Objective. The aims of this study were to describe the mechanisms likely to be responsible for color Doppler twinkling artifacts and their associated machine factors and to illustrate the various conditions that cause twinkling artifacts and those pitfalls. Methods. We evaluated various sonographic machine-associated factors that influence artifact appearance and identified various conditions that display twinkling artifacts during abdominal and pelvic sonography. Results. The presence of twinkling artifacts was found to be dependent on focal zones, gray scale gains, color write priorities, and pulse repetition frequencies. Twinkling artifacts were found to be associated with calcified lesions in the liver, gallbladder adenomyomatosis, hepatic bile duct hamartoma, gallstones and choledocholithiasis, chronic pancreatitis, urinary stones, encrusted indwelling urinary stents, bowel gas, and metallic foreign bodies. However, some of the twinkling artifacts were found to be associated with false-negative and -positive results. Conclusions. Color Doppler twinkling artifacts are additional useful sonographic signs in the diagnosis of calcified lesions, urinary and biliary stones, gallbladder adenomyomatosis, and some miscellaneous conditions. Key words: abdomen; color Doppler sonography; pelvis; sonography; twinkling artifact.

Color Doppler sonography is commonly used to assess tissue vascularity rapidly. However, any tissue or fluid motion can generate a Doppler signal; thus, a variety of artifacts can be produced. Among these artifacts, color Doppler twinkling artifacts are regarded as useful diagnostic signs. These artifacts appear as rapidly alternating red and blue signals behind certain highly reflective structures (Figure 1A) and may mimic flow. Spectral Doppler analysis produces a fine heterogeneous broadband signal without a discernable spectrum (Figure 1B). Twinkling artifacts have been mainly reported in association with urinary calculi, but they have also been encountered during abdominal and pelvic sonography in association with calcifications in various tissues, biliary stones, encrusted indwelling urinary stents, gallbladder adenomyomatosis, and bile duct hamartomas. Although twinkling artifacts do not occur in every case with the above-mentioned conditions, their visualization can improve diagnostic confidence and facilitate lesion detection.
In this study, we describe the possible mechanisms responsible for twinkling artifacts and the various sonographic machine factors that influence their appearances. On the basis of our experiences with the clinical use of twinkling artifacts during abdominal and pelvic sonography, we present various conditions that cause twinkling artifacts and some of the correlations between twinkling artifacts and the findings of other imaging modalities, such as simple radiography, computed tomography (CT), and magnetic resonance imaging. The pitfalls of using a twinkling artifact as a diagnostic sign are also discussed.

Mechanisms

Two hypotheses have been proposed to explain twinkling artifacts. The first was offered by Rahmouni et al, who suggested that a twinkling artifact is an artifact generated by a strongly reflecting medium with a rough interface. When an incidental ultrasound beam is reflected by a flat interface, the acoustic waves are reflected by the interface at the same time, which results in the production of short-wave sound signals. However, when a beam impinges on a rough interface composed of individual reflectors, the acoustic wave is split into a complex beam pattern caused by multiple reflections in the medi-
um, accounting for the prolonged pulse duration of the transmitted sound signal. This is interpreted by Doppler units as movement and thus is assigned different colors. The second hypothesis was offered by Kamaya et al, who proposed that a twinkling artifact is caused by a narrow band of intrinsic sonographic machine noise, referred to as “phase jitter,” which is probably generated by slight random time fluctuations in the path lengths of transmitted and reflected acoustic waves. It was proposed that at a strong reflector with a rough interface, these slight time fluctuations are amplified to produce apparent aliased Doppler shifts.

Machine Parameters and Twinkling Artifacts

The detection of twinkling artifacts is highly dependent on machine settings. Lee et al. reported that the location of a focal zone can influence the occurrences and intensities of twinkling artifacts. When a focal zone is located below a rough reflecting surface, the twinkling artifact becomes more obvious (Figure 2A). However, when a focal zone is located above such a surface, the twinkling artifact is weakened (Figure 2B). The appearance of a color Doppler signal is affected by several machine settings, such as color write priority, gray scale gain, and

Figure 3. Effect of color write priority on twinkling artifacts. A, Color Doppler sonogram at the upper level of the color write priority (oval) showing a prominent twinkling artifact from gallbladder adenomyomatosis. B, However, when the color write priority (oval) was reduced, the twinkling artifact disappeared.

Figure 4. Effect of gray scale gain on twinkling artifacts. A, Color Doppler sonogram showing prominent twinkling artifacts from the balloon of a Foley catheter at a gray scale receiver gain of 49% (oval). B, When the gray scale receiver gain was increased to 75% (oval), the twinkling artifacts were substantially weakened.
pulse repetition frequency. Color write priority decides whether a pixel should be depicted as color or as gray scale, and increasing the color write priority causes more color information to be displayed and thus twinkling artifact enhancement (Figure 3). Similarly, but conversely, increasing the gray scale gain reduces the amount of color in an image (Figure 4). Therefore, a twinkling artifact usually increases on increasing the color write priority and reduces when the gray scale gain is increased. However, this rationale does not hold in all situations. With regard to the pulse repetition frequency, a reduction may increase the twinkling artifact intensity and produce a strong broadband signal (Figure 5).

