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Inflammation and infection

# Dissolution of struvite stones with ascorbic acid

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ABSTRACT

This case report describes an elderly man with a history of recurrent urinary tract infections and obstructive pyelonephritis with struvite stones caused by Proteus mirabilis. Despite appropriate antibiotic treatment, the stones increased in size, necessitating alternative therapy. This case highlights the use of ascorbic acid to lower the urine pH, which contributes to the dissolution of struvite stones. Dual-energy CT was used to differentiate the stone composition for the initiation of ascorbic acid. These findings suggest that ascorbic acid can accelerate struvite stone dissolution, and that dual-energy CT is valuable for both initial diagnosis and follow-up.

## 1. Introduction

Struvite stones, also known as infection stones, are a type of kidney stone that forms in the presence of urease-producing bacteria such as *Proteus mirabilis*. These bacteria cause urine to become alkaline, leading to the precipitation of magnesium ammonium phosphate (struvite) crystals. Struvite stones are challenging to treat due to their rapid growth and recurrence, often requiring urological intervention.[1] Traditional antibiotic therapy is essential for managing the underlying infection but generally ineffective in dissolving stones.[2] Acetohydroxamic acid inhibits stone growth, but its side effects limit its use.[3–6] Although the use of ascorbic acid is controversial because of the potential risk of forming other types of stones, particularly calcium oxalate stones,[7,8] it theoretically has the potential to dissolve struvite stones.[9] Additionally, when collecting stones is difficult, dual-energy CT (DECT) effectively identifies compositions, providing key insights for targeted treatment without requiring crystallography.[10–12] Here, we describe a case in which struvite stones, identified by DECT, were successfully dissolved using ascorbic acid.

## 2. Case presentation

An elderly man in his 80s residing in a nursing home presented with fever, rigors, and back pain. He had no family history of urolithiasis or recurrent stones. A CT scan two years prior showed two right kidney stones and three left, the largest measuring 6.0 mm. Three months before this presentation, the patient was admitted for left obstructive pyelonephritis due to an 8.6 mm ureteral stone and a right kidney stone of 6.0 mm. The patient was treated with a double-J stent and effective antibiotics. *Proteus mirabilis* was detected in both blood and urine cultures. The patient was discharged after two weeks of antibiotics. A CT scan ten days before admission showed a residual left ureteral stone of 4.6 mm and a right kidney stone, the largest now 11.0 mm. Although asymptomatic, urinalysis revealed a pH of 8.0 and struvite crystals. He presented with a temperature of 39.3 °C and tenderness in the right costovertebral angle. Laboratory values showed a WBC count of 9800/μL, creatinine at 1.78 mg/dL, and CRP at 1.51 mg/dL. Urinalysis indicated a pH of 7.5, with WBC >100/HPF and the presence of struvite crystals. Gram stain of the urine revealed granulocytes and phagocytosis of Gram-negative bacilli. The overall clinical course of the patient is illustrated in Fig. 1. DECT performed on the day of admission showed right hydronephrosis due to right ureterolithiasis, bilateral kidney stones, and left ureterolithiasis (Fig. 2), with a DJ stent already in place on the left side. The right kidney stone had enlarged from 11.0 mm to 15.2 mm in just ten days (Fig. 2A and C, dashed arrows). While almost all of the struvite stones appeared hazy (Fig. 2A-D, dashed arrows), the left kidney stone (Fig. 2E, white arrow) and left ureteral stone (Fig. 2F, arrowhead) were dense. Zeff from DECT suggested the right kidney stone and ureteral stone were struvite (Fig. 3). Right obstructive pyelonephritis was diagnosed, and a DJ stent was placed. Urine cultures from the bladder and right renal pelvis were positive for *Proteus mirabilis*. Although stone analysis was not performed due to the absence of

*Abbreviations:* DECT, Dual-energy CT; DJ stent, double-J stent; rsDECT, rapid kilovolt peak-switching DECT; AUC, area under the receiver operating characteristic curve.

