Ultrasonography - diagnostics in medicine

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- frequency 2-15 MHz
- velocity of propagation
  - air: 330 $m.s^{-1}$
  - bone: 1080 $m.s^{-1}$
  - soft tissues: approx 1540 $m.s^{-1}$
    - fat: 1450 $m.s^{-1}$
    - muscle: 1580 $m.s^{-1}$
- deepness of boundary: from velocity of US and interval between sending and return of a pulse
- different environment differs by their physical density
- velocity of propagation x environment density = acoustic impedance
  - the more different acoustic impedance of two neighboring environments is, the higher amount of ultrasound wave is reflected and the more distinct (bright) the boundary is shown
- „big“ boundaries (diaphragm, bigger vessels, wall of urinary bladder) reflect practically all waves
- smaller boundaries organs parenchyma are diffuse, and that is why they are less intensive

Artifacts

- part of not reflected waves goes through the boundary and changes its direction in the same ratio as the ratio between propagation velocities in the environments in question
- consequence: deeper boundaries are depicted in incorrect distance or direction
- refraction is lowest in the direction of wave propagation which is perpendicular to the boundary

Attenuation

- a consequence of reflection, scattering and absorption is an attenuation
  - in air 12 dB/cm/Hz
  - in fat 0,63 dB/cm/Hz
  - in blood 0,18 dB/cm/Hz
  - in water 0 dB/cm/Hz
- modern devices are equipped by programs for compensation of attenuation (time gain compensation)

Grey levels

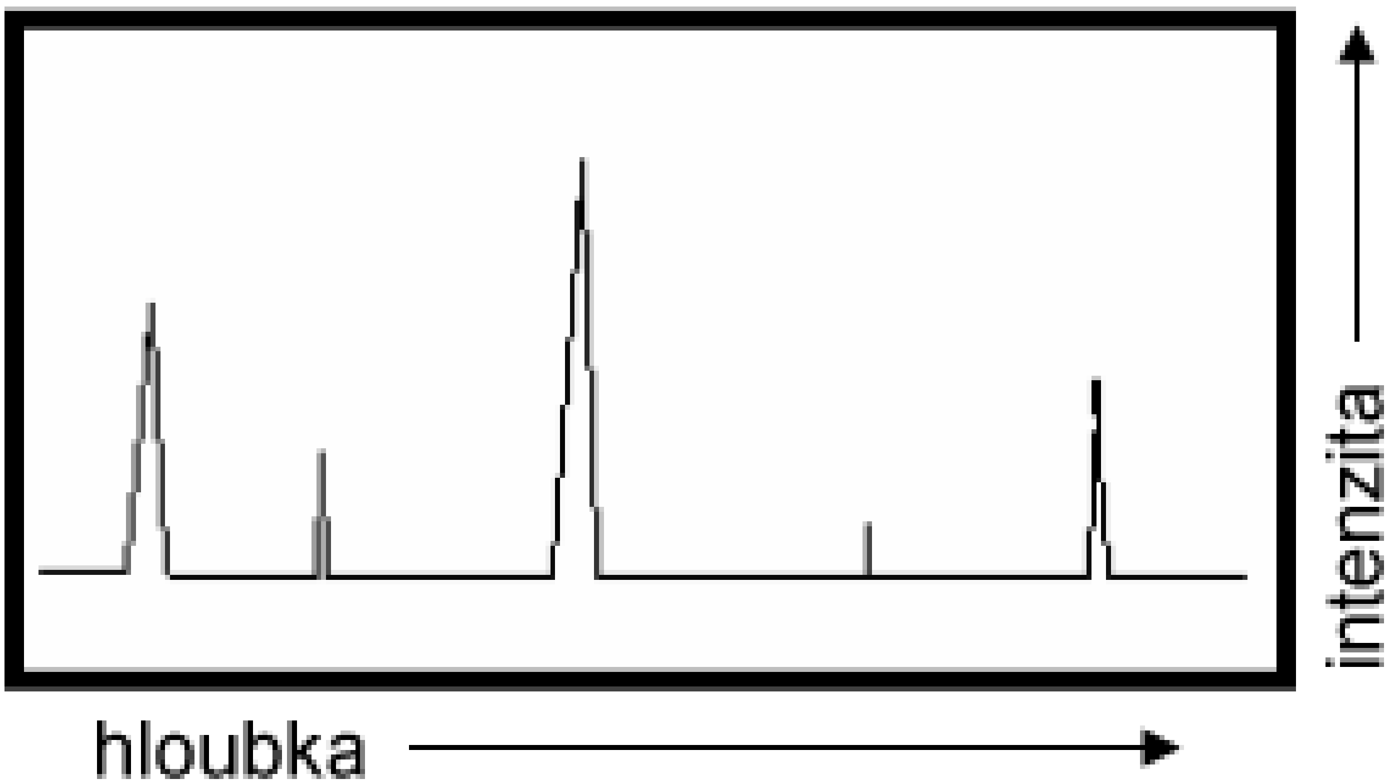
- adjusting of high range of received intensities (up to 1000) to the possibilities of displaying in the grey level scale
- most of devices show 256 grey levels

Image formation

- an image of examinated plane is created by
  - information about time between sound impulse and reflected waves return
  - amplitude
  - frequency

- the impulse is generated in a transducer which contains one or more piezoelectric crystals
- sending a pulse takes only a small amount of time, in the most of time the transducer acts as a receiver of reflected ultrasound waves
- the received waves incur reverse piezoelectric phenomenon
- formed electric currents are registered as amplitudes which are proportional to the intensity of received ultrasound waves

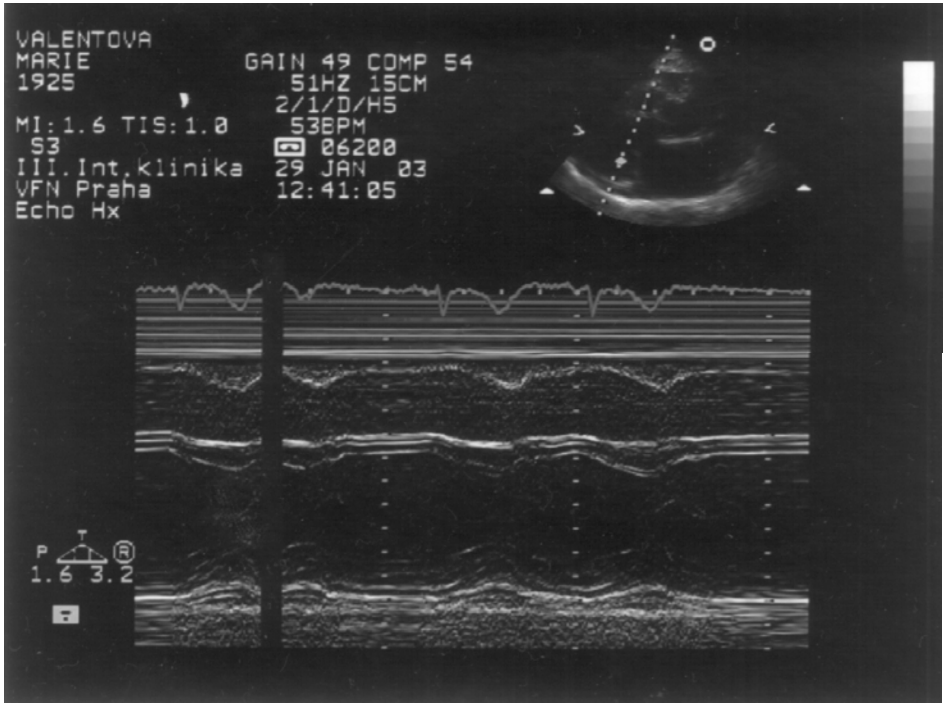
A-mode



A-image shows the trajectory of sent ultrasound beam (static and 1D)

the beginnings of clinically usable ultrasound – e.g. the differentiation between cysts and solid findings (tumors)

M-mode



Representation of received signals as points with different intensities in the vertical axis (i.e., rotation by 90 degrees) allows to continuously monitor A-image. So that M-mode is created. It is still used especially in echocardiography for depiction of movement of heart valves and other heart structures

