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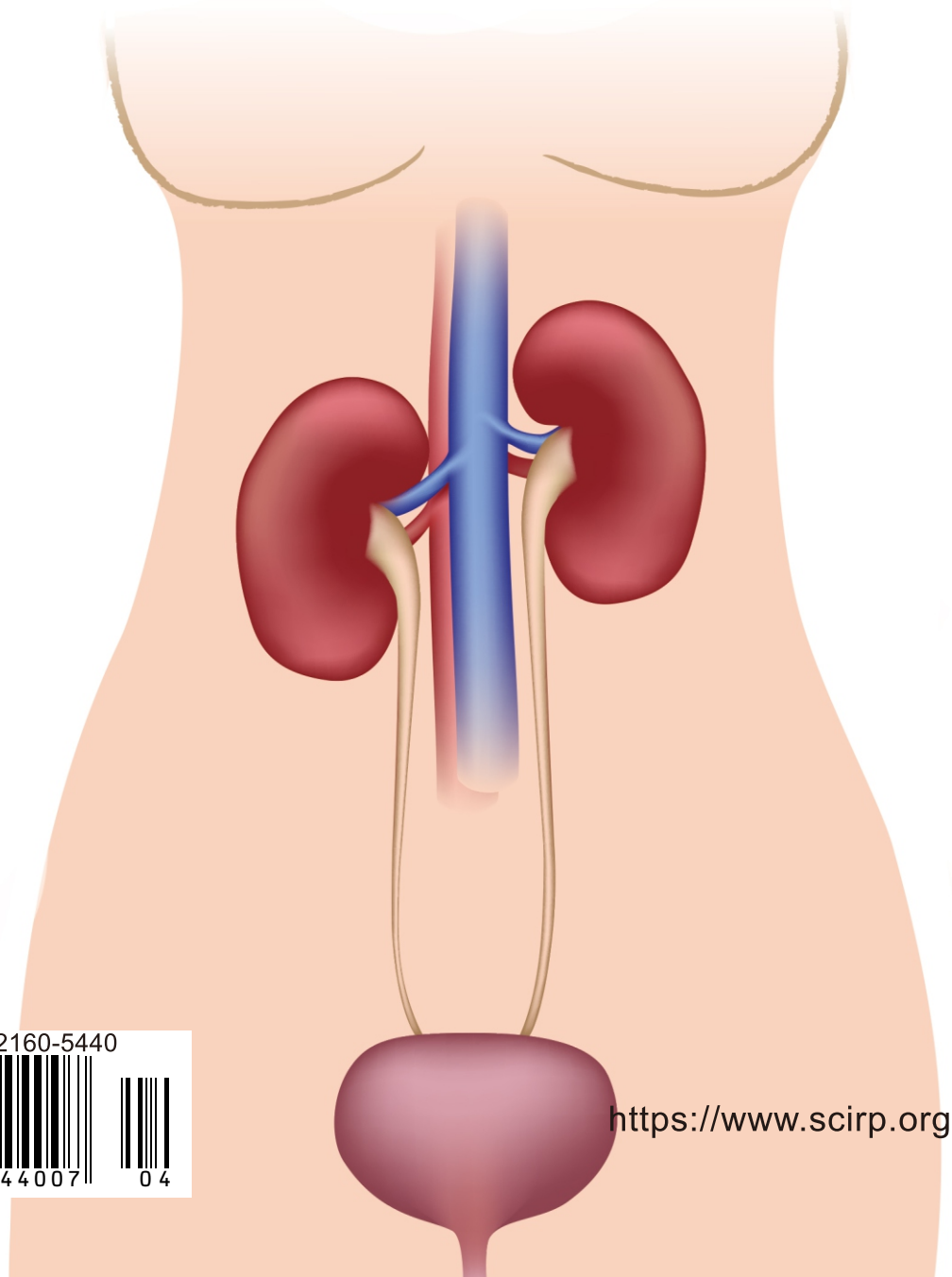

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Ureteric Stone Containing Gas: First Case Report with Review of Cases of Urolithiasis with Gas within the Stone and Its Clinical Implications

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Abstract

We report the first case of a ureteric stone containing gas. This rare stone with gas within it was found during the management of a diabetic patient with urosepsis as the initial presentation. Literature review of cases of renal stone containing gas, mechanisms of gas within the stone, and clinical implications of stone containing gas are discussed. Also, a new terminology is proposed to describe this phenomenon.

Keywords

Urolithiasis Containing Gas, Pyelonephritis, Pneumourolithiasis

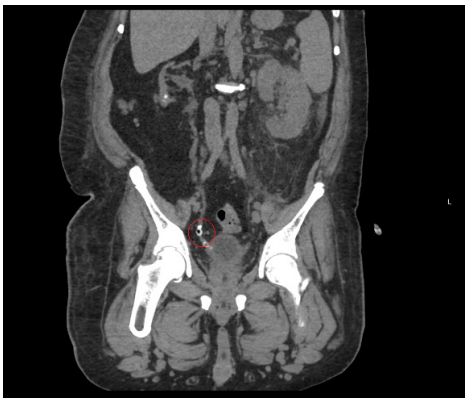
1. Introduction

Gas in the pelvicalyceal system (pyelitis) and/or gas in the renal parenchyma (emphysematous pyelonephritis-EPN) is a relatively common finding. However, gas trapped inside a stone (we propose a new term pneumourolithiasis to describe this condition) is exceedingly rare and was reported for the first time in 1998 [1]. Renal or ureteric stones containing gas are rare with 14 cases reported so far in our literature review. We report the first case of ureteric stone containing gas along with a literature review and discuss its pathogenesis, implications of these findings.

2. Case Report

A fifty-six-year-old diabetic male presented with abdominal distention, fever, and reduced urine output. On evaluation, he had generalized abdominal disten-

tion, along with high creatinine of 5.2 mg/dL, neutrophilic leucocytosis of 30,000/dL and pyuria. Non-contrast CT scan showed bilateral perinephric stranding (but no gas in the pelvicalyceal system or renal parenchyma), a small right kidney and a stone in the right ureter containing air within it (**Figure 1**). He required meropenem (for pyelonephritis) along with bilateral double J (DJ) stenting, after which sepsis settled, counts normalized and abdominal distention reduced. Intraoperative finding of turbid urine efflux from both ureteric orifices was noted during cystoscopy at the time of DJ stenting. The urine culture of this turbid urine showed *E. coli* sensitive to meropenem which was continued for 14 days. He settled clinically with antibiotics and DJ stenting but nadir creatinine remained at 3.8 mg/dL after 2 weeks. At that time, a functional study with a renal scan showed a right renal split function of 12%. He underwent a right ureteroscopy with stone fragmentation along with left DJ stent removal. During fragmentation, once the stone was fragmented with a holmium laser, the inner hollow part of the stone was exposed (**Figure 2**, **Figure 3**). The stone was rather soft easily breakable only with jaws of the ureteroscopic grasper. Stone analysis showed predominant calcium oxalate monohydrate stone (**Figure 4**). Stone culture corresponded to the urine culture. He had an uneventful recovery and the stent was removed after 2 weeks. Creatinine however remained 3.3 mg/dL after a period of 2 months of follow-up and urine culture became negative.



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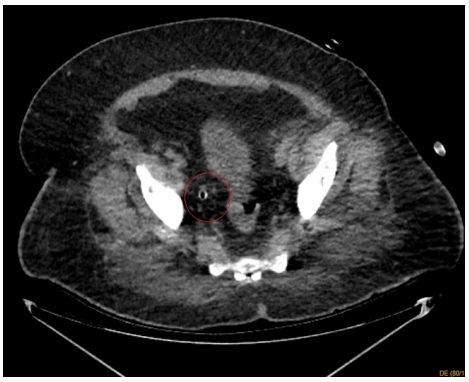


(b)

Figure 1. CT scan showing the stone and the gas within the stone.

