Classification of Urinary Stone into Uric Acid & Non-uric Acid by Dual-Energy

Myung-Jin Jung[1,2], Sung-Gil Kim[3,*]

[1]Department of Health Science, Graduate School of Chosun University, Korea

[2]Department of Radiology, Chosun University Hospital, Korea

[3]Department of Radiology, Gwangju Health University, Korea

Received: November 11, 2023. Revised: November 28, 2023. Accepted: November 30, 2023.

ABSTRACT

The aim of this study is to evaluate the diagnostic ability of dual-energy computed tomography (DECT) for Composition determination of urinary stones in phantom model. Seventeen cases with urinary stones who underwent DECT were enrolled in the study. The composition of the urinary stones was extracted from the seventeen patients were analyzed with DECT in phantom model with fresh pork. The volume scan method using Dual-energy software was used and the scanned image sets were assessed. All 17 urinary stones of the phantom model were analyzed according to the stone composition using DE stone Analysis were divided into uric acid stones (n=6, 35.29%) and non-uric acid stones (n=11, 64.71%). These urinary stones were pathologically confirmed. The mean attenuation values of uric acid stones at 135 kV, 100 kV and 80 kV was 348.87 ± 166.37 HU, 345.33 ± 151.18 HU and 337.94 ± 172.77 HU, respectively. The mean attenuation values of non-uric acid stones at 135 kV, 100 kV and 80 kV was 551.93 ± 297.09 HU, 747.04 ± 351.31 HU and 958.19 ± 424.72 HU, respectively. At 80 kV, uric acid stones and non-uric acid stones showed significant difference in the attenuation values($P<0.05$). The attenuation values of DECT could differentiate the compositions of urinary stones between uric acid and non-uric acid stones at 80 kV in phantom model.

Keywords: Dual-Energy CT, Dual energy Analysis, Urinary stone, Uric Acid Stone, Non-Uric Acid Stone

I. INTRODUCTION

Urinary stone appears in lifetimes of approximately 12% of population. The rate of recurrence of urinary stones in ten years reaching 50% is relatively higher than other diseases, and 87% of patients suffering from urinary stone appeal pains in flank; it accompanies other symptoms such as hematuria, nausea, and vomiting[1-3].

Treatment for urinary stones exhibited extraordinary improvement through advancements in extracorporeal shock wave lithotripsy (ESWL) and urology.

However, the causes of urinary stone are yet to be clarified and therefore the recurrence rate is still high.

In particular, it turned out to see approximately 14% in a year, 35% in five years, and 52% in 10 years in a study related with the rate of recurrence of urinary stones[4].

The symptoms, size, and composition of urinary stones are very important as definite factors of the treatment [5]. Among those factors, the information on composition of urinary stones plays a crucial role for the effective treatment; the information also enables the prediction on disintegration of urinary stones[6-8].

* Corresponding Author: Sung-Gil Kim E-mail: stardrangio@naver.com Tel:+82-1-3649-3456
Address: Gwangju Health University, 73, Bungmun-daero 419beon-gil, Gwangsan-gu, Gwangju, Republic of Korea

In 1983, Mitcheson et al. reported an experimental study that the measurement of Hounsfield Unit (HU) vafter conducting computed tomography (CT) can be exploited to distinguish composition in the other urinary stone[9].

Therefore, We intended to identify the accuracy and the clinical feasibility of the composition analysis of urinary stones through using dual-energy computed tomography (DECT).

II. MATERIAL AND METHODS

1 Subjects

Urinary stones were collected after the ESWL for urinary stones of patients who had been diagnosed on DECT. To simulate the conditions of urinary stones embedded in human body, the flesh of pork (length: 555 mm, width: 358 mm, height: 176 mm) was prepared wherein small plastic bottle (diameter: 10 mm, length: 45 mm) containing urinary stones was inserted for the examination as illustrated in Fig. 1.

Fig. 1. Pork which embeds the urinary stone to simulate situation.

2 Examination and Measurement

The mode of dual-energy(DE) of 640 slices multi-detector computed tomography(MDCT, Aquilion ONE, Canon Medical Center, Japan) enabling DECT was employed for the examination with the following parameters: Beam Collimation 0.5×320 mm, tube voltage of 135+80 kV, tube current of 50+290 mA, Rotation Time of 0.5 sec, D-FOV(Display-Field of View) 99.8 (S-FOV(Scan-Field of View): SS), and Volume Scan were used.