B-mode

- two-dimensional image in real time
- ultrasound waves are sent in a thin plane with frequency 15-60 Hz synchronized by a larger amount of crystals:
  - in transducer placed beside each other (linear transducer)
  - in convex shape (convex and sector transducers)
- reflected and received waves are analyzed, processed and are shown in the monitor as points with different intensities, their position corresponds to the distance from the transducer
- rapid frequency of images forms fluent sequence of moving structures

Doppler techniques

- flowing blood is anechogenic in A and B-mode
- blood cells are sound reflectors
- with red blood cell approaching or moving away from transducer, the wave length of reflected waves changes
- continuous Doppler
  - does not allow to recognize the deepness from which analyzed signals originate (it is used only at the bedside for examination of superficially located bigger vessels)
- pulse Doppler
  - it allows, by choosing the time period between sending wave and returning its reflection, to aim to certain place in 2D grey-scale image (**duplex Doppler**)

color flow Doppler imaging

- most often used
- a combination of B-image in real time with image representation of blood flow with assigned color scale (from bright red to bright blue)

power mode Doppler

- brightness of used color depicts an amplitude of Doppler signals
- less noise and more sensitive in imaging of small blood vessels (it does not inform about the velocity and the direction of flow)

Application of echocontrast agents

- to increase the outcome of Doppler examination
- invasive
- e.g., microparticules of galactose with a small amount of palmitic acid, encompassing microbubbles of air
- substantially improves possibilities of imaging of very small vessels with slow blood flow
- e.g., detection of neovascularization in tumors

Benefits and drawbacks of US

- non-invasive method
- high resolution (< 1 mm)
- imaging in a broad grey scale (usually 256 grey levels)
- possibility of examination of perfusion (Doppler methods, echocontrast substances)
- real time imaging

- examination quality depends on the position of the organ or tissue and on the (actual) status of the patient
- subjective evaluation
- structure of the tissue is shown in the text by indirect way
- identical US image for different histological changes

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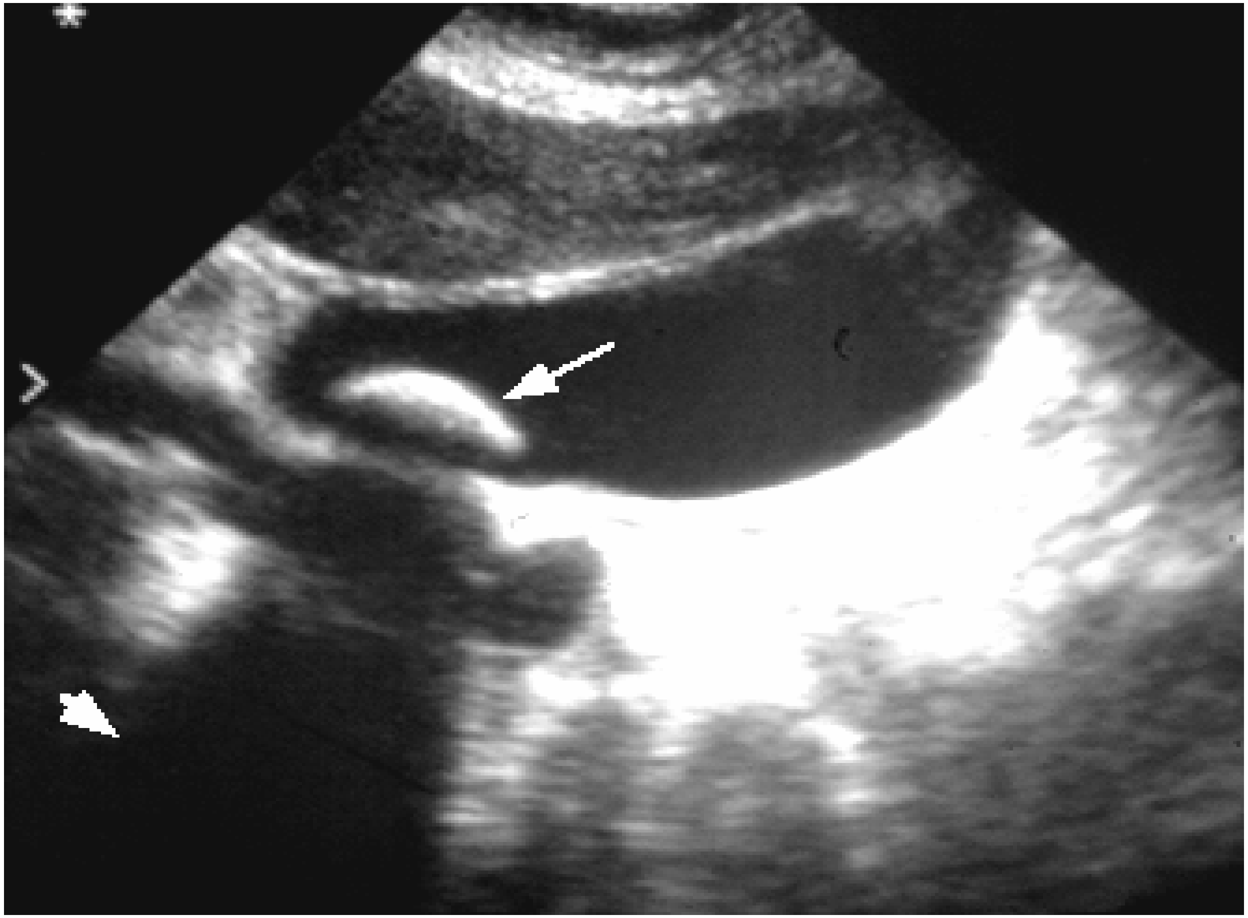
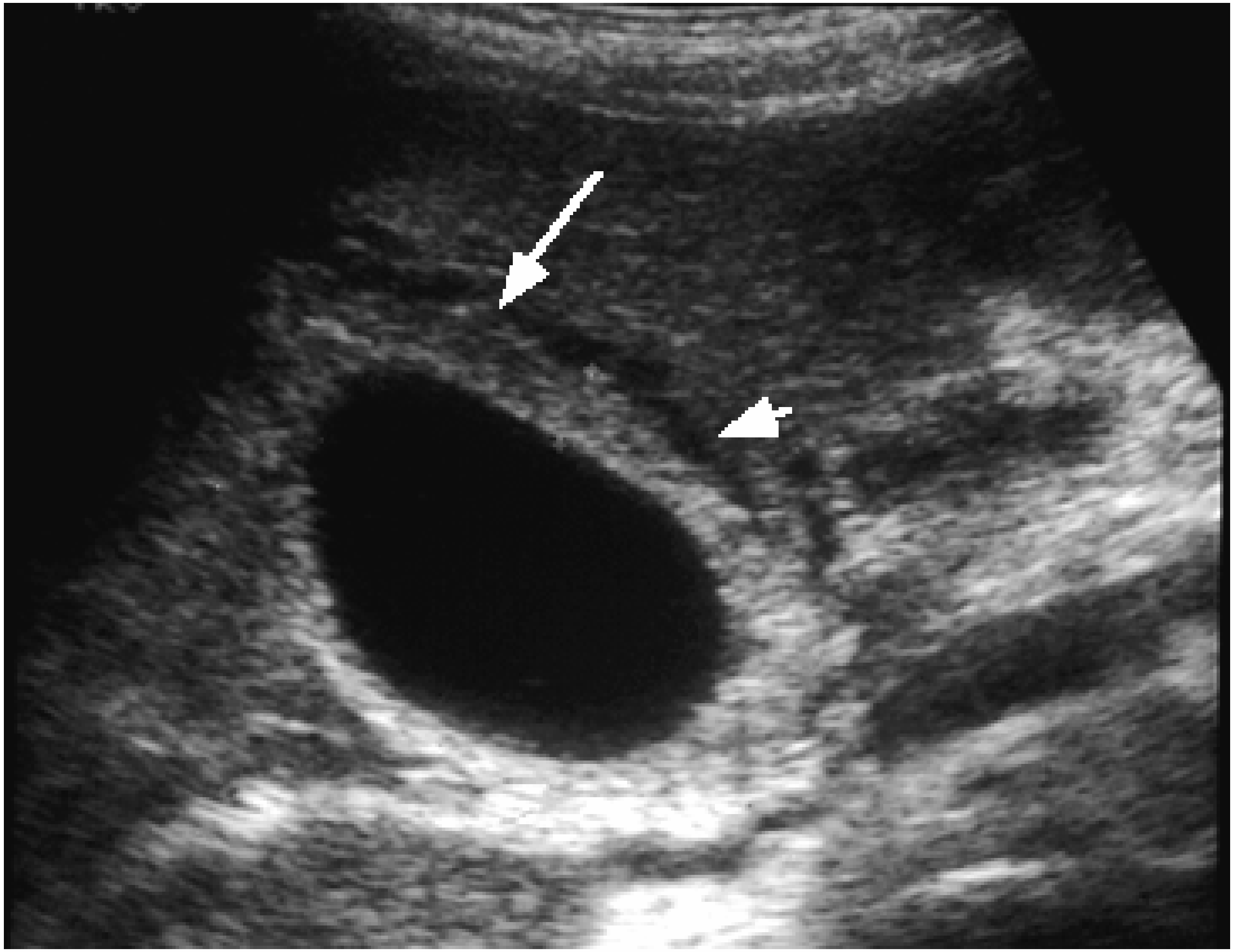
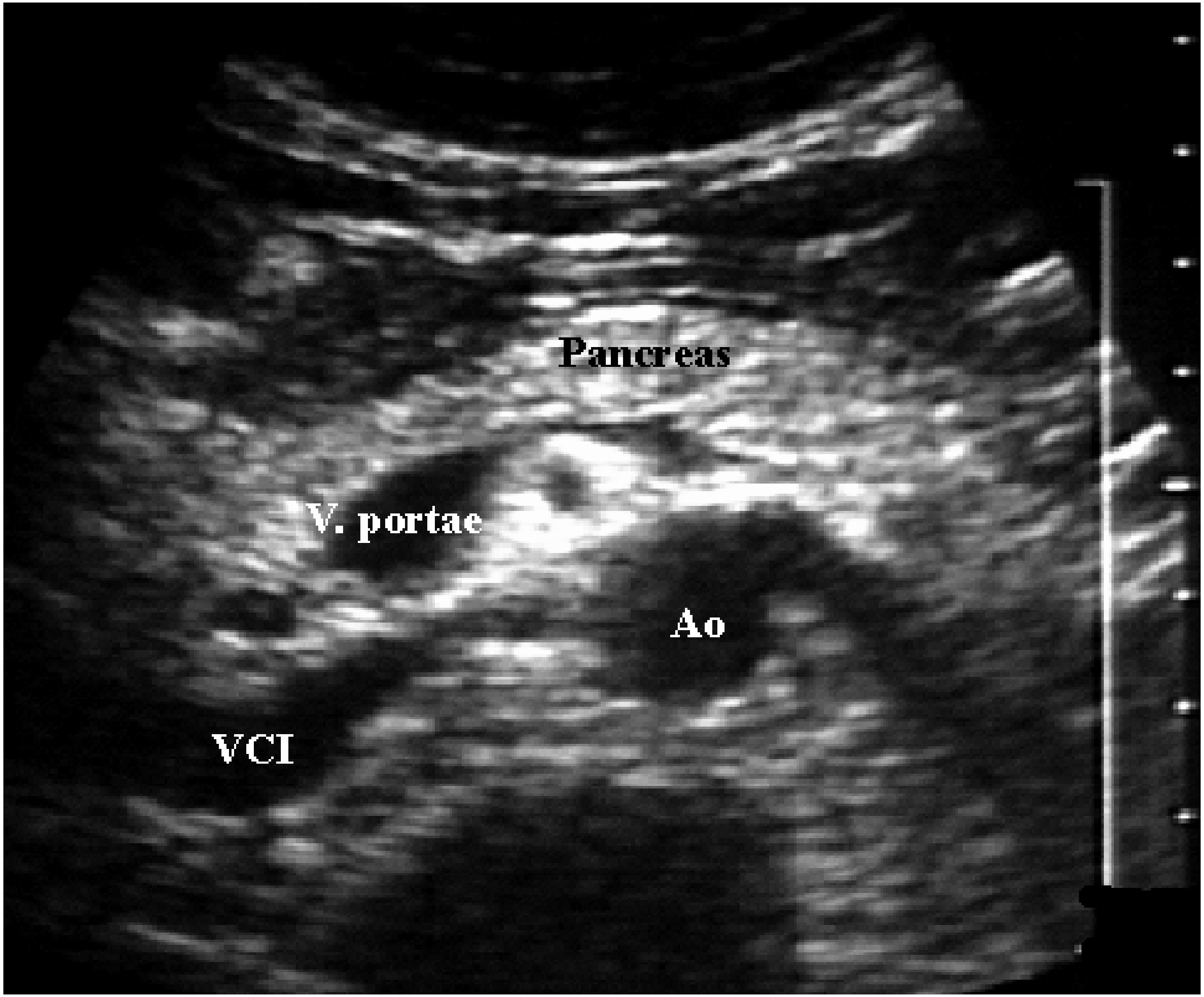


