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ORIGINAL ARTICLE

Optimal timing of delayed excretory phase computed tomography scan for diagnosis of urinary extravasation after high-grade renal trauma

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BACKGROUND: Excretory phase computed tomography (CT) scan is used for diagnosis of renal collecting system injuries and accurate grading of high-grade renal trauma. However, optimal timing of the excretory phase is not well established. We hypothesized that there is an association between excretory phase timing and diagnosis of urinary extravasation and aimed to identify the optimal excretory phase timing for diagnosis of urinary extravasation.

METHODS: The Genito-Urinary Trauma Study collected data on high-grade renal trauma (grades III-V) from 14 Level I trauma centers between 2014 and 2017. The time between portal venous and excretory phases at initial CT scans was recorded. Poisson regression was used to measure the association between excretory phase timing and diagnosis of urinary extravasation. Predictive receiver operating characteristic analysis was used to identify a cutoff point optimizing detection of urinary extravasation.

RESULTS: Overall, 326 patients were included; 245 (75%) had excretory phase CT scans for review either initially (n = 212) or only at their follow-up (n = 33). At initial CT with excretory phase, 46 (22%) of 212 patients were diagnosed with urinary extravasation. Median time between portal venous and excretory phases was 4 minutes (interquartile range, 4–7 minutes). Time of initial excretory phase was significantly greater in those diagnosed with urinary extravasation. Increased time to excretory phase was positively associated with finding urinary extravasation at the initial CT scan after controlling for multiple factors (risk ratio per minute, 1.15; 95% confidence interval, 1.09–1.22; $p < 0.001$). The optimal delay for detection of urinary extravasation was 9 minutes.

CONCLUSION: Timing of the excretory phase is a significant factor in accurate diagnosis of renal collecting system injury. A 9-minute delay between the early and excretory phases optimized detection of urinary extravasation. (*J Trauma Acute Care Surg.* 2019;86: 274–281. Copyright © 2018 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Diagnostic tests/criteria study, level III.

KEY WORDS: Renal trauma; urinary extravasation; computed tomography; wounds and injuries; trauma centers; multicenter study.

Contrast enhanced computed tomography (CT) scans are the mainstay of abdominal trauma evaluation. A typical abdominal trauma CT protocol includes a portal venous phase scan, 65 seconds to 80 seconds following the administration of 100 mL to 150 mL of intravenous (IV) contrast. Delayed excretory phase images are often obtained 5 minutes to 10 minutes after contrast administration and are necessary to evaluate for urinary collecting system injuries and some solid organ vascular injuries.[1]

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Accurate grading of high-grade renal trauma (HGRT) depends on the ability to evaluate for urinary extravasation from the kidneys. Patients with more severe renal trauma are at higher risk of renal collecting system injuries and most trauma centers use CT scans with delayed excretory phase images in the initial assessment of these patients. However, optimal timing of the excretory phase imaging that allows detection of such extravasation is not established in the context of HGRT.[2–6] Although shorter delays or omitting the excretory phase during the initial scan may be necessary in time-sensitive scenarios after multiple injuries, inadequate assessment of HGRT can lead to missed or delayed diagnosis of urinary extravasation. This can lead to persistent urine leak from renal injury, urinoma and abscess formation, urinary tract infection, and even nephrectomy due to intractable sepsis.[7] Thus, adequate timing of the excretory phase is important for complete and accurate assessment of HGRT.

We hypothesized that there is a significant association between excretory phase delay interval length and diagnosis of urinary extravasation and we also aimed to identify the optimal timing for excretory phase imaging in the setting of HGRT. It stands to reason that with a longer delay before excretory imaging, more instances of urinary extravasation will be detected; however, we hypothesized that there is a time point beyond which very few additional injuries would be identified.

PATIENTS AND METHODS

The data used for this study was collected as part of the Genito-Urinary Trauma Study (full study sites and collaborators' information is available at: http://www.turnsresearch.org/page/aast-gu-trauma-study-group-author-list-renal-trauma). Details on the renal trauma study protocol and data collection have been previously published.[8] In brief, the study is a multi-institutional collaborative effort of the American Association for the Surgery of Trauma (AAST) and the Genito-Urinary Trauma Study Group that involved 14 Level I trauma centers across the United States for Phase 1 of the study. Clinical and imaging data on all patients with HGRT (defined as AAST grades III-V)[9] were gathered from the participating centers from 2014 to 2017. Patients who underwent immediate surgery without imaging were excluded from the current study. Patients who did not undergo initial CT scan with excretory phase imaging were not included in the statistical analyses.

