Radiology

ORIGINAL RESEARCH ■ **GENITOURINARY IMAGING**

Evaluation of Kidney Stones with Reduced–Radiation Dose CT: Progress from 2011–2012 to 2015–2016—Not There Yet[1]

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Purpose: To determine if the use of reduced-dose computed tomography (CT) for evaluation of kidney stones increased in 2015–2016 compared with that in 2011–2012, to determine variability in radiation exposure according to facility for this indication, and to establish a current average radiation dose for CT evaluation for kidney stones by querying a national dose registry.

Materials and Methods: This cross-sectional study was exempt from institutional review board approval. Data were obtained from the American College of Radiology dose registry for CT examinations submitted from July 2015 to June 2016. Study descriptors consistent with single-phase unenhanced CT for evaluation of kidney stones and associated RadLex® Playbook identifiers (RPIDs) were retrospectively identified. Facilities actively submitting data on kidney stone–specific CT examinations were included. Dose metrics including volumetric CT dose index, dose-length product, and size-specific dose estimate, when available, were reported, and a random effects model was run to account for clustering of CT examinations at facilities. A z-ratio was calculated to test for a significant difference between the proportion of reduced–radiation dose CT examinations (defined as those with a dose-length product of 200 mGy · cm or less) performed in 2015–2016 and the proportion performed in 2011–2012.

Results: Three hundred four study descriptors for kidney stone CT corresponding to data from 328 facilities that submitted 105 334 kidney stone CT examinations were identified. Reduced-dose CT examinations accounted for 8040 of 105 334 (7.6%) CT examinations, a 5.6% increase from the 1010 of 49 903 (2%) examinations in 2011–2012 ($P < .001$). Mean overall dose-length product was 689 mGy · cm (95% confidence interval: 667, 712), decreased from the mean of 746 mGy · cm observed in 2011–2012. Median facility dose-length product varied up to sevenfold, from less than 200 mGy · cm to greater than 1600 mGy · cm.

Conclusion: Use of reduced–radiation dose CT for evaluation of kidney stones has increased since 2011–2012, but remains low; variability of radiation dose according to facility continues to be wide. National mean CT radiation exposure for evaluation of renal colic during 2015–2016 decreased relative to 2011–2012 values, but remained well above what is reasonably achievable.

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A kidney stone will form in approximately one in 11 people in their lifetime (1). More than 2 million people visit U.S. emergency departments annually with flank or back pain related to kidney stones, and approximately half of these patients undergo computed tomographic (CT) evaluation, the preferred modality for acute kidney stone evaluation due to short examination time and accuracy for detection of acute alternative diagnoses (2,3). More than 70% of kidney stones in the United States are diagnosed by means of CT, and many of these patients are relatively young, averaging 45 years old at first diagnosis (4–7). Kidney stones may be recurrent, and 20% of patients with an acute stone episode receive a 1-year cumulative medical imaging radiation dose of greater than 50 mSv, which is equivalent to the regulatory dose limit set by the International Commission on Radiological Protection for occupational radiation workers (4,8,9). This level of radiation, therefore, is a potential patient safety hazard and is inconsistent with the "as low as reasonably achievable," or ALARA, principle for radiation dose. The risk of radiation to this large and relatively young population is, therefore, a substantial concern in the establishment of CT protocols for kidney stone evaluation.

A 2008 meta-analysis of reduced-dose CT (estimated effective dose < 3 mSv or dose-length product [DLP] < 200 mGy · cm) showed high sensitivity and specificity for diagnosis of urolithiasis (10). The American College of Radiology (ACR) 2012 Appropriateness Criteria (11) recommends use of reduced-dose techniques for evaluation of acute flank pain. The Image Wisely campaign, established by the ACR in conjunction with the Radiological Society of North America, the American Association of Physicists in Medicine, and the American Society of Radiologic Technologists, works to promote use of reduced–radiation dose CT (12). Despite this, Lukasiewicz et al (13) found that in 2011–2012 only 2% (1010 of 49 903) of CT examinations for kidney stone evaluation were performed with a reduced dose, and only 10% (nine of 93) of institutions performed more than half of these CT examinations with a DLP lower than 400 mGy · cm (approximate adult effective dose, 6 mSv), with a national average DLP of 746 mGy · cm (approximately 11 mSv).

