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Usefulness of Corticomedullary-Phase CT Urography in Patients with Suspected Acute Renal Colic Visiting the Emergency Department

응급실을 방문하는 급성신산통이 의심되는 환자에서 요로조영술 컴퓨터단층촬영의 피질-수질기의 유용성

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Purpose To evaluate the sensitivity of corticomedullary-phase imaging for detecting urinary stones in patients with renal colic who visited the emergency department.

Materials and Methods This retrospective study included 253 patients with suspected renal colic from two tertiary hospitals in South Korea, who visited the emergency department and underwent CT urography. Two radiologists blinded to the clinical history independently reviewed the corticomedullary-phase images. The sensitivity for identifying urinary stones were evaluated for each reviewer. After the initial evaluation, the images were re-evaluated based on patient history. The sensitivity of re-evaluation were recorded.

Results Of 253 patients, 150 (59%) had urinary stones. Among them, significant stones were observed in 138 patients (92%), and obstructive changes on CT in 124 patients (82.7%). For identifying significant urinary stones, the sensitivity was 98.6% (136/138) for both the reviewers. For identifying significant urinary stones with urinary obstruction, the sensitivity was 99.2% (123/124) for reviewer 1, and

100% (124/124) for reviewer 2. The sensitivity for identifying significant stones increased from 98.6% to 100% for reviewer 1, and from 98.6% to 99.3% for reviewer 2 in the re-evaluation session.

Conclusion The corticomedullary-phase CT urography was sensitive for diagnosing urolithiasis in patients with acute renal colic who visited the emergency department.

Index terms Multidetector Computed Tomography; Urography; Renal Colic; Emergency Service, Hospital

INTRODUCTION

Urolithiasis is a major problem causing emergency department visits. Therefore, it should be considered in the differential diagnosis of acute abdominal pain. The overall standardized lifetime prevalence of acute renal colic is approximately up to 11.5% in the general population of South Korea (1). In the USA, approximately 1 to 2 million individuals visit the emergency department because of renal colic (2).

Non-enhanced CT is the imaging modality of choice for patients presenting with acute renal colic and suspected urolithiasis (3-5). However, in emergency situations, dynamic contrast-enhanced CT, including the non-enhanced phase, is often used for rapid and accurate diagnosis because symptoms similar to those of renal colic can be caused by other non-calculous conditions (6, 7). Non-enhanced CT has high sensitivity (95%–100%) and specificity (94%–96%) for the diagnosis of urolithiasis (8) but has some limitations in the differential diagnosis of non-urologic cases of abdominal pain and other pathologies. Conversely, a few studies have reported that enhanced CT, including portal venous-phase imaging, is highly sensitive for the evaluation of 2–3-mm urolithiases (5, 9).

In our hospital, dynamic enhanced CT, such as CT urography, prescribed by clinician, is routinely performed for patients with renal colic in the emergency department, except when contrast media could not be used. In daily practice, we observed that it was possible to diagnose patients with symptomatic urolithiasis who visited the emergency department with only enhanced CT. Therefore, the purpose of this retrospective study was to evaluate the diagnostic sensitivity of corticomedullary-phase CT for significant urolithiasis in patients who visited the emergency department.

MATERIALS AND METHODS

STUDY DESIGN AND PATIENT DEMOGRAPHICS

This retrospective study was approved by our Institutional Review Board, and the requirement for informed consent was waived. Herein, patients were identified from two academic tertiary hospitals (Korea University Guro Hospital [institution A] and Korea University Anam Hospital [institution B]) in South Korea. For patients with acute renal colic or suspected genitourinary symptoms visiting the emergency department, CT urography is commonly ordered by the emergency physicians in these two hospitals. Therefore, we used a picture archiving and communication system to identify consecutively registered patients who underwent CT urography in the emergency department from December 2019 to January 2020 (n = 289). After reviewing the electronic medical records, we excluded 36 patients who did not have acute renal colic or urinary symptoms. We, however, did not exclude patients who underwent previous surgery, such as renal transplantation (n = 3), radical nephrectomy (n = 4), or other genitourinary-related procedures (n = 2) to simulate the usual clinical setting. Finally, 253 patients (mean age, 48.9 years; age range, 15–93 years; 141 male and 112 female) were included in this study (94 patients from institution A and 159 patients from institution B).