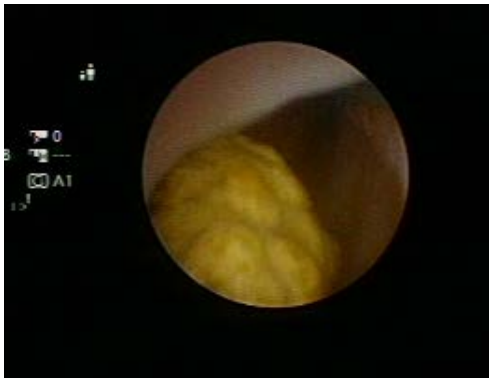


Figure 2. Intact stone visualised in the ureter before start of fragmentation.

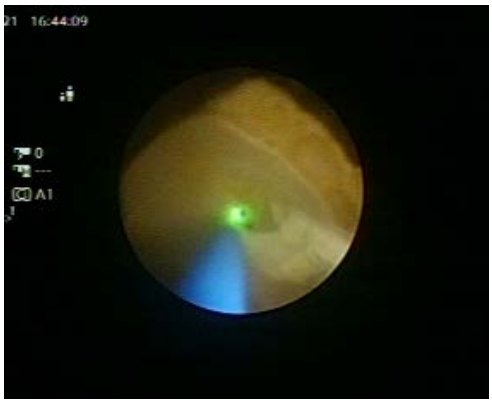
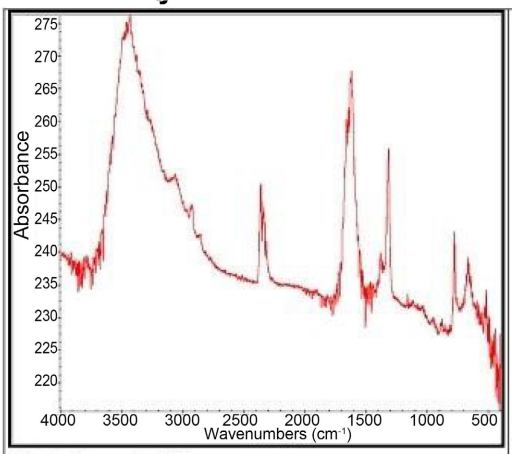
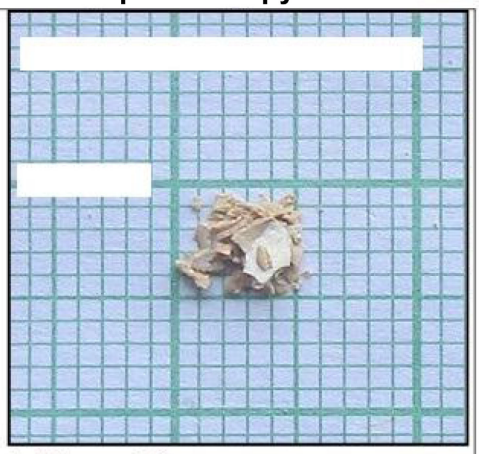


Figure 3. The stone broken with laser and the inner hollow shell exposed.

FT-IR Analysis: Fourier Transform Infrared Spectroscopy



Analysis graph of stone



Each Square = 1 Sq.mm

Principal Stone Components (Results):

Chemical Name	Approximate Percentage	Mineralogical Name	Formula
Calcium Oxalate Monohydrate	76%	Whewellite	*CaC204*H20*
Calcium Oxalate Dihydrate	16%	Whewellite	*CaC204*2H20*
Protein and Blood	08%		

Figure 4. Stone analysis showing calcium oxalate composition of the stone.

3. Discussion

Gas in the kidney (without any prior instrumentation or communication to the bowel) occurs due to gas-producing infection in the kidney (emphysematous pyelonephritis). A cumulative 14 cases of pneumourolithasis so far are reported including a series of 5 cases in the last 15 years, which are summarised in **Table 1** [1]-[10]. Current case is the first case of ureteric stone containing gas to be best of our knowledge. (Rapport has mentioned ureteric stones containing gas in the abstract, but in the full-text article review, the stones in the kidney were containing gas, not ureteric stones)

In presence of obstruction by stone and emphysematous pyelitis, gas formed will not be cleared quickly and will be incorporated inside the stone as it is being formed. Pneumourolithiasis without emphysematous infection of the kidney can also be explained by the bacteria within the stone producing gas, as gas is not seen in the rest of the renal pelvicalyceal system in the imaging in the cases reported. Looking at the cases cited in **Table 1**, we are of the opinion that if the stones are of matrix composition, then both these theories may be implicated in the formation of gas within the stone. But in the case, the stone is made up of

Table 1. Pubmed summary of cases of urolithiasis with gas within the stone.

Author	Clinical details	Treatment	Stone characteristics
Simpson, 1998 [1]	Left non functioning kidney; left pelviureteric junction obstruction with stones, urosepsis as initial presentation (IP), urine culture *E. coli*	Left nephrectomy	Matrix
Nilsen 2001 [2]	Pyonephrosis, urine culture *E. coli*	DJ stenting, later Percutaneous nephrolithotomy (PCNL)	Uric acid
Paterson 2002 [3]	Recurrent febrile UTI as presentation, hyperpathyroidism, left partial staghorn calculus, urine culture Klebsiella		Hydroxyapetiete, stone culture negative
Rapoport 2006 [4]	Radiopaque stones in kidney (containing gas) and ureter, sarcoidosis, diabetes, urosepsis as IP,	DJ stenting	Not mentioned
Manny 2012 [5]	5 young females with pelvic stones, 4 cases as urine culture —*E. coli* in 3 cases, Streptococcus and Staphylococci	PCNL (4 cases), Robot assisted pyelolithotomy (1)	Soft stones, hydroxyapetite, stone culture negative in 3
Durhan 2015 [6]	*E. coli* infection in nondiabetic 60 year female, sepsis	Death antibiotic treatment	CT scan reported as hyperdense stone
Wazzan 2019 [7]	1st UTI episode in 32 yr female. Only radiological features discussed	Not mentioned	No stone analysis mentioned.
Peter 2020 [8]	Left staghorn stone with perinephric collection in 68 year female Urine culture *E. coli*	PCNL	Stone culture Klebsiella
Ying 2020 [9]	92 year female with fever	Settled with only antibiotics	-
Hammad 2020 [10]	30 year female, associated emphysematous pyelitis, pneumoureter and pneumobladder	PCNL after 6 weeks	Matrix stone

calcium oxalate, as in our case, the possibility of the bacteria forming the gas within the stone is more likely. As in our case, *E. coli* is the most common infection which ferments sugar, but Klebsiella is not uncommon. Importantly urine culture does not always correlate to stone culture in the majority of cases in the review of earlier cases [5] [6]. Diabetes is the most common risk factor for infection (EPN) as high sugars will aid in the formation of sugars. Other factors reported in addition to sarcoidosis, hyperparathyroidism and gout.

Radiologically, it may be possible to see gas within the stone on a plain Xray [2]. But it is best seen in CT scans and characteristically, these stones tend to float in the renal pelvis, which can be appreciated in a CT scan done in the supine and prone position [2].

These stones are soft stones due to infection playing a role in playing its formation [5]. Stone analysis in earlier cases shows those stones to be hydroxyapatite, matrix and uric acid stones. Again calcium oxalate monohydrate in the analysis in our case is less commonly reported. As compared to a standard calcium oxalate stone, we feel the stone was softer (very easily breakable with only a ureteroscopic grasper after initial breakage with a laser). This may be due to gas being present in the scaffolding of the stone [5].

