Ultrasound imaging of the gallbladder

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The gallbladder on ultrasound appears as a pear-shaped structure lying in the inferior margin of the liver, along the principal plane separating the anatomic right and left lobe.[1] The normal gallbladder has a well-defined thin wall separated by a fluid filled anechoic lumen. The posterior wall often has an apparent brighter and thicker wall due to through transmission of sound.

Technique

Assessment of the gallbladder is performed routinely with a 5-7Mhz curved array sector probe. The high-resolution linear probe (10-15Mhz) can be used in selected cases to provide greater detail of the gallbladder wall (**figure 7b**).

Evaluation of the gallbladder is performed on a routine sweep across the liver in the sagittal and transverse oblique plane. A subcostal oblique sweep in the cranial to caudal direction will demonstrate the middle hepatic vein cranially and when angled caudally will identify the gallbladder fossa.[1]

The patient must be examined in at least two positions, typically in the supine and decubitus position. This should be performed after adequate fasting, usually a minimum of four hours. The consumption of food, particularly a fatty meal, causes the gallbladder to contract thus potentially obscuring intraluminal pathology such as gallstones and can potentially mimic pathology such as acute cholecystitis.

Anatomy and normal variants

The gallbladder is divided into neck, body and fundus. The fundus is the most anterior part.[1] In the region of the neck, there may be an infundibulum also known as the Hartmann's pouch which is a common site for impaction of gallstones (**figure 2a**).

Although rare, the most common ectopic position of the gallbladder is under the left lobe of the liver followed by an intrahepatic gallbladder.[2] Recognising this variant is important, as this may preclude laparoscopic surgery.

Failure to identify the gallbladder is usually due to inadequate fasting, previous cholecystectomy and a contracted gallbladder due to a chronic cholecystitis. A gas filled gallbladder and also a gallbladder packed with stones may also be misinterpreted as a bowel loop. The wall echo shadow (WES) complex is a useful sign seen in the latter[1] (**figure 1**).

Variations in the ultrasound appearances of the gallbladder have been well described. Commonly the gallbladder may have several junctional folds. The term Phrygian cap the most common manifestation, referring to a fold in the gallbladder fundus resulting in a localised pouch-like appearance.[2]

Gallstones

Gallstone disease is common worldwide, with increased prevalence in Europe where 10% of all adults have gallstones. Risk factors include female sex, increasing age, obesity, pregnancy, diabetes and haemolytic disorders. Women are three times more likely to have gallstones during the fertile years then men. By the age of 80, 60% of both men and women have gallstones.[3]

The gallbladder acts as a reservoir for storage of bile produced by the liver. It can become supersaturated with cholesterol, leading to crystal precipitation and subsequent gallstone formation.

There are two major types of gallstones. 80% are cholesterol stones, which are associated with bile supersaturated with cholesterol. The remaining 20% are pigment stones. Only 10-20% of gallstones contain enough calcium to be visible on plain film.[4]

Findings

Ultrasound is highly sensitive in the detection of stones within the gallbladder and is the gold standard test for the demonstration of gallstones.[1] The appearances of gallstones are variable dependant on the size and number (**figures 1, 2a and 2c**).

On US scans, gallstones are hyperechoic and cause posterior acoustic shadowing as with calculi elsewhere in the body (**figure 2a**). Small gravel-like stones typically less than 5mm in size may not shadow but will remain hyperechoic. In addition to the appearance, mobility is another key feature that is helpful to distinguish gallstones from polyps. The dynamic and real time imaging with ultrasound allows for the assessment of the patient in different positions, for instance in the decubitus position that may allow the stones to roll into view.

Although the majority of patients with gallstones are asymptomatic, between 0.3-1.2% will develop complications per annum, this rises to 0.7-2% if the patient already has symptoms, for instance biliary colic.[5]

Biliary sludge

Biliary sludge is a mixture of particulate matter and bile that occurs when solutes in bile precipitate.[1] There is a long list of predisposing factors, for instance critical illness, pregnancy and total parenteral nutrition. Biliary sludge can result in biliary colic and other complications seen with gallstones, for instance acute cholecystits and acute pancreatitis.

The typical sonographic appearance of sludge is low level echoes within the gallbladder with no acoustic shadowing (**figure 2a**). The biliary precipitates can coalesce and form sludge balls that can create unwanted anxiety and mimic polypoidal lesions.

