Changing Default Fluoroscopy Equipment Settings Decreases Entrance Skin Dose in Patients

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Abbreviations and Acronyms

CT = computerized tomography
ESD = entrance skin dose
fps = frames per second
FT = fluoroscopy time
OSLD = optically stimulated luminescence dosimeter
PCNL = percutaneous nephrolithotomy
RPG = retrograde pyelogram
URS = ureteroscopy

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Purpose: Proper fluoroscopic education and protocols may reduce the patient radiation dose but few prospective studies in urology have been performed. Using optically stimulated luminescent dosimeters we tested whether fluoroscopy time and/or entrance skin dose would decrease after educational and radiation reduction protocols.

Materials and Methods: At default manufacturer settings fluoroscopy time and entrance skin dose were prospectively measured using optically stimulated luminescent dosimeters in patients undergoing ureteroscopy, retrograde pyelogram/stent or percutaneous nephrolithotomy with access for stone disease. A validated radiation safety competency test was administered to urology faculty and residents before and after web based, hands-on fluoroscopy training. Default fluoroscopy settings were changed from continuous to intermittent pulse rate and from standard to half-dose output. Fluoroscopy time and entrance skin dose were then measured again.

Results: The cohorts of 44 pre-protocol and 50 post-protocol patients with stones were similarly matched. The change in mean fluoroscopy time and entrance skin dose from pre-protocol to post-protocol was −0.6 minutes and −11.6 mGy (33%) for percutaneous nephrolithotomy ($p = 0.62$ and <0.001), 0.5 minutes and −0.1 mGy (34%) for ureteroscopy ($p = 0.42$ and 0.31), and 0.1 minute and −0.1 mGy (29%) for retrograde pyelogram/stent ($p = 0.85$ and 0.49, respectively). Urologist post-training test scores increased 30% from pretraining scores ($p = 0.1$).

Conclusions: Radiation safety training protocols improved clinical knowledge but did not significantly alter fluoroscopy time. Changing equipment default settings to intermittent pulse rate (12 frames per second) and half-dose lowered the entrance skin dose by 30% across all endourology patients but most significantly during percutaneous nephrolithotomy. To limit patient radiation exposure fluoroscopy default settings should be decreased before all endourology procedures and image equipment manufacturers should consider lowering standard default renal settings.

Key Words: kidney, nephrolithiasis, radiation dosage, skin, fluoroscopy

MEDICAL imaging in urology is necessary to make the correct diagnosis and monitor the response to treatments. Because stone formers are subjected to recurrent imaging to detect and treat kidney stones,

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radiation risk in this population has recently gained considerable attention. In addition to diagnostic CT, intraoperative C-arm fluoroscopy has been identified as a common source of radiation risk for these patients, of which the extent has been quantified in cadaveric and validated phantom studies.[1,2]

Radiation reduction strategies to decrease this risk have focused on increasing operator awareness and correcting a number of modifiable causes, including source factors (use of a laser positioner and an image intensifier near the patient), machine settings (low refresh rates and dose output, and last-image capture hold), procedural factors (tactile cues, experienced technicians and patient landmarks) and FT (surgeon experience, foot pedal control and audible time keeping).

While all agree that intraoperative fluoroscopy should be performed judiciously, the impact of these urological radiation reduction strategies has not been well studied. Several retrospective case series confirmed that FT can be dramatically decreased by implementing radiation reduction protocols but actual dose estimates were not calculated.[3–6] The only prospective PCNL study to incorporate a radiation reduction protocol excluded percutaneous renal access FT and lacked data to calculate the patient radiation dose.[7]

We hypothesized that surgeon FT and patient radiation ESD, that is the radiation dose measured at the skin surface level, would decrease after implementing a surgeon education and radiation reduction protocol. We tested this hypothesis prospectively in 2 cohorts of stone formers using OSLDs.[8]

MATERIALS AND METHODS

After institutional ethics committee approval endourology patients at a single institution undergoing unilateral ureteral stenting for ureteral stones (RPG/stent), URS for renal or proximal ureteral stones, or PCNL with intraoperative access obtained by an attending urologist and interventional radiologist concomitantly were consecutively enrolled between September 2012 and April 2013. Preoperative information (age, gender and body mass index) and CT stone characteristics (stone greatest diameter, laterality, multiplicity and morphology) were recorded for all patients. Patients were then brought to the operating room and placed under general anesthesia.

Postoperatively patients in the RPG/stent group were excluded from further study of their definitive URS or PCNL procedure. Patients treated with URS were asked to undergo renal ultrasound and plain x-ray of the kidneys, ureters and bladder within 3 months of followup. According to our standard routine all patients treated with PCNL underwent low dose CT on postoperative day 1 for stone burden determination.[9] Patients were deemed stone-free as long as no stones 3 mm or greater were seen on any followup imaging.

Dosimeter Placement and Standard C-Arm Protocols

Two 1 × 10-inch reusable adhesive plastic strips, each containing 10 small nanoDot™ Dosimeter OSLDs, were placed on all patients by a radiation physics graduate student (LS or AMM). Because our C-arm x-ray emitter is below the operating table, for PCNL the strips were placed anterior over the ipsilateral kidney and midline over the suprapubic area (part *A* of figure). The patient was then placed prone. For URS and RPG/stent strips were placed over the same areas posterior with the OSLDs facing down. Operating room staff were broadly informed of the study but contact was decreased between those collecting data (physicists and technologists) and surgeons. Using a BV Pulsera® mobile C-arm unit with a standard 30 cm intensifier, automatic brightness controls and standard default settings (continuous mode at 30 fps and standard dose output), intraoperative FT and machine settings were recorded. Endourology patient enrollment was repeated in a similar post-reduction protocol.

Radiation Quiz and Reduction Protocol

Following pre-protocol enrollment of patients an internally validated radiation safety quiz designed by our radiological physics staff was administered to all 14 urology faculty and 12 residents. To limit supplemental material use when answering the questions participants were quizzed in a live format using the audience response system, QClick QRF500 Classroom Response System (QOMO, Wixom, Michigan). Subsequently all faculty and residents participated in a 1-hour hands-on training course on the proper use of fluoroscopic equipment, including positioning the intensifier near the patient, prudent foot control, and use of visual/tactile cues and last-image hold. As the C-arm does not leave our endourology suite, we contacted a manufacturer service engineer who changed the C-arm unit default software settings from continuous 30 fps to pulsed 12 fps and from full to half-dose output. After the training course the radiology quiz was readministered as an online survey. Quiz answers were graded and compared.

Dosimetry Calculations

The microStar® dosimetry system used to measure the direct patient surface dose has been previously characterized in our diagnostic energy range with reported sensitivity of approximately 91% and accuracy ± 2%.[10,11] To ensure study reproducibility the microStar reader was calibrated according to the operations manual using microStar Software, version 4.3. The reader was set to an 80 kVp beam with a half-value layer of 2.9 mm, consistent with that used for fluoroscopy according to the manufacturer user manual. Prior to each procedure the background dose on each OSLD was read to ensure that the dosimeter had been fully erased. The dosimeters were then placed in 2 sealed plastic strips (10 dosimeters per strip), brought to the operating room and placed on the patient as previously described. After irradiation the dosimeters were unsealed and the dose read was repeated. The final skin dose was calculated by dosimeter software, which produced a single weighted ESD in mGy.