CT TECHNIQUES

CT urography was performed using two 128-MDCT scanners (Somatom Definition Edge and Somatom Definition AS Plus; Siemens Healthcare, Erlangen, Germany). CT scans were obtained with the following parameters: tube voltage, 100 kVp with automatic tube current modulation; beam collimation, 0.6 mm; and rotation time, 0.5 seconds. The scan protocols in the two institutions were not identical. The reference tube current was 150 mAs in the unenhanced scan and 245 mAs in the enhanced scan at institution A and 289 mAs in all scans at institution B. After an unenhanced scan was obtained, 1.5 mL/kg of non-ionic contrast material was administered through a 20- or 22-gauge antecubital venous catheter at a rate of 3.5 mL/s. At institution A, corticomedullary- and excretory-phase images were acquired 60 seconds and 5 minutes after contrast medium injection for all patients, respectively. At institution B, corticomedullary- and excretory-phase images were acquired 40 seconds and 5 minutes after contrast medium injection, respectively. The definition of corticomedullary-phase is images acquired 25-70 seconds after contrast injection (10, 11). The image data were reconstructed at slice thicknesses and intervals of 5 mm (institution A) and 3 mm (institution B).

IMAGE ANALYSIS

Axial corticomedullary-phase images were independently reviewed by two radiologists (Y.S.P., who has 13 years of experience in abdominal imaging, and S.Y.L., who is in the second year of residency training at the time of writing), who were blinded to the other phase CT images and clinical history. They assessed the presence of urolithiasis with free adjustment of the window setting and recorded the number and location of stones, if any. When there were multiple urolithiases, the reviewers were asked to select one significant stone in consideration of urinary obstruction or size. Except for significant stones, urolithiasis was identified as an incidental stone. Each reviewer's confidence level was scored for each CT scan (from 1 = not confident at all to 5 = very confident). The time taken to detect suspected urolithiasis was recorded for each patient. When there was no urolithiasis, the time taken to be certain that there was no urolithiasis was recorded. At 2-week intervals after the initial evaluation, the corticomedullary-phase images were re-evaluated on the basis of patient history.

As a reference standard, the CT urography images at all phases were retrospectively reviewed by a board-certified radiologist (B.P. with 6 years of experience in abdominal imaging) with access to information on clinical history. The number, size, and location of the stones were recorded. The stone size was measured as the greatest diameter on the non-enhanced axial image at a magnification of 5 to minimize potential measurement errors. To determine urinary obstruction on the CT images, we evaluated asymmetric hydronephrosis, delayed re-

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nal enhancement, or perinephric fat infiltration ipsilateral to the side of the stones (12). A significant stone was defined as a case in which the location of the identified stone was correlated with the symptoms or urinary obstruction and there were no other causes of acute abdominal pain or urinary obstruction. Accordingly, the patients with urolithiasis were assigned to the significant and incidental stone groups. For each patient, the radiation dose of CT urography and corticomedullary-phase imaging was recorded.

STATISTICAL ANALYSIS

To compare the patient characteristics and stone demographics between the two institutions, we used an independent two-sample t test. To evaluate the inter-reader agreement for the detection of urolithiasis on the corticomedullary-phase images, we used Cohen's κ value. The sensitivity for the detection of all urolithiases and significant stones for each reviewer was evaluated. The sensitivity for the detection of significant stones was compared between the groups with and without urinary obstruction using the chi-square test. The confidence level and interpretation time were compared between the group with significant stones and group with incidental stones or no stones using the Mann–Whitney method. For significant stones, the confidence level and interpretation time were also compared between the groups with and without urinary obstruction using the Mann–Whitney method. Statistical analyses were performed using commercially available software SPSS version 24 (IBM Corp., Armonk, NY, USA). Statistical significance was set at $p < 0.05$.

