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Exposure to Radioactive Emanations of Medical Personnel in Percutaneous Nephrolithotomy

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Abstract

The use of radioactive emanations has been of great importance for the performance of endourology procedures, such as percutaneous nephrolithotomy (NLP). The damage to health caused by radiation has been a sensitive issue. The objective of this work was to determine the dose received by the surgeon during NLP and the total dose generated by the fluoroscope. A cross-sectional study was conducted with data from a cohort study with a duration of 18 months that included 101 patients. Radiation was measured with dosimeter during the last 6 months. During the last 6 months of the study, 34 patients were submitted to surgery. The average age was 47 years. Average fluoroscopy time was 58.3 second (24-122 seconds) in both male and female groups, with 57.16 seconds and 58.95 seconds per case, respectively ($P = .6$). Radiation emitted during 6 months for the 34 patients was 330.5 mGy. The total radiation measured by the dosimeter was 1 mSv, which is equivalent to 0.3% of the total radiation applied during the procedures. Doses measured by the dosimeter on the surgeon were within the recommended annual doses although dose received by the hands exceeds the authorized limits (500 mSv/y).

Keywords

percutaneous nephrolithotomy, radioactive emanations, fluoroscopy time, radioactive emissions in health personnel

Introduction

The utilization of radioactive emissions has been of great usefulness in the development of endourological processes over the past 4 decades. In 1985 and 1987, Lowe et al and Rao et al, respectively, conducted studies with the aim of measuring exposure to radioactive emanations in health personnel with percutaneous nephrolithotomies (PNLs).[1,2]

Currently, PNL is the surgical standard in the treatment of complex kidney stones and those of great volume.[3] Despite the advances in diagnostic imaging techniques, fluoroscopy continues to be the most utilized method for carrying out percutaneous procedures. Exposure to other methods for percutaneous kidney access, such as ultrasound, has been mentioned in the literature as a radioactive emission-free alternative.[4,5]

Radiation exposure of health personnel has been a reason for concern due to its short- and long-term consequences. Effects at the short term occur when exposure exceeds 10 Gy, while long-term effects present due to multiple periods of exposure at levels greater than 0.1 Gy.[6,7] There are diverse articles in the literature that mention the time of exposure and the dose of radiation received by patients and health personnel during percutaneous procedures. The data reported have been useful for taking precautions and diminishing health risks.

The purpose of this study was to measure the extent of radiation exposure in surgeons performed during PNLs in patients with ventral decubitus position with double flexion.

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Figure 1. Position of the patient in prone decubitus with double flexion.

Materials and Methods

A cross-sectional study was conducted with information taken from a database obtained from a cohort study with duration of 18 months that included patients submitted to PNLs conducted by the same surgeon. The cohort study was approved by the institutional ethics committee with registration number R-2016-1310-108; the study included 101 patients selected through consultations at a tertiary-level hospital (Western National Medical Center, Mexico), both genders, older than 16 years, with a diagnosis of kidney lithiasis, and who were candidates for PNL. All patients had a complete study protocol that included conventional serum tests, urine culture, and simple computed tomography (CT). All patients were submitted to preoperatory anethesiological, cardiological, or internal medicine assessment. Due to the measurement of exposure began from month 13, only patients attended on during the last 6 months were taken into account for this study.

PNL Technique

All of the patients were operated on under general anesthesia. The occlusion catheter placement was performed under fluoroscopic control. Next, the patient was repositioned in prone decubitus position with double flexion, as depicted in Figure 1. This position is a modification of that reported by Ray et al in 2009.[8] Our modification consisted of flexing the patient's torso at a more open angle, combined with a more closed flexion angle of the knees. With this position, it was demonstrated that the puncture site is modified from 1 to 2 cm in the caudal direction, as illustrated in Figure 2, not interposing the costal arch in terms of performance of the percutaneous tract. Once it was in position, the occlusion catheter was inflated and, prior to administration of the contrast medium, stone(s) localization was marked in the monitor. Puncture was performed with the "bull's eye" technique, and 90% of the tracts were carried out between the ribs 11 and 12, with the 1-shot technique with Amplatz sheath 26F dilators (Boston Scientific,Way Marlboroug, MA, USA). Kidney stone fragmentation was performed with Lithoclast through a Storz 24F nephroscope. Extraction of the fragments was conducted by means of aspiration devices and extraction tweezers. At the end of the procedure and after occlusion catheter was withdrawn, descending pyelography was performed in all patients.

