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Original Article

A Study on Radiation Dose Received by Patients during Extracorporeal Shock Wave Lithotripsy

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Abstract

Background: Extracorporeal shock wave lithotripsy (ESWL) is considered as the method of choice for treatment of most stone diseases. The present study aims to evaluate radiation dose received by patients undergoing ESWL.

Methods: In total, 46 patients from both genders were referred to the Shohadaye Ashayer hospital of Khorramabad, Iran and were included in the present study. Patients were positioned in anteroposterior (AP) projection and along 30° anterior oblique (AO) projection upon the X-ray fluoroscopy table and exposures were conducted. Thermoluminescent dosimeters (TLDs) were used for radiation dose measurements. To evaluate the entrance surface dose (ESD), each TLD chip was taped on back of patient at the entrance surfaces of the X-ray beam.

Results: The mean number of stones in each patient was 1.4. The stone sizes ranged from 7 to 29 mm, and a mean of 3200 pulses were need for each patient. The mean ESD in the postero-anterior (PA) and oblique X-ray beam entrance were obtained at 12.04 and 68.84 mGy, respectively. There was linear correlation between patient dose with fluoroscopy time, tube current (mA), tube potential (kVp) and patient position ($P < 0.001$); however, we found no strong correlation between patient dose with patient body mass ($P = 0.837$), number of shock wave pulses ($P = 0.089$), stone size ($P = 0.773$) and locations ($P = 0.463$).

Conclusion: The data obtained in the current study are comparable with information available in the literature. They emphasized that ESWL exposes patients to much more radiation compared to those from conventional radiography and is in the range of computed tomography (CT) procedures. Therefore, following safety guidelines is recommended.

Keywords: Exposure, Extracorporeal Shock Wave Lithotripsy (ESWL), Patient, Urinary stone

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Introduction

Introduction of extracorporeal shock wave lithotripsy (ESWL) and its use in the 1980s revolutionized treatment of stone disease.[1-3] ESWL, as an alternative to the percutaneous ureteroscopy and surgery, is the most common and minimally invasive treatment for renal stones and most urinary calculi.[3,4] An estimate indicated that more than 80% of the urinary tract stones can be treated with ESWL[1,2] with a high satisfactory rate of approximately 90%.[5] With the increasing incidence of stone disease in the last 2 decades, there was a concomitant increase in use of ESWL for treatment of stone diseases.[1]

In ESWL, a lithotripter, located outside the patient's body, is used to generate high-energy shock waves and focuses on renal stones to pulverize them into small fragments to pass via the urinary tract. Fluoroscopy and ultrasonography (US) are 2 imaging modalities used for the localization of the stones, image formation and track treatment progress during ESWL. US is the preferred imaging modality for those patients who suffer from kidney or bladder stones while fluoroscopy is the method of choice for treatment of ureteral stones.[4] However, most clinical departments still insist on use of traditional fluoroscopy localization for calculi targeting.

During the procedure, a fluoroscopy X-ray unit is used for stone localization. The patient moves until the stone is located at the center of the fluoroscopy monitor. In this position, a large number of shock waves are pulsed for stone fragmentation. The process of stone fragmentation is in control using alternative x-ray fluoroscopy and high quality spot films until satisfactory stone destruction occurs.[6]

ESWL exposes patients to radiation in 2 ways and important health issues that should be taken into consideration should be addressed. The first source of radiation is during X-ray fluoroscopy to localize stones, and the second source of radiation is the pre-and post-treatment exposures needed for initial diagnosis and to follow-up therapy success.[7] Given that most patients who undergo fluoroscopy for ESWL are young adults and fluoroscopy extends to different areas of the body, it is imperative to monitor patients receiving these doses.[4,5] However, despite increasing use of ESWL in the last 2 decades, there are limited number of studies that address these exposures and most are dated.[4,6,8,9]

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Sandilos et al[6] studied the radiation dose received by patients during ESWL and found the mean entrance surface dose (ESD) to be 76.5 mGy for the oblique x-ray beam entrance and 44.5 mGy for the PA X-ray beam entrance. In a similar study, Sulieman et al[5] assessed ESD and radiation risk in 75 patients undergoing ESWL and found that the mean ESD and the probability of radiation induced carcinogenesis to be 36 mGy and 100 per million patients, respectively.

