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RESEARCH

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Comparative study between radiation exposure in common urological procedures

Akrm A. Elmarakbi[1], Ali Korany Elnoiry[1*], Nashaat Deiab[2] and Amr M. Lotfy[1]

Abstract

Background Fluoroscopy has become essential to urological surgery since advancement of endourology. Fluoroscopy use has increased, placing urologists as well as staff members at risk for occupational radiation exposure and related dangers. This study compared radiation exposure for staff personnel in percutaneous nephrolithotomy (PCNL), ureteroscopy (URS) and extracorporeal shock wave lithotripsy (ESWL). Then, study determined the maximum number of PCNL, URS and ESWL cases that staff members can handle safely each year.

Results Radiation exposure in PCNL group was higher than URS and ESWL especially for surgeon. Dose of radiation exposure in ESWL for surgeon, assistant and nurse was 2.4 microsievert (μSv), 0.9 μSv and 0.8 μSv, respectively. Dose of radiation exposure in URS for surgeon, assistant and nurse was 18.5 μSv, 14.3 μSv and 13.1 μSv, respectively. Dose of radiation exposure in PCNL for surgeon, assistant and nurse was 73 μSv, 51.3 μSv and 47.6 μSv, respectively.

Conclusion Increased stone size and increased fluoroscopy time were associated with high radiation exposure. PCNL procedure was 8.8 times more likely to exhibit high-dose exposure than other procedures. Urologists can perform: 274 PCNL case, 1081 URS case and 8333 ESWL case per year within safe radiation exposure limits advised by International Commission on Radiation Protection (ICRP).

Keywords Radiation dosage, Radiation safety, Fluoroscopy, Background

1 Background

PCNL, URS and ESWL, currently, considered the first line of management for urinary calculi. Retrograde pyelography (RPG) is an essential part of urology predominantly as a diagnostic procedure and an adjunctive to other urologic interventions such as PCNL, URS and ureteric stenting. This increased use of fluoroscopy has raised the possibility of occupational exposure of the urologist and assisting staff to radiation and its hazards [1].

Fluoroscopy utilizes X-rays which are high-energy ionizing radiations. Ionizing radiation enters the human body, causing cellular damage and even cell death due to their energy. Damage amounts vary according to total dose, duration of exposure and site of exposure. Such damage may result in biological consequences that could be stochastic (independent of the dose received) or deterministic (dose-dependent effects) [2].

Direct or indirect radiation exposures are both possible. Direct exposure occurs when a person is directly in contact with radiation rays from the fluoroscopy machine. Indirect exposure occurs from scattered rays resulting from the interaction of the primary beam with the patient who disseminates in all directions [3].

Renal stones can be treated either by ESWL or PCNL. PCNL is an endoscopic surgical intervention for treating large renal calculi more than 2 cm for which ESWL has failed [4]. Low morbidity and early return to work are

*Correspondence:
Ali Korany Elnoiry
aliqorany60@gmail.com
[1] Department of Urology, Faculty of Medicine, Beni Suef University, Beni Suef, Egypt
[2] Department of Medical Radiation Physics, National Cancer Institute, Cairo University, Cairo, Egypt

advantages that have popularized PCNL for the treatment of renal calculi [5].

Although ultrasonography has been used to gain renal access in some institutions, in most centers worldwide, PCNL is carried out under fluoroscopy to gain renal access, since it has the benefit of being a single-stage procedure. Fluoroscopy has been used at almost every step of the PCNL. Long use of fluoroscopy for calculus localization and for making the tract to the calculus during PCNL necessitates measuring the radiation dosage for workers and patients [6].

Fluoroscopy predisposes health workers to ionizing radiation. Ongoing efforts have been made to raise the efficacy of fluoroscopy and reduce radiation exposure in surgical centers [7].

Hazards associated with high radiation exposure among medical staff in urology field have received little attention among studies. Providers carry out hundreds to thousands of procedures throughout their careers, raising cumulative radiation dosage to them and probability of stochastic consequences. Adverse effects of radiation exposure, even at low doses, are possible. So recognizing the basic rules of radiation safety is essential for urologists in order to protect both patients and medical professionals [8].