RESULTS

In terms of patient characteristics, there was no significant difference in the items other than the CT radiation dose between the two institutions (Table 1). For all phases of CT urography, the total dose length product (DLP) was significantly lower at institution A than at institution B (810.5 vs. 1359.2; $p = 0.001$). For the corticomedullary-phase, the DLP was significantly

Table 1. Demographic and Clinical Characteristics of the Study Population

	Total	Institution A	Institution B	*p*-Value
No. of patients	253	94	159	
Age, years	98.8	51.4	47.4	0.051
Sex				0.241
Male	141	57	84	
Female	112	37	75	
Patient with renal stones	150	63	87	0.064
Significant renal stones	138	61	77	
With urinary obstruction	124	52	72	
Without urinary obstruction	14	9	5	
Incidental renal stones	12	2	10	
Dose length product, mGy-cm				
Of corticomedullary-phase		386.8	454.1	0.003
Of total		810.5	1359.2	0.001

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lower at institution A than at institution B (386.8 vs. 454.1; $p = 0.003$).

Of the 253 patients, 150 (59.3%) had a total of 260 urolithiases. Of the 260 urolithiases, 138 (53.1%) were significant stones, and the remaining 122 (46.9%) were incidental stones. Among the 138 significant stones, 124 (89.9%) showed urinary obstruction on the CT images, while the remaining 14 (10.1%) did not. The mean size of all urolithiases was 4.3 mm (range, 1–13 mm). Approximately 124 (47.6%) of the urolithiases were ≤ 2 mm in size. For all urolithiases, the most common location was the calyx, followed by the ureterovesical junction (UVJ) and ureteropelvic junction (UPJ). For the significant stones, the most common location was the UVJ, followed by the UPJ and distal ureter. For the incidental stones, the most common location was the renal calyx (90.9%) (Table 2). Except for 138 patients with significant stones, the remaining 115 patients of 253 had a diagnosis other than stone; prostatitis or urinary tract infection such as acute pyelonephritis or cystitis in 43 patients; gastrointestinal problem such as ileus or enterocolitis in 32 patients; ovarian problem, such as tubo-ovarian abscess, ovarian torsion, or ovarian cyst rupture in 10 patients; 30 patients received only conservative treatment for their symptoms without a diagnosis.

For identifying urolithiasis on the corticomedullary-phase images, the inter-reader agreement was almost perfect ($\kappa = 0.876$). For all urolithiases, the per-stone sensitivity was 89.2% for reviewer 1 and 85.4% for reviewer 2 (Table 3). For all significant stones, the sensitivity was 98.6% for both reviewers (Fig. 1). For all significant stones with urinary obstruction, the sensitivity was perfect for reviewer 2; meanwhile, reviewer 1 missed one significant stone with urinary obstruction located in the mid ureter, regarded as a phlebolith (Fig. 2). For reviewer 2, the sensitivity was higher in the significant stones with urinary obstruction than in those without urinary obstruction (100% vs. 85.7%; $p = 0.001$); for reviewer 1, there no significant

Table 2. Characteristics of the stones

Location	Overall Stones	Significant Urolithiasis	Significant Urolithiasis with Urinary Obstruction	Significant Urolithiasis without Urinary Obstruction	Incidental Stones
Total number of stones	260 (100)	138 (53.1)	124 (47.7)	14 (5.4)	122 (46.9)
Calyx	119 (45.7)	9 (6.5)	2 (1.6)	7 (50)	111 (91.0)
Renal pelvis	7 (2.7)	3 (2.2)	3 (2.4)	0 (0)	4 (3.3)
Ureteropelvic junction	36 (13.8)	35 (25.4)	35 (28.2)	0 (0)	1 (0.8)
Proximal ureter	15 (5.7)	14 (10.1)	13 (10.4)	1 (7.1)	1 (0.8)
Mid ureter	9 (3.4)	9 (6.5)	9 (7.3)	0 (0)	0 (0)
Distal ureter	24 (9.2)	23 (16.7)	21 (16.9)	2 (14.3)	1 (0.8)
Ureterovesical junction	46 (17.6)	42 (30.4)	40 (32.3)	2 (14.3)	4 (3.3)
Bladder	4 (1.5)	3 (2.2)	1 (0.8)	2 (14.3)	1 (0.8)
Stone Size, mm	**All Urolithiasis**	**Significant Urolithiasis**			
≤ 0.2	124 (47.7)	29 (21.0)			
0.3–0.4	71 (27.3)	56 (40.6)			
0.5–0.6	42 (16.2)	34 (24.6)			
≥ 0.7	23 (8.8)	19 (13.8)			

Percentage after number in parentheses refers to the ratio.