To the best of our knowledge, no study has been performed on patients' dosimetry during ESWL in Iran and this is the aim of this study to evaluate the radiation dose received by patients during ESWL.

Material and Methods

Patients

This was an analytical descriptive study conducted in the largest stone center of Khorramabad, Iran named Shohadaye Ashayer from February to December, 2017. Based on previous studies and considering $\alpha = 0.05$, the study population was calculated to be 46 patients from both genders referred to the ESWL department. Patients with renal pelvis or calyx radio-opaque stones with diameter of < 3 cm, were included in the study. Patients with urinary tract problems and pregnant women were excluded from the study.

ESWL Procedure

The ESWL procedure was performed using the MODULITH SLK (STORZ MEDICAL CO, Switzerland) unit which was equipped with a singular fluoroscopic x-ray unit (GE OEC 7700) and a sonography unit (SSD-1000ALOKA). The electromagnetic method is used for production of shockwaves and the focal spot size was 0.2 mm. The coupling mechanism was water coupling and used an acoustic lens to focus the shockwaves.

Our departmental policy for fluoroscopic exposures during ESWL included exposure along the anteroposterior (AP) projection and exposure along a 30° anterior oblique (AO) projection.

ESD is the most prevalent indicator to evaluate the radiation dose received by the patient during a radiological examination. The ESD can be directly obtained using thermoluminescent dosimeters (TLDs) or indirectly obtained using measurement of the tube output at free-air or by applied exposure parameters using a mathematical formula.[10] TLDs are widely used for radiation dose measurement in diagnostic radiology. It can measure the intensity of visible light emitted from a crystal in the detector when the crystal is heated in the oven named the TLD reader. The intensity of light emitted is proportional to the absorbed dose.[11] In this study, we used TLD (GR200) for radiation dose measurements (LiF: Mg, Cu, P; Radiation Dosimetry TLD, Hangzhou Freq-Electronic Control Technology Ltd, China). These TLDs have a small size (near tissue equivalent) and, consequently, are not visible on the image. Prior to the study, the TLDs were calibrated to provide the absorbed dose in miligray (mGy). A group of TLDs were irradiated by diagnostic X-rays (100 kV, total filtration of 3.0 mmAl) to a known dose (mGy range) measured by a 6 cm ion chamber and Radcal monitor. According to the manufacturer's protocol, before and after each use, the TLDs were annealed at 245˚C for 10 minutes and then cooled to 35°C. Acalibrated Harshaw 3500 TLD Reader (Thermo Fisher Scientific, USA) was used to anneal and read the TLDs.

For patient dosimetry, each TLD chip was placed into a thin waterproof plastic bag and was taped on the patient's back at the entrance surfaces of the x-ray beams. Following Sandilos et al,[6] during fluoroscopy, a small radio-opaque identification indicator was placed along with the TLDs to achieve each TLD position. A set of three TLDs were employed for each side, but only those that were imaged in the respective monitor were used to calculate the mean ESD in the oblique and the PA X-ray beam entrance surface.

Statistical Analysis

The analytical and descriptive statistics were performed using SPSS 24.0 software (SPSS Inc., Chicago, Illinois, United States).[12] Descriptive statistics were shown in terms of mean (SD) for continuous variables. The chi-square test was applied to evaluate the univariate relationship between independent variables and outcome. A P value < 0.05 was considered to be statistically significant.

Results

A total of 46 patients (aged 27–65 years) were referred to ESWL, one of the largest stone centers in Lorestan Province in western Iran and included in the present study. Most participants were male (29, 63%); whereas 17 of the patients (37%) were female. The characteristic of patients and exposure parameters are presented in Table 1.