Clinically, the detection of pneumourolithasis has many implications. Even in absence of emphysematous infection in the kidney, aggressive treatment should be initiated as mortality in pneumourolithiasis without EPN is reported [6]. Stone culture should be sent routinely in such cases, as they do not always respond to urine culture [5]. Stone culture may be a better guide to antibiotic selection for any possible postoperative urosepsis [5]. Since the stones are soft, endourologic treatment options may be preferred to options like pyelolithotomy as there will be a high chance that stone may break down into fragments during removal and intact removal will be difficult [5].

4. Conclusion

Gas-containing stones are very rare and we report the first case of ureteric stone containing gas. It occurs due to gas-producing bacterial infection within the stone or the gas being incorporated into the stone during the emphysematous infection. Most commonly, these stones are found in diabetic patients. Finding gas within stone should prompt us to start aggressive antibiotic therapy guided by the stone culture which may be different from urine culture. Surgical therapy, initially DJ stenting and later definitive stone removal should consider the softness of the stones in decision making. Probably, endourologic options may be better than options like pyelolithotomy.

Informed Consent

Permissions were taken from the patients prior to the publication of case report.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Kidney Stones in Transfusion-Dependent Thalassemia: Prevalence and Risk Factors

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Abstract

Purpose: As patients with transfusion-dependent thalassemia (TDT) are living longer, novel morbidities are being recognized. The purpose of this review is to summarize the current knowledge regarding the prevalence and risk factors of nephrolithiasis in patients with TDT. *Methods*: A non-systematic, narrative review of the current literature published up to August 2021 was conducted. *Results*: Nephrolithiasis has been reported in 18% - 59% of patients with TDT, which is at least twice the prevalence in the general US population. The risk factors for nephrolithiasis can be classified into behavioral (dietary and lifestyle), environmental, metabolic, disease-specific, and genetic factors. While clarifying the true prevalence of nephrolithiasis in different age groups and diagnostic categories of TDT requires further research, prevention, and management of nephrolithiasis is a growing clinical concern. Physicians should be aware of the potential increased risk of stone disease in splenectomized and diabetic patients as well as those treated with certain chelation regimens. *Conclusions*: The etiology of nephrolithiasis and potential TDT-specific risk factors that may put patients at greater risk are highlighted. There is insufficient evidence at this time to recommend universal screening for nephrolithiasis using ultrasound. Evidence-based recommendations on monitoring, prevention, and management of nephrolithiasis in TDT are provided.

Keywords

Thalassemia, Nephrolithiasis, Kidney Stone, Etiology, Risk Factors

1. Background

Nephrolithiasis (kidney stone disease) is a disorder of mineral metabolism characterized by episodes of acute renal colic that often recurs accompanied by pain, nausea, and vomiting [1]. For those who suffer a stone, quality of life is reduced during the time surrounding the occurrence. At least 50% of all patients will experience recurrence of stone formation in their lifetime. Kidney stones are also associated with end-stage renal disease [2], decreased bone density, and increased fracture risk [3] [4] [5]. The prevalence of kidney stones in thalassemia patients has been estimated to be double that of the general population [1] [3] [6], but the true prevalence is unknown since large, population-based studies have yet to be conducted. As the life expectancy of patients with thalassemia increases, age-related conditions such as nephrolithiasis are becoming more common [7] [8]. A better understanding of the risk factors that predispose to nephrolithiasis in thalassemia will help develop primary and secondary prevention strategies.

1.1. Beta Thalassemia

Beta thalassemias are a group of inherited hematological disorders characterized by reduced synthesis of beta globin chains of the hemoglobin molecule. Beta thalassemia major is characterized by severely decreased production of beta-globin chains resulting in increased hemolysis, ineffective erythropoiesis, and severe anemia. These patients require chronic blood transfusions starting in infancy for survival. Beta thalassemia intermedia is characterized by a milder reduction in beta-globin production resulting in a less severe phenotype. Patients may need transfusion support later in life to suppress complications of ineffective erythropoiesis and worsening anemia. A key feature of transfusion-dependent thalassemia (TDT) is the development of iron overload from repeated red cell transfusions, which is a significant cause of morbidity and mortality secondary to liver cirrhosis, cardiac failure, and endocrinopathies such as hypogonadism, diabetes, osteoporosis, and hypothyroidism. Survival of patients with TDT has significantly increased in the last several decades due to advances in monitoring and treatment of iron load [9]. As patients are living into their sixties and beyond, chronic conditions such as nephrolithiasis, are emerging as a new challenge to their health and the quality of life [7] [8]. In the past decade, reviews have focused on risk factors related to renal dysfunction and proposed biomarkers for renal disease [10] [11] [12] [13] [14], yet there remains a paucity of evidence-based information for clinicians in monitoring nephrolithiasis, an increasing problem for patients with TDT.

1.2. Epidemiology of Nephrolithiasis

Currently, the prevalence of kidney stones in the general population is 9%, which represents a 70% increase since the 1990s [15]. Historically, kidney stones were most common among middle-aged white men, but the incidence of stones

has increased substantially among women, children, and African-Americans [16]. Though the cause of these shifts is unclear, hypotheses include increased use of diagnostic imaging, and increasing incidence of dietary, metabolic, and environmental impacts including global warming [17] (**Table 1**). There is also a growing awareness that nephrolithiasis can be associated with other chronic diseases, as exemplified by thalassemia, where prevalence estimates are as high as 18% to 59% [3] [18].

1.3. Types of Kidney Stones

Kidney stones are a consequence of pathophysiological biomineralization at the interface of the renal papilla or collecting duct with the urine, or seeded within the urine itself. Stone formation may be triggered by changes in saturation, solubility, hydrodynamics, or the balance between stone promoting and inhibiting constituents [19]. Most stones are calcium-based, and for this review, we will focus on risk factors for the most common, calcium oxalate stones. There is at least one report that patients with thalassemia may have a different profile of stone components, that is, both struvite and calcium oxalate type stones are equally observed [18], but this has not been well studied.

Table 1. Risk factors for nephrolithiasis in the general population.

Factor Category	Risk Factor
Dietary and Lifestyle Factors	High animal protein intake High fructose intake High sodium chloride intake Low fluid intake Low dietary calcium intake High dose vitamin C supplementation (>1000 mg/day) Low physical activity High dietary oxalate
Environmental Factors	Living in warm climates with daily temperatures > 30˚C Occupations with a high ambient temperature
Biochemical Factors	Hypercalciuria Hyperuricosuria Hyperoxaluria Hypocitraturia
Disease Associated Factors	Diabetes Obesity Metabolic syndrome Osteopenia/osteoporosis Neurogenic bladder Sarcoidosis Primary hyperparathyroidism Intestinal malabsorption

Adapted from information found in: Scales CD *et al.* 2016 [1].

2. Risk Factors for Nephrolithiasis in Patients with Thalassemia

In the general population, approximately 50% of the risk of nephrolithiasis is heritable [20]. The remainder of the risk is determined by modifiable (behavioral, environmental) and non-modifiable (metabolic, disease-associated) exposures. Few reports are available on the risk factors for kidney stones in thalassemia. Here we discuss the relevance of established risk factors in the general population to patients with thalassemia, highlighting the disease-specific features and metabolic abnormalities (Table 2).

2.1. Disease-Associated Factors

Several pathological conditions have been associated with an increased risk of developing kidney stones, including diabetes, hypertension, hyperlipidemia, and chronic kidney disease [21] [22]. Nephrolithiasis, therefore, may be just one manifestation of a more complex syndrome. In thalassemia, disease-specific factors are some of the most unique aspects of additional risk factors for nephrolithiasis, including splenectomy, increased erythropoiesis, iron overload and chelation therapy.

1) *Splenectomy and Excess Erythroblasts*. Splenectomy has been identified as a major risk factor for stone formation in thalassemia [6]. In one study, 91% of patients with kidney stones were splenectomized [6]. Higher circulating erythroblasts due to decreased clearance post-splenectomy may lead to increased urinary uric acid. Hyperuricemia and hyperuricosuria in patients with thalassemia may also be due to the increased cell turnover and higher number of erythroblasts as a result of the increased ineffective erythropoiesis [23]. Up to 40% of

Table 2. Proposed risk factors for nephrolithiasis in patients with thalassemia.

