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Terminology for Contrast-Enhanced Sonography

A Practical Glossary

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Objective. The purpose of this glossary is to offer an updated guide to the correct terminology for contrast-enhanced sonography. **Methods.** This report was prepared by a panel of radiologists from the Sonography Section of the Italian Association of Medical Radiology. A leading author prepared a list of terms based on a comprehensive literature survey. The draft was analyzed by 3 experts on the topic of contrast-enhanced sonography. These reviewers reached a consensus and prepared the final version. **Results.** A list of 137 terms is included. These terms are briefly defined. Their proper application is discussed, with special reference to potential misleading uses. **Conclusions.** Contrast-enhanced sonography is a relatively new diagnostic tool, now entering clinical practice in several countries. Use of appropriate, universal terminology is mandatory in the scientific setting to allow comparison between different published experiences. Additionally, use of clear, standardized terminology is necessary in the clinical setting to facilitate report understanding by the referring physician. Standardized, nonequivocal nomenclature may also help future diffusion of sonographic contrast media in countries where their application is still not approved. **Key words:** contrast media; contrast-enhanced sonography; ultrasound terminology.

Abbreviations

CT, computed tomography; HCC, hepatocellular carcinoma; MI, mechanical index; MRI, magnetic resonance imaging

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Sonographic contrast media became commercially available in the mid-1990s. In the United States, heart chamber opacification and delineation of the endocardial border are the only applications approved by the US Food and Drug Administration to date. Conversely, in many European and Asian countries, sonographic contrast media have greatly entered clinical practice. The first noncardiac application was to boost the Doppler signal from medium to small vessels. Subsequently, specific imaging techniques were developed to obtain optimal contrast-enhanced gray scale scans, intermittently or in real time. This spread of technologies has created some nomenclature confusion among different modalities.¹ Additionally, although many imaging findings are similar between contrast-enhanced sonography and contrast-enhanced computed tomography (CT) or magnetic resonance imaging (MRI), these techniques are not properly superimposable. Sonographic contrast media have different behavior

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within the human body compared with iodinated and paramagnetic agents. The signal from contrast medium microbubbles varies with the type of insonation, and each contrast medium has its own peculiarities. All published articles should clearly state in the abstract **and full text** the contrast medium and the contrast-enhanced sonographic techniques used.

As in any field of medicine, use of appropriate, agreed terms is mandatory, both in the scientific setting and in clinical practice.¹ This glossary is the result of a consensus panel of the Sonography Section of the Italian Association of Medical Radiology, including its president and 3 other experts. The purpose is to clarify some potentially confusing aspects of contrast-enhanced sonographic terminology. Terms included mostly refer to contrast-enhanced sonographic findings and to contrast-enhanced sonographic techniques (also including the terminology used by the various manufacturers). The various terms are only briefly described because a detailed comparison of the different techniques is outside the scope of this report. Consistency of terminology may improve comparison of published results and may help radiologists in daily reporting. In some instances, the descriptions listed below may reflect the authors' own opinions. Hence, some readers may disagree. We invite all readers to send us their suggestions and comments.

Glossary

1.5 harmonic contrast-enhanced sonography—A contrast-enhanced modality in which images are obtained in a frequency band intermediate between the fundamental mode and second harmonic mode and whose center frequency is higher than the fundamental by a factor of 3/2.²

acoustic power (or energy)—The amount of energy contained in the acoustic waves transmitted by a transducer per second. See *mechanical index*.

acoustic pressure—The stress, either tension or compression, exerted on the material (eg, tissue, blood, or bone) through which the acoustic wave travels. See *mechanical index*.

advanced dynamic flow—A high-resolution, wideband pseudo-Doppler technique capable of showing macrovascularization.³ Applicable to contrast imaging (contrast-enhanced advanced dynamic flow) as a high-mechanical index (MI) technique in which bright color signals are superimposed on a B-mode image.

agent detection imaging (cadence)—A nonlinear, multipulse intermittent contrast-enhanced sonographic technique that detects signals from microbubble disruption within a color Doppler box.^{4,5} Two identical high-amplitude pulses are transmitted, with temporary storage of the received related echo sequences and subsequent subtraction of the second from the first. Both fundamental and contrast-enhanced harmonic echoes are used, and echoes are coded according to the intensity scale of the color Doppler signal.

angiosonography (also sonographic angiography or angiographic sonography)^{6,7}—Real-time gray scale assessment of organ and lesion enhancement (perfusion). May be confused with an intravascular, catheter-assisted technique; hence, this term should be avoided.

annular (arterial) enhancement—See *rim (arterial) enhancement*.

