Prospective Measurement of Patient Exposure to Radiation During Pediatric Ureteroscopy

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Abbreviations and Acronyms

ALARA = as low as reasonably achievable

AP = anterior to posterior

CT = computerized tomography

ESD = entrance skin dose

MLD = midline absorbed dose

SSD = source to skin distance

URS = ureteroscopy

Submitted for publication August 9, 2011.

Study received institutional review board approval.

* Supported by Grant T32-DK60442 from the National Institute of Diabetes and Digestive and Kidney Diseases.

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Purpose: Few data have been reported regarding radiation exposure during pediatric endourological procedures, including ureteroscopy. We measured radiation exposure during pediatric ureteroscopy and identify opportunities for exposure reduction.

Materials and Methods: We prospectively observed ureteroscopy procedures as part of a quality improvement initiative. Preoperative patient characteristics, operative factors, fluoroscopy settings and radiation exposure were recorded. Our outcomes were entrance skin dose and midline dose (both mGy). Specific modifiable factors were identified as targets for potential quality improvement.

Results: Direct observation was performed in 54 consecutive ureteroscopy procedures. Mean ± SD patient age was 14.8 ± 3.8 years (range 7.4 to 19.2), with 9 children being younger than 12 years. Mean ± SD entrance skin dose was 46.4 ± 48 mGy. Mean ± SD midline dose was 6.2 ± 5.0 mGy. The most important major determinant of radiation dose was total fluoroscopy time (mean ± SD 2.68 ± 1.8 minutes) followed by dose rate setting, child anteroposterior diameter and source to skin distance (all $p < 0.01$). Analysis of factors affecting exposure levels revealed that use of ureteral access sheaths ($p = 0.01$) and retrograde pyelography ($p = 0.04$) were significantly associated with fluoroscopy time. We also found that dose rate settings were higher than recommended in up to 43% of cases and ideal C-arm positioning could have reduced exposure by 14% (up to 49% in some cases).

Conclusions: Children receive biologically significant radiation doses during ureteroscopy procedures. Several modifiable factors contribute to dose and could be targeted in efforts to implement dose reduction strategies.

Key Words: calculi, kidney, nephrolithiasis, pediatrics, urolithiasis

INCREASING medical radiation exposure is generating considerable concern in the United States. By some estimates per capita radiation exposure today is more than 7 times greater than 30 years ago.[1] Children are particularly vulnerable to long-term effects of ionizing radiation, due to their long anticipated lifespan and to the relatively higher radiosensitivity of rapidly growing tissues.[2] The United States National Council on Radiation Protection and Measurements advocates the ALARA principle when using ionizing radiation for medical purposes, particularly in children.[3]

Previous work has shown that children with urolithiasis have a nearly 40% chance of stone recurrence and that many will undergo multiple stone procedures during their lifetime.[4] The

0022-5347/12/1874-1408/0
THE JOURNAL OF UROLOGY®

Vol. 187, 1408-1415, April 2012
Printed in U.S.A.
DOI:10.1016/j.juro.2011.12.013

incidence of urolithiasis in the pediatric population may be increasing,[4,5] and with this increase comes the need for medical imaging and surgical intervention. Although shock wave lithotripsy has long been considered first-line therapy for children with stones, urologists have increasingly turned to URS techniques in these patients,[6,7] which are typically performed using fluoroscopic guidance. In addition to surgical intervention, many patients will undergo radiation intensive diagnostic imaging such as CT.[8] There are few studies documenting the radiation exposure associated with URS,[9] and none in pediatric patients. The aims of this quality improvement project were to measure systematically radiation exposure during URS in children, to determine factors associated with increased exposure and to identify potential opportunities to reduce exposure.