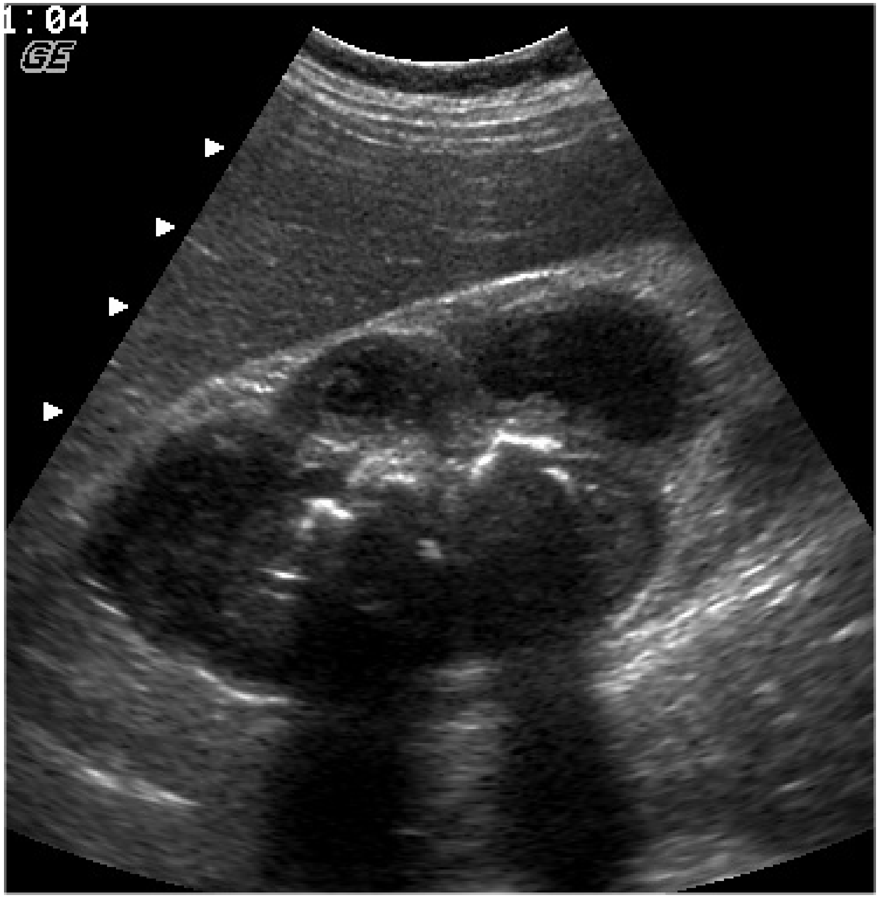
Cholelithiasis Ultrasound of the gallbladder shows posterior acoustic shadowing (arrowhead) produced by a stone in the lumen of the gallbladder (arrow). There is no gallbladder wall thickening, a finding that may be seen with cholecystitis. Courtesy of Jonathan Kruskal, MD.