arterial phase of enhancement—The phase of contrast medium circulation when contrast-enhanced blood reaches an organ through its arterial supply. It starts a few seconds after the enhancement of large arteries. In this phase, parenchymal and lesional enhancement results exclusively from arterial flow (although in the liver, there is a rapid overlap with the portal-venous induced enhancement). In the liver, this vascular phase starts 10 to 20 seconds after contrast medium injection in a peripheral vein and ends as soon as 30 to 40 seconds after injection, also depending on the agent used.^{1,8-11} The synonymous term *early phase*¹² should be avoided because it may be erroneously intended as the whole vascular phase (in opposition to the late or postvascular phase).

atypical hemangioma—A hemangioma without the typical enhancement pattern (ie, peripheral

globular enhancement with progressive fill-in).^{6,13–15} An atypical hemangioma may show a very fast and homogeneous enhancement or a very slow enhancement with incomplete fill-in.

avascular lesion—A lesion appearing anechoic, with lack of contrast enhancement (markedly negative lesion-to-parenchyma contrast gradient). There is no subjective or measured difference in lesion echogenicity before and after contrast medium injection.

backscattering—Energy (ultrasound) reflected or radiated backward by a scatterer, in a direction opposite to the incident beam's direction of travel.^{16,17}

bandwidth—The range of frequencies contained in an ultrasound beam.^{16,17} Frequencies within which a transducer can operate. Frequencies may vary from a broad band to a narrow band. Contrast-enhanced sonography typically uses a limited range of frequencies, but wideband modalities have also been developed.¹⁸

basket pattern—Color Doppler and contrast-enhanced sonographic pattern of macrovascularization consisting of a vascular ring that circumscribes the lesion starting from a pole and then gives discrete, irregular branches intralesionally. A common feature of hepatocellular carcinoma (HCC).^{13,19}

blood pool contrast media—Those contrast media that remain within the vascular bed and do not spread in the interstitium. Blood pool agents act as flow tracers.

blooming artifact (color)—A contrast medium-induced color Doppler artifact resulting from color signal oversaturation at the moment of contrast-enhanced blood arrival in the scanned area.^{20–22} Specifically, gray scale pixels are seen changing to a color display in regions where flow is not present. To avoid this phenomenon, it is necessary to decrease color gain, decrease output power, or inject the contrast medium more slowly. Any of these maneuvers, however, may present an obstacle to effective imaging of lesions.

B-mode (or brightness modulation) contrast-enhanced sonography—Use of the term B-mode may create confusion with B-flow sonography, a recently developed non-Doppler-based modality capable of showing large vessel flow with a high frame rate and without contrast medium injection. Use *contrast-enhanced sonography*.

bubble noise artifact (spectral)—A spectral Doppler artifact due to the presence of contrast medium microbubbles within the sampled volume.^{20–22} Sharp, needle-shaped signals of high amplitude appear on the Doppler spectrum, and a crackling noise is heard in the audio. Spectral Doppler analysis should be performed before contrast medium injection. Otherwise, it may be necessary to decrease Doppler gain and to increase Doppler signal filtering. Further research is needed to determine the effects of sonographic contrast media on the spectral waveform.

carbon dioxide-enhanced sonography—Transabdominal imaging of the liver during transcatheter injection of carbon dioxide in the hepatic arterial system. Vascularized lesions become hyperechoic for up to 10 to 15 minutes.²³

C-cube (C³) mode—A nonlinear, harmonic intermittent contrast-enhanced sonographic technique using comparative digital decorrelation and a digital adaptive bandpass filtering process.²⁴ Two identical pulses are transmitted for each line; returning signals are compared; and the nonlinear response from microbubbles is selected.²⁵

central (arterial) spider sign⁴—See *centrifugal (arterial) blood supply*.

centrifugal (arterial) blood supply—Color Doppler and contrast-enhanced sonographic pattern of intralesional macrovascularization consisting of a vessel that branches from the center toward the periphery of a lesion.²⁶ Discrete arteries show progressive enhancement from the center to the periphery, with an overall stellate distribution. It is a common pattern of focal nodular hyperplasia. Overall appearance is also referred to as spoke wheel like, stellate, star like,

or spider like,^{4,10,12,13} but these figurative terms should be avoided. Do not confuse with *centrifugal enhancement*.

centrifugal enhancement—Progressive enhancement of a lesion from the center to the periphery. An uncommon feature of liver hemangioma and peliosis hepatis. Centrifugal blood supply has also been described²⁷ as *centrifugal radiating enhancement*, which is confusing.

centripetal enhancement—Progressive enhancement of a lesion from the periphery to the center, predominantly during the arterial or the portal phase. A common pattern of liver hemangioma, in which globular enhancement is followed by progressive (rapid or slow, complete or incomplete) filling in.

