https://doi.org/10.5392/JKCA.2017.17.01.120

비확장성 요관결석에 대한 컬러 도플러의 유용성
Usefulness of Color Doppler for Non-dilatational Ureteral Stone

심현선
고려대학교 보건과학대학 방사선학과/인구보건복지협회

Hyun-Sun Sim(shs2017@hanmail.net)

요약

요로결석증으로 인한 급성 옆구리 통증은 환자들이 응급실로 방문하는 가장 흔한 질병이다. 연구의 목적은 수신증이 동반되지 않은 환자에서 컬러 도플러를 이용하여 요관결석 검출의 유용성에 대하여 알아보고자 한다. 신장, 요관, 방광의 단순 x-ray 검사에서 요로결석 의심 소견자 또는 소변검사에서 혈뇨 양성반응을 보인 161명의 환자를 대상으로 초음파 검사를 시행하고 후향적으로 분석하였다. 초음파검사에서 진단된 요관결석은 161명 환자 중 154례 (95.6%) 이었다. 수신증이 없고 컬러 도플러 초음파검사에서 섬광인공물(TA)을 동반한 요관결석은 21명 중 18례 (85.7%)이었다($p<0.001$). 초음파는 비교적 저렴하고, 보편적으로 사용하므로 옆구리 통증을 갖는 환자의 요로결석 진단에 우선적으로 이용할 수 있다. 컬러 도플러를 이용하여 구분되지 않은 결석, 비확장성 요관결석, 중간요관 결석 검출에 높은 진단 효과를 갖는다.

■ 중심어 : | 요관결석 | 요로결석증 | 섬광인공물 | 컬러 도플러 | 초음파 |

Abstract

Acute flank pain from urolithiasis is the most common condition in people visiting emergency rooms. This study is to evaluate the usefulness of color Doppler in detecting ureteral stones in patients without hydronephrosis. We performed ultrasonography and retrospective analysis on 161 patients who were suspected of urinary stones through plain radiography of the kidney, ureter, and bladder examination or urine tests that showed positive signs of hematuria. In ultrasonography, a total of 154 (95.6%) cases from the 161 patients were diagnosed with ureteral stones. In color Doppler, ureteral stones with twinkling artifact (TA) in the absence of hydronephrosis was shown in 18 (85.7%) cases of the 21 patients($p<0.001$). The use of color Doppler has a high diagnostic efficacy for the detection of indistinguishable stones, non-dilatational ureteral stones, and middle ureter stones.

■ keyword : | Color Doppler | Twinkling Artifact | Ultrasonography | Ureteral Stone | Urolithiasis |

I. Introduction

Acute flank or costal angle pain from urolithiasis is the most common condition in outpatients and those visiting emergency rooms[1]. Acute pain occurs at the narrowest anatomical areas of the ureter as a result of obstruction of the urinary tract from urinary stones. Urinary stone is a common morbidity and

접수일자 : 2016년 11월 17일
수정일자 : 2016년 12월 09일
심사완료일 : 2016년 12월 11일
교신저자 : 심현선, e-mail : shs2017@hanmail.net

3-15% of the adult population suffers with urinary stones in their lifetime[2-4]. It is estimated that almost 50% of urinary stone patients will show recurrence within 10 years[5].

In the past when urinary stones were suspected, to determine the location of the stones, plain radiography of the kidney, ureter, and bladder (KUB) and intravenous urography was preferably used for evaluation. Computerized tomography is used for the diagnostic modality of urolithiasis due to less disturbance from abdominal gas, high sensitivity of 100%, and specificity of 97.4%[6]. Nevertheless, computerized tomography has a disadvantage of high radiation dose exposure[7], and limits to children and pregnant women.

Ultrasonography is relatively highly sensitive to conditions like acute pancreatitis, acute appendicitis, cholelithiasis, abdomen masses, pelvic masses[8], abdominal aortic aneurysms[9], renal infarction[10], and tubal pregnancy[11] that mimic renal colic. Since ultrasonography is safe, non-invasive, and inexpensive, it can be used first for diagnosing patients with a suspicion of urolithiasis[12]. The detection sensitivity in ultrasonography of urinary stones with the presence of hydronephrosis was 90% for stones greater than 6mm and 75% for those less than 6mm[13]. However in non-dilatational ureteral stones of the excretory system, the sensitivity of ultrasonography is further reduced to 12-37%[14]. Regarding the detection of ureteral stones, stones in the middle ureter and that are less echogenic and not accompanied by posterior acoustic shadow are difficult to identify, especially in obese patients.