The values of HU were measured by using DE software (“DE stone Analysis” software version 48.3, Canon Medical Center, Japan) from the two images obtained as illustrated in Fig. 2-3, thereafter the compositions of uric acid stone and non-uric acid stone were analyzed, respectively.

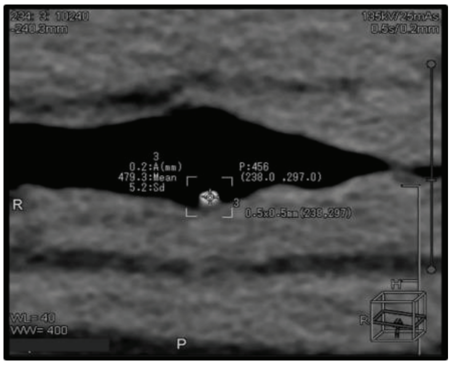
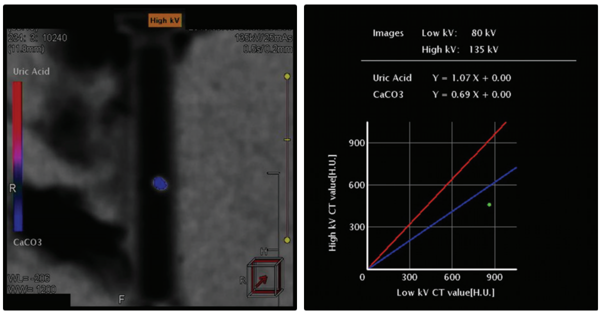


Fig. 2. Measurement of the HU value of a Urinary stone.

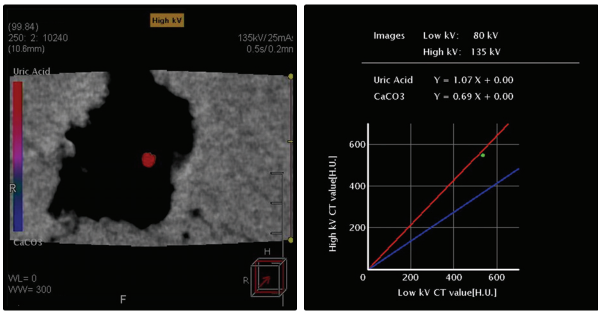
3 Statistical Analysis

The SPSS software (Version 21.0; SPSS Inc., Chicago) was used for the statistical analyses the means and standard deviations of measurement of HU of urinary stones which varied according to of the tube voltage.

The t-test over the corresponding samples was carried out to determine the presence of significant differences between the HU values of a uric acid stone and a non-uric acid stone which corresponds to of $p<0.05$.



(A) An example of a non-uric acid stone which in placed color to the blue line.



(B) An example of a uric acid stone which in placed color to the red line.

Fig. 3. Dual-energy Analysis of urinary stones by plotting the two HU value of high and low kV.

III. RESULT

1. Gender of Patients & Composition of Urinary Stones

The patients (10 males and 7 females) participated in the present study and compositions of urinary stones are as presented in Table 1. The urinary stones collected from the patients consisted of six uric acid stones (35.29%) and 11 non-uric acid stones (64.71%).

Table 1. Gender of Patients and Compositions of Urinary Stones

Parameters		N (%)	Total (%)
Gender	Male	10 (58.82)	17 (100)
	Female	7 (41.18)	
Compositions of Urinary stone	Uric acid	6 (35.29)	17 (100)
	Non-Uric acid	11 (64.71)	

2. HU values of Urinary Stones

As presented in Table 2, the measurement of HU of uric acid stone appeared at each level of voltage: 135 kV for 348.87±166.37, 100 kV for 345.33±151.18, and 80 kV for 337.94±172.77. Whereas the mean HU ± standard deviation (SD) of non-uric acid stone appeared as in the following: 135 kV for 551.93±297.09, 100 kV for 747.04±351.31, and 80 kV for 958.19±424.72. The values of HU, corresponding to the values of tube voltage, appeared constantly for the cases of uric acid stone, whereas the values of HU of non-uric acid stone appeared higher in accordance with lower tube voltage.