coded harmonic angio—A pulse inversion technology in which pulse inversion harmonic imaging is combined with a so-called coded excitation technique, transmitting coded pulse sequences and decoding them on receipt. The decoder suppresses the immobile (nonvascular) signals for each scan line.^{26,28}

coherent contrast imaging—A nonlinear, harmonic, high-frame rate technique in which the phase of each transmitted pulse is alternated during the scanning process. Echoes, corresponding to the scan line between 2 pulses, are calculated and summed. Nonlinear echoes are finally selected and form the basis of the enhanced image. This is a pulse inversion technique based on alternate line phasing.^{10,29}

continuous mode—Real-time (rapid-frame rate, sequence display) acquisition techniques for imaging microbubbles, usually with a low-intensity beam.

contrast arrival (imaging at)—Assessment of echogenicity during the first passage of contrast-enhanced blood through an organ, at the moment of a notable rise in signal. The optimal phase for functional studies.^{12,30}

contrast arrival time—The time intervening between the beginning of contrast medium

bolus injection and notable arrival of enhanced blood within a given organ vessel.³⁰

contrast burst imaging—A technique derived from power Doppler sonography in which pulses are broadband and with high power output levels, which may destroy or modify microbubble shape and size.³¹ These changes are reflected in the amplitude and spectral energy distribution of the echoes, so that short sequences of 6 to 10 pulses per line can reveal microbubble presence. The changes are then detected as broadband noise in the Doppler spectrum. Alternatively, changes are shown as characteristic features of microbubbles using dedicated algorithms (see *time variance imaging*).³²

contrast-coded sonography—Synonymous with *contrast-enhanced sonography*. Radiologists prefer avoiding *contrast-coded* sonography because of lower similarity with *contrast-enhanced CT* and MRI.

contrast-enhanced Doppler technique—Color Doppler or especially power Doppler acquisition being performed after contrast medium injection. The Doppler signal is amplified (increased in intensity) by the circulating contrast agent.

contrast-enhanced sonographic angiography—Also described as *B-mode sonographic angiography*. These terms are occasionally used to indicate imaging of large vessels with contrast-enhanced sonography. The term *angiography* may raise the idea of an intravascular, catheter-assisted technique and should be avoided.

contrast-enhanced sonography—Every sonographic technique performed with injection of a contrast medium. Nevertheless, this term should be used to indicate gray scale modalities, whereas use of Doppler techniques should be specifically indicated (ie, the term *contrast-enhanced sonography* without any other explanation should be considered as referring to a gray scale modality).

contrast enhancement—The increase in echo intensity in an organ or lesion due to a contrast medium. *Contrast enhancement* is a commonly

used term in diagnostic imaging, although *post-contrast intensity* would be a more appropriate term in contrast-enhanced sonographic nomenclature.^{1,19} Similarly, *hypoechoic*, *isoechoic*, and *hyperechoic* might be useful to describe static findings underlying unenhanced sonographic imaging but are ambiguous for explaining dynamic phenomena underlying contrast-enhanced sonographic imaging. A lesion may show an enhancement weaker than, equal to, or stronger than surrounding parenchyma. Hence, terms to be used for contrast-enhanced sonography should properly be *hypoenhanced*, *isoenhanced*, and *hyperenhanced*.^{1,19} Nevertheless, *hypoechoic*, *isoechoic*, and *hyperechoic* have entered clinical practice. Enhancement is also termed the increase in echo amplitude from tissue lying distal to a weak reflector such as a cyst. Avoid confusion between these two uses of the word *enhancement*.¹

contrast extravasation—The detection of microbubble signals from extravasated blood after intravenous contrast medium injection.³³ From this point of view, it is a sign of ongoing macroscopic bleeding because usual sonographic contrast media are intravascular. Nevertheless, *extravasation* is also the term to be used for micromolecular contrast agents. This is a class of experimental sonographic contrast media in the nanomolecular range, in which extravasation occurs in early stages of cancer (before neovascularization) because of increased capillary permeability.

contrast medium—A sonographic contrast medium is an agent capable of changing the acoustic impedance through tissues.^{11,16,17,34} Although these agents work rather differently from x-ray and MRI agents, the term *contrast medium* is universal in diagnostic imaging and should be preferred to *echo amplifier* and *echo enhancer*. “First-generation” contrast media include those microbubbles containing air and capable of emitting a signal during disruption at high-MI beam exposure. “Second-generation” media include those microbubbles filled with gases other than air and capable of emitting a signal also during oscillation at low-MI beam exposure. Each contrast medium has its own

kinetics when injected and shows its own behavior when insonated at different acoustic powers and frequencies.^{1,34}

contrast pulse sequencing (cadence)—A real-time, multipulse technique in which 3 pulses that differ in amplitude and phase are sent down each scan line. Opportune scaling and subsequent addition of each echo allow detection of contrast medium-related, nonlinear fundamental and harmonic signals while the linear tissue signal is rejected. Contrast pulse sequencing has the immediate advantage of enabling observation of the fundamental signals coming from tissue at the same time as signals coming from a nonlinear fundamental response of the contrast medium. Contrast pulse sequencing may result in an increase in signal intensity greater than that of second harmonics of the contrast medium alone.^{1,10,32}

contrast-specific sonography^{10,25}—Synonymous with *contrast-enhanced sonography*. To be avoided.

