Gas-containing renal stones: a red flag for renal infection

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Abstract

Background: Gas in the renal excretory system is described as a consequence of recent procedures but it can be a sign of severe conditions such as fistulas or infections; however, gas-containing renal stones are only rarely encountered.
Purpose: To describe the association of gas-containing renal stones and urinary tract infection.
Material and Methods: We performed a retrospective evaluation of the clinical and imaging findings in a series of six patients with gas-containing renal stones and compared our findings with those of patients with gas-containing renal stones reported in the literature. Urine and stone cultures were used as a diagnostic standard for urinary tract infection.
Results: Including the present series, there is a total of 21 patients with gas-containing renal stones in the literature. Based on clinical presentation, urinary tract infection could be suspected in 10 (57%) patients, while urine and/or stone cultures showed infection in 18 of 19 (95%) patients, with only one case with no bacterial growth in both (5%); in the remaining patient the information was not available.
Conclusion: Gas-containing renal stones are a rarely reported entity usually diagnosed with computed tomography. They are a radiological sign often associated with urinary tract infection that can also be encountered in patients with non-specific renal symptoms.

Keywords
Kidney, computed tomography, renal stone, urinary tract infection

Introduction

The presence of gas in the renal excretory system is a finding described in different situations: it is frequently seen as a consequence of recent endoscopic and percutaneous procedures or, rarely, can be a sign of severe conditions such as fistulas or infections (1,2). Gas also seen within renal stones is rare and, to the best of our knowledge, only 15 cases have been previously described in the literature (3–13). We report on a series of six patients with gas-containing renal stones who differed in symptoms, clinical presentation, and radiologic findings as well as in management, and review the literature on this topic. The aim of the present study was to underline the association of gas-containing renal stones with urinary tract infection (UTI).

Material and Methods

We performed a retrospective evaluation of the imaging and clinical findings in a series of six patients with gas-containing renal stones and compared them with those of patients with the same condition reported in the literature. Patients were collected from the teaching files of five different institutions. Stone cultures and urine cultures were used as a diagnostic standard for UTI. Categorical

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variables were reported as number and percentages; continuous variables were reported as mean ± standard deviation (SD). This research study was conducted retrospectively from data obtained for clinical purposes and teaching files. Informed consent was not required by institution policy.

Results

Patient series

Case 1. A 69-year-old woman was admitted for acute right-sided flank pain, urosepsis, and dysuria. She had a history of hypertension. Ultrasound revealed hydronephrosis and stones in the right renal pelvis. Computed tomography (CT) confirmed multiple stones and showed they had gas in their center. A small stone was obstructing the ureterovesical junction and a small quantity of gas was visible in the urinary bladder (no history of prior catheterization was recorded). After contrast medium injection, no CT features of parenchymal infection were observed (Fig. 1). Urine and blood cultures resulted negative at this time. She passed the small obstructing stone spontaneously and elective percutaneous nephrolithotomy was performed after two weeks. Recovery was uneventful; stones were composed of struvite and their culture revealed the presence of *Citrobacter freundii*.

Case 2. A 78-year-old diabetic woman with a long history of renal stones and recurrent UTIs developed pneumaturia. At unenhanced CT, the left kidney had several small-volume stones with gas-containing centers and gas was visible in the dilated pelvis and in urinary bladder (Fig. 2). Urinary culture identified *Proteus* and *Pseudomonas*. The patient started antibiotic therapy and refused stone removal. No sign of sepsis developed during follow-up.

Case 3. A 74-year-old man, with a history of transurethral resection of the prostate (TURP), hypertension, and colonic diverticula was referred for chronic left flank pain. Unenhanced CT revealed grade I dilatation of the left renal pelvis with some stones. The largest (18 mm) had gas in its center (Fig. 3). No gas was identified within the urinary tract. A ureteric stent was placed to prevent further hydronephrosis and the patient was submitted to endoscopic lithotripsy. During surgery, after the rupture of the largest stone, the patient developed high fever and sepsis. Antibiotic therapy with meropenem and amikacin was given, and the patient recovered. Both blood and urine cultures revealed the presence of *Escherichia coli*. No cultures were done on the stone fragments.