Since 2012, national awareness about CT-associated radiation has continued to increase and literature (14–16) validating the use of reduced-dose CT for kidney stone evaluation has been published. CT technology that reduces radiation dose while maintaining image quality is used more widely (17–19). Therefore, it is reasonable to expect a downward trend in radiation dose for this indication, as well as subsequent reductions in dose variation. We sought to determine if the use of reduced-dose

Advances in Knowledge

- Proportion of reduced–radiation dose CT examinations (dose-length product < 200 mGy · cm; effective dose, < 3 mSv) used for evaluation of kidney stones has increased from 1010 of 49 903 CT examinations(2%) to 8040 of 105 334 CT examinations (slightly less than 8%) in 4 years, showing some progress but demonstrating persistent underuse.
- The average national radiation dose-length product for kidney stone CT examinations was 689 mGy · cm (95% confidence interval: 667, 712) during this time period, representing a decrease from 2011–2012 levels of 746 mGy · cm.
- There continues to be variability in CT study descriptors and use of the Dose Index Registry's RadLex® Playbook identifiers (RPIDs), with 304 discrete descriptors from 328 facilities mapping to 23 distinct RPIDs, which suggests a need for education and/or regulatory guidelines.
- There is a large variation in exposure to radiation dose at CT of kidney stones, both within and between facilities nationwide, with CT dose-length products ranging from 40 to 6336 mGy · cm (interquartile range, 357–906 mGy · cm), which is beyond what might reasonably be expected on the basis of the difference in CT equipment within an institution.

Implications for Patient Care

- Imaging facilities nationwide have made modest improvements in optimizing radiation exposure to patients evaluated with CT for renal colic; however, the majority of institutions participating in the Dose Index Registry are not applying best practices to their kidney stone CT protocols.
- Of almost 1700 actively participating institutions in the Dose Index Registry, only 328 facilities (< 20%) have and are regularly performing kidney stone–specific CT; this illustrates the need not only for identified facilities to optimize current kidney stone CT protocols, but also for many facilities to establish dedicated kidney stone CT protocols.

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Abbreviations:
ACR = American College of Radiology
CI = confidence interval
DIR = Dose Index Registry
DLP = dose-length product
IQR = interquartile range
RPID = RadLex® Playbook identifier
SSDE = size-specific dose estimate

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Guarantors of integrity of entire study, K.W., M.S., D.S., C.M.; study concepts/study design or data acquisition or data analysis/interpretation, all authors; manuscript drafting or manuscript revision for important intellectual content, all authors; approval of final version of submitted manuscript, all authors; agrees to ensure any questions related to the work are appropriately resolved, all authors; literature research, K.W., M.S., C.M.; clinical studies, K.W.; statistical analysis, K.W., P.K., M.S., D.S., M.B.C., A.M., C.M.; and manuscript editing, K.W., M.S., D.S., M.B.C., J.B., A.M., M.K., C.M.

Conflicts of interest are listed at the end of this article.

CT for kidney stone evaluation increased in 2015–2016 compared with use in 2011–2012, to determine variability in radiation exposure according to facility for this indication, and to establish a current average radiation dose for CT evaluation of kidney stones by querying a national dose registry.

Figure 1

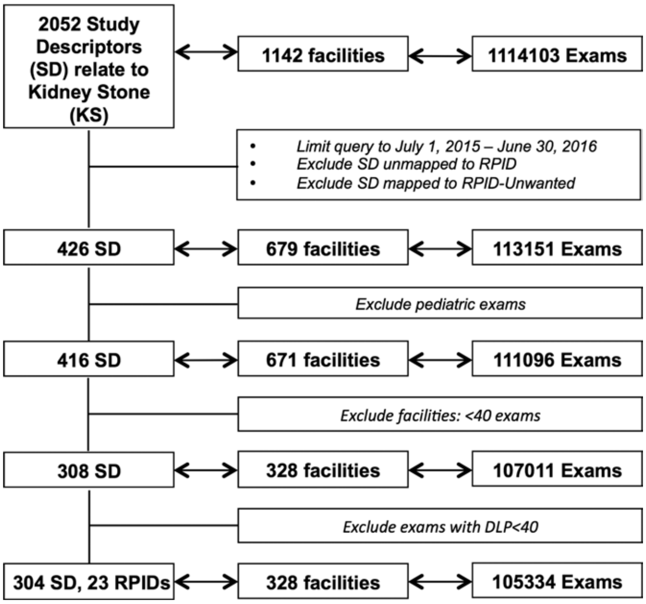

Figure 1: Flowchart shows exclusion criteria for dataset query. RadLex® Playbook identifier (RPID), the internal categorization system of the DIR. *RPID-unwanted* indicates scan originally performed at outside facility. Study descriptors *(SD)* are termed unmapped if the facility had not completed its DIR set up and had not mapped the given study descriptor to an RPID.