Table 3. Sensitivity of the Initial Evaluation and Re-Evaluation for Urolithiasis

	Initial Evaluation		Re-Evaluation	
	Reviewer 1	Reviewer 2	Reviewer 1	Reviewer 2
Overall stones, %	89.2	85.4	91.9	86.9
Significant urolithiasis, %	98.6 (136/138)	98.6 (136/138)	100 (138/138)	99.3 (137/138)
With urinary obstruction, %	99.2 (123/124)	100 (124/124)	100 (124/124)	100 (124/124)
Without urinary obstruction, %	92.9 (13/14)	85.7 (12/14)	100 (14/14)	92.9 (13/14)

Parentheses refers to the ratio of the ground truth to each reviewer findings.

Fig. 1. Example of successful detection by two reviewers.
A. A stone (arrow) is located at the distal ureter.
B. This stone makes urinary obstruction in the left kidney.

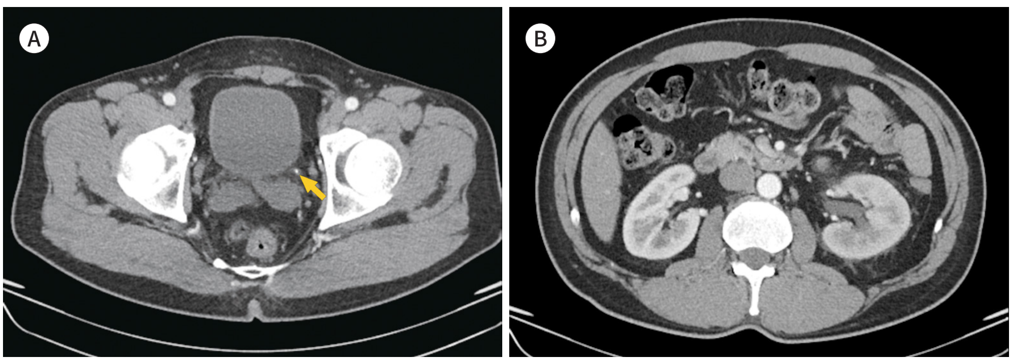
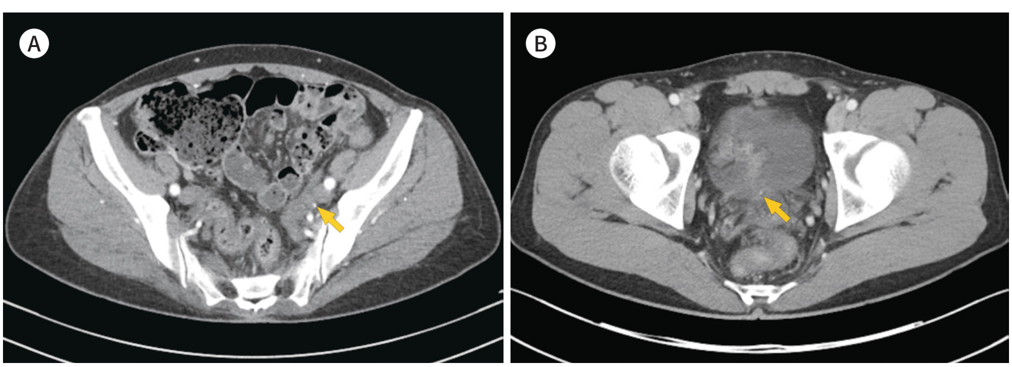


Fig. 2. Example of a missed significant stone by each reviewer.
A. Reviewer 1 considered this stone (arrow) to be phlebolith.
B. Reviewer 2 missed this stone (arrow) in bladder.



difference was observed (99.2% vs. 98.6%; $p = 0.09$). One case with a significant stone was missed by both reviewers. The size of the missed stone was less than 1 mm, and the stone was located in the calyx, which was difficult to distinguish from the renal parenchyma on the enhanced CT images (Fig. 3). Another case with a significant stone of less than 1 mm located in the urinary bladder was missed by reviewer 2 (Fig. 2).

