Chapter 2
Pitfalls in Musculoskeletal Ultrasound

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Introduction

Taking a good ultrasound (US) picture is an art. Interpreting it is a science. This is in fact everything US is about. Anatomic details should be carefully studied at the very beginning of US formation. However, good anatomy knowledge is not sufficient. The passage of US beam through human tissues, though so rewarding, is not without negative technical consequences. US images are the final result of multiple reflection processes combined with the machine technical capabilities and the knowledge of the performing physician. Any deviation of one of these three cornerstones leads to pitfalls—acknowledged as "difficulties/ traps"—and possible mistakes in images interpretation. Most of the pitfalls in US are represented by artifacts.

Oxford English dictionary [1] defines artifacts as "something observed in a scientific investigation or experiment that is not naturally present but occurs as a result of preparative or investigative procedure." Artifacts have been described since US was used for the first time as a diagnostic method in medical practice. The first musculoskeletal US report, published by T. Dussik in 1958 [2], led to the first description of anisotropy. Since then, the technique has known an exponential development and, consequently, a lot of artifacts have been described in literature, being defined, illustrated, and classified according to various criteria [3–13].

The first step for understanding artifacts is the admittance of the basic assumptions regarding the way an US image is obtained [3]:

1. Sound travels in straight lines.
2. Reflections occur from structures along the central axis of the beam.
3. Intensity of reflection corresponds to the reflector scattering strength.

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Table 2.1 Classification of US pitfalls

1. *Pitfalls due to GS artifacts*	Due to transducer position	Anisotropy Bone pseudodefect	–
	Due to interaction of US beam to the tissues	Attenuation	Shadowing
			Reverberation
			Mirror
			Side lobe/grating lobe
			Cartilage interface
		Enhancement through transmission	–
		Associated with velocity errors	
2. *Pitfalls due to Doppler artifacts*	Mirror	–	
	Reverberation		
3. *Pitfalls due to human error (GS and Doppler)*	Drop out		
	Machine incorrect adjustment		
	Transducer incorrect handling		
	Insufficient anatomy knowledge		
4. *Pitfalls due to machine error (GS and Doppler)*	Piezoelectric crystals damage		
	Transducer's fibers damage		

US ultrasound, *GS* grayscale

4. Sound travels at exactly 1540 m/s.
5. Sound travels directly to the reflector and back.

If any of these conditions is impaired, artifacts are generated.

This chapter focuses on the detailed description of all pitfalls that could lead to wrong acquisition/ interpretation of US images. As artifacts are connected to technical issues, it could be emphasized that pitfalls include artifacts and other possible sources of misinterpretation connected to human mistakes or machine inaccuracy. Both grayscale (GS) and Doppler pitfalls could be due to the technique itself, the particular type of machine used in the exploration, or the insufficient anatomic/ technical knowledge of the physician performing it. The chapter covers separately GS and Doppler artifacts, and then covers together the pitfalls due to the machine and human errors.

The classification of US pitfalls is given in Table 2.1.

Pitfalls Due to GS Artifacts

Artifacts Due to Transducer Position

Anisotropy, according to Wikipedia [14], is the property of being directionally dependent, as opposed to isotropy, which implies identical properties in all directions. US, especially musculoskeletal, is an anisotropic technique—in abdominal US the only tissue exhibiting anisotropy is the renal tissue [7]. Anisotropy is an artifact that appears in all the situations where the US beam is not strictly perpendicular to the examined tissue for ensuring maximal reflectivity. Anisotropy appears mostly in tendons; muscles and ligaments can exhibit it at a lesser extent. Nerves do not show anisotropic properties [9]. Any tissue containing parallel linear fibers can exhibit anisotropy. Due to highly organized structure of collagen fibers inside tendons, these are highly anisotropic structures. A tendon becomes anisotropic mainly at the point of its insertion where it follows the round shape of the bone epiphysis. Any angle deviation from 90° decreases the tendon echogenicity, making it resembling the muscle in appearance and obscures structural details; at higher deviation angles, the echogenicity will decrease even more [9, 11]. The presence of a hypo-echoic area near a tendon's insertion must lead to anisotropy considering before making a tendon tear diagnosis. The most important places to encounter anisotropy are: bicipital tendon inside the groove, quadriceps, and Achilles tendons at their insertion. Patellar tendon (also known as patellar ligament) has a straight direction, so it is usually visualized without anisotropy at both insertions (Figs. 2.1, 2.2, 2.3, 2.4, and 2.5).