The lack of internal vascularity, mobility and normal gallbladder wall are all useful pointers of biliary sludge (**figures 9a and 9b**). When in doubt, contrast enhanced examination is indicated with ultrasound, CT or MR.

Acute cholecystitis

The most frequent complication of gallstones is acute cholecystitis (**Figures 2a, 2b and 2c**). The risk of acute cholecystitis or serious complication with a history of biliary colic is about 1-2% a year.[4]

Classical ultrasound findings of acute cholecystitis include:

1, Significantly distended gallbladder >4cm wide (**figure 2b**)
2, Wall thickening >3mm.
3, Gallstones typically impacted stone in the neck (**figure 2c**)
4, Pericholecystic fluid or focal collections.

Other supporting features are hyperaemia of the gallbladder wall on Doppler examination (**figure 4b**).

Sonographic Murphy's sign can be reproduced as focal tenderness over the gallbladder when direct compression with the probe is applied on deep inspiration.

Mimics

Gallbladder wall thickening can be physiological and occur in the post-prandial state. However several abdominal conditions can lead to a positive Murphy's sign and gallbladder wall thickening. These include generalised oedema (**figure 3**), acute hepatitis, pyelonephritis, duodenal perforation, colitis and AIDS. Absence of gallbladder distension or gallstones should raise the suspicion of these alternative pathology.[1]

Acute cholecystitis can progress and further complications may occur, including focal perforation, gangrenous and emphysematous cholecystitis. An understanding of the pathophysiology of the associated complications of gallstones is important to allow for the appreciation of the sonographic findings.

Perforated cholecystitis

This occurs in cases of prolonged inflammation and is usually seen as a focal defect in the gallbladder wall with a localised collection in the gallbladder fossa (**figure 4a**) or into the liver parenchyma with abscess formation (**figure 4c**).

Clues to perforation:

1, Decompressed gallbladder

2, Defect in the wall with an associated focal pericholecystic collection.

Murphy's sign is less pronounced due to the decompression of the sepsis. Direct surgical intervention in complicated acute cholecystitis is hazardous with the risk of biliary complications. Initial choleystostomy tube placement to decompress the gallbladder and drainage of sepsis allows for an elective cholecystectomy once the acute episode settles. This can be performed under ultrasound guidance.

Gangrenous cholecystitis

The risk factors for gangrenous cholecystitis include cardiovascular disease, diabetes and untreated prolonged acute cholecystitis. Ischaemic necrosis of the gallbladder wall can occur leading to perforation. The patients are usually very unwell.

In the appropriate clinical context, the visualisation of the sloughed gallbladder mucosa can be identified, seen as linear structures floating in the gallbladder lumen (**figure 5a**). Unsurprisingly there is often absence of sonographic Murphy's sign.

Emphysematous cholecystitis

This is a rapidly progressive and fatal condition in approximately 15% of patients,[6] characterised by the presence of gas in the wall and lumen of the gallbladder. The gas is produced by gas forming bacteria, presumably after an ischaemic event affecting the gallbladder. This is more common in diabetics. Treatment is urgent surgical management for all patients.

The appearance depends on the volume of gas both within the lumen and gallbladder wall. A striking bright echogenic line with reverberation artifact that varies with position and compression are typical signs[1] (**figure 5b**).

Acalculous cholecystitis

This diagnosis should be reserved in critically ill patients rather than in the well patient in the outpatient clinical setting.

This condition is challenging to accurately diagnose as a thick walled, distended gallbladder with sludge is often seen in sick patients due to various other causes, rather than an underlying acute cholecystitis.

Distinguishing these two clinical entities requires careful consideration of the clinical picture. Alongside further cross sectional imaging with CT, there is an indication for percutaneous drainage in establishing the right diagnosis. This is usually a decision taken with the surgical team.

Porcelain gallbladder

Calcification of the gallbladder wall is termed porcelain gallbladder. The true incidence of porcelain gallbladder is unknown but is estimated to be 0.6-0.9%. Most porcelain gallbladders occur in association with gallstones and chronic cholecystitis. Porcelain gallbladder is an important clinical finding because of the association with gallbladder carcinoma.