Acute cholecystitis Ultrasound of the right upper quadrant in a patient with acute cholecystitis reveals marked thickening of the gallbladder wall (arrow) with fluid surrounding the distended gallbladder (arrowhead). Courtesy of Jonathan Kruskal, MD.



- harmonic imaging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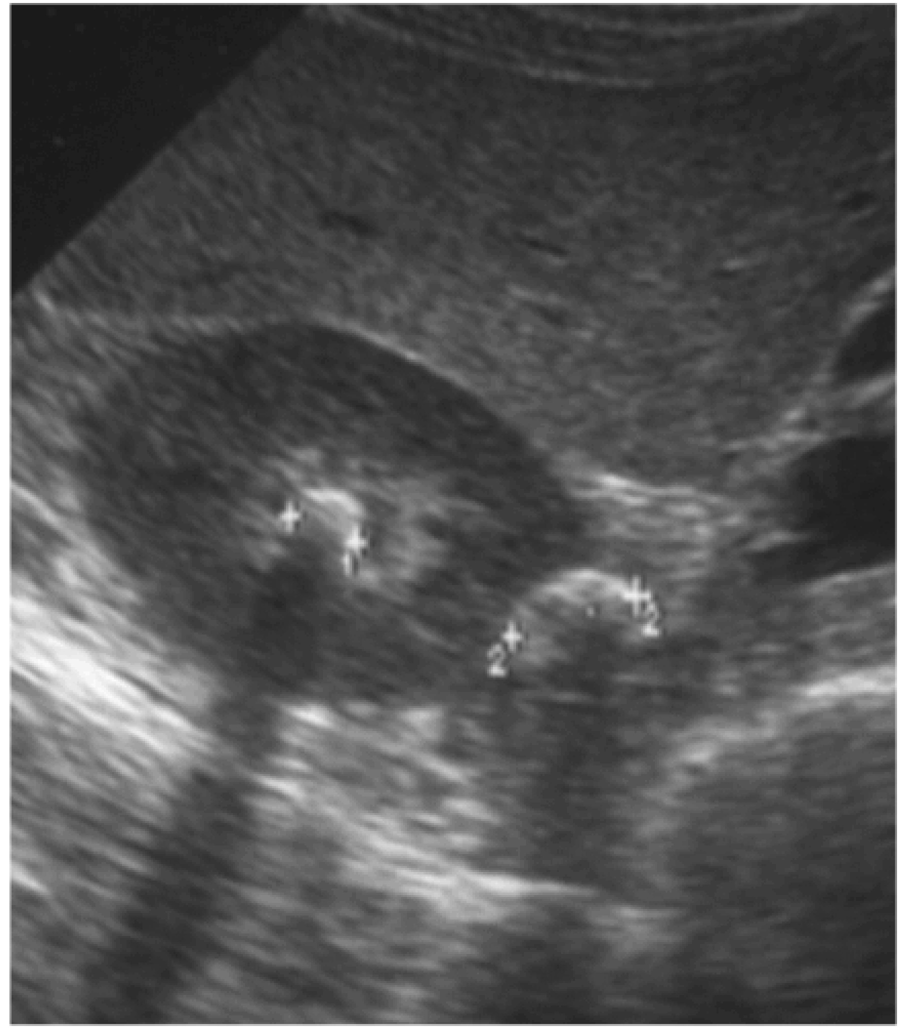


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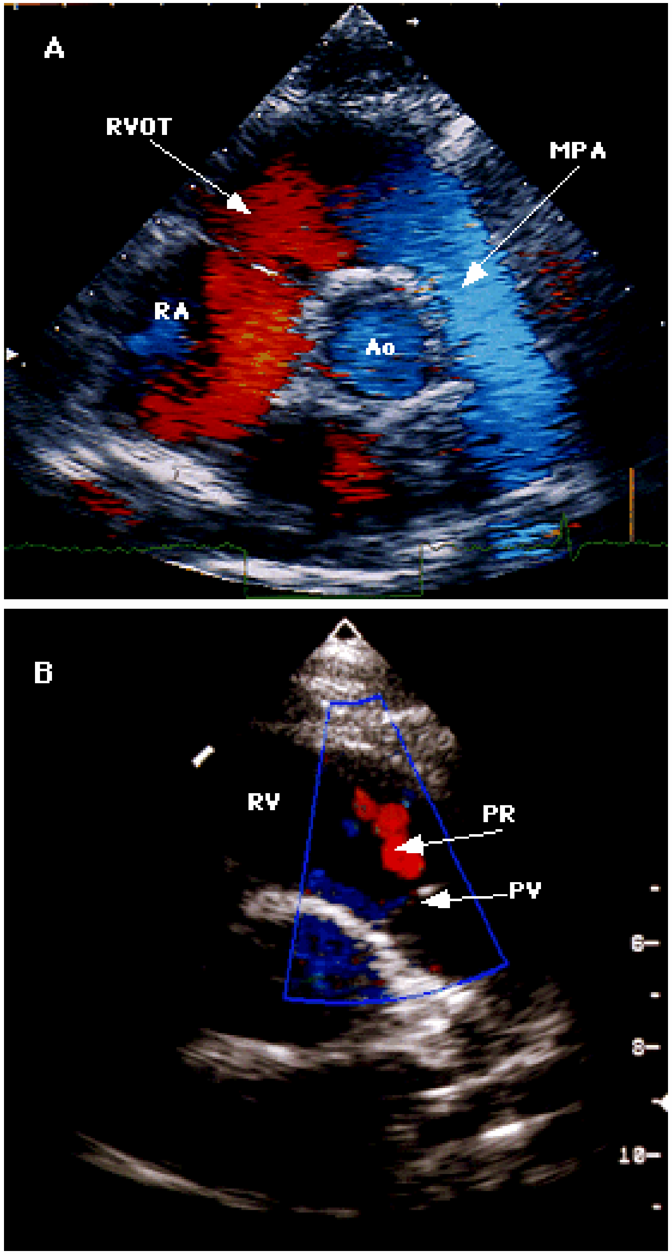
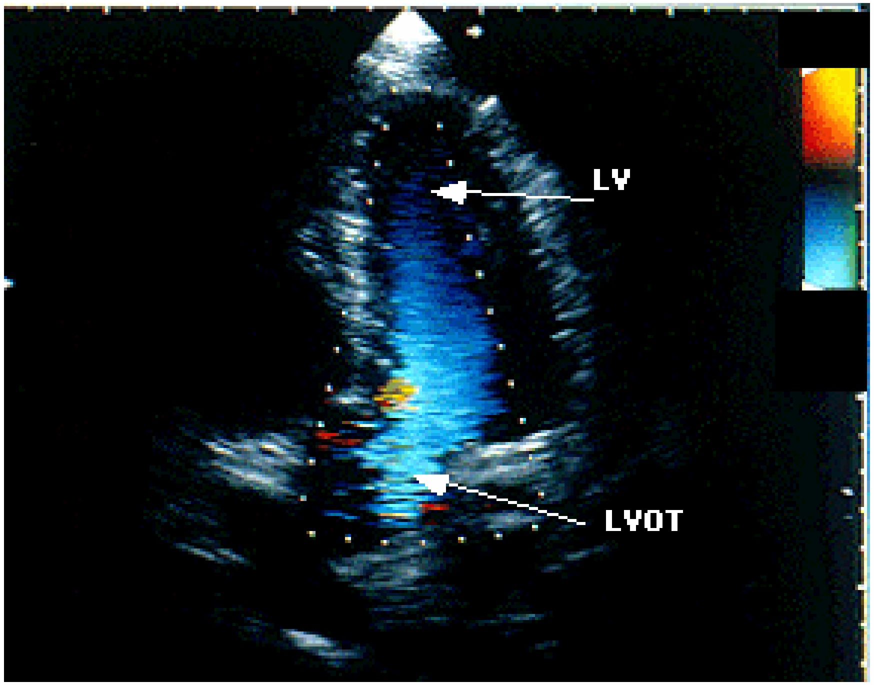
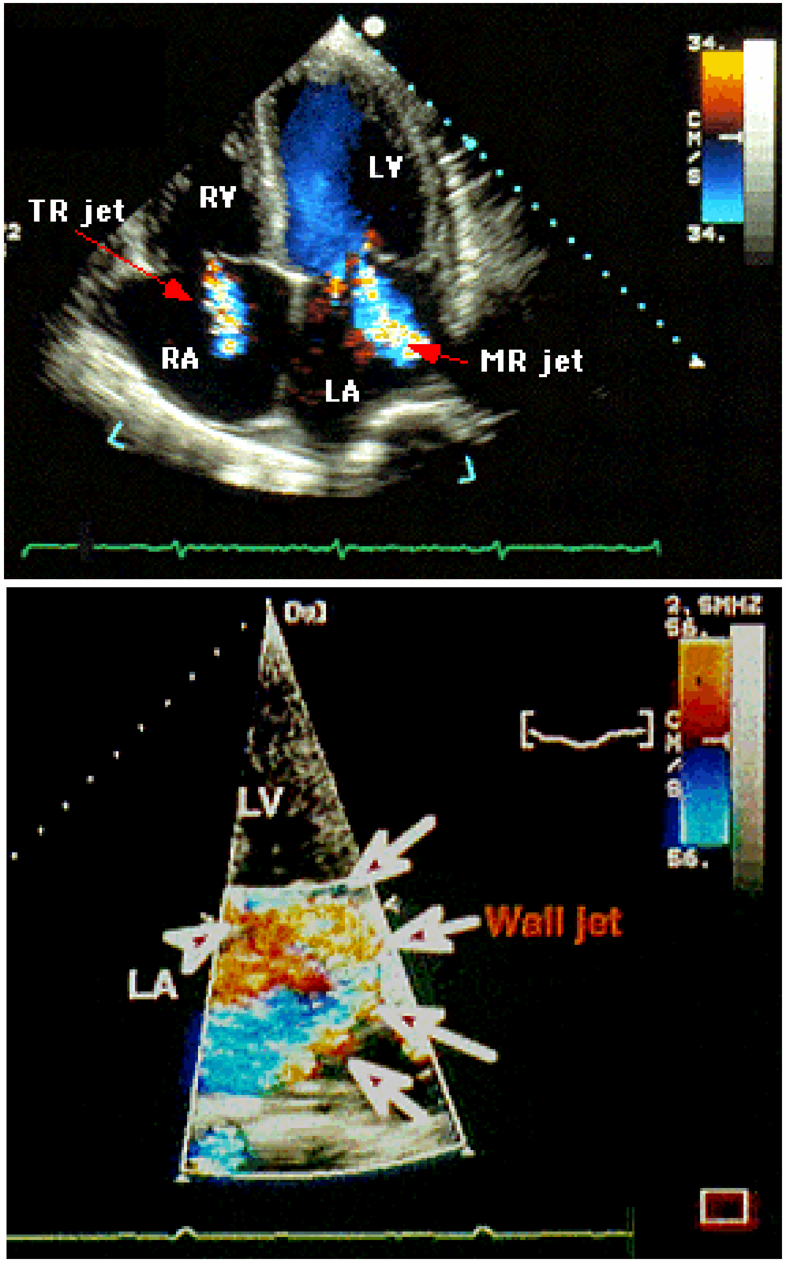