2 Patients and methods

The study was performed in the urology department of our hospital. Ninety-nine patients undergoing PCNL, URS and ESWL, which done under fluoroscopic guidance divided equally into three groups, were observed during all stages of the procedure, and data on personnel radiation exposure were prospectively obtained for all cases. Dose reported between August 2020 and April 2022. Doses of radiation exposure estimated and recorded for operating room personnel: surgeon, assistant and nurse. The dose of radiation exposure was measured by digital electronic personal dosimeter (DEPD). This study was approved by local ethical committee.

Dose of radiation collected in the form of the cumulative dose. Dose reported for each group separately and categorically divided into: high-dose group and low-dose group utilizing a safe dose threshold of 10 μSv per hour as recommended by ICRP. Predictors of increased radiation exposure more than 10 μSv were determined using multivariate analysis. DEPD applied on outer surface of apron near neck collar. As a conventional measure of radiation exposure prevention, all staffs wore lead aprons throughout every procedure. Data were recorded in surgical report for every patient then compared for PCNL, URS and ESWL.

The medical history was gathered before the procedure plain radiography of the kidney, ureter and bladder (PUT), CBC, physical examinations and noncontract-enhanced computed tomography on urinary tract (NCTUT). According to the radiological results, stone characteristics such as stone size, position, hydronephrosis presence or absence and average HU for stone density were recorded.

Comparative parameters included gender, surgeon dose, assistant dose, nurse dose, fluoroscopic time, stone size, stone density (HU), stone position, operative time, tube voltage (K.V), tube current (M.A), preoperative double-J ureteric stent (DJ), preoperative nephrostomy tube and postoperative DJ. Perioperative complication: Hematuria, need for blood transfusion, urine leakage, second look and fever were recorded.

Three types of dosimeters used: The first dosimeter is DKG-21 PERSONAL GAMMA RADIATION dosimeter (Ecotest CARD, Operating manual BICT.412118.031-02HE. UKraine). The second dosimeter is Dositec dosimeter (Dositec.INC.model L36.MA. USA). The third dosimeter is direct reading dosimeter named pen dosimeter (Model W 138-S, 0-2 mSV. Arrow Tech. USA), serial number for third dosimeter is TC346964, TC346962 and TC346975. Dosimeters rotated regularly between staff members in different cases in three groups. Following each case, the amount of radiation recorded, and then, the dosimeter is resetted, enabling its reuse for each following case.

Our research utilized single electronic dosimeter device for each person placed on outer surface of apron (0.5-mm equivalent lead thickness) near neck collar. The dosimeter is positioned over the apron at neck collar level. The location typically can be used for estimating lens dose, thyroid dose, chest dose and waist dose but not accurate to measure radiation exposure of another parts of body like extremities. Because of the expectedly greater recorded doses if the dosimeter had been worn at the waist due to the typical radiation scatter pattern, so it worn at the neck collar.

Two multidirectional C-arm fluoroscopic units were used with an over-couch image intensifier and an under-couch X-ray tube (source of radiation waves). The first C-arm fluoroscopic unit was used during ESWL (EMD: NO 1806370 Ostim/Ankara TURKEY). The second C-arm fluoroscopic unit was used during PCNL and URS (Siemens: NO 12791052 Eriangen, Germany). Ureteroscope two types: Karl storz and Wolf, while nephroscope type: Karl storz. The ideal tube voltage and current were automatically set by the fluoroscope using a mode for automatic brightness adjustment. The study's ranges for tube voltage and current were 63–110 kV and 0.9–7.8 MA, respectively.

During the fluoroscopic exposures in three groups, the anterior–posterior (AP) projection was mostly used, with some contributions from 30° left- or right-oblique projections, only in PCNL group. Location of each personnel was accurately fixed, distance between personnel and fluoroscopy tube was standardized 80 cm for surgeon, 100 cm for assistant and 150 cm for nurse. Factors which may increase radiation exposure, e.g., decreased distance between staff and tube, excessive tube angulation, continuous X-ray and excessive manipulation, were being avoided.

Variables that affect radiation exposure in each group were reported then compared between three groups. Type of procedure, fluoroscopy time, stone size, HU, K.V and M.A of calculi were correlated with dose. Calculating number of ESWL, URS and PCNL cases can be safely done over the course of a year, with respect for the annual safe permissible radiation dose by ICRP.

Staff personnel investigated every 6 months for TSH, CBC and fundus examination. The duration of the procedure was measured from the initial surgical maneuver such as inserting the cystoscope to the final maneuver such as inserting the catheter. All surgeons received information on their average recorded results after 6 months. Procedures with any missing data excluded from statistical analysis.