Fluoroscopy

We utilized Philips LCLI9 BV Libra equipment (Koninklijke Philips N.V., Amsterdam, Netherlands), applying solely intermittent pulses of low doses (10 mGy/min) and managed directly by the surgeon (Figure 3). The medical team utilized protection based on international standards (goggles, a neck protector, a 0.5-mm thick lead vest), except for gloves for radiation. We employed a dosimeter for the surgeon, placed under the protective vest at the chest level and at a distance of approximately 30 cm under the imaging intensifier arm and approximately 60 to 80 cm above the diaphragm of the C arm of the fluoroscope.

Exposure to radiation was quantified from the time of the occlusion catheter placement to the descending pyelography at the end of the procedure. Measurement of exposure to radiation was carried out only during the last 6 months, although the

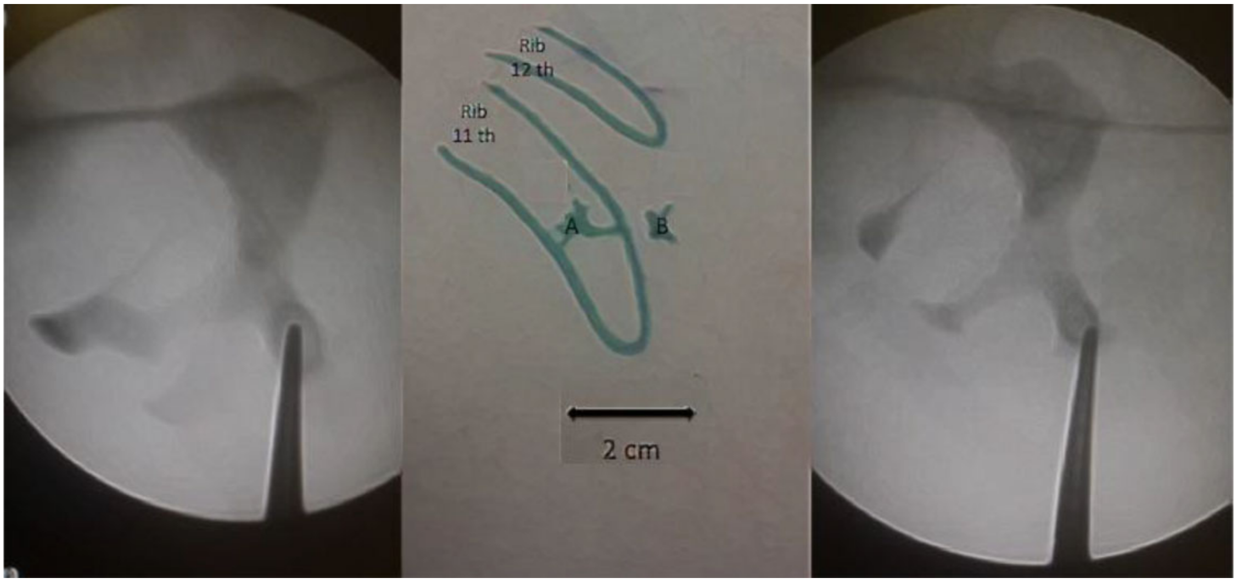

Figure 2. Caudal displacement of the puncture site with the prone decubitus position with double flexion.

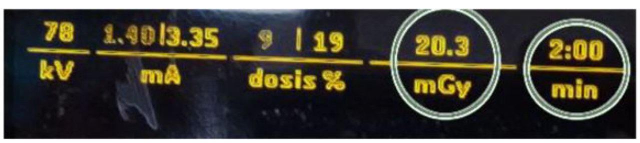

Figure 3. Fluoroscopy equipment screen adjusted to intermittent pulses (10 mGy/min).

protocol followed the same standards during 18 months. The dosimeter was sent each month for evaluation to determine the dose received monthly.

Statistical Analysis

Data analysis was conducted with Microsoft Excel for (Microsoft, Redmond, WA, USA) Apple statistical software utilizing descriptive statistics and central trend measurements. The mean difference was calculated with Epi Info version 3.0 statistical software.

Results

During the last 6 months of the study, 34 patients were submitted to surgery, with an average of 5.6 patients per month. Of the total number of patients, 22 (64.7%) were females. The age range was 26 to 75 years, with an average of 47 years for both groups. The body mass index (BMI) range was 18.6 to 41, with an average of 28.3. Regarding kidney stone density, average density was 1005.7 Hounsfield Units (HU), with ranges of 453 to 1800 HU. Average fluoroscopy time was 58.3 seconds (range, 24-122 seconds) in both groups; the average for males was 57.16 seconds per case, while that for females was 58.95 seconds ($P = .6$). Total fluoroscopy time emitted by the fluoroscope during the procedures was 1983 seconds (equivalent to 33.05 minutes). Table 1 shows the data corresponding to age, gender, BMI, HU, fluoroscopy time, and the number of tracts of each of the patients included in the study.