Case 4. A 59-year-old hypertensive woman underwent surgery for cancer of the left breast. On postoperative day 1, she developed right flank pain and fever. Unenhanced CT showed a slightly swollen kidney with mild perirenal stranding, a gas-containing stone in a mildly dilated renal pelvis, and two smaller stones at caliceal level. Air was visible within both the renal pelvis and urinary bladder. After contrast injection, delayed and diffuse heterogeneous enhancement of the renal parenchyma was observed (Fig. 4). Urine cultures grew *E. coli*. The patient underwent antibiotic therapy with levofloxacin as well as endoscopic lithotripsy which made her stone-free. Cultures of the stone fragments were not taken.

Case 5. A 75-year-old woman with a history of prior kidney stones, left renal artery stenosis, dyslipidemia, and aortic aneurysm was referred for left flank pain and high fever. Unenhanced CT showed, on the left side, mild hydronephrosis, perirenal and periureteral fat stranding, and a single gas-containing stone localized within the lower renal calyces. There was no air in the renal pelvis or the urinary bladder. No obstructive stones were seen. Urine cultures demonstrated *E. coli* infection. A ureteric stent was positioned, and the patient was placed under antibiotic therapy with amoxicillin/clavulanic acid. Endoscopic lithotripsy was performed after resolution of urinary infection.

Case 6. An 88-year-old hypertensive, diabetic woman in chronic peritoneal dialysis was referred for urosepsis and worsening anemia. The patient had a history of recurrent UTIs and a previous CT diagnosis of small kidneys with bilateral staghorn stones. At a new CT study, the staghorn stones were unchanged but the left one demonstrated internal gas. Gas was also visible in the dilated pelvis and calyces, ureter, and urinary bladder. A small amount of intraparenchymal gas was also within the upper pole of the left kidney, with adjacent perirenal fat stranding. Both blood and urine cultures grew *E. coli*. Multiple co-morbidities made surgery impossible; the patient underwent antibiotic therapy and urinary infection improved. A follow-up CT scan obtained six days later revealed disappearance of gas in the left renal parenchyma, reduction of the left perirenal stranding, and marked bilateral reduction of the air in the urinary tract. Despite the improvement of the abdominal disease, the clinical course was complicated by COVID-19 pneumonia and the patient died two weeks later.

Literature analysis

To the best of our knowledge, including the present series, there is a total of 21 patients (17 women [80.9%], 4 men; mean age = 60 years; age range = 43–77 years) with gas-containing renal stones in the literature (3–14). Demographic information including age, associated diseases, and clinical presentation are summarized in Table 1.

Radiological findings. All patients had gas containing renal stones; they were a unilateral finding in all cases (10 on the left side); they were single in 10 cases (three defined as staghorn stones), and although five patients had history

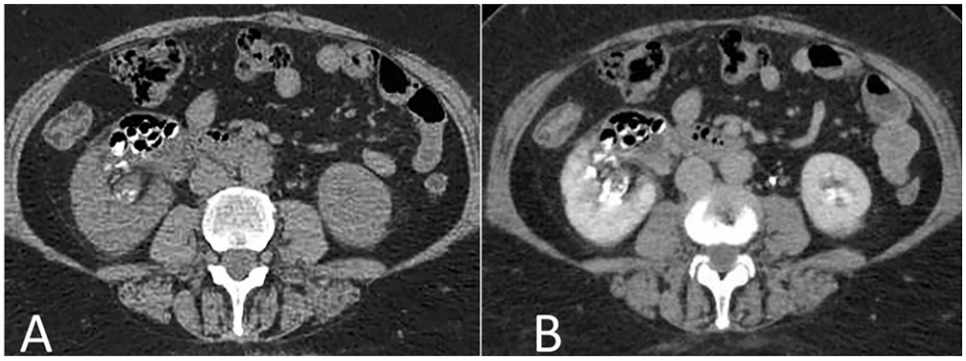

Fig. 1. Case 1. A 69-year-old woman. (A) Unenhanced CT reveals a dilated pelvis of the right kidney within several small stones characterized by gas in their center. (B) Delayed phase CT demonstrates homogeneous parenchymal enhancement. CT, computed tomography.

of prior stone disease, they were associated with stones in the contralateral kidney in one case only.