However in recent years, the B-mode and color Doppler ultrasonography facilitates the detection of urolithiasis, and the presence of twinkling artifact (TA) implies the presence of urinary stones[15][16].

The TA presents as a rapidly changing mixture of red and blue behind a rough interface object. TA theories that when an incidental ultrasound beam is reflected by a flat interface, the acoustic waves are reflected by the interface at the same time, and so it results in production of short wave acoustic signals. When the incidental ultrasound beam is reflected on a rough interface, the acoustic wave is split into a complex beam pattern caused by multiple reflections in the medium, resulting in prolonged pulse duration of the transmitted acoustic signal and this result the Doppler units interpret this as movement and thus is assigned different colors[17].

The twinkle sign may be affected by the location of the focal zone. When the focal zone is located below a reflecting surface, the TA becomes more obvious than when the focal zone is above rough reflecting surface[18]. The TA usually decreases when the gray scale gain is increased and increases on increasing the color write priority, also pulse repetition frequency decrease may produce stronger broadband signal[19].

The purpose of this study is to evaluate the usefulness of color Doppler in detecting ureteral stones in patients without hydronephrosis.

II. Patient and methods

One hundred ninety three patients who complained of acute flank, abdominal, or costal angle pain, and suspected of urolithiasis were first examined with plain radiography of KUB and urine tests[Fig. 1]. However, patients with fever or pain due to trauma were excluded.

We performed ultrasonography and retrospective analysis on 161 patients who were suspected of urinary stones through plain radiograph of KUB or showed positive signs of hematuria. Thrity-two patients that showed no signs of urinary stones on plain radiograph of KUB or negative signs of hematuria in the urine test were excluded from the study.

In ultrasonography, 154 out of 161 patients were diagnosed with ureteral stones.

The ureteral stones detected by ultrasonography were all confirmed by intravenous urography and/or computerized tomography. The evaluation period was from August 2015 to September 2016.

The locations of detected ureteral stones are classified like the following: upper ureter including ureteropelvic junction, middle ureter, and lower ureter including ureterovesical junction. TA was confirmed on patients of ureteral stones without hydronephrosis or hydroureter by color Doppler.

The ureteral calculi detection method in the absence of hydronephrosis or hydroureter are: 1) examination of the ureter begins at the ureteropelvic junction and follows the ureter towards the feet, 2) the middle ureter was examined at the level where the ureter crosses the iliac blood vessels, 3) the distal ureter and ureterovesical junction were examined on patients with a full bladder.

The middle ureteral calculi stone detection method are: 1) turn the patient 45° opposite of the examination side, 2) set the penetration depth to 8.0cm, 3) use convex 5.0MHz transducer, 4) use 10.0MHz linear transducer, 5) to visualize posterior acoustic shadowing of the stone, focal zone should be set at stone depth.

In color Doppler ultrasonography, the color box size was adjusted to include the stone and adjacent tissue. The color Doppler gain was set just below the threshold for color noise in order to eliminate the noise generated from adjacent fat or muscle tissues[20]. B-mode ultrasonography and color Doppler examinations were performed with GE Logiq 5, a commercially available real-time ultrasonography equipment, a 2.5 to 5.0MHz convex transducer, and a 8.0 to 12.0MHz linear transducer (GE Company, USA).

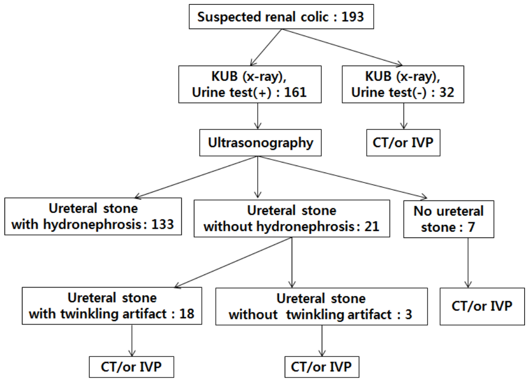

Fig. 1. Flow chart to detect ureteral stone in patients with renal colic in the emergency departments or outpatient

III. Results

In ultrasonography, a total of 154 (95.6%) cases from the 161 patients were diagnosed with ureteral stones. The overall seasonal incidence of ureteral stones were most common in February and August[Fig. 2]. Ureteral stones occurred most frequently in January and July for males, and in February and August for females.

