PICTORIAL REVIEW

The imaging appearances of calyceal diverticula complicated by uroliathasis

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ABSTRACT. The presence of diverticula arising from the calyceal system is a relatively uncommon urological problem, occurring with an incidence of 2.1–4.5 per 1000 intravenous urogram (IVU) examinations. While the incidence of calyceal diverticula is low, the frequency of stone formation within them is high. We describe the aetiology and clinical presentation and describe the role of imaging with ultrasound, intravenous and retrograde pyelography and CT in diagnosis and planning treatment. We also describe the potential of fluid-sensitive magnetic resonance imaging techniques as a radiation-free alternative to the use of more conventional modalities, such as intravenous urography and retrograde pyelography, in delineating the anatomy of calyceal diverticula before surgical and radiological intervention especially in young patients and pregnant women.

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The term calyceal diverticulum or pyelocalyceal diverticulum refers to a urine-containing cystic cavity within the renal parenchyma. The diverticulum is lined by transitional epithelium and surrounded by muscularis mucosae, communicating with the collecting system via a narrow isthmus or infundibulum [1]. Calyceal diverticula might be diagnosed as an incidental finding or can be symptomatic owing to recurrent urinary tract infection (UTI) or stone formation within the diverticulum, both of which are precipitated by urinary stasis within the diverticulum. Other common presenting features include ipsilateral flank pain and haematuria [2–5]. Isolated reports exist of transitional cell carcinoma occurring within a calyceal diverticulum [6] and calyceal diverticular rupture [7]; however, such cases are rare. Auge et al [8] analysed a group of patients with symptomatic calyceal diverticular stones and found them to have at least one metabolic abnormality predisposing to stone formation; the authors recommended that these patients undergo the same cohort of investigations as other stone-forming patients. The increasing use of cross-sectional imaging, in particular CT urography, has resulted in the increased detection of calyceal diverticula, although the majority of calyceal diverticula can be diagnosed by ultrasound. Intravenous urogram (IVU) and retrograde studies can be required to confirm diagnosis. In some cases, the diverticulum might be misdiagnosed as a complex cyst or even as a neoplasm; this is most likely to

happen when the diverticulum contains multiple layering calculi or echogenic debris.

Once a renal calyceal diverticulum becomes symptomatic, the primary aim of imaging is to accurately localise the diverticulum and to assess if there are calculi within it. Such an analysis will guide subsequent treatment, whether by radiological intervention, extracorporeal shock-wave lithotripsy (ESWL) or surgical procedures.

Incidence and classification

The incidence of calyceal diverticula is 2.1–4.5 per 1000 IVU examinations [1], but their true prevalence is likely to be higher as some diverticula are successfully opacified only at the time of retrograde pyelography [2, 9]. Although the incidence of calyceal diverticula is low, the incidence of stone formation within them is relatively high and occurs in up to 50% of cases [2, 10]; patients are often asymptomatic until stone formation occurs [2, 10, 11]. Calyceal diverticula occur with equal frequency in male and female patients and there is no predilection for the left or right side. The diverticula are bilateral in only 3% of cases [12]. Two types of calyceal diverticula have been described in the literature [1, 12]. Type I are the more common subtype and communicate with a minor calyx. These diverticula are more commonly located at the upper pole of the kidney with over 50% occurring in the upper one-third of the kidney alone in some series [3]. Type II calyceal diverticula communicate with a major calyx or the renal pelvis itself and are much less common. These diverticula tend to be larger, are more commonly symptomatic and are often located at the mid-pole of the kidney.

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Aetiology

The term “calyceal diverticulum” was first suggested by Prather in 1941 [13] and, since then, a number of potential aetiologies have been described in the literature. The most widely held hypothesis is that their development is likely to be congenital in origin, resulting from failure of regression of the third or fourth divisions of the ureteric buds of the Wolffian duct [1, 2]. Diverticula can rarely be acquired as a result of infection or passage of a small stone [14]. The formation of calculi or milk of calcium within a calyceal diverticulum occur secondary to a combination of urinary stasis and recurrent infection within the diverticulum.