Presence of gas within the renal pelvis was reported in six patients (30%) and in the urinary bladder in four. Intraparenchymal gas was noted in only one case of the present series and was not described in any of the literature.

Only three patients of the present series had contrast-enhanced CT and two showed heterogeneous parenchymal enhancement of the affected kidney (one with intraparenchymal gas). With regard to the patients from the literature survey, 11 were examined with unenhanced CT only (either specifically described or from analysis of the published images), and among the four who had contrast injection, one who had dilatation of the renal pelvis, showed delayed parenchymal enhancement. None demonstrated a fistula track or had any recent endoscopic and/or percutaneous procedures reported.

Clinical findings. Symptoms and signs suggesting urinary infection were noted in 10 cases (five defined as affected by urosepsis, three reported with flank pain and sepsis, and two with flank pain and fever) and this condition could also be suspected in the two cases with pneumaturia; on the contrary, symptoms that did not immediately suggest a urinary infection were seen in the remaining nine cases (five flank pain only, two flank pain and hematuria, one hematuria only, and one non-specific fever).

All patients had co-morbidities: there were 6 (28%) who were diabetic; 10 (47%) who had hypertension; 2 (10%) were under chronic steroid therapy; and 1 (5%) was in peritoneal dialysis. History of recurrent stone disease was recorded in 7 (30%), of whom 1 (5%) had hyperparathyroidism. There were 2 (10%) patients with congenital renal malformation (one horseshoe kidney, one crossed fused renal ectopia) and 1 (5%) had a neurogenic bladder.

Urine cultures were obtained in 20 of 21 patients and were positive in 18. Of them, 14 (70%) grew *E. coli*, 2 (10%) grew *Klebsiella*, 1 (5%) grew *Proteus* and *Pseudomonas*, and the last *Staphylococcus* (5%).

The stone culture was obtained in 10 cases and resulted positive in 6 (60%) of them. Five had both stone and urine cultures positive, three had *E. coli* in both, one was positive for *E. coli* in the urine and for *Staphylococcus* in the stone, and one had *E. coli* in the urine and *Klebsiella* in the stone. One patient had positive stone culture for *C. freundii* and negative urine culture. In the whole group of 20 patients who had cultures performed, no bacterial growth in both the urine and the stone was observed in one case only (10).

Six patients did not undergo intervention for the stones (three due to poor clinical conditions, two refused surgery, and one improved with medical therapy after retrograde stent placement); among them, one died of unrelated causes and one died due to septic shock and renal failure. There was one patient who underwent nephrectomy; 13 were submitted to a variety of procedures and no information on management was available for the remaining case.

Discussion

The first patient with a gas-containing renal stone was reported by Frija et al. in 1982 (3). Since then, only 20 additional cases with this condition (including the present series) have been described. Although an uncommon condition, an increased number of cases has been recently published, suggesting increasing prevalence over time.

In 2012, Manny et al. (10) reported on five consecutive patients seen over a period of 20 months at their institution starting in 2009. Since they did not find any cases with this condition in the preceding 20 years, they suggested that changes in microbiology, a shift towards patients with co-morbidities, or the widespread use of CT in urologic practice could explain the increased incidence at their institution. We believe the latter of the given reasons, that is the increasing use of CT in urologic patients is, most probably, the reason why gas-containing renal stones are increasingly