Tips to Overcome Gently tilting the transducer until it becomes perpendicular to the structure makes anisotropy disappear, and the tendon's fibers appear intact. Sometimes it is enough to slightly move the patient's joint, like in hand flexors

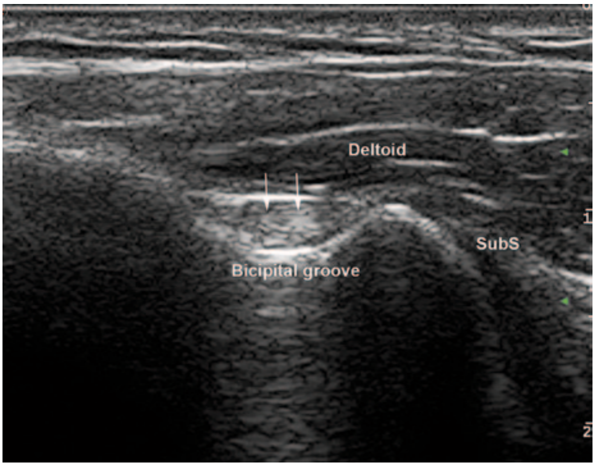


Fig. 2.1 Transverse view of bicipital tendon (*arrows*) inside the groove. The transducer is perpendicular to the tendon. *SubS* subscapularis tendon

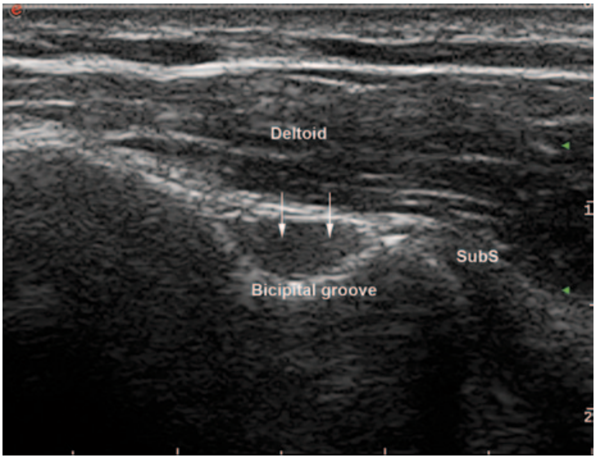


Fig. 2.2 Transverse view of "empty" bicipital groove (*arrows*). The transducer is not perpendicular to the tendon. *SubS* subscapularis tendon

evaluation. Knee flexion also makes anisotropy of quadriceps insertion disappear. Tendon tears should always be visualized in two perpendicular planes and they remain unchanged when tilting the probe. Dynamic evaluation of the tendon's movements can also help ruling out tears.

Bone pseudodefect is another artifact linked to the position of the probe in relation to the bone contour. When the beam touches the bone in a semi tangential way, the reflected echoes will have a different direction compared to the normal return and will not be detected on the screen. There will be no captured image in that area, so it will falsely look like a break in the bone contour. This artifact must be carefully differentiated from various pathologic cortical defects, which appear on two

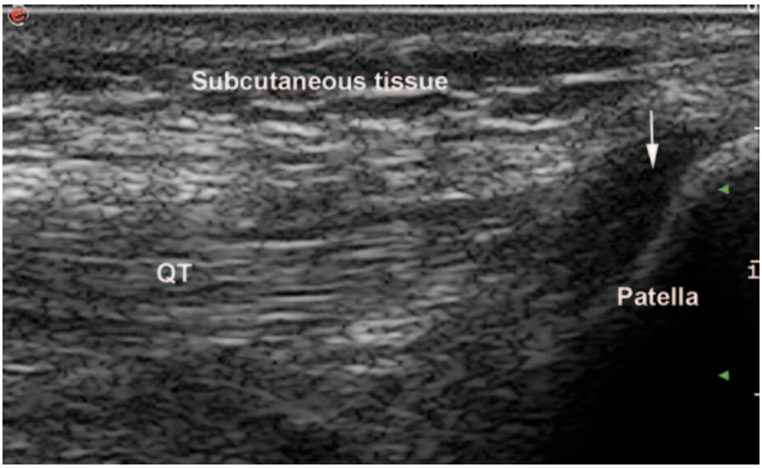


Fig. 2.3 Longitudinal view of quadriceps insertion on patella. The transducer is not parallel to the fibers at the insertion. *QT* quadricipital tendon. *Arrow:* anisotropy at insertion