For identifying urolithiasis, the overall confidence level was 4.64 for reviewer 1 and 3.98 for reviewer 2. The confidence level was higher in the patients with significant stones than in those with incidental stones or no stones (4.95 vs. 4.27 for reviewer 1 and 4.75 vs. 3.03 for reviewer 2; $p = 0.001$). For identifying significant stones, the confidence level was higher in the patients with urinary obstruction than in those without urinary obstruction (4.98 vs. 4.71 for re-

Fig. 3. Example of a missed case by two reviewers.
A. A significant stone is located at the left calyx (arrow), which is difficult to differentiate from the renal parenchyma on the enhanced CT images.
B. This stone (arrow) is repeatedly missed by reviewer 2, despite knowing the patient's clinical information.

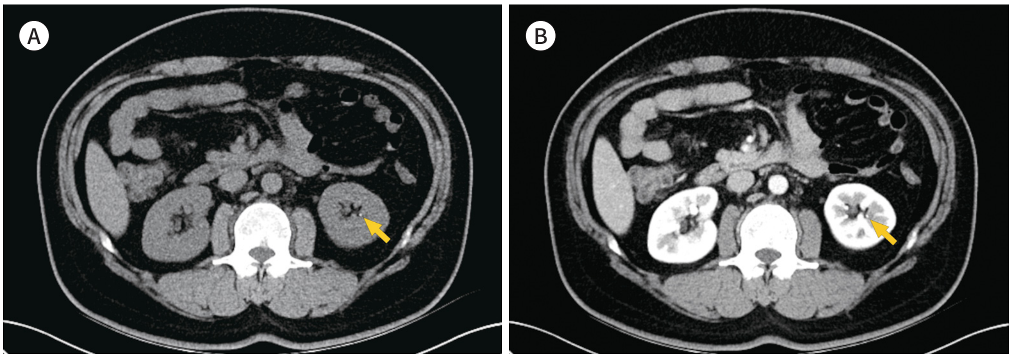


Table 4. Interpretation Time and Confidence Score for Detecting Stones of Each Reviewer

	Interpretation Time (s)		Confidence Level	
	Reviewer 1	Reviewer 2	Reviewer 1	Reviewer 2
Overall CT	27.10	41.80	4.64	3.98
Incidental stones or no stones	31.20	46.20	4.27	3.03
Significant urolithiasis	23.60	38.10	4.98	4.87
With urinary obstruction	22.80	37.60	4.98	4.87
Without urinary obstruction	30.10	41.90	4.71	3.79

viewer 1 and 4.87 vs. 3.79 for reviewer 2; all $p = 0.001$) (Table 4).

The mean CT interpretation time among all patients was 27.1 seconds for reviewer 1 and 41.8 seconds for reviewer 2. For both reviewers, the interpretation time was significantly shorter in the patients with significant stones than in those with incidental stones or no stones (23.6 seconds vs. 31.2 seconds for reviewer 1 and 38.1 seconds vs. 46.2 seconds for reviewer 2; all $p = 0.001$). For significant stones, the interpretation time was shorter in the patients with urinary obstruction than in those without urinary obstruction (22.8 seconds vs. 30.1 seconds for reviewer 1, $p = 0.002$; 37.6 seconds vs. 41.9 seconds for reviewer 2, $p = 0.265$) (Table 4).

When the patient history was provided, and the CT images were re-evaluated, the sensitivity for identifying significant stones increased from 98.6% to 100% for reviewer 1 and from 98.6% to 99.3% for reviewer 2 (Table 3).

DISCUSSION

Our study demonstrated that significant urolithiasis was sensitively detected only with the corticomedullary-phase of CT urography in the patients with renal colic who visited the emergency department. Even an inexperienced radiologist could detect significant stones with a high confidence level and sufficient sensitivity. In addition, the sensitivity of stone detection slightly improved when the images were reviewed with access to the patient's clinical information.