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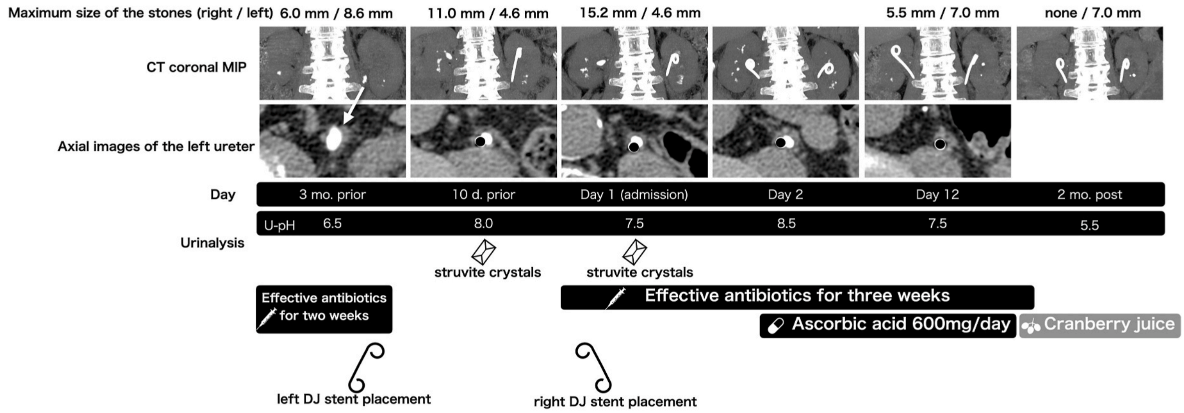


**Fig. 1.** The timeline of the patient's clinical course is shown. Maximum size of the bilateral renal and ureteral stones, coronal CT maximum intensity projection (MIP) images, axial images of the left ureter (white arrow) and DJ stent (black circle), urinalysis, and treatment are shown. On the day of admission, the number and size of the right renal stones rapidly increased, with the largest stone reaching 15.2 mm, whereas the left ureteral stones decreased in size from 8.6 mm to 4.6 mm. By day 12, almost all stones had diminished in number and size following 10 days of 600 mg ascorbic acid administration, although two left renal stones remained: one increased in size from 3.6 mm to 7.0 mm, and the other remained unchanged. The urine pH showed a limited reduction from 8.5 on day 2 to 7.5 on day 12, likely due to neutralization from the ongoing stone dissolution. The remaining two stones showed no changes in size two months after admission, following the transition from ascorbic acid to cranberry juice.