Clinical variables included: age, sex, trauma mechanism (blunt vs. penetrating), side of renal injury (right, left, bilateral), Injury Severity Score (ISS), hypotension (defined as systolic blood pressure less than 90 mm Hg during the first 4 hours from emergency department admission), and presence of concomitant injuries (including any solid organ, gastrointestinal, spinal cord, major vascular, and pelvic fracture). All deidentified images were uploaded to a secure Web-based Orthanc[10] server for central review. Two radiologists, blinded to the data on interventions and patient outcomes, reviewed the CT scans to extract injury specifics, including presence of vascular contrast extravasation (VCE) on early phase images and urinary extravasation on delayed excretory phase images. Interradiologist disagreements for VCE and urinary extravasation diagnoses were resolved by rereviewing the images and reaching a consensus; if needed a third reviewer's input was used. Initial interrater reliability was substantial for both VCE (kappa coefficient, 0.81) and urinary extravasation (kappa coefficient, 0.63). The time between portal venous (early) and excretory (delayed) phases was recorded. A truncation approach to outliers was used to set this time at 15 minutes when the excretory phase was part of the same CT series but was obtained after 15 minutes (n = 12 patients).[11] For patients with bilateral renal trauma, specifics from the side with more severe renal injury, based on the AAST grading, were included in the analysis. Urinary extravasation was defined as presence of contrast extravasation, from the renal collecting system at or above the ureteropelvic junction, in the delayed excretory phase CT scan. Isolated ureteral injuries and nonrenal urinary extravasation were not included. Presence of urinary extravasation (yes/no/inconclusive) was assessed using the first available CT scan with excretory phase imaging after trauma patient admission. Findings were deemed inconclusive when the injury pattern was highly suggestive of collecting system injury but there was inadequate opacification of the collecting system (e.g., large renal lacerations with adjacent low attenuation fluid collection). Follow-up CT scans, when available, were also reviewed and assessed for presence of urinary extravasation to find patients with missed diagnosis of urinary extravasation.

Descriptive statistics were used to summarize the baseline data. Continuous variables are presented using mean (standard deviation, SD) or median (25th–75th interquartile range [IQR]) when appropriate. Kruskal-Wallis and Wilcoxon ranked-sum tests with Hommel's correction for multiple comparisons were used to compare excretory phase time in different urinary extravasation diagnosis groups (yes/no/inconclusive). Mixed-effect Poisson regression, with robust variance estimation and clustering by facility, was used to measure the association between excretory phase timing (continuous) with diagnosis of urinary extravasation (binary outcome: yes vs. no/inconclusive), controlling for covariates; risk ratios (RR) and 95% confidence intervals (CI) are reported.

Minute-specific prevalence of urinary extravasation was calculated for patients who underwent excretory phase imaging at each exact time point (e.g., percentage of patients diagnosed with urinary extravasation who underwent imaging at X minutes). As no gold standard was available for diagnosis of urinary extravasation to calculate diagnostic test characteristics (e.g., sensitivity, specificity, positive predictive value, negative predictive value), it was not possible to use conventional diagnostic accuracy calculations. Instead, the cumulative prevalence of urinary extravasation was used as a surrogate for the diagnostic accuracy of each time cutoff point for acquisition of the excretory phase. The cumulative positive prevalence (CPP) of urinary extravasation was calculated by grouping all patients who underwent imaging at or after a specific time cutoff point. Cumulative negative prevalence (CNP) of urinary extravasation was calculated for patients who underwent imaging before a specific cutoff point. For example, CNP was calculated as percentage of patients without diagnosis of urinary extravasation in those who underwent imaging before X minutes. Reciprocally, 1-CNP represents the cumulative percentage of urinary extravasation for patients who underwent imaging before X-minutes.

