Comet Tail Artifacts in Gray Scale Ultrasound and Colour Doppler Ultrasound in Various Anatomical Regions and Their Clinical Significance

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Abstract

Artifacts are very common in ultrasound diagnostics. An artifact refers to any occurrence on the image that does not accurately represent the actual anatomical structures. Radiologists and doctors using ultrasound diagnostics should be able to recognize artifacts that have clinical significance in order to properly interpret ultrasound images. There are numerous examples in everyday clinical practice, which will be presented in this paper, where knowledge of the “comet tail” artifact in greyscale ultrasound and the “twinkling” artifact when using color Doppler can assist in clinical dilemmas.

Keywords: Ultrasound artifacts, Comet tail artifact, Twinkling artifact, Reverberation artifact, Greyscale ultrasound, Clinical significance, Differential diagnosis

Sažetak:

Artefakti repa kometa na klasičnom ultrazvuku i obojenom Dopplеru u različitim anatomskim regijama i njihova klinička važnost

Artefakti su uobičajena pojava u ultrazvučnoj dijagnostici. Artefakt predstavja bilo koju pojavu na slici koja ne predstavlja stvarne anatomske strukture. Radiolozi i ostali doktori koji upotrebljavaju ultrazvuk trebali bi moći prepoznati artefakte koji posjeduju kliničku važnost kako bi ispravno mogli protumačiti ultrazvučne snimke. Brojni primjeri iz svakodnevne prakse predstvaljeni u ovom radu pokazat će kako spoznaje o artefktima repa kometa u klasičnom ultrazvuku i svetlucajućem (twinkling) artefaktu na obojenom Doppleru mogu pomoći pri rješavanju kliničkih nedoumica.

Ključne riječi: ultrazvučni artefakti, artefakt repa kometa, artefakt svjetlucanja, reverberacijski artefakt, klasični ultrazvuk, diferencijalna dijagnoza

Figure 1: Haley comet, Edward Emerson Barnard, Yerkes Observatory, Wisconsin, 1910. Public domain, source: The New York Times, published July 3, 1910. Available on Wikipedia.

Introduction

The creation of an ultrasound image is based on the physical properties of the ultrasound wave, the passage of sound through tissue, the interaction of sound with reflecting obstacles, and the detection and processing of reflected waves. In radiological imaging, the term artifact is used for any occurrence on the image that does not faithfully represent the actual anatomical or pathological structures. [1] The "comet tail" artifact in greyscale ultrasound and the color comet tail or "twinkling" artifact when using color Doppler are subtypes of the "reverberation" artifact and they have appearance of comet on night sky. (Fig.1) [1,2] Therefore, artifacts can help us in clinical practice with many clinical dilemmas in ultrasound diagnostics. [1-4]
Small calculi in the bile ducts with minimal or no ductal dilatation, small kidney or ureteral stones with or without dilatation of the ductal system, calcifications of the ducts or parenchyma of the pancreas (in chronic pancreatitis), small calculi in intrahepatic bile ducts (in patients with cystic fibrosis), adenomyomatosis, gallbladder sludge (Fig.2), surgical clips, and foreign materials are some of the conditions where knowledge of the „comet tail" and „twinkling" artifact can lead to better detection and interpretation of underlying pathologies and therefore can benefit in everyday ultrasound practice. [2-4]