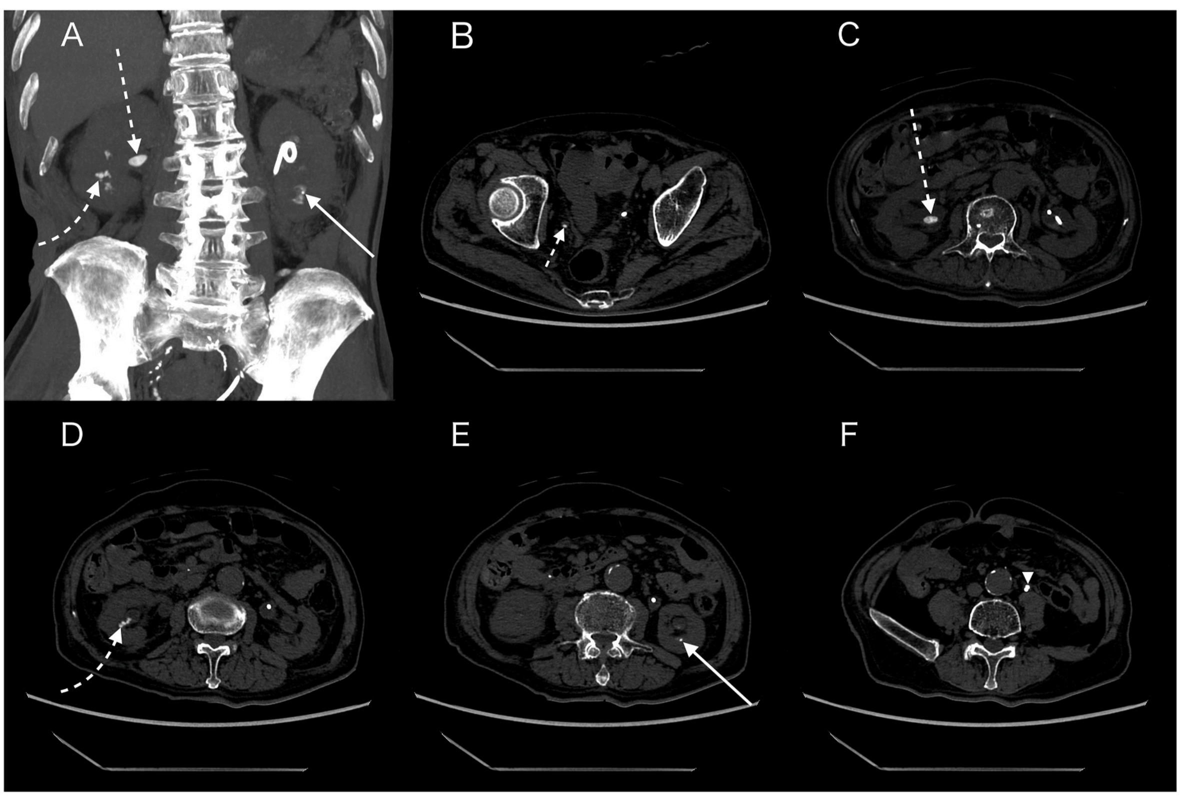


**Fig. 2.** Coronal MIP images (A) and axial CT images (B–F) taken on the day of admission showed bilateral kidney stones (A, C, D, E), a right ureteral stone (B, short dashed arrow), and a left ureteral stone (F, arrowhead). Most of the stones had a hazy appearance (A-D, dashed arrows), except for two dense stones in the left kidney (A, E, white arrows) and left ureter (F, arrowhead).

passed stones, high urine pH, detection of *Proteus mirabilis*, and DECT findings led to the diagnosis of struvite stones. Blood and urine test results did not support the presence of other stone types. Given the rapid size increase over the previous ten days and the acute phase of infection, we opted for an emergency intervention with the administration of cefmetazole 1 g twice daily and DJ stenting, with the intention of performing ureteroscopy after the patient's condition stabilized. High-dose ascorbic acid (>1000 mg/day) was avoided due to the risk of calcium oxalate stones; instead, ascorbic acid 200 mg three times a day was started on day 2. CT on day 12 revealed most stones had disappeared or reduced in size, except for two left renal stones: one remained at 2.3 mm, while the other increased from 3.6 mm to 7.0 mm (Fig. 1). The urine pH decreased from 8.5 on day 2 to 7.5 on day 12, showing only a limited reduction. This is likely due to the neutralization effect caused by the ongoing dissolution of the stones. Given the dramatic dissolution of most stones within just ten days, we considered the potential benefits of continued vitamin C administration to be minimal, while the observed increase in the size of one stone suggested a higher risk of adverse