The mean age of the subjects was 42.6±13.7 years and the age range was 14-78 years. Patients with ureteral stones consisted of 109 male (70.8%) and 45 female (29.2%) cases. The male to female ratio was 2.4:1. The range of the diameter of ureteral stones was 2.0-13.0 mm (mean±SD, 5.4±2.43 mm).

From the 154 patients with ureteral stones identified by ultrasonography, 79 (51.3%) cases involved the right ureter and 75 (48.7%) cases involved the left ureter[Table 1]; both ureters showed similar incidence.

The vertical location of the calculi was 40 (26.0%) in the upper ureter, 10 (6.5%) in the middle ureter, and 104 (67.5%) in the lower ureter[Table 2]; the incidence was highest in the lower ureter.

Table 1. Gender and location of the stones by ultrasound

Gender	Location of urinary stone detection			Total
	Upper ureter	Middle uterer	Lower ureter	
Male	30	8	71	109 (70.8%)
Female	10	2	33	45 (29.2%)
Total	40 (26.8%)	10 (6.5%)	104 (67.5%)	154 (100.0%)

Table 2. Location and site of the stones by ultrasound

Location	Location of urinary stone detection			Total
	Upper ureter	Middle uterer	Lower ureter	
Right ureter	20	5	54	79 (51.3%)
Left ureter	20	5	50	75 (48.7%)
Total	40 (26.0%)	10 (6.5%)	104 (67.5%)	154 (100.0%)

Table 3. Presence or absence of twinkling artifact of ureteral stone without hydronephrosis

Twinkle artifact	Location of urinary stone detection			Total
	Upper ureter	Middle uterer	Lower ureter	
Positive	0	5	13	18 (85.7%)
Negative	0	2	1	3 (14.3%)
Total	0 (0.0%)	7 (33.7%)	14 (66.7%)	21 (100.0%)

The P-value is less than 0.0001.

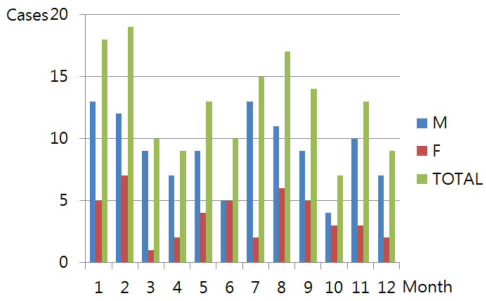

Fig. 2. Incidence of male and female ureteral stones according to season

Ureteral stones with the presence of hydronephrosis were shown in 133 (82.6%) cases of the 154 patients. Ureteral stones with the absence of hydronephrosis was shown in 21 (13.0%) cases of the 154 patients: 7 cases (33.3%) in the middle ureter, 14 cases (66.7%) in the lower ureter including the ureterovesical junction[Table 3].

Ureteral stones with TA in the absence of hydronephrosis in color Doppler ultrasonography was shown in 18 (85.7%) cases of the 21 patients ($p<0.001$)[Fig. 3]. Ureteral stones without TA in the absence of hydronephrosis in color Doppler ultrasonography was shown in 3 (14.3%) cases of the 21 patients[Fig. 4]. There was a significant difference between the two groups. Seven cases (4.3%) had no ureteral stones or hydronephrosis($P<0.001$).

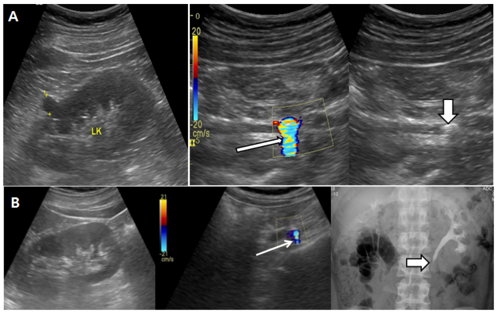

Fig. 3. Ureteral stone with twinkling artifact. A. Color Doppler application of the kidney without the presence of hydronephrosis: a middle ureteral stone with twinkling artifact posterior (thin arrow) to the hyperechoic focus (fat arrow). B. Color Doppler of the kidney application without the presence of hydronephrosis: a suspicious upper ureteral stone with a posterior weak twinkling artifact (thin arrow) and an intravenous urography examination shows a sudden ureteral closure (fat arrow)

