Evaluation of Technologist-Controlled Factors Used During CT Kidney Stone Examinations

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Purpose To identify technologist-controlled factors to decrease dose and improve image quality and evaluate their use during computed tomography (CT) kidney stone examinations.

Methods Online scholarly databases were searched to acquire peer-reviewed, published articles involving methods of optimizing radiation dose during CT. These articles were reviewed, and the technologist-controlled factors identified were protocol selection, patient centering in the bore, and scan length. The author retrospectively reviewed CT kidney stone examinations performed at a free-standing emergency department to evaluate the use of these factors.

Results Technologists consistently chose the correct scan protocol. Reviewed literature was used to determine the acceptable variance for positioning at isocenter and overscanning beyond anatomical landmarks. All patient positioning was off-center in the vertical direction, and in 3 of those examinations, patient positioning was off-center more than the 3 cm threshold. Horizontal off-center positioning was less frequent. All examinations had some amount of overscan, with 73.1% of patients being overscanned more than the determined threshold of 10% of total scan length.

Discussion Accurate labeling of protocols at the console assist technologists in choosing protocols correctly. Technologists were inconsistent with patient centering and scan range. The amount of which images were off-center was consistent with previous research studies, while the amount of overscan was less than that found in previous studies.

Conclusion Technologists have an important role in optimizing patient radiation dose. Education and quality assurance could help technologists gain awareness of these factors and use them effectively.

Keywords | *Kidney, CT radiation dose, CT patient centering, CT scan range*

Computed tomography (CT) frequently is used in the rapid diagnosis of injury and to diagnose and monitor disease processes.[1] However, the increasing use of CT has been accompanied by concerns about the associated increase in radiation exposure to patients. Estimations are that CT is responsible for nearly half of the total population dose attributed to medical imaging.[1] The volume of CT examinations performed in the United States increased from approximately 3 million scans in 1980 to 91.4 million in 2019.[2] Estimates also show that radiation from CT imaging directly leads to 2% of current cancer diagnoses.[1] External agencies like the American College of Radiology, Image Wisely, and the Centers for Medicare and Medicaid Services have acted to control the overuse of CT but have had limited success. CT manufacturers also have developed innovations to reduce patient dose and continue to deliver diagnostic examinations. Although the increased use of CT might not be in the control of CT technologists, some the factors that affect patient dose can be controlled.

Literature Review

Technologists should understand the effect their decisions can have on mitigating patient radiation dose. Databases used for the literature search were EBSCO Host, Elsevier, PubMed, Google Scholar, CINAHL Plus. Key words used were *CT dose, CT dose reduction, CT radiation dose, CT patient centering, CT off-centering, CT scan range*. The literature review identified manufacturer and external efforts to decrease patient dose from CT, as well as technologist-controlled factors that can be used to lower patient dose.

Manufacturer Efforts

The first photon-counting CT system approved for clinical use was introduced in 2021.[3] These systems are not used widely, but the use of photon counting is estimated to reduce patient dose by up to 30% while delivering acceptable levels of image noise and contrast.[3] However, photon-counting CT is a novel technology, and the full capability to reduce dose has not been evaluated in detail.[3]

Split-filter, dual-energy CT systems can reduce patient dose by up to 11% when compared with single-energy CT.[4] This is achieved by using gold and tin filters to alter the x-ray beam emitted by the tube.[4] The tin filter absorbs low-energy x-ray photons, creating a higher energy beam and increasing dose efficiency.[4]

Decreasing the radiation emitted during the CT examination can increase the noise in the image, thus decreasing the detail and diagnostic value.[5] Iterative reconstruction allows for lower radiation dose during scanning while maintaining an acceptable level of image noise and allows for image processing after the scan, decreasing noise independent of x-ray beam quality.[5]

External Efforts

In 2014, the Protecting Access to Medicare Act established a program to increase the rate of appropriate diagnostic imaging, including CT, by Medicare providers.[6] This program requires providers to consult a clinical decision support system to improve ordering practices.[6] However, exceptions exist for critical access facilities, provider hardship, and emergency medical conditions.[6] In addition, claims are still paid by Medicare if the appropriate use criteria are not adhered to.[6] A 2019 study of radiologic technologists in the United States found that approximately 76% of CT technologists felt that 15% or more of their examinations were inappropriate, and approximately 27% of CT technologists believed that 50% or more of examinations were inappropriate.[6]

