Original Article

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Correlation Between Urinary Tract Pure Stone Composition and Stone Morphology on Plain Abdominal Film

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Key Words
extracorporeal shock wave lithotripsy;
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Background. Crystallographic composition of urinary tract stone varies in several chemical groups and determines the degree of fragmentation to extracorporeal shock wave lithotripsy (ESWL) which has been widely used for the treatment of renal and ureteral calculi. Visual prediction of stone composition by its morphology from plain radiograph may provide a simple method and clinical hint to decide therapeutic modalities. A prospective study was designed to determine the correlation of stone composition with its radiographic morphology.
Methods. One hundred patients of urolithiasis with passage of stone fragments (after ESWL, surgical lithotomy or endoscopic lithotripsy) analyzed as pure stone by infrared spectrometry were reviewed by plain abdominal film to classify their morphology, location and size. Five experienced surgeons familiar with the radiographic patterns of different types of pure stones were invited to predict the stone composition on plain abdominal film.
Results. Five different patterns of radiographic appearances of the stones were identified. Calcium oxalate monohydrate referred to the smooth-shaped and homogeneous ones with denser opacity. Calcium oxalate dihydrate referred to those smaller ones that had irregular margin with stippled border and were less dense. Calcium phosphate (CaP) had moderate density and size without significant figures. Struvite meant staghorn stone; usually bilateral. Uric acid referred to those being radiolucent, slightly opacified, and in large size. The 5 surgeons achieved an overall accuracy of 27.4%. There was no obvious relations between accuracy and location or size of the stones. CaP stone was the most likely to be misclassified, and achieved only 20% accuracy.
Conclusions. Different stone composition showed grossly specific radiographic appearances, but clinical test revealed poor correct rate in prediction of stone composition from plain abdominal film. The results of our study suggest that prediction of stone component based on stone morphology on plain abdominal film may not be accurate enough. Patient's clinical information and other laboratory data should be considered while interpreting plain abdominal film for better treatment choice of urolithiasis.

Urinary calculi are the third most common affliction of the urinary tract, exceeded only by urinary tract infections and pathologic conditions of the prostate. Many treatment modalities including surgical intervention, endoscopic methods, medical agents, and extracorporeal shock wave lithotripsy (ESWL) have been used for urinary calculi. The concept of ESWL began in the 1950s in Russia and was first applied with successful fragmentation of renal stone in 1980.[1] With the widespread use of ESWL, urologists noticed that the fragmentation rate of urinary tract stones correlates with stone location, size and, first of all, fragility.

The fragility of the stones of different crystallographic composition was known to make a decreasing order of fragmentation for struvite (magnesium ammonium phosphate hexahydrate), uric acid, calcium oxalate

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dihydrate (COD), calcium oxalate monohydrate (COM), and finally cystine.[2] Several techniques have been introduced for detection of stone composition including tomodensitometry,[3] dual-energy radiographic bone densitometry,[4] noncontrast spiral computerized tomography,[5] Tc-99m bone scan,[6] low-angle X-ray scattering (LAXS),[7] pulsed dye laser[8] and infrared analysis.[9] Pretreatment understanding of the stone composition provides more information for urologists to make better decision of treatment modalities. Therefore, the aim of this study was to determine the correlation between pure stone composition and its morphology by a simple, non-invasive and cost-effective radiographic method.

METHODS

Five experienced surgeons were invited to participate in a prospective study to read pretreatment plain abdominal roentgenograms (KUB) of 100 patients with urolithiasis. All stones were obtained from surgical procedures (open lithotomy, endoscopic lithotripsy, percutaneous nephrolithotomy, or spontaneous passage after ESWL) and proved to be "pure stone", defined as having more than 80% components to be crystal from infrared spectrometry. These pure stones were classified into 5 groups according to their compositional characteristics shown on plain abdominal film: group 1, COM, homogeneous with smooth shape, often in dentate appearance and denser than 12 th rib or spinal transverse process (Fig. 1A); group 2, COD, smaller in size with stippled border, less dense (Fig. 1B); group 3, calcium phosphate (CaP), medium in size with smooth surface, moderately dense and usually multiple (Fig. 1C); group 4, struvite, staghorn stone, inhomogeneous with caliceal or infundibular shape, sometimes bilateral (Fig. 1D); group 5, uric acid, radiolucent but slightly opacified with round and smooth shape when in large size (Fig. 1E). These different radiographic appearance have been well-documented.[2,10,11] All our 5 participants were well educated about the radiographic information before reading the pretreatment plain abdominal films. They were also blind to the patient history, laboratory data and treatment results. The plain abdominal films were interpreted to determine the composition of the stones, and the accuracy was then calculated.