Table 2. HU Values of Urinary Stones

Com -positions	Tube Voltage (kV)	Minimum HU	Maximum HU	Mean ± SD
Uric acid (n=6)	135	93.67	481.33	348.87 ± 166.37
	100	120.67	459.33	345.33 ± 151.18
	80	85.67	499.00	337.94 ± 172.77
Non-Uric acid (n=11)	135	117.00	1031.33	551.93 ± 297.09
	100	209.67	1342.00	747.04 ± 351.31
	80	321.00	1660.67	958.19 ± 424.72

3. Comparison of Respective Values of HU of Urinary Stones at Each Tube Voltage

At each level of 135 kV and 100 kV of tube voltage, the values of HU of uric acid and non-uric acid stones exhibited no statistically significant differences ($P>0.05$), whereas at the level of tube voltage of 80 kV, the difference between HU values of uric acid and non-uric acid stones revealed statistically significant differences ($P<0.05$) (Table 3).

4. Comparison of HU Values at 135 kV and 80 kV of Uric acid and non-uric acid Stones

For the case of uric acid stone, the values of HU at 80 kV and 135 kV were not statistically different ($p>0.05$), whereas for the case of non-uric acid stone, the values of HU at 80 kV and 135 kV were statistically significantly different ($p<0.05$) (Table 4).

Table 3. Comparison of Respective Value of HU of Urinary Stones at Each Tube Voltage

Tube voltage(kV)	Compositions of Urinary stone	Mean ± SD	P-value
135	Uric acid	348.87 ± 166.37	0.78213
	Non-Uric acid	551.93 ± 297.09	
100	Uric acid	345.33 ± 151.18	0.12050
	Non-Uric acid	747.04 ± 351.31	
80	Uric acid	337.94 ± 172.77	0.04468
	Non-Uric acid	958.19 ± 424.72	

Table 4. Comparison of HU Values of 135 kV and 80 kV of Uric acid and non-uric acid Stones

Compositions of Urinary stone	Tube voltage(kV)	Mean ± SD	P-value
Uric acid	135	348.87 ± 166.37	0.25290
	80	337.94 ± 172.77	
Non-Uric acid	135	551.93 ± 297.09	0.00003
	80	958.19 ± 424.72	

IV. DISCUSSION

The discovery of stones in the bladder dates to 4,800 years B.C. in Egypt, and the urolithiasis of which prevalence varies according to regions and environment is found on the increasing trend along with the westernization of dietary lives wherein the overweight, hyperlipidemia, and excessive uptake of animal protein etc. are frequently found[10-12].

Urinary stone is a consequence of disease that appears in approximately 12% of population in their lifetimes[1]. Approximately 87% of patients experience acute side abdominal pains thereby come to hospitals together with symptoms of nausea, vomiting, and visually observable urinary bleeding. The patients of acute side abdominal pain as chief complaint are frequently put into radiological examination to discriminate the presence of diseases associated with urinary stone.

For the patients suspected with the presence of urinary stone, the ‘unenhanced helical CT’ has been reported as more prompt, safer, and accurate diagnostic alternative than conventional urography for internal jugular vein or ultrasonic examination[13]. In addition, the ‘unenhanced helical CT’ has additional advantages of diagnosing radiolucent urinary stones and finding causes of the acute side abdominal pains by urinary stones, simultaneously[14,15].

Since the employment of CT by Mitcheson et al. in 1998 to distinguish compositions of urinary stone, the values of HU have been employed in many studies to distinguish compositions of urinary stone[9].

Mostafavi et al. reported that the uric acid stones were distinguished easily from stones of calcium, cystine, brushite, and struvite by CT imaging of 1mm thickness of urinary stones, and the employment of dual voltage CT was reported that it would show significant differences in values of HU of respective compositions at the level of significance of $p<0.03$ except for the uric acid stone[16].

Newhouse et al. conducted the study in laboratory with the spacing of 2 mm and reported that uric acid stones and stones of cystine can be distinguished from other components of urinary stone; Deveci et al. captured images of 107 urinary stones by the spacing of 1 mm in their study conducted in the laboratory and reported that they could distinguish all kinds of uric acid stones except for calcium oxalate dehydrate[17,18].

