individual patient, is global indicators and provides key information for evaluating medical radiation exposure. Also they serve to estimate the impact of the different kinds of lithotripters in different centers and related biological impacts. Moreover, as far as we know there is no study has been published in the open literature concerning patient's radiation dose measurements during ESWL procedure in Sudan as far as we know.

The objectives of this study are to: (i) measure patients entrance surface dose (ESD) dose and organ dose during the aforementioned procedure.(ii) Estimate the radiation risk.(iii) and compare the radiation dose between two lithotripsy departments (two lithotripsy machines).

MATERIALS AND METHODS

Lithotripter machines:

Two types of lithotripters were used in this study

Siemens (lithostar multilines)

This type of lithotripters is available at al-neelain diagnostic center with a serial number 3127011 (Siemens , Germany), the maximum number of shock waves is 4000 combined with maximum power equal to 4 for kidney and 9 for ureteral, the c-arm has ability to orientate horizontally between two angels (-10) and (+30) and from a point of safety the machine is disconnect the shock waves every 500 shock also this device provide reasonable shock waves speed reach to 90.

The x-ray fluoroscopy machine which is related to lithostar multilines Lithotripter with a serial number 1184696 (Germany); it's manufactured with 0.6/1 focal spot sizes, 0.5 mm Al as a tube filtration, 0.5 mm Al as an added filtration and a total filtration equivalent to 2.8 mm Al. The technician can not change the orientation of the c-arm without exposing the patient.

Dorneir compact Delta lithotripter

This type is available in Khartoum Advance Diagnostic Center KADC; it's manufactured by Dornier med Tech Company in Germany, its supply a continues shock waves until the term of the procedure with variable speeds according to the variety of the kV for example: among 60 kV the speed is 110 and 120 among 70kV, the maximum number of shock waves is 3000 associating with maximum power equal to 5 for renal and 6 for uretal , the c-arm orientate vertically in three positions AP, crenicordal and cordiernial around a stationary couch.

The related fluoroscopy machine to Dornier delta lithotripter is anti scattering grid has 1:10 ratio in the company of a focal distance equal to 120 cm, the stationary anode provide0.5 and 1.5 mm Al as a focal spot sizes, the total filtration is 1.4 mm Al, the machine supplied by 230voltage and 50/60 Hz, the initial kv is 70 kV and the maximum is 110 kV. Nevertheless as in lithostar lithotripsy the images are presented on a TV monitor but this device offer the ability for the technician to change the orientation without exposing the patient.

Ionization chamber

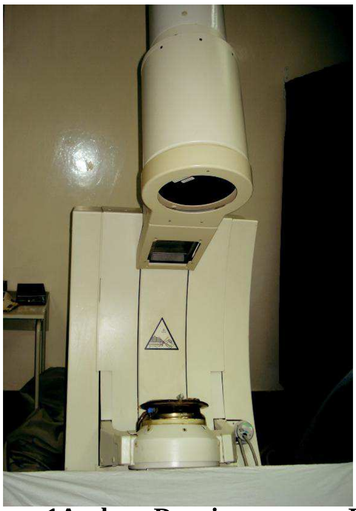

Figure 1A, show Dornier compact Delta lithotripter

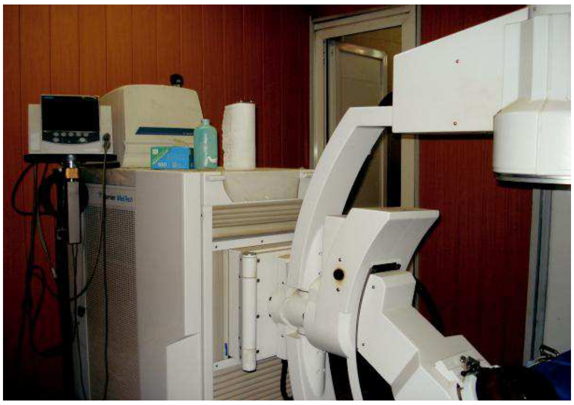

Figure 1B, lithostar multilines lithotripter

The standard dosimeter which was used to obtain the standard doses during the TLD reader calibration was a farmer-type ionization chamber FC 65-G manufactured by Scanditroix-wellhofer GMBH, in Schwarzeburck-Germany with a calibration certificate no.2300958 from Scanditroix-wellhofer GMBH standard laboratory.The electrometer is manufactured by

Scanditroix-wellhofer GMBH with the same certificate number of the FC-65G ionization chamber.

TLD material

The most preferable material in dosimetry is LiF, in this study the selected TLD material was GR200A LiF doped with Mg, Cu and P in a fine circular shape with 4.5 mm diameter and 0.8 mm thickness from PTW Company-France, moreover they have a linear response from 1 micro Gy to 12 Gy.[10]

TLD annealing oven

Most of trapped electrons in the TLDs materials do not released completely due to background radiation or dark currents so they need an annealing process to remove these electrons, the annealing of these TLDs in this study was achieved by using PTW-Theldo oven at temperature of 240° C for 10 min followed by w quickly cooling assist by liquid N2, the TLDs were placed in the conductive tray and inserted to the oven which is controlled the temperature and the time using computer under windows XP through Theldo version [1.1] software.