There are limitations in using metrics that do not incorporate information on disease prevalence when the aim is to predict the operational consequences related to using one cutoff over another.[12,13] As traditional receiver operating characteristic (ROC) analysis does not account for disease prevalence, alternative methods are used to incorporate the pretest probability. Use of metrics, such as positive and negative predictive values, number needed to evaluate, and reclassification indices, has been proposed to take the clinical context of the test into account.[12–14] Instead of the traditional ROC, we used a predictive ROC (PROC) analysis based on the methods suggested by Shiu and Gatsonis,[14] with some modifications. Using measures of predictive value would provide information more relevant to the process of clinical decision making and how to assess the implications of different test results.[14] To generate a PROC curve and calculate the area under the curves (AUC) for each time-point, CPP and CNP were treated as hypothetical positive and negative predictive values, respectively. The purpose of the AUC analysis was to find the cutoff point that balanced highest CPP versus lowest 1-CNP. This translates to the time cutoff that balances the highest positive diagnosis of urinary extravasation achievable if one waits at least for X minutes or more, versus having the lowest prevalence of positive diagnosis if waiting less than X minutes. However, the crude values of PROC AUC should not be interpreted as a probabilistic analogue of the area under the traditional ROC curve. All statistical tests were two-sided and statistical significance was assessed at the 0.05 level. All analyses were performed using STATA 15 (Stata Corp, College Station, TX).

RESULTS

From a cohort of 431 patients, 326 met the selection criteria. Mean age was 35.0 years (SD, 16.6) and mean ISS was 25.0 (SD, 12.6). Trauma mechanism was blunt in most patients (n = 263, 81%), and 67% had one or more concomitant injuries; 23% of patients presented with hypotension/shock. Renal injuries were left-sided in 156 (48%), right-sided in 144 (44%), and bilateral in 26 (8%). Based on the initial CT scans, injuries were graded as AAST grade III in 78%, IV in 17%, or V in 5%.

A total of 245 (75%) patients had delayed phase CT scans available for review either initially (n = 212) or only at their follow-up (n = 33). Of the initial CT scans with a delayed phase (n=212), 46 (22%) were diagnosed with urinary extravasation, and 25 (12%) had inconclusive images. Median time between early and delayed phases was 4 minutes (IQR, 4–7 minutes). The time to initial delayed phase was significantly higher in those with urinary extravasation (median, 7 minutes; IQR, 4–10 minutes) compared with those without urinary extravasation (median, 4 minutes; IQR, 4–6 minutes) and those with initial inconclusive images (median, 4 minutes; IQR, 4–5 minutes) ($p < 0.001$ and 0.03, respectively).

Multiple cases of missed diagnosis of urinary extravasation were identified on follow-up imaging of patients with either inconclusive or negative findings on the initial delayed phase CT scan or in patients who did not undergo a delayed phase scan initially. Of the 25 patients with initially inconclusive findings on delayed phase imaging, 12 (48%) had follow-up CT scans with excretory phase images. Eight (67%) of 12 were diagnosed with urinary extravasation on the follow-up imaging. Of the 13 patients with inconclusive findings who did not undergo follow-up excretory phase imaging, 5 (38%) were clinically diagnosed with urinoma and underwent ureteral stenting. Therefore, 13 (52%) of the 25 with initial inconclusive CT findings were later discovered to have radiographic or clinical evidence of urinary extravasation. Of the 141 patients who were not diagnosed with urinary extravasation on their initial delayed phase CT scan, 28 underwent follow-up CT scans with excretory phase imaging. Five of these 28 (18%) patients were subsequently diagnosed with urinary extravasation and underwent ureteral stenting. Of the 114 patients who did not undergo initial delayed phase imaging, 33 had follow-up imaging with an excretory phase. Of these, eight (24%) were diagnosed with urinary extravasation and five underwent ureteral stenting (Fig. 1).

In univariable mixed effect Poisson regression, the relative risk of diagnosing urinary extravasation on the initial CT scan increased 15% per minute increase in excretory phase delay time. The same results were obtained after controlling for ISS, trauma mechanism, VCE, and hypotension, and after clustering by facility (RR of detecting urinary extravasation per extra minute, 1.15; 95% CI, 1.09–1.22; $p < 0.001$; Table 1). To explore the possibility that decision on timing of excretory phase was affected by the injury pattern or severity, we tested the univariable associations between timing of the excretory phase as the outcome and trauma mechanism, ISS, hypotension/shock, VCE, size of renal parenchymal laceration, and size of perirenal hematoma as individual predictors; none of these associations were statistically significant (data not shown).