In term of stone locations, 43.6% of the stones were located in the calyx, 20.5% were in the renal pelvis, 28.2% were in the ureters, 2.6% were in both the calyx and pelvis, 2.6% were in both the pelvis and ureter, and 2.5% were in the bladder. The stone sizes ranged from 7 to 29 mm, and a mean of 3200 pulses were required for each patient.

Table 1. Characteristics of Patients and Exposure Parameters

	kVp	mA	Fluoroscopy Time (s)	Height (cm)	Weight (kg)	Body Mass (kg/m²)
Mean	90.18	2.66	106.24	164.5	76.4	27.55
Minimum	66.83	1.2	5	149	45	17.57
Maximum	138	3.7	472	187	97	36.21

kVp, kilovoltage peak; mA, milliampere-second

The mean number of stones in each patient was 1.4; the minimum and maximum numbers werealso1 and 4, respectively. The mean ESD in the PA and oblique x-ray beam entrance were obtained to be 12.04 and 68.84 mGy, respectively (Figure 1). There was linear correlation between patient dose with fluoroscopy time, tube current (mA), tube potential (kVp) and patient position ($P < 0.001$); however, we found no strong correlation between patient dose with patient body mass ($P = 0.837$), number of shock wave pulses ($P = 0.089$), stone size ($P = 0.773$) and locations ($P = 0.463$).

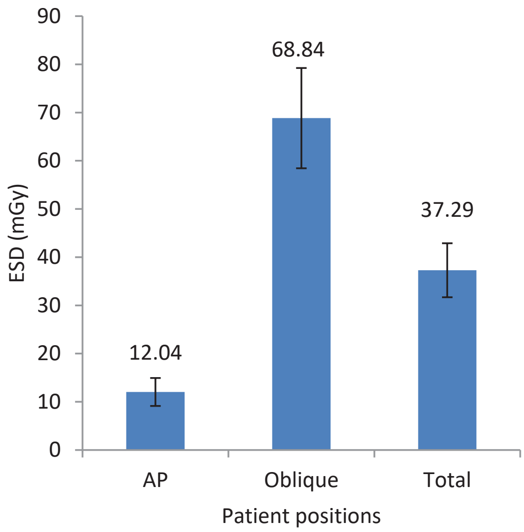

Figure 1. The Mean ESD as a Function of Patient Positions During ESWL. Standard deviations presented as error bars.

Discussion

Patients with stone disease are being increasingly referred to ESWL and it is essential to monitor the received dose to enhance radiation protection optimization. Our study demonstrated that there is wide variation in the ESD values and fluoroscopy times during ESWL and this is consistent with previous literature.[6,9,13] These variations could be attributed to various factors such as patient size, number, and composition of the stones, position of the patient and skill of the operators. In agreement with previous literature,[6,9] our study demonstrated that there is strong linear correlation between ESD and the tube current (mA), tube potential (kVp), fluoroscopy times and patient position. In a similar study, Sandilos et al[6] assessed patient radiation dose from ESWL and reported that the largest patient dose comes mainly from larger-sized patients with medium radio-opacity stones and or the medium-sized patients with low radio-opacity stones. The mean fluoroscopy time in our study was obtained at 106 sec which is consistent with previous literature[4]; with the exception of value reported by Chen et al[14] However, it was generally lower than those reported previously.[6,9,13] It seems that stone size and composition as well as the skill of operator can affect fluoroscopy time. In agreement with the referenced studies,[6,8,9] our study showed that the patient position strongly affected ESD values. In the oblique X-ray beam entrance surface, the ESD was substantially higher than the PA X-ray beam entrance surface by a factor of 5.7 (68.84 mGy vs. 12.04 mGy; $P < 0.001$). This is due to the fact that the source-to-skin distance (SSD) is smaller for large-sized patients than for the medium-or-small-sized patients and consequently, the skin dose tended to be greater.[6] The mean ESD values in our study are comparable with the referenced studies in the literatures[4,5,15]; however, they are generally lower than others[8,13,16] with the exception of value reported by Chen et al,[14] and this may be related to dose optimization issues (Table 2).