Short axis view through the base of the heart with color flow Doppler imaging The short axis view is recorded from the base of the heart. Color flow Doppler imaging during systole (panel A), demonstrates normal systolic flow from the right ventricular outflow tract (RVOT) to the main pulmonary artery (MPA). The flow signal is red in the proximal RVOT as it travels towards the transducer. As it moves at right angles to the interrogating beam the signal briefly disappears. When the flow turns away from the transducer and exits into the MPA it is coded blue. Imaging from short axis view through the base of the heart during diastole (panel B) shows diastolic flow signal (red) from pulmonic valve (PV) denoting trivial pulmonary regurgitation (PR) which is found in 90 percent of normals. Ao, aorta; RA, right atrium.

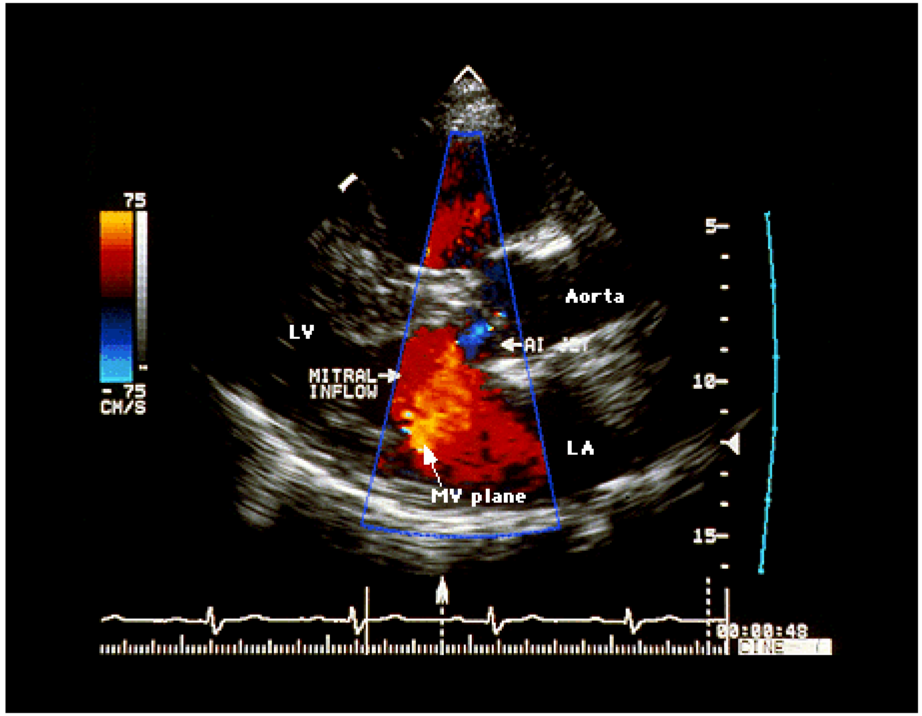


Apical four chamber view with color flow Doppler The apical four chamber view with color flow Doppler was obtained from a normal subject during systole. The systolic flow signal is shown in blue, ie flow is moving away from the transducer. This signal is used to position a pulsed wave Doppler sample volume in the left ventricular outflow tract (LVOT) so that flow characteristics can be quantitated. LV, left ventricle.

