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Gas-Containing Renal Stones: Findings from Five Consecutive Patients

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Abstract

OBJECTIVE—To describe the clinical course, microbiology, and metabolic findings of five patients presenting to our institution with gas-containing renal stones.

MATERIALS & METHODS—Over a 20 month period beginning in 2009, five patients were identified by computed tomography scanning to harbor gas-containing renal calculi. Despite similar imaging and referral practice patterns, no such cases had been seen at our institution in the preceding 20 years. The records of these patients were reviewed to better characterize this unique condition.

RESULTS—All five subjects were premenopausal women. One patient presented with urosepsis while the other four had flank pain. All had urinary tract infections, and *Escherichia coli* was isolated from a voided urine specimen in three. Stone culture was positive in two and was concordant with the voided specimen in one. Stones were solitary in four and multiple in one. All stones were composed of calcium phosphate. Three were pure, and two had calcium oxalate monohydrate components. Three subjects had diabetes mellitus, three were hypertensive, and one had a history of gout. Two subjects underwent 24 hour urine metabolic testing, and abnormalities were identified in both. All patients were rendered stone free: four with percutaneous nephrostolithotomy and one via robotic pyelolithotomy.

CONCLUSIONS—Gas-containing renal stones are rare but may be increasing in prevalence. The pathophysiology is unknown but is most likely influenced by a combination of metabolic and infectious factors.

Keywords

Calcium; Phosphate; Gas; Nephrolithiasis; Pyelonephritis; Robotics

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CONFLICTS OF INTEREST:

Ted B. Manny, M.D. – none

Patrick W. Mufarrij, M.D. – none

Jessica N. Lange, M.D. – none

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INTRODUCTION

Gas in the collecting system or within the renal parenchyma can occur in a variety of circumstances. The presence of gas in the upper urinary tract along with renal calculi has been described in the setting of recent urinary tract instrumentation, emphysematous renal infections, and gastrointestinal and pulmonary fistulas involving the urinary tract.¹ Rarely, however, have renal stones been reported to contain gas within them. Only four cases have been previously described in the literature, and all were isolated case reports.²⁻⁵ Herein, we report our recent experience with a cluster of five new cases of gas-containing renal calculi.

MATERIALS & METHODS

After gaining approval from our Institutional Review Board, the records of five patients with gas-containing renal calculi managed at our institution from November 2009 to July 2011 were reviewed. Data on demographics, comorbidities, clinical course, surgical intervention, urinary microbiology, stone composition and culture, and metabolic evaluation were extracted and characterized.

RESULTS

All five patients were premenopausal females ranging in age from 31 to 47 years with a mean age of 40.4 ± 6.5 years (Table 1). The mean body mass index was 28.4 ± 8.3 kg/m². Initial manifestations included flank pain in four and sepsis in one. The youngest patient was referred four weeks post-partum, as her stone was initially identified during the third trimester of pregnancy. Three subjects had diabetes mellitus, two of which were poorly controlled. Three subjects had hypertension, and one had a history of gout. Two patients also had a history of nephrolithiasis, but neither required prior intervention. The compositions of their initial stones were unknown.

All patients were evaluated with computed tomography which demonstrated hydronephrosis of all involved renal units and normal appearing renal parenchyma. A solid component was dominant in three of the patients' stones while gas comprised the major portions of the other two. Two patients also underwent abdominal radiography, and gas was apparent in the stones in each of these cases. The largest stone dimension for each respective case (as measured on computed tomography) ranged from 2.1 to 6.5 cm. Four had solitary gas-containing stones, and gas was seen within all stones in the subject harboring multiple stones. Contralateral calculi were not demonstrated in any patient. Stones were located in the right kidney in two patients, and in the left kidney in the remaining three. Stones were located in the renal pelvis in all five cases, and one patient with multiple stones also had calyceal calculi.

Preoperative voided urine cultures grew *E. coli* in three patients and *Streptococcus bovis* and *Staphylococcus* species in the other two (Table 1). All patients initially received broad-spectrum antibiotics which also covered the aforementioned cultured organisms for at least one week prior to stone removal. Initial emergent or urgent urinary drainage procedures were performed in four of the patients prior to stone removal (percutaneous nephrostomy tube placement in three and retrograde stent placement in one). Four patients ultimately underwent percutaneous nephrostolithotomy (PCNL) in which stone was removed with a dual ultrasound device (CyberWand™) and grasping devices. The remaining patient underwent a robot-assisted trans-peritoneal pyelolithotomy without prior drainage. Three patients were rendered stone free with one PCNL, and one patient required a second PCNL for removal of the remaining stone material. Intraoperatively, all stones were noted to have hollow cavities and obvious crystalline components alternating with striking areas of soft

texture. All patients were rendered stone free, defined as no residual fragments of any size on postoperative computed tomography scanning shortly after their respective surgical interventions. At a mean follow up of 3.4 months (range 1–5), all patients remained stone free on surveillance imaging with combined ultrasonography and plain abdominal radiography. No intraoperative or postoperative complications occurred as based on the Clavien-Dindo classification system.⁶

Culture of surgical stone specimens revealed no growth in three patients, coagulase-negative *Staphylococcus* in one patient, and *E. coli* in one patient. Both patients with positive stone cultures had growth of *E. coli* from their preoperative voided urine cultures. On gross examination, all stones appeared to be partly composed of large areas of soft, “mushy” consistency. Specifically, the large 6.5 cm stone removed via robotic pyelolithotomy was subsequently desiccated and, upon sectioning, was noted to have multiple lamellae with multiple interspersed hollow compartments (Figure 2).

