



Correlation of the Interval Between Single Phase Computed Tomography and Direct Abdominal Radiography with the Success of Collecting System Imaging in Trauma Patients

Travma Hastalarında Tek Fazlı Bilgisayarlı Tomografi ve Direkt Batın Grafisi Arasındaki Sürenin Toplayıcı Sistem Görüntüleme Başarısı ile İlişkisi

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¹University of Health Sciences Turkey, İzmir Tepecik Training and Research Hospital, Clinic of Pediatric Surgery, İzmir, Turkey

²University of Health Sciences Turkey, İzmir Tepecik Training and Research Hospital, Clinic of Pediatric Urology, İzmir, Turkey

ABSTRACT

Objective: A triple-phase computed tomography (CT) is required to visualize post-traumatic ureteral injury in children. An abdominal X-ray following single-phase contrast enhanced CT is performed both to evaluate urinary tract and to reduce the radiation exposure in our center. The aim of this study was to designate an optimal interval between CT and X-ray in imaging the urinary collecting system.

Method: Records of pediatric trauma patients who underwent a CT scan were analyzed. CT and X-ray images were evaluated and the time interval between two imaging modalities was calculated. The success of X-ray in demonstrating bilateral renal pelvises, ureters and bladder was evaluated.

Results: The study population consisted of 190 patients with a male predominance (72.6%) and a median age of 9 years (2 months-17.9 years). The median time interval between the CT and X-ray was 59.5 minutes. Time interval between both imaging modalities was significantly longer if the images were not satisfactorily demonstrative (72.5 vs. 39.5 minutes) ($p<0.001$). Age ($p=0.722$), gender ($p=0.203$) and type of trauma ($p=0.796$) had no effect on this time interval. When the patients were grouped according to the time elapsed between these two imaging modalities as 10-30 minutes (Group 1) and longer (Group 2), the proportion of patients with optimally demonstrative X-rays was significantly higher in Group 1 ($p=0.001$).

Conclusion: Ureter injuries are rare and cannot be mostly diagnosed with single-phase CT-scans, but a triple-phase scan increases the radiation burden especially for children. Our plan is to validate our technique using an X-ray following CT-scan for evaluating the urinary tract in trauma, and this preliminary retrospective study confirmed that time interval of 10-30 minutes between these two imaging modalities should be considered in future studies.

Keywords: Trauma, injuries, tomography, X-ray, children, ureter

ÖZ

Amaç: Çocuklarda travma sonrası üreter hasarını görüntülemek için 3 fazlı bilgisayarlı tomografi (BT) gereklidir. Merkezimizde radyasyon maruziyetini azaltmak için üriner sistemi değerlendirmek için tek fazlı BT'yi takiben bir abdominal röntgen çekilmektedir. Bu çalışmanın amacı, üriner toplayıcı sistemin görüntülenmesinde BT ve röntgen arasındaki optimal süreyi belirlemektir.

Yöntem: BT taraması yapılan pediatrik travma hastalarının kayıtları analiz edildi. BT ve röntgen görüntüleri değerlendirildi ve iki modalite arasındaki süre hesaplandı. X-ışınının bilateral renal pelvisleri, üreterleri ve mesaneyi görüntülemesinde başarıları değerlendirildi.

Bulgular: Erkek ağırlıklı (%72,6) ve ortalama yaşı 9 yıl (2 ay-17,9 yıl) olan 190 hasta vardı. BT ve röntgen arasındaki ortalama süre 59,5 dakika idi. Süre, başarısız görüntülerde (72,5 dakika) başarılı olanlara (39,5 dakika) göre anlamlı olarak daha uzundu ($p<0,001$). Yaş ($p=0,722$), cinsiyet ($p=0,203$) ve travma tipinin ($p=0,796$) etkisi yoktu. Hastalar süreye göre 10-30 dakika arası (Grup 1) ve diğerleri (Grup 2) olarak gruplandırıldığında, Grup 1'de optimal röntgen çekilen hasta oranı anlamlı olarak daha yüksekti ($p=0,001$).