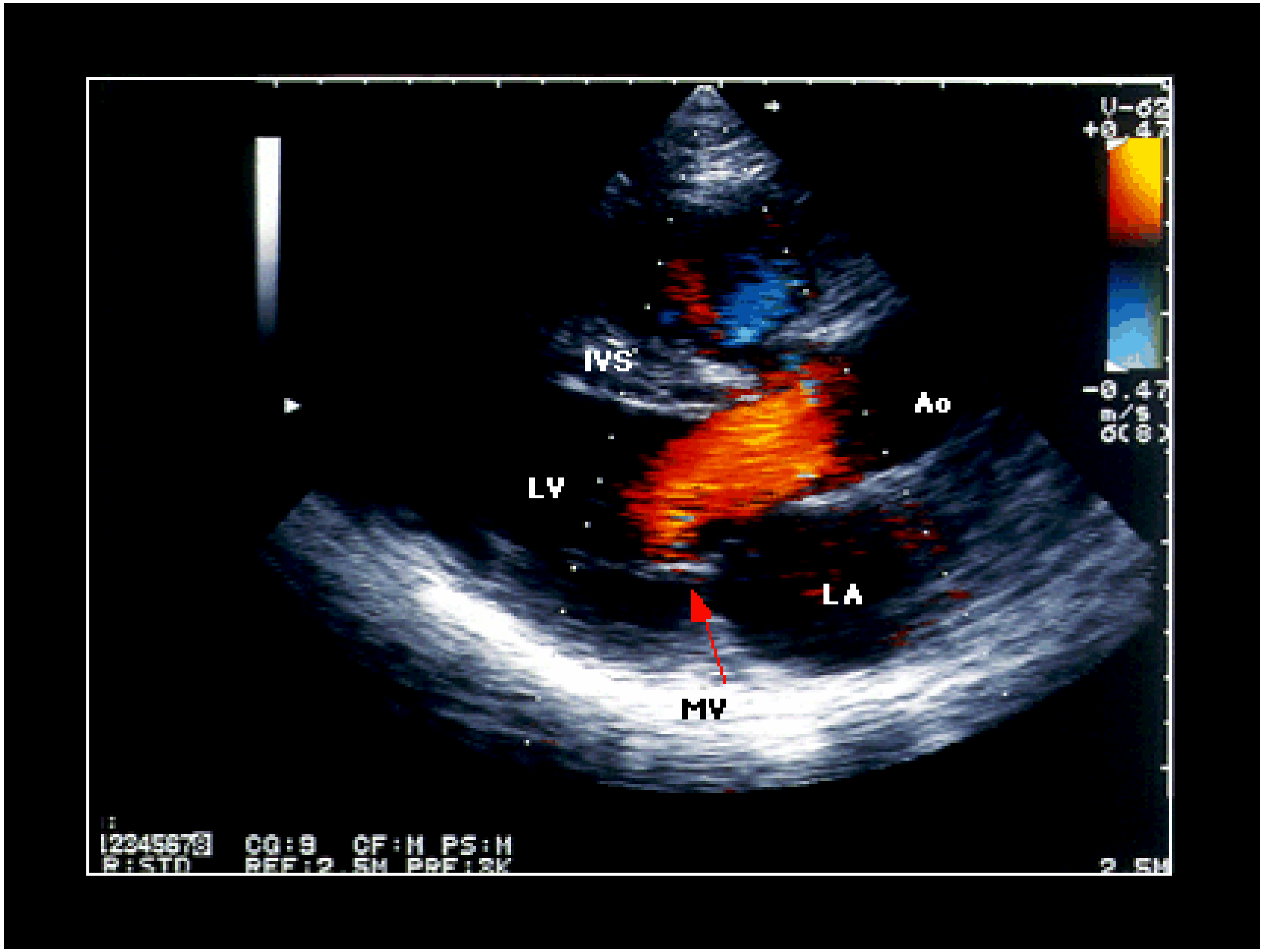


Color flow Doppler of mitral regurgitation

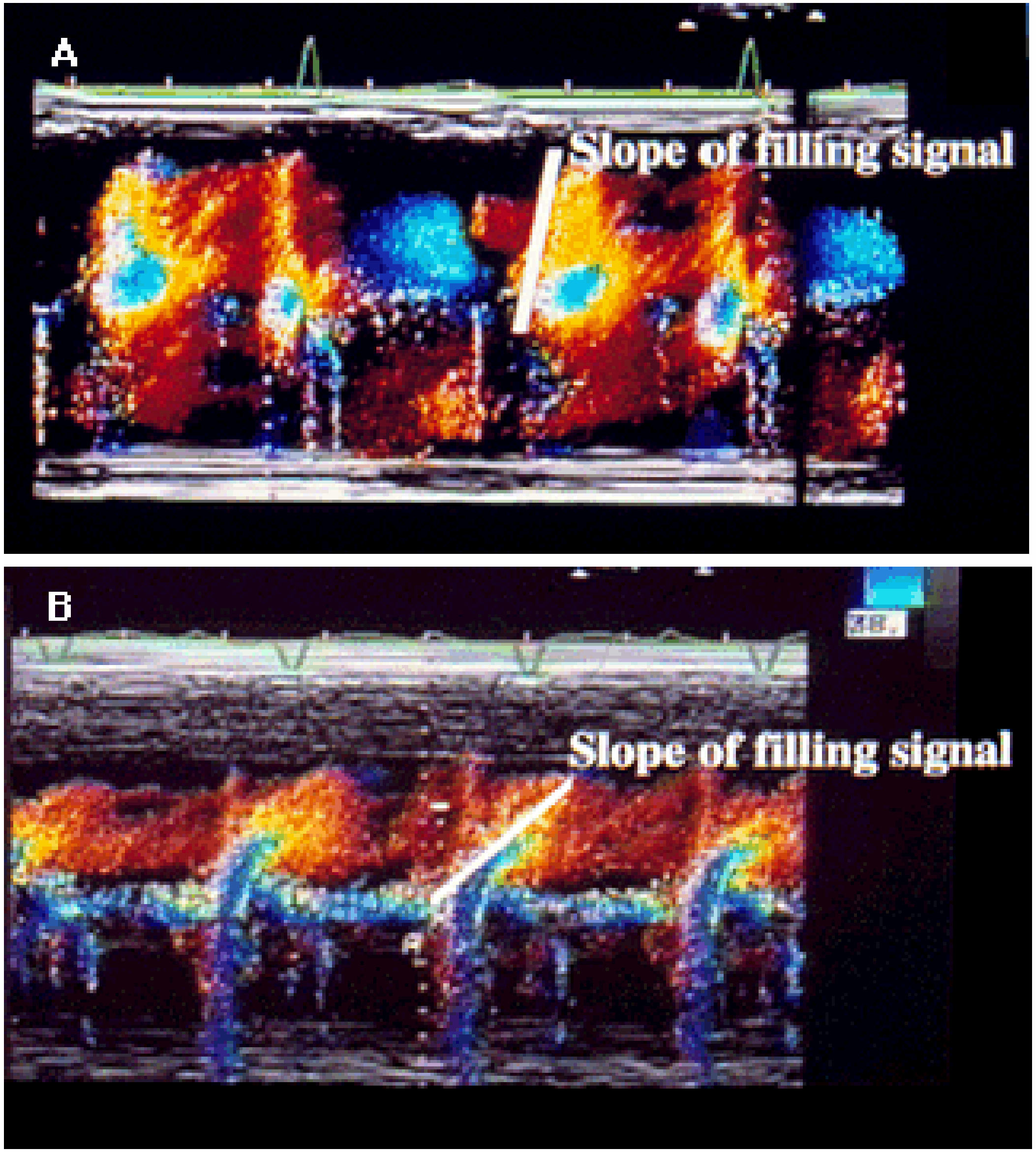
Panel A is a four chamber view in systole showing color jets of mild mitral (MR) and tricuspid regurgitation (TR). The jets are central and do not penetrate the left atrium (LA) beyond the mid cavity. Panel B shows severe MR; the arrows outline the course of a jet during systole that adheres to and follows the contour of the LA. Such wall hugging jets are typical of severe regurgitation. Since their area is smaller than central jets, the use of wall hugging jet area as a sign of MR severity is not recommended. LV, left ventricle; RA, right atrium; RV, right ventricle.