A joint task force between the American College of Radiology and the Radiological Society of North America launched the Image Wisely campaign in November 2010.[7] The purpose of Image Wisely is to address concerns about the dramatic increase in public exposure to radiation from medical imaging.[7] The Radiological Society of North America website allows referring practitioners and imaging professionals to sign a pledge to optimize the use of radiation imaging and offers free continuing education on the topic.[7] Since the inception of Image Wisely, the task force also has collaborated with the American Society of Radiologic Technologists and the American Association of Physicists in Medicine.[7] The initial campaign addressed CT technique optimization; nuclear medicine and fluoroscopy have been added in additional campaigns.[7]

Technologist-Controlled Factors

Three technologist-controlled factors that can be used to lower patient dose were identified from the literature review: protocol selection, scan length, and patient centering.

Protocol Selection

The Joint Commission requires accredited institutions to create examination-specific CT protocols and to review the protocols regularly.[8] Sites also are required to track radiation dose indices for CT examinations and to review and analyze CT studies when the radiation exceeds a predetermined threshold.[8] Patients with specific diagnoses or requiring disease surveillance are atincreased risk of radiation exposure, therefore sites should have protocols tailored for these diseases or diagnoses.[9]

A study at a multisite imaging institution found that despite having appropriately named and maintained protocols, technologists continued to select incorrect protocols or to manipulate existing protocols.[8] The reasoning provided was that technologists were comfortable with legacy protocols and were reluctant to change.[8] Timely, data-driven feedback and recurring education on the importance of correct protocol selection improved compliance and reduced radiation dose alerts.[8]

Scan Length

Technologists have an important role in the selection of an appropriate scan region to comply with specific examination requests.[10] Limiting the tissue exposed to radiation by reducing the scan range is an efficient method of reducing patient dose.[10] A recent phantom study revealed that a 6 cm increase in scan length beyond the prescribed anatomy resulted in an increase of 1 mSv of radiation dose.[10] Because scan range is decided entirely by the radiographer's judgement, education and ongoing feedback through quality control are vital to optimizing patient radiation dose.[10] Researchers have been effective at reducing patient dose for common CT examinations through targeted education and follow-up with technologists.[10,11] One study found that the neck region was routinely overscanned due to lack of compliance with established protocols.[10] Authors collected baseline data, educated CT staff, and collected data immediately after the scan and 1 year later.[10] The incidence of overscanning was reduced from 58% to 27%, resulting in a decrease in patient dose by 20%.[10] Another study found that CT scans performed to assess renal colic were overscanned routinely.[11] Through discussions with staff, the study discovered that technologists often struggled to find anatomical landmarks at which to start the scan, resulting in 89% of scans being overscanned.[11] When scans were analyzed for anatomical landmarks, the T11 vertebra was found to be an appropriate and easily identifiable landmark for all scans.[11]

Patient Centering

Accurate patient centering often is overlooked as a critical component for dose reduction.[12] Research has shown that being off-center in the vertical direction by approximately 4 cm can increase patient dose by 35% when using automated tube current modulation.[13] If the patient is positioned closer to the tube rather than at isocenter, the resulting scout image is magnified.[12] This effect causes an increase in the milliamperes to compensate for the artificially magnified patient body habitus.[12]

Another factor contributing to the increase in dose when patients are off-center is the use of bow-tie filtration in CT.[13,14] Bow-tie filters are designed to shape the beam to accommodate for variations in patient anatomy and x-ray attenuation by anatomical structures.[12] The thinnest part of the filter should align with the thickest patient anatomy so that the maximum beam intensity is used.[12] The thicker parts of the filter should align with the periphery of the patient so that beam intensity is reduced.[12] A study by DeWeese et al found that serial technologist educational opportunities had a positive effect on vertical patient centering.[13] Horizontal centering was consistently more accurate throughout the study, including at baseline.[13] Another study by Barreto et al found a similar result in that improper centering occurred more frequently in the vertical direction compared with horizontal.[12]