Imaging

Plain abdominal radiography

Plain abdominal radiography is often the first radiological investigation performed in patients presenting with renal angle or flank pain suggestive of underlying renal stone disease. Plain radiography has a high sensitivity in the detection of renal tract calculi; however, this approach can be limited by overlying bowel gas and

by faecal material obscuring the renal outlines. Up to 90% of renal calculi are radiopaque on plain radiographs [15]. A calyceal diverticulum containing multiple radiopaque calculi in the right kidney can be mistaken for gallstones on plain film [2] (Figure 1a). Such patients typically present with right-sided abdominal pain and are frequently referred for abdominal ultrasonography to further evaluate for presumed gallstone disease. Following such an investigation, the diagnosis of stone-containing calyceal diverticula is often made (Figure 1b). Plain abdominal radiographs can demonstrate the characteristic appearance of radiopaque milk of calcium, which appears as a half moon or meniscus-shaped calcification that changes position in erect or lateral decubitus positions apparently lying dependently within the diverticulum [3, 5, 16]. Milk of calcium is a fine colloidal suspension of precipitated calcium crystals of varying size (primarily calcium carbonate crystals) [16, 17]. When present within the urinary tract, milk of calcium is most commonly encountered in association with calyceal diverticula and is strongly associated with low-grade inflammation and inadequate drainage of the diverticulum [16]. Milk of calcium can appear radiolucent on radiographs, particularly in the early stages of its formation. Analyses of milk of calcium *in vitro* have shown the compound to separate out slowly with a thick

(a)

(b)

Figure 1. A 55-year-old female with right upper quadrant pain. (a) A supine abdominal radiograph demonstrates a rounded area of calcification in the right upper quadrant (arrow), which was initially misinterpreted as gallstones. The patient was subsequently referred for abdominal ultrasonography. (b) Longitudinal ultrasound of the right kidney with the patient supine demonstrates a cystic lesion at its upper pole with hyperechoic material lying dependently within it (arrow). The material demonstrates moderate posterior acoustic shadowing with gravitational change evident on scanning in the prone position.

calcium sludge settling in the bottom of the test tube [16, 17]. These observations closely mimic the *in vivo* behaviour of this compound, which is often observed gradually settling in the dependent portion of the urine-filled calyceal diverticulum at the time of ultrasound examination. These observations help to explain the difficulty in diagnosing calyceal diverticula containing milk of calcium using standard supine plain film radiographs and IVUs, particularly in the early stages of milk of calcium formation [16]. Real-time ultrasonography is therefore preferable to plain film radiography for the diagnosis of this condition [3, 16].

Ultrasonography

Ultrasound is generally accepted as having several advantages over plain radiographs and IVUs in the diagnosis of calyceal diverticula [3, 16]. Up to 50% of calyceal diverticula contain calculi or milk of calcium. The identification of a cystic renal lesion in close proximity to the renal sinus with curvilinear, plaque-like calcification along its posterior wall should alert the sonographer to the potential presence of a stone-containing calyceal diverticulum. Multiple small stones within a diverticulum become layered along its posterior wall when the patient is supine [3, 16, 18]. A calyceal diverticulum can often be misinterpreted as a complex cystic lesion on ultrasound if the sonographer is unfamiliar with this entity. Therefore, it is advocated that when echogenic material or posterior wall calcification is identified within a renal cystic lesion, the patient should be scanned in both the supine and prone position to determine whether mobile calculi are present within a calyceal diverticulum [16, 18]. The presence of mobile echogenic content strongly suggests the diagnosis of a calyceal diverticulum, as complex renal cysts contain calcification in other non-mobile forms (e.g. septal or mural calcification) [19]. Indeed, the demonstration of gravitational change of this echogenic content is diagnostic and further imaging is not deemed necessary by many authorities [3] (Figures 1b, 2a).

The high acoustic impedance of milk of calcium crystals, whether radioopaque or radiolucent on plain radiographs, favours their detection by ultrasonography [16]. When present, milk of calcium crystals within the diverticulum can cause reverberation echoes with minimal or no posterior acoustic shadowing; this can lead to diagnostic uncertainty if the sonographer is unfamiliar with this finding. It is thought that this observation could relate to variations in the physical and chemical components of the milk of calcium crystals and that the presence or absence of acoustic shadowing might relate to both the individual component sizes of the crystals and the concentration of calcium, which may or may not be sufficient to cast an acoustic shadow [16, 17]. Correlation does exist between the presence of dense calcium within diverticula on plain radiographs and those with strong acoustic shadowing at ultrasound [16]. Other conditions to be considered in the differential diagnosis include renal angiomyolipomas, nephrocalcinosis, renal artery calcification or echogenic renal scarring due to prior pyelonephritis. These echogenic lesions can usually be distinguished from calyceal

diverticula containing echogenic calculi or milk of calcium by the lack of a demonstrable calcium–urine interface and the absence of gravitational change of the echogenic content.