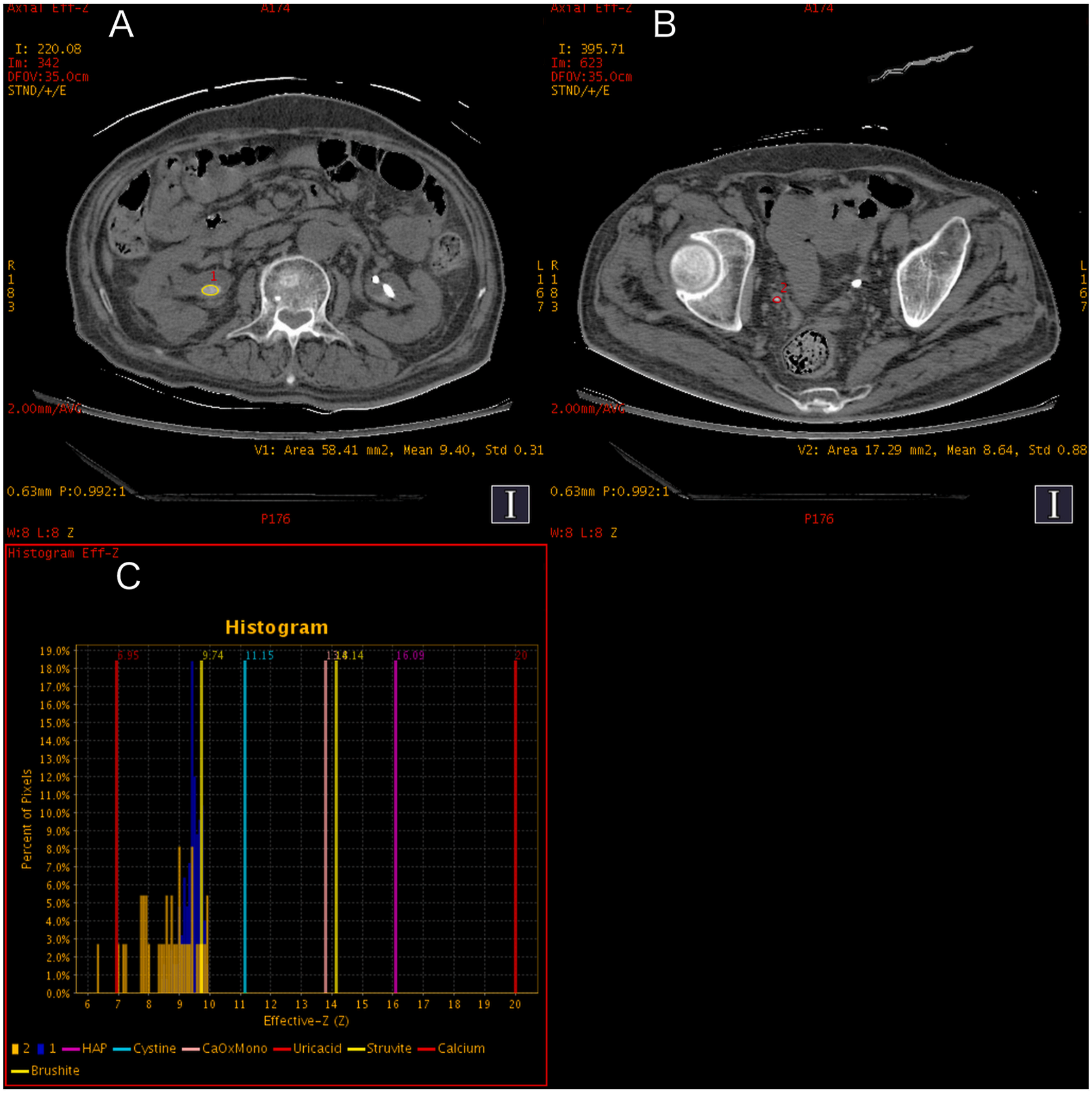


**Fig. 3.** The effective atomic number (Zeff) calculated from the DECT dataset on the day of admission demonstrated that the right kidney stone and ureteral stone (A–C) were composed of struvite.

effects. Therefore, at the time of discharge, we decided to discontinue vitamin C and switch to cranberry juice, which was considered a safer alternative for the prevention of stone recurrence. Retrospective DECT analysis suggested the remaining left kidney stone was uric acid (Fig. 4A and B), while the dissolved left ureteral stone was brushite (Fig. 4C and D). He was treated with antibiotics for three weeks: two weeks of IV therapy (cefmetazole 1 g twice daily for four days and ampicillin 2 g four times daily for ten days) during hospitalization, followed by one week of oral amoxicillin 500 mg three times daily post-discharge. CT two months later showed the sizes of the two remaining left renal stones were unchanged, while all other stones had disappeared (Fig. 5A). Based on this finding, the bilateral DJ stents were removed without ureteroscopy. The residual left kidney stone was suggested to be uric acid based on Zeff (Fig. 5B and C). The patient had no recurrence of pyelonephritis or ureteral stones nine months post-discharge.

## 3. Discussion

This case highlights two important findings: the potential role of ascorbic acid and cranberry juice in managing struvite stones, and the utility of DECT in stone analysis, particularly for identifying struvite stones.

First, ascorbic acid dissolved struvite stones. Despite receiving appropriate antibiotic treatment for *Proteus mirabilis* over an adequate duration, almost all patients' urolithiasis increased in both number and size over a three-month period. However, a dramatic reduction in both the number and size of stones was observed within only ten days after the administration of antibiotics and 600 mg of daily ascorbic acid. Struvite stones are notoriously difficult to treat and typically require urological intervention.[1] While antibiotics might contribute to struvite dissolution in this case, antibiotic therapy is generally considered not to dissolve but to prevent the recurrence or re-growth of stones after treatment.[2] Acetohydroxamic acid, which has been shown to stop struvite growth in approximately 80 % of patients,[3–5] is rarely used because of its significant side effects.[6] The use of ascorbic acid for urine acidification is controversial. Daily intake of 2000 mg ascorbic acid may lead to increased oxalate generation after metabolism, resulting in elevated urinary oxalate excretion and potentially causing the formation of