Based on the calibration of the fluoroscope, the radiation emitted during 6 months for the 34 patients was 330.5 mGy (10 mGy/min $\times$ 33.05). As mentioned previously, the dosimeter was sent monthly to determine the dose received.

The radiation measured by the dosimeter was 1 mSv, which is equivalent to 0.3% of the total radiation applied during the procedures.

Average dose accumulated per month based on the measurement of the dosimeter was 0.17 mSv, with ranges of 0.1 to 0.26 mSv. Total doses during 6 months were 1.0 mSv, which indicate that per surgical procedure, the dose absorbed by the dosimeter was 0.029 mSv on average.

Discussion

Our results showed that the radiation absorbed by the dosimeter during 6 months of exposure was low; however, it is evident that the average dose emitted by the fluoroscope during a PNL in our study is considerable (9.71 mGy), if we take into account that average fluoroscopy time was 58.3 seconds. It has already been mentioned that the dose emitted during 6 months was 330.5 mGy, which is equivalent to 1 mSv absorbed by the dosimeter. The cohort study conducted involved the same steps during 18 months for a total of 101 patients. Fluoroscopy time for 101 patients was 5758econdss (95.96 minutes), with an average of 57.0 seconds per patient, and the dose emitted by the fluoroscope was 959.66 mGy. Therefore, on having employed the dosimeter during 18 months, it can be assumed that the dose received could correspond to 2.9 mSv in 18 months.

Table 1. Data Related to Variables Measured in the Patients Included in the Study.

Patient	Age	Gender (Male)	BMI	HU	Fluoroscopy Time (seconds)	Number of Tracts
1	43	2	26.30	650	49	1
2	37	2	31.2	650	55	1
3	32	1	26.21	580	35	1
4	46	1	24.4	453	70	1
5	54	2	33.81		57	2
6	75	2	26	1053	31	1
7	32	2	28.55	1577	33	1
8	61	1	32	1300	34	1
9	75	2	26.8	1053	28	1
10	55	2	29	1443	122	2
11	46	2	35.2		46	1
12	51	2	33.3	1120	36	1
13	32	2	24	950	86	3
14	62	2	24		46	1
15	62	1	29.7	870	24	1
16	46	1	24.6	1500	44	1
17	44	1	27.5	1100	120	3
18	41	2	41		82	1
19	54	2	32.9		76	1
20	43	1	31.4	654	72	1
21	52	2	28	1030	81	1
22	38	2	32	800	43	1
23	72	1	23		32	1
24	31	1	30.7		45	1
25	49	2	29		37	1
26	47	1	29	1400	51	1
27	44	2	22	724	52	1
28	43	1	29	1050	91	2
29	26	2	20.2	680	80	2
30	44	1	27.1	1100	68	2
31	34	2	22.1	600	61	1
32	48	2	38.27		39	1
33	28	2	18.6		70	2
34	52	2	26	1800	87	1
Mean	47.02	Female (64.7%)	28.23	1005.70	58.3	1.30

Abbreviations: BMI, body mass index; HU, Hounsfield Units.

There are published conversion tables with which we can have an idea of the dose utilized during 1 semester. Based on these tables, 330.5 mGy is equivalent to approximately 33 simple CT or 23 positron emission tomography scans.[9]

Despite this dose received, the exposure of our surgical team did not exceed maximal recommended standards (20 mSv/y or 50 mSv in 5 years). Nonetheless, it is noteworthy that maximal exposure recommended in the hands and feet is 500 mSv/y; thus, in this aspect, we exceed the recommendations (661 mSv/y).

We obtained these results in spite of short-time fluoroscopy and fluoroscope adjustment at minimal doses. This can explained considering that 1 minute of fluoroscopy at a low dose is equivalent to 10 mGy/min, at a medium dose to 20 mGy/min, and at a high dose to 40 mGy/min. On employing low doses, it is not possible to use continuous fluoroscopy, and the quality of the images is not the best. However, were it not for this, the dose received would be more than double to that of the medium dose and up to 400% greater if high doses were used. It is noteworthy that on turning on the fluoroscope, the latter is automatically adjusted to a high dose (40 mGy/min), and it can be adjusted to lower doses according to the surgeon's preference.