The inclusion criteria will be: Age is more than or equal 18 years. Stone density is less than or equal 1000 HU. PCNL for renal stone size is 20–30 mm and renal stone less than 20 mm if failed ESWL. ESWL for renal stone size is less than or equal 20 mm. ESWL for proximal ureteral stone is less than or equal 10 mm. URS for single ureteral stones is more than or equal 10 mm.

The exclusion criteria will be: Stone density is more than 1000 HU. Renal stone size is more than 30 mm. Patient has ureteric or urethral stricture.

3 Statistical analysis

In order to perform the statistical analysis, SPSS (SPSS Inc., Chicago, Illinois, USA) was used. The analysis of variance test (ANOVA) was used to determine the level of significance between the various exposed groups, for normally distributed data. Data that were not-normally distributed were tested by Shapiro–Wilk test of normality; Kruskal–Wallis test (the nonparametric test of ANOVA) was used, followed by Bonferroni post hoc analysis for pairwise comparison to examine the significance among the studied groups. For categorical data, Chi-square test was used. Differences among means were considered statistically significant at p values ≤ 0.05.

To identify the potential predictors of radiation exposure, univariate analyses with Mann–Whitney U or Chi-squared tests were used (P 0.05). In order to ascertain associations between radiation exposure and the potential predictors, multivariate analysis utilizing binary logistic regression models was then conducted. Significance was set at two-tailed p value of 0.05. Radiation exposure was transformed into a binary variable with ≥ 10 micro-SV, as significant for high exposure; radiation exposure below 10 micro-SV was regarded as low exposure.

4 Results

See Tables 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11.

5 Discussion

The dosage of various operating room personnel was measured to compare radiation exposure levels in several spatial areas during different three procedures. It is essential for urologists to know the factors that raise the risk of radiation exposure in order to safeguard themselves against radiation hazards [9, 10].

Doses delivered to surgeon 73, 18.5 and 2.4 µSv higher than that for assistant that were 51.3, 14.3 and 0.9 µSv and nurse that were 47.6, 13.1 and 0.8 µSv during PCNL, URS and ESWL, respectively, this is in line with data from studies published by Hellawell, Majid pour, Giblin, Kumari and their colleagues: whom revealed that surgeons were more radiation exposed than assistants and nurses. Surgeon and assistants were exposed to increased radiation exposure more than nurses because of their proximity to the radiation source. Due to participation of assistant in the PCNL procedure as well as in fluoroscopy-guided retrograde passage of ureteric catheter, assisting urologist received more radiation than nurse [11–13].

The effect of tube staff distance on radiation dose has been shown by Hellawell and colleagues, who showed that the average space between the surgeon, assistant and nurse and radiation source was about 75, 90 and 150 cm (cm), respectively. So, nurse was exposed to lesser radiation than surgeon and the assistant [12].

Doses delivered to our surgeon, assistant and nurse in PCNL were higher than delivered for them in URS and ESWL, mostly due to increased fluoroscopic time in PCNL than other procedures: due to excessive manipulation to localize urinary tract and increased use of continuous fluoroscopy mode. Otas and colleagues found that using pulse mode rather than continuous mode

Table 1 Gender distribution according to the type of procedure

		Female $N = 28$		Male $N = 71$	
		N	**%**	***N***	**%**
Procedure	ESWL	10	35.7	23	32.4
	URS	6	21.4	27	38.0
	PCNL	12	42.9	21	29.6

Table 2 Distribution of the stone side and location according to different procedures

	Procedure					
	ESWL		URS		PCNL	
	N	%	*N*	%	*N*	%
Side						
Left side	25	75.8	21	63.6	13	39.4
Right side	8	24.2	12	36.4	20	60.6
Stone location						
Lower ureter	0	0.0	23	69.7	0	0.0
Mid-ureter	0	0.0	4	12.1	0	0.0
Upper ureter	5	15.2	6	18.2	0	0.0
Renal pelvis	25	75.8	0	0.0	26	78.8
Calyceal	3	9.1	0	0.0	7	21.2