The predominant stone component in these cases was hydroxyapatite (Table 1). Patient 2 had two separate specimens from the same stone sent for compositional analysis. Postoperative metabolic evaluation was performed in two patients, with one patient demonstrating hypocitraturia, hypercalciuria, hyperoxaluria, hyperuricosuria, and increased sodium excretion and the other patient hypocitraturia and low urinary volume.

COMMENTS

Renal stones containing gas are very rare. A total of nine cases including this series have been reported. The characteristics of the prior cases are listed in Table 2. The majority of subjects have been female. This is not unexpected as patients of this gender are more susceptible to developing urinary tract infections (UTI). Co-existent medical co-morbidities were common including some associated with stone risk such as diabetes mellitus, gout, hyperparathyroidism, and sarcoidosis. Five of the nine subjects had prior stone events. Some patients manifested with sepsis while the presentation was indolent in others. One patient underwent nephrectomy as a consequence of deteriorating clinical status.²

The genesis of these stones is multi-factorial, but both metabolic and infectious factors appear to be involved. The predominance of hydroxyapatite as a stone component, the associated medical co-morbidities, and abnormal urinary stone risk parameters demonstrated in some of the subjects provide an aggregate of inferential evidence supporting the role of metabolic factors. Calcium phosphate composition has been increasing in incidence since the 1970s, is more common in women, and may be associated with UTI.^{7,8} The limited number of patients undergoing an assessment of urinary risk parameters does not permit further commentary about metabolic factors. We recommend that such studies should be considered in future cases to provide more information regarding etiologic factors. The role of infection is underscored by the presence of UTI in the majority of cases with *E. coli*, a known gas-forming pathogen. This was the most prevalent organism in our series as well as in the other reported cases. *Proteus*, *Streptococcus*, *Staphylococcus*, and *Klebsiella* species are also known to have this property.^{9–12} Gas production by bacteria is thought to be due to fermentation of glucose and other substances.^{13,14} Three of the patients in the present series had diabetes mellitus and thus may have had glucose in their urine. Other fermentative pathways including those of lactate, butyrate, butanediol, and propionic acid are also thought to play a role.¹⁵ This can result in the generation of formate which is converted to CO₂ and H₂. Analyses of gas generated in emphysematous UTI demonstrated the presence of the latter two gases and also nitrogen and oxygen.¹⁶ The presence of the latter two gases is thought to be due to equilibration with surrounding tissues which have high concentrations of oxygen and nitrogen. *Proteus* species are also capable of producing hydrogen sulfide

gas.¹¹ The consistency of these stones is soft, and this may be due to the dissection of the gases through the metabolic scaffold. While increased urine pH promotes the formation of calcium phosphate stones, this did not appear to be a major driving force in the generation of stones in our study, as pH was normal or reduced; the latter profile being expected due to the majority being diabetic.¹⁷

The previously reported cases of gas-containing calculi were over an eight year span. In contrast, within a 20 month period, we observed this phenomenon in five patients and did not encounter any such cases in the previous two decades despite similar referral and practice patterns. The reasons for this recent increased incidence at our institution are unclear but perhaps can be attributed to a change in microbiology, a demographic shift towards patients with increased co-morbidities such as obesity and diabetes mellitus that predispose them to UTIs and nephrolithiasis, and/or to a selection bias due to the increased utilization of cross-sectional computed tomography imaging in current medical practice.

Surgical stone removal is required in the management of these patients because of the threat of sepsis and renal damage if no treatment is undertaken. Four of the patients in our series underwent initial decompression of the collecting system including an internalized stent in one and percutaneous nephrostomy tubes in three. It was thought that this approach might limit the risk of sepsis, a postoperative problem that did not occur in our series. However, proceeding directly to stone removal is an option if the patient has no signs of sepsis. This approach was used in one of our patients and in one of the reported cases. We feel that perioperative antibiotic therapy with broad-spectrum agents that also cover the pathogen isolated from voided urine as well as other potential organisms that may be in the stone should be undertaken. We also advocate stone culture because of the potential discordance with voided urine culture, as this provides more timely directives for antibiotic therapy if the patient develops sepsis. We believe that PCNL is the preferred method of removing these stones. While the first patient in our series underwent successful robotic pyelolithotomy, this was before we knew about the soft consistency of these stones which could increase the risk of stone fragmentation and spillage during extraction resulting in bacterial seeding of the peritoneal cavity.