Methods

This study evaluated CT technologists' use of factors in their control to decrease patient radiation dose, including protocol selection, scan range, and patient centering. The CT scans evaluated were performed in a free-standing emergency department in the author's organization in a suburb of Columbus, Ohio. The author chose CT kidney stone as the specific examination due to increases in emergency department visits for urolithiasis. Between 2006 and 2014, annual emergency department visits for stones increased by approximately 18%, but the number of visits for stones that involved advanced imaging increased by more than 100%.[15] As part of The Joint Commission accreditation, the author's health care system maintains detailed scan instructions in a system-wide protocol. This protocol is named appropriately, preprogrammed into all CT systems, and available in protocol binders kept at the scanner consoles.

Examinations performed for diagnoses other than renal calculi were excluded. Also excluded were CT kidney stone examinations performed at the same time as other CT examinations. For example, reconstruction of a lumbar spine using data from the kidney stone examination could affect the technologist's decision of the anatomy to be included in the kidney stone examination.

Using the facility protocols for ensuring protection of patient health information, CT kidney stone examinations performed between November 13 and November 20, 2022, were viewed retrospectively from the medical image management and processing system (MIMPS). This research was exempt from review by an institutional review board because identifying patient information was not collected during research.

The author included all examinations, other than those meeting the exclusion criteria, that were performed during this period to eliminate bias due to patient selection, ordering physician, or scanning technologist. Examinations were evaluated for protocol selection, scan range, and patient centering.

Protocol Selection

The scanning protocol is available to technologists in a protocol book kept near the scanner for reference. The protocol also is built into the scanner for ease of selection. The technologists select the correct protocol, which includes predetermined exposure factors. Different protocols have been built for pediatric and adult patients and for patients with metallic hardware that might cause beam hardening or obscure anatomy.

The protocol for CT kidney stone examinations should be performed for the clinical indications of hematuria, flank pain, or known kidney stones. Slice thickness for the protocol was 2.5 mm (0.25 cm) at a standard reconstruction algorithm. Scan range was from just above the highest kidney through the pubic rami.

Scan Range

The acceptable scan range for the CT examination was from just above the highest kidney through the symphysis pubis. For this study, the acceptable length of overscan above the kidneys was determined to be 10% of the total scan length, correlating with the study by Ghoshal and Gaikstas.[11] No acceptable amount of overscan below the symphysis pubis was determined; however, data were collected so they could be compared with the more superior overscan. As part of this data collection, the vertebral level that corresponded to the level of the highest kidney was recorded to correlate with the same study.

Patient Centering

Patient centering was evaluated in relationship to isocenter in the CT bore. Correct horizontal centering aligns the patient's midsagittal lumbar spine with the midsagittal center of the bore. For vertical centering, the distance measurement tool on MIMPS was used to determine the anterior-to-posterior diameter of the thickest part of the patient's abdomen. This value was then divided in half to determine the center of the patient. This methodology followed that used in the study by Barreto et al.[12] An acceptable variance was determined to be 3 cm to correlate with the study by DeWeese et al.[13]

Statistical Analyses

Evaluation for adhering to the protocol was indicated by yes, the technologist chose the correct protocol, or no, the technologist did not. Next, the scan range was evaluated in relationship to the anatomy included in the examination. Total scan length and overscan beyond the anatomy of interest was calculated using DICOM to determine the CT table location during the first image and comparing that with the table location during the final image. Total scan length was the difference between the 2 values. Superior overscan was determined by counting the number of images acquired superior to the level of the top of the highest kidney in which it was visualized and multiplying this number by the slice thickness (2.5 mm [0.25 cm]). Inferior overscan was determined by counting the number of images acquired inferior to the symphysis pubis and multiplying by slice thickness (2.5 mm [0.25 cm]). The length of the superior overscan was divided by the length of the total scan to determine the percentage of overscan. During this step, the level of the highest kidney in relationship to the spine vertebral level also was recorded.