Factor Category	Risk Factors
Dietary and Lifestyle Factors	Low dietary calcium intake Calcium supplementation High dose vitamin C supplementation High fat mass per body mass index Low physical activity
Environmental Factors	Living in warm climates with daily temperatures > 30˚C.
Biochemical Factors	Hypercalciuria Hyperuricosuria Hyperoxaluria Hypocitraturia
Disease Associated Factors	Splenectomy Ineffective erythropoiesis Iron overload Iron chelation Diabetes Hypoparathyroidism

TDT patients have increased uric acid excretion. Patients with thalassemia intermedia have a high prevalence of hyperuricemia needing treatment as well as nephrolithiasis [6]. Further research is needed to evaluate the role of hyperuricemia and hyperuricosuria in the pathogenesis of nephrolithiasis in thalassemia.

2) *Iron Overload and Chelation Therapy*. Control of systemic iron burden is the most important determinant of morbidity and overall survival in thalassemia. However, Wong and colleagues found serum ferritin to be significantly lower in thalassemia patients with nephrolithiasis, suggesting a complex relationship with chelation therapy [3]. Urinary iron is elevated in thalassemia compared to the general population, although it is mostly present as iron-chelator complexes and varies widely, based on the type of chelator [24]. In the general population, the iron content in calcium-based kidney stones is highly variable (0.005 - 5.6 mg/g) [25], but comparable studies have not been published for iron-overload conditions such as thalassemia. Like calcium, iron excreted in the urine can bind to oxalate and phosphate anions, which might interfere with calcium mineralization and slow the rate of stone formation. However, iron binding to citrate and other important endogenous inhibitors of calcium oxalate nucleation, aggregation, and crystal growth can indirectly promote stone formation [26]. Interestingly, lower urinary iron excretion was correlated with poor shockwave lithotripsy success rates for calcium oxalate stones [27]. The balance of these chemical interactions of iron on lithogenic potential has not been defined for patients with or without iron overload.

Currently, the three options for iron chelation are deferoxamine, deferasirox and deferiprone. Each chelator has its own profile of efficacy, toxicity and acceptability, and some patients are prescribed a combination of two drugs to overcome these limitations. Of the three chelators, deferasirox has the greatest effect on renal function, causing a reversible mild elevation of creatinine and proximal tubular dysfunction; patients most affected appear to be those with low total body iron burden [10] [28] [29]. A few studies have suggested that deferasirox might increase the incidence of nephrolithiasis [8] [30]. However, baseline abnormalities in renal function are present in thalassemia irrespective of the chelation regimen [14]. Mean urinary calcium excretion is 3-fold higher compared with non-thalassemia controls in younger patients (4 - 23 years), with hypercalciuria observed in 36% [31]. Urine calcium excretion is significantly associated with proteinuria, but not with ferritin, serum creatinine, Cystatin C, beta2-microglobulin or creatinine clearance. Urine calcium excretion is greater with deferasirox compared with deferoxamine and is correlated with the dose of deferasirox. The effect of deferasirox on the incidence of nephrolithiasis was suggested by one retrospective study [30], but not by another [32]. Thus, baseline hypercalciuria is present in many patients with TDT from an early age, which may be exacerbated by deferasirox. The mechanism by which deferasirox increases tubular damage may be related to mitochondrial swelling from the excessive removal of iron from cells [28]. Prospective studies to evaluate the risk of nephrolithiasis using different chelators are lacking.

3) *Zinc*. Both insufficient and excess dietary zinc have been associated with a higher risk of nephrolithiasis in the general population [33] [34]. Urinary zinc loss is nearly 4 times higher in patients with thalassemia compared with controls [35], which is further increased in the presence of diabetes [36] and the use of iron chelators [37]. Zinc deficiency is observed in 18% of patients using deferiprone for chelation [37], and up to 30% of non-diabetic TDT patients [38]. However, the impact of zinc deficiency on the risk of nephrolithiasis in thalassemia has not been evaluated.

4) *Diabetes*. In the general population, diabetes is an independent risk factor for the development of kidney stones, increasing the risk by 29% - 60% [39]. The mechanism may be related to the effect of insulin resistance on ammoniagenesis and the resultant changes in urine composition, a lower urine pH, and hypercalciuria. Diabetes is a common complication of pancreatic iron overload in TDT occurring in approximately 20% [40] of adult patients, and thus could contribute to the risk of nephrolithiasis in this population.

2.2. Dietary and Lifestyle Factors

In the general population, vegetarians have reduced stone incidence due in part to low animal protein intake and higher intakes of citrate and phytate, which act as inhibitors of stone formation in the urine by competing for the binding of calcium and other minerals [19]. Elevated consumption of animal protein increases stone risk, presumably by increasing calciuria and uricosuria, reducing citrate excretion, and increasing oxaluria [41]. Elevated consumption of fructose increases urinary excretion of calcium, oxalate, and uric acid, and has therefore been associated with an increased risk of incident kidney stones among adults [42]. High dietary sodium chloride intake also increases stone risk by increasing calciuria and reducing urinary citrate excretion [43]. Diets containing average amounts of calcium, moderate protein, and low sodium content reduce the risk of kidney stone recurrence [44]. Although dietary risk factors have not been specifically studied in thalassemia, diets tend to contain less meat (purine-rich foods), sodium (processed food), and foods with high iron and zinc content (meats and seafood) due to nutrition and disease management recommendations [45].

Fluid intake has an inverse relationship with stone formation in the general population likely by increasing the dilution of minerals and other components in the urine [46]. Tea beverage consumption is encouraged in thalassemia since the bioactive components in tea including epicatechins decrease absorption of dietary non-heme iron [45] [47]. While tea consumption was associated with 10% fewer stones in the general population, in part due to higher urine output, its association with stone risk has not been specifically studied in thalassemia [43].

1) *Calcium*. In the general population, increasing dietary calcium progressively from one to five servings daily has been associated with a decreased risk of incident nephrolithiasis [43]. This seemingly paradoxical effect has been attributed

to dietary calcium-binding oxalate in the gut, which reduces intestinal oxalate absorption and urinary excretion. There is, however, a difference between dietary and supplemental calcium, with supplemental calcium increasing the risk of stone formation [48]. Many thalassemia patients avoid dairy foods, the optimal dietary source of calcium, due to either self-reported lactose intolerance, personal choice, or cultural beliefs [45]. The prevalence of hypolactasia can reach nearly 100% in East-Asian populations [49]. Given the majority of patients with thalassemia in North America are Asian, dairy avoidance leading to low dietary calcium intake is a concern. Calcium supplementation is used to fill the gap between inadequate dietary intake and the requirement for osteoporosis prevention. In one small case-control study evaluating renal calculi in patients with thalassemia on iron chelation with deferasirox or deferoxamine, vitamin D and calcium supplementation did not appear to increase the risk for stone formation [32].

2) *Vitamin D*. Vitamin D deficiency is common in patients with thalassemia due to limited sun exposure and avoidance of dairy foods that are usually fortified with vitamin D. High-dose, infrequent supplementation of vitamin D (50,000 IU every 3 weeks) has become an effective tool to improve vitamin D status. It is uncertain if daily or intermittent supplementation with vitamin D increases the risk of kidney stones. In a 2016 meta-analysis, vitamin D supplementation was not associated with a higher risk of nephrolithiasis [50]. However, an increased incidence of hypercalciuria in thalassemia patients with serum 25OH vitamin D concentration > 30 ng/mL has been observed [14], but the impact on stone formation or recurrence was not studied. Since patients have baseline hypercalciuria, it is possible that vitamin D deficiency normalized the urinary calcium levels, which is reversed by supplementation. Clearly, further evaluation of the role of vitamin D supplementation in the development of nephrolithiasis in thalassemia is warranted.