Materials and Methods

This was a cross-sectional analysis of deidentified facility and CT examination data submitted to the Dose Index Registry (DIR), a database maintained by the ACR. This study was considered exempt from institutional review board approval because all data came from a deidentified registry database. The DIR was established in May 2011 and includes 1693 actively contributing facilities with 35 099 380 total CT examinations as of November 2016. Funding for this study came from the Agency for Healthcare Research and Quality grant R18HS023778.

We sought to review data from facilities that actively contributed kidney stone CT examinations to the DIR from July 1, 2015, to June 30, 2016 (Fig 1). Facilities submit information by using study descriptors established by their radiology department, which are matched according to the facility to a standardized RPID that allows similar study descriptors to be grouped with their counterparts on the basis of examination elements including body part and indication. When a study descriptor is matched with an RPID, all instances of the descriptor in the database are then matched with that RPID, including studies performed before matching.

We reviewed all study descriptors for CT examinations in the DIR database. From 161 293 total study descriptors, we retained those that indicated a noncontrast material–enhanced, single-phase CT examination with terminology consistent with kidney stone evaluation by using the following inclusion key words: “kidney,” “renal,” “stone,” “flank pain,” “calculi,” “KUB,” “hematuria,” and “urogram,” which yielded 2052 study descriptors. Examinations not mapped to an RPID were excluded to ensure that only examinations that had been reviewed and assessed were included. In addition, “unwanted” RPIDs from an outside facility, pediatric examinations, and institutions that contributed fewer than 40 examinations were excluded. Examinations with a DLP of less than 40 mGy · cm that were presumed to be scout views or incomplete CT examinations were also excluded.

Each facility submitting to the DIR sends deidentified data for individual CT scans that includes age, sex, study descriptor, RPID, volumetric CT dose index, and DLP. During DIR setup, facilities manually map each study descriptor to an RPID by using an online mapping tool. Facilities have the option to include a scout image that allows for calculation of size-specific dose estimates (SSDEs), which provide a closer approximation of radiation dose received by the patient than those of the DLP and volumetric CT dose index (20). Mean facility values for volumetric CT dose index, DLP, and SSDE (when available) were collected for study descriptors and RPIDs corresponding to CT for evaluation of renal colic as defined previously.

Statistical Analysis

Summary statistics and proportions of examinations for DLP levels are reported for the entire group and according to facility, study descriptor, geographic region, setting, institution type, and trauma designation. Effective dose was estimated from the DLP by using 0.015 mSv · mGy^{-1} · cm^{-1} as the conversion factor to allow for comparison of radiation exposure from abdominal and pelvic CT with that emitted from other radiation sources (21). A random effects model was run on the 2015–2016 data to account for clustering of CT examinations at facilities. Use of reduced-dose CT in 2015–2016, defined as CT with a DLP of 200 mGy · cm or less, was compared with use in 2011–2012. A z-ratio was calculated to test for significance of the difference between the proportion of CT scans that met criteria for

Table 1

Facility Demographics

Variable	No. of Institutions*	Median DLP (mGy · cm)†	Mean DLP mGy · cm‡	No. of CT Examinations (*n* = 105 334)
Trauma designation				
Level 1	31 (9.45)	589 (346–929)	690 (683, 696)	19 280
Level 2	42 (12.80)	602 (378–952)	696 (690, 702)	17 280
Level 3	22 (6.71)	645 (415–960)	741 (730, 752)	7176
Level 4	8 (2.44)	528 (778–603)	603 (580, 625)	930
Not available	225 (68.60)	578 (345–883)	652 (649, 655)	60 668
Institution type				
Academic	32 (9.76)	616 (355–959)	716 (707, 726)	10 439
Community hospital	206 (62.80)	616 (379–922)	692 (689, 695)	76 638
Multispecialty clinic	13 (3.96)	415 (284–681)	537 (524, 549)	3068
Freestanding center	76 (23.17)	479 (276–789)	565 (559, 571)	15 083
Other	1 (0.30)	551 (429–664)	561 (528, 593)	106
Setting				
Metropolitan	159 (48.48)	589 (344–919)	666 (663, 670)	52 126
Suburban	121 (36.89)	563 (354–846)	642 (638, 646)	43 430
Rural	48 (14.63)	729 (455–1111)	831 (821, 841)	9778
Location				
Northeast	61 (18.60)	575 (366–822)	635 (631, 640)	23 815
Midwest	101 (30.79)	577 (321–959)	677 (673, 682)	39 266
South	126 (38.41)	636 (401–942)	711 (706, 715)	33 585
West	40 (12.20)	505 (327–786)	596 (588, 604)	8668

* Data in parentheses are percentages.