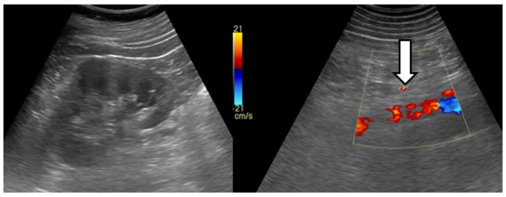

Fig. 4. Ureteral stone without twinkling artifact. Color Doppler application of the kidney without the presence of hydronephrosis: a middle ureteral stone without a posterior twinkling artifact (fat arrow)

VI. Discussion

The pain of unilateral ureteric colic is due to obstruction of urinary flow, with a subsequent increase in ureteric wall tension. The assessment of acute flank pain is diverse and the efficacy varies according to radiologic modalities. The results are different depending on what is considered appropriate. This is because there are merits and limitations according to each diagnostic modality.

Plain radiography of KUB was useful to find the size and location of radiopaque stone calculi as upper ureteral stones were more common than lower. However in plain radiography used in renal colic, there is a limited diagnostic value: 53-62% in detection sensitivity and 63-69% in specificity of urinary stones[22][27]. As a disadvantage, in KUB 10-20% of radiolucent stones cannot be visualized, and is affected by body size, gas in the intestines, and requires preparation of the patient[23].

Intravenous urography provides structural and functional information, including location, size of stone, and degree and nature of obstruction, and can also visualize 80% of radiopaque stones[24]. Despite its usefulness, there are some undesirable aspects of intravenous urography, including radiation exposure, contrast reaction, and risk of nephrotoxicity[25]. In patients with pre-existing renal failure and diabetes mellitus, the risk of contrast-induced nephrotoxicity is 25%[26].

The helical computed tomography was accurate for the diagnosis of the major disease that caused not only flank pain, but also acute abdominal pain. Unenhanced helical computed tomography (UHCT) is the gold standard for detecting urinary stones[27] and has been established to be the most useful method in the detection of ureteral stones with a sensitivity of 97%[8]. The unenhanced helical computed tomography has proved to be more diagnostically accurate than excretory urography and no contrast-related side effects, particularly in vulnerable patients, were discovered. Computed tomography has a concern for radiation exposure, such as additional radiation dose and cumulative effective doses during follow-up examinations[28].

Ultrasonography is a radiation-free diagnostic tool that can be very accurate. However, it has a limited role in the diagnosis of urinary stones. Mahmoud et al.[22] studies showed a low specificity of 65.4% for detecting ureteral stones by B-mode ultrasound examination alone. By contrast, Ripollés et al.[29] stated that the sensitivity increased from 12% to 81% when secondary signs of ureteral obstruction were included in the diagnosis of urolithiasis. Ozden et al.[30] reported that the sensitivity of ureteral stones was 65.9% in grade 1 and 95% in grade 3 hydronephrosis. In this study, the detection sensitivity of ureteral stones with the presence of hydronephrosis was 86.3%. Similar results were obtained with other studies.

In non-dilatational ureteral stones, the sensitivity of B-mode ultrasonography decreases. Therefore recently, color Doppler ultrasound is used to increase the sensitivity of the detection of ureteral stones. The presence of TA is strongly suggestive of the presence of urolithiasis[31] and have replaced posterior shadowing as a major diagnostic sonographic finding[32]. In this study, the sensitivity of color Doppler ultraosonography was 85.7% for ureteral stones with TA in the absence hydronephrosis. Kim et al.[33] reported a sensitivity of 93% and a specificity of 95% for urinary stones with color Doppler equipment. Previous article reported that color Doppler sensitivity was 100% for absolutely positive urinary stones, and 25.8% for suspected positivity shown in B-mode ultrasonography[34]. Therefore, the use of color Doppler equipment for detecting urinary stones will be very useful. In the cases of ureteral stones without TA in the absence of hydronephrosis was 14.3%, probably due to obesity, short breathing, or lack of cooperation of the patient with the ultrasonography techniques.