The exact relationship between gallbladder cancer and the porcelain gallbladder is controversial. The reported frequency of carcinoma found in porcelain gallbladder specimens in the 1960s ranged from 12.5-61%.[7] Two studies in 2001 reported a much lower incidence of gallbladder cancer in porcelain gallbladder (0 to 5%).[8,9]

A prophylactic cholecystectomy should be considered and ideally performed in a hepatobiliary unit.

US scan shows a calcified hyperechoic gallbladder wall with acoustic shadowing that needs to be differentiated from wall-echo-shadow sign of a gallbladder packed with stones (***figure 6a and figure 1***). It can be easily differentiated on plain film or CT.

Adenomyomatosis

This is a benign condition caused by proliferation of the mucosa and muscularis propria with outpouching of the mucosa though the muscularis forming diverticula called Rokitansky Aschoff sinuses. This gives rise to a thickened gallbladder wall with internal cystic spaces. This is often an incidental finding noted on ultrasound and increasingly on CT studies. It is reported in up to 8% of cholecystectomy specimens.[10]

The ultrasound features include small rounded anechoic cystic spaces within the gallbladder wall with or without comet tail artifact.[1] (**figure 7a**). This artifact refers to the echoes from the internal biliary concretions within the cystic spaces (**figure 7b**). Adenomyomatosis can be segmental, typically around the gallbladder fundus where the cystic spaces are often appreciated, or diffuse with mural thickening and multifocal regions of comet tail artifact.

Polypoidal lesions

Polyps can mimic gallstones, appearing as hyperechoic foci lying adjacent to the dependent wall. However, polyps do not demonstrate posterior acoustic shadowing and lack of mobility allows differentiation between the two.

Cholesterol polyps

Strawberry gallbladder/cholesterolosis is characterised by deposits of cholesterol within macrophages in the submucosa of the gallbladder. This produces a spotty appearance – hence the name strawberry gallbladder.[1]

Typically these are 2-10mm in diameter, multiple oval shaped, non-shadowing and not mobile (**figure 8a**). These are benign, incidental and have no clinical significance.

Adenomatous polyps

These are true benign neoplasms of the gallbladder with premalignant potential. Commonly a solitary lesion and can be pedunculated or sessile (***figures 8b and 8c***). Adjacent mural thickening should raise the possibility of malignancy. In general, polyps greater than 10mm should be removed given the increased risk of malignancy. Other features that indicate a cancer risk are a sessile morphology and increase in size on follow-up.

Gallbladder cancer

Primary carcinoma of the gallbladder is an uncommon malignancy that often presents late with metastatic spread and has a poor prognosis. The five-year survival rate is less than 5%.[11] In the majority of cases, it is associated with gallstones. Early stage carcinoma is usually found incidentally on post cholecystectomy histology examination.

The presence of a polypoidal vascular mass lesion in the gallbladder is highly suspicious for a gallbladder cancer[1] (***figures 9a and 9b***). Other patterns of gallbladder cancer include irregular focal or diffuse mural thickening and gallbladder mass directly invading adjacent structures. In cases of gallbladder cancer where the only finding is focal or diffuse mural thickening, this can be challenging to accurately distinguish from chronic cholecystitis. Further work-up with contrast enhanced CT or MRI is indicated.

Useful local staging information such as liver invasion, vascular and bile duct encasement, hepatic and nodal metastasis can also be detected on ultrasound. Ultrasound can be used to direct puncture of the bile ducts in percutaneous transhepatic biliary procedures.

Conclusion

Ultrasound is the well-established first line imaging modality that is highly sensitive and specific in the assessment of the gallbladder wall and luminal content. The inherent strengths of ultrasound, namely absence of ionising radiation, dynamic test that is well tolerated, ability to get a clinical history and elicit useful clinical signs, significantly adds to the power of this modality.

Ultrasound somewhat paradoxically plays a key role in problem solving equivocal findings related to the gallbladder seen on initial CT and MR studies. Ultrasound is particularly valuable in demonstrating gallstones and characterising abnormal indeterminate thickening seen on CT and MRI. The development of contrast enhanced ultrasound has also provided an alternative means of assessing the vascularity of the gallbladder wall and any focal mass during the same examination.

Ultrasound has a role in the intervention, particularly in the placement of cholecystostomy tubes and direct puncture of the bile ducts under direct vision.

An understanding of the pathophysiology of the respective disease processes described above is crucial to allow for the accurate identification and appreciation of the ultrasound findings. This will avoid any unwanted delay in making the correct diagnosis.