3) *Vitamin C*. The use of high-dose vitamin C (≥1000 mg/d) has been associated with nephrolithiasis in healthy men, likely resulting from the metabolism of excess vitamin C to oxalate [51]. Therefore, patients at risk for renal stones are warned against taking high-dose vitamin C. In thalassemia, iron overload and the concomitant increase in non-transferrin bound iron leads to an exhaustion of circulating antioxidants, most notably vitamin C [52]. The majority of patients with TDT have low serum ascorbate levels, which further decrease with increasing iron overload [52]. At very high liver iron concentrations (>25 mg Fe/g liver tissue), nearly 100% of patients have serum ascorbate levels characteristic of vitamin C deficiency. Moderate doses of vitamin C are recommended to improve the efficacy of iron chelation. However, given the relationship between high-dose ascorbate supplementation and oxalate metabolism, it is prudent to avoid large doses of vitamin C [51].

4) *Obesity.* Obesity is an important risk factor for nephrolithiasis among adults in the general population. The association of obesity with incidence and prevalence of nephrolithiasis is stronger in women than in men, possibly because women have greater adiposity than men at a given body mass index [53].

While patients with thalassemia typically have a body mass index (BMI) within the normal range, their fat content may be unusually high for body weight [54] [55]. This is due to a combination of lower lean mass for height and low bone mass. Since body fat is a predictor of stone formation, the disproportionate body fat in thalassemia may be a risk factor for kidney stones. Patients with a history of nephrolithiasis have been observed to have a higher BMI than those without kidney stones [3] [18].

5) *Physical activity.* Physical activity protects against stone formation in the general population, especially among postmenopausal women [56]. Typically, levels of daily physical activity are lower in thalassemia and patients are more sedentary due to, fatigue, pain and other factors [41]. While feasible, the association of obesity, metabolic syndrome, or limited physical activity with nephrolithiasis in thalassemia has not been evaluated.

2.3. Environmental Risk Factors

Chronic exposure to the extremes in temperature due to season, climate and occupational conditions increases stone risk. The risk of kidney stone formation increases up to 68% within 2 days of high (>28˚C) daily temperatures [57]. Occupations that promote exposure to high temperatures are associated with higher stone risk [58]. The increase due to high ambient temperatures is probably mediated by low urine volume and increased concentration of lithogenic minerals (e.g. calcium, oxalate), leading to stone growth in susceptible patients. An inverse dose-response relationship between fluid intake and risk of stones has been observed with the greatest reduction (RR 0.52) occurring with daily intake > 2.5 L [43]. A urine output volume of 2.5 L is thus recommended for decreasing kidney stone recurrence [59]. The majority of patients with thalassemia reside in climates where the average annual temperature is above 26˚C, although the environmental risk factors for kidney stones have not been specifically evaluated in thalassemia.

2.4. Metabolic Risk Factors

Metabolic risk factors for stone formation are hypercalciuria, hypocitraturia, hyperuricosuria, hyperoxaluria, low urine volume, and alkaline urine pH. Hypercalciuria is most commonly due to increased intestinal calcium absorption, increased bone resorption, or increased postprandial renal fractional excretion of calcium. It is exacerbated by high salt and protein diets. Hypocitraturia is usually related to metabolic acidosis, as in chronic kidney disease, chronic diarrheal states, or a high protein diet. Hyperuricosuria, typically due to dietary purine excess or genetic predisposition, is a risk factor for calcium oxalate stones [60]. Hyperoxaluria may be due to a genetic mutation (primary hyperoxalurias), intestinal fat malabsorption, high dose vitamin C supplements, high dietary oxalate, or low dietary calcium.

1) *Hypercalciuria.* Although symptomatic kidney stones have only been re-

ported in 18% of thalassemia patients [3], the prevalence of hypercalciuria is much higher. In a study of 216 thalassemia patients (51% female, average age 23 yrs), nearly 30% had hypercalciuria as defined by 24-hour urinary calcium to creatinine ratio (UCa: UCr) ≥ 0.21 mg/mg [14]. Hypercalciuria was more common (32.2%) in the 180 subjects who were regularly transfused, compared to those not regularly transfused (11.1%). Most patients were on deferoxamine (89%) for iron chelation, while a small number were receiving deferasirox (10%), or deferiprone (1%). A 25-OH vitamin D level > 30 ng/ml was associated with a higher prevalence of hypercalciuria compared levels < 11 ng/ml (OR 4.1, CI 1.3 - 13.1) [14]. The possible association of iron chelators with stone risk is important to explore. In a prospective study of 30 young thalassemia patients, 24-hour urine collections were checked at baseline and 6 months after starting deferasirox (20 mg/kg/d) [61]. Only 2 patients had hypercalciuria (urine calcium > 4 mg/kg/d) at baseline, while 8 had hypercalciuria after deferasirox ($p = 0.037$). In a more recent study of 152 subjects with transfusion-dependent hemoglobinopathies (86% thalassemia, 58% female, and average age of 34 yrs), hypercalciuria was reported in 92% of the patients on deferasirox and 83% of the patients on deferoxamine [62]. In this study, hypercalciuria was defined as UCa:UCr ≥ 0.4 mol/mol (equivalent to UCa:UCr of 0.14 mg/mg), a lower threshold that may help explain the higher prevalence. Severe hypercalciuria (UCa:UCr > 1.5 mol/mol), however, was restricted to those receiving deferasirox. These two studies raise the possibility of the association of deferasirox with urinary calcium excretion. The true prevalence of hypercalciuria in thalassemia remains unknown since 24-hour urine collections are rarely performed. In addition, the definition of hypercalciuria in published studies is variable, which makes comparisons difficult. In thalassemia, the etiology of hypercalciuria is likely to be multifactorial, including renal dysfunction, hypoparathyroidism, iron chelation, diabetes, and high bone turnover. However, it is plausible that hypercalciuria is more common in patients on regular transfusions and exacerbated by deferasirox [62].

a) *Renal Dysfunction*. Patients with thalassemia are at risk for renal and tubular dysfunction due to anemia, hypoxia, iron overload, and the use of iron chelators [10] [14] [63]. Deferasirox has the most effect due to its role in producing a reversible increase in serum creatinine and proximal tubular dysfunction manifesting as renal tubular acidosis or Fanconi syndrome [61]. The pathogenesis of renal damage with deferasirox is not fully understood, but there is a direct toxic effect on the proximal renal tubule, which is responsible for most calcium reabsorption. Phosphate wasting in Fanconi syndrome causes hypercalciuria by stimulating 1,25-OH vitamin D production and promotes nephrolithiasis and nephrocalcinosis [64]. Whether hypercalciuria due to deferasirox is primarily associated with phosphate depletion has not been investigated.

b) *Hypoparathyroidism.* Iron overload in thalassemia is associated with several endocrinopathies, including hypoparathyroidism. In a study of 243 patients, subclinical hypoparathyroidism was present in 13.5% [65], although the preva-

lence of overt hypoparathyroidism is much lower at 1.4% [66]. Low parathyroid hormone (PTH) reduces renal calcium re-absorption. Patients with hypoparathyroidism and hypocalcemia often require calcium supplementation and calcitriol, and since calcium reabsorption is decreased, they can develop hypercalciuria with an increased risk of kidney stones. In these patients, hypercalciuria can be alleviated by targeting lower serum calcium in the range of 8.0 - 8.5 mg/dL.

c) *High Bone Turnover.* A link between hypercalciuria, kidney stones, osteoporosis and increased risk of fractures has been observed in several studies [3] [4] [5]. Patients had idiopathic hypercalciuria, which is accompanied by either elevated or suppressed PTH, is associated with increased bone turnover. Thiazide diuretics enhance renal tubular calcium re-absorption, and decrease urine calcium, PTH and bone turnover, which is associated with improved bone mineral density [67] [68].

