Contrast enhanced ultrasound in trauma: Where do we stand?

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Principles of Contrast-enhanced Ultrasound

The use of contrast-enhanced ultrasound (CEUS) in trauma patient has gained increasing attention in the recent years. Ultrasound contrast agents are composed of air or gas containing microbubbles surrounded by a stabilizing shell which consists of albumin, surfactant or phospholipids[1], see figure 1.

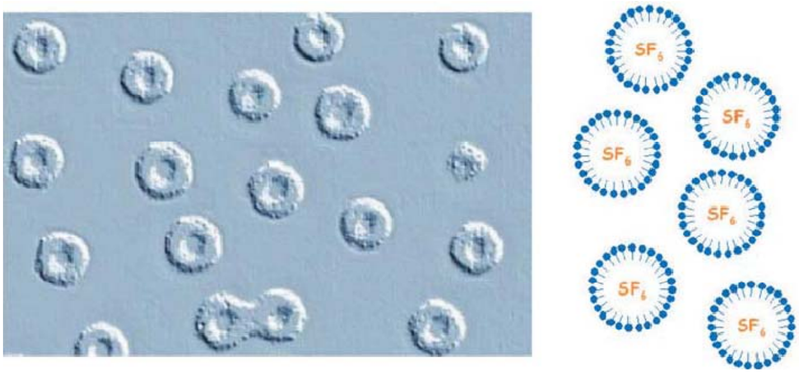

Figure 1Microbubble with sulfur hexafluoride gas (SF6) surraounded by a thin and flexible shell of phospholipids[2]

The microbubbles are smaller than 10 micrometer in diameter and pass easily through the lung capillary. Microbubbles undergo alternate contraction and expansion when exposed to the compression-rarefaction sequence of an ultrasound pulse [3]. They vibrate or resonate most readily at frequencies used in diagnostic ultrasound (2-10MHz) and return thereby very much stronger signals than tissue reflectors. At higher acoustic power, contraction and expansion becomes unequal, because the microbubbles resist compression more than expansion. This response is called “non-linear” and returns signals with fundamental and harmonic frequencies that differ from the transmitted signals, see figure 2.

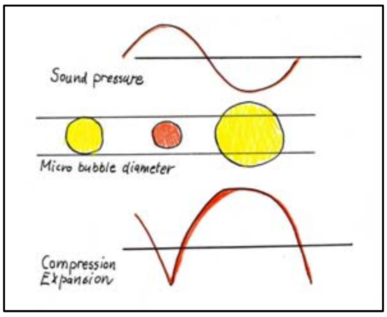

Figure 2 The nonlinear response of microbubbles to ultrasound beams. Adapted from Greis[2].

In order to separate these non-linear microbubbles signals from tissue signals, low mechanical index (MI) imaging is used. The MI is defined as MI = peak negative pressure/√frequency and can be adjusted on the ultrasound keyboard. At low MI, usually under 0.15, bubble destruction is avoided and special pulse sequences are used to separate the nonlinear from the linear signals.
A simple approach to this separation technique is the interpulse phase inversion (PI). Two consecutive pulses are transmitted with initial phases differing by 180^0, see figure 3. The received responses from linear scatters (tissue) and non-linear scatters (microbubble) and the summation from the first and the second received response are shown. The addition of the two signals will cancel the linear signals. The received signals from microbubbles will no longer mirror images of each other and not cancel. The addition of the two pulses results in a harmonic non-linear signal.

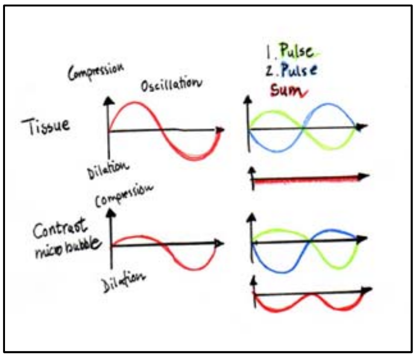

Figure 3 Summation of interpulse phase inversion sequences for linear tissue response and non-linear microbubble response.

Newer pulse sequences incorporate both phase and amplitude modulation between three or more transmitted pulses, like the contrast pulsing sequencing (CPS). The received echoes are weighted selectively and combined such that linear signals are rejected and nonlinear signals are retained [4]. US contrast agents are intravascular enhancers and will in general not penetrate through the endothelial cells .However, in the spleen, they accumulate in the sinusoid and have a prolonged tissue-specific phase that last over five minutes[5].

CONTRAST-ENHANCED ULTRASOUND OF TRAUMATIC LESIONS

The usefulness of CEUS in trauma has been proven recently in several studies.
CEUS can depict different kinds of solid organ injuries and several studies have shown that it is superior to US for detection of injuries. Parenchymal lesions like lacerations, hematomas and infractions lack blood supply and therefore do not enhance. On CEUS, they appear as dark areas without echogenicity. CEUS is highly sensitive for depicting these lesions. Sensitivities range from 69%-100% , specificities from 84%-100%[6-13]. Table 1 shows the typical appearance of lesions on CT and CEUS.

Table 1 Appearance of traumatic lesions on CT, grayscale ultrasound and contrast-enhanced ultrasound.

CT -Findings	US	CEUS
Perisplenic fluid	Hypo-, iso- or hyperechoic rim along the splenic surface.	Unechoic rim along the splenic surface.
Subcapsular hematoma	Iso- or hyperechoic mass flattening the splenic surface.	Unechoic mass flattening the splenic surface.
Intrasplenic hematoma	Hypo, iso- or hyperechoic roundish or stellate mass.	Unechoic roundish or stellate mass.
Laceration	Hypo, iso -or hyperechoic mass with linear or wedge-shape appearance.	Hypo- or anechoic mass with linear or wedge-shaped appearance.
Infarction	Hypo or anechoic wedge-shaped mass with base at the splenic surface.	Anechoic wedge-shape mass with base at the splenic surface.
Scars	Linear hyperechoic band at the splenic surface.	Linear anechoic band at the splenic surface.

Also active bleeding can be visualized by CEUS[8;14;15]. This may be important in hemodynamically unstable patients. When the source of bleeding in this patient group is detected, immediate interventional or surgical treatment can be live-saving.

ADVANTAGES AND DISADVANTAGES OF CONTRAST-ENHANCED ULTRASOUND IN TRAUMA

CEUS does not harm the patients because it lacks ionizing radiation and because the contrast agent is not nephrotoxic. The microbubbles are decomposed in the liver and the gas is exhaled through the lungs. CEUS can easily be performed in the emergency room, the intensive care unit and even in the operating room. With one bolus, it visualizes arterial, portal venous and parenchymal phases. However, in the severe injured patient, CEUS cannot be used as admission imaging modality, because it does not visualize sufficiently retroperitoneal structures and is useless for detection of fractures. The ideal patients groups in the trauma setting are therefore (1) patients with isolated parenchymal trauma (2) patients who cannot undergo CT for injury evaluation for several reasons and (3) patients in follow-up after trauma.

Future perspectives:
CEUS is a promising diagnostic tool in the evaluation of parenchymal injuries. In defined patient groups, it may be used instead of CT. Integrating CEUS in the trauma evaluation implicates meticulous training and experience of the CEUS performing radiologist and a sufficient patient volume.

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