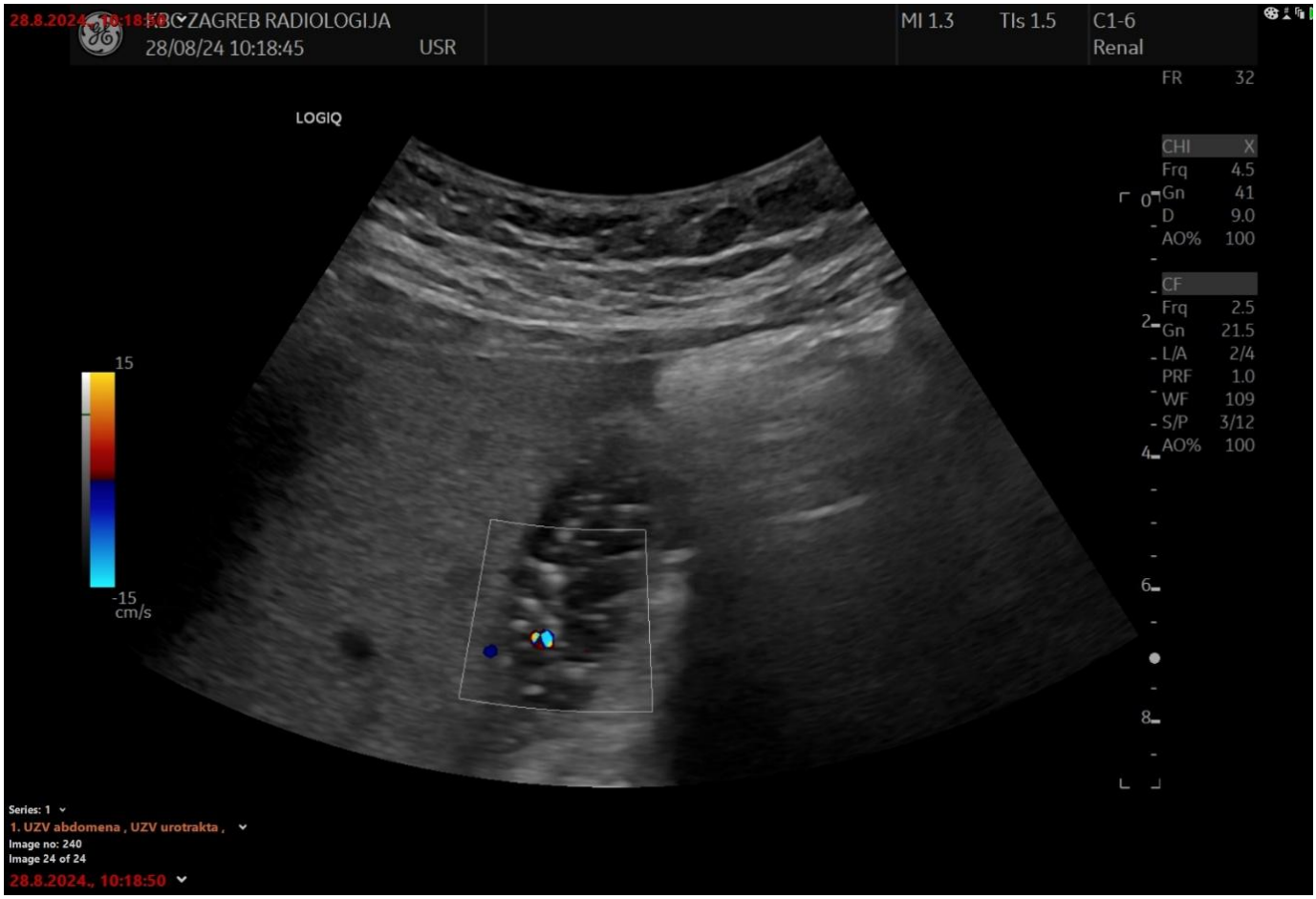

Figure 2 : Color comet tail or„Twinkling" artifact in gallbladder sludge and small calculi