Table 3 Cumulative dose according to the exposed personnel in each procedure

		N	Mean	SD	95% confidence interval for mean			Minimum	Maximum	*p* value
					Median	Lower bound	Upper bound			
Surgeon dose	ESWL	33	2.4 µSv	4.8	0.43 µSv	0.74	4.1	0.009 µSv	22.4 µSv	0.000
	URS	33	18.5 µSv	15.7	14.5 µSv	12.9	24.1	0.370 µSv	54.0 µSv	
	PCNL	33	73 µSv	76.8	104.4 µSv	45.7	100.2	2.400 µSv	354.5 µSv	
	Total	99	31.3 µSv	54.2	39.7 µSv	20.5	42.1	0.009 µSv	354.5 µSv	
Assistant dose	ESWL	33	0.9 µSv	1.6	5 µSv	0.3	1.5	0.002 µSv	6.7 µSv	0.000
	URS	33	14.3 µSv	14.0	8.7 µSv	9.3	19.3	0.150 µSv	52.2 µSv	
	PCNL	33	51.3 µSv	47.2	82.3 µSv	34.5	68.0	2.400 µSv	179.7 µSv	
	Total	99	22.2 µSv	35.3	32 µSv	15.1	29.2	0.002 µSv	179.7 µSv	
Nurse dose	ESWL	33	0.8 µSv	1.4	5 µSv	0.28	1.3	0.002 µSv	6.7 µSv	0.000
	URS	33	13.1 µSv	13.6	7.4 µSv	8.2	17.9	0.150 µSv	52.2 µSv	
	PCNL	33	47.6 µSv	40.1	82.3 µSv	33.4	61.9	2.400 µSv	167.9 µSv	
	Total	99	20.5 µSv	31.4	31.5 µSv	14.2	26.7	0.002 µSv	167.9 µSv	

Table 4 Post hoc Bonferroni pairwise comparison of the dose in procedure

	Procedure	ESWL	URS	PCNL
Surgeon dose	ESWL	1	0.451	0.001
	URS	–	1	0.001
	PCNL	–	–	1
Assistant dose	ESWL	1	0.176	0.001
	URS	–	1	0.001
	PCNL	–	–	1
Nurse dose	ESWL	1	0.133	0.001
	URS	–	1	0.001
	PCNL	–	–	1

fluoroscopy significantly decreased total fluoroscopy time and radiation exposure [14].

The scatter radiation experienced during C-arm fluoroscopy, which varies with the arm's rotating direction, is a significant factor in the radiation exposure. When the primary beam tilted 30 degrees, notably in the PCNL group, more dispersed radiation is produced toward the urologist's head than when it is oriented 0 degrees, as in URS and ESWL. Therefore, mean dose for staff personnel is higher in PCNL than URS and ESWL [15].

Angulation of C-arm in PCNL makes source of X-ray above table which called over-couch that makes excessive scattered radiation exposing staff to more dose.

Table 5 Association between type of surgery and dose level among staff personnel

Dose		Procedure						*p* value
		ESWL		URS		PCNL		
		Count	Row *N* %	Count	Row *N* %	Count	Row *N* %	
Surgeon	10 µSv or less	31	64.6%	15	31.3%	2	4.2%	0.001
	More than 10 µSv	2	3.9%	18	35.3%	31	60.8%	
Assistant	10 µSv or less	33	58.9%	20	35.7%	3	5.4%	0.001
	More than 10 µSv	0	0.0%	13	30.2%	30	69.8%	
Nurse	10 µSv or less	33	57.9%	21	36.8%	3	5.3%	0.001
	More than 10 µSv	0	0.0%	12	28.6%	30	71.4%	

Table 6 Intraoperative characteristics according to the procedure

		N	Mean	SD	95% confidence interval for mean		Minimum	Maximum
					Lower bound	Upper bound		
Operative time	ESWL	33	46.8 min	8.4	43.8	49.8	29.00 min	62.00 min
	URS	33	48.1 min	15.8	42.5	53.7	30.00 min	90.00 min
	PCNL	33	92.8 min	24.1	84.3	101.4	50.00 min	120.00 min
	Total	99	62.6 min	27.5	57.1	68.1	29.00 min	120.00 min
Fluoroscopic time	ESWL	33	165.3 sec	2.0	3.6	5.0	60 sec	372 sec
	URS	33	193.5 sec	36.9	51.8	78.0	60 sec	468 sec
	PCNL	33	289 sec	67.3	109.8	157.6	90 sec	606 sec
	Total	99	215.9 sec	68.9	53.9	81.4	60 Sec	606 Sec
K.V	ESWL	33	109.0	2.3	108.2	109.8	103.00	110.00
	URS	33	75.2	7.8	72.4	78.0	63.00	93.00
	PCNL	33	77.2	5.2	75.4	79.1	66.00	92.00
	Total	99	87.1	16.5	83.8	90.4	63.00	110.00
M.A	ESWL	33	40.0	0.001	40.0	40.0	4.00	4.00
	URS	33	5.0	2.6	4.1	6.0	0.90	7.80
	PCNL	33	2.9	1.8	2.3	3.6	1.70	7.30
	Total	99	4.0	2.0	3.6	4.4	0.90	7.80