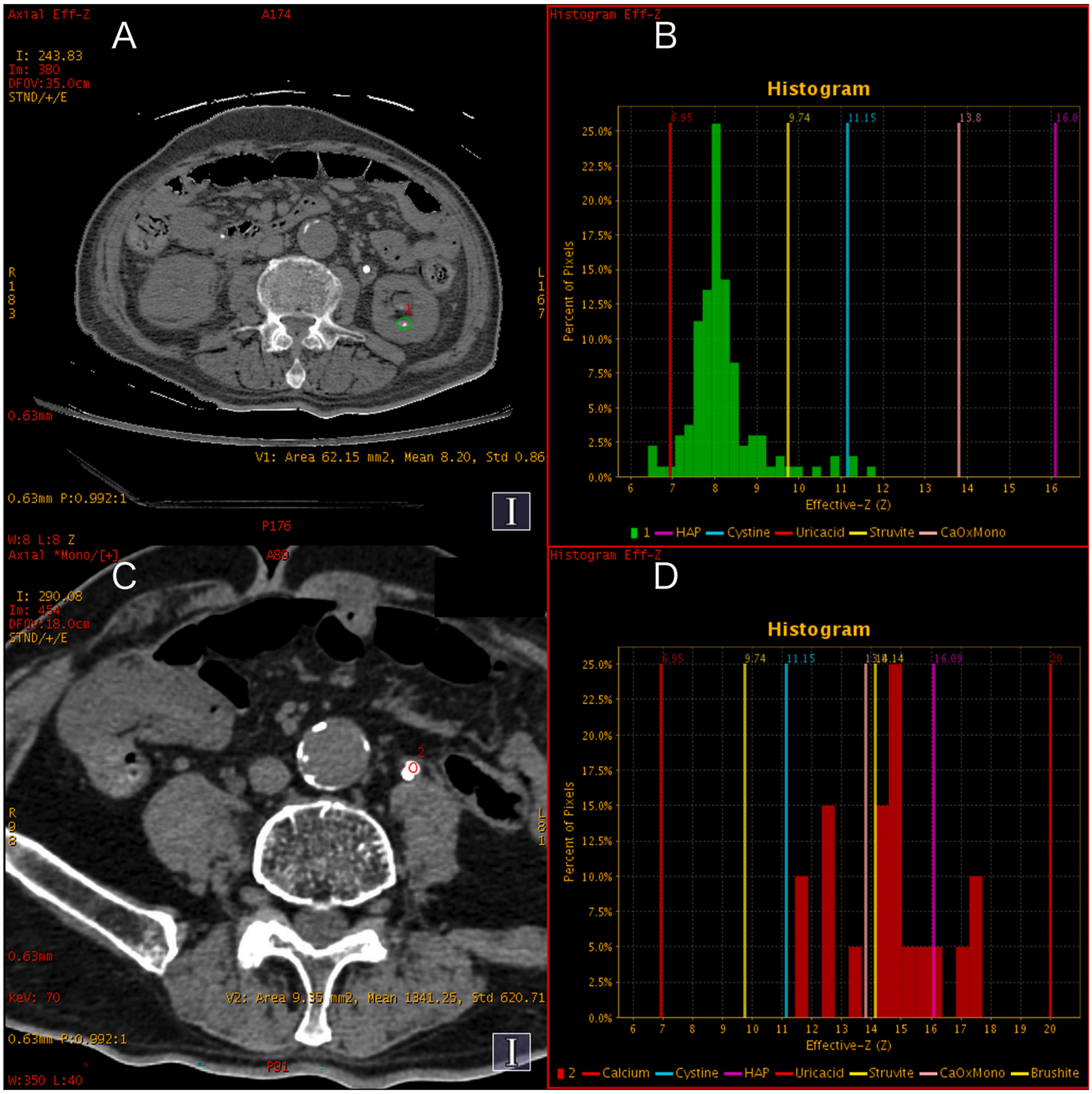


**Fig. 4.** Retrospective analysis using the Zeff value on the day of admission suggested that the enlarged stone in the left kidney was a uric acid stone (A, B), whereas the dissolved stone in the left ureter was a brushite stone (C, D).

