VOLGOGRAD STATE MEDICAL UNIVERSITY

Lecture

“Analyzing the results of ultrasound studies”

Department of Radiologic Diagnostics

Types (methods) of radiation diagnostics

- ***X-ray*** **(including CT)**
- ***Ultrasonic***
- ***Radionuclide***

(radioisotopic)

- ***Magnetic resonanceOuch tomography***
- ***Thermal imaging*** **(thermographic)**

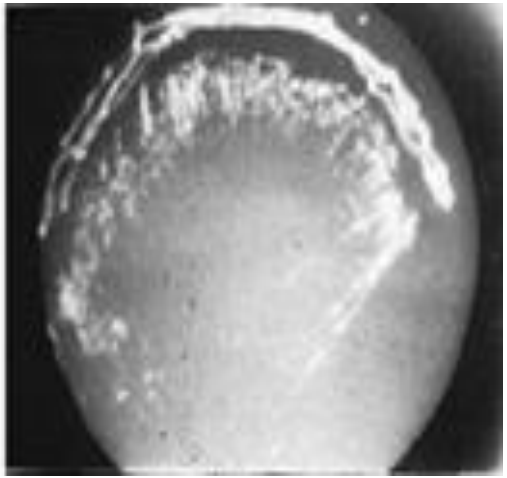
Ultrasonic type (method) radiology diagnostics

- The ultrasonic method is a method for remotely determining position and shape. size, structure and movement of organs and tissues, as well as pathological foci using ultrasound radiation

Ultrasound began to be used in medical diagnostics only in the second half of the twentieth century. But this event was preceded by a large number of studies and inventions in physics, mathematics, materials science, electronics, biology, which occurred in science starting from the 15th century.

XV centuryLeonardo Da Vinciused a tube immersed in water to determine the movement and speed of encounters with enemy ships at sea. In 1826scientists from SwitzerlandColladon and Sturm(Jean-Daniel Colladen, Charles-Francois Sturm) conducted a series of experiments in Lake Geneva, as a result of which they were able to calculate the speed of sound in water ~1435 m/s– which is confirmed by modern measurement methods.

Tom Brownworked as an engineer in Donald's laboratory. He created a completely new device, the Mark 4. The Mark 4 could differentiate between solid and cystic tumors well.
First B-scannerwas developed in**1956 by Tom Brown**, like an attachment to a hospital bed.



The first B-scanner and ultrasound image of the abdominal organs obtained with its help

What is common to all methods of radiation diagnostics is use of radiation as a carrier of information passing through the object under study.

Each method of radiodiagnosis involves the use

 ***radiation source***

 ***the radiation itself passing through the object research or coming from it***

 ***object of study (patient, biological liquid)***

 ***sensing device (detector)***

 ***converter of received information***

 ***researcher***

Ultrasound machines

Ultrasonic radiation source -ultrasonic sensor

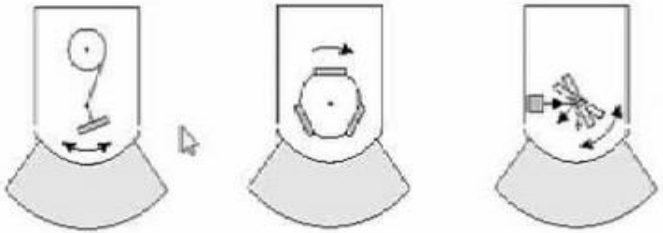
(included in the ultrasound machine)

- ***Ultrasonic sensors by application area***
- Universal sensors for external inspection (abdominal probe) - operating frequency 3.5-5 MHz.
- Sensors for superficial organs (small parts probe) - operating frequency 7.5-10 MHz.
- Cardiac sensors (cardiac probe) – operating frequency 3.5-5 MHz.
- Pediatric sensors (pediatric probes) – operating frequency 5-7.5 MHz.
- Intracavitary sensors (intracavitary probes):
- Transvaginal.
- Transrectal.

radiation

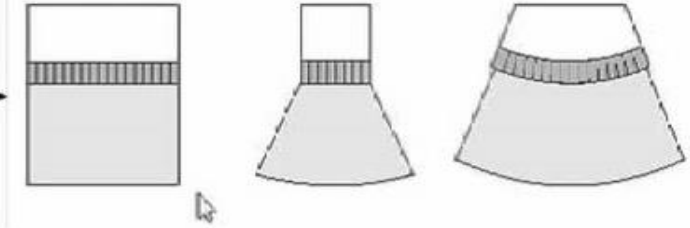
- ***Ultrasonic sensors by application area***
- Intraoperative.
- Transurethral.
- Transesophageal.
- Intravascular.
- Biopsy or puncture.
- Highly specialized sensors.
- Ophthalmological.
- Transcranial.
- For veterinary medicine.