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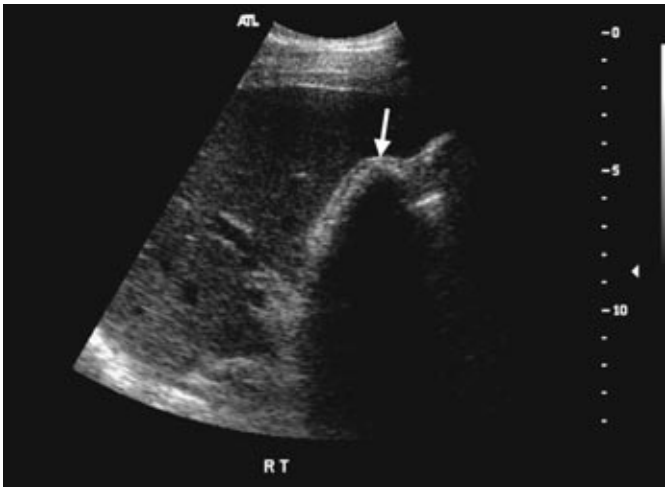
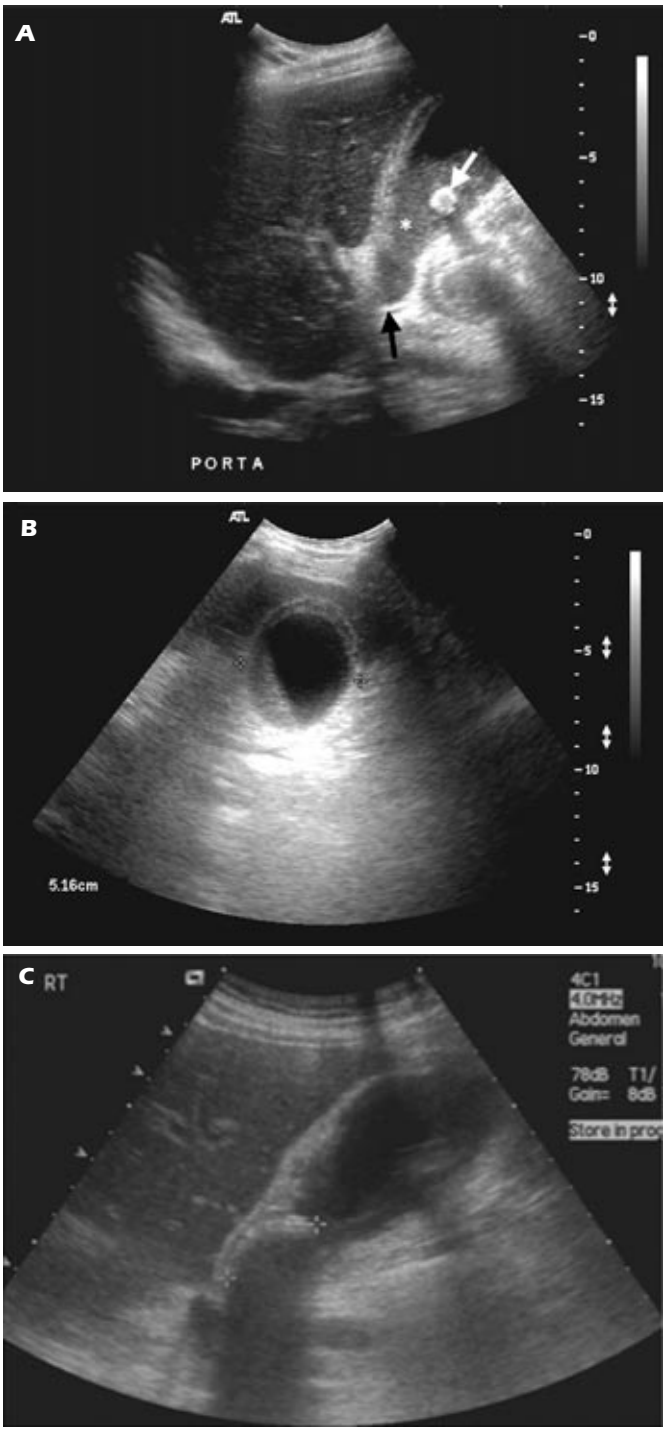


FIGURE 1
Wall-echo-shadow (WES sign) in a gallbladder packed with stones. Arrow points to the normal gallbladder wall. Dense echogenic arc casting a posterior acoustic shadow represents lumen packed with gallstones. Note WES sign absent in porcelain GB (see *figure 6a*).