Table 2 shows the minute-specific prevalence of urinary extravasation at each cutoff point, the cumulative prevalence of positive urinary extravasation diagnosed in patients undergoing imaging at or after each cutoff point (CPP), and the cumulative prevalence of positive urinary extravasation diagnosed in patients undergoing imaging before each cutoff point (1-CNP). Also, the PROC AUC values for balancing CPP and 1-CNP are provided. There was an overall increasing trend for minute-specific prevalence of urinary extravasation as well as PROC AUC with higher time cutoffs up to 9 minutes when they reached a plateau. Figure 2 depicts the same trends in time-specific and CPP of urinary extravasation (panel A) and PROC AUC (panel B), which shows that the optimal cutoff for detecting urinary extravasation was at 9 minutes (PROC AUC, 68%).

DISCUSSION

In our multi-institutional study, longer time before delayed phase imaging was significantly associated with a higher detection rate of urinary extravasation after adjusting for injury severity, hemodynamic status, and trauma mechanism. A 9-minute delay from the portal venous phase provided the highest diagnostic accuracy for predicting the presence of urinary extravasation. Of note, the median time between early (portal venous) and delayed (excretory) phase CT scans was about 4 minutes, which was suboptimal for diagnosis of urinary extravasation.

Optimal timing for acquisition of excretory phase images has not been thoroughly studied in the setting of renal trauma. Although a 10-minute delayed scan is commonly referred to as the “gold standard”,[15] recommendations vary from 2–15 minutes in the literature.[16–18] The American Urological Association (AUA) genitourinary trauma guidelines recommend CT scans with both early and delayed phase images when renal trauma is suspected. A 10-minute delay from injection of contrast material is recommended for assessment of ureteral injuries, although no specific

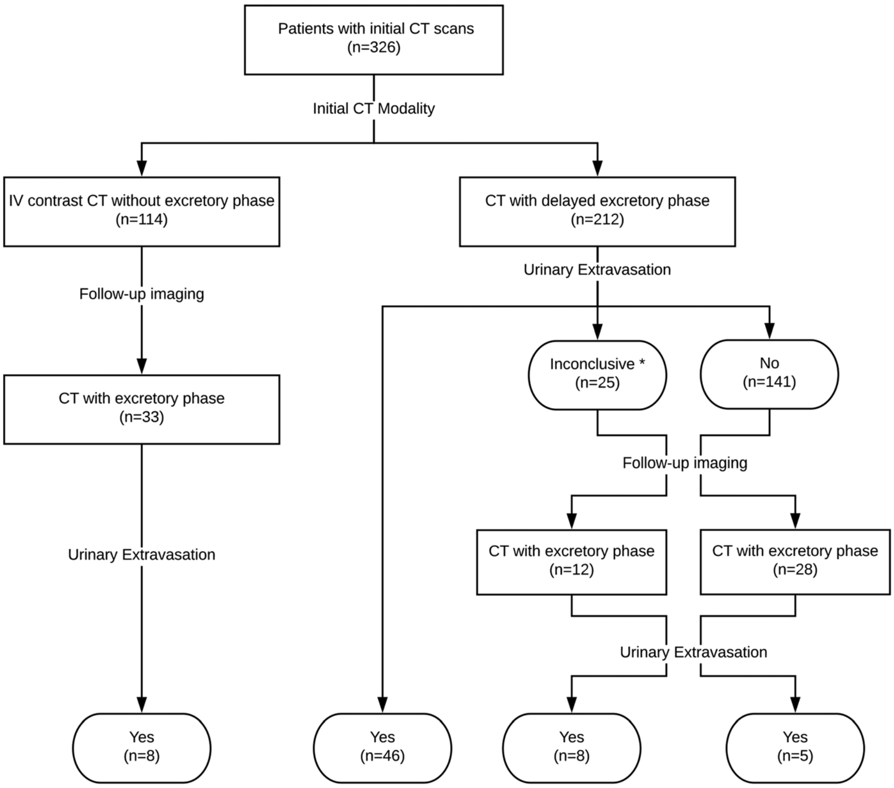

Figure 1. Diagram for process of urinary extravasation diagnosis in patients who underwent initial CT scan. *13/25 did not undergo follow-up imaging with excretory phase, but urinary extravasation was diagnosed clinically in additional 5 patients.

timing recommendations are provided in the renal trauma guidelines.[2] The Eastern Association for the Surgery of Trauma (EAST) genitourinary trauma guidelines also recommend 5 minutes to 8 minutes of delay for diagnosis of ureteral injuries.[3] This recommendation is based upon two case series from the late 1990s that suggested rapid trauma CTs with only a portal venous phase are not adequate to assess collecting system injuries.[19,20] The evidence underlying these practice guidelines are based on Level III studies and grade C evidence strength.