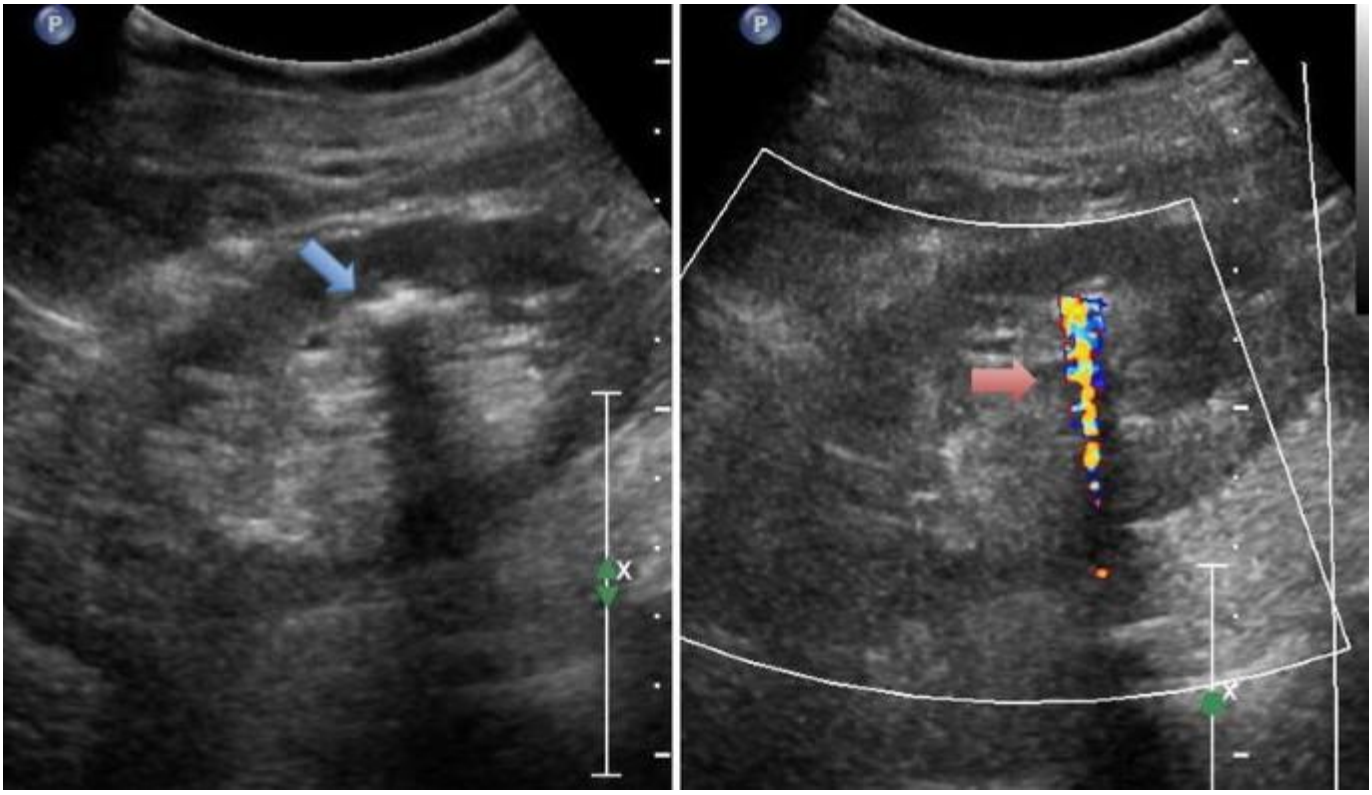

Figure 3: Color comet tail arterfact or „twinkling" aeterfact in small renal calculus

Figure 4: Comet tail artifact in the thyroid coloid cyst

Discussion

The ultrasound image is created based on several assumptions: every received reflected wave originates in the ultrasound probe itself, the reflected wave returns to the probe after a single reflection, the depth of the object from which the wave is reflected is proportional to the travel time of the emitted wave, the speed in tissue is constant, the path of the wave is straight, and the acoustic energy is uniformly attenuated through the tissue. [1,2,4] Such assumptions hold in ideal conditions, but in real clinical ultrasound practice, the received ultrasound waves are often displayed as artifacts. [1]

In radiological imaging, the term "artifact" is used for any occurrence on the image that does not faithfully represent the actual anatomical or pathological structures. In ultrasound diagnostics, artifacts can cause some structures to appear that do not actually exist. Conversely, some structures that do exist may not be displayed on the image, or the displayed structures may not be of the actual size, location, or appropriate brightness. It is important to note that the ultrasound technique itself is prone to artifact creation and therefore has the potential to interfere with the interpretation of findings. Therefore, radiologists and other physicians who use ultrasound as a diagnostic method should be able to recognize artifacts in order to properly interpret ultrasound images. [1]

The "comet tail" artifact in greyscale diagnostics and the color comet tail or „twinkling" artifact when using color Doppler are subtypes of the "reverberation" artifact. This means that parallel, closely positioned surfaces that reflect the ultrasound wave emitted from the probe cause the waves to bounce between themselves, resulting in the return of signals to the probe, which is "perceived" as a signal coming from deeper structures. [1,2,5] This occurs because there is a time delay from the emitted signal, which is displayed on the screen as an echogenic echo "posteriorly." In the case of the "comet tail" artifact, the reflecting surfaces are extremely close together and are not distinguished by the system, and in addition, their amplitude is reduced due to attenuation, so they appear as reduced in width. This effect on the screen or ultrasound image is seen as a triangularly narrowed shape described as the „comet tail" sign resembling the comet in the night sky (Fig.1). [1,5] If we use color Doppler, this will be displayed as turbulent flow. [2-4]

The formation of the artifact is primarily influenced by the hardness of the object being observed, but the settings during the ultrasound examination also play an important role. The artifact is sometimes more pronounced when increasing the color gain, moving the focus deeper than the object or when using a lower frequency probe. For example, with a high filter and high pulse frequency, the visualization of the resulting artifact increases. It is not fully clarified whether this occurs due to the enhancement of the artifact or simply better visualization, as the artifact Doppler shift is much greater than the actual Doppler shift of blood flow.

The „comet tail" artifact and the „twinkling" artifact can help us in everyday clinical practice, as seen through examples in further text. [3,4]

In the finding of cholelithiasis or choledocholithiasis, stones within the gallbladder are relatively clear when using B-mode, but sometimes when color Doppler is used, the artifact can help differentiate a certain formation from the artifact posterior to the lithiasis or, for example, in distinguishing a polyp from adenomyomatosis in which the artifact appears. Ultrasound shows focal or diffuse thickening of the wall, small anechoic cystic spaces of the affected segment of the gallbladder wall (Rokitansky-Aschoff sinus), and intramural echogenic foci with or without associated dorsal shadowing or reverberation artifact. As previously mentioned, cholesterol deposits and calcifications themselves cause the comet tail artifact, and when using color Doppler, the twinkling artifact. [1-3]