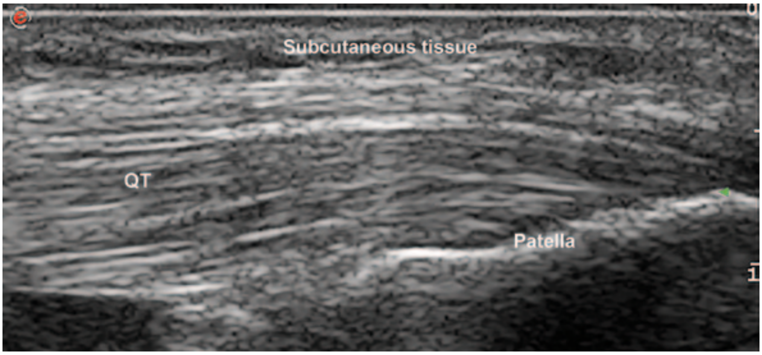
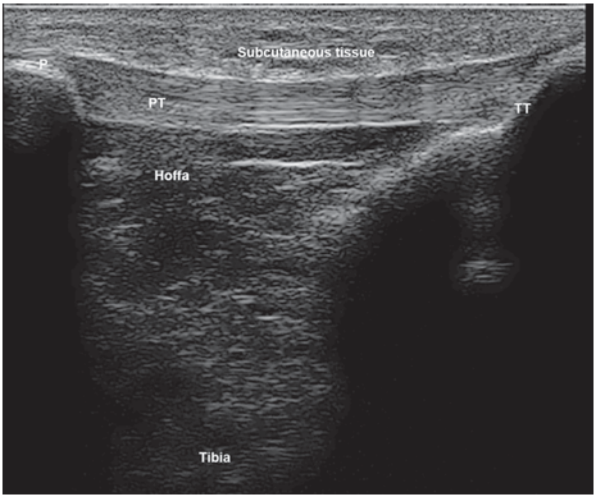


Fig. 2.4 Longitudinal view of quadriceps insertion on patella. When angulating the transducer it becomes parallel to the fibers at insertion and anisotropy disappears. *QT* quadricipital tendon

Fig. 2.5 Longitudinal view of patellar tendon. Due to its straight trajectory, no anisotropy appears at insertions. *P* patella, *TT* tibial tuberosity, *PT* patellar tendon



perpendicular planes and usually have a floor that may be visualized on the US image. Bone pseudodefect is frequently visible in the elbow area, at the coronoid fossa evaluation (Fig. 2.6).

Tips to Overcome Same as for anisotropy—gently tilting the probe for changing the angle of the beam toward the bone will make the defect disappear.

Artifacts Due to Interaction of Beam with Tissues

US beam interacts with tissues according to their specific characteristics. Generally, the waves are attenuated inside tissues because of reflection, scattering, refraction, or absorption processes, but sometimes their transmission might be enhanced. US

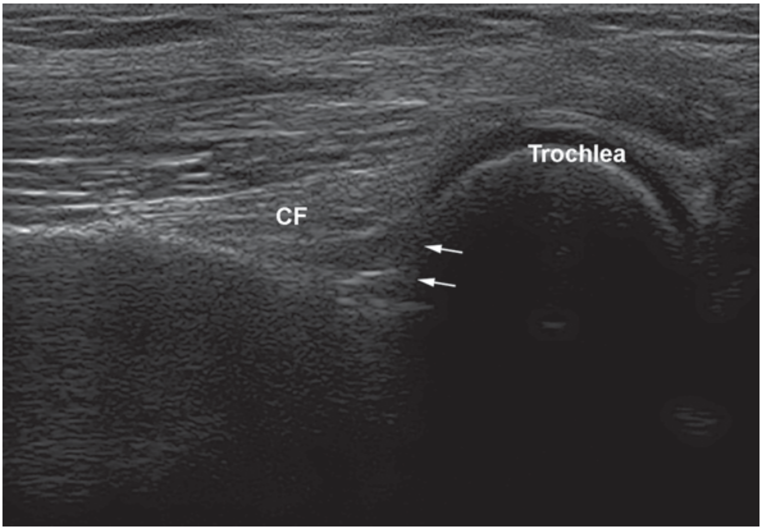


Fig. 2.6 Longitudinal view of the anterior elbow. Bone pseudodefect artifact is seen because of the transducer position, semitangential to the bone (*arrows*). *CF* coronoid fossa