Table 7 Post hoc comparison of the intraoperative characteristics according to the procedure

	Procedure	ESWL	URS	PCNL
Operative time	ESWL	1	0.756	0.001
	URS	–	1	0.001
	PCNL	–	–	1
Fluoroscopic time	ESWL	1	0.001	0.001
	URS	–	1	0.001
	PCNL	–	–	1
K.V	ESWL	1	0.001	0.001
	URS	–	1	0.145
	PCNL	–	–	1
M.A	ESWL	1	0.024	0.029
	URS	–	1	0.001
	PCNL	–	–	1

Majidpour compares dose for leg (0.1 μSv) that near fluoroscopy beam and for neck (0.01 μSv) found that table decreases scattered radiation 10 times, this study explains excessive angulation increase the radiation exposure in PCNL than ESWL and URS [11].

Our study median dose for surgeon 104.4 μSv in PCNL group was higher than that median dose reported by Wenzler and colleagues that was 40.7 μSv. Our dose for assistant 51.3 μSv and for nurse 47.6 μSv was higher than that reported by Wenzler and colleagues, which were 40.7 and 1.3 μSv, respectively. Cause for increased dose in our study may be due to smaller sample size (33 cases in our study versus 91 cases in Wenzler study). Nurse dose in Wenzler study was very low than our nurse dose who exposed to more scattered radiation waves, because our nurse was closer to source of ionizing radiation than

Table 8 Association between stone characteristics among different procedures

		N	Mean	SD	95% confidence interval for mean		Minimum	Maximum	*p* value
					Lower bound	Upper bound			
Stone size	ESWL	33	16.6 mm	3.8	15.2	18.0	10.00 mm	20.00 mm	0.001
	URS	33	12.1 mm	2.8	11.1	13.1	10.00 mm	20.00 mm	
	PCNL	33	27.5 mm	3.3	26.3	28.7	20.00 mm	30.00 mm	
	Total	99	18.7 mm	7.3	17.3	20.2	10.00 mm	30.00 mm	–-
Stone density	ESWL	33	896.9 HU	146.2	845.1	948.8	500.00 HU	1000.00 HU	0.675
	URS	33	863.6 HU	166.8	804.4	922.8	450.00 HU	1000.00 HU	
	PCNL	33	874.2 HU	154.1	819.5	928.9	400.00 HU	1000.00 HU	
	Total	99	878.2 HU	155.0	847.3	909.2	400.00 HU	1000.00 HU	–-

Table 9 Correlation between doses among staff and stone characteristics and fluoroscopic time

		Stone size	Stone density	Fluoroscopic time
Surgeon dose	Pearson correlation	0.482**	– 0.222*	0.743**
	P value	0.000	0.027	0.000
	N	99	99	99
Assistant dose	Pearson correlation	0.486**	– 0.220*	0.794**
	P value	0.000	0.029	0.000
	N	99	99	99
Nurse dose	Pearson correlation	0.507**	– 0.199*	0.805**
	P value	0.000	0.048	0.000
	N	99	99	99

*significant ($p < 0.05$)

**highly significant ($p < 0.001$)

Table 10 Perioperative characteristics of the studied patients in each procedure

		Procedure					
		ESWL		URS		PCNL	
		N	%	*N*	%	*N*	%
Hydronephrosis	No	8	24.2	0	0.0	7	21.2
	Yes	25	75.8	33	100.0	26	78.8
Preoperative DJ	No	18	54.5	30	90.9	31	93.9
	Yes	15	45.5	3	9.1	2	6.1
Preoperative PCN	No	33	100.0	29	87.9	31	93.9
	Yes	0	0.0	4	12.1	2	6.1
Postoperative DJ	No	18	54.5	23	69.7	33	100.0
	Yes	15	45.5	10	30.3	0	0.0
Blood transfusion	No	33	100.0	33	100.0	29	87.9
	Yes	0	0.0	0	0.0	4	12.1
Urine leakage	No	33	100.0	33	100.0	30	90.9
	Yes	0	0.0	0	0.0	3	9.1
Second look	No	11	33.3	33	100.0	31	93.9
	Yes	22	66.7	0	0.0	2	6.1
Fever	No	33	100.0	31	93.9	32	97.0
	Yes	0	0.0	2	6.1	1	3.0