FIGURES 2A, B AND C
Acute cholecystitis. Thick walled, distended gallbladder with gallstones and biliary sludge (x). Note large impacted gallstone (between marker) in the neck of the gallbladder. (white arrow – gallstone, black arrow – Hartmann's pouch).

FIGURE 3
Symmetrical gallbladder wall thickening – 'onion peel' appearance due to mural oedema secondary to hepatic cirrhosis. Absence of gallstones and non-distended state – NOT acute cholecystitis.

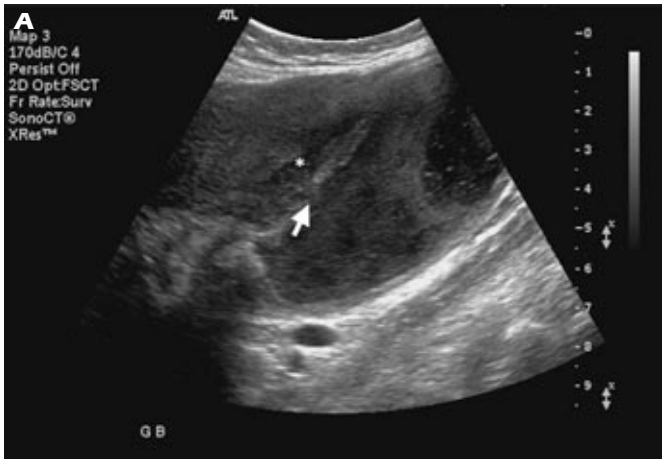


FIGURE 4A
Perforated gallbladder. Focal defect in the gallbladder wall (arrow) and a pericholecystic collection. Note the internal linear strands (x) within the collection a feature of abscess.

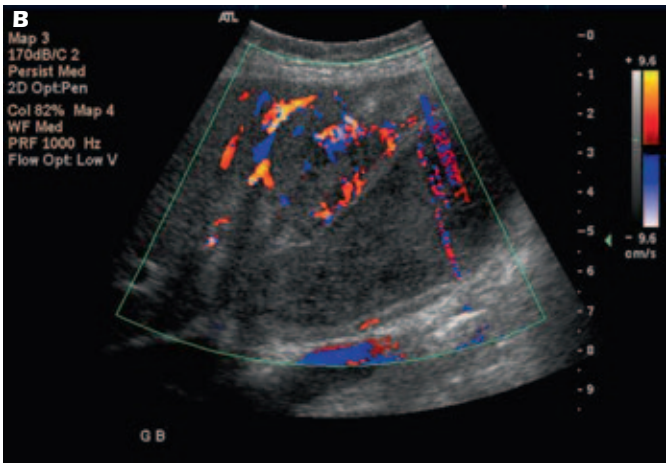


FIGURE 4B
Perforated gallbladder. Colour Doppler shows striking hyperaemia due to the localised sepsis.

FIGURE 4C
Localised gallbladder perforation with liver abscess formation. Arrow points to floating gallstone in the gallbladder fossa and hepatic abscess (x) formation.

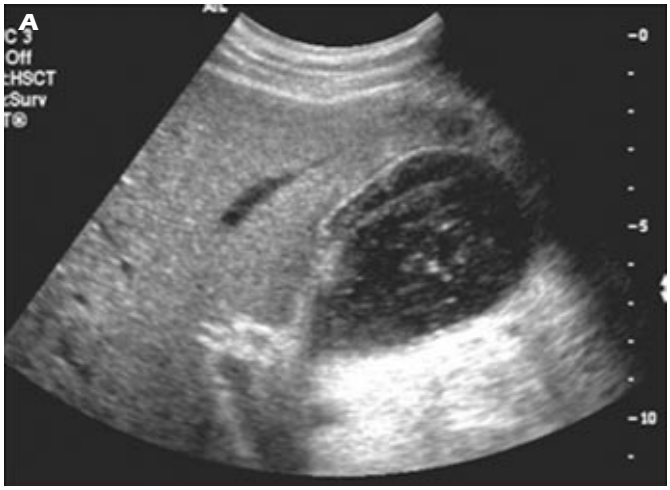


FIGURE 5A
Linear echogenic strands in the lumen representing the sloughed mucosa in a gangrenous cholecystitis.