Ультразвуковые датчики



Механические датчики могут быть одно- и многоэлементные (анулярные). Развертка ультразвукового луча может достигаться за счет качания элемента, вращения элемента или качания акустического зеркала

Электронные датчики являются многоэлементными и в зависимости от формы получаемого изображения могут быть секторными, линейными, конвексными (выпуклыми)



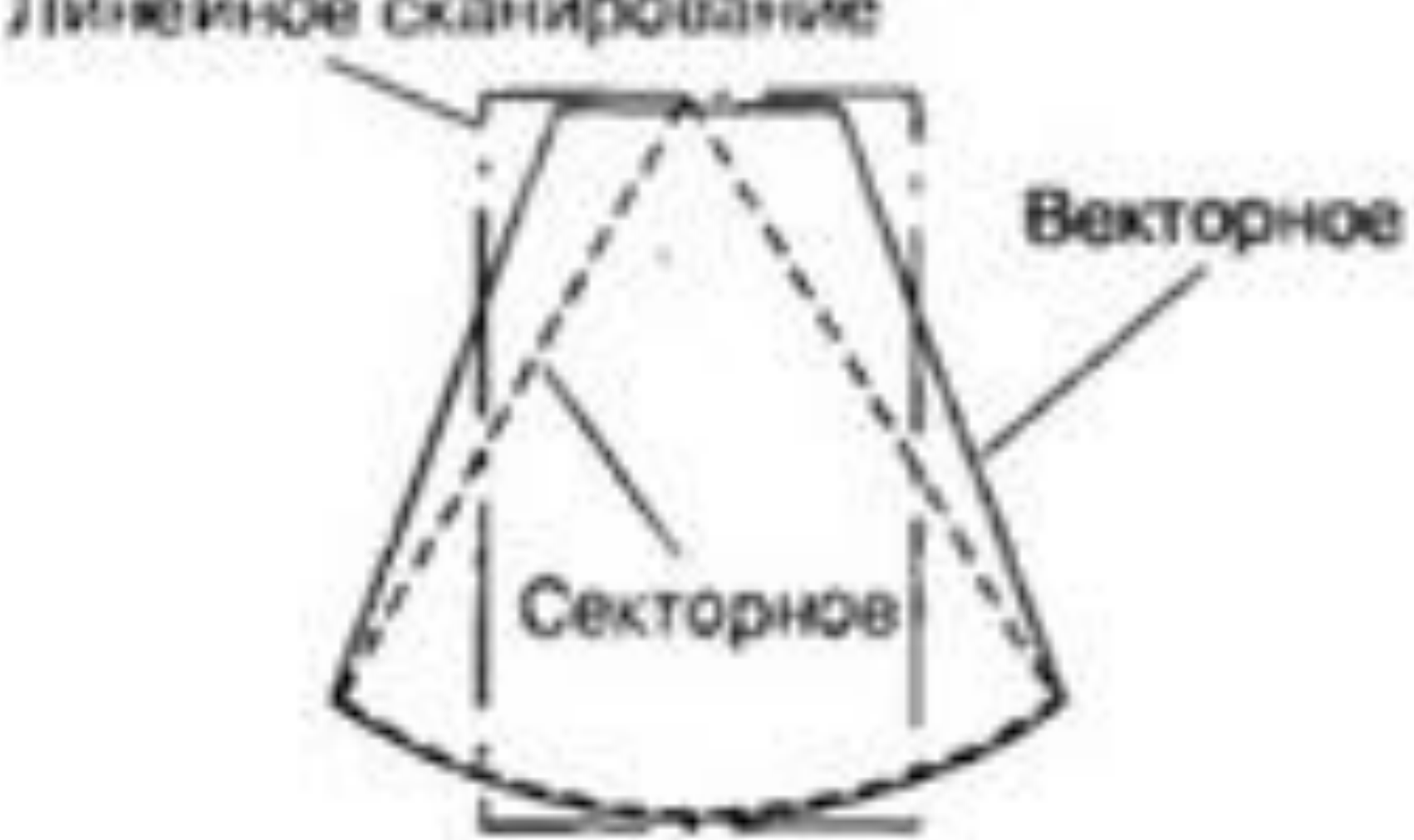
Scan formats

- **Linear** (sound waves are parallel to each other and create a rectangular image)
- **Advantage:** equal line density at shallow and large depths, good resolution in the near field.
- **Flaw:**limited viewing area at great depths.