Previous research on the timing of delayed phase imaging has been limited in the context of renal trauma. In an attempt to make assessment of renal trauma faster and more efficient, a few studies have evaluated using shorter delays, but have reported disparate findings. For example, Fisher et al.[5] suggested that a 5-minute excretory phase scan can accurately diagnose urinary extravasation with very low incidence of delayed or missed diagnosis; however, not all high-grade injuries in this study underwent initial imaging, which may have introduced bias into the results. In contrast, Baghdanian et al.[6] studied a cohort of renal trauma patients who had excretory phase imaging at 5 minutes to 7 minutes after contrast injection, and reported that half of the collecting system injuries were missed on the initial excretory phase images. Although the authors hypothesized that tamponade effect from large hematomas may have masked the injuries in the initial scans, inadequate delay of the excretory phase may have also played a role.

Most data and recommendations on timing of delayed excretory phase originates from CT urography studies used to assess upper and lower urinary tract tumors. Elective CT urography is used in the diagnostic work-up of hematuria and can delineate the anatomic location of a mass in relation to the collecting system. The timing of excretory phase for this purpose is typically 4 minutes to 5 minutes, as longer delays can lead to higher contrast density in the collecting system, which may obscure subtle filling defects and urothelial thickening.[21] In contrast to the goal of tumor detection in CT urography, the goal of excretory phase in the setting of renal trauma is to distend the collecting system and detect extravasation from the renal collecting system or ureters. Additionally, ancillary techniques (such as diuretic use and prehydration) are often used to increase collecting system distension and visualization when obtaining elective CT urography images.[21–23] Despite these measures, timing of the excretory phase acquisition remains controversial, even in the elective setting, and shorter delays may be associated with

TABLE 1. Multivariable Mixed Effect Poisson Regression of Association Between Excretory Phase Delay Time and Diagnosis of Urinary Extravasation After HGRT

Variables	RR (95% CI)	p
Delay time	1.15 (1.09–1.22)	<0.001
ISS	1.02 (1.00–1.03)	0.04
Trauma mechanism (penetrating vs. blunt)	1.23 (0.63–2.42)	0.53
VCE	0.68 (0.35–1.34)	0.26
Hypotension/shock*	1.20 (0.65–2.20)	0.55

* Systolic blood pressure < 90 mm Hg recorded during the first 4 hours after patient admission.

TABLE 2. Prevalence-based Diagnostic Accuracy for Finding Urinary Extravasation at Different Excretory Phase Time Cutoff Points*

Time Between Early and Excretory Phase, min	Minute-specific Diagnosis of UE at Each Time-Point (%)	CPP (%)	1-CNP (%)	PROC AUC**
2	0% (0/6)	22% (44/200)	—	—
3	7% (2/27)	23% (44/194)	0% (0/6)	0.61 (0.58–0.64)
4	15% (11/73)	25% (42/167)	6% (2/33)	0.59 (0.54–0.65)
5	21% (5/24)	33% (31/94)	12% (13/106)	0.60 (0.55–0.66)
6	20% (3/15)	37% (26/70)	14% (8/130)	0.62 (0.55–0.68)
7	23% (4/17)	42% (23/55)	14% (21/145)	0.64 (0.56–0.71)
8	33% (2/6)	50% (19/38)	15% (25/162)	0.67 (0.59–0.76)
9 †	62% (5/8)	53% (17/32)	16% (27/168)	0.68 (0.59–0.78)
10 ‡	50% (4/8)	50% (12/24)	18% (32/176)	0.66 (0.55–0.76)
13 ‡	50% (1/2)	50% (8/16)	20% (36/184)	0.65 (0.52–0.78)
14	50% (1/2)	50% (7/14)	20% (37/186)	0.65 (0.51–0.79)
15	50% (6/12)	50% (6/12)	20% (38/188)	0.65 (0.50–0.80)

* Time of excretory phase was unknown for 12 of 212 patients with initial excretory phase imaging.

** AUC for the predictive ROC curve based on the prevalence of positive findings beyond and negative findings before each time cutpoint.

† Suggested time cutpoint based on highest % of minute-specific diagnosis of urinary extravasation, cumulative prevalence of positive findings beyond each time cutoff, and AUC for positive findings beyond and before each cutpoint.