In our experience, we have found that calyceal diverticula more commonly contain multiple small calculi (Figure 3a, Figure 4a) rather than a single large calculus. Nevertheless, the presence of a single calculus within a calyceal diverticulum can be difficult to differentiate from an obstructed calyx. Furthermore, pyonephrosis with a pus–urine interface may provide diagnostic difficulty in a septic patient. Although ultrasonography provides a diagnosis in up to 80% of cases [3], in some cases ultrasound alone might be insufficient to accurately diagnose this condition and other investigations such as intravenous urography, CT and retrograde pyelography may be necessary to confirm the diagnosis.

Intravenous urography and retrograde pyelography

Several series have described the role of intravenous urography in the diagnosis of calyceal diverticula. Middleton et al [2] described eight cases of calyceal diverticula, all of which were detected by intravenous urography. Rathaus et al [3] described a series of 11 patients with calyceal diverticula; out of five patients in whom IVU examination was performed, the calyceal diverticulum was opacified in four. The authors report that most calyceal diverticula become apparent at the time of IVU study, owing to their inherent connection with the collecting system. Delayed imaging is thought to demonstrate the diverticulum to best effect, as it fills retrogradely from its connection to the renal pelvis or calyx (Figure 4a). Contrast should be seen to surround the stone and this completes the diagnostic picture. It has been our experience, however, that calyceal diverticula are poorly visualised on IVU and retrograde pyelography has been necessary in a number of cases to definitively demonstrate the diverticulum and delineate the infundibulum (Figure 3b). In cases in which the infundibulum of the calyceal diverticulum is obstructed, the diverticulum does not opacify either at the time of IVU or retrograde pyelography. Here, it is difficult to differentiate between a complex renal cyst and obstructed calyceal diverticulum [12], although contrast examination findings should be interpreted in conjunction with sonographic appearances. Although the calyceal diverticulum might opacify at the time of IVU, the small communicating neck or infundibulum of the diverticulum is rarely visualised. The presence of a narrow and poorly draining neck is expected, however, and contributes to the process of stone formation. The failure to demonstrate the neck does not detract from the diagnosis.

Retrograde pyelography is recognised as having a higher success rate in demonstrating the infundibulum and its communication with the renal collecting system [2], as it allows greater distension of the collecting system than can be attained with IVU. Retrograde pyelography is therefore invaluable in delineating anatomy and in planning the appropriate treatment approach [11]: either percutaneous or open surgical techniques.

(a)

(b)

(c)

Figure 2. A 23-year-old female with recurrent urinary tract infection and right flank pain during pregnancy. (a) Transverse ultrasound image of the upper pole of the right kidney demonstrates layering echogenic material within an upper pole cystic structure (arrow). The echogenic material exhibited gravitational change on scanning the patient prone, confirming the diagnosis of a stone-bearing calyceal diverticulum. (b) Coronal true fast MRI demonstrates a calyceal diverticulum arising from an upper pole calyx (arrow); this observation correlates well with the ultrasound study. (c) T_2 weighted transverse MRI demonstrating high-signal calyceal diverticulum arising from the upper pole of the right kidney with low-signal areas (arrow) lying dependently within it in keeping with calculi.

Computed tomography

Multislice CT with its ability to perform multiphase contrast-enhanced scans has led to increased diagnostic accuracy in the evaluation of cystic renal masses.

Furthermore, coronal and sagittal reformatted images provide valuable anatomical information and delineate the location of the calyceal diverticulum and its relationship to the collecting system to much better effect. Such information aids planning of percutaneous and open

(a)

(b)

Figure 3. A 47-year-old male with right flank pain. (a) A magnified view from a control film of an intravenous urogram (IVU) demonstrates a 2 cm opacity in the right upper quadrant (arrow). This image clearly shows that the opacity is made up of multiple tiny calculi rather than a single large calculus, which should raise the suspicion that they lie within a calyceal diverticulum. (b) An oblique radiograph from a retrograde pyelogram study elegantly depicts the short, narrow infundibulum of a calyceal diverticulum arising from a mid-pole calyx (arrow).

surgical procedures. Both non-contrast and contrast-enhanced imaging is advocated. Gayer et al [20] described their experience with CT in seven patients with calyceal diverticula; they performed CT with either 5 or 10 mm collimation at 5–10 mm intervals through the renal parenchyma. Unenhanced, post-contrast and delayed phase imaging (15–60 min post-injection) was performed in all patients. Non-contrast scans demonstrated heterogeneous round lesions in all cases measuring up to 2 cm in diameter. The lesions contained high attenuation material of calcific density lying inferiorly within the cystic structure and fluid of water density. Following administration of intravenous contrast, the attenuation of fluid in the upper part of the cyst increased by approximately 20 Hounsfield units. Delayed imaging demonstrated opacification of the entire lesion with a similar density to that of the collecting system, confirming the presence of a calyceal diverticulum.