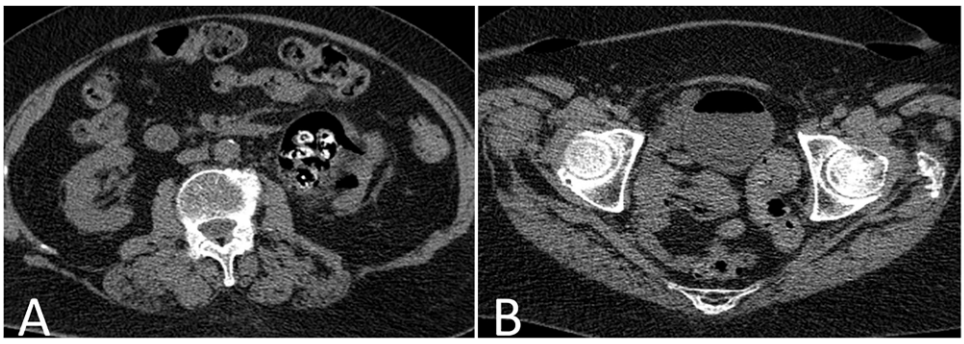

Fig. 2. Case 2. A 78-year-old woman. (A) Unenhanced CT reveals a left kidney with reduced cortical thickness and several small-volume stones with gas-containing center in the dilated pelvis. Free gas was seen in the renal pelvis. (B) A large amount of gas is visible also in the urinary bladder. CT, computed tomography.

diagnosed. In fact, the first case reported of this condition was in 1982, with the diagnosis made through CT demonstration of gas within the stone in a patient with hematuria (3). In the 21 reported cases, stones were visible on plain radiographs or urography in six cases (4,5,7,10,12), and on CT in all other cases; furthermore, CT was always used to confirm the findings after identification using radiography.

All patients had risk factors for increased susceptibility to UTI or prior history of renal stones; urinary stasis, induced by the stones themselves or from congenital anomalies, can be a factor predisposing to infection.

Although some patients showed signs of urosepsis and UTI could be suspected in those with pneumaturia, many cases did not have any sign of acute infection, presenting with flank pain and/or hematuria only. Identification of gas within the stone was therefore the first finding indicating possible infection, which was later confirmed by urine and/or blood cultures. Therefore, it can be considered that identification of gas-containing renal stones is suggestive of infection even when this cannot be suspected on clinical grounds only.

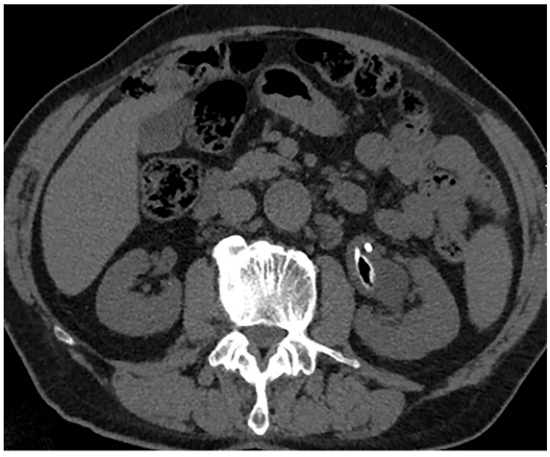

Fig. 3. Case 3. A 74-year-old man. Unenhanced CT revealed grade I dilatation of the left renal pelvis, which contained a few stones. The largest (18 mm) is characterized by gas in its center. CT, computed tomography.

Renal infection can be the cause of severe complications and extended hospitalization. Of the two patients who died, one died due to this infection (14) and one underwent nephrectomy (4); in all other cases, the kidney could be spared and intervention on the stones was possible in most of the patients.

The present study has some limitations. The most important is the retrospective nature of this narrative synthesis. From our data, it is difficult to confirm, in each patient, whether the stones represent the primary source of infection or had become infected from bacteria within the urine. In fact, only a part of the analyzed stones demonstrated a positive stone culture. On the other hand, gas-containing renal stones resulted in having high positive predictive value of UTI considering both urinary and stone cultures. Another limit of this retrospective study is the impossibility to draw a firm conclusion if gas-containing stones represent an acute infection. In this regard, Paterson et al. (6) described a case of gas-containing stone with positive urinary culture with remaining gas within the renal stone after antibiotic treatment and resolution of symptoms and urine culture.

However, our results show that gas-containing stones are associated with the presence of UTIs. Positive cultures were found, in fact, in 18 of 19 cases (95%), with only one case showing no bacterial growth in both the urine and the stone (5%) (10). In the remaining case, the information was not available (1).