† Data in parentheses are interquartile ranges (IQRs).

‡ Data in parentheses are 95% CIs.

reduced-dose CT in 2011–2012 and the proportion of CT scans that met criteria for reduced-dose CT in 2015–2016. Finally, because SSDE was available for less than 50% of the dataset, simple regression was performed on the median DLPs and SSDEs from each facility that submitted data on SSDEs for greater than 50% of examinations to verify that the DLP was an appropriate surrogate. All statistical analysis was performed by using software (VassarStats; *http://vassarstats.net/* and SAS 9.4; SAS Institute, Cary, NC).

Figure 2

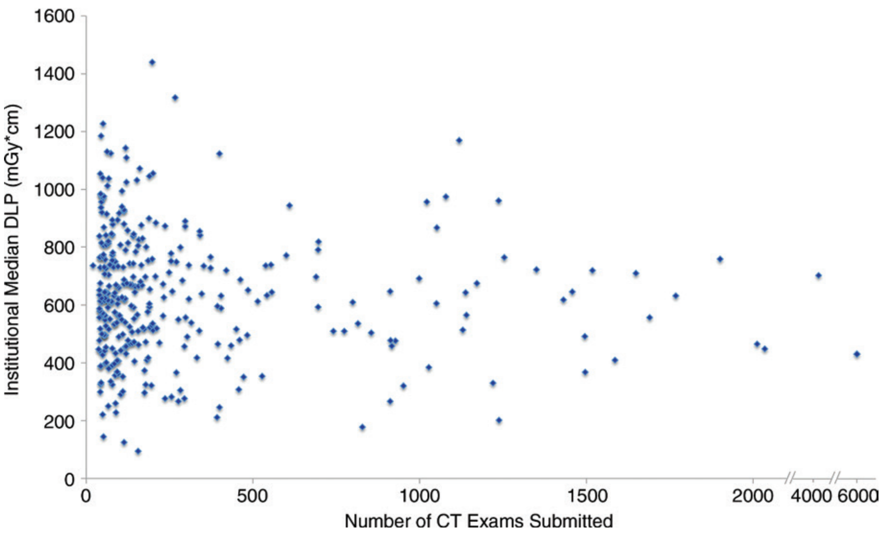

Figure 2: Scatterplot shows data from all facilities. X-axis represents number of kidney stone CT examinations submitted to the DIR during study period. Y-axis represents median DLP of examinations submitted by facility.

Results

The final dataset included 328 facilities that submitted a total of 105 334 kidney stone CT examinations with 304 study descriptors that were mapped to 23 RPIDs (Fig 1). Facilities were categorized according to institution type, geographic location, setting, and trauma designation (Table 1). There was a median of 134 (IQR, 68–304) CT examinations submitted per facility, with 63 558 (60%) examinations submitted by 50 facilities. Mean and median facility DLPs were 172–1327 mGy · cm and 94–1440 mGy · cm, respectively, with the number of examinations contributed per facility ranging from 21 to 6041 (Fig 2). The median number of examinations per study descriptor was 54 (IQR, 4–299), with 54 596 (52%) examinations including the 20 most common study descriptors.

Median DLP for all CT examinations was 588 mGy · cm (IQR, 357–906 mGy · cm). After we accounted for examination clustering at facilities, the mean DLP for all CT examinations was 689 mGy · cm (95% confidence interval [CI]: 667, 712). Overall, 8040 of 105 334 (7.6%) CT examinations met criteria for reduced-dose CT (DLP < 200 mGy · cm, approximately 3 mSv). Compared with the 1010 of 49 903 (2%) reduced-dose CT examinations performed for kidney stone evaluation in 2011–2012, this was an increase in use of reduced-dose CT of 5.6% (95% CI: 5.4%, 5.8%; *P* < .001).

Overall, 31 340 (29.8%; 95% CI: 29.5%, 30.0%) CT examinations had DLPs of less than 400 mGy · cm (effective dose, approximately 6 mSv), while 20 340 (19.3%; 95% CI: 19.1%, 9.6%) CT examinations had DLPs of greater than or equal to 1000 mGy · cm (effective dose, 15 mSv) (Fig 3). Four facilities achieved a median DLP of less than 200 mGy · cm, 46 facilities had median DLPs of less than 400 mGy · cm, with 19 facilities having a median DLP of greater than or equal to 1000 mGy · cm (Fig 4).

The 304 study descriptors were mapped to 23 RPIDs. Fifteen RPIDs had fewer than 10 study descriptors mapped to each, and seven RPIDs had only one study descriptor mapped to it (Table 2). There were 16 instances of the exact same study descriptor mapping to two or more different RPIDs. One study descriptor was incorrectly mapped to an RPID for thoracic spine CT.