Rathaus et al [3] similarly described the role of CT in their cohort of patients with calyceal diverticula. These authors retrospectively reviewed the imaging and clinical data of 11 patients with calyceal diverticula. CT was performed in four of the patients using conventional non-helical scanning, again using 5 or 10 mm collimation at 5–10 mm intervals through the renal parenchyma. Unenhanced and contrast-enhanced imaging was performed

in all patients with delayed imaging performed 15–30 min post-injection in three of the four patients. The identification of mobile, gravity-dependent stones on non-contrast CT when patients were scanned supine and prone or the demonstration of opacification of the diverticulum on delayed imaging (thus indicating a connection with the collecting system) are considered diagnostic of calyceal diverticula.

CT is a valuable modality in the evaluation of a complicated cystic lesion identified on ultrasound that does not have the typical sonograph appearances of a calyceal diverticulum. Delayed imaging is of paramount importance as it demonstrates layering of contrast medium within an apparent cystic mass containing calcific densities, which is considered pathognomonic of a calyceal diverticulum [19] (Figure 5). Opacification of the diverticulum on delayed imaging also serves to establish patency of the diverticular infundibulum, thereby aiding treatment planning [11] and avoiding the need for retrograde pyelography in some cases. In particular, the use of coronal reformats can elegantly display the diverticulum and its infundibulum. As highlighted by Gayer et al [20], following intravenous contrast administration there is a slight increase in density of the cystic lesion. If delayed imaging is not routinely performed, this increase can be mistakenly perceived as “enhancement” of a cystic renal malignancy, rather than early

Figure 4. A 50-year-old female with left flank pain. (a) Two radiographs from an intravenous urogram (IVU) study: 20 min (left) and post-micturition (right). The images demonstrate contrast opacifying a lower pole calyceal diverticulum containing numerous calculi (arrow). Further opacification of the diverticulum is evident on the later film (right-hand image; arrow), highlighting the need for delayed images. Note that the infundibulum cannot be seen on either radiograph. (b) Coronal and transverse images from an MR urogram identify the lower pole calyceal diverticulum on the left side (arrow). Multiple areas of low signal are identified within the diverticulum and correspond to calculi (arrow).

opacification of a calyceal diverticulum. The key to the correct identification of such lesions as calyceal diverticula lies in the recognition that the apparent enhancement represents delayed filling of a calyceal diverticulum from the collecting system, rather than vascular supply to a cystic mass.

Magnetic resonance imaging

Although the role of conventional radiographic techniques such as contrast-enhanced CT and retrograde

pyelography in the diagnosis of calyceal diverticula is well established, MRI could offer an alternative that avoids the use of ionising radiation. We have had success in delineating two cases of calyceal diverticula using fluid-sensitive MR sequences (Figures 2b, c and 4b). The use of MRI could become greater established in cases where the ionising radiation dose associated with CT and retrograde pyelography is undesirable, in particular in the paediatric population, young females and pregnant patients. Similar to reconstructed CT images, multiplanar MRI can delineate calyceal divertici and their infundibulum.

Figure 5. A 35-year-old female who presented initially with flank pain and recurrent urinary tract infection. She had undergone several sessions of unsuccessful extracorporeal shock wave lithotripsy (ESWL) for a left upper pole renal calculus. The size of the left upper pole opacity remained unchanged on serial radiographs. (a) Non-contrast CT of the kidneys and (b) following intravenous contrast. Non-contrast CT demonstrates a cystic lesion at the upper pole of the left kidney with apparent mural calcification posteriorly (arrow). This could be mistaken for a complicated or indeterminate renal cystic lesion. However, following administration of intravenous contrast the low attenuation fluid within the cystic cavity when compared with the normally enhancing renal parenchyma confirms the presence of an upper pole calyceal diverticulum (arrow). Delayed imaging demonstrated layering of contrast material in the cavity of the diverticulum; this observation confirmed its connection to the collecting system (not shown).

Conclusion

Calyceal diverticula containing calculi remain an uncommon urological condition, although when present are frequently symptomatic. It is important for both the urologist as well as the general radiologist to be familiar with their appearances, thus avoiding diagnostic uncertainty and unnecessary investigation for suspected complex renal cysts. A combination of imaging modalities might be necessary to reach a definitive diagnosis in difficult cases, although in most cases the diagnosis can be made by ultrasound. We have described and illustrated the imaging appearances of calyceal diverticula across the spectrum of imaging modalities.

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