Sonuç: Üreter yaralanmaları nadirdir ve çoğunlukla tek fazlı BT taramaları ile tanınmamaktadır. Üç fazlı BT ise özellikle çocuklar için radyasyon yükünü artırır. Planımız, travma sonrası üriner sistem değerlendirilmesi için tek fazlı BT'yi takiben çekilen röntgen ile uyguladığımız tekniğimizi geliştirmektir. Bu ön retrospektif çalışma, gelecekteki çalışmalar için 10-30 dakikanın uygun bir zamanlama olduğunu doğrulamıştır.

Anahtar kelimeler: Travma, yaralanmalar, tomografi, X-ışını, çocuklar, üreter

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Corresponding Author

Bade Toker Kurtmen,
University of Health Sciences Turkey,
İzmir Tepecik Training and Research
Hospital, Clinic of Pediatric Surgery,
İzmir, Turkey

✉ badetoker@gmail.com

ORCID: 0000-0001-8963-5755

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INTRODUCTION

Kidneys are the most commonly injured organ of the urinary system in children⁽¹⁾. Children have a higher risk of renal injury than adults because of lesser perirenal fat, smaller abdominal muscles, and lack of ossification of the rib cage⁽²⁾. Ureteral injuries are rare, accounting for only 1% of pediatric abdominal traumas⁽³⁾. They are most commonly caused by a penetrating injury, but they can also occur during blunt trauma⁽⁴⁾. Besides its rarity, ureteral injury is a hard to diagnose problem with no pathognomonic sign or a specific symptom⁽⁵⁾. European Association of Urology and American Urological Association guidelines recommend obtaining intermediate and delayed images with intravenous contrast-enhanced abdominal/pelvic computed tomography (CT) for the diagnosis of ureteric injury^(6,7).

CT is a part of common practice for pediatric traumas with strong evidence of intra-abdominal injury when they are hemodynamically stabilized.⁽⁸⁾ On the other hand, it carries a high burden of radiation exposure; therefore, clinicians try to limit its use according to the ALARA principles. ALARA is the acronym for "As Low as Reasonably Achievable" which means that the radiation dose delivered to the patients should be as low as reasonably achievable while still providing image quality adequate to enable an accurate diagnosis^(9,10). Abdominopelvic CT scans carry a higher risk of developing radiation-associated malignancies when compared to CT scans of other areas, especially in children⁽¹¹⁾. The effective doses of CT-scans vary widely depending on the number of phases obtained; the area scanned or the slice thickness. A single CT scan delivers doses in the range of 10-30 millisievert (mSv), however radiation doses that should be delivered in multiple-phase scanning increase up to of 50-200 mSv due to the use of pre-contrast and post-contrast phases⁽¹²⁾.

Portal phase CT is mostly sufficient in detecting renal trauma but it can also fail to reveal ureteric injury. An X-ray following single-phase CT is performed to evaluate the urinary tract to reduce radiation exposure in our center. Up to now, the time interval between CT-scan and X-ray was not standardized as there was no determined protocol for the sequential use of these two imaging modalities. Our plan is to validate the use of this technique in evaluating urinary tract in pediatric trauma patients. This pilot study aims to designate a proper time interval between CT and X-ray in visualization of the collecting system using current data before starting prospective studies.

MATERIALS and METHODS

After approval of the University of Health Sciences Turkey, İzmir Tepecik Training and Research Hospital Non-Interventional Clinical Research Ethics Committee (approval number: 2022/09-12, date: 15.09.2022), the medical records of the pediatric trauma patients between January 2021 and 2022 were retrospectively reviewed. Our hospital is the largest trauma center in a city with a population of 4 million people. A single-phase contrast enhanced CT followed by anteroposterior abdominal X-ray routinely performed in our center. Both to evaluate urinary tract and also to reduce the radiation exposure. All children (<18 years old) who admitted to our hospital and underwent CT were included in the study. Patients with incomplete medical records and who did not undergo X-ray scanning following CT scans were excluded from the study. Informed consent was obtained from the parents/guardians of all children.