In the results obtained from the present study, the uric acid stones exhibited no differences at both levels of tube voltage of 135 kV and 100 kV except for the level of 80 kV wherein the decrease by the difference of 10.93 was observed. However, the difference between two values was not significant with the level of significance on $p>0.05$ (Table 3). On the contrary, the varied level of energy from 135 kV to 80 KV and 100 kV rendered the increase in values of HU by

406.26 and 195.11 respectively suggesting significant differences($p<0.05$) (Table 4). That is, for the case of uric acid stone, the difference in values of HU almost did not appear despite differences in levels of energy. On the contrary, for the case of non-uric acid stones, the values of HU varied greatly according to variation in level of energy thus it was possible to distinguish two stones in DECT by using such properties.

Limitations of this study would be the small number of the entire samples, and it would be hard to generalize the results of this study with only six uric acid stones. Due to such limitations, it would be improbable to use in clinical guidelines. However, the results obtained from this study would be of help for further large scaled prospective studies in the future.

V. CONCLUSIONS

In the phantom experimental study using urinary stones extracted after the procedure, uric acid stones and non-uric acid stones could be distinguished by the difference in the HU value which was changed differently according to the energy value investigated using DECT. Uric acid and non-uric acid stones was distinguished by non-invasive examination. In the case of uric acid stone, the stone may be treated through the treatment of alkalinization of urine rather than invasive. These results may help to treatment methods for urinary stone patients.

In the future, If the study of DE and reconstruction methods will in progress, the DECT test is expected to be useful for the treatment of urinary stones.

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이중에너지 전산화단층촬영을 이용한 요로결석의 성분 분석에 관한 연구

정명진[1,2], 김성길[3,*]

[1]조선대학교병원 영상의학과
[2]조선대학교 대학원 보건학과
[3]광주보건대학교 방사선학과

요 약

팬텀모델에서 이중에너지 전산화단층촬영(DECT)를 이용한 요로결석의 성분분석을 통해 임상적 유용성에 대해 알아보고자 한다. 17명의 환자로부터 요로결석을 추출하여, 작은 플라스틱 병(Plastic Bottle) 안에 각각의 요로결석을 삽입한 후, 인체와 비슷한 돈육을 이용하여 실험팬텀을 제작하였다. 640-Slice MSCT(Auquilion ONE, Toshiba Medical Center, Japan)의 이중에너지 방식에서 Volume scan 방식을 사용하여 촬영하였고, 얻어진 두 가지의 영상을 Dual-energy software(“DE stone Analysis” software version 4.3, Toshiba)에서 요산석과 비요산석의 성분분석하고 HU값을 각각 측정하였다. 요로결석의 성분은 전체 17개의 요로결석 중에서 요산석은 6개(35.29%)였고, 비요산석은 11개(64.71%)로 나타났다. 요산석의 경우 135kV는 348.87±166.37, 100kV는 345.33±151.18, 80kV는 337.94±172.77로 나타났고, 비요산석의 경우 135kV는 551.93±297.09, 100kV는 747.04±351.31, 80kV는 958.19±424.72로 나타났다. 80kV에서는 요산석과 비요산석의 HU값의 차이가 통계적으로 유의한 차이를 보였고($P<0.05$), 비요산석의 경우에 80kV와 135kV의 HU값은 통계적의 유의한 차이를 보였다($P<0.05$). 시술 후 적출된 요로결석을 이용한 팬텀실험연구에서는 DECT를 이용하여 에너지에 따라 서로 다르게 변화하는 HU값의 차이로 요산석과 비요산석을 구분할 수 있었다. 향후, 이중에너지에 대한 연구와 재구성방법의 연구가 진행된다면, 요로결석의 치료에 DECT가 유용할 것으로 기대된다.

중심단어: 이중에너지CT, 이중에너지분석, 요로결석, 요산석, 비요산석

연구자 정보 이력

	성명	소속	직위
(제1저자)	정명진	조선대학교병원 영상의학과 조선대학교 대학원 보건학과	방사선사 대학원생
(교신저자)	김성길	광주보건대학교 방사선학과	겸임교수