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Kidney stones: pathophysiology, diagnosis and management

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Kidney stones: pathophysiology, diagnosis and management. A case study approach.

Abstract

The prevalence of kidney stones is increasing, and approximately 12,000 hospital admissions every year are due to this condition. This article will use a case study to focus on a patient diagnosed with a calcium oxalate kidney stone. It will discuss the structure and function of the affected structures in relation to kidney stones and will describe the pathology of the condition. Investigations for kidney stones, differential diagnosis and diagnosis of kidney stones, possible complications of kidney stones and prognosis of the condition will be discussed. Finally, a detailed account of management strategies of the patient presenting with kidney stones, which will look at pain management, medical procedures and dietary interventions, will be described.

Introduction and Case History

Kidney stones, or calculi, form in the kidneys as a result of precipitation of urinary constituents (Waugh and Grant, 2010) and may develop in one or both of the kidneys (NICE, 2007). The lifetime risk of urinary stone disease is 12% in males and 6% in females (Curhan, 2007) and the prevalence of the condition is increasing, resulting in approximately 12,000 hospital admissions every year (BAUS, 2014). Calcium is present in 80% of kidney stones, and most commonly in the form of calcium oxalate (60%), with calcium phosphate accounting for 20% of stones (Bultitude and Rees, 2012). This article looks at the case of Omar, a twenty-eight year old teacher who suddenly suffered intense pain in his side and lower back whilst at his desk one evening. Deep breathing helped the pain to subside but discomfort remained. An appointment was made to see his doctor for the next morning, and during the car journey Omar again experienced severe pain radiating into his abdomen and groin, accompanied by nausea. The doctor ordered an abdominal x-ray, blood samples and a urinalysis. Visible haematuria was noted and confirmed by urinalysis. The doctor diagnosed a very small (less than 5mm) kidney stone and, given its size and configuration, suggested it would pass in his urine in a day or two. Omar was prescribed non-steroidal anti-inflammatory drugs for his pain, advised to rest and drink four-to-six pints of water every day. The stone passed the next morning and brought to the doctor. Its composition showed that it was a calcium oxalate stone. Omar was advised to continue drinking four-to-six pints of water daily and was also given a list of foods containing oxalate to avoid.

Structure and Function of Affected Structures

The kidneys are two bean-shaped, retroperitoneal viscera located at the posterior abdominal wall, and they lie in the extraperitoneal connective tissue immediately lateral on either side of the vertebral column (Drake, Vogl and Mitchell, 2014). The kidneys extend from the level of the twelfth thoracic vertebra to the third lumbar vertebra (Waugh and Grant, 2010). The left

kidney is closer to the midline, longer and more slender than the right (Drake, Vogl and Mitchell, 2014).

The renal hilum, an entrance to the space in the kidney called the renal sinus, is a cleft lying at the concave medial margin of the kidney and is where the structures serving the kidney enter and exit (Moore, Dalley and Agur, 2014). Each kidney has circa one million nephrons—the nephron is composed of the glomerulus, proximal convoluted tubule, loop of Henle, distal convoluted tubule and the collecting duct (Waugh and Grant, 2010; Braun and Anderson, 2011). Each kidney is composed of a fibrous capsule, perirenal fat, renal fascia and pararenal fat (Snell, 2008). The renal infrastructure consists of the renal cortex (which forms the external layer of the renal parenchyma and lies immediately below the renal capsule) and the renal medulla (which is composed of approximately a dozen, inverted, cone-shaped medullary pyramids). The arterial supply to each kidney arises at the hilum from the renal artery (from the aorta) and venous drainage via the renal vein which drains into the inferior vena cava (Snell, 2008). The function of the kidneys is to: produce urine; remove excessive amounts of substances such as water, salt, and waste products from the blood; reabsorb important nutrients; and produce select regulatory hormones (Moore, Dalley and Agur, 2014).

Pathology of Condition

The pathophysiology of kidney stones (nephrolithiasis) is not yet fully understood (Bao and Wei, 2012). Nevertheless, risk factors toward kidney stone development can be intrinsic (such as age and sex) or extrinsic (such as diet and climate) (BAUS, 2014). According to BAUS (2014) a potentially underlying cause of kidney stone formation is an acquired or congenital anatomical structural abnormality. Anatomical abnormalities may worsen stone formation, particularly if the abnormality results in urinary stasis in conditions such as pelviureteric junction obstruction or horseshoe kidney (Gambaro et al, 2006).

Crystallisation occurs when the concentration of two ions exceeds their saturation point in the solution (Parmar, 2004). The crystals in the supersaturated urine then adhere to the urothelium which may enhance subsequent stone growth (Dawson and Thomson, 2012), and interstitial stone formation can occur. As dilute urine can aid prevention of crystallisation of stone-forming salts, dehydration may lead to the development of kidney stones (Curhan et al, 1997).