Data concerning qualifying demographic features, age at diagnosis, present symptoms, physical examination findings, and type of diagnostic imaging technique performed were retrieved from the hospital records. CT and X-ray images were evaluated and the time interval between two modalities was calculated. The success of X-ray in visualizing renal pelvises, ureters and bladder was evaluated. The X-rays that demonstrated all urinary collecting system (including pelvises, ureters, and bladder) were termed as "Optimal X-rays".

Statistical Analysis

All pre-organized forms were collected, and data were transferred to Excel 2010 (Microsoft, Redmond WA, USA). The homogeneity of variances was checked using Levene's test. Shapiro-Wilk test was used to test the assumption of normality. To compare the differences between the two groups, an independent sample t-test was used when the parametric test prerequisites were fulfilled, and the Mann-Whitney U test when they were not. The statistical significance between frequencies was calculated by the Pearson's chi-squared/Fisher's exact test. Significance was set at $p < 0.05$. Data were evaluated using IBM SPSS Statistics 22.0 (IBM Corp., Armonk, NY, USA).

RESULTS

A total of 190 patients met inclusion criteria. The median age was 9 years (2 months-17.9 years) and 72.6% of patients were male. The majority (89%) had blunt trauma. Falls were the most frequent mechanism of injury ($n=84$, 44.2%). The median time interval between

CT scan and X-rays was 59.5 minutes (interquartile range: 37-97 minutes, and range: 7-775 minutes).

Optimal visualization of pelvises, ureters, and the bladder (optimal X-ray group) was achieved in 38% of all the X-rays taken (Figure 1). None of the patients had urinary tract injury during the study period. One patient who had a normal X-ray underwent an additional delayed CT scan for a high suspicion of ureteral injury which did not reveal any relevant pathology. There was no significant difference between optimal and suboptimal X-ray groups in terms of age, gender, and trauma type (Table 1). Median time interval between these two imaging modalities was found significantly shorter in optimal X-ray group than suboptimal X-ray group. Comparison of optimal and suboptimal X-ray groups is summarized in Table 1.

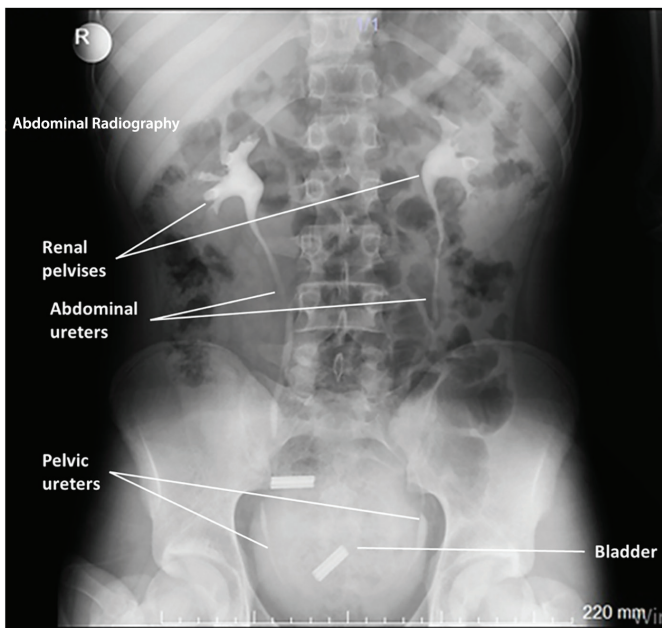


Figure 1. An X-ray of the optimal group obtained approximately 25 minutes after single-phase CT scan
CT: Computed tomography