contrast transit time—The time interval between microbubble arrival in the artery feeding an organ and their arrival within the related venous drainage. Useful for functional studies because microbubbles do not spread within the interstitium.

contrast-tuned imaging—A harmonic, contrast-enhanced technique producing images on the basis of both maintenance of microbubbles at low acoustic pressure and subtraction imaging. The sonographic system is selectively synchronized to the harmonic signal from microbubbles when stimulated by a very narrowband, single pulse at the contrast medium resonance frequency.^{10,13}

conventional sonography—Frequently used to indicate a sonographic acquisition that is not based on contrast media injection. The term *unenhanced sonography* should be used instead.

destruction (or destructive) mode¹¹—Transmission of 1 or more high-intensity acoustic pulses to temporarily reduce or eliminate con-

trast enhancement, used in combination with low-power continuous mode or intermittent mode imaging techniques (see above and below). Not a standalone imaging modality. This term should be avoided because it may raise an idea of radiation invasiveness, recalling, for example, high-intensity focused ultrasound. Use *intermittent mode*.

destruction-replenishment (or destruction-reperfusion) technique—A method of perfusion quantification based on microbubble disruption within a selected area of interest and subsequent assessment of its refilling by new, incoming microbubbles.

delayed phase of enhancement—See *parenchymal phase of enhancement* and *sinusoidal phase of enhancement*.

diffuse enhancement—Enhancement distributed throughout a lesion. Can be homogeneous or heterogeneous and in the liver may occur in the arterial, portal, or sinusoidal phase.

dynamic (contrast-enhanced) sonography—Occasionally used to indicate contrast-enhanced sonography with intermittent or especially with continuous acquisition of the images.³⁵ Strictly, only real-time images can be termed *dynamic*. Term to be avoided.

early phase of enhancement^{1,2}—See *arterial phase of enhancement*.

echo amplifier (or enhancer)—An agent increasing gray scale or color-coded echo levels. This term arose during the early days of contrast-enhanced sonography, when these agents were used to amplify hard-to-detect Doppler signals. The term *contrast medium* should be used instead.

echo contrast agent—Synonymous with *sonographic contrast medium*. Avoid.

filling in—See *centripetal enhancement*. Not to be used¹² to describe the enhancement of a central branching vessel within a focal nodular hyperplasia nodule (see *centrifugal blood supply*).

filling out—See *centrifugal enhancement*.

flash—A sudden rise in acoustic power (MI) that is triggered by the operator to better assess a given area or to destroy the microbubbles filling the insonated parenchymal region and obtain functional data from the refilling kinetics of microbubbles (*destruction-replenishment technique*).

flash echo imaging—A nonlinear, intermittent harmonic contrast-enhanced sonographic technique based on generating 2 high-power pulses separated by a variable interval. The longer the time interval between the 2 high-transmit power pulses, the greater the microbubble accumulation and the higher the signal produced by the second insonation. The subtraction image is derived from combining the second image with the first.

focus—The concentration of a pulse into a smaller area than would be the case otherwise.^{16,17} In contrast-enhanced sonography, the beam focus is placed by the operator at the level of the region of interest or at its deeper aspect. The MI varies with focus depth choice.

frame rate—The number of frames (images) displayed per second.¹⁷

fundamental mode—“Conventional” (gray scale) sonographic and Doppler techniques based on the transmission frequency of a sonography system.^{16,17} The echo at the same frequency as that of the transmitted frequency is chosen to create the image (linear response). Opposite to nonlinear, harmonic mode.

globular enhancement (peripheral)—A discontinuous ring of contrast-enhanced peripheral globules (puddles or nodules) predominantly in the arterial or portal phase.^{6,9} These globules usually enlarge over time, with centripetal enhancement of the lesion. This is a common feature of liver hemangioma. Terms such as *nodular* and *peripheral nodular* are also used,^{5,10,15,19,36,37} but they can be misleading, raising in the reader the idea of smaller nodules within the nodule. Terms such as *cotton-like* and *wool-like* enhancement²⁷ should be avoided.

gray scale contrast-enhanced sonography—Brightness-mode (B-mode) display of echo intensity enhanced by the presence of a contrast medium. Initially, this term was used to distinguish contrast-enhanced sonography from former contrast medium-amplified Doppler techniques. There is no current need to specify either gray scale or B-mode when simply referring to contrast-enhanced sonography. Instead, use of Doppler techniques should be clearly indicated.