The effect of radioactive emissions has been a reason-for-study dating from many years due to diverse consequences, such as skin and ocular diseases and cancer.[10] Kumari et al carried out a study with the aim of measuring radiation in patients and medical personnel during PNL; the results after 50 procedures reflected an average time of 6.04 minutes (range, 1.8-12.1 minutes). Despite the ranges in fluoroscopy time, this study reported exposure levels as low as 0.024 mSv in the surgeon, and in the resident, as low as 0.012 mSv.[11] On comparing our results, we may perceive an important difference with respect to the fluoroscopy time relation versus the dosimeter-measured dose per procedure (6.04 minutes/0.024 mSv vs 0.97 minutes/0.029 mSv). It is worthwhile to emphasize that in our protocol, fluoroscopy was utilized at a minimal dose and in pulses.

In 2013, a study reported the radiation time between 2 groups of 40 patients each. One of the groups was managed under a protocol to reduce the dose emitted during a PNL, while for the second group, the procedure was managed without this protocol. Average time was 33.7 seconds (range, 6.0-126) and 175.6 seconds (range, 12-725.4), respectively ($P < .001$). In this protocol, the authors refer the utilization of pulsed fluoroscopy and control of the radiation on the part of the surgeon by means of a pedal.[12]

A retrospective analysis published in 2015 reports on 376 PNL carried out within a period of close to 6 years. The average fluoroscopy time reported was 96 seconds per patient. This study also reports that fluoroscopy time is inversely proportional to the experience and improvement of the technique.[13]

In 2016, a work reported on fluoroscopy time in 20 patients submitted to a PNL surgical procedure, with an average age of 48.6 years and kidney stones with an average volume of 30 mm. Average fluoroscopy time was 337 seconds (range, 200-671 seconds) and an average radiation dose was 142 mSv (range, 44.7-221 mSv) per patient. The dose reported by the dosimeter was less than 0.1 mSv per case. The average fluoroscopy time of this study was 278.7 seconds above than that found in our work. However, the radiation doses measured by the dosimeter could be similar (<0.1 mSv vs 0.029 mSv).[14]

The evolution is clear of fluoroscopy times utilized for PNL. The scientific evidence reported by other centers and the experience at our Hospital agree in many aspects, similar to that published by Bush et al who, in 1984, reported average fluoroscopy times of 26 minutes for a PNL.[15] Up to some years ago, our fluoroscopy times continued to exceed the average of 180 seconds per procedure, and at present, we have fluoroscopy times of up to 26 seconds for noncomplex cases, that is, single kidney stone of less than 3 cm. It is also important to take into account that in our study, the total time of radiation utilized for placement of the occlusion catheter, which usually occupies an average of 8 to 15 seconds of the fluoroscopy. At the end of the cohort study (18 months), none of the patients showed complications related to the dose received. The surgeon who performed the total of the procedures does not present any short-term side effects derived from the received dose.

Conclusions

The scientific evidence has demonstrated the harmful effects of radioactive emissions. This fact leads to a dynamic evolution in the utilization of radioactive emanations for minimally invasive procedures. The worldwide tendency demonstrates a progressive diminution in fluoroscopy times. At our center, nearly 200 PNL were performed in 2015, which has allowed us to refine the technique. The experience and the punctual application of pre- and transoperative protocols have achieved that, in the last 4 years, fluoroscopy time has been reduced by one-third. The doses received measured by the dosimeter placed on the surgeon's chest were within the recommended annual doses (20 mSv/y). However, the dose received by the hands was 661 mSv/y, which exceeds the limits allowed (500 mSv/y).

We consider that details such as the presurgical assessment, the position of the patient, the adjustment of the fluoroscope, the dilation technique of the tract, and the elimination of dead times are fundamental processes for the reduction of fluoroscopy time. We recommend to those who perform this type of procedure that they choose the position most comfortable for the surgeon and the least harmful for the patient, in that this can, to a great extent, depend on the time of the fluoroscopy, adjusting the fluoroscope to the minimal dose and utilizing pulsed fluoroscopy; the surgeon should be the individual who performs the fluoroscopy pulses, adjusting the technique based on international standards with the aim of eliminating dead times and always utilizing protective equipment. Lastly, it is important to mention that the only way to calculate the dimensions of the dose received is by measuring them.

Declaration of Conflicting Interests

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