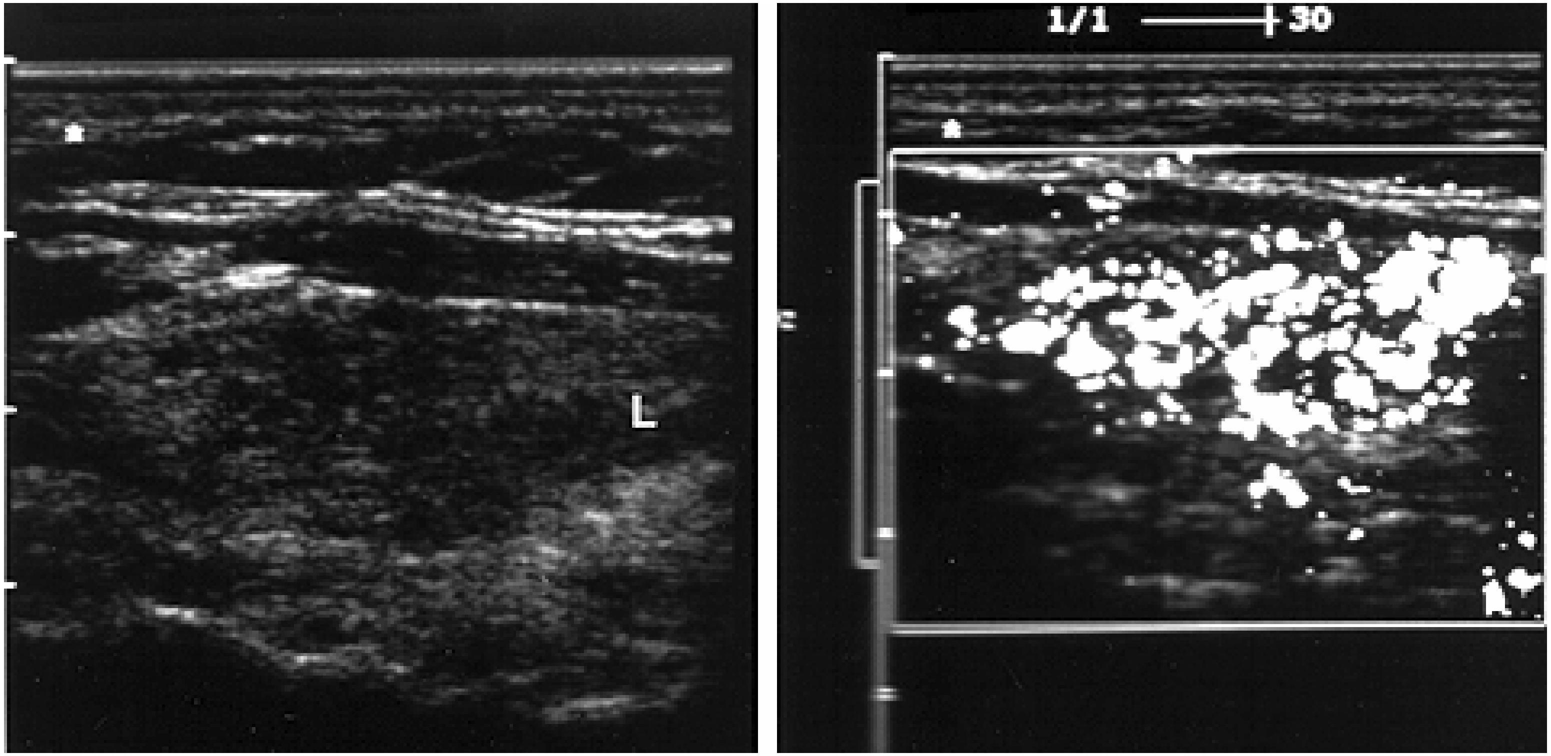
Parasternal long axis view with color flow Doppler The long axis parasternal view with superimposed color flow Doppler mapping of the left ventricular inflow and outflow tracts was obtained during diastole. The color bar in the left side of the image indicates that red designates flow towards the transducer and that orange shades of red indicate velocities at the preset Nyquist limit of 0.75m/sec; blue identifies flow that is away from the transducer. Normal diastolic mitral inflow from the left atrium (LA) to the left ventricle (LV) is color coded in shades of red. At the point flow crosses the mitral valve (MV) plane it becomes bright orange, ie, flow accelerates as it crosses the narrower diameter of the mitral valve ring, reaching a velocity that is at the upper limits of the instruments ability to measure. There is a small diastolic signal in blue that arises from the central portion of the coapted aortic valve leaflets and represents mild aortic regurgitation (AI); at its point of origin, this flow is characterized by red, white and blue dots that, by convention, identifies the flow as being "disturbed" or chaotic and high velocity. As the flow decelerates it becomes blue identifying it as flow that is away from the transducer.



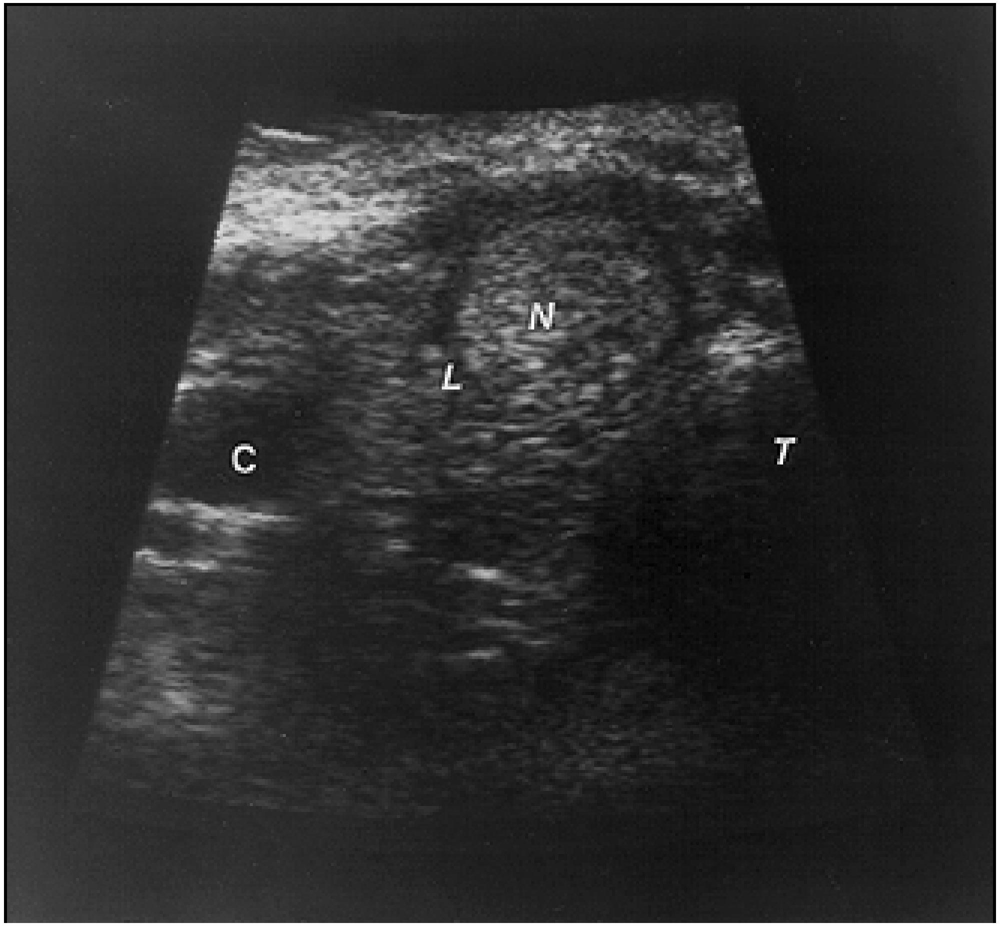
Long axis parasternal view with color flow Doppler mapping Seen is the long axis parasternal view of the left ventricular outflow tract during systole; a normal color flow signal (red-orange) in seen the left ventricular outflow tract. The occasional blue patches in the signal represent aliasing and suggest that the signal is at or exceeds the Nyquist limit. LV, left ventricle; LA, left atrium; MV, mitral valve, Ao, aorta, IVS, interventricular septum.