Table 2

RPID Use

RPID	Description	No. of Study Descriptors Mapped to RPID
RPID390	CT abdomen, pelvis, and kidney calculi	110
RPID1842	CT abdomen and pelvis without intravenous contrast material	68
RPID144	CT abdomen and pelvis without intravenous contrast material	40
RPID1521	CT abdomen, pelvis, and kidney calculi without intravenous contrast material	23
RPID1067	CT abdomen, pelvis, and low-dose kidney calculi without intravenous contrast material	16
RPID164	CT abdomen and pelvis urogram with and without intravenous contrast material	12
RPID3	CT abdomen without intravenous contrast material	11
RPID344	CT abdomen and kidney calculi without intravenous contrast material	11
RPID891	CT abdomen, pelvis, and kidney without intravenous contrast material	6
RPID962	CT abdomen and pelvis urogram without intravenous contrast material	6
RPID1075	CT abdomen and pelvis kidney calculi dual energy CT without intravenous contrast material	5
RPID1839	CT abdomen, pelvis, and kidney with and without intravenous contrast material	4
RPID1900	CT abdomen and pelvis low dose with intravenous contrast material	3
RPID1885	CT abdomen, pelvis, bladder, and kidney without intravenous contrast material	2
RPID46	CT pelvis without intravenous contrast material	2
RPID54	CT abdomen and pelvis urogram	2
RPID1352	CT abdomen and pelvis urogram multiphasic with and without intravenous contrast material	1
RPID188	CT abdomen	1
RPID196	CT abdomen and pelvis	1
RPID334	CT thoracolumbar spine with and without intravenous contrast material	1
RPID861	CT abdomen and pelvis without intravenous contrast material	1
RPID890	CT abdomen and kidney	1
RPID894	CT abdomen and kidney without intravenous contrast material	1

Twenty of the 304 study descriptors, representing 2284 of the total 105 334 CT examinations, were labeled to indicate a low-dose or follow-up CT examination. Nine (45%; 95% CI: 26%, 66%) of these descriptors maintained a median DLP of less than 200 mGy · cm, 18 (90%; 95% CI: 70%, 97%) maintained a median DLP of less than 400 mGy · cm, and two (10%; 95% CI: 3%, 30%) study descriptors included 50% of examinations with a DLP greater than or equal to 600 mGy · cm. One study descriptor (CT abdomen pelvis low-dose kidney calculi without intravenous contrast material, or "CT Abd/Pelv Lo Dose Kidney Calc wo IV Con") accounted for more than 80% of the CT examinations (1854 examinations) labeled as low-dose or follow-up CT and had a median DLP of 646 mGy · cm (IQR, 400–1027 mGy · cm).

There was large variability both between and within facilities. Facility median DLPs were 94–1440 mGy · cm (Fig 4). One hundred seventy-six (54%) facilities had IQRs for DLPs of greater than 400 mGy · cm, and 104 (32%) facilities had IQRs of DLPs of greater than 500 mGy · cm.

SSDEs were reported for 51 570 of 105 334 (49%) CT examinations. SSDEs were reported for 100% of CT examinations submitted by 59 of 328 (18%) facilities in the dataset; however, these facilities only submitted 6799 (7%) CT examinations to the dataset. One