Bultitude et al.[35] demonstrated that urinary stones occur almost twice more in males than females, and the peak age is between 40 and 60. In this study, half of the cases of ureteral stones were discovered in people in their 40s and 50s (46.8%), and the male to female ratio was 2.4:1, which was similar to other studies.

Increased incidence of nephrolithiasis is strongly associated with race or ethnicity, region of residence[36], association with temperature, various meteorological parameters, climates, and geographical locations[37]. Seasonal changes showed high urinary calcium saturation in males during summer and in females during early winter[38]. Park et al.[39] found that the incidence of urinary stones was at peak from June to September, and decreased remarkably after September. When the temperature passed 18.4 °C, urinary stones increased significantly and reported association with temperature. In the study, the seasonal incidence of urinary stones is most common in January, February and August. Ureteral stones occurred most frequently in males in January and July, and in females in February and August. Therefore, urinary stones occur mainly in cold winter and hot summer. In other studies, the occurrence of urinary stones is higher in warmer climates[40]. In the same country, the incidence of urinary tract stones may be due to differences in the subject's area, occupation, and economic income level.

In this study, the vertical location of urinary stones was most common in the lower ureter with a percentage of 67.5, followed by 26.0% in the upper ureter, and 6.5% in the middle ureter. In the study of Ahmad et al.[41] stones were most common in the lower ureter with 50%, followed by the upper ureter with 20%. Oh et al.[42] showed that 66.8% of urinary stones were detected in the lower ureter, 25.6% in the upper ureter and 7.5% in the middle ureter. In this study, the location of the stones was similar to the results of other researchers.

V. Conclusions

Ultrasonography is relatively inexpensive, universally available, and preferential, so it can be used to diagnose urinary stones in patients with flank pain. The use of color Doppler has a high diagnostic effect for the detection of indistinguishable stones, non-dilatational ureteral stones, and middle ureter stones.

참 고 문 헌

[1] R. C. Smith, J. Levine, N. C. Dalrymple, M. Barish, and A. T. Rosenfield, "Acute flank pain: A modern approach to diagnosis and management," Semin Ultrasound CT MR, Vol.20, pp.108-135, 1999.

[2] V. Nobel and D. F. Brown, "Renal ultrasound,"