Low bone mineral density with an increased risk of fracture is one of the most prevalent comorbidities in thalassemia. Approximately 50% of patients have low bone mineral density and 30% have had fractures [66]. The etiology for low bone mineral density in thalassemia is multifactorial, due to chronic anemia and bone marrow expansion, vitamin D deficiency, iron overload, iron chelators, hypogonadism and other endocrinopathies, nutritional deficiencies, decreased physical activity, and high bone turnover.

Bisphosphonates are anti-resorptive agents that are routinely employed to treat osteoporosis. In patients without thalassemia, alendronate reduces bone turnover and hypercalciuria [69]. The use of bisphosphonates in thalassemia leads to improvement in bone mineral density and a decrease in bone turnover markers [70]. However, these studies were not powered to determine fractures risk reduction, and the change in urinary calcium excretion was not reported [70]. The mechanism of hypercalciuria and low bone mineral density in thalassemia is multifactorial, but thiazide diuretics and bisphosphonates may have therapeutic potential by correction of hypercalciuria.

2.5. Genetic Causes

In twin studies, approximately 50% of the risk of nephrolithiasis among males was shown to be heritable [20]. While some genetic causes of kidney stones manifest from single-gene mutations (e.g. primary hyperoxaluria, cystinuria, and type 1 renal tubular acidosis), the large majority of heritable stone disease is polygenic [71]. The contribution of single gene polymorphisms to idiopathic calcium stone disease, including polymorphisms of the calcium receptor, vitamin D receptor, and osteopontin has been actively investigated [72] [73]. The role of these polymorphisms in stone formation in thalassemia patients is unknown.

3. Recommendations

Based on our evaluation of the specific risk factors for nephrolithiasis, we provide general recommendations on monitoring, prevention and management in patients with thalassemia (**Table 3**). In this evolving area, there is insufficient

Table 3. Proposed monitoring, prevention and management of nephrolithiasis in patients with thalassemia.

Monitoring for Risk Factors	
Variable to Measure	*Frequency*
Serum Ca, phosphorus, 25OHD, PTH, zinc, vitamin C, uric acid	Annual Monitoring
24-hour urine: Ca and creatinine	Annual Monitoring
DXA Assessment	Annual Monitoring starting at 10 years

Prevention of Nephrolithiasis	
Factor Category	*Guidance*
Hydration	Encourage adequate hydration. If prior history of nephrolithiasis, encourage fluid intake > 2.5 L/day
Sodium intake	Encourage less than 2300 mg sodium/day
Fruit and vegetable intake	Encourage 5 to 7 servings a day
Body weight	Encourage BMI between: 18.5 - 22.9 kg/m^2 (Asian) or: 18.5 - 24.9 kg/m^2 (all other races)
Non-contact weight bearing physical activity	Encourage minimum of 150 min/week of moderate intensity activity (adults); 60 min/day (children and adolescents)
Calcium intake	1000 mg/day (adults < 50 years) with focus on dietary sources. Limit supplemental calcium to 500 mg Ca (elemental) per day
25OH Vitamin D	Maintain between: 30 - 50 ng/mL (75 - 125 nmol/L)
Manage Diabetes	Maintain serum fructosamine < 270 umol/L
Transfusion therapy	Optimize therapy to reduce ineffective erythropoiesis
Vitamin C supplements	Avoid supplements > 1000 mg/day
Hypogonadism	Focus on prevention and management of hypogonadism
Chelator therapy	Monitor adverse effects of chelators on zinc, phosphate and calcium excretion

Management of Nephrolithiasis	
Factor Category	*Guidance*
Comprehensive care	Encourage clinical care management from team of specialists: urologist, nephrologist, endocrinologist, and dietitian
Treat hypercalciuria	Low salt diet, protein restriction (adults only) and consider a thiazide diuretic. In adults with hypercalciuria and osteoporosis, bisphosphonate therapy may be considered
Treat hyperuricosuria	Dietary purine restriction, increased fluid intake and urine alkalinization, improve transfusion regimen if evidence of increased ineffective erythropoiesis, and consider allopurinol
Treat hypocitraturia	potassium citrate

Continued

Hydration	Maintain urine output greater than 2 - 2.5 L/day
Chelation therapy	Reducing chelation dose or switching chelation therapy is unclear. May not be possible for many patients to change chelation due to concerns over iron overload and tolerance

Ca: calcium; PTH: parathyroid hormone; 25OHD: 25 hydroxy vitamin D; BMI: body mass index.

evidence in the thalassemia population for many of the recommendations. Hence, it is appropriate to adapt guidelines for the general population to known or proposed mechanisms of kidney stone formation in thalassemia.

4. Conclusions

The prevalence of nephrolithiasis is increased in adults with thalassemia as a result of multiple risk factors related to the underlying disease process, the co-morbidities of thalassemia as well as environmental, nutritional and biochemical risk factors. The elements of primary prevention of nephrolithiasis should be incorporated into routine health maintenance for thalassemia. The pathogenesis of hypercalciuria, which is frequent in thalassemia and may be associated with chelation, requires further elucidation. Until such time, it is reasonable to focus on the prevention of osteopenia, encouraging patients to meet daily calcium requirements through dietary sources, avoiding mega-dose nutritional supplements, staying physically active, and managing their weight.

Despite the increased risk of nephrolithiasis in the thalassemia population, there is insufficient evidence at this time to recommend universal screening of adults with thalassemia for nephrolithiasis using ultrasound. However, physicians should be aware of the potential increased risk of stone disease and consider 24 hr urine analysis for calcium, sodium, creatinine, pH, oxalate and citrate. Patients with symptomatic or asymptomatic nephrolithiasis should be placed under the care of an experienced medical team as several risk factors may not be modifiable.

Various questions about the prevalence, pathogenesis and management of nephrolithiasis in thalassemia remain unanswered. Prospective studies are necessary for this population, especially since patients are now living well into old age. An improved understanding of the risk factors for nephrolithiasis will help in primary and secondary prevention, which are important to maintain the quality of life of the aging patient with thalassemia.

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Declaration

This manuscript has not been published previously, is not in consideration of publication elsewhere.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Atypical Presentation of Prostatic Cancer with Left Axillary and Supraclavicular Lymphadenopathy

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Abstract

Introduction: The burden of prostatic cancer is rising in Sudan. Usually, they present late in their disease with urinary tract obstruction, hematuria, bony pain, or cachexia because there is no screening program. Here we present a patient with prostatic cancer who presented with left axillary mass as his main concern. **Case Description:** 82-year-old Sudanese male presented with a left axillary and left supraclavicular lymphadenopathy of a few months' duration. He underwent a decisional biopsy which showed metastatic adenocarcinoma. Upper and lower GI endoscopy were performed but the latter was complicated by a sigmoid perforation with peritonitis. During laparatomy, multiple enlarged pelvic lymphnodes were encountered and a biopsy result suggested a metastatic prostatic neoplasm. Later, prostatic biopsy confirmed the diagnosis. The patient was treated with bilateral orchidectomy. **Clinical Discussion:** Lymphatic metastasis to axillary lymph nodes is a very rare manifestation of prostate cancer and only a few cases have been reported in the literature. It can cause diagnostic difficulty since prostate cancer typically metastasis to the pelvic lymph node and very rarely involves he supradiaphragmatic lymph node. **Conclusion:** Metastatic prostatic carcinoma should be considered among the causes of supra-diaphragmatic lymph adenopathy. Careful physical and imaging examinations combined with PSA and pathological analysis are essential in the diagnosis of advanced prostate cancer with unusual presentation.