FIGURE 5B
Gallbladder filled with air. Bright echogenic focus with reverberation artefact characteristic of gas. Note the gallbladder itself is not visualised but can be traced to the expected position and should not be mistaken for bowel gas.

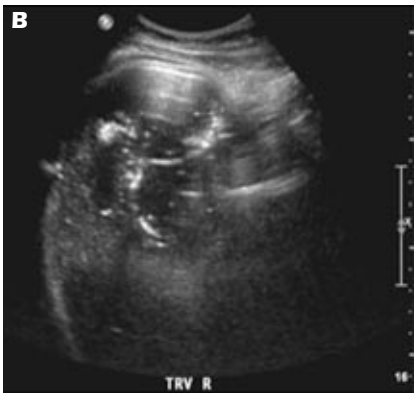


FIGURE 6
Porcelain gallbladder: Note calcified echogenic wall constant in all positions and absence of WES sign.

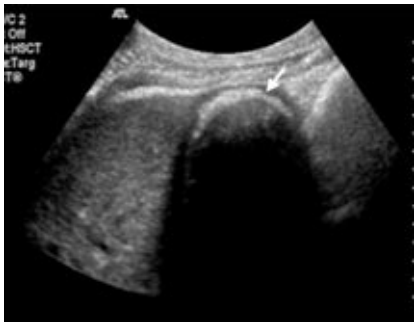


FIGURE 7A
Focal fundal adenomyomatosis. Note comet tail artefact.

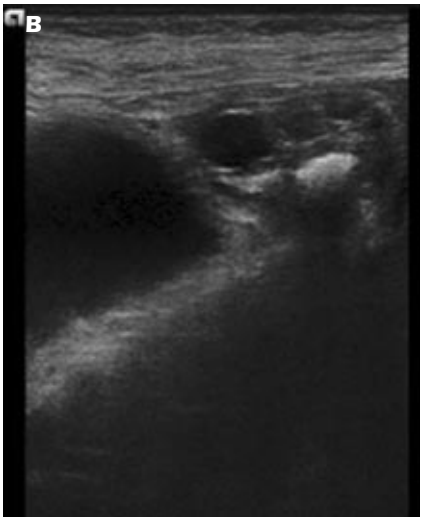
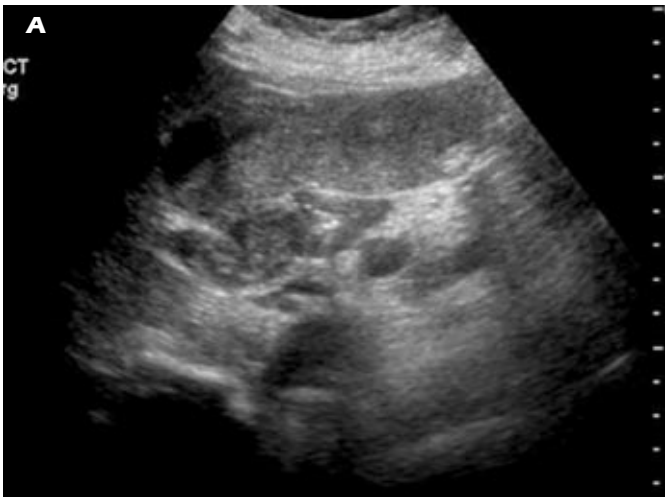
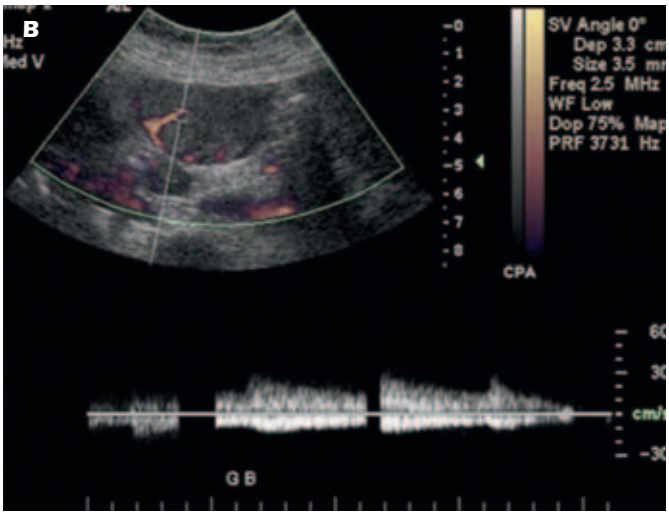


FIGURE 7B
High resolution linear probe showing localised adenomyomatosis seen as cystic spaces in the gall-bladder fundus with small calcified stones.