Figure 3

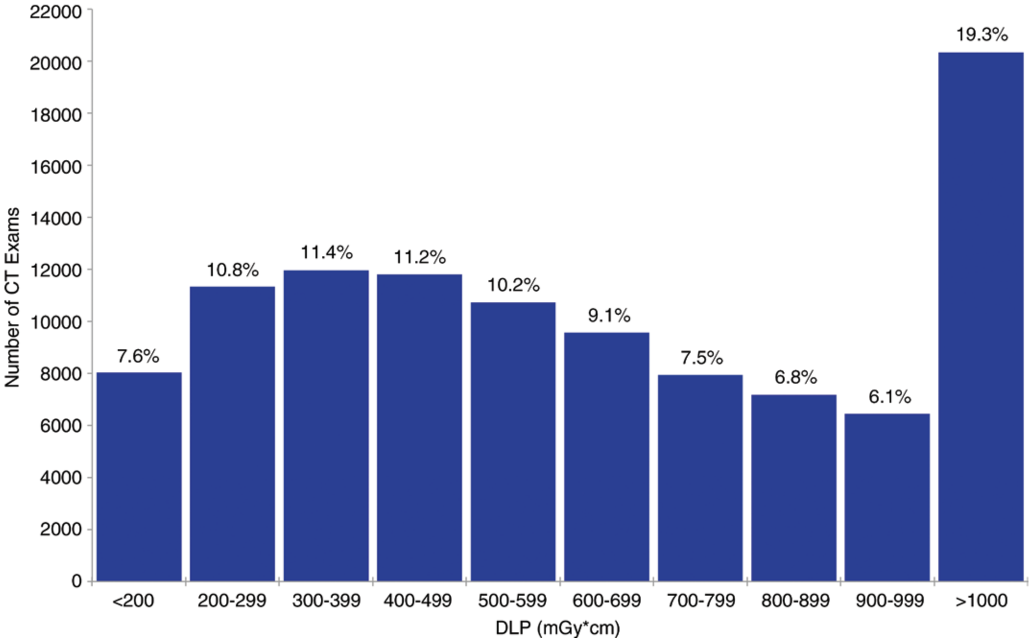

Figure 3: Histogram shows DLP for all kidney stone CT examinations in dataset grouped in 100-mGy · cm increments. Number on top of bars indicates total percentage of CT examinations in that DLP range. DLPs less than 200 mGy · cm = reduced-dose CT and correspond to effective dose of 3 mSv.

hundred fifty-one facilities (47%) reported SSDEs for 49 452 examinations (at least 50% of examinations). Figure 4 shows a histogram of median SSDEs for facilities that submitted SSDEs for at least 50% of examinations. Results of the simple regression analysis for DLP and SSDE indicated that the two values were strongly correlated (r^2 = 0.844) (Fig 5).

Discussion

Our results showed that use of reduced-dose CT for evaluation of kidney stones has increased significantly in the last 4 years, rising from 2% to nearly 8%, while mean overall DLP for kidney stone CT decreased from 746 mGy · cm to 689 mGy · cm (95% CI: 667, 712) (13,22). The increased use of reduced-dose CT and decrease in mean radiation dose likely can be attributed to more awareness of radiation in medical imaging, advances in CT technology, current recommendations by the ACR, and literature (11,18,23–25) that supports use of reduced-dose CT, particularly for kidney stone evaluation.

Although use of reduced-dose CT has increased, the proportion of kidney stone examinations performed with reduced-dose CT remains disappointingly low. Nine years since Niemann et al (10) reported in their meta-analysis a pooled sensitivity and specificity of reduced-dose CT for urolithiasis of 96.6% and 94.9%, respectively, and 5 years since the ACR published its appropriateness criteria (11) for acute-onset flank pain, which recommended the use of dose reduction techniques, less than 10% of CT examinations for kidney stone evaluation performed during the period of July 1, 2015, to June 30, 2016, involved use of appropriately reduced-dose techniques. In addition, less than one-third of these CT examinations were performed with a DLP of less than 400 mGy · cm (effective dose, 6 mSv), which is still twice the recommended radiation dose. Moreover, nearly 20% of the kidney stone CT examinations in our dataset had DLPs of greater than or equal to 1000 mGy · cm or effective doses greater than or equal to 15 mSv, which represent a radiation dose that is five times that recommended for evaluation of kidney stone disease.

Study descriptors that included the words “low-dose” or “follow-up” in their labels were used infrequently and accounted for 20 of 304 study descriptors and only 2284 CT examinations. However, even among CT examinations labeled as low dose, the radiation dose did not appear to be reduced. For example, the most commonly used study descriptors for reduced-dose CT (CT abdomen pelvis low-dose kidney calculi without intravenous contrast material, or “CT Abd Pelvis Lo Dose Kidney Calc wo IVCon”) represented more than 80% of the labeled reduced-dose CT examinations and had a median DLP of 646 mGy · cm (IQR, 400–1027 mGy · cm) for an effective dose of approximately 10 mSv, which is three times the level of radiation that has been shown to be sufficient to identify kidney stones at CT.