Last, the anatomical center of the patient was compared with the center of the CT scanner bore. The amount that the patient was positioned off-center was measured using the measurement tool in MIMPS, and the amount and direction (ie, horizontal, vertical) were recorded. Off-center horizontal positioning was indicated as left or right. For vertical off-centering, patient positioning low in the bore with the anatomical center of the patient below isocenter was indicated by a negative number. Positioning high in the bore with the center of the patient above isocenter was indicated by a positive number.

Results

A total of 30 CT kidney stone examinations were performed during the observation period. Four examinations were excluded because they were combined with a reconstructed lumbar spine examination. The remaining 26 examinations were evaluated on the use of scanning protocol, scan length, and patient centering during the examination.

Protocol Selection

All 26 patients were scanned with the correct protocol for a compliance rate of 100%. One examination used a metal artifact reduction protocol; this protocol uses a retrospective reconstruction filter to produce an additional set of images. The purpose of the filter is to reduce the beam hardening artifact from metallic implants and hardware, preventing the artifact from obscuring anatomy. The use of this protocol did not affect radiation dose to the patient.

Scan Length

The amount of overscan in the superior direction ranged from 1.5 to 9.5 cm, which was 3.7% to 22.4% of total scan length, respectively (see **Table**). Eighteen out of the 26 (69.2%) examinations included more than 10% overscan, the threshold determined to be acceptable. In the inferior direction, the percentage of overscan was not calculated, but the amounts were less, ranging from 0 to 4.8 cm.

Patient Centering

All 26 examinations were off-center in the vertical direction. The amount of vertical off-center positioning ranged from −2.01 to +6.09 cm. Among the 26 CT examinations, 3 were off-center more than 3 cm, the acceptable threshold. Horizontal off-center positioning occurred less frequently with less than half (11 of 26) being affected. The amount of horizontal off-center position ranged from 0.90 cm to the right and 1.5 cm to the left. Seven examinations were off-center to the right and 4 to the left.

Discussion

Technologists can have a direct effect on the amount of radiation a patient receives during a CT examination. All CT examinations that are ordered should be medically necessary. However, a 2019 study of radiologic technologists in the United States found that almost 27% of CT technologists believed that more than 50% of examinations were inappropriate, and more than 76% of CT technologists felt that more than 15% of their examinations were inappropriate.[6] The American Society of Radiologic Technologists Practice Standards for Medical Imaging and Radiation Therapy include verifying imaging appropriateness as part of the professional role of radiologic technologists.[6] However, technologists are not always aware of the patient's complete medical history or the ordering clinician's rationale for ordering the examination.[6] When an examination is ordered, 3 factors in the technologist's control that directly affect the amount of radiation received by the patient are examination protocol selection, scan length, and patient centering in the CT bore.

This study found that protocols were being selected appropriately at the imaging location, indicating a good understanding of protocol appropriateness and clear naming and labeling of protocols.

The findings were that 69.2% of examinations exceeded the 10% threshold for overscanning above the highest kidney. This was less than the 88.8% found in the study by Ghoshal and Gaikstas.[11] The minimum distance of overscan above the highest kidney was 1.5 cm (3.7%), and the maximum distance was 9.5 cm (22.4%). These are in range of the Ghoshal and Gaikstas study results of 12.5 mm (3.8%) minimum and 149 mm (32.8%) maximum.[11] Although an acceptable amount of overscan in the inferior direction was not calculated, scanning beyond the symphysis pubis occurred less frequently when compared with superior landmarks. The mean distance of overscan inferiorly was 2.29 cm (5.4%), similar to the results of Ghoshal and Gasikstas.[11] The symphysis pubis is located easily on localizer images regardless of patient body habitus, and study findings seem to support that. The superior border of the highest kidney can be difficult to locate due to body habitus or superimposed abdominal structures. Vertebral level T11 would have been an appropriate landmark to begin scanning for all examinations included in the study, the same results as the comparison study.