harmonic imaging—Any technique in which nonlinear echoes, that is, echoes at frequencies greater than the transmission frequency, are preferentially selected to create the image.^{12,16,17,25} Usually, it is the signal at twice the transmission frequency that is considered. Hence, this modality is also termed *second harmonic imaging*. Images can be based on tissue (native) harmonics generated from beam propagation through matter to obtain high-quality, detailed images (tissue harmonic imaging).²⁵ Images can also be based on contrast medium-induced harmonics (contrast-enhanced harmonic imaging).²⁴

high-flow lesion—A lesion showing a very rapid enhancement in the arterial phase.

honeycomblike enhancement—Inhomogeneous enhancement with gross enhancing septa and with small or large unenhanced areas that are more than half the size of the lesion area (on 2-dimensional images).^{12,27,38} Found in liver abscesses. A particular type of inhomogeneous enhancement.

hypervascular (or hyperenhanced) lesion—A lesion with relatively stronger echogenicity (enhancement) than the surrounding normal parenchyma (positive lesion-to-parenchyma contrast gradient). Lesion echogenicity (vascularity) may vary over contrast medium circulation phases, aside from lesion vessel density at pathologic evaluation.⁸ Describing a lesion as “with intense signal”¹ or as “with increased intensity”¹⁹ when related to contrast-enhanced sonography would be better than naming it “hyperechoic.”

hypovascular (or hypoenhanced) lesion—A lesion with relatively weaker echogenicity (enhancement) than the surrounding normal parenchyma (relatively negative lesion-to-parenchyma contrast gradient). Lesion echogenicity (vascularity) may vary over contrast medium circulation phases, aside from lesion vessel density at pathologic evaluation.⁸ Describing a lesion as “with low signal” or as “with decreased intensity”¹⁹ when related to contrast-enhanced sonography would be better than naming it “hypoechoic.”

inhomogeneous enhancement—Coexistence of enhanced and unenhanced areas without particular positions or morphologic characteristics of these areas. Patterns such as mosaic or honeycomblike enhancement are included among inhomogeneous enhancement patterns.

intermittent mode—Very low-frame rate acquisition, generally used during and immediately after the destruction mode.^{14,16,17} The high-power pulses of the destruction mode may be emitted automatically under software control or manually by the operator. Some protocols include continuous acquisition during the arterial phase and intermittent imaging thereafter.²⁶

interpulse phase inversion²⁹—See *pulse (or phase) inversion mode imaging*.

interval delay imaging—When microbubbles are disrupted by a high-pressure beam (see *intermittent mode*) and intense enhancement is detected, it is necessary to wait a minimum interval to have replenishment of the insonated area by new incoming microbubbles. Hence, the *intermittent mode* is also known as an interval delay scanning technique, but the former term should be preferred.^{11,25,37}

isovascular (or isoenhanced) lesion—A lesion with the same echogenicity (enhancement) of surrounding normal parenchyma and consequently not identifiable from its own echogenicity. Lesion echogenicity (vascularity) may vary over contrast medium circulation phases, aside from lesion vessel density at pathologic evaluation.⁸ Describing a lesion as “with a similar signal

in comparison with surrounding parenchyma”¹ or as “isointense”¹⁹ when related to contrast-enhanced sonography would be better than naming it “isoechoic.”

jail bar artifact—A lack of color along some image lines due to power Doppler signal saturation after contrast medium injection.

late phase of enhancement^{9–11,19,27,36,39,40}—See *parenchymal phase of enhancement* and *sinusoidal phase of enhancement*.

liver-specific (late) phase of enhancement^{9,39,41}—See *parenchymal phase of enhancement*.

loss of correlation mode—See *stimulated acoustic emission (acoustically)*.

low-flow lesion—A lesion showing very slow enhancement over time.

macrocirculation (tumor)—Major intranodular vessels seen as discrete, hyperechoic (hyperenhanced) vessels on contrast-enhanced scans.

marginal enhancement—Similar to *rim enhancement* but with a rim particularly irregular and thick. Feature of hypovascular metastasis.

mechanical index—The peak rarefactional pressure (in megapascals) divided by the square root of the acoustic center frequency (in megahertz) at a specified location in a uniform medium having specific acoustic properties.^{1,4,16,17} The MI is a safety parameter indicating the relative potential risk of inducing an adverse effect in a patient by a nonthermal mechanism. The MI decreases with increasing focal depth, but it is only indirectly related to the acoustic output power; thus, the MI is not necessarily comparable between different imaging machines. High-MI techniques (by definition, MI >1.0) can be performed with any contrast medium, but these generally perform well only with intermittent image acquisition (although some researchers⁴ have tried to combine high-MI and continuous-mode imaging). Low-MI techniques (by definition, MI <0.2) are generally performed only with second-generation contrast media and allow prolonged real-

time image acquisition.¹¹ Low- and high-acoustic pressure sonography would be more descriptive nomenclature, but low- and high-MI sonography has entered practice.