calcium oxalate stones.[7,8] In contrast, another retrospective study indicated that ascorbic acid resulted in lower urinary pH in patients with urolithiasis and alkaline urine, without an increase in daily oxalate excretion.[9] This could be explained by the reduction or discontinuation of ascorbic acid in 8.4 % of the patients, with a median daily dose of 1000 mg. Additionally, ascorbic acid inhibits the crystallization of struvite in vitro.[13] Despite the difficulty of dissolving struvite stones,[1] the rapid dissolution observed in this case may be attributed to the early administration of ascorbic acid. The CT scan in this case showed that almost all the struvite stones appeared hazy (Fig. 2A-D, dashed arrows) and had formed within three months, suggesting that they were loose and more susceptible to dissolution. Loose stones, with their relatively larger surface area compared to their volume, were more likely to be exposed to low-pH urine, facilitating their rapid dissolution. In contrast, the smaller surface area of dense stones, such as the left kidney stone in our case (Fig. 2A and E, white arrows) or staghorn kidney stones, makes them less susceptible to dissolution under similar conditions. However, despite the dissolution of the dense large stone on the left ureter (Fig. 2F, arrowhead) that was observed two years earlier, a small, dense stone on the left kidney (Fig. 2A and E, white arrows) did not dissolve and instead increased in size (Figs. 1 and 5A). This suggests that other factors may have contributed to the outcome. Based on DECT evaluation, the left ureteral stone was identified as a brushite stone (Fig. 4F), which is known to dissolve under acidic conditions[14]. In contrast, the remaining stone in the left kidney was presumed to be a uric acid stone (Fig. 4A, B, 5B, 5C), which may have increased in size due to the acidification of the urine. Ascorbic acid administration should be limited to the short term, with close monitoring of urine pH, as it may lead to the formation of calcium oxalate stones, as mentioned above. In our case, ascorbic acid was switched to cranberry juice on day 14 after confirming the dissolution of nearly all struvite stones (Fig. 3A-C) and brushite stone (Fig. 4C and D) on day 12. This change was made to prevent the potential formation of calcium oxalate stones due to ascorbic acid while continuing to lower the urine pH. Previous studies on the effect of cranberry juice on urinary stones have yielded conflicting results.[15–18] The effect of cranberry juice on urinary stones is thought to be due to the quinic and benzoic acids in cranberries, which are precursors of hippuric acid. This acid is excreted by the kidneys, thereby acidifying urine.[19] Although