CONCLUSIONS

Gas-containing renal stones are rare and are likely due to a combination of metabolic and infectious factors. Female patients with diabetes mellitus may be most susceptible. Proper patient preparation including both targeted and broad-spectrum antibiotic therapy, initial renal drainage in those with any signs of sepsis, and eventual PCNL appear to be steps of successful management.

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Figure 1.
A–E – Computed tomography images of gas-containing stones

Figure 2.
Sectioned large left gas-containing renal stone

Table 1

Characteristics of Present Series

	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5
Age	31	37	42	45	47
Sex	F	F	F	F	F
Presentation	Flank Pain, Hematuria during Pregnancy	Urosepsis	Flank Pain	Flank Pain	Flank Pain
Comorbidities	Gout	DM, HTN	HTN, Recurrent Nephrolithiasis	DM, HTN	DM, Recurrent Nephrolithiasis
Stone Composition	100% CaP (hydroxyapatite)	100% CaP (hydroxyapatite)	88% CaP (hydroxyapatite) 12% COM (whewellite)	20% CaP (hydroxyapatite) 30% COD (weddelite) 50% Matrix	100% CaP (hydroxyapatite)
		78% ammonium hydrogen urate 22% magnesium ammonium phosphate (struvite)			
Preoperative Urine Culture	<i>E. coli</i>	<i>E. coli</i>	<i>E. coli</i>	<i>Staph</i>	No Growth
Preoperative Urinary pH	5.0	5.5	6.5	6.0	6.0
Largest Stone Dimension (Number of Stones)	6.5 cm (1)	2.5 cm (1)	2.5 cm (1)	4.5 cm (10)	2.1 cm (1)
Stone Location and Laterality	Left Renal Pelvis/UPJ	Left Renal Pelvis	Left Renal Pelvis/UPJ	Right Renal Pelvis and Calyces	Right Renal Pelvis/UPJ
Hydronephrosis ?	Yes	Yes	Yes	Yes	Yes
Stone Culture	<i>E. coli</i>	Coagulase-negative <i>Staph</i>	No Growth	No Growth	No Growth
Management	Robotic extended pyelolithotomy	Initial PCN, subsequent PCNL	Initial Stent, subsequent PCNL	Initial PCN, subsequent PCNL	Initial PCN, subsequent PCNL
Metabolic Abnormalities	NA	Hypocitraturia Hypercalciuria Hyperoxaluria Hyperuricosuria Hypemnatruria	NA	NA	Hypocitraturia, Hyperoxaluria, Hypercalciuria
Stone Free? (Follow-Up Period)	Yes (5 months)	Yes (3 months)	Yes (5 months)	Yes (1 month)	Yes (3 months)

F = female, DM = diabetes mellitus, HTN = hypertension, CaP = calcium phosphate, COM = calcium oxalate monohydrate, PCN = percutaneous nephrostomy, PCNL = percutaneous nephrostolithotomy, UPJ = ureteropelvic junction

Table 2

	Simpson et al. ²	Nilsen et al. ³	Paterson et al. ⁴	Rapoport et al. ⁵
Age	68	55	46	65
Sex	M	F	M	F
Presentation	Flank Pain, Sepsis	Flank Pain, Sepsis	Febrile UTI, Pneumaturia	Abdominal Pain, Sepsis
Comorbidities	Nephrolithiasis	Nephrolithiasis	Nephrolithiasis, Primary Hyperparathyroidism	Hypertension, DM, Chronic Renal Insufficiency, Sarcoidosis
Stone Composition	Matrix	Uric Acid	Hydroxyapatite	NA
Preoperative Urine Culture	<i>E. coli</i>	<i>E. coli</i>	<i>Klebsiella pneumoniae</i>	<i>E. coli</i>
Largest Stone Dimension (Number of Stones)	NR (multiple)	NR (multiple)	NR (1)	1 cm (multiple)
Stone Location and Laterality	Left Renal Pelvis and Calyces	Right Renal Pelvis	Branched Stone into Left Interpolar and Lower Calyces	Right Renal Pelvis, Calyces, and Proximal Ureter
Hydronephrosis?	Yes	Yes	Yes	Yes
Stone Culture	NA	NA	No Growth	NA
Management	Simple Nephrectomy	Initial PCN, subsequent PCNL	PCNL	Retrograde Stent Placement
Metabolic Abnormalities	NA	NA	Hypercalcemia	NA
Stone Free? (Follow-Up Period)	NR	Yes (12 months)	NR	NA

UTI = urinary tract infection, DM = diabetes mellitus, NA = not applicable, NR = not reported, PCN = percutaneous nephrostomy, PCNL = percutaneous nephrostolithotomy