TLD reading system

TLDs signals are detected by TLD reader system which is basically consist of photo multiplayer tub PMT, two access for loading holders and other electrical circuits. The uses TLD reader in this study was PLC3 which was manufactured by fimel in France. The irradiated TLDs were picked by an electrical vacuum placer and placed in a small blank steal cupells taking into account the numerical arrangement of the TLDs, and then the cupells were recognized inside PCL3 loading holder, five cupells were leaved empty to let the TLD reader warming up, then by an automatically slow movement the cupells fill the holder and then the loaded holder and the unloaded one were placed inside the PLC3 TLD reader. Figure 6 and 7 present the steal cupells and the loading holder.

Between the loaded and unloaded holders inside the TLD reader there are circular halls where the TLDs are released from the loaded holder and stay inside it one by one for 60 seconds on 155° C as a pre-heating temperature and 260° C as post- heating, after that the TLDs completes there rotation reaching a photo multiplayer tube PMT which is supplied by 850V, the signals were detected after passing through one or more filtration processes. The output light from the TLDs is proportional to the quantity of the absorbed dose, therefore to the output current and the area under the curve in the apparent glow curve on the Theldo version [1.1] software at the end. All this procedure takes about 130 second. Figure A and B present the halls and the circular path between the loaded, unloaded holders and the PMT inside the PCL3 TLD reader.

Experimental procedure for dose measurement

TLDs Calibration

The calibration process was achieved with three repetition annealing procedures using a calibration source which is contain an ionization source claimed closed to the photomultiplier tube PMT. A totalof 30 TLDs were selected. TLDs were picked carefully using the electrical vacuum tweezer and arranged in the center of Perspex tray (a density tissue equivalent material) , the center of this tray was preferred as a suitable position to prevent mixing up.

Before irradiating the TLDs set, the ionization chamber was exposed to known parameters (70kV, 160 mA and 20mAs) at 100 cm FFD using a conventional x-ray apparatus manufactured by Toshiba KX-22 R Company. Afterwards, the arranged TLDs in the Perspex tray were irradiated by the same exposure parameter.

Subsequently the correction factor CF was calculated individually for each TLD using Microsoft office excel, at first the values of the TLDs reading was divided by the average TLDs reading and all the TLDs with correction factors exceeded ±5% were eliminated

$$cal = \frac{SD}{\bar{S}} \; (mG/nC) \quad \ldots \quad 1$$

The individual correction factor was obtained by using the following equation:

Where:

$\bar{S}$ cal= calibration factor (Dose correction factor)

SD=standard dose

$$\bar{S} = \frac{S_1 + S_2 + S_3 + \ldots + S_n}{n}$$

= average signal

The average signal is obtained by using the following equation:

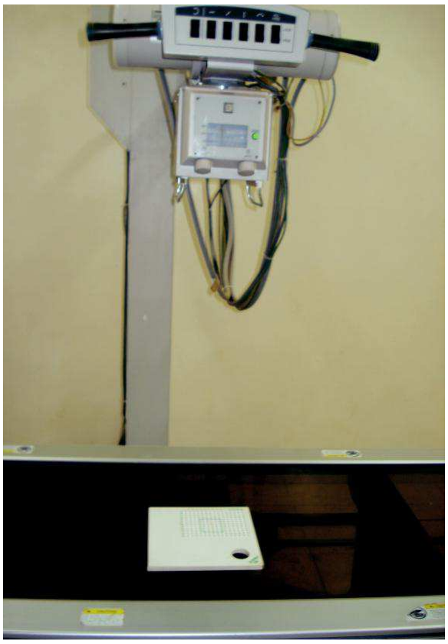

Figure 2, A TLD calibration

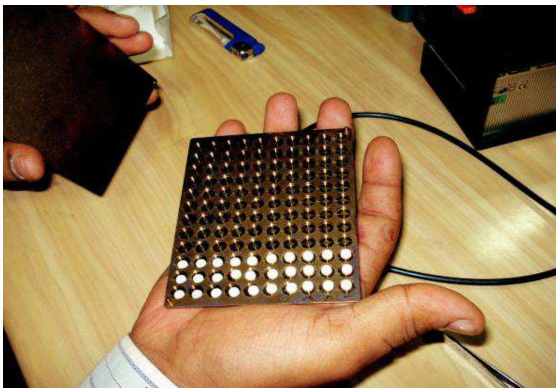

Figure B TLD in a copper Tray

Where:

S1, S2, S3,…………….. , Sn is the signals of the exposed TLDs

n= number of TLDs signals.

Entrance surface dose

The entrance surface a dose was measured for the 33 patients in Al-Naileen Diagnostic center.

The measured entrance surface dose for 18 patients in Al-Khartoum advance diagnostic centre.

Plastic envelopes were prepared in order to accommodate 3 TLD chips. Each envelop was placed in the entrance of the x-ray fluoroscopy beam on the patient and the ordinary lithotripsy procedure was established after preparation of the patient, The start time, end time and the total time of exposing for both of usage two lithotripters were also recorded.

