Are Urologists Performing Semi-rigid Ureteroscopic Lithotripsy Safe From Radiation Exposure? A Guidance to Reduce the Radiation Dose

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OBJECTIVE To measure radiation exposure of urologists during ureteroscopic (URS) lithotripsy, and hence estimating the number of procedures that can be performed safely considering the annually permissible radiation dose, and to identify influential variables.

MATERIALS AND METHODS The radiation exposure dose was measured at the neck, chest, arm, and hands of a single urologist who performed 49 URS lithotripsies. The number of annually performed URS lithotripsies was estimated based on the annual permissible occupational exposure radiation dose guidelines. The fluoroscopy screening time, tube voltage, and tube current were evaluated to determine their correlation with operative time, position, size, and Hounsfield unit (HU) values of the ureteral stones, and patients' body mass index (BMI).

RESULTS Our findings showed that 45 URS lithotripsies can be safely performed without a whole-body apron vs 1725 cases with one; considering the permissible dose for the hands, 448 cases without radiation protection were possible. Significant correlations were observed between operative time and fluoroscopy screening time ($P < .001$), ureteral calculi location and fluoroscopy screening time ($P = .027$), HU value and fluoroscopy screening time ($P = .016$), HU value and operative time ($P = .041$), and tube current and patients' BMI ($P = .009$).

CONCLUSION Considering radiation exposure risk, protective gear is necessary to ensure safety and efficacy of URS lithotripsy. Efforts to reduce radiation dose before and during surgery are required when ureteral calculi are in upper locations or have large HU, or the patient has a high BMI. UROLOGY 95: 54–59, 2016. © 2016 Published by Elsevier Inc.

Ureteroscopic (URS) lithotripsy has been the technique used to remove lower ureteral calculi.[1] Extracorporeal shock wave lithotripsy (ESWL) has historically been the preferred therapy in patients with upper and middle ureteral calculi. However, the recent advancements in surgical equipment and techniques have eased the approach to operating on upper and middle ureteral calculi using URS lithotripsy. The popularity of URS lithotripsy for the treatment of upper and middle ureteral calculi has increased with the improvement in success rates and the decrease in complications.[2]

Fluoroscopic guidance is routinely used when ureteral calculi are removed by URS lithotripsy. Consequentially, urologists who implement URS lithotripsy are at risk of radiation exposure. The frequency of radiation emitting equipment used for diagnosis and treatment has been continually on the rise, increasing the awareness for radiation exposure risk. Moreover, many studies have reported a dose-dependent effect between various adverse reactions and the radiation dose.[3] Accordingly, efforts have been made to recognize the radiation risk and minimize exposure of patients and other susceptible individuals.[4] However, few studies have investigated the safety of URS lithotripsy in terms of annual radiation doses to guide radiation dose limits for urologists performing URS lithotripsy.

This study aimed to measure the radiation dose to which urologists are exposed when performing URS lithotripsy, and to calculate the number of procedures that can be safely performed by each surgeon considering the annual allowable radiation dose. In addition, the guidance to reduce the radiation dose during URS lithotripsy for urologists was sup-

Financial Disclosure: *The authors declare that they have no relevant financial interests.*

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Submitted: March 25, 2016, accepted (with revisions): June 3, 2016

http://dx.doi.org/10.1016/j.urology.2016.06.001
0090-4295

ported by identifying variables that can influence the amount of radiation exposure.

MATERIALS AND METHODS

Study Design and Radiation Dose Measurement

From March to September 2015, we prospectively tracked the radiation dose and its variables to which urologist are exposed while performing URS lithotripsy. During this period, a single urologist performed a total of 49 URS lithotripsy procedures for ureteral calculi therapy. Prior to surgery, medical history was obtained and the patients underwent physical examination, routine blood and urine tests, plain radiography of the kidney-ureter-bladder, and noncontrast-enhanced computed tomography with three-dimensional reconstruction. Based on the radiological findings, stone factors including size, location, presence or absence of hydronephrosis, tissue rim sign, and average Hounsfield units (HU; stone density) were investigated.