The acute, intermittent pain caused by kidney stones is called renal colic, and occurs due to contraction of the smooth muscle of the ureter as an attempt to move the stone (Waugh and Grant, 2010). Hydronephrosis (dilation of the kidney) and distention of the renal capsule occur and may cause nausea and vomiting (Teichman and Joel, 2004).

Investigations

Omar provided a sample of urine for urinalysis. Microscopic analysis involves special biochemical analysis of urine constituents and can also be extended to include techniques such as crystallography and spectroscopy of retrieved and submitted calculi. A 'pinkish cast' was noted in Omar's urine, suggesting the presence of blood. Macroscopic analysis involves visually analysing the sample in terms of colour and clarity, with colour changes indicating the presence or absence of a substance (Braun and Anderson, 2011).

A plain abdominal x-ray was ordered for Omar, which revealed a radio-opaque 3mm stone. Calculi can be diagnosed through x-ray (Jabbar et al, 2014), with approximately 90% being radio-opaque. Computerised tomography (CT) has been considered the best imaging source available for diagnosing kidney stones (Teichman and Joel, 2004), and non-contrast enhanced CT remains the gold standard imaging technique for the evaluation of kidney stones (Renard-Penna et al, 2014). A plain radiograph of the kidneys, ureters and bladder (KUB) is still an appropriate alternative should CT facilities be unavailable and a combination of KUB with non-invasive renal ultrasound is especially sensitive and specific, with minimal radiation risk (Manjunath, Skinner and Probert 2013).

Omar's doctor took blood samples after describing his symptoms. Full blood count, urea and electrolytes, serum creatinine, C-reactive protein, liver function tests and amylase are useful tests to consider for patients presenting with suspected kidney stones (Manjunath, Skinner and Probert, 2013), ordered to differentiate from other potential causes of abdominal pain, such as pancreatitis and cholecystitis. Omar's bringing his stone to the doctor is important, as this may allow for the deployment of specialised techniques to analyse stone constituents and structure.

Differential Diagnosis

There are a number of differential diagnoses to consider following assessment of the patient—musculoskeletal pain or certain infections of the abdominal organs such as cholecystitis or appendicitis may mimic renal colic (Manjunath, Skinner and Probert, 2013). According to NICE (2009), differential diagnoses that must be considered include:

- appendicitis, if the pain is experienced on the right side;
- gastrointestinal problems, such as diverticulitis (if pain is on the left side) and pyelonephritis (kidney infection);
- gynaecological problems, such as salpingitis (infection of the fallopian tubes);
- vascular problems, such as ruptured abdominal aortic aneurysm.

Testicular torsion may be characterised by testicular pain and tenderness and is often found in younger males and is important when assessing individuals like Omar given his age and sex—referred pain to the loin or groin is a symptom of acute testicular pathology (Manjunath, Skinner and Probert, 2013).

Diagnosis

Following the preliminary investigations, Omar was informed that he had a kidney stone. According to guidelines by the European Association of Urology (EAU, 2011) an appropriate imaging source should be used to support the diagnosis of kidney stones. Plain radiography of KUB can be useful in detecting radio-opaque stones (American Urological Association (AUA), 2014). Ninety percent of kidney stones contain some calcium (calcareous stones), rendering them radio-opaque (Parmar, 2004). The pink hue in Omar's urine is suggestive of the presence of blood (visible haematuria). Non-visible (microscopic) haematuria and symptoms of renal colic may strongly suggest stone formation, but stones may uncommonly occur in the absence of haematuria (Eskelinen, Ikonen and Lipponen, 1998).

Possible Complications

A number of complications may potentially arise following the development of kidney stones. According to Alexander et al (2012), the development of kidney stones (even a single episode) may cause adverse renal outcomes, such as an associated increased risk of the development of end stage renal disease (although it was noted that the increases were small in absolute terms). A serious sequel of kidney stones requiring urgent intervention is acute obstruction—this can occur when the stone passes into the ureter, leading to reduced glomerular filtration rate and renal blood flow (Miller and Lingerman, 2007). Bilateral obstruction and obstruction in an infected kidney is considered an emergency requiring surgical intervention (Bultitude and Rees, 2012). Similarly, stasis with resultant infection is a urological emergency, necessitating surgical intervention to prevent life-threatening urosepsis (EAU, 2011).

Prognosis

Kidney stones are a major cause of morbidity and complications, such as obstruction and sepsis, may prove fatal. NICE (2009) states that the recurrence rate for renal colic as a result of stones is high, with an individual's risk of recurrence of kidney stones being 40% at five years and 75% at twenty years (Worcester and Coe, 2010). NICE (2009) add that the prognosis relating to the likelihood of spontaneous passage of a kidney stone depends on the stone's size, location and degree of obstruction. Omar's stone was 3mm in diameter—stones larger than 10mm in diameter will not pass in the urine (although the outcome can vary in stones between 5mm and 10mm) (Worcester and Coe, 2010). Metabolic testing is important following stone passage and when normal diet is resumed to screen for hypercalcaemia, chronic kidney disease, and renal tubular acidosis (Worcester and Coe, 2010).