FIGURES 9A AND 9B
Gallbladder lumen filled with echogenic mass which can mimic sludge but note internal vascularity consistent with an underlying malignancy. This was confirmed at surgery.

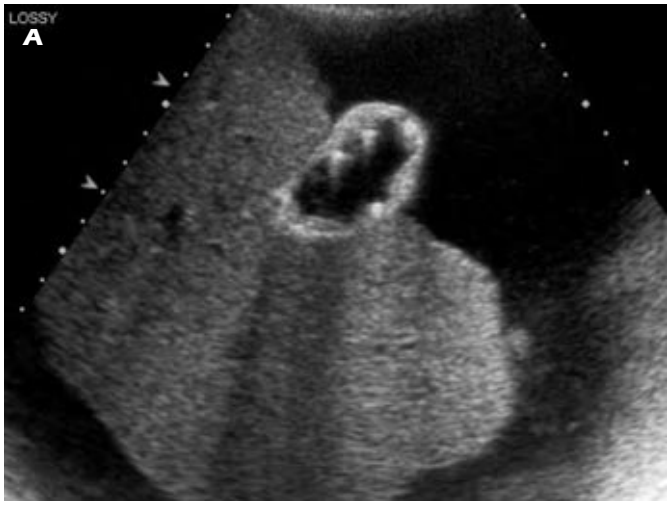


FIGURE 8A
Cholesterol polyps. Mutiple and small size (echogenic, non-shadowing).

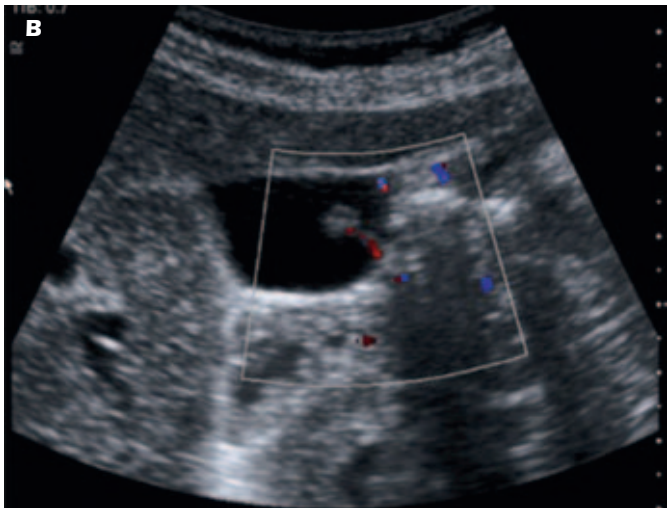


FIGURE 8B
Pedunculated polyp. True adenomatous polyp-Doppler demonstrating vessels within stalk.

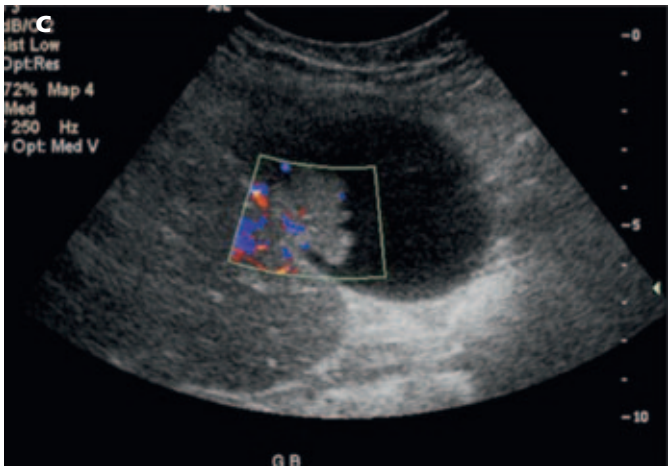


FIGURE 8C
Sessile polyp 'cauliflower morphology' >than 10mm increased risk of cancer – requires surgery.