‡ No data available for minutes 11 and 12; percentages and AUC value are the same as minute 13.

UE, urinary extravasation; CPP, Cumulative positive prevalence of urinary extravasation for patients who underwent imaging at or after X minutes; 1-CNP, 1 minus cumulative negative prevalence of urinary extravasation for patients who underwent imaging before X minutes; PROC, predictive receiver operating characteristic; AUC, area under curve.

suboptimal images. For example, Metser et al.[24] reported that even after prehydration and IV furosemide injection, adequate and uniform opacification of the collecting system was not achieved in as high as 30% of patients being assessed for urothelial tumors. Similarly, using low-dose furosemide to facilitate assessment of renal collecting system, Kemper et al.[25] suggested that a 7-minute delay is needed to obtain adequate opacification in patients with a normal creatinine. Renal trauma patients commonly present with multiple injuries and hypovolemic shock, which can lead to lower renal perfusion and delayed excretion of contrast into the collecting system (Fig. 3). Additionally, there may be delayed contrast excretion by the injured kidney due to extensive parenchymal or vascular injury. Thus, it is intuitive that longer delays are needed to obtain diagnostic excretory phase images in the setting of renal trauma when compared to elective urography.

Most cases of urinary extravasation are believed to heal spontaneously, although ureteral stenting is used in about 30% of patients to facilitate the healing process or to treat subsequent complications.[26] It may be argued that the immediate assessment of urinary extravasation is not as important as evaluation of parenchymal and vascular injuries that are associated with the risk of hemorrhage. However, knowledge of urinary extravasation is important for accurate grading of the injuries and remains critical for development of an appropriate management plan, particularly for determining if early intervention is justified. Even if expectant management is attempted, one would be more prepared to intervene promptly if complications develop. Although the utility of routine excretory phase imaging for all renal trauma patients is controversial, it has been suggested that patients with high-grade injuries and especially those with perirenal fluid collection would benefit from complete assessment of the collecting system.[27,28] When a decision is made to obtain excretory phase images, proper timing is of paramount importance to allow adequate contrast excretion by the injured

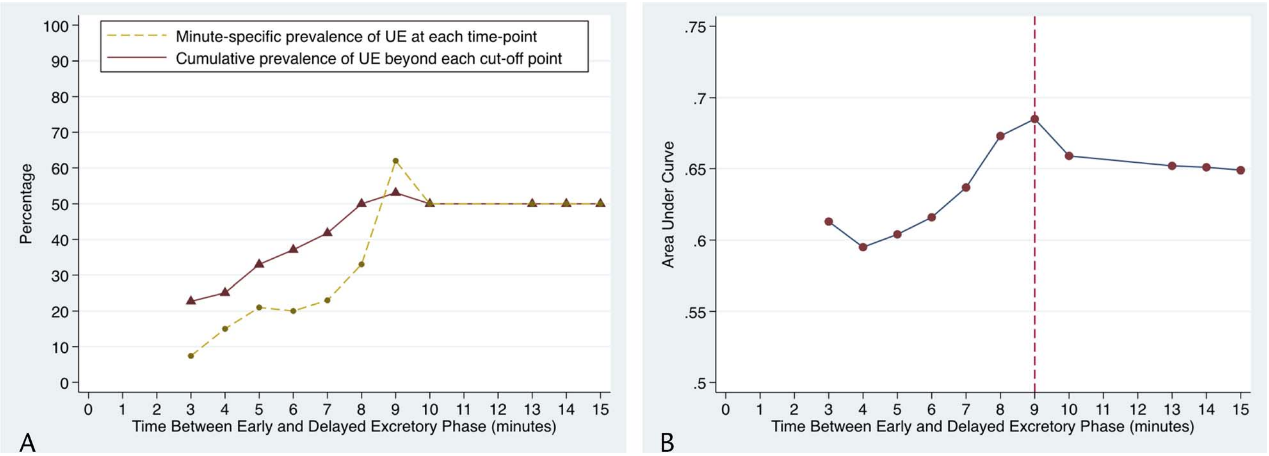

Figure 2. (*A*), Minute-specific prevalence of urinary extravasation (*yellow*) and CPP of urinary extravasation for patients who underwent imaging at or after each cutoff point (*red*). (*B*), AUC for different excretory phase time cutoff points.