Management Strategies

According to the EAU (2011) it is important to consider each patient's individual circumstances before deciding on the most appropriate treatment. Initial management should focus on pain alleviation, admitting the patient to hospital or requesting a referral for an outpatient assessment as a matter of urgency (if the case is not urgent, focus should be based on initial investigations required) (Manjunath, Skinner and Probert, 2013). Stones not causing complications do not require removal (Worcester and Coe, 2010).

Non-steroidal anti-inflammatory drugs (NSAIDs) are the analgesia of choice for pain management—diclofenac is the most commonly used NSAID for renal colic and can be absorbed effectively if administered rectally to the patient who is vomiting (Manjunath, Skinner and Probert, 2013). Opiate analgesia, such as morphine, can be used alongside NSAIDs if NSAIDs alone are not effective (Albala et al, 2010). Medical expulsive therapy (MET), which involves the use of alpha-blockers, should be the first treatment option for the management of ureteral stones, as these can increase the stone passage by decreasing intra-ureteral pressure (Campschroer et al, 2014) by dilating the distal ureter and thus facilitating stone passage. Increasing the rate of stone passage and expulsion may help reduce the risk of complications associated with stones as well as the need for invasive treatments, which could and eventually decrease healthcare costs (Campschroer et al, 2014).

Symptomatic kidney stones can undergo fragmentation to help relieve pain and prevent harm from chronic renal obstruction—shock wave lithotripsy (a non-invasive technique which uses high-energy shock waves to fragment stones) or ureteroscopy (a minimally invasive technique which uses endoscopy to view all parts of the ureter and renal collecting system, followed by fragmentation of stones using a laser or electrohydraulic device) are both effective interventions. In Omar's case, however, despite his symptoms, the doctor informed him that the stone should pass naturally given its size, reinforcing the importance of individual patient assessment (EAU, 2011). As non-invasive or minimally invasive treatment options have been developed to replace unnecessary open surgery, consideration of the size and shape of the stone is also important (Renard-Penna et al, 2014). Approximately 90% of kidney stones do not require surgical intervention as most pass naturally after three to six weeks (Jabbar et al, 2014). AUA (2014) guidelines on medical management of kidney stones recommend thiazide diuretics should be offered to patients with (relatively) high urine calcium and recurrent calcium stones, and potassium citrate therapy to patients with recurrent calcium stones and (relatively) low urinary citrate.

Diet and poor water intake are significantly influence the formation of kidney stones (Jabbar et al, 2014). The EAU (2011) advises against excessive consumption of oxalate-rich products to prevent an oxalate load, but calcium intake should not be restricted unless there is a strong positive correlation between dietary calcium and calcium stone formation. This is because dietary restrictions of calcium may increase urinary oxalate excretion and result in negative calcium balance (Borghi, 2002).

Nurses have a role to undertake in the management of the patient with kidney stones at initial presentation, during treatment and on discharge of the patient (Steggall and Omara, 2008), who must receive information on any tests and investigations being carried out, as a provision of support for the patient (Steggall, 2001). It is important for nurses to not only assess the patient's level of pain, but also what relieves or exacerbates the pain (Steggall, 2001). In Omar's case, while deep breathing helped to somewhat relieve the pain, he was still uncomfortable and was prescribed NSAIDs to help manage the pain. Omar's urine showed visible haematuria—such monitoring of urine output is also important, and both a urinalysis and mainstream specimen of urine (MSSU) should be obtained from the patient (Steggall, 2001). Clinical observations should be also be recorded as often as required (Steggall and Omara, 2008). Stone recurrence is likely, and so nurses should provide the patient with advice on prevention strategies (Steggall and Omara, 2008), such as changes to fluid and dietary intake which are important to help prevent recurrence of kidney stones (Barnela et al, 2012). Whilst the doctor advised Omar to drink four-to-six pints of a water a day, he was also advised to drink more water when exercising and during hot weather or in warm environments. He was provided with a list of oxalate-rich foods to avoid (examples include, rhubarb, nuts and sweet potatoes).

Conclusion

The case study was based on a twenty-eight year old male named Omar who was diagnosed with having a calcium oxalate kidney stone. Kidney stones can result from anatomical abnormalities or supersaturation. CT remains the gold standard imaging technique for the evaluation of kidney stones, and blood samples are important to identify signs of renal impairment and infection. This case study has highlighted the important of considering differential diagnoses in clinical practice, particularly in young men like Omar as the symptoms of kidney stones can mimic that of testicular torsion. A range of complications may arise from kidney stone formation. Nurses play a key role in the management of the patient with kidney stones on initial presentation, during treatment and on discharge. The management of the patient with kidney stones may include pain relief, MET and possible admission to hospital or to outpatients. Kidney stone disease is common—therefore, assessing the long-term impact on health would be useful to help inform interventions for future practice. The likelihood of stone recurrence highlights the importance of providing information to patients to prevent recurrence, to which nurses are suitably placed to do so.

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