Table 2.2 Attenuation coefficients and US speed for selected tissues at 1 MHz

Material	Attenuation coefficient	US speed (c)m/s
Water	0.0002	–
Air	40	330
Fat	0.5–1.8	1450
Soft tissue	0.3–0.8	1540
Bone	13–26	4080

US ultrasound

attenuation is 80 % due to absorption, a small reminder of the beam being reduced by reflection, refraction, diffraction, and dispersion [15]. Different tissues have different attenuation coefficients (calculated at 1 MHz). The values are listed in Table 2.2 [4, 16].

Attenuation Artifacts

A brief description of the physical phenomena leading to beam attenuation would increase their understanding.

Reflection of the beam appears at the boundary between two types of tissues with different densities; as a consequence, the propagation speed of waves will be different too. The property of tissues that involves density and speed of waves is called acoustic impedance, marked as Z (Z = speed × density of the tissue). The final US image is the result of multiple reflection processes. At the boundary between two

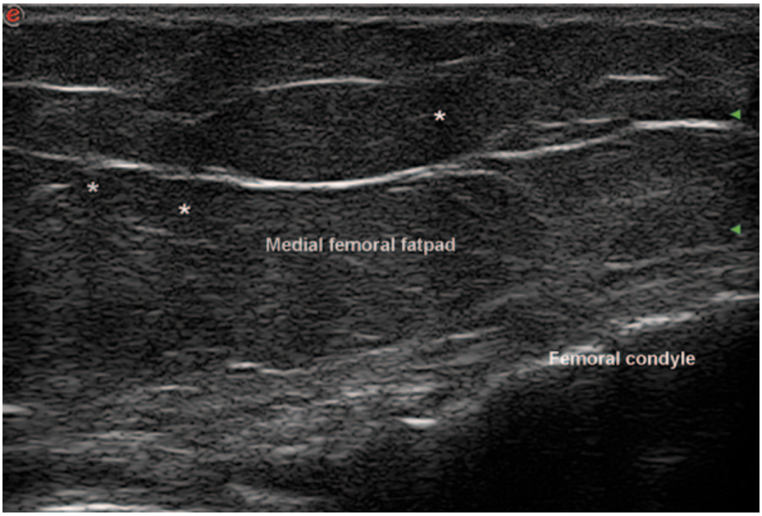


Fig. 2.7 Longitudinal view of the medial fat pad of the knee in an obese patient. Scattering and diffusion of US create shadows (*asterisks*) and allow a fair visualization of the structures below (femoral condyle). *US* ultrasound

tissues with highly different acoustic impedance, the reflection of the waves will be strong, so a strong echo will be generated. This situation is particularly encountered at the interface between air/bone and soft tissues. At the interface between soft tissue and air, 99 % of the waves are reflected, so no image will appear behind this. A particular situation illustrating this is the presence of an air gap between the transducer and the skin. To avoid that, a thick, uniform layer of gel must be applied on the transducer. Air is, though, a strong attenuator of the beam. Other strong attenuators are bone and calcifications. Behind these structures the attenuation will be so high that a shadow will appear, suggesting US waves do not penetrate that structure because they are all reflected. If the adjacent tissues have similar acoustic impedance, no echoes are generated. Most of the soft tissues have close values of acoustic impedance, so very few waves are reflected, most of the beam passing further to deeper structures [10].

Refraction is a change of US beam direction at interfaces between media with small differences in acoustic impedance (fat/muscle). Because of this phenomenon, real structures may appear in false locations. The degree of direction changing is influenced by the difference of impedance and also by the angle of the beam, which may easily be adjusted by tilting the transducer.

Scattering of the beam occurs when the reflecting surface is very small compared to the wavelength of US, and echoes are reflected through a wide range of angles, consequently reducing their detected intensity. When the beam encounters a number of small interfaces, comparable to the wavelength, a particular type of scattering appears, called *diffusion*. This is the situation of the fat or fibrous tissue (Fig. 2.7). Scattering and diffusion of the waves must be considered for correctly interpreting the echogenicity of small parts nodules.