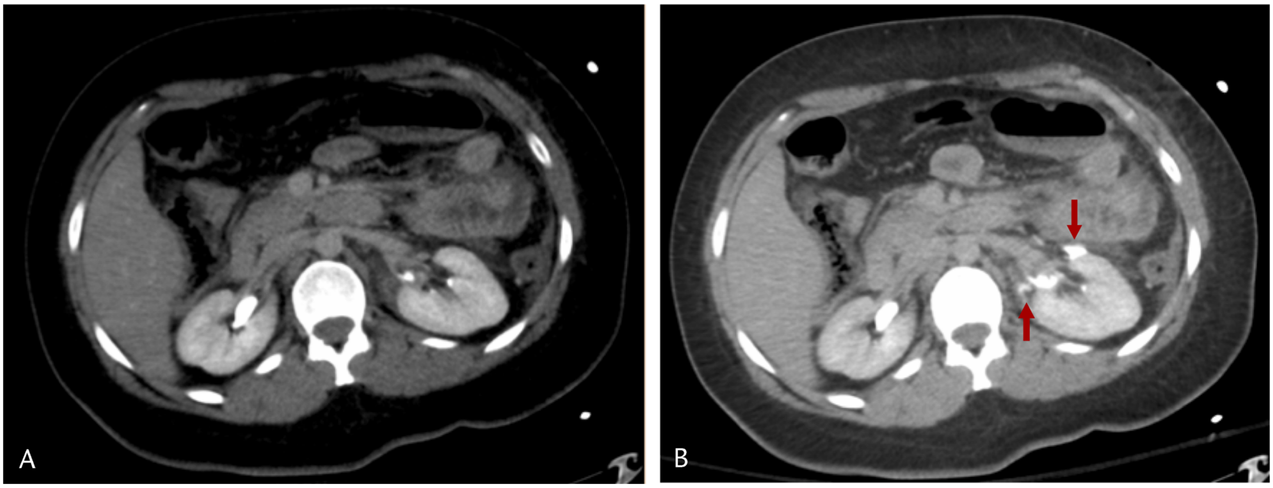

Figure 3. Delayed excretory phase images after 4 minutes (*A*) and 9 minutes (*B*) from a patient in the same CT scan series; note the urinary extravasation from the left kidney apparent in the 9-minute delayed image that was not evident in the 4-minute delayed image (*red arrows*).

kidney; otherwise, the excretory phase images provide little if any additional information compared to the early phase while delaying patient management, exposing them to additional radiation, and increasing the cost of diagnostic work-up. Importantly, hemodynamically unstable patients and those with severe vascular injuries (e.g., renal hilar avulsion) may not need initial assessment of the collecting system with delayed phase imaging until more life-threatening injuries are addressed.

In this study, of the 326 initial CT scans reviewed, only 65% (n = 212) included excretory phase images, which is in line with the previously reported compliance rate with imaging recommendations at Level I trauma centers.[28] Of the patients without initial excretory phase (n = 114), 8 (7%) were diagnosed with urinary extravasation with 5 of them being treated with ureteral stenting. This was lower than the 25% rate of missed diagnosis reported by Hardee et al.,[28] which was attributed to failure to obtain excretory phase images; however, only 33 of the 114 patients in our study underwent follow-up CT scan with excretory phases, suggesting that about 24% (8/33) of those who underwent adequate imaging in the follow-up were missed diagnoses.

Of the patients who had initial excretory phase imaging, 12% (n = 25) had "inconclusive" images. More than half of these patients were diagnosed with urinary extravasation either in a follow-up excretory phase image or because of developing clinical signs or symptoms of urinary extravasation. We believe that inadequate timing of the excretory phase was the most important reason for having inconclusive images despite high suspicion for collecting system injury (Fig. 4). However, factors, such as hydration status, hypotension, and the effects of acute injury on the kidney, may all play a role in inadequate contrast excretion during the initial trauma CT scan. Nevertheless, these represent a subset of patients at high risk of having urinary extravasation who would likely benefit from repeat scans with proper timing of the excretory phase. We believe that these findings should prompt the physicians to increase the delay time of the excretory phase imaging when there is a high suspicion for renal collecting system injuries. The current delay between the venous and excretory phases (median: 4 minutes) is suboptimal, has not been vigorously studied in the context of renal trauma, and may be associated with higher rates of inconclusive imaging and missed injuries.