Emerg Med Clin North Am, Vol.22, pp.641-659, 2004.
[3] D. Manthey and J. Teichman, "Nephrolithiasis," Emerg Med Clin North Am, Vol.19, pp.633-654, 2001.
[4] M. S. Pearle and Y. Lotan, "Urinary lithiasis: etiology, epidemiology, and pathogenesis. In: Wein AJ, Kavoussi LR, Novick AC, eds. ampbell-Walsh Urology," 10th edn. Philadelphia: Elsevier Saunders, pp.1257-1286, 2012.
[5] P. F. Fulgham, D. G. Assimos, M. S. Pearle, and G. M. Preminger, "Clinical effectiveness protocols for imaging in the management of ureteral calculous disease: AUA technology assessment," J Urol, Vol.189, pp.1203-1213, 2013.
[6] CHRISTINE L. Gray Sears, JOHN F. Ward, STEPHEN T. Sears, MICHAEL F. Puckett, CHRISTOPHER J. Kane, and CHRISTOPHER L. Amling, "Prospective Comparison of Computerized Tomography and Excretory Urography in the Initial Evaluation of Asymptomatic Microhematuria," J Urol, Vol.168, No.6, pp.2457-2560, 2002.
[7] M. D. Sorensen, J. D. Harper, and R. S. Hsi, "B-mode ultrasound versus color Doppler twinkling artifact in detecting kidney stones," J Endourol, Vol.27, pp.149-153, 2013.
[8] Muhammad Ali Zul Hasnain, Malik Muhammad Khalid, and Saima Perveen, "Renal colic patient; comparison of un-enhanced helical computed tomography, intravenous urography and ultrasound + plain x-ray," Professional Med J, Vol.22, No.1, pp.40-48, 2015.
[9] S. D. Eckford and D. A. Gillatt, "Abdominal aortic aneurysm presenting as renal colic," Br J Urol Nov, Vol.70, No.5, pp.496-498, 1992.
[10] Z. Korzets, E. Plotkin, J. Berheim, and R. Zissin, "The clinical spectrum of acute renal infarction," Isr Med Assoc J, Vol.4, No.10, pp.781-784, 2002.
[11] A. M. Malik and A. Aziz, "Evaluation & management of Tubal ectopic pregnancy," J Surg Pakistan, Vol.5, No.4, pp.23-25, 2000.
[12] P. J. Dalziel and V. E. Noble, "Bedside ultrasound and the assessment of renal colic: a review," Emerg Med J, Vol.30, pp.3-8, 2013.
[13] J. Riddell, A. Case, R. Wopat, S. Beckham, M. Lucas, D. C. McClung, and S. Swadron, "Sensitivity of emergency bedside ultrasound to detect hydronephrosis in patients with computed tomography-proven stones," West J Emerg Med, Vol.15, No.1, pp.96-100, 2014.
[14] D. Sinclair, S. Wilson, A. Toi, and L. Greenspan, "The evaluation of suspected renal colic: ultrasound scan versus excretory urography," Ann Emerg Med, Vol.18, pp.556-559, 1989.
[15] H. C. Kim, D. M. Yang, and Jin Wook, "Color Doppler Twinkling Artifacts in Various Conditions During Abdominal and Pelvic Sonography," J Ultrasound Med, Vol.29, pp.621-632, 2010.
[16] H. S. Sim and K. T. Kwon, "Usefulness of Twinkling Artifacts in Color Doppler Ultrasonography," J. of Contents Association, Vol.16, No.10, pp.291-298, 2016.
[17] A. Rahmouni, R. Bargoin, A. Herment, N. Bargoin, and N. Vasile, "Color Doppler twinkling artifact in hyperechoic regions," Radiology, Vol.199, pp.269-271, 1996.
[18] J. Y. Lee, S. H. Kim, J. Y. Cho, and D. Han, "Color and power Doppler twinkling artifacts from urinary stones: clinical observations and phantom studies," AJR Am J Roentgenol, Vo.176, pp.1441-1445, 2001.
[19] A. Kamaya, T. Tuthill, and J. M. Rubin, "Twinkling artifact on color Doppler sonography: dependence on machine parameters and underlying cause," AJR, Vol.180, pp.215-222, 2003.
[20] L. Brunese, A. Romeo, S. Iorio, G. Napolitano, S. Fucili, P. Zeppa, G. Vallone, G. Lombardi, A.

Bellastella, B. S. Biondi, and A. Sodano, "Thyroid B-flow twinkling sign: A new feature of papillary cancer," European Journal of Endocrinology, Vol.159, No.4, pp.447-451, 2008.

[21] Mahmoud Abdel-Gawad, Ravi Kadasne1, Chandrashekar Anjikar, and Emad Elsobky, "Value of color doppler ultrasound, kub and urinalysis in diagnosis of renal colic due to ureteral stones," Int Braz J Urol, Vol.40, pp.513-519, 2014.

[22] E. Svedstrom, A. Alanen, and M. Nurmi, "Radiologic diagnosis of renal colic: the role of plain films, excretory urography and sonography," Eur J Radiol, Vol.11, pp.180-183, 1990.

[23] Sameh Khodair Ahmad and Mohamed Marzouk Abdallah, "The diagnostic value of the twinkle sign in color Doppler imaging of urinary stones," The Egyptian Journal of Radiology and Nuclear Medicine, Vol.45, pp.569-574, 2014.

[24] O. F. Miller, S. K. Rineer, and S. R. Reichard, "Prospective comparison of unenhanced spiral computed tomography and intravenous urogram in the evaluation of acute flank pain," Urology, Vol.52, pp.982-987, 1998.

[25] M. Masarani and M. Dinneen, "Ureteric colic: new trends in diagnosis and treatment," Postgrad Med J, Vol.83, pp.469-472, 2007.

[26] B. J. Barrett and E. J. Carlisle, "Meta analysis of the relative nephrotoxicity of high-and low-osmolality iodinated contrast media," Radiology, Vol.188, pp.171-175, 1993.

[27] T. J. Dubinsky and C. T. Sadro, "Acute onset flank pain - suspicion of stone disease," Ultrasound Q, Vol.28, pp.239-240, 2012.

[28] S. J. Park, B. H. Yi, H. K. Lee, Y. H. Kim, G. J. Kim, and H. C. Kim, "Evaluation of patients with suspected ureteral calculi using sonography as an initial diagnostic tool: how can we improve diagnostic accuracy?," J Ultrasound Med, Vol.27, pp.1441-1450, 2008.