As a final point, we want to underline that although case series are often regarded as studies with poor scientific evidence, it must be remembered that renal stones containing gas are rare (we have been able, in fact, to collect only a small number of cases, even with cooperation among five different institutions) and that it is difficult to gather evidence on how to diagnose and treat rare conditions. We believe that in these diseases a retrospective collection of

Table 1. Summary of clinical histories of reported patients with gas-containing renal calculi.

Case No. Author (year)	Age (years)	Sex	Co-morbidities	Stone	Stone culture	Urine culture	Gas in urinary tract	Abnormal renal enhancement	Management	Presentation
1. Frija (1982)	61	F	Liver cirrhosis	Right, one	NA	NA	NA	NA	Conservative	Hematuria
2. Simpson (1898)	68	M	Replacement therapy with thyroxine steroids, testosterone	Left, multiple	*E. coli*	*E. coli*	No	NA	Nephrectomy	Flank pain, sepsis
3. Nilsen (2001)	65	F	Prior stone disease	Right, multiple	NA	*E. coli*	No	NA	Percutaneous nephrostomy followed by percutaneous nephrolithotomy	Urosepsis
4. Paterson (2002)	46	M	Primary hyperparathyroidism; crossed fused renal ectopia	Left, one, staghorn	No growth	Klebsiella	Yes	No	Percutaneous nephrolithotomy	Recurrent UTIs, pneumaturia
5. Kiris (2004)	65	f	Horseshoe kidney	Left multiple	NA	*Klebsiella*	Yes	Delayed enhancement	Nephrolithotomy	Urosepsis
6. Rapoport (2006)	65	F	Diabetes, hypertension, sarcoidosis, chronic use of steroids	Right, multiple	NA	*E. coli*	No	NA	Ureteral stent	Urosepsis
7. Manny #1 (2011)	31	F	Gout	Left, one	*E. coli*	*E. coli*	No	NA	Robotic extended pyelolithotomy	Flank pain, hematuria
8. Manny #2 (2011)	37	F	Diabetes, hypertension	Left, one	*Staphylococcus aureus*	*E. coli*	No	NA	Ureteral stent, then percutaneous nephrolithotomy	Flank pain
9. Manny #3 (2011)	42	F	Hypertension, prior stone disease	Left, one	No growth	*E. coli*	No	NA	Ureteral stent, then percutaneous nephrolithotomy	Flank pain
10. Manny #4 (2011)	45	F	Diabetes, hypertension	Right, multiple	No growth	*Staphylococcus*	No	NA	Percutaneous nephrostomy, then percutaneous nephrolithotomy	Flank pain
11. Manny #5 (2011)	47	F	Diabetes, prior stone disease	Right, one	No growth	No growth	No	NA	Percutaneous nephrostomy, then	Flank pain

(continued)

Table 1. (continued)

Case No. Author (year)	Age (years)	Sex	Co-morbidities	Stone	Stone culture	Urine culture	Gas in urinary tract	Abnormal renal enhancement	Management	Presentation
									percutaneous nephrolithotomy	
12. Durhan (2015)	60	F	Epilepsy, hypertension, hemiplegia	Right, multiple	NA	*E. coli*	Yes	No	Medical therapy, death	Fever
13. Wazzan (2019)	32	F	Recurrent UTI and prior stone disease	Right, multiple	NA	*E. coli*	No	No	NA	Flank pain, hematuria
14. Peter (2020)	68	M	Coronary heart disease, hypertension	Left, one, staghorn	*Klebsiella*	*E. coli*	No	NA	Percutaneous nephrolithotomy	Flank pain, fever
15. Benjamin (2020)	92	F	Parkinson, neurogenic bladder	Right, one	NA	*E. coli*	No	NA	Conservative management	Fever, urosepsis
16. Zawaideh #1 (2021)	69	F	Hypertension	Right, multiple	*Citrobacter freundii*	No growth	Yes	No	Percutaneous nephrostomy, then percutaneous nephrolithotomy	Urosepsis, flank pain
17. Zawaideh #2 (2021)	78	F	Diabetes	Left, multiple	NA	*Proteus*, *Pseudomonas*	Yes	NA	Conservative management	Recurrent UTI, pneumaturia
18. Zawaideh #3 (2021)	74	M	Hypertension, prior TURP, Colon diverticula	Left, multiple	*E. coli*	*E. coli*	No	NA	Ureteral stent, then percutaneous lithotripsy	Flank pain
19. Zawaideh #4 (2021)	59	F	Breast cancer, hypertension	Right, multiple	NA	*E. coli*	No	Heterogeneous enhancement	Ureteral stent, then endoscopic lithotripsy	Flank pain, fever
20. Zawaideh #5 (2021)	75	F	Dyslipidemia, aortic aneurysm, treated left renal artery stenosis, prior stone disease	Left, one	NA	*E. coli*	No	NA	Ureteral stent, then endoscopic lithotripsy	Flank pain, urosepsis
21. Zawaideh #6 (2021)	88	F	Hypertension, diabetes, peritoneal dialysis, recurrent UTI, prior stone disease	Bilateral, staghorn Gas in left one	NA	*E. coli*	Yes	Gas in parenchyma; heterogeneous enhancement	Conservative management	Urosepsis