METHODS

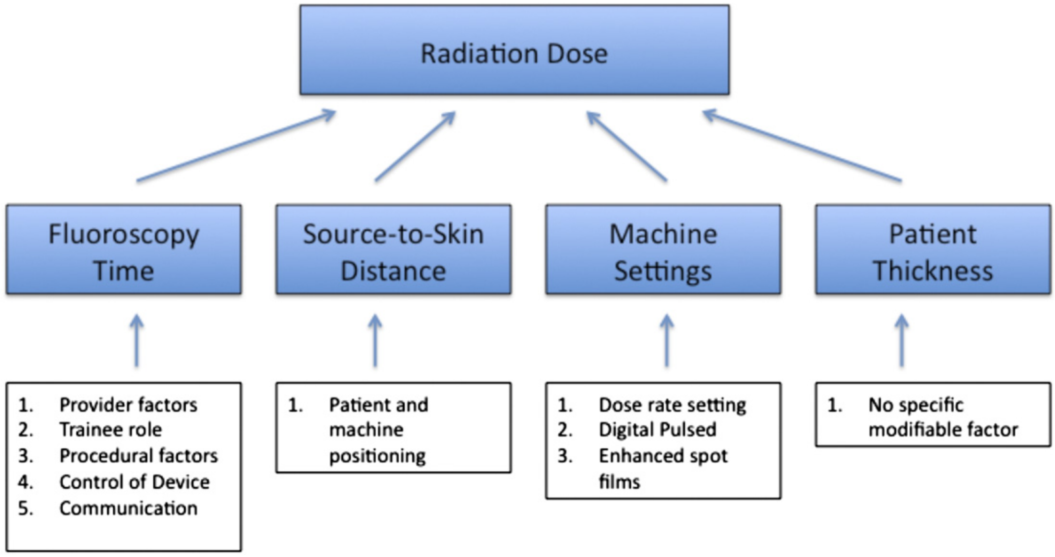
After institutional review board approval, we prospectively monitored all URS procedures at our institution from September 2009 to December 2010. A research assistant (urology fellow or master level research associate familiarized with ureteroscopic procedures) was present in the operating room for each case. Preoperatively we collected demographics, medical history and stone burden from imaging. After induction of anesthesia, we measured patient AP diameter at the umbilicus with calipers. Intraoperatively equipment and techniques (eg ureteral access sheath, retrograde pyelography, safety wires, mode of lithotripsy, basket extraction, preoperative or postoperative ureteral stent), fluoroscopy unit factors (unit identification, position, individual directly controlling the unit, total fluoroscopy time, machine settings) and other relevant factors (surgeon, level of trainee involvement, total anesthesia time) were recorded. Philips® BV Pulsera mobile units with 23 cm intensifiers were used for fluoroscopy.

Operating room staff were broadly informed of the study. However, to minimize the Hawthorne effect,[10] the specific data collected were not disclosed, and the individual collecting data minimized interactions with operating room personnel.

Radiation exposure was calculated as ESD and MLD. ESD estimates radiation dose to the skin, the organ that receives the maximum dose, while MLD is a better approximation of the average dose received by all irradiated tissue. ESD was indirectly measured from the fluoroscopy unit dosimeter as air kerma at 70 cm from the radiation source. To calculate ESD, the air kerma is adjusted for back scatter (factor of 1.2), bed/pad attenuation (measured as 0.40 at 70 kV) and observed SSD (using the inverse square law). MLD at the midpoint of the umbilical AP diameter was estimated from the calculated ESD by applying appropriate tissue attenuation factors for a 70 kV beam from a mobile fluoroscope. SSD was calculated from direct measurements of the patient and fluoroscopy unit. All dose calculations were performed by a radiation physicist (KS).

The known determinants primarily responsible for radiation exposure in the setting of fluoroscopy include patient AP diameter, total fluoroscopy time, SSD and fluoroscope exposure parameters (eg voltage, tube current). We used these determinants to develop a conceptual model of factors affecting radiation exposure (see figure). The independent effect of each of these determinants was estimated using multivariate regression. The relative importance of each determinant was established by comparing a series of nested models.

To assess how technique modification might be expected to impact ESD, we conducted sensitivity analyses. We assumed that ideal SSD would result if the image intensifier were placed no more than 7 cm above the umbilicus. Appropriate fluoroscopy machine dose rate set-



Conceptual model