Sometimes it is difficult to visualize small calculi within the common bile duct with or without ductal dilatation; in such cases, the artifact is extremely useful. For example, in clinical suspicion of the presence of calcifications in intrahepatic bile ducts in patients with cystic fibrosis, the artifact can help if calcifications in intrahepatic bile ducts are not clearly seen in greyscale ultrasound. The next application or benefit of the artifact is found in chronic pancreatitis, where the ultrasound finding of extensive calcifications does not pose a significant problem in diagnosis using greyscale ultrasound. However, if the parenchyma is diffusely hyperechoic, for example, in fatty infiltration of the pancreas, it is then difficult to display small microcalcifications, in which case the display of the artifact serves as a method of differentiating existing microcalcifications. Similarly, the artifact can help in the diagnosis of splenic calcifications, for example, in granulomatous diseases. [3]

In the diagnosis of nephrolithiasis and urolithiasis, due to the nature and echogenicity of the background in the renal sinuses, small mineral concretions are sometimes almost impossible to visualize (Fig.3). Early renal nephrocalcinosis (Anderson-Carr kidney) is sometimes difficult to differentiate from hyperechoic fat of the renal sinuses themselves, and the artifact effect visible in nephrocalcinosis is then very helpful.Similarly, cortical nephrocalcinosis can differentially appear as hyperechoic renal parenchyma in diffuse parenchymal kidney disease. Another useful example of the artifact is when the presence of a stone in the middle and distal third of the ureter without dilatation is difficult to visualize due to the presence of air in the intestines or surrounding echogenic echoes of soft tissue. [3,4] Also, in polycystic kidney disease, linear calcifications along the wall may appear as hyperechoic echoes of the wall, without clear presence of calcifications, in which case the presence of the artifact helps in the final differentiation of what is displayed on ultrasound. [4]

In vascular ultrasound diagnostics, the clinical significance of the artifact can be applied in the finding of vascular wall calcifica-

tions and calcifications of the aneurysm wall and in the measurement of lumen diameter, where the artifact confirms the presence of calcifications.

There are also examples when the displayed ultrasound images do not show artifacts, for example, in the presence of intratesticular and extratesticular calcifications. The absence of the artifact is probably explained by the small surface area of the calcifications and the use of high-frequency probes. [3]

On the other hand, there are cases when it is not desirable to use the effect of the artifact because it can lead to incorrect conclusions. [3,5] For example, coarse thyroid calcifications very often cause the artifact, while punctate ones rarely do, so it is not advisable to use it for differentiation of punctate colloid calcifications in thyroid ultrasound, because in rare cases malignant microcalcifications may show signs of the comet tail artifact [3]. Some studies cited in the work of Van Trung Hoang et al. show that the comet tail artifact is typically found within or on the periphery of the follicle, while malignant microcalcifications are often scattered within solid tissue. Therefore, nodules with a large comet tail artifact that are within a cystic nodule are almost always benign (Fig.4). Other ultrasound characteristics of the lesion, such as taller-than-wide nodules, solid structure, or markedly hypoechoic and other specific characteristics, are more suspicious for malignancy. [5]

Hosokawa et al. described in their work the proven ultrasound presence of air in the portal vein, where by tracking hyperechoic foci distally, they identified the origin of the focus, i.e., the air bubble, which indicated intestinal pneumatosis of the stomach wall, sigmoid colon, and rectum. Intestinal pneumatosis can be the first sign of necrotizing enterocolitis, with air as a byproduct of bacterial metabolism entering the bloodstream. By tracking the origin of the gas bubble, we can detect the cause. [6] Since it is sometimes difficult to evaluate air in the intestinal wall due to motility and dorsal shadowing of air within the intestines, a clinically significant alternative can be tracking air in the branches of the portal vein to the intestinal wall. This is an example where differentiation of air in the lumen of the portal vein with the help of the artifact can be extremely important in making the correct diagnosis. [1,6] .

Conclusion

Ultrasound artifacts are an inherent part of diagnostic imaging and play a dual role: while they can sometimes obscure or distort anatomical structures, their recognition and understanding can also provide valuable clinical information. [1-6] The “comet tail” and color comet tail or “twinkling” artifacts, both subtypes of reverberation artifacts, are particularly significant in differentiating benign from some malignant lesions, identifying small calculi, and aiding in the diagnosis of various conditions such as gallbladder diseases, nephrolithiasis, and vascular calcifications. [2-4]

Recognizing these artifacts allows clinicians to avoid misinterpretation, reduce unnecessary additional testing, and improve diagnostic accuracy. [1,3] However, artifacts can also lead to diagnostic pitfalls if not properly identified, emphasizing the need for a thorough understanding of their physical mechanisms and clinical implications. [1,3,4] Ultimately, the ability to distinguish and appropriately utilize ultrasound artifacts enhances the utility of ultrasonography as a reliable and efficient diagnostic tool in everyday clinical practice. [1-6]

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