However, in particularly strong areas of a twinkling artifact, spectral broadening is present at all pulse repetition frequencies.

**Conditions That Display Twinkling Artifacts**

**Calcified Lesions in the Liver**

Hepatic calcifications may be encountered in inflammatory lesions and in benign and malignant tumors. Inflammatory conditions such as granulomatous diseases (eg, tuberculosis and histoplasmosis) are the most common causes of calcified hepatic lesions. Most of these calcifications are small and have a rough surface; thus, twinkling artifacts are observed because of reflections from the surfaces of calcifications (Figure 6). The recognition of the association between hepatic lesions and twinkling artifacts is important because the presence of color might be erroneously interpreted as real blood flow and might lead to suspicions of a hypervascular mass.

**Gallbladder Adenomyomatosis**

Gallbladder adenomyomatosis is characterized by benign hyperplasia of the gallbladder mucosa with thickening of the muscular layer, and its sonographic appearance is focal or diffuse thickening of the gallbladder wall. Intramural echogenic foci cause V-shaped reverberation artifacts and are highly specific for adenomyomatosis; in fact, they represent the acoustic signature of cholesterol crystals within Rokitansky-Aschoff
sinuses.\textsuperscript{14} Some echogenic intramural foci are composed of calcifications or cholesterol deposits with rough interfaces, and these are likely to cause twinkling artifacts.\textsuperscript{10} A twinkling artifact may facilitate the detection of adenomyomatosis in the gallbladder fundus, which is affected by reverberation artifacts arising from the subcutaneous layer (Figure 7). In addition, the presence of a twinkling artifact can also provide an important diagnostic clue that allows the differentiation of gallbladder adenomyomatosis and gallbladder cancer (Figure 8).

\textbf{Hepatic Bile Duct Hamartomas}

Bile duct hamartomas of the liver are composed of cystic dilatation of the bile duct accompanied by variable amounts of collageneous stroma.\textsuperscript{15} Sonographically, these hamartomas have an inhomogeneous coarse echo texture resembling cirrhosis, multiple small hyperechoic or hypoechoic nodules, or multiple bright spotty echoes with comet tail artifacts.\textsuperscript{11} Bile duct hamartomas are clinically important because they can mimic cirrhosis or metastasis on imaging studies.\textsuperscript{16} Twinkling artifacts can also be produced by bile duct hamartomas due to multiple reverberations.
from cholesterol crystals within cystic dilatations of bile ducts (Figure 9) and are similar to those observed in gallbladder adenomyomatosis.\textsuperscript{11}

**Cholelithiasis and Choledocholithiasis**

Twinkling artifacts are often observed in gallstones but have little or no diagnostic impact in this context because gallstones are readily diagnosed by gray scale sonography.\textsuperscript{6} The production of twinkling artifacts by gallstones is related to biochemical composition. Most mixed stones and about half of cholesterol stones produce twinkling artifacts, whereas most pigment stones do not (Figure 10).\textsuperscript{17} Thus, gallstone compositions can be predicted on the basis of the presence of twinkling artifacts, although this is of little use clinically. However, the identification of common bile duct stones is challenging because they are sometimes obscured by bowel gas during gray scale sonography; thus, the presence of a twinkling artifact sometimes provides a useful means of detection (Figure 11).

**Chronic Pancreatitis**

Chronic pancreatitis is often associated with punctate calcifications in parenchyma, which can be subtle on gray scale sonography when they are small and posterior acoustic shadowing

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**Figure 9.** Bile duct hamartoma in a 58-year-old man. **A**, Gray scale sonogram (left) showing spotty echogenic foci (arrows) with subtle comet tail artifacts. The corresponding color Doppler sonogram (right) shows twinkling artifacts behind the echogenic foci. **B**, Contrast-enhanced axial CT showing numerous tiny hypoattenuating lesions in the entire liver, suggestive of bile duct hamartoma. No biopsy was conducted in this case.

**Figure 10.** Twinkling artifact and gallbladder stone composition. **A**, Gray scale sonogram (left) showing an echogenic stone (arrow) with posterior acoustic shadowing in the gallbladder. The corresponding color Doppler sonogram (right) shows a twinkling artifact behind the stone. The stone was confirmed as a cholesterol stone after surgery. **B**, An echogenic stone in the gallbladder did not produce a twinkling artifact on the color Doppler sonogram. This stone was found to be a pigmented stone after surgery.
is absent. However, they can become obvious in the color Doppler mode because of the presence of twinkling artifacts; thus, twinkling artifacts can help establish a diagnosis of chronic pancreatitis (Figure 12).