The amount and direction of off-center patient positioning was consistent with the serial findings of a

Table

Results From Statistical Analyses of Technologist-Controlled Factors Used During Computed Tomography Kidney Stone Examinations

Examination date	Adherence to protocol (Y/N)	Total scan length, cm	Overscan above kidney, cm (%)[a]	Overscan below symphysis, cm (%)	Vertebral level of highest kidney	Vertical off-center positioning, cm[b]	Horizontal off-center positioning, cm[b,c]
11/20/22	Y	39.0	7.5 (19.2)	3.3 (8.5)	T11	+0.86	0
11/20/22	Y	40.8	1.5 (3.7)	3.8 (9.3)	T12	−2.01	0.68 (R)
11/20/22	Y	52.5	3.5 (6.7)	1.8 (3.4)	T12	+0.81	0.52 (L)
11/18/22	Y	40.0	3.0 (7.5)	1.0 (2.5)	T11	+1.39	0
11/18/22	Y	41.3	6.3 (15.3)	1.8 (4.4)	T12	+0.74	0.24 (R)
11/17/22	Y	43.0	7.3 (17.0)	3.5 (8.1)	L1	+0.38	0.27 (R)
11/17/22	Y	35.0	5.8 (16.6)	1.0 (2.9)	T12	+0.62	0.84 (R)
11/17/22	Y	47.3	2.3 (4.9)	3.0 (6.3)	T12	+0.63	0
11/16/22	Y	38.5	1.8 (4.7)	0 (0.0)	T11	+1.01	0
11/16/22	Y	42.5	9.5 (22.4)	0.5 (1.2)	L1	−1.89	0.20 (R)
11/16/22	Y	40.0	6.0 (15.0)	1.0 (2.5)	L1	+0.51	0.36 (L)
11/16/22	Y	34.8	2.5 (7.2)	0 (0.0)	L1	+0.62	0
11/15/22	Y	34.8	3.8 (10.9)	0 (0.0)	L1	+3.22	0.90 (R)
11/15/22	Y	41.3	3.8 (9.2)	2.3 (5.6)	T11	+2.91	0
11/15/22	Y	47.7	9.3 (19.5)	2.3 (4.8)	T11	+2.57	0
11/15/22	Y	37.5	7.5 (20.0)	1.5 (4.0)	T12	−0.54	0
11/15/22	Y	43.5	6.3 (14.5)	1.8 (4.1)	T12	−0.61	1.50 (L)
11/14/22	Y	39.3	4.5 (11.5)	1.5 (3.8)	T12	−1.75	0
11/14/22	Y	40.0	4.5 (11.3)	2.0 (5.0)	T11	−0.47	0
11/14/22	Y	43.0	6.0 (14.0)	4.5 (10.5)	T11	−1.6	0
11/14/22	Y	45.5	5.8 (12.7)	4.8 (10.5)	T11	+5.77	0.50 (L)
11/13/22	Y	44.3	6.0 (13.5)	4.3 (9.7)	T12	+6.09	0.30 (R)
11/13/22	Y[d]	50.0	9.0 (18.0)	3.8 (7.6)	T12	+2.55	0
11/13/22	Y	40.0	4.5 (11.3)	2.8 (7.0)	T11	+0.82	0
11/13/22	Y	35.5	4.5 (12.7)	4.3 (12.1)	T12	+0.66	0
11/13/22	Y	43.0	3.3 (7.7)	3.5 (8.1)	T12	+1.21	0

[a] *Acceptable amount of overscan above the kidneys was ≤ 10% of the total scan length. No threshold of overscan below the symphysis pubis was determined.*

[b] *Acceptable amount of off-center positioning was ≤ 3 cm.*

[c] *Horizontal direction is indicated as left (L) or right (R).*

[d] *Examination used a metal artifact reduction protocol.*

study by DeWeese et al.[13] Vertical off-center positioning was much more prevalent (100%) than that in the horizontal direction, and 3 patients (1.2%) were positioned off-center by more than the acceptable threshold of 3 cm vertically. Horizontally, less than half of patients were off-center, none beyond the 3 cm threshold. This indicates a difficulty for technologists in locating anatomical landmarks in the vertical direction.