In several guidelines, low-dose non-enhanced CT is commonly recommended as the imaging modality of choice for an accurate evaluation of adult patients with acute renal colic or suspected urolithiasis (sensitivity, 97%; specificity, 95%) (13). According to the American College of Radiology (ACR) criteria, non-enhanced CT scans were rated at 8 points (usually appropriate), CT with and without enhancement at 6 points (may be appropriate), and CT with enhancement only at 2 points (usually not appropriate) (13). However, in a previous study, 20%–35% of non-enhanced CT for acute flank pain showed that the pain originated from causes other than urolithiasis (14, 15). In some cases, patient symptoms are too vague and ambiguous to suspect urolithiasis before selecting an imaging modality for diagnosis. Therefore, in actual clinical practice, enhanced CT, including the non-enhanced phase, is often prescribed, and dynamic enhanced CT is frequently used. In addition, non-enhanced CT and enhanced CT each have their own advantages and disadvantages; however, owing to the limited information provided by non-enhanced CT images, clinicians tend to prefer enhanced CT images over non-enhanced CT images.

Although the ACR criteria indicate that enhanced CT images are unsuitable for diagnosing urolithiasis, a few recent studies reported that urolithiases ≥ 2–3 mm in size could be diagnosed very sensitively (82%–96%) even on portal-phase images (5, 9, 16). This is probably because the CT image quality, such as spatial and contrast resolutions, has improved owing to the recent developments in CT equipment and technology. Previous studies have investigated the sensitivity of CT to diagnose urolithiasis on enhanced CT images (5, 9, 16). Therefore, these studies included urolithiases regardless of the presence or absence of symptoms and incidentally found stones without symptoms. In contrast, our study targeted patients with suspected urolithiasis who visited the emergency department with acute symptoms, such as acute renal colic. This study aimed to investigate the diagnostic ability of enhanced corticomedullary-phase CT for significant or symptomatic urolithiasis encountered in the emergency department. We found that 89.9% of the significant or symptomatic stones were accompanied with urinary obstruction on CT. Signs of urinary obstruction, hydronephrosis, and perinephric fat infiltration can be seen on non-enhanced and enhanced CT images; however, delayed renal enhancement can only be seen on enhanced CT images. These signs of urinary obstruction are helpful in the detection of urolithiasis and can be easily observed on enhanced CT images. Herein, these urinary obstructive changes might have contributed to the improvement of the sensitivity (98.6%) and confidence level for detecting stones and reducing the interpretation time. In addition, they might have affected the results of the second-year resident, who showed performance in the detection of significant stones comparable to that of the abdominal specialist.

Meanwhile, the sensitivity of corticomedullary-phase imaging for identifying all urolithiases, including incidental stones, was 89.2% in this study, similar to that of other previous studies (5, 9). This result may be related to the absence of urinary obstruction in most incidentally discovered urolithiases. Because the diagnosis of significant stones rather than incidentally discovered urolithiases is more important for the care of patients visiting the emergency department, the relatively low sensitivity (89.2%) for identifying all urolithiases, including incidental stones, is not a great concern in emergency situations. Therefore, we believe that corticomedullary-phase imaging can be used to diagnose acute renal colic in the emergency department. Although a total of three cases with significant stones were missed by the two reviewers, the sensitivity increased to 100% and 99.3% for reviewers 1 and 2, respectively, after the patients' clinical information was provided. Thus, CT interpretations with patients' clinical information could improve the relatively limited sensitivity for the detection of urolithiasis on enhanced CT scans.

In real medical practice, it is not uncommon for a patient visiting the emergency department to take only a portal phase enhanced CT at first, and then retake a non-contrast CT or dynamic CT including non-enhancement because a renal stone is suspected later. Considering our results, since the corticomedullary-phase, an enhanced CT phase with corticomedullary differentiation, showed high sensitivity in diagnosing symptomatic renal stones, additional non-enhanced CT would not be necessary in the aforementioned situation if there were patients with single phase enhanced CT of corticomedullary-phase. However, a commonly used abdomen CT in the emergency department is a portal venous phase CT image, obtained 70–90 seconds after contrast injection. Since the portal venous phase is acquired slightly later than the corticomedullary-phase (25–70 seconds), it may affect the diagnosis of renal stones due to renal parenchymal enhancement. Therefore, it may be difficult to apply our study results to portal venous phase CT.