Keywords

Prostatic Cancer, Adenocarcinoma, Axillary Metastasis, Supraclavicular Metastasis, Atypical Presentation

1. Introduction

Prostatic cancer is the third most commonly diagnosed malignancy in males after lung and colorectal cancer with 1,414,259 new cases registered by WHO in 2020. And it is one of the death-leading malignancies worldwide [1].

The risk of developing the disease is linked to factors such as age, race, and family history, with the highest incidence being in the elderly (over 55 years). The incidence and mortality rates are higher among African Americans than Caucasians [2].

The symptoms of advanced prostatic cancer are variable and sometimes not recognized which may lead to delayed diagnosis hematogenous spread frequently affects the bone but can occur in the lungs, liver, pleura, and adrenals. Metastasis to lymph nodes is commonly seen in the pelvic and abdominal groups [3].

The left supraclavicular or Virchow lymph node enlargement is classically linked to carcinoma of the stomach. Other causes include thoracic, abdominopelvic malignancy, lymphoma, tuberculosis, and hydatid disease [4]. Furthermore, the causes of axillary lymphadenopathy include metastatic breast carcinoma, melanoma [5] lymphoma leukemia, and various infections [6].

The combination of supraclavicular and left axillary lymph nodes in a patient may suggest carcinoma of the stomach or other abdominal malignancies [7].

Here we present an unusual presentation of prostatic adenocarcinoma with axillary and supraclavicular mass as the main presentation. This work has been reported in conformity with the SCARE 2020 criteria [8].

2. Case Report

An 82-year-old male presented with complains of left axillary and left side neck swellings for a period of 5 months duration. The patient noticed painless small swellings like the size of a bean mainly in the left axillary area and left side of the neck. They were painless and gradually increased in size with normal overlying skin. There were no swellings in other sites of the body. The patient denied any symptoms of fever, loss of weight or loss of appetite. He was complaining of burning micturition, but there was mild dysurea with no symptoms of obstruction or hematurea. His systemic review was unremarkable and he denied any GI complaints.

His systemic examination revealed a left supraclavicular lymph node and a left axillary lymph node. No neck mass or cervical LN involvement. His chest and abdominal examination were normal. The axillary lymph node was about 4 cm, hard, but mobile.

His labs were normal CBC: HB 11.7 g/dl, TWB CS 4.9 × 10^3/µl, PLT 270 × 10^3/µl, RFT: urea: 32 mg/dl, creatinine: 0.9 mg/dl, Na: 141, K: 3.5. Urine general: no hematuria.

Cervical and axillary ultrasonography showed suspiciously enlarged lymph nodes (Figure 1). Fine needle aspiration cytology was inconclusive. As a result decisional biopsy was done and showed metastatic adenocarcinoma (Figure 2(A) and Figure 2(B)).

The treating team's main suspicion was GI malignancy, hence, the patient was referred to the gastroenterology department where upper and lower GI endoscopies were done to exclude gastrointestinal malignancy and they revealed no pathology. Four days later, he presented with signs and symptoms of massive pneumoperitoneum and peritonitis. Therefore, colonic perforation was suspected (Figure 3). His rectum was empty and the prostate was mildly enlarged with hard palpable nodules bilaterally and obliterated median sulcus.

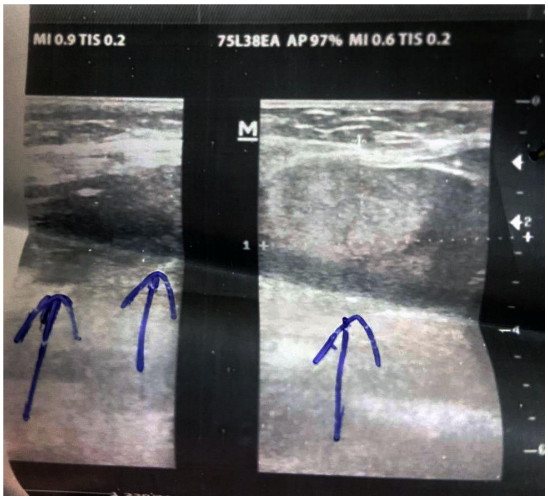

Figure 1. Left supraclavicular and axillary targeted ultrasonography, using linear soft tissue probe, showing enlarged lymph nodes with loss of the normal kidney shape and central fatty hilum.

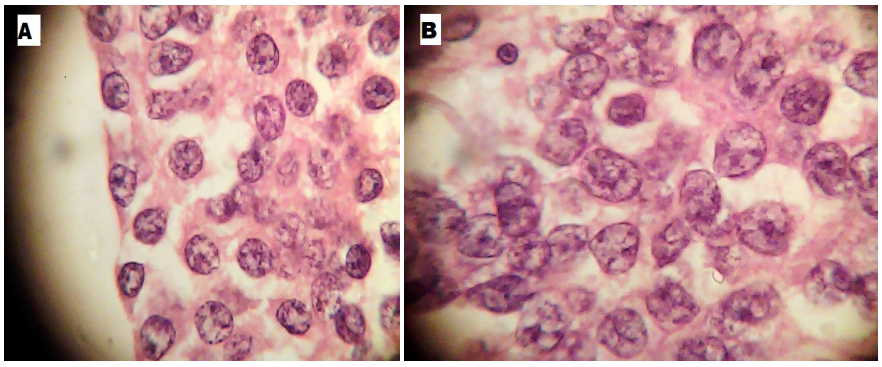

Figure 2. (A) Left supraclavicular and (B) left axillary lymph nodes. Affected lymph nodes by infiltrative tumor composed of diffuse infiltrative sheets. The tumor cells are monomorphic cells with enlarged vesicular nuclei and prominent large nucleoli with focal plasmacytoid features. Stain: H&E. Lens: ×100/1.25 oil immersion.

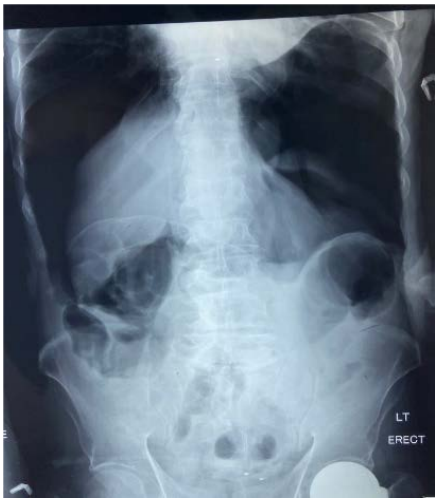

Figure 3. Erect abdominal X-ray showing massive pneumoperitoneum.

Exploratory laparotomy was performed and revealed moderate intraperitoneal pus collection and sigmoid perforation for which a colostomy was made. The rest of the abdomen was unremarkable apart from enlarged pelvic and para-aortic lymph nodes. A biopsy was taken from the iliac nodes and sent for histopathology. The PSA at that time was 449 ng/ml.

The histopathology of the pelvic lymph nodes resulted in metastatic adenocarcinoma of the prostate (**Figure 4**). Tru-cut biopsy from the prostate confirmed the diagnosis with a Gleason score of (3 + 4 = 7/10) (**Figure 5**). Then the patient was offered surgical castration, and a reversal of colostomy was done after he became fit again. Currently, the patient has no symptoms and his last PSA was 0.01ng/ml.

Staging CT chest and abdomen showed Significant enlarged LNs involving most of the abdominal groups and side pelvic wall with the largest on aortocaval (4.7 × 2.7 cm), no lung or mediastinal metastasis was detected (**Figures 6-8**).

3. Discussion

The prostatic cancer burden is increasing in Sudan [9] [10]. Three decades ago, prostate cancer ranked tenth among all men's cancers diagnosed at the Sudan Cancer Registry in 1978, less frequent than skin cancers and non-Hodgkin lymphoma [10]. However, it is now the most common cancer in Sudanese males. It ranked second among all cancers in both sexes after breast in 2012 [11].