[29] T. Ripollés, M. Agramunt, J. Errando, M. J. Martinez, B. Coronel, and M. Morales, "Suspected ureteral colic: plain film and sonography vs unenhanced helical CT. A prospective study in 66 patients," Eur Radiol, Vol.14, pp.129-136, 2004.

[30] Eriz Ozden, Tamer Karamursel, Onder Yaman, and Tansel lnal, "Detection rate of ureter stones with US: relationship with grade of hydronephrosis," Journal of ankara medical school, Vol.24, No.4, pp.183-168, 2002.

[31] H. C. Kim, D. M. Yang, and W. Jin, "Color Doppler Twinkling Artifacts in Various Conditions During Abdominal and Pelvic Sonography," J Ultrasound Med, Vol.29, pp.621-632, 2010.

[32] J. Y. Lee, S. H. Kim, J. Y. Cho, and D. Han, "Color and power Doppler twinkling artifacts from urinary stones: clinical observations and phantom studies," AJR Am J Roentgenol, Vol.176, pp.1441-1445, 2001.

[33] M. Patlas, A. Farkas, D. Fisher, I. Zaghal, and I. Hadas-Halpern, "Ultrasound vs CT for the detection of ureteric stones in patients with renal colic," Br J Radiol, Vol.74, pp.901-904, 2001.

[34] Gianfranco Vallone1, Giuseppina Napolitano, Paolo Fonio, Gabriele Antinolfi, Antonio Romeo, Luca Macarini, Eugenio Annibale Genovese, and Luca Brunese, "US detection of renal and ureteral calculi in patients with suspected renal colic," Critical Ultrasound Journal, Vol.5, No.1, p.S3, 2013.

[35] M. Bultitude and J. Rees, "Management of renal colic," BMJ, Vol.345, p.e5499, 2012.

[36] K. K. Stamatelou, M. E. Francis, C. A. Jones, L. M. Nyberg Jr, and G. C. Curhan, "Time trends in reported prevalence of kidney stones in the United States: 1976-1994," Kidney Int, Vol.63, pp.1817-1823, 2003.

[37] Jesmar Buttigieg, Stephanie Attard, Alexander Carachi, Ruth Galea, and Stephen Fava, "Nephrolithiasis, stone composition, meteorology, and seasons in Malta: Is there any connection?," Urol Ann, Vol.8, No.3, pp.325-332, 2016.

[38] J. H. Parks, R. Barsky, and F. L. Coe, "Gender differences in seasonal variation of urine stone risk factors," J Urol, Vol.170, pp.384-388, 2003.

[39] H. K. Park, S. R. Bae, S. E. Kim, W. S. Choi, S. H. Paick, and K. Ho, "The effect of climate variability on urinary stone attacks: Increased incidence associated with temperature over 18°C: A population-based study," Urolithiasis, Vol.43, pp.89-94, 2015.

[40] A. Ramello, C. Vitale, and M. Marangella, "Epidemiology of nephrolithiasis," J Nephrol, Vol.13, pp.45-50, 2000.

[41] Sameh Khodair Ahmad and Mohamed Marzouk Abdallah, "The diagnostic value of the twinkle sign in color Doppler imaging of urinary stones," The Egyptian Journal of Radiology and Nuclear Medicine, Vol.45, pp.569-574, 2014.

[42] I. Y. Oh, S. P. Choi, Y. M. Kim, K. N. Park, W. J. Lee, and S. K. Jeong, "Incidence and significance of negative hematuria in patient with urolithiasis visiting the emergency room with flank pain," Ko J Emerg Med, Vol.15, No.3, pp.146-150, 2004.

저 자 소 개

심 현 선(Hyun-Sun Sim) 정회원

▪ 2001년 8월 : 인제대학교 보건대학원 보건학과(보건학 석사)
▪ 2007년 8월 : 제주대학교 대학원 의학과(예방의학 박사)
▪ 2001년 3월 ~ 2014년 12월 : 한서대학교 방사선학과 대우교수
▪ 2013년 3월 ~ 현재 : 고려대학교 보건과학대학 외래교수

<관심분야> : 암역학, 방사선학, 초음파영상학, 초음파물리학