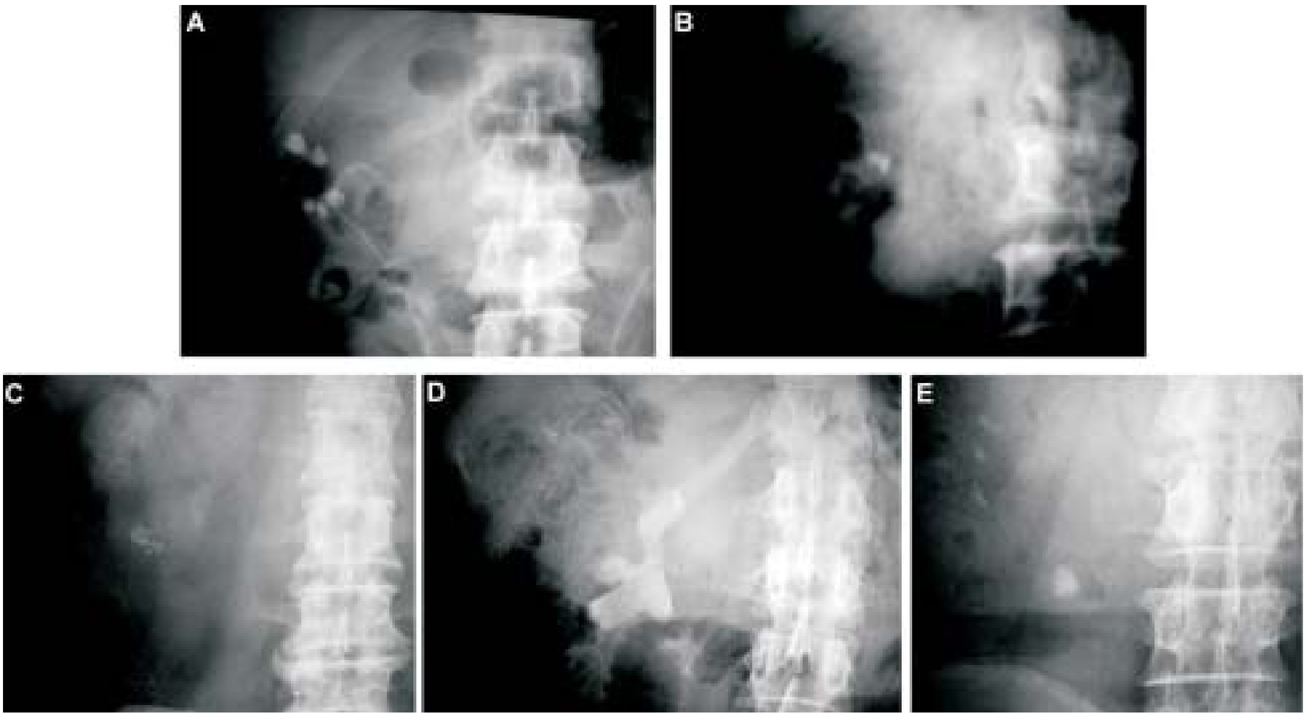

Fig. 1. Radiographic characteristics. (**A**) Calcium oxalate monohydrate (COM) stone. (**B**) Calcium oxalate dihydrate (COD) stone. (**C**) Calcium phosphate (CaP) stone. (**D**) Struvite stone. (**E**) Uric acid stone.

RESULTS

The 100 pretreatment plain abdominal films of the pure stones of the urinary tract were classified based on crystallographic composition, stone size and location. COM was the most common (57%) and there only 3 cases with uric acid stones (Fig. 2). When stratified by size, 45% of stones were larger than 2 cm, 20% between 1 cm to 2 cm, and 35% were smaller than 1 cm. Renal calyceal stone accounted for 60% of the stones, and there were more lower pole renal stones (35%) than upper pole stones (25%). Other stones were located within renal pelvis (5%), ureter (18%), and bladder (17%).

The average accuracy of predicting stone composition by 5 surgeons was 27.4%. No single participant achieved accuracy over 50%. Nor was there any significant difference of accuracy noted among them (Fig. 3). The accuracy rate was found to slightly increase with larger stones, but the difference was not statistically significant ($p = 0.427$) (Fig. 4). Calcium phosphate was the most frequently misdiagnosed, achieving only 20% accuracy. However, the accuracy of struvite stone was 84% (Fig. 5), since all 5 struvite stones appeared as bilateral staghorn ones on plain abdominal film.