ESWL exposes patients to a large amount of radiation in comparison to those exposed to conventional radiography and it is necessary to follow safety guidelines to decrease the dose received by a patient to levels as low as reasonably achievable (ALARA). In our study, the mean ESDs in the oblique and PA X-ray beam entrance were obtained at 68.8 and 12.04 mGy which are equivalent to 299 and 52 consecutive adult PA chest radiographs, respectively.[17] According to Table 2, the ESDs from ESWL ranged from 30.1 to 162 mGy in the literature; corresponding to 130 to 704 consecutive adult PA chest radiographs, respectively. Moreover, the pre-and post-treatment exposures are also an added source of radiation to the patients that should be taken into account. In a retrospective study, Talati et al[7] assessed the patient radiation dose before and after ESWL for 78 patients with radio-opaque upper urinary tract stones and found that the mean pre-and post-treatment exposures were 5.38 and 5.78 mSv, respectively; corresponding to the total dose of 11.09 mSv. This can be interpreted to be 554 consecutive adult PA chest radiographs.

There are many dose optimization strategies that can be used to decrease the patient's radiation dose during ESWL procedures. Reducing the time of X-ray fluoroscopy, collimating the primary beam to the region of diagnostic interest, increasing the focus-to-skin distance, use of intermittent X-ray fluoroscopy and considering the operator experience level can significantly reduce the patient radiation exposure during ESWL.[4] However, the most effective way may be to easily use US, instead of X-ray fluoroscopy, as the method of choice for calculi targeting. US is radiation-free and has demonstrated to have the localization equivalence to X-ray fluoroscopy.[18] For the unavoidable pre- and post-treatment exposures, implementation of the departmental safety policies may be effective.[19] A study revealed that using unilateral X-rays of the kidney, ureter and bladder, whenever possible and appropriate during pre-and post-treatment exposures, has the potential to reduce patient radiation exposure by 22%.[7]

This study may serve as a guide to establish the diagnostic reference level in our province during ESWL. Additional direction for future studies may be toward optimizing the radiation dose received by the patients and medical practitioners during percutaneous nephrolithotomy which is the method of choice for treating larger kidney stones (≥2 cm) when ESWL has failed in treatment. The main

Table 2. Exposure Parameters, Fluoroscopy Times and ESD Values During ESWL in the Literature

Study Type	Sample Size	kVp	mA	Fluoroscopy Time (s)	ESD (mGy)			Ref.
					Oblique	PA[f]	Total	
Patient	46	90.18	2.66	106.24	68.84	12.04	36.49	The current study
Patient	75	94.85	3.9	-	-	-	38	5
Patient	50	-	-	204	76.5	44.5	-	6
Patient	60	-	-	271	100	55	-	9
Patient	276	-	-	162	-	-	101	16
-	33	-	-	218	-	-	120	13
Patient Phantom[b]	125	-	-	186	162[a]	121[a]	-	8
Patient Phantom[d]	124	68 66.5	2.9 2.9	108	-	-	54[b] 38[c]	4
Patient	-	-	-	160	-	-	47	15
Patient	-	-	-	25.2	-	-	30.1	14

Abbreviations: PA, posterior anterior; ESD, entrance surface dose.
[a] Estimated values from phantom measurements and analysis of 125 ESWL in patients; [b] proximal ureteral stone treatment; [c] distal ureteral stone treatment; [d] Estimated values from phantom measurements and analysis of 124 ESWL in patients.

limitation of the current study was the unavailability of a TLD reader and ion chamber in our institution that lead to delays in data collection.

Authors' Contribution

NH and MG collected data. MG and VK performed statistical analysis. MG and VK wrote the manuscript.

Conflict of Interest Disclosures

The authors have no conflicts of interest.

Ethical Statement

This study was approved by the Ethics Committee of the Lorestan University of Medical Sciences, Khorramabad, Iran (No. IR.LUMS. REC.1396.341). Moreover, a written consent was obtained from the patients before the study.

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