Something or Nothing: Accurately diagnosing gallbladder sludge on MRI.

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Learning objectives

1. To understand the components of gallbladder sludge and the importance of proper diagnosis.
2. To understand how to diagnose gallbladder sludge on MRI.
3. To understand the pitfalls of diagnosing gallbladder sludge on MRI.

Background

- Gallbladder sludge is a culprit of biliary symptoms leading to cholecystitis, cholangitis, and pancreatitis. Because of these risks, it is important to diagnose gallbladder sludge.
- Familiarity with the imaging characteristic of bile on MRI is necessary for the diagnosis of pathology in the pancreaticobiliary tract in order to determine treatment.
- However, with MRI modality, false positives are rampant and may lead to unnecessary tests, procedures, and patient worry.
- We will present a series of cases that compare MRI gallbladder findings with the gold standard of ultrasound.

Findings and procedure details

Gallbladder sludge composition

Biliary sludge is composed of a mixture of particular matter which have precipitated from bile including cholesterol monohydrate, calcium bilirubinate pigment, and other calcium salts and mucous produced by the gallbladder.

Biliary sludge generally forms after reduced motility in the gallbladder secondary to reduced food intake or parenteral nutrition.

MR imaging principles
On MRI, gallbladder sludge appears as dependently layering hyperintensity on T1 and hypointensity on T2.

Gallbladder sludge is also delineated on gradient echo sequences using the principle of in and out of phase imaging. This is based on the principle that fat and water have different precession frequencies on MRI immediately after the excitation pulse, when fat and water are in phase with each other their signals intensities are additive and result in hyperintensity. Conversely, when differences in precession frequencies result in fat and water being out of phase with each other, the resultant signal intensities cancel each other out and result in hypointensity.

MRI post-contrast subtraction imaging can be helpful in imaging the gallbladder contents, specifically differentiating gallbladder tumefactive sludge from gallbladder wall thickening secondary to carcinoma.

MRI post-contrast subtraction is a technique in which unenhanced, T1-weighted images are digitally subtracted from the same sequence after gadolinium administration. Absence of enhancement will indicate biliary sludge instead of a neoplasm. However, there are pitfalls that lead to over diagnosing gallbladder sludge.

In addition to sludge, a high-intensity T1 signal from bile can also be seen in concentrated bile, stones or hemobilia.

**MR pitfalls in imaging gallbladder sludge**

Due to the composition of bile, there can be many pitfalls which may lead to over diagnosing gallbladder sludge. For example, in a fasting patient, layering T1 hyperintensity seen on in phase imaging which is lost on out of phase imaging may indicate dilute bile mixing with more concentrated lipid-rich bile rather than sludge.

It is not uncommon to see layering T1 hyperintensity on GRE images but have no T2 correlate and vice versa. In our experience, layering T2 hypointensity is a more reliable finding for gallbladder sludge.

Hemobilia may appear similar to sludge on both the T1 and T2 weighted images. However, blood products should not lose signal intensity on the in and out of phase sequences.
Cases:

In these cases, the MRI and ultrasound were obtained within one month of each other.

Fig. 1 on page 5 shows no evidence of stones or biliary sludge on ultrasound and MRI sequences.

In Fig. 2 on page 5, there are shadowing dependent stones visualized on ultrasound. Layering material is visualized on both T1 and T2 weighted imaging, indicating sludge (red arrows). In addition, the stone visualized on ultrasound is also seen on the T1 in and out of phase as a round hyper-intensity and on the T2 as a round hypo-intensity (yellow arrows).

Fig. 3 on page 6a shows a sonogram of the gallbladder which demonstrates mobile layering echogenic material compatible with sludge and stones. There are multiple small focal T2-hypo-intense lesions compatible with cholelithiasis on a background of layering T2-hyper-intense material that represents surrounding sludge. On T1 imaging, the layering is subtle, and careful attention with windowing is needed to detect the dependent hyperintense material.

In Fig. 4 on page 7, there are shadowing dependent stones visualized on ultrasound. Layering material is visualized on both T1 and T2 weighted imaging, which is similar in appearance to sludge, however, no discrete stones are visualized. This may indicate that the stones are small or that there may be sludge present in addition to the stones which is obscured by artifact from the stones on ultrasound.

Fig. 5 on page 8 shows no biliary sludge or stones in the gallbladder on ultrasound examination, however, on T1 weighted imaging there is clear layering of hyperintense material and on T2 there is clear layering of hypointense material. This is likely due to separating concentrated bile.

Fig. 6 on page 9 shows no evidence of sludge or stones on ultrasound. On in phase T1 imaging, Fig. 6c shows layering hyperintense material, however this hyperintensity is subtracted from the out-of-phase imaging and suggests the presence of lipid content. T2 shows a subtle layering gradient of hypointensity, without a clear definitive fluid/sludge level. Caution must be taken to ensure all sequences show a definite line defining bile and sludge before diagnosing biliary sludge. Of note, the liver parenchyma is much more hypointense on out of phase imaging when compared to in phase imaging which indicates hepatosteatosis.
Fig. 7 on page 10 ultrasound shows stones in the gallbladder, however, T1 in and out of phase as well as T2 weighted sequences show subtle layering without evidence of discrete stones. This demonstrates that, at times, MRI may not be the optimal modality for detecting stones and must be correlated with ultrasound, which is more sensitive.

These cases demonstrate that the presence of layering material in the gallbladder may indicate sludge, however it may also indicate separating concentrated bile. Ability to identify stones is also difficult at times depending on the rest of the contents of the gallbladder as well as the composition of the stones. In the end, detection of biliary sludge and stones is difficult on MRI and correlation with ultrasound is necessary for accurate diagnosis.

Images for this section:

![Images for section](image-url)

**Fig. 1:** A) Ultrasound of gallbladder. B) T2 weighted sequence on MRI. C) T1 in phase sequence on MRI. D) T1 out of phase sequence on MRI.
Fig. 2: A) Ultrasound of gallbladder. B) T2 weighted sequence on MRI. C) T1 in phase sequence on MRI. D) T1 out of phase sequence on MRI.
Fig. 3: A) and B) Ultrasound of gallbladder. C) T1 in phase sequence on MRI weighted sequence on MRI. D) T2 weighted imaging on MRI.
Fig. 4: A) Ultrasound of gallbladder. B) T2 weighted sequence on MRI. C) T1 in phase sequence on MRI. D) T1 out of phase sequence on MRI.
**Fig. 5:** A) Ultrasound of gallbladder. B) T2 weighted sequence on MRI. C) T1 in phase sequence on MRI. D) T1 out of phase sequence on MRI.
Fig. 6: A) Ultrasound of gallbladder. B) T2 weighted sequence on MRI. C) T1 in phase sequence on MRI. D) T1 out of phase sequence on MRI.
Fig. 7: A) Ultrasound of gallbladder. B) T2 weighted sequence on MRI. C) T1 in phase sequence on MRI. D) T1 out of phase sequence on MRI.
Conclusion

The gallbladder serves as the repository of bile made in the liver and is the source of most biliary pathology.

Gallbladder sludge has a characteristic appearance on T1 and T2 weighted sequences. However, conditions such as fasting can result in concentrated bile appearing similar to sludge and may lead to an over-diagnosis.

Findings suggestive of sludge, ie layering T1 hyperintense and T2 hypointense material in the gallbladder should raise the possibility of sludge and a confirmatory ultrasound should be performed.

Personal information

References