This study has a number of limitations. First, inherent to multicenter observational studies, management of renal trauma and the CT protocols used (including timing of excretory phase imaging) were variable in different centers. Patients without initial CT scans were excluded, and not all patients underwent initial imaging with excretory phase images. Thus, rates of urinary extravasation may be underestimated in our study. Additionally, this study is focused on patients with renal trauma, thus isolated ureteral injuries and urinary extravasation from injuries below the ureteropelvic junction were not included; diagnosis of urinary extravasation in patients with ureteral injuries may need longer delays between the portal venous and excretory phases.

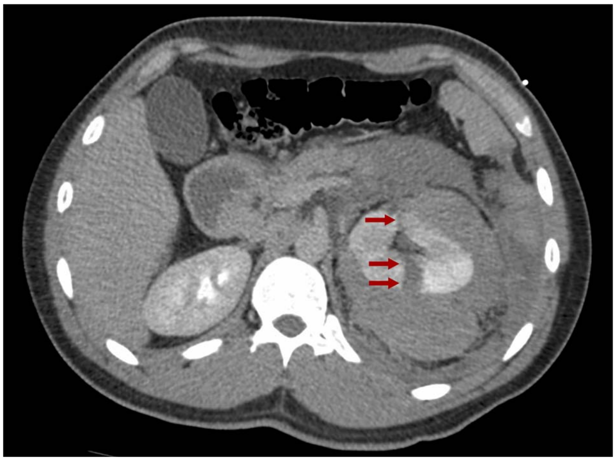

Figure 4. Inconclusive excretory phase image obtained at 5 minutes after contrast injection. Note the perinephric fluid collection and deep parenchymal laceration (*red arrows*) in the left kidney with potential extension to the collecting system; however, the injured kidney is not excreting any contrast material at 5 minutes to allow adequate assessment of the collecting system.

Data on follow-up imaging, complications, and readmissions were limited to information from the participating institutions, so the rate of missed diagnoses might be higher than that captured in our study if patients were readmitted or followed up at other hospitals. The actual time of IV contrast injection was unknown and could not be obtained from the meta data from CT scans, so the delay time was calculated from the early phase to excretory phase. Although the portal venous phase images are typically obtained 65 seconds to 80 seconds after contrast injection, this time may vary in different centers, so the delayed phase timing in our study cannot be directly interpreted as time from contrast injection. Additionally, blood pressure and renal function (e.g., creatinine level) can influence the excretion of the contrast material from the kidneys and this information was not available at the time of imaging for this study. Despite these limitations, to our knowledge, this is the first study to assess different excretory phase time cutoff points in the setting of renal trauma. The multi-institutional setting of the study allowed for reliably incorporating the prevalence of urinary extravasation in calculating the diagnostic accuracy of different time cutoff points. All images were reviewed by two radiologists blinded to the outcomes, and we were able to adjust for multiple factors such as presence of VCE, which is important to differentiate from urinary extravasation and important to differentiate from urinary extravasation.

CONCLUSION

Adequate delay of excretory phase imaging is important for timely diagnosis of urinary extravasation and accurate grading of renal trauma. We identified the optimal timing for excretory phase imaging to be 9 minutes after the initial portal venous phase scan. Of note, the median time for excretory phase imaging in this cohort of patients with known HGRT was only 4 minutes, meaning that even in an at-risk population, the excretory phase imaging is usually performed too early. Future studies are needed to prospectively assess the optimal timing of excretory phase imaging in the setting of trauma and also to evaluate the significance of missed renal collecting system injuries during the early assessment of HGRT.

AUTHORSHIP

J.B.M. and S.K. designed the study. B.E.P, D.M.R, M.E.H, and S.K. reviewed the imaging and interpreted the results. G.J.S, S. K., and J. B. M. participated in data analysis and interpretation. J.B.M. D.P.P and S.K. drafted the article. X.L., K.M., B.J.M., S.M., J.P., C.M.D., I.S., S.P.E., E.S.D., S.Z., B.G.S., B.A.E., N.B., B.N.B., B.P.S., B.U.O., R.A., B.M., R.A.S., M.M.C., J.F.K., T.H., F.N.B., S. K., and J. B. M. participated in the data collection and revisions for this article. J. B. M., B.N.B, S.P.E, J. M. H., and R.N. provided critical revisions for this article. All the authors read and approved the final submission.

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DISCLOSURE

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