In addition, we found a large overall variability in dose indexes within

Figure 4

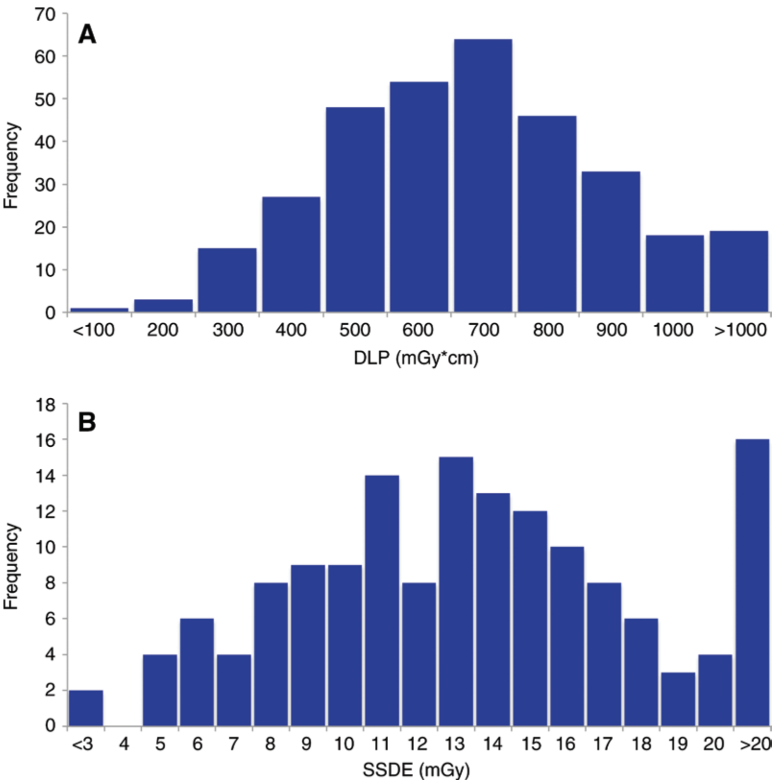

Figure 4: *A*, Histogram shows facility median DLPs grouped in 100-mGy · cm increments. Forty six of 328 (14%) facilities achieved median DLPs of less than 400 mGy · cm. *B*, Histogram shows facility median SSDEs grouped by 1-mGy increments for 151 facilities that submitted data on SSDEs for at least 50% of kidney stone CT examinations submitted to DIR.

facilities and throughout institutions, with an institutional mean DLP ranging from 172 to 1327 mGy · cm and more than 50% of facilities maintaining IQRs greater than 500 mGy · cm. This variability cannot be explained by body mass index alone and supports data from other studies that radiation dose varies in CT examinations beyond what can be accounted for by patient characteristics (25,26). This issue is not unique to kidney stone imaging (22). Results of one study (27), in which authors evaluated whole-body CT, showed an institutional mean DLP from 12 level 1 trauma centers were 1268–3988 mGy · cm, while in another (28) authors showed median DLPs for cardiac CT angiography at 50 sites of 568–1259 mGy · cm .

In light of these results, we think that careful review of institutional kidney stone protocols is warranted to ensure closer alignment to the ALARA principle. While the Image Wisely campaign continues to be a resource for educating providers on best practices at CT imaging, more direct intervention may be required to see substantial and consistent dose reductions. Collaboration of not only radiology departments but also of emergency medicine and urology departments is needed to instill confidence in proper ordering of these reduced–radiation dose CT examinations. One such on-going project is the Dose Optimization for Stone Evaluation, or DOSE, initiative. DOSE is an Agency for Healthcare Research and Quality–funded, delayed-intervention trial that offers online informational modules on kidney stone CT radiation optimization and allows the user to explore cases and gain confidence in interpreting reduced-dose CT examinations. In addition, DOSE offers free consultation on current CT protocols to aid in optimizing radiation dose while limiting compromise of image quality. Participation in a quality initiative to reduce radiation dose exposure may satisfy American Board of Radiology Practice Quality Improvement for part IV Maintenance of Certification requirements, and DOSE offers templates to help facilities to fulfill these requirements.

Critics may point out that many of the new dose reduction techniques are best achieved with updated iterative reconstruction and automatic exposure control technology and that it is unreasonable to expect facilities to purchase new scanners and/or software packages in the relatively short span of 4 years; and therefore, it is unreasonable to expect a large increase in use of reduced-dose CT. However, Niemann et al (10) found that reduced–radiation dose CT with an effective dose of less than 3 mSv was highly sensitive and specific for kidney stone evaluation in studies performed with CT technology that was in place between 2000 and 2007 that lacked these new technologies. The dose reduction in these studies was achieved by decreasing tube current, a method of dose optimization available to all scanners in 2015 even without iterative reconstruction and automatic exposure control. Thus we surmise that dose reductions are possible even in the absence of new technology, and through dissemination of knowledge by the ACR and the Choose Wisely campaign, we might have expected a larger increase in use of these reduced-dose CT examinations. Unfortunately, given the nature of working with a large national database, we were limited in our ability to determine the CT scanner technology available to facilities in our dataset.