Limitations

Limitations of this study include the retrospective review of examinations on MIMPS. If the images had been viewed from the scanner console, the exact centering offset would have been available, and use of the measurement tool would have been unnecessary. The author was the sole reviewer of the CT examinations. Multiple reviewers and measurements might have resulted in slightly different values. Whether the results of this study are transferrable to other CT examinations is unclear, but they demonstrate technologists' use of dose reduction factors in their control.

Conclusion

Although manufacturers and external agencies have made efforts to decrease patient dose during CT, these efforts are not controlled by technologists at the CT console. The technologist does not control the use of advanced equipment or lowest-dose system protocol, or how often patients are being imaged. However, technologists can control whether the patient is scanned with the correct protocol, has exposure limited to the anatomy clinically indicated, and is centered appropriately in the gantry.

The results of this study demonstrate that an opportunity for further education exists. An additional study could be performed after serial education to evaluate the effectiveness of the education and the effect on patient scans. Opportunities for further research would include evaluating other types of CT examinations to explore whether these results are transferrable. If an organization's high-volume examinations include radiosensitive organs, such as the lens, breasts, or gonads, these examinations would provide an appropriate starting point. Serial follow-up after technologist education would evaluate the effectiveness of education.

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References

1. Mahmoudi F, Naserpour M, Farzanegan Z, Davudian Talab A. Evaluation of radiographers' and CT technologists' knowledge regarding CT exposure parameters. *Polish J Med Phys Eng.* 2019;25(1):43-50. doi:10.2478/pjmpe-2019-0007
2. Young L. IMV: CT procedure volume fell 20% in 2020. AuntMinnie. Published January 19, 2021. Accessed March 8, 2023. https://www.auntminnie.com/index.aspx?sec=sup&sub=cto&pag=dis&ItemID=131349
3. Niehoff JH, Carmichael AF, Woeltjen MM, et al. Clinical low dose photon counting CT for the detection of urolithiasis: evaluation of image quality and radiation dose. *Tomography.* 1675;8(4):1666-1675. doi:10.3390/tomography8040138
4. Euler A, Obmann MM, Szucs-Farkas Z, et al. Comparison of image quality and radiation dose between split-filter dual-energy images and single-energy images in single-source abdominal CT. *Eur Radiol.* 2018;28(8):3405-3412. doi:10.1007/s00330-018-5338-x
5. Li X, Shu H, Zhang Y, et al. Low-dose CT with adaptive statistical iterative reconstruction for evaluation of urinary stone. *Oncotarget.* 2018;9(28):20103-20111. doi:10.18632/oncotarget.25047
6. Moore QT. Radiologic technologists' perceptions of imaging appropriateness in radiography, CT, and mammography. *Radiol Technol.* 2022;93(5):437-453.
7. Mayo-Smith WW, Morin RL. Image Wisely: the beginning, current status, and future opportunities. *J Am Coll Radiol.* 2017;14(3):442-443. doi:10.1016/j.jacr.2016.11.027
8. Zygmont ME, Neill R, Dharmadhikari S, Raach P, Duong PT. Achieving Joint Commission regulatory compliance: quality improvement process for CT protocol review and dose alert reduction. *J Am Coll Radiol.* 2019;16(2):196-201. doi:10.1016/j.jacr.2018.08.019
9. Joyce S, O'Connor OJ, Maher MM, McEntee MF. Strategies for dose reduction with specific clinical indications during computed tomography. *Radiography.* 2020;26(suppl 2):S62-S68. doi:10.1016/j.radi.2020.06.012
10. Badawy MK, Lane H, Galea M. Radiation dose associated with over scanning in neck CT. *Curr Probl Diagn Radiol.* 2019;48(4):359-362. doi:10.1067/j.cpradiol.2018.05.010
11. Ghoshal N, Gaikstas G. CT KUB scans for renal colic: optimisation of scan range to reduce patient radiation burden. *Radiography.* 2021;27(3):784-788. doi:10.1016/j.radi.2020.12.006
12. Barreto I, Lamoureux R, Olguin C, et al. Impact of patient centering in CT on organ dose and the effect of using a positioning compensation system: evidence from OSLD measurements in postmortem subjects. *J Appl Clin Med Phys.* 2019;20(6):141-151. doi:10.1002/acm2.12594