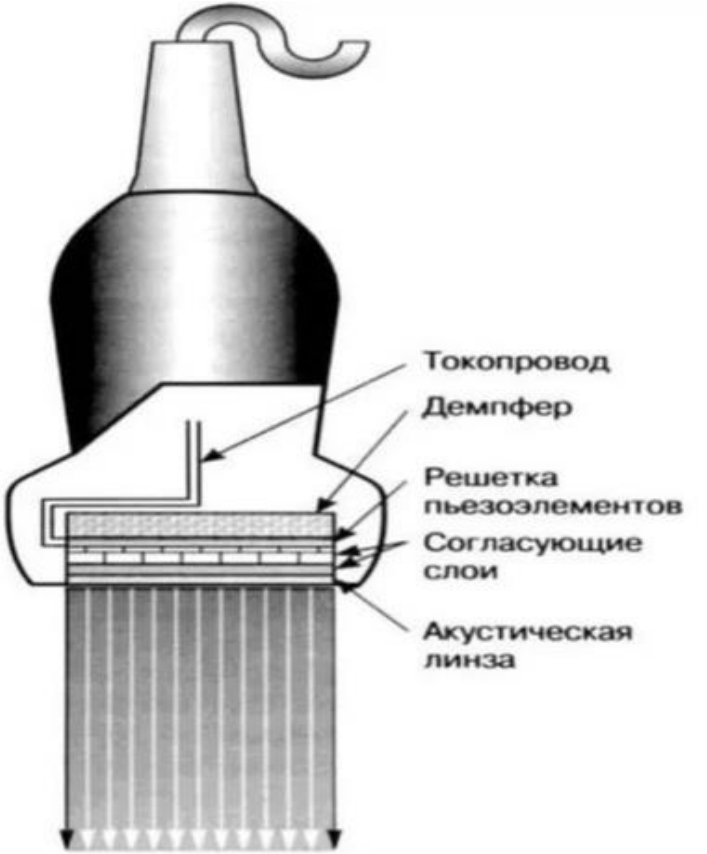
- **Convex** (convex lattice, rays diverge in the form of a fan)
- **Advantage:** large viewing area of deep structures.
- **Flaw:** visualization of nearby structures is limited.

- **Sectoral** (will produce a fan-shaped image that is narrow near the sensor and widens as depth increases).
- **Advantage:** a narrow beam in the near zone provides a small aperture.
- **Flaw:** low resolution in the near field.

- **Vector** – a sophisticated version of the sectoral format to expand the viewing area at shallow depths.