Table 11 Predictors of high-dose exposure among surgeons

	B	S.E	Wald	Df	Sig	Exp(B)	95% CI for Exp (B)	
							Lower	Upper
Step 1								
Procedure (PCNL)	2.175	1.033	4.435	1	0.035	8.801	1.163	66.609
Operative time	− 0.019	0.019	1.050	1	0.305	0.981	0.945	1.018
Fluoroscopic time	0.029	0.014	4.014	1	0.045	1.029	1.001	1.058
Stone size	0.021	0.078	0.073	1	0.787	1.021	0.877	1.189
Stone density	0.000	0.002	0.005	1	0.945	1.000	0.996	1.004
Hydronephrosis (yes)	− 1.494	1.375	1.181	1	0.277	0.224	0.015	3.323
Constant	− 3.796-	2.181	3.028	1	0.082	0.022		

The cut value is 0.500.

circulating nurse in operating room in Wenzler study [16].

Mean dose for our surgeon PCNL group was higher than that reported by Safak and colleagues that surgeon dose over apron collar was 12.7 µSv [17]. Our mean dose for surgeon was higher than reported by Shrader for urologist that was 24 µSv [18]. Mean dose for our surgeon PCNL group was higher than that reported by Jaco and Miller that was 16 µSv for surgeon [19]. Mean dose for our surgeon was lower than that reported by Law and colleagues: for surgeon 250 µSv [20].

Dose range reported per URS cases in our study for assistant (0.15–52.2 µSv) was lower than reported by Hellawell and colleagues that was 1.6–180 µSv, but for nurse (0.15–52.2 µSv) was higher than reported in Hellawell study that was 0.4–30 µSv as he reported dose for circulating nurse [12]. Annually reported dose for surgeon in ESWL procedure was 1800 µSv lower than that reported by Baldock and colleagues that was 4800 µSv may be due to decreased awareness of radiation safety and protection in this old study when compared with our recent study that done with more recent fluoroscopic units and recent protective methods [21].

Our study reported that doses were higher than similar studies probably due to highly sensitive and accurate DEPD dosimeter used in our study when compared with thermoluminescent dosimeter (TLD) that used for the estimation of dose in most of these studies [22].

Radiation exposure may also be influenced by the decrease in fluoroscopy time, which was noticeably higher in older research compared to more recent trials. Previously, a single case of PCNL required fluoroscopic guidance for about 20 min; now, it only takes 4–6 min. Our mean total fluoroscopy time in PCNL group was 4.8 min that was very low than reported by Franklin, was 27.8 min per procedure. Our mean total fluoroscopy time was lowest 4.8 min if compared with similar studies like, that reported by Kumari was 6.04 min and that reported by Hellawell 10 min, mostly due to that our study done recently if compared with these oldest studies increased awareness of radiation risks, increased experience in manipulations of procedures, advancements in instruments, techniques and recent C-arm [22].

Our study showed moderate positive correlation between dose and stone size, also positive correlation between dose and fluoroscopy time. This similar to that reported by Tepeler and colleagues, who also observed that the duration of the fluoroscopy considerably increased with the size of the stone [23].

Similar to our study, Mancini and colleagues retrospectively found that: Increased radiation exposure was correlated with larger stones, based on a survey of 96 individuals' radiation exposures that underwent PCNL. The reported data in our study were in line with the previous studies that reported by Wenzler, Cohen, Kumari and their colleagues [3, 8, 16].

Our study's 12-month cumulative radiation exposure was lower than safe annual maximum occupational dose limit (20,000 µSv). Our surgeon does 5 PCNL cases × 50 week × 73 µSv (dose per case), 10 URS cases × 50 week × 18.54 µSv (dose per case) and 15 ESWL cases × 50 week × 2.47 µSv (dose per case) so our results resembled the results reported by Wenzler, Cohen and their colleagues [8, 16].

The recommended dose for radiation workers during a 5-year period is 20 mSv for the entire body, according to the (ICRP 60) study. Our urologist can complete 274 PCNL cases, 1081 URS cases and 8333 ESWL cases per year while staying under safe radiation exposure limits which is lower number of PCNL procedures than that is reported by Safak and colleagues 416 (20 mSV/48 µSv) PCNL per year within safe radiation exposure limits [17].