With the primary objective of identifying a clinically appropriate, and applicable time interval to all trauma patients, we reassessed our data by categorizing the images obtained at 10-minute intervals. We found out that one patient whose X-ray was performed unintentionally within the first ten minutes. No clear image could be obtained in this patient. Bladder could be visualized in at least 90% of the patients in the first hour. However, for ureter and pelvis this rate decreased rapidly if this time interval exceeded half an hour (Figure 2). So, we subgrouped patients according to time intervals in-between as 10-30 minutes (Group 1) or longer (Group 2). There was no significant difference between the two groups in terms of age, gender, and trauma type. The proportion of patients with optimal X-rays was significantly higher in Group 1 ($p=0.001$). Both ureters and pelvises were visualized optimally in Group 1 ($p<0.001$ and $p=0.011$ respectively), while visualization rates of bladders did not differ significantly between both groups ($p=0.437$). Comparison of subgroups is summarized in Table 2.

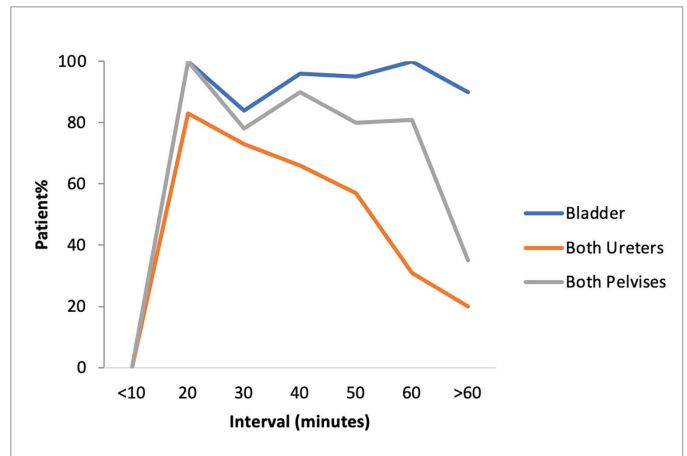


Figure 2. Percentages of patients with imaged bladder (blue), ureters (red) or pelvises (green) on the X-rays performed following CT-scans, grouped according to time intervals between these two imaging modalities
CT: Computed tomography

Table 1. Comparison of optimal and non-optimal X-ray groups (n=190)

	Optimal X-ray group (n=72)	Non-optimal X-ray group (n=118)	p-values
Median age: years (Q1-Q3)	9.3 (5-15)	8.8 (5-15)	0.722 ^a
Gender distribution: male; n (%)	48 (67%)	90 (76%)	0.203 ^b
Type of trauma exposed: blunt trauma; n (%)	60 (89.8%)	106 (87.5%)	0.796 ^b
Median interval time elapse: minutes (Q1-Q3)	39.5 (31-60)	72.5 (47-112)	<0.001 ^a

^aMann-Whitney U test, ^bYates' continuity correction test, Q1-Q3: First and third quartiles

Table 2. Comparison of subgroups (n=190)			
	X-rays obtained 10-30 minutes following CT-scans (n=26)	Others (n=164)	p-values
^a Median age: years (Q1-Q3)	9.0 (5-15)	9.0 (5-14)	0.726 ^a
Gender distribution: male: n (%)	20 (77%)	118 (72%)	0.771 ^b
Type of trauma exposed: blunt trauma; n (%)	24 (92%)	145 (88%)	0.744 ^c
Success of imaging both ureters; n (%)	20 (77%)	57 (35%)	<0.001 ^b
Success of imaging both pelvises; n (%)	22 (85%)	92 (56%)	0.011 ^b
Success of imaging bladder; n (%)	23 (89%)	152 (93%)	0.437 ^c

^aMann-Whitney U test, ^bYates' Continuity correction test, ^cFisher's exact test, ^dQ1-Q3: First and third quartiles

DISCUSSION

Trauma is the most common cause of mortality and morbidity in children. Approximately 25% of pediatric trauma patients had abdominal injury and genitourinary tract injury occurs in 10% of the cases with abdominal trauma^(7,13-15). Ureteral trauma is uncommon, accounting for less than 1% of all urologic traumas⁽¹⁶⁾. Although genitourinary tract trauma in children accounts for 10% of all abdominal trauma, there are not many studies in the literature on the most appropriate imaging modalities to be used in children. Especially visualization of ureters is more problematic. Because ureters cannot be visualized appropriately unless triple-phase CT is performed. Use of this imaging modality increases radiation exposure. There are no studies on how detailed demonstration of ureters can be performed with lower radiation exposure.