A urologist wore the lead apron (0.35-mm-equivalent lead thickness) (Bar-ray Inc.), knee-length and front protection, and thyroid shield (0.35-mm-equivalent lead thickness) (Bar-ray Inc.), and did not wear protective glasses and gloves. Two optically stimulated luminescence albedo neutron dosimeters (Landauer Inc.,) were placed on the chest inside the lead apron and thyroid shield, whereas two dosimeters were placed outside the lead apron and thyroid shield. The effective dose, a quantity that is related to the stochastic radiation risk, was considered as the radiation dose to which workers are exposed.[5] Several algorithms and methods of measurements have been proposed to obtain estimates of the effective dose, the weighted sum of several organ doses, because it cannot be measured in practice.[6-10] In this study, we used the following formula, proposed by Faulkner et al, to calculate the surgeon's effective dose: (0.5 × dose for chest below lead apron) + (0.025 × dose for chest above lead apron).[11]

The radiation dose to which the extremities were exposed was tested by placing a dosimeter on the right upper arm and 2 dosimeters on both hands. After study completion, all the dosimeters were sent to the radiation measurement company (Hanil Nuclear Co., Ltd., Korea) for calculation of the total radiation dose to which a single urologist was exposed during the study period.

URS Lithotripsy Technique With Fluoroscopy

The fluoroscope was located on the left side of the surgeon and the monitors of fluoroscope and ureteroscope were located on the right side. General anesthesia was used for the URS lithotripsy procedure. After induction of anesthesia, the urologist checked the bladder and the orifice of the ureter using a semirigid ureteroscope (9.5Fr) that was inserted into the orifice of the ureter after the insertion of a ureteral guide wire alongside the ureteral calculi, as a safety guide wire, to the level of the kidney.

On visualization of the ureteral calculus, it was pulverized by a Holimum:YAG laser (Omnipulse-Max, Trimedyne) and removed using stone forceps or stone basket. A 365-µm end firing fiber was used for laser with a 1.0 J/pulse energy setting and a 10-Hz frequency. The ureteral stent was maintained for 1 week after surgery in all cases to prevent ureteral stricture and reduce the incidence of postoperative renal colic secondary to ureteral edema.

A fluoroscope (OEC Fluorostar 7900, GE) was used for all surgeries. The X-ray source was positioned underneath the patients because URS lithotripsy is performed with patients in the lithotomy position. Tube voltage (in kV), tube current (in mA), fluoroscopy screening time, and operative time were recorded for each case. The fluoroscope used an automatic brightness control mode to automatically set the optimal tube voltage and current. The tube voltage and current ranges in this study were 69-84 kV and 2.12-2.94 mA, respectively.

Annually Allowed URS Lithotripsy Cases, Variables Affecting Radiation Exposure, and Statistics

The surgeon's effective dose and the measured radiation doses on the neck and hands were converted to the radiation dose per URS lithotripsy case. Thereby, the number of URS lithotripsy cases that can be safely performed over 1 year was calculated by comparison with the annual allowable radiation dose from the occupational exposure guideline of the National Council on Radiation Protection and Measurements (NCRP) and the International Commission on Radiological Protection (ICRP).[12,13]

The fluoroscopy screening time, tube voltage, and tube current were evaluated for their correlation with operative time, ureteral calculi location, ureteral calculi size, HU values of the ureteral calculi, presence of hydronephrosis, tissue rim sign, and patients' body mass index (BMI) by Pearson correlation analysis.

This study was approved by the Institutional Review Board (IRB No. GCIRB 2015-337).

RESULTS

The average age of the 49 patients (31 men, 18 women) who underwent URS lithotripsy was 52.1 years (range: 21-75 years), whereas the mean BMI was 24.5 kg/m^2 (range: 19.5-31.3 kg/m^2) (Table 1). The radiation doses to which the urologists who performed URS lithotripsy were exposed are shown in Table 2. The cumulative radiation dose was 16.40 mSv for the neck, 54.67 mSv for the chest, 15.07 mSv for the right arm, 29.40 mSv for the right hand, and 39.73 mSv for the left hand. The cumulative radiation dose was 0.93 mSv inside the lead apron and 0.60 mSv inside the thyroid shield. The cumulative surgeon's effective radiation dose was 1.42 mSv. The radiation dose per URS

Table 1. Patient demographics and stone characteristics

Parameters (Unit)	Value
Demographic and clinical parameters	
Mean age (years)	52.1 (21-75)
Gender (male/female)	31/18
Mean body mass index (kg/m^2)	24.5 (19.5-31.3)
Mean serum creatinine (mg/dL)	0.9 (0.4-4.5)
Comorbidity	
HTN	10 (20)
DM	5 (10)
Tbc	1 (2)
Radiologic parameters	
Mean stone size (mm)	9.8 (0.7-30.0)
Stone location (proximal or mid or distal)	28/8/13
Stone laterality (right or left)	21/28
Mean Hounsfield unit	864.3 (204-1472)
Presence of hydronephrosis	42 (86)
Presence of tissue rim sign	23 (47)

DM, diabetes mellitus; HTN, hypertension; Tbc, tuberculosis.
Values are presented as mean (range) or number (%).