We evaluated the predictors of radiation doses given to staff members during PCNL, URS and ESWL. In our study, type of procedure and fluoroscopic time were linked to excessive radiation exposure in the operating room. Similar to our study, on multivariate analysis of Wenzler study, only fluoroscopy duration has significant impact. No additional factors on radiation exposure were significant. The only variation in our study's multivariate analysis that type of procedure has significant effect on radiation exposure as PCNL procedure was 8.8 times more likely to exhibit high-dose exposure than other procedures. But this factor, type of procedures is absent in Wenzler study as this study done for radiation exposure in only PCNL group unlike our study compares between three groups PCNL, URS and ESWL [16].

The prospective measurement of radiation exposure, where radiation doses of each staff member were gathered after each case, is a significant strength of this study. In addition, we assessed radiation doses in relation to fluoroscopy time. In order to provide comparative data for the radiation risk of workers at different spatial locations in the operating room during a particular surgery, radiation doses from various operating room personnel, including the surgeon, assistant and nurse, were collected. Another point of strength for this study: It is the first study worldwide in published studies to compare the radiation exposure data between three urological procedures ESWL, URS and PCNL. Most published studies reported radiation exposure data in PCNL only, few studies reported radiation exposure data in URS only. Only two studies reported radiation exposure data in ESWL. Three of these studies compare radiation exposure data between URS and PCNL procedures [22].

This study has also another point of strength: use DEPD dosimeter to measure radiation dose unlike most of other studies use TLD. Our DEPD has more updated recent techniques, accurate, on time reading, highly sensitive and can detect very low doses when compared with (TLD) that used for the estimation of dose in most of these studies. Radiation dose was continuously observed, readed, informed and alarmed by DEPD dosimeter, unlike TLD that must need calibration before being utilized in typical dosimetry. To calibrate TLD, the chips are heated and read in the TLD reader after being subjected to known doses [22].

Our dosimeter has easy and rapid on time reading data unlike, the Instadose™ device which used in Wenzler study that is only able to read data via: a USB-compatible detector that can be used to read data from a computer after each case. Our DEPD dosimeter has no limits of detection of small doses unlike Instadose TM used by Wenzler study that its lower limit 1 mrem with potential drawbacks in its capacity to quantify radiation doses exactly [16].

Our study is not without limitations. Electronic dosimeter was situated on the external surface of the lead apron, which raises doubts about the beneficial implications of our findings, considering how much radiation really reaches the urologist's skin compared to the anticipated 95% shielded by the lead apron. Fluoroscopic shielding roughly 70-fold cut the urologist's radiation exposure from scatter [13]. Modified radiation shields lessen radiation level by an average of 96.1% at a distance of 25 cm and 71.2% at a distance of 50 cm [24].

In addition to the aforementioned limitations, C-arm systems were not standardized across all cases. Another limitation in our study is that study measures dose at neck collar only unlike Majidpour and Safak studies that included measurements for dose at multiple body parts of urologists [11, 17].

6 Conclusion

PCNL procedure, increased stone size and increased fluoroscopy duration were associated with high radiation exposure. PCNL procedure was 8.8 times more likely to exhibit high-dose exposure than other procedures. Staff personals radiation exposure was substantially below the annual maximum permitted limits during urological procedures (20 mSV per year). Regarding our mean radiation dose per procedure of the whole body, urologists can perform: 274 PCNL case, 1081 URS case and 8333 ESWL case per year within safe radiation exposure limits as recommended by ICRP.

Abbreviations

PCNL	Percutaneous nephrolithotomy
URS	Ureteroscopy
ESWL	Extracorporeal shock wave lithotripsy
DEPD	Digital Electronic Personnel Dosimeter
μSv, mSV	Microsievert, millisievert
ICRP	International Commission on Radiation Protection
RPG	Retrograde pyelography
EUA	European Association of Urology
PUT	Plain radiography of the kidney ureter bladder
NCTUT	Noncontract computed tomography on urinary tract
HU	Stone density
K.V, M.A	Tube voltage, tube current
DJ	Double-J ureteric stent
TLD	Thermoluminescent dosimeter

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Author contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by AK, AE, ND and AL. The first draft of the manuscript and idea of the study were written by AE, and all authors commented on the previous versions of the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials
All data are available.