In our literature search, we found a few studies on the imaging of genitourinary tract injuries in children. All these studies have referenced research studies performed in adults and recommended intravenous contrast-enhanced CT with a delayed excretory phase⁽¹⁷⁻¹⁹⁾. Although CT scans are sensitive in detecting ureteral injuries; they come with the significant drawback of high radiation exposure. However, the literature does not provide any recommendations for reducing radiation exposure in these patients.

At our clinic, we employ a cutting-edge technique to visualize the urinary system, and use radiography following a single-phase CT scan. Despite its widespread use in our practice, this method is not supported by existing literature. Therefore, in this study, our goal is to determine the optimal time interval between X-ray and single-phase CT. However, we are planning a prospective study to assess the diagnostic sensitivity and specificity of this technique.

The rarity of ureteral injuries made us question the necessity of triphasic CT scan in pediatric trauma patients.

Therefore, we prefer single phase (portal venous) tomography to reduce the radiation exposure in the evaluation of trauma patients and reserve delayed phase CT imaging only for patients with a highly suspected ureteral injury. Instead of a delayed phase CT scan, we routinely perform an X-ray following CT to evaluate the urinary tract. Since we obtained similar image similar to intravenous pyelography in some patients (Figure 1), we aimed to constitute a standardized protocol and validate our technique in diagnosing ureteral injury. This preliminary study was performed to determine an optimal time interval for this protocol, and we found an approximately 38% success rate in visualizing the complete urinary tract and 41% success rate in visualizing both ureters regardless of the time interval elapsed between two scans. Also, as expected, the median time interval between two scans was significantly shorter in optimal X-rays than suboptimal ones. Diagnostic success rates of X-ray was statistically significantly reduced in those taken 60 minutes after CT-scans. The urinary tract as a whole could be visualized in 65% and both ureters in 77% of patients when the X-rays were performed between 10 to 30 minutes after CT scans.

Study Limitations

The major limitation of this study is retrospectively collected data and unstandardized imaging protocol with varying time intervals between these two radiological techniques, but this study provided us the information that predetermined time intervals between two imaging techniques should be between 10 to 30 minutes in future studies. Obtaining this data will allow us to constitute a standardized protocol and our current plan is a prospective study to reveal the diagnostic sensitivity and specificity of this technique.

CONCLUSION

Ureteral disruption is an exceptional injury following trauma in children. Guidelines recommend multi-phase

CT scans to diagnose ureteral injuries, but ALARA principles advise us to reduce radiation exposure especially in children. Our preliminary study showed that an image which provides sufficient anatomic detail to visualize the collecting system could be obtained if an X-ray is performed 10-30 minutes following CT scan. We think this can guide future studies and help constitute a standardized protocol to image urinary tract in trauma patients.

Ethics

Ethics Committee Approval: After approval of the University of Health Sciences Turkey, İzmir Tepecik Training and Research Hospital Non-Interventional Clinical Research Ethics Committee (approval number: 2022/09-12, date: 15.09.2022), the medical records of the pediatric trauma patients between January 2021 and 2022 were retrospectively reviewed.

Informed Consent: Informed consent was obtained from the parents/guardians of all children.

Author Contributions

Surgical and Medical Practices: B.T.K., B.K., S.T., Concept: S.T., Design: B.T.K., S.T., Data Collection and Processing: B.K., Analysis and Interpretation: B.T.K., S.T., Literature Search: B.T.K., Writing: B.T.K.

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