microbubble—Modern sonographic contrast media usually consist of encapsulated gas bubbles with a mean diameter small enough (<10 μm) to pass through the capillary bed.^{11,34} Currently, there is no need to specify *microbubble contrast medium*.

microcirculation (tumor)—Tumor microvessels developing as a consequence of neoangiogenesis. These vessels have a diameter of 2 to 5 μm, which is below the resolution threshold of all in vivo imaging modalities, contrast-enhanced sonography included. Contrast-enhanced gray scale sonography can detect signals from small vessels, below the resolution of unenhanced sonography and Doppler techniques. Contrast-enhanced gray scale sonography allows demonstration of tumor enhancement, but it should be always remembered that this only indirectly reflects the tumor microcirculation.

microflow (microvascular) imaging—A technique based on summation of multiple consecutive frames and representing a multi-intensity projection algorithm of data. Improves depiction of small capillary vessels with a low concentration of contrast medium.

mosaiclike enhancement—A term derived from CT terminology to indicate patchy enhancement, with only some enhanced area within a lesion. Small unenhanced irregular portions, which are less than half the lesion area, are visible. An HCC pattern.^{27,35} To be included within the concept of *inhomogeneous enhancement*.

nodule-in-nodule appearance—Postcontrast recognition of a nodule of different (usually increased) echogenicity within a larger one. Identified in early HCC.⁴²

nondestructive mode—See *continuous mode*.

nonlinear mode—Those techniques mainly detecting and forming images using the nonlin-

ear components of the echo.^{16,17} When stimulated by an acoustic beam, microbubbles oscillate and emit signals at integer multiples of the frequency of the stimulating pulse. Opposite to the *fundamental mode*, in which a linear portion of the response is used to form the image.

opacification—A term derived from x-ray terminology. Increased echogenicity should be termed *enhancement* and not opacification.

parametric imaging—Depiction of different quantitative levels of a parameter in a color scale according to their value. In contrast-enhanced sonography, parametric imaging is used to depict the different values of flow or perfusion magnitude in the different parenchymal regions.

parenchymal phase of enhancement—Some sonographic contrast media show first an intravascular phase and then a more or less pronounced phase of extravascular retention within liver and spleen parenchyma. To image the liver during this phase, scans are taken from 2 to 5 minutes after contrast medium injection up to 6 to 10 minutes, when the enhancing effect vanishes (depending on the type of contrast medium used).^{9,28,35,37,39–41} The parenchymal phase is also described as *late*, *delayed*, *liver specific*, or *postvascular*, but *parenchymal phase of (contrast) enhancement* is the most appropriate description. To avoid confusion, *parenchymal postvascular* should not be used to describe the venous-sinusoidal vascular phase of enhancement. Terms such as *late* and *delayed* should be eventually reserved for this vascular phase⁹ and not to indicate postvascular enhancement.

peak intensity—Maximum increase in signal produced by an intravenously injected contrast medium.

perfusion—Total blood flow, including capillary flow, in an organ (blood flow/tissue unit). Perfusion of a tumor includes its microcirculation, but it is not a synonymous term.

perfusion defect—An area of poor or absent enhancement within the parenchyma. Infarction, ischemia, or injury may appear as perfusion

defects within the normally enhanced surrounding parenchyma. This term should not be used to describe a focal lesion with lack of enhancement.⁴⁰

perfusion imaging—Imaging of flow at the capillary level. Usually used as synonymous with *continuous mode*, allowing real-time demonstration of parenchymal and lesional perfusion.

phase inversion imaging^{26,39}—See *pulse (or phase) inversion mode imaging*.

phases of contrast enhancement—In dynamic CT and MRI, the concept of phase is limited to the peak of enhancement in a given phase of contrast-enhanced blood distribution. In contrast-enhanced sonography, instead, the term *phase* refers to the entire duration of a given phase.^{13,43} Particularly for the liver, which has a double blood supply system, there is partial overlap between the final part of the arterial phase and the initial part of the portal phase, the latter starting when the enhancement of portal branches starts.³⁵ For the liver, phases for contrast-enhanced sonography should be termed *arterial* (vascular, ranging approximately from 15 to 40 seconds after peripheral contrast medium injection), *portal-sinusoidal* (vascular, ranging approximately from 40 to 300 seconds after contrast medium injection), and eventually *parenchymal* (postvascular, for those contrast media showing late intraparenchymal uptake, lasting up to 10 minutes after contrast medium injection). All other terms are confusing.

pooling (contrast)—A delimited (pseudoaneurysm) or an undelimited (extravasation) collection of contrast medium.³³ The term *pooling* is also used^{26,28} to describe areas of enhancement, such as the enhanced globes at hemangioma periphery. This latter use is confusing and should be replaced by *globular enhancement*.