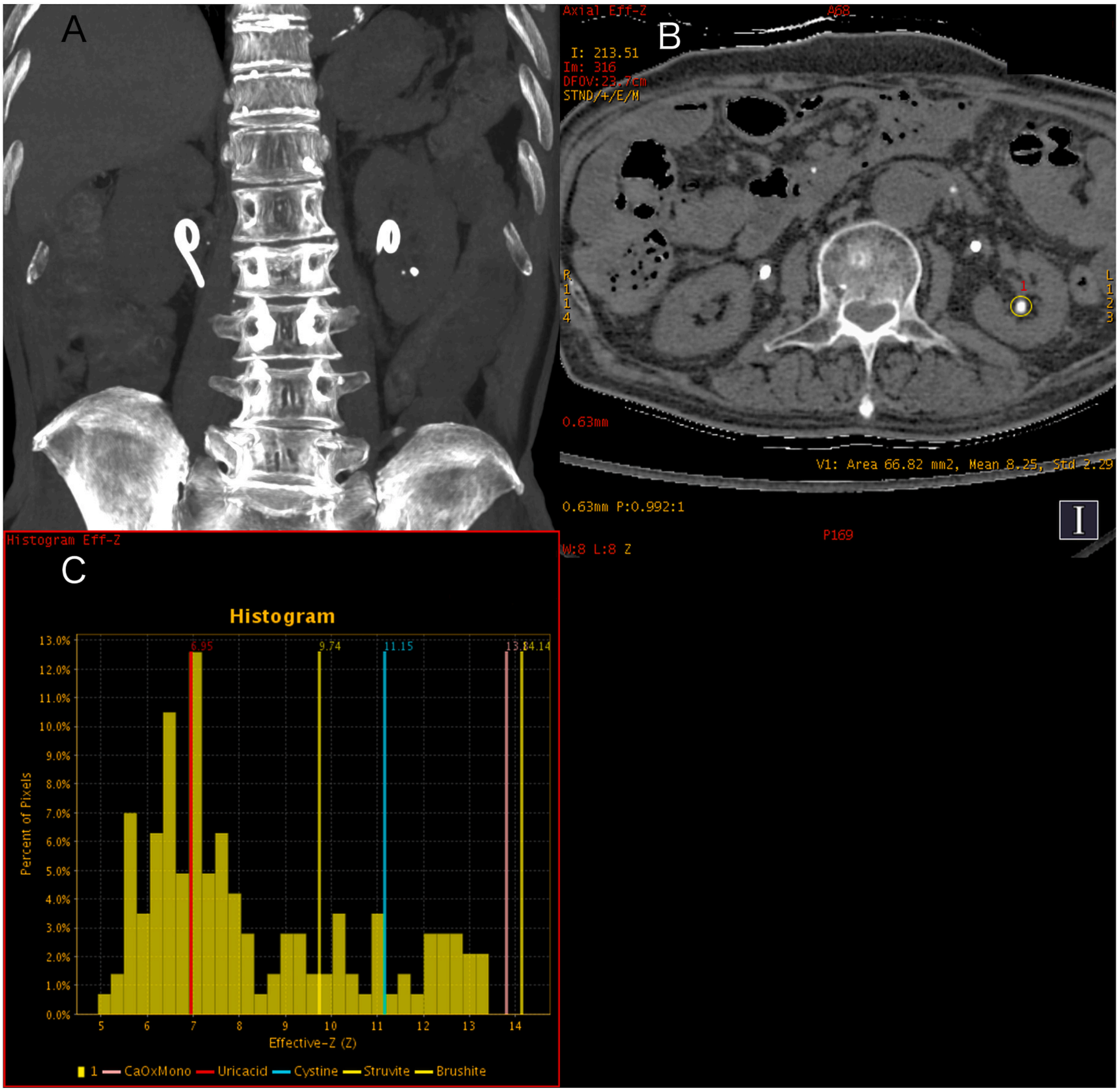


**Fig. 5.** Coronal MIP CT (A) performed two months after discharge demonstrated two remaining left renal stones, while all other stones had disappeared. The residual left kidney stone had a Zeff value similar to that of uric acid (B, C).

cranberry juice has complex effects on urinary stones, it generally increases the risk of calcium oxalate and uric acid stone formation, while decreasing the risk of struvite and brushite stones, which are more likely to form in relatively alkaline urine.[14] However, it cannot be definitively determined whether the urine pH of 5.5, observed during a visit two months after discharge with a negative urine culture, was due to the effects of cranberry juice, its antibacterial properties, or other factors.

Second, DECT can detect struvite stones (Fig. 3A-C), particularly in the context of suspected urinary tract infection caused by urease-producing bacteria. Differentiating stone composition with DECT can be done in two ways: using Hounsfield Units (HU) at two different energies and attenuation ratios or by calculating the effective atomic number, known as Zeff. By applying two X-ray beam energies to a renal stone, Zeff can be calculated, which allows the estimation of stone composition.[10] Zeff has been shown to perform better than HU and attenuation ratios in differentiating non-uric acid stones.[11] Additionally, differentiation of non-uric acid stones can be performed both in vitro and in vivo, and Zeff accurately reflects the dominant composition, even in cases of mixed stone compositions.[12] Our DECT system is a second-generation rapid kilovolt peak-switching DECT, with a diagnostic performance of 0.84 in terms of the area under the receiver operating characteristic curve (AUC) for differentiating uric acid stones from non-uric acid stones, and 0.93 for differentiating struvite stones.[20] Mixed stones containing up to 20 % calcium components are reported to be diagnosable as struvite stones, which are the primary component, using DECT[11]. Therefore, even in cases of mixed stones, if diagnosed as struvite by DECT, they can be considered predominantly struvite, allowing for the initiation of ascorbic acid treatment in the context of urinary tract infection and high urine pH. As in this case, crystallography cannot always be performed before initiating treatment; therefore, differentiating stone compositions is crucial for the dissolution of struvite stones. Moreover, careful observation and differentiation of residual stones are essential because not all stones have the same composition. Other types of stones may not only fail to dissolve but can also increase in size.

## 4. Conclusion

Ascorbic acid may accelerate the dissolution of struvite stones, and DECT is particularly useful for differentiating stone compositions, especially when stone collection is difficult.

## Consent

Informed consent was obtained from the patient for publication of the report and associated images.

## AI use

During the preparation of this work S. Yoshikawa used GPT-4o and Paperpal in order to improve language. After using this tool/service, S. Yoshikawa reviewed and edited the content as needed and takes full responsibility for the content of the publication.

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