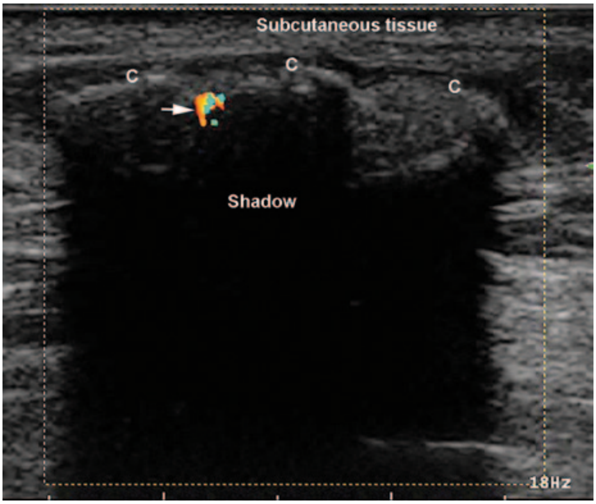


Fig. 2.8 Longitudinal view of the thigh of a young patient with juvenile dermatomyositis. A compact layer of calcifications are seen just under the skin. A "clean" shadow is covering all structures behind. The inflammatory aspect of calcifications, which were painful, is shown by the incomplete mirror Doppler artifact—the only two parts seen in the image are the bone and the mirror (*arrow*). *C* calcium deposits

Shadowing

Shadowing is the lack of US image behind structures like air or bone. Because of this artifact, bones and organs containing air like digestive tube cannot be visualized with US. Different types of shadows are produced by air and by bone—while shadow behind the bony structures and calcifications is uniform and homogeneous, called "clean," shadow behind the air is called "dirty." Dirty shadow has a heterogeneous aspect, with mixed areas of hypo- and anechogenicity. Sometimes dirty shadow may appear behind bony structures with a large radius of curvature, like humeral head [5]. A particular example of shadowing is represented by skin calcifications in dermatomyositis or scleroderma patients—the continuity of calcium deposits forms a continuous line immediately under the skin with no echoes behind it (Figs. 2.8 and 2.9). When the shadow is generated by a superficial structure, it may run over a deeper structure in the image and mimic pathology like tendon tear. A shadow may appear behind wood fragments as foreign bodies in subcutaneous tissue or deeper [5].

When a strong reflecting structure like a calcification is very small compared to the width of the main US beam, the posterior acoustic shadowing will be eliminated. This situation may occur in case of small calcifications inside a fluid collection. Awareness of this artifact, called *beam width,* will ensure proper diagnosis of calcium deposits, even without shadow (Figs. 2.10 and 2.11). Sometimes focus adjustment strictly in the area of interest will remove the artifact [5].

At the margins of a structure with different acoustic impedance compared to the tissue around it and with a highly curved surface (tendons' margins, cyst, etc.), an artifact called *lateral shadowing* (or refraction shadowing) appears. After reflection of the beam, marginal waves get also refracted at the edges of the structure, therefore no sound beam is returning to the probe; as a consequence, a shadow near

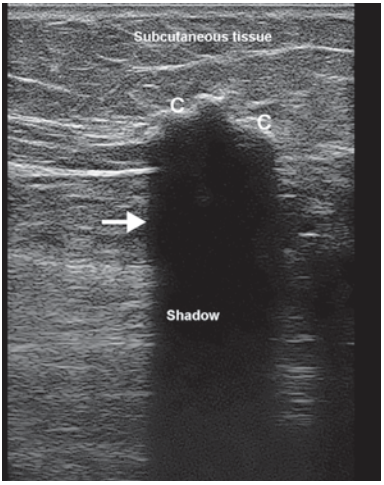


Fig. 2.9 Transverse view of the gluteal region in a scleroderma patient. A big calcification (*C*) is seen in the subcutaneous tissue. A "clean" shadow appears behind (*arrow*)

each lateral border of the structure may appear (Fig. 2.12). A particular case of refraction at the edges is represented by superficial varicosities (Fig. 2.13). Refractile shadowing also appears in case of tendon full-thickness tears, and sometimes it might be the only US sign of the tear.

Tips to Overcome Shadowing cannot be overcome, but it is of great help in interpreting US pathology. However, this type of artifact may look like another pitfall, caused by machine damage, presented below, so careful distinction is needed.