portal (or portal venous) phase of enhancement—The phase of contrast medium circulation when contrast-enhanced blood reaches the liver through the venous portal system (from 40 to 50 seconds after contrast medium injection to 100 to 120 seconds after injection).^{8–10} Because

the liver has a double feeding system, arterial and portal, the portal phase of enhancement is not exactly the same concept as the venous phase in other organs. This is the phase when liver parenchyma (properly, small intrahepatic portal vessels) reaches its peak of enhancement.

postvascular phase of enhancement—Some sonographic contrast media show first an intravascular phase and then a more or less pronounced phase of intraparenchymal accumulation. See *parenchymal phase of enhancement*.

power modulation imaging—Nonlinear techniques in which 2 separate pulses are transmitted down each scanning line, the second being at half the acoustic pressure of the first. The second returned signal is doubled and subtracted from the first. The symmetric echoes from linear structures such as tissues cancel each other, whereas those from contrast-induced, harmonic components (nonlinear scattering) produce the image line.

power pulse inversion imaging²⁹—A multiply transmitted pulse, color-coded pulse inversion technique.

puddle enhancement—A term occasionally used³⁵ to describe areas of enhancement, such as the enhanced globes at hemangioma periphery. To be replaced by *globular enhancement*.

pulse inversion Doppler²⁹—See *power pulse inversion imaging*.

pulse (or phase) inversion mode imaging—Nonlinear techniques in which 2 separate pulses are transmitted down each scanning line, the second being an inverted copy of the first (ie, 2 pulses phase shifted by 180° for 1 image frame). On summation of the 2 returned signals, the symmetric echoes from linear structures such as tissues cancel each other, whereas those from contrast-induced, harmonic components (nonlinear scattering) are summed to produce the image line. Tissue pulse inversion imaging and contrast-enhanced coded pulse inversion harmonic imaging are both possible.^{10,12,25,26,29,37,42,44} Contrast-enhanced pulse inversion may be used either as a continuous mode or an intermittent mode.

pulse subtraction imaging—A nonlinear, wide-band technique based on the phase modulation principle to display a signal from microbubbles as a B-mode, high-resolution image. Both intermittent acquisition and continuous acquisition are possible.

pure harmonic detection (extended)—A harmonic technique in which a distortion-free, pure sinusoidal fundamental pulse is transmitted, and second harmonic echoes are selectively registered.¹⁰

real-time contrast-enhanced sonography—See *continuous mode*.

recirculation—The effect of continuous circulation of contrast-enhanced blood through the pulmonary and peripheral circulation. Microbubbles circulate through the lungs several times before vanishing, and this allows sonographic scanning for several minutes. Oppositely, this phenomenon may impede functional studies because the recirculated microbubbles interfere with building of a pure time-intensity curve.

reflux—Contrast medium backflow within a hollow viscus through an ostium, for example, spread of contrast medium from the bladder to the ureter (ureterovesical reflux) or from the stomach to the esophagus (gastroesophageal reflux).

regurgitation—Contrast medium backflow through a vascular ostium or segment, for example, retrograde flow of contrast-enhanced blood from the right atrium to hepatic veins.

rim (arterial) enhancement—Also described as *ring enhancement* or *annular enhancement*. A continuous (thin or thick) annulus of peripheral contrast enhancement in a lesion. This is a typical pattern seen in liver metastasis.^{4,9,10,19}

ring (arterial) enhancement^{35,40}—See *rim (arterial) enhancement*.

second harmonic imaging—See *harmonic imaging*.

signal amplifier (or enhancer)—An agent increasing color-coded or spectral Doppler color-coded signal levels. Refers to the beginning of contrast-enhanced sonography practice, when these agents were used to amplify a scarce Doppler signal. The term *contrast medium* is preferred.

single-level (or single-slice) technique—Contrast-enhanced sonographic acquisition modality done without any movement of the transducer over the patient's body surface. Used for lesion characterization and functional studies.⁴⁵

sinusoidal phase of enhancement—The phase of contrast medium circulation when contrast-enhanced blood leaves the liver through its venous drainage (from 90–120 seconds after contrast medium injection to about 300 seconds after contrast injection, depending on the contrast medium used).^{1,8,9,11} Liver enhancement progressively declines to the baseline appearance. Because most sonographic contrast media are blood pool agents, the sinusoidal phase of enhancement is different from the interstitial equilibrium phase of CT imaging.^{1,9} Probably, the term *portal-sinusoidal phase* more appropriately describes the enhancement modality of the liver on contrast-enhanced sonography. As a matter of fact, there is a clear difference between arterial and portal phases, whereas there is a kind of continuity between portal and sinusoidal phases, which merge together. The sinusoidal phase is also referred to as the *late vascular phase*⁹ or *extended portal venous phase*.⁴⁴

sonoscintigraphy—Synonymous with *stimulated acoustic emission*.³⁴ Not related to scintigraphy in nuclear medicine. To be avoided.