**Urinary Stones**

The detection of renal stones by sonography can be problematic when they are obscured by indistinct echogenicity caused by renal sinus fat or when their posterior acoustic shadowing is indiscrte. However, 80% of renal stones exhibit twinkling artifacts, and in most cases these artifacts are easily detected (Figure 13). Furthermore, in cases of hydronephrosis and hydroureter caused by ureteral stones, it is sometimes difficult to detect stones by gray scale imaging because of the obscuring effects of bowel gas. However, a twinkling artifact facilitates stone detection, and its presence strongly supports a diagnosis of a ureteral stone (Figure 14). Therefore, a twinkling artifact can be considered a major diagnostic sonographic finding in this context. Chelfouh et al reported that stone composition has a major influence on twinkling artifacts. For example, stones composed of calcium oxalate dehydrate or calcium phosphate produce twinkling artifacts, whereas most of those composed pre-

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**Figure 11.** Common bile duct stone in a 39-year-old woman. A, Gray scale sonogram (left) obtained in a sagittal scan showing an echogenic stone (arrow) with posterior acoustic shadowing in the common bile duct. The corresponding color Doppler sonogram (right) shows a prominent twinkling artifact behind the stone. B, Contrast-enhanced coronal CT showing a hyperattenuating stone (arrow) in the distal common bile duct.

**Figure 12.** Chronic pancreatitis in a 70-year-old man. A, Gray scale sonogram (left) showing increased echogenicity with uncertain posterior acoustic shadowing in the pancreas body and tail. The corresponding color Doppler sonogram (right) shows prominent twinkling artifacts in the regions of increased echogenicity. B, Nonenhanced axial CT showing multiple tiny parenchymal calicifications involving the whole pancreas, suggestive of chronic pancreatitis.
dominantly of calcium oxalate monohydrate or urate do not.

**Bowel Gas**

Intraluminal echogenic gas in the bowel can also be recognized by a twinkling artifact (Figure 15), which might be due to the rough surfaces of bowel contents. However, a twinkling artifact caused by the bowel lumen can obscure an artifact from a lesion of the gallbladder or urinary system.

**Encrusted Indwelling Urinary Stents**

Indwelling urinary stents are widely used to relieve urinary obstructions, but encrustation of a stent tip can obstruct the urinary system. Encrustation rates vary and depend on the biochemical composition of urine and on stent materials. The calcium phosphate or calcium oxalate deposits responsible for these encrustations cause stent surfaces to become irregular or crystalline and produce twinkling artifacts (Figure 16). Thus, the presence of a twinkling artifact enables encrustation to be identified.

**Metallic Foreign Bodies**

Twinkling artifacts can also aid the identification of needle tracts during sonographically guided biopsies, probably because entrapped air and...
the metallic needle along the biopsy tract cause a rough interface (Figure 17). Twinkling artifacts can also be helpful for identifying metallic foreign bodies with rough rusty surfaces (Figure 18).

**Pitfalls of Using Twinkling Artifacts as Diagnostic Signs**

Although twinkling artifacts are frequently observed behind calcifications with a rough surface, some calcifications do not produce artifacts. We have found that cases of gallbladder adenomyomatosis of the fundal type or cases without cholesterol crystal deposition do not produce twinkling artifacts (Figure 19). Furthermore, although bowel gas frequently produces twinkling artifacts, biliary air does not (Figure 20).

During kidney sonography, echogenic foci with twinkling artifacts do not always suggest stones. In fact, calcifications of the renal artery, renal tumor, renal cyst, and renal parenchyma may produce twinkling artifacts. These can usually be differentiated from renal stones because they tend to pulsate and because of their locations and patient history. A renal arteriovenous fistula is a well-known complication of renal biopsies and appears as an abnormally high velocity with localized turbulent flow on color Doppler images. This turbulent flow produces perivascular vibrations, which result in combined red and blue signals that resemble twinkling artifacts (Figure 21). However, an arteriovenous fistula usually can be differentiated from a twinkling artifact by Doppler spectra and by a history of renal biopsy.

**Conclusions**

Color Doppler twinkling artifacts are additional sonographic signs that can be useful during the diagnoses of calcified lesions, urinary and biliary stones, gallbladder adenomyomatosis, and other miscellaneous conditions. Our experiences indicate that the recognition of twinkling artifacts during abdominal and pelvic sonography can improve diagnostic confidence for a considerable number of clinical conditions.
Color Doppler Twinkling Artifacts on Abdominal and Pelvic Sonography

Figure 17. Liver biopsy in a 70-year-old woman with hepatitis. A, Gray scale sonogram showing an echogenic line (arrows) along the metallic needle tract in the liver. B, Color Doppler sonogram showing twinkling artifacts from the needle tract.

Figure 18. Small-bowel perforation due to the swallowing of a metallic needle in a 16-year-old boy. A, Gray scale sonogram (left) showing an echogenic line (arrows) indicating the metallic needle in the small-bowel loop. The color Doppler sonogram (right) shows twinkling artifacts from the echogenic line. B, Conventional abdominal radiograph (left) showing the needle in the left side of the abdominal cavity and the rusty needle retrieved during surgery (right).

Figure 19. Gallbladder adenomyomatosis in a 39-year-old woman. A, Gray scale (left) and color Doppler (right) sonograms showing focal wall thickening (arrows) of the gallbladder fundus without twinkling artifacts. B, Magnetic resonance cholangiography showing a grapelike cystic lesion (arrow) in the fundus of the gallbladder, suggestive of adenomyomatosis. This patient underwent surgery and was confirmed to have adenomyomatosis.
References


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