A limitation of our results was that we did not have complete data on patient size. Larger patients require more radiation to obtain adequate images and also receive lower organ doses of radiation than do smaller patients undergoing a scan with an equivalent DLP. SSDEs can help normalize this, but

Figure 5

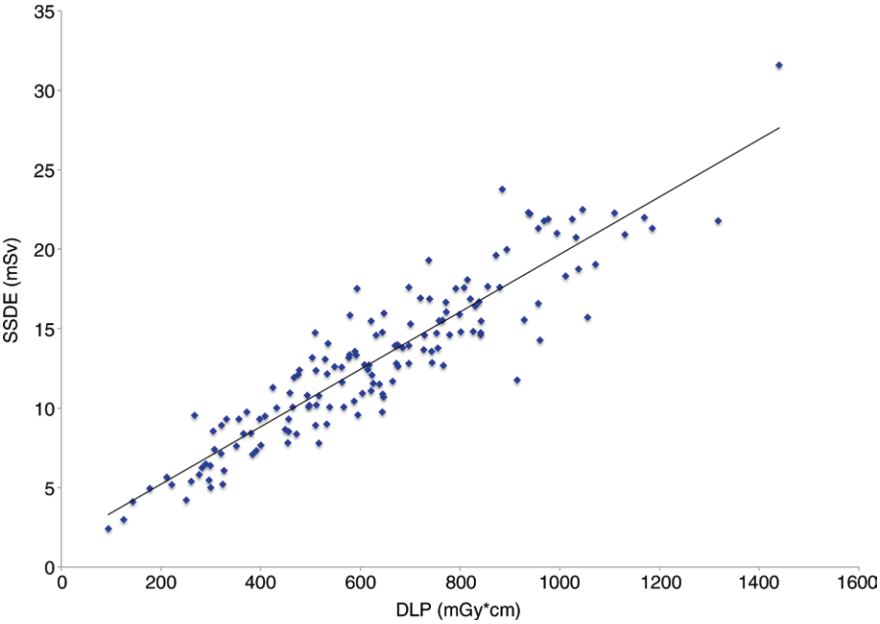

Figure 5: Scatterplot shows facility median DLPs and SSDEs for facilities that contributed greater than 50% of examinations with data necessary to calculate SSDE with best fit line.

were available in less than half of the studies submitted to the DIR. However, even when an SSDE was used, the median radiation values according to facility still ranged widely, which suggests that variability according to facility cannot be attributed primarily to differences in patient population. Moreover, simple regression showed that SSDEs were strongly correlated with DLPs, which suggests that use of the latter measure did not distort our results. Another limitation was our inability to run a random effects model on the 2011–2012 data, so the 2% we used as a baseline could have been slightly different if clustering of examinations at facilities had been taken into account.

One of the challenges of this work was the large variability in naming CT protocols. The greatest opportunity for appropriate dose reduction occurs when the study protocol is matched to the clinical scenario and patient characteristics (29). A limitation of our study was that we did not look at study descriptors for generic single-phase unenhanced CT of the abdomen and pelvis. It is possible that many or even most studies from some institutions contributing to the DIR perform CT scans for kidney stones but use a study descriptor that is not specific to the terms we used to define our population. It is also possible that clinicians may have ordered a study with a renal colic or kidney stone descriptor when they simply wanted an unenhanced study of the abdomen and pelvis (such as for appendicitis in a patient with an elevated creatinine).

Kidney stone CT represents a particularly attractive opportunity for dose reduction given the high attenuation from kidney stones that allows visualization at reduced dose. Facilities interested in optimizing doses thus need to ensure that names and study descriptors are accurate, and we suggest that facilities submitting to the DIR (or other registry) revisit their naming and mapping algorithms periodically. As we saw, incorrect mapping of study descriptors to RPIDs can happen, and this strategy will aid in correcting those mistakes. When separate protocols exist (such as for repeat studies), these should be named appropriately and mapped to an appropriate RPID. RadLex® Playbook occasionally updates some RPIDs and discontinues others. When performing the set-up process with DIR, use the current version of the Playbook found at *http://playbook.radlex.org*. Under the current Playbook, we recommend selecting RPID390 CT abdominal pelvis kidney calculi or “CT Abd/Pelv Kidney Calc,” because it is the most commonly used RPID and is specific to both kidney and calculus.

Nationally, kidney stone CT radiation exposure has decreased, but reduced-dose CT (DLP $<$ 200 mGy · cm, effective dose $<$ 3 mSv) continues to be disappointingly underused, representing less than 10% of examinations performed in 2015–2016, despite the ACR’s recommendations. National benchmarks for kidney stone CT radiation dose, improved naming of examination protocols, and increased stakeholder education are warranted to increase use of reduced-dose CT for evaluation of kidney stones.

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