Organs doses calculations

The organ dose relative to entrance surface dose in air was obtained using the below equation:

Do = ESD × f (1).

Where:

Do= the organ dose.

ESD = the mean entrance surface dose.

f=the incidence absorbed dose fraction.

Probability of carcinogenesis

The Probability of carcinogenesis or (nominal risk) for each organ was obtained by using the following equation:

Ñ = Do × € (2)

Where:

Ñ= Probability of carcinogenesis.

Do= organ dose.

€= nominal risk coefficient.

RESULTS

Entrance surface dose

The mean entrance surface dose was 0.34 mGy averaged between 0.17 mGy as a minimum value and 0.57 mGy as a maximum for Al-Naileen diagnostic centre. The mean entrance surface dose is 0.211mGy averaged between 0.10 mGy as a minimum value and 0.46 mGy as maximum for Al-Khartoum Advance diagnostic centre. Adults Patients were divided into two groups A and B within average age 47 yrs, 161 cm height and about 75 kg weight.

Organs doses calculations

The calculated organs doses for those patients who are submitted to ESWL in Al-Naileen diagnostic centre through Siemens (lithostar multilines) lithotripter are presented in Table 4.

The calculated organs doses for those patients who are submitted to ESWL in Al-Khartoum diagnostic centre through Dorneir compact Delta lithotripter are presented in table 5.

DISCUSSIONS

The most common indications were renal stones and uretric stones, 51% and 37% for group1 and 2 respectively. From the results of measurements the mean entrance surface dose for group A is equaled to 0.34 mGy (0.17-0.57) and the mean entrancesurface dose for group2 is 0.214871mGy (0.10-0.46), as it observed group1 was irradiated to higher dose than group2 that's because of the x-ray fluoroscopy equipment in the first group 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 mSv = 1.2 mGy which is measured by Macanamara and others. In their study they select a group of patients weighing about 82 kg and the results previews that there is a linear relationship between weight and measured doses. This result is does not typically consent to our results where group1 provide a weak liner correlation between the measured dose and weights where $R2$ =0.036 but in group2 $R2$=0.94 which it consider a strong relation and agree with the previous study; it's assumed that the different methods of the x-ray fluoroscopy machines monitoring, different indication and the large number of patients in group1 also contributing in variation of the measured doses for group1.

Since the measured doses were strongly depending on weight therefore; it has been found that BMI is exponentially affecting the measured dose where $R2$=0.87 and $R2$=0.93 for group1 and 2 respectively, also an observed differ relation shown in group1 for the same reasons which had been mentioned above, furthermore; mA and kV were affecting the measured dose linearly. Table 1 present the results of the current study compared to previous studies. 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 group1 and 2 respectively); chart 9 and 10 provide completely related proportions.

CONCLUSION

The mean entrance surface dose is 0.3415 mGy and 0.214871mGy for the both of centers, these values are considered an acceptable values if compared with 4 Gy as a lethal dose for adult man weighing about 70 kg, also these values regard as insignificant amount for producing ionization event in each cell that because of 1 mGy is the threshold of inducing ionization event per cell as it had been mentioned in chapter 1, although the measured doses were infinitesimal but ESWL can not consider a safety treatment procedure because of the accumulative effect due to repetition of procedures in addition to the exposures from pre and post-examination.

RECOMMENDATION

Based on the results we recommended the technician should undergo to intensive training courses because the experience of technician in lithotripsy field is the key of patients protection. Also we recommended establishing strong and regular quality assurance program to optimize ESWL procedure. An alternative treatment such as surgery or endoscopies is more valuable for those patients with a very large or multiple stones.

Since there is a clear relation between patients characteristic and

Table 1 the current study results compared to the previous one.

	no. of patients		age range	mean weight	mean length	mean BMI	mean mA	mean kV	mean doses	mean effective doses
Nada thesis	G1	33	47yrs (18-82)	72.9 kg (49-100)	162.6 cm (150-182)	27.6 (21-40.8)	4.2 mA (4-4.8)	100.7 kV (85_108.3)	0.34 mSv (0.17-0.57)	0.0135 mSv
	G2	8	47yrs (29-66)	77.7kg (50-100)	160.5 cm (138-172)	31.5 (17.5-52)	3.6 mA (3.3-4)	89 kV (69.3-102)	0.21 mSv (0.1-0.46)	0.00975 mSv
Perisinakis et al (2002)	124		-	-	-	-	-	-	-	male / female
										proximal ureteral: 1.82 mSv / 1.71 mSv
										distal ureteral: 1.62 mSv / 0.76 mSv
j.Talati et al (2000)	G1	78	38 yrs	-	-	-	-	-	5.78 mSv	-
	G2	67yrs	40 yrs	-	-	-	-	-	3.43 mSv	-
Macanamara & Hoskin (1999)	40		-	-	-	-	-	95.7 kV	401.2 DAP	0.95 DAP

measured dose it is good idea sketching guiding charts to provide a suitable fluoroscopy exposure factors through a range of patient characteristics and indications.

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