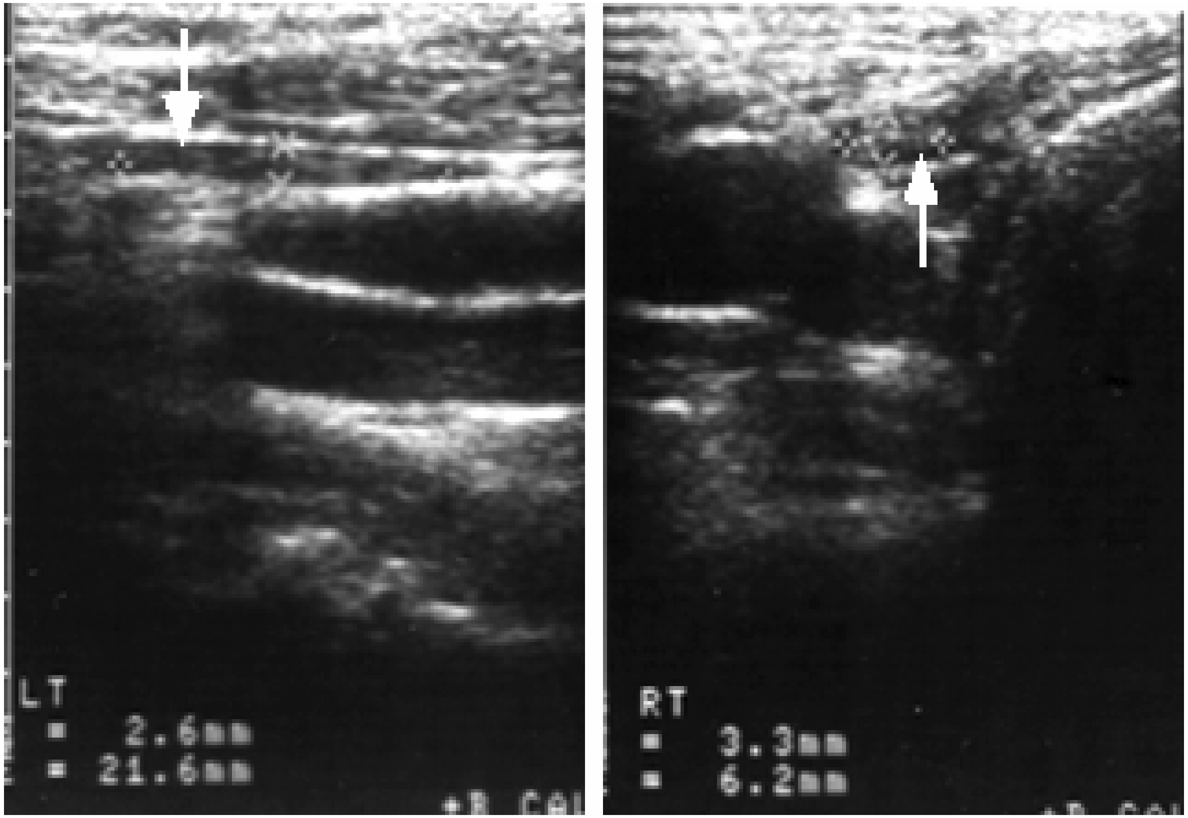
Color Doppler M-mode echocardiogram Color Doppler M-mode from the four chamber view, recorded at a speed of 100 mm/sec, demonstrates the rate at which flow propagates into a the ventricle, represented by the slope of the filling signal. In the normal ventricle, the flow propagation is rapid and the slope is steep (panel A). The rate at which flow propagates into the ventricle of a patient with cardiomyopathy and diastolic dysfunction is considerably slower (panel B). This observation is particularly useful when trying to differentiate normal from "pseudonormal" filling patterns in diastolic dysfunction.



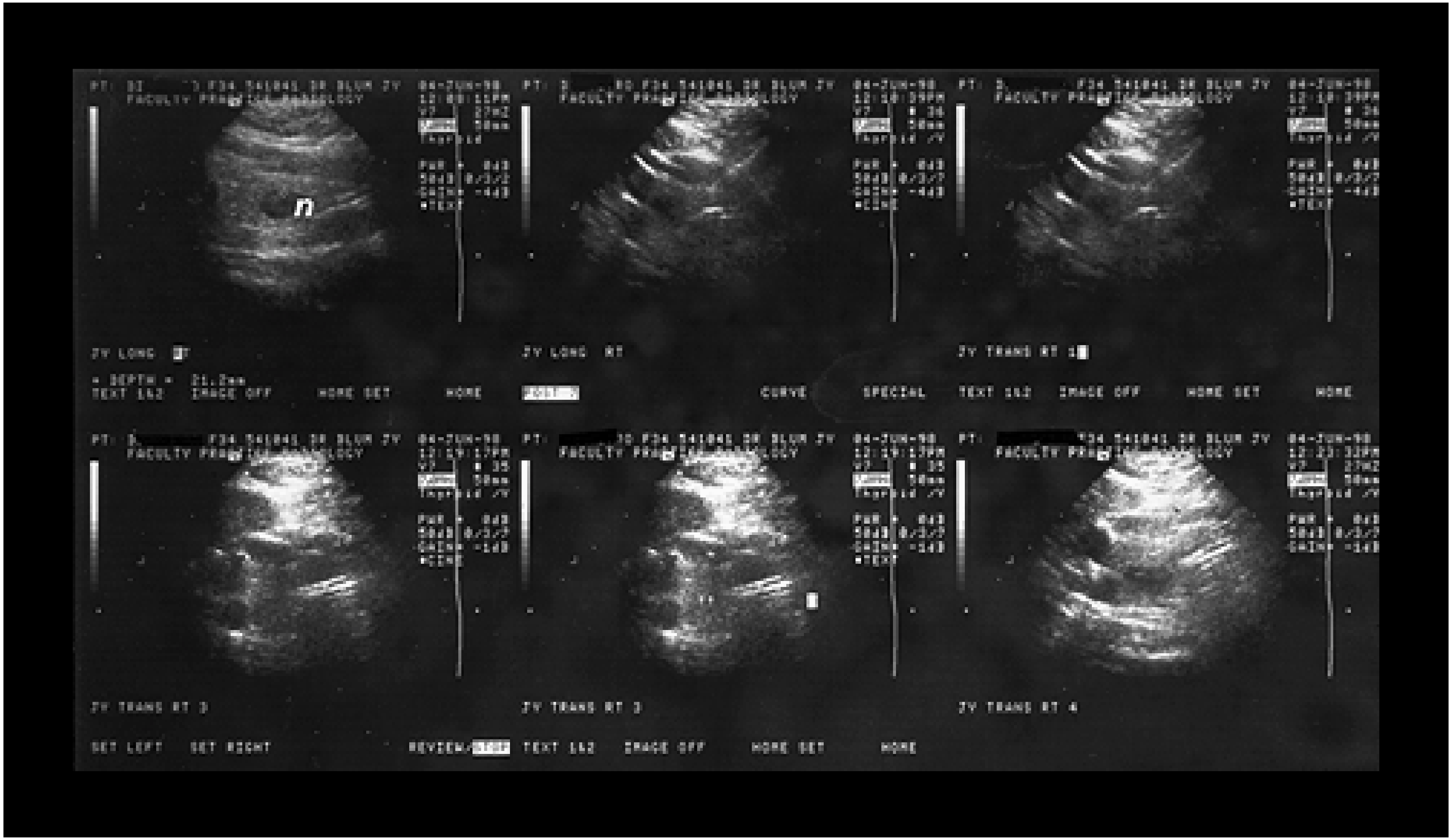
Graves' disease Sonogram of the left thyroid lobe in the longitudinal plane from a patient with Graves' disease. The left panel shows a hypoechoic enlarged lobe (L), while the Doppler image in the right panel demonstrates intense hyperemia. Courtesy of Manfred Blum, MD.



Hyperechoic thyroid nodule Sonogram of the right lobe of the thyroid gland in the transverse plane from a 73-year-old woman that shows a nodule that is sonically more intense than the rest of the thyroid. N = nodule, L = thyroid lobe, I = isthmus, C = carotid artery, and T = trachea. Courtesy of Manfred Blum, MD.



Benign lymph node Thyroid sonograms in the longitudinal (left panel) and transverse (right panel) planes shows a thin elliptical benign lymph node (arrows). Courtesy of Manfred Blum, MD.



Ultrasound guided FNA Multiple sonograms in the transverse and longitudinal planes during an ultrasound-guided fine-needle aspiration (FNA) biopsy of a nodule (N). The straight parallel bright lines represent the needle in or near the nodule. The needle is within the nodule in frames 4 and 5. In frame 4, the large arrow points to the needle entering the nodule. In frame 5, the small arrows point to the tip of the needle in the nodule at the time of aspiration. Courtesy of Manfred Blum, MD.