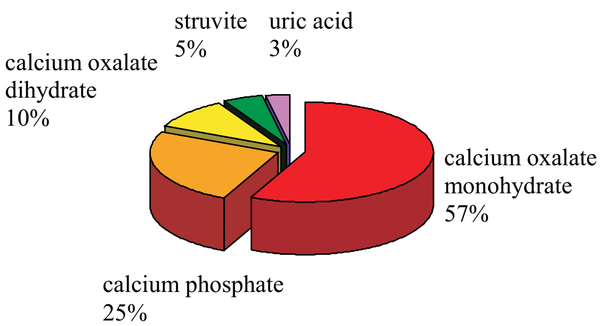

Fig. 2. Distribution of pure stone component in decreasing order: COM (57%), CaP (25%), COD (10%), struvite (5%), uric acid (3%).

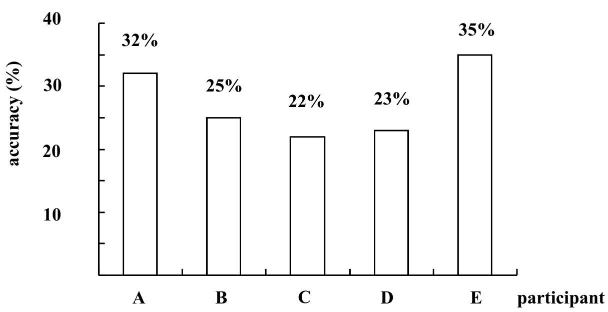

Fig. 3. Overall accuracy of stone component prediction. A ~ E represents each participant invited to predict stone composition. No single participant achieved accuracy over 50%. The highest accuracy is 35% by participant E.

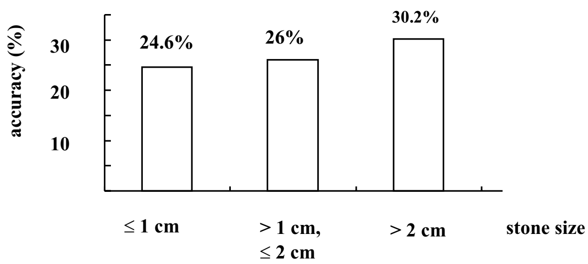

Fig. 4. Accuracy according to stone size. The accuracy rate was found to slightly increase with larger stones, but the difference was not statistically significant ($p = 0.427$).

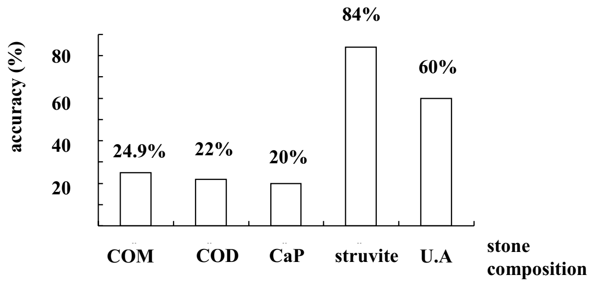

Fig. 5. Accuracy according to stone component. Note the Calcium phosphate stone was the most frequently misdiagnosed with only 20% accuracy while struvite stone achieved 84% accuracy due to all struvite stones appeared as bilateral staghorn stones on plain abdominal film.

DISCUSSION

Some technical difficulties were encountered in this prospective study. Among them the sampling error is an uncontrolled factor. Major crystal composition may be missed or under-represented in the process of stone collection and mismatch of morphology on plain abdominal film and infrared analysis may occur. Furthermore, different radiographic settings, such as K*v* value and zoom degree of the KUB films, affect the interpretation. Although the radiographic appearances of different types of pure stone had been introduced to the participants before reading the KUB films, poor prediction accuracy was still noted. Sanjay *et al.* have reported a similar prospective study to predict renal stone composition from plain radiographs to assess the predictive ability of a panel of physicians (2 urologists, 2 radiologists and 2 nephrologists). In their study, the composition guessed more than 40% of the total stone composition was considered to be correct. The average accuracy was 39%.[2] The obvious difference in accuracy between the studies (27.4% *versus* 39%) may come from the lack of experiences in dealing with urolithiasis patients and interpreting plain roentgenograms. Another concern was lack of clinical information and laboratory data such as clinical presentation, stone history, infection status and urinalysis. With the knowledge of these clinical hints, we were able to "guess" the stone composition more confidently.

Different stone composition reflects grossly specific radiographic appearance. At present, no diagnostic modalities are capable of accurately predict stone crystal component. With the development of technology, CT scan was used not only for detecting the urinary tract stones but also for predicting stone composition. Stephen *et al.* reported that by using noncontrast CT at 120 K*v*, 200 mA, 1.4:1 pitch, he was able to differentiate between uric acid and calcium oxalate stones.[5] Nevertheless, there are no valuable tools to predict other stone composition *in vivo* accurately.

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