Declarations

Ethics approval and consent to participate
The study was approved by the ethical review boards in the Faculty of Medicine Beni Suef University, Approval No. FWA 00015574, FMBSUREC/07062020/Hassan. Ethics committee's name: FM-BSU REC (Faculty of Medicine Ben Suef University). Date of approval: 7 June 2020. Consent to participate in the study was provided by all participants.

Consent for publication
Not applicable.

Competing interests
All authors declare that they have no competing interests.

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References

1. Tonnessen BH, Pounds L (2011) Radiation physics. J Vasc Surg 53:6S–8S
2. Rehani MM, Ciraj-Bjelac O, Vañó E, et al (2010) Radiological protection in fluoroscopically guided procedures performed outside the imaging department. Ann ICRP 40(6):1–102
3. Kumari G, Kumar P et al (2006) Radiation exposure to the patient and operating room personnel during PCNL. Int Urol Nephrol 38(2):207–210
4. Wen C, Nakada SY (2007) Treatment selection and outcomes: renal calculi. Urol Clin North Am 34:409–419
5. Lingeman JE, Miller NL (2007) Management of kidney stones. BMJ 334:468–472
6. Ko R, Soucy F, Denstedt JD et al (2007) Percutaneous nephrolithotomy made easier: a practical guide, tips and tricks. BJU Int 101:535–539
7. Lipkin ME, Preminger GM (2013) Imaging techniques for stone disease and methods for reducing radiation exposure. Urol Clin North Am 40:47–57
8. Cohen SA, Rangarajan SS, Chen T et al (2013) Occupational hazard: radiation exposure for the urologist. Developing a reference standard. Int Braz J Urol 39:209–213
9. Friedman AA, Ghani KR, Peabody JO et al (2013) Radiation safety knowledge and practices among urology residents and fellows: results of a nationwide survey. J Surg Educ 70:224–231
10. Söylemez H, Sancaktutar A, Silay MS et al (2013) Knowledge and attitude of European urology residents about ionizing radiation. Urology 81:30–35
11. Majidpour HS (2010) Risk of radiation exposure during PCNL. Urol J 7(2):87–89
12. Hellawell GO, Mutch SJ, Thevendran G et al (2005) Radiation exposure and the urologist: what are the risks? J Urol 174(3):948–952
13. Giblin JG, Rubenstein J, Taylor A et al (1996) Radiation risk to the urologist during endourologic procedures, and a new shield that reduces exposure. Urology 48(4):624–627
14. Durutovic O, Dzamic Z, Milojevic B et al (2017) Pulsed versus continuous mode fluoroscopy during PCNL: safety and effectiveness comparison in a case series study. J Urol 197(1):172
15. Thomas KR, Brannall J, Wilson BC (1982) A "'flagpole"' lead glass screen for radiographic procedures. Radiology 143:557–558
16. Wenzler DL, Abbott JE, Su JJ et al (2017) Predictors of radiation exposure to providers during percutaneous nephrolithotomy. Urol Ann 9:55–60
17. Safak M, Olgar T, Bor D et al (2009) Radiation doses of patients and urologists during percutaneous nephrolithotomy. J Radiol Prot 29:409–415
18. Shrader Frechette K (2007) Trimming exposure data, putting radiation workers at risk: improving disclosure and consent through a national radiation dose-registry. Am J Public Health 97:1782–1786
19. Jaco JW, Miller DL (2010) Measuring and monitoring radiation dose during fluoroscopically guided procedures. Tech Vasc Interv Radiol 13:188–193
20. Law J, Inglis JA, Tolley DA (1989) Radiation dose to urological surgeons during x-ray fluoroscopy for percutaneous stone extraction Br. J Radiol 62:185–187
21. Baldock C, Greener AG, Batchelor S (1992) Radiation dose to patients and staff from Storz Modulith SL20lithotripter. J Stone Dis 4(3):216–219
22. Jindal T (2013) The risk of radiation exposure to assisting staff in urological procedures: a literature review. Urol Nurs. 33(3):136-139, 147
23. Tepeler A, Binbay M, Yuruk E et al (2009) Factors affecting the fluoroscopic screening time during percutaneous nephrolithotomy. J Endourol 23:1825–1829
24. Yang RM, Morgan T, Bellman GC (2002) Radiation protection during percutaneous nephrolithotomy: a new urologic surgery radiation shield. J Endourol 16:727–731

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