NA, not available; TURP, transurethral resection of the prostate; UTI, urinary tract infection.

cases, although with its inherent limitations and biases, is probably the highest level of evidence that can be available currently (15).

In conclusion, gas-containing renal stones are a rarely reported entity that is usually diagnosed with CT. This narrative synthesis demonstrates that gas-containing renal stones are a radiological sign often associated with UTIs that can also be encountered in patients with non-specific renal symptoms. Radiologic identification should prompt a search for the causative organism with blood and urine cultures, as well as of the stones themselves.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship and/or publication of this article.

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References

1. Huang J, Tseng C. Emphysematous pyelonephritis: clinicoradiological classification, management, prognosis and pathogenesis. Arch Intern Med 2000;160:797–805.
2. Roy C, Pfleger DD, Tuchmann CM, et al. Emphysematous pyelitis: findings in five patients. Radiology 2001;218:647–650.
3. Frija J, Tuil R, Katz M, et al. Gas in a pyelic calculus. J Radiol 1982;63:207–208.
4. Simpson AD, Rytina ER, Ball RY, et al. Stones, gas and gaiters: gas-filled matrix calculi of the renal pelvis. Br J Urol 1998;81:770–772.
5. Nilsen FS, Karlsen SJ, Gjertsen O. Gas-containing renal stones treated with percutaneous nephrostolithotomy: case report. J Endourol 2001;15:915–917.
6. Paterson RF, Welsch JM, Koerner T, et al. Urinary calculus containing gas. Urology 2002;60:164III–164V.
7. Kiris A, Ozdemir H, Bozgeyik Z, et al. Ultrasonographic target appearance due to renal calculi containing gas in emphysematous pyelitis. Eur J Radiol Extra 2004;52:119–121.
8. Rapoport MJ, Sadah AY. Gas-containing renal stones. Urology 2006;890.e13–890.e15.
9. Manny TB, Manny JS, Hemal AK. Transmesocolic robotic extended pyelolithotomy of a large gas-containing renal stone: Case report and review of the literature. Urol Ann 2013;5:126–128.
10. Manny TB, Mufarrij PW, Lange JN, et al. Gas-containing renal stones: findings from five consecutive patients. Urology 2012;80:1203–1208.
11. Wazzan MA, Abduljabbar AH. Gas containing renal stone - case report. Urol Case Rep. 2019;25:10088.
12. Peter J, Bhat S, Paul F. Gas-containing renal stones. Indian J Urol 2020;36:67–68.
13. Benjamin LTY, Lim SK, Koh L. Gas-containing renal stones: a case report and literature review. Surgery Case Reports. DOI: 10.31487/j.JSCR.2020.01.08
14. Durhan G, Ayyildiz VA, Ozmen M. et al. Gas containing renal stone: a fatal sign. Causapedia 2015;4:1188.
15. Patel A, Oszahim M, Mirimanoff RO, et al. The rare cancer network achievements from 1993 to 2012. Rare Tumors 2012;4:e35.