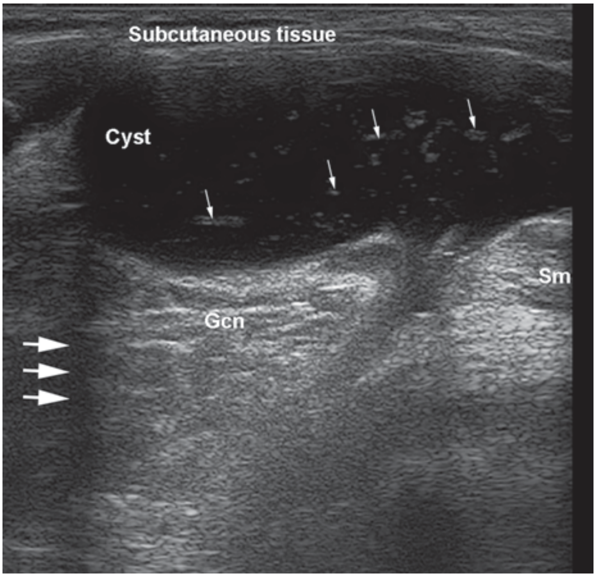


Fig. 2.10 Transverse view of the medial part of popliteal fossa. A Baker cyst is seen with small white deposits inside without shadow—calcifications exhibiting beam width artifact (*small arrows*). Also, a lateral shadowing phenomenon appears at the cyst margin (*large arrows*). *Gcn* gastrocnemius muscle and tendon, *Sm* semimembranosus tendon

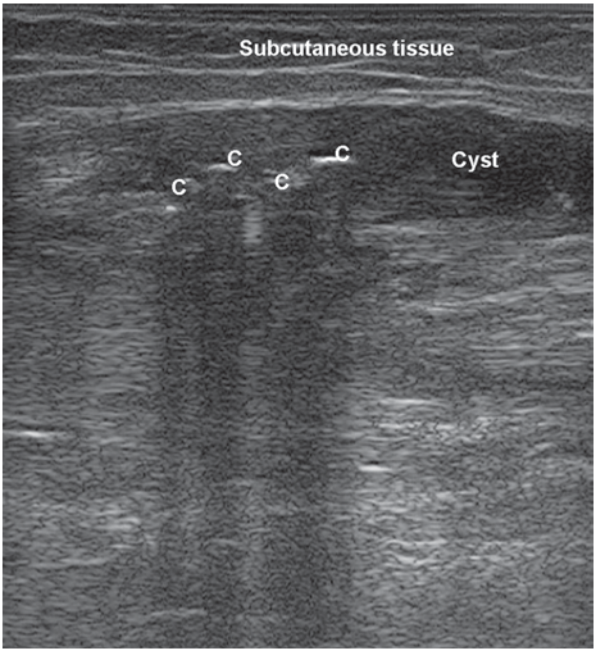


Fig. 2.11 Calcifications (*C*) in a small Baker's cyst with mixed echogenicity. Each calcification, though very small, has its own separate shadow, covering tissues behind

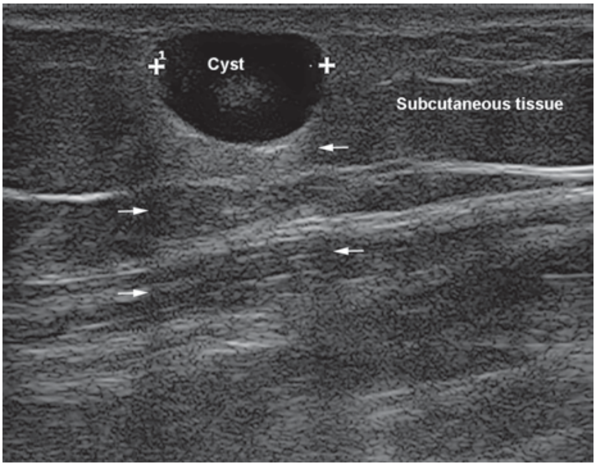


Fig. 2.12 Subcutaneous cyst, showing lateral shadows due to refraction (*arrows*)

Reverberation

Reverberation is an attenuation artifact generated by structures with two parallel surfaces, both highly reflective. Examples may be the prostheses used by orthopedists (shoulder, knee, hip) or a needle/biopsy device (Figs. 2.14 and 2.15). In such structures, US echoes will experience repeated reflections between the two surfaces

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