spleen-specific phase of enhancement—See *parenchymal phase of enhancement*.

spoke wheel-shaped pattern^{10,11}—See *centrifugal blood supply*.

starlike pattern—See *centrifugal blood supply*.

stellate pattern^{11,37}—See *centrifugal blood supply*.

stimulated acoustic emission (acoustically)—An intermittent pseudo-Doppler technique based on high-frequency harmonic echoes arising from microbubble disruption due to high-intensity pulses. Mosaiclike, intense, but very transient echoes are color coded using color Doppler velocity.^{4,16,34} Also known as *color stimulated acoustic emission* or *transient scattering*.^{16,36}

stippled pattern of enhancement—Diffuse, chaotically disposed discrete vessels within a lesion. This is a typical color Doppler and contrast-enhanced sonographic pattern seen in HCC.¹²

subharmonic contrast-enhanced sonography—An experimental technique using that portion of the returned signal having a frequency half that of the transmission frequency. See *harmonic imaging*.

supplying artery—A hypertrophied artery that feeds a mass. It enhances before the mass itself and is seen as an enhanced vessel outside the nodule (malignant lesions) or even central to the nodule (focal nodular hyperplasia).

targeted (or target-specific or therapeutic) microbubble—A microbubble prepared to vehiculate ligands specific for a tumor, thrombus, or other target. Used in therapeutic ultrasound.³⁴

time-intensity (washin-washout) curve^{30,34}—Graphic plotting of the intensity of a microbubble signal over time from contrast medium injection.

time to peak—The time intervening between contrast medium injection and the moment of maximum contrast enhancement.³⁰

time variance imaging—A technique derived from power Doppler sonography in which pulses are broadband and with high levels of acoustic power.⁴⁶ The changes in microbubble shape and size are reflected in the amplitude and spectral

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energy distribution of the echoes, so that short sequences of 6 to 10 pulses per line can reveal the presence of microbubbles. The changes are then detected as characteristic features of microbubbles using a dedicated algorithm.³²

tissue (or tissue-specific) contrast medium—A sonographic contrast medium capable of being retained within parenchyma (mainly, liver and spleen). As a matter of fact, some contrast media are blood pool media, whereas others also show a delayed parenchymal (postvascular) phase, similar to superparamagnetic iron oxide agents used in MRI. Technologies such as stimulated acoustic emission and pulse inversion are necessary for imaging.³⁴

tissue harmonic imaging²⁵—Harmonic signals from tissues. See *harmonic imaging*.

tissue signature imaging—A high-MI, wideband technique performed with an advanced dynamic flow modality.

transient hepatic echogenicity difference—Similar to the transient hepatic attenuation difference encountered in dynamic CT imaging. Indicates a nontumoral area, hyperechoic on arterial phase scans and mainly isoechoic on venous and delayed phase scans. It reflects perfusion changes such as those developing in cases of perifocal hyperemia, arterioportal fistulas, and portal venous thrombosis.⁴⁷

transient scattering—See *stimulated acoustic emission*.

transpulmonary contrast medium—All modern, commercially available contrast media consist of microbubbles able to pass through the pulmonary vascular bed and reach the left cardiac chambers and the peripheral circulation. It is no longer necessary to specify this characteristic.

tumor stain—Dense (homogeneous or inhomogeneous) enhancement of a (hypervascular) lesion during the arterial phase. An angiographic term that should be avoided in contrast-enhanced sonography.

vascular phases of enhancement—Used to indicate the phases when contrast medium microbubbles circulate within the vascular system of the body. They are useful because some contrast media also show a postvascular phase.

vascular recognition imaging—A real-time, contrast-enhanced, single-pulse technique using the Doppler effect and color coding the flow direction of contrast-enhanced blood. Signals from static and moving microbubbles are discriminated into different colors and superimposed on the B-mode image.

venous phase of enhancement—The phase of contrast medium circulation when contrast-enhanced blood leaves an organ through its venous drainage. For liver imaging, it is synonymous with the *sinusoidal phase* rather than with the *portal phase*.

washin—Enhancement of a vascularized lesion, vessel lumen, or cardiac chamber. A lesion (or vessel or chamber) becomes rapidly or slowly enhanced.

washout—De-enhancement of a vascularized lesion, vessel lumen, or cardiac chamber. A formerly enhanced lesion (or vessel or chamber) becomes rapidly or slowly less enhanced than previously. The time of washout indicates when (if) a lesion turns hypo-enhanced, which is a feature of malignancy. Oppositely, sustained enhancement is commonly encountered in benign lesions.

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