Risk factor for prostate cancer includes older men and non-Hispanic Black men. About 6 cases in 10 are diagnosed in men who are 65 or older, and it is rare in men under 40. The average age of men at diagnosis is about 66 [12].

The most common presentation of Prostatic Cancer in the pre-PSA era was urinary complaints or retention, back pain, and hematuria. Currently, with PSA screening, most prostate cancers are diagnosed at an asymptomatic stage. When symptoms do occur, diseases other than prostate cancer may be the cause. For example, urinary frequency, urinary urgency, and decreased urine stream often

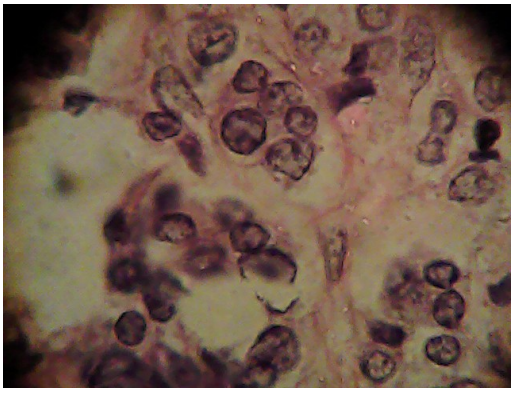

Figure 4. Lymph node biopsy suggesting prostatic origin. Stain: H&E. Lens: ×100/1.25 Oil immersion.

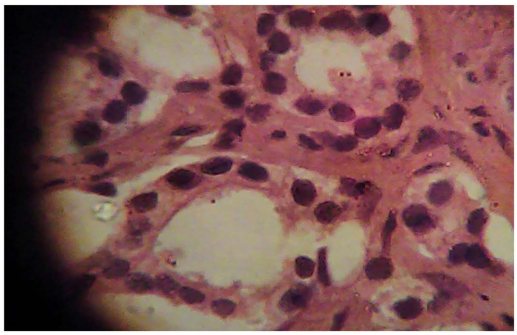

Figure 5. Prostatic tissue infiltrated by malignant gland with foci exhibiting cribriform pattern. Stain: H&E. Lens: ×100/1.25 oil immersion.

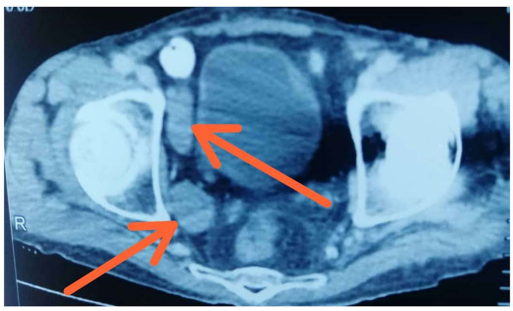

Figure 6. A selected axial cutof CT pelvis, portovenous phase, showing enlargement of the right obturator lymph nodes (arrows).

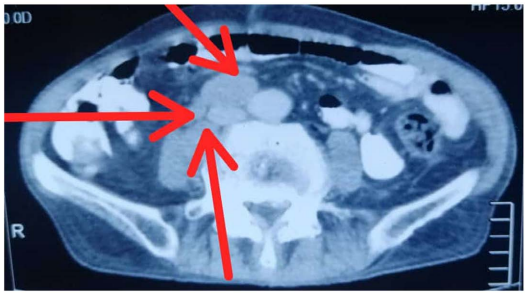

Figure 7. A selected axial cut of CT pelvis, portovenous phase, showing enlargement of the right pelvic sidewall lymph nodes (arrows).

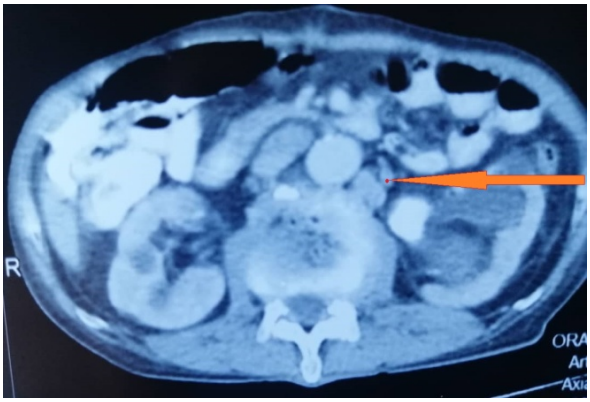

Figure 8. A selected axial cut of CT abdomen, portovenous phase, at the level of the kidneys, showing left para-aortic lymph node and a left renal pelvic stone as an incidental finding.

result from benign prostatic hyperplasia [13]. Our patient was having minimal urinary tract symptoms and only presented to seek medical care after he noticed an axillary mass. This pattern of presentation is very rare and only seldom physicians include prostate cancer in their list of differential diagnosis [14]. Our patient is a male patient so exclusion of breast cancer is very easy based on clinical examination. Next head and neck malignancy was ruled out because no clinical abnormality was present. Hematological malignancy was unlikely based on his CBC and peripheral blood picture. When we received the result of lymph node histopathology which was showing metastatic adenocarcinoma, we diverted our attention to the GI cause (esophagi gastric/pancreatic/colonic origin). Prostatic cancer was not entertained as a differential diagnoses until DRE and exploratory laparotomy was done for the sigmoid perforation.

Metastatic prostate cancer has a recognizable pattern of spread, most often to regional lymph nodes and the bones. Pelvic and abdominal retroperitoneal lymph nodes typically occur in the obturator and internal iliac nodes. Any lymphadenopathy occurring outside the abdomen and pelvis is considered atypical [15]. In one study, the most frequent sites of atypical metastases were the lungs and pleura, liver, supradiaphragmatic lymph nodes, and adrenal glands [16].

Reports describing atypical metastatic sites such as single or generalized lymphadenopathy with the absence of other symptoms of the disease have been documented [17]. But axillary lymph node metastasis was extremely rare and only mentioned in literature as a case report [14] [16] [18]. Other described supraclavicular and mediastinal lymphadenopathy which caused confusion with bronchial carcinoma [19].

Theories behind spread to the left supraclavicular lymph node include spread via Batson's venous plexus. Another theory is that these nodes are located close to the entry of the thoracic duct into the subclavian vein predisposing to retrograde metastasis. Further studies in this regard are necessary to elucidate the exact way of such involvement [20].

Detection of lymph node metastasis is of major prognostic significance for many

cancers. This observation also holds true for prostate cancer where patients with lymph node metastases exhibit a poor prognosis with significantly decreased disease-specific and biochemical recurrence-free survival rates [21].

Our patient fell in grade group 2 according to the 2014 International Society of Urological Pathology (ISUP) Consensus Conference [22]. However, the presence of a left axillary lymph node places him on stage IV as it is regarded as a distant metastasis [23]. A review of the literature has shown that the survival and treatment should be approached with the same protocols used in the patient that initially presented with bony or visceral metastasis. Therefore, surgical castration was offered to him.

4. Conclusion

Atypical presentation in prostatic adenocarcinoma can include left axillary mass. Suspicion of prostate cancer should be included in all elderly patients present with signs suggestive of malignancy. Early PSA measurement could have spared our patients from unnecessary endoscopes.

Consent

Written informed consent was obtained from the patient for publication of this case report and accompanying images. A copy of the written consent is available for review if requested.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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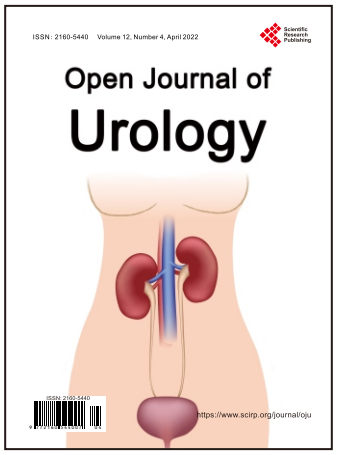

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