In our study, one case of calyceal stone accompanied with acute flank pain was missed by reviewer 2 despite knowing the patient's clinical information (Fig. 3). In this case, additional non-enhanced CT images are needed for accurate diagnosis. Since several guidelines recommend lowering the radiation dose of non-enhanced CT for diagnosing urolithiasis (3, 4, 13), it would be preferable to use only the necessary phase image rather than the whole-phase dynamic enhanced CT image, such as CT urography image, if contrast enhancement is needed. In a previous study, there was no difference in the diagnostic performance of portal-phase CT and multiphasic CT for the diagnosis of the causes of abdominal pain in patients who visited the emergency department (17).

Our study has several limitations. First, it had a retrospective design and included a relatively small number of patients with urolithiasis. To overcome these problems, we included patients who underwent CT urography performed using different CT protocols and reconstruction methods from two institutions in the analysis. Second, the reviewers were aware of the purpose of our study; accordingly, the sensitivity might have been affected by the presumably meticulous inspection of the images to identify stones. However, to limit this effect as much as possible, we simulated a setting similar to the actual clinical practice by reviewing and analyzing all CT urography performed in the emergency department, including CT performed in patients without urolithiasis. Nevertheless, in order to validate this result and apply the results to clinical practice, a prospective study on the diagnostic ability of contrast enhanced CT for symptomatic renal stone will be needed in the future. Third, we analyzed the corticomedullary-phase image on CT urography, which has a slightly more rapid acquisition time than the portal venous-phase image, a commonly used single-phase enhanced CT image. Therefore, additional studies on the portal venous phase are needed for the application of our results to all single-phase enhanced CT performed in the emergency department.

In conclusion, corticomedullary-phase CT urography was sensitive in diagnosing urolithiasis in the patients with acute renal colic who visited the emergency department. CT interpretation with patient clinical information improved the sensitivity for the detection of significant urolithiasis. Although non-enhanced CT is the modality of choice for diagnosing urolithiasis, corticomedullary-phase imaging can be used as an alternative in emergency situations. Furthermore, prospective study will be needed to validate the usefulness of contrast enhanced CT imaging in the diagnosis of symptomatic renal stone in the emergency department in the future.

Author Contributions

Conceptualization, L.S., P.Y.S.; data curation, L.S., P.B.; formal analysis, L.S.; methodology, P.Y.S., L.J.; resources, L.S., L.J.; supervision, P.Y.S., K.K.A., L.C.H.; validation, P.Y.S., L.J., C.J.W., K.K.A., L.C.H.; writing—original draft, L.S.; and writing—review & editing, L.S., P.Y.S.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

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응급실을 방문하는 급성신산통이 의심되는 환자에서 요로조영술 컴퓨터단층촬영의 피질-수질기의 유용성

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목적 응급실의 급성신산통을 호소하는 환자에서 피질-수질기 요로조영술 컴퓨터 단층촬영(이하 CT)에서 요로결석 발견을 기존의 CT 요로조영술과 비교하였다.

대상과 방법 이 후향적 연구는 한국의 두 삼차 병원의 응급실에서 CT 요로조영술을 촬영한 253명의 요로결석이 의심된 환자를 대상으로 시행하였다. 임상 병력을 알지 못한채로 두 명의 영상의학과 의사가 독립적으로 CT 요로조영술의 피질-수질기를 판독하여 요로결석에 관한 정보를 기록하였다. 판독자들의 요로결석 발견에 대한 민감도를 측정하였다. 초기 평가 후, 임상 정보를 바탕으로 다시 피질-수질기를 판독하였고 민감도를 측정하였다.

결과 253명 중 150명(59%)이 요로결석이 있었고, 요로결석이 응급실 방문의 원인(의미 있는 요로결석)이었던 사람은 138명(92%)이었고, 요로 폐쇄로 인한 변화를 보인 환자는 124명(82.7%)이었다. 의미 있는 요로결석에 대해서는 두 판독자의 민감도는 98.6% (136/138)이었다. 요로 폐쇄로 인한 변화가 동반되었을 때의 민감도는 판독자 1은 99.2% (123/124)였고 판독자 2는 100% (124/124)였다. 임상 정보를 바탕으로 다시 판독했을 때 의미 있는 요로결석 발견의 민감도는 판독자 1이 98.6%에서 100%, 판독자 2는 98.6%에서 99.3%로 증가하였다.

결론 CT 요로조영술의 피질-수질기는 급성신산통으로 응급실을 내원한 환자에서 요로결석을 진단하는데 민감하다.

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