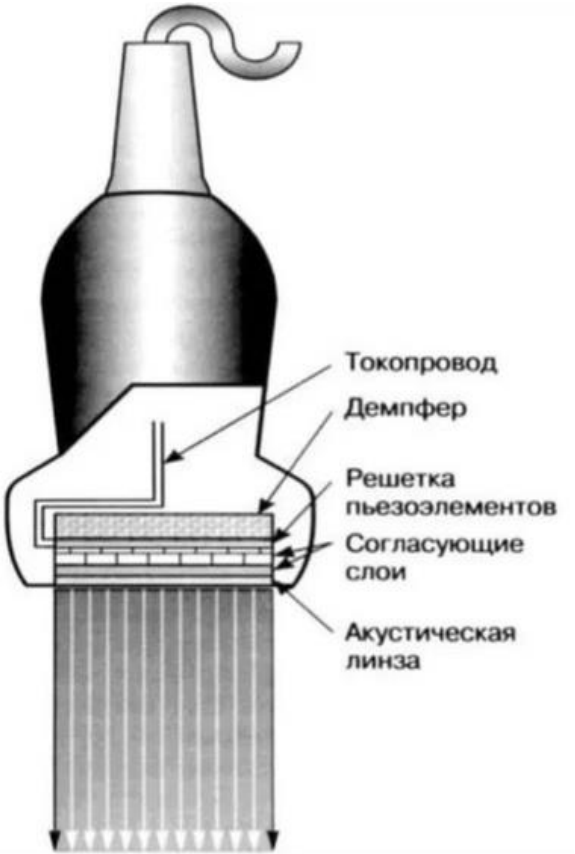

Линейное сканирование
Векторное
Секторное

Main components of ultrasonic transducers



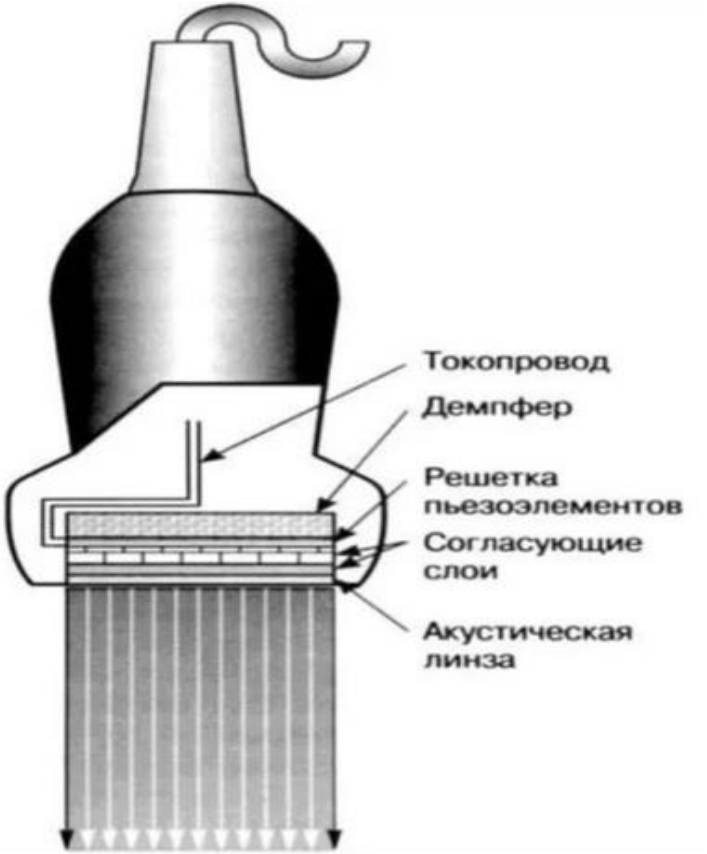
- ***Piezo element.*** It is made of a special material (usually piezoceramics) that has the property of a piezoelectric effect.
- ***Current conductors.*** Electrodes are applied to the radiating surface of the piezoelectric element and to the opposite (rear) surface - thin layers of conductive metal (usually silver), and conductors are soldered to them -*conductors*.

Ultrasound scanners. Essential elements.



- ***Damper.The main purpose of the damper is to partially soften (damping) the mechanical vibrations of the piezoelectric element.***
- ***This is done in order to maximize the range of ultrasonic frequencies emitted and received by the sensor, which increases the longitudinal resolution of the device.***
- ***Another duty of the damper is to absorb radiation from the back side of the piezoelectric element, i.e. the one on the opposite side of the working side in contact with the patient's body.***
- ***Matching layers. They are applied to the working surface of the piezoelectric element on top of the electrode.***
- ***Serve to match the acoustic resistance of the piezoelectric element material and biological tissues. Good matching is absolutely necessary in order to ensure the transmission of acoustic (ultrasonic) signals from the piezoelectric element to the biological environment and vice versa with minimal losses, and therefore to increase the sensitivity of the sensor.***

Main components of ultrasonic transducers



- ***Acoustic lens.***
- ***The acoustic lens focuses the ultrasound beam, i.e. ensures a minimum beam width in a certain depth range and therefore improves resolution (made of a material with specially selected properties).***
- ***At the same time, the acoustic lens acts as a protector - a protective layer that protects the piezoelectric transducer from damage during operation.***

Ultrasound methods of radiation diagnostics

Physical and technical basis of ultrasonic research methods

- **Sound**in its physical essence it is a mechanical wave with longitudinal propagation.
- Ultrasonic vibrations include vibrations with frequencies above 20,000 Hz (20 kHz). For diagnostic purposes in medicine, ultrasound is used from 2 to 40 MHz.

Generation of ultrasonic vibrations.

- **Inverse piezoelectric effect**– consists in the displacement of the crystal faces in response to the influence of electrical voltage. In this case, its sequential compression and expansion occurs, which is what causes the creation of a high-frequency change in pressure around it, causing the occurrence of directed mechanical vibrations, i.e. ultrasound.

- **Direct piezoelectric effect**– the appearance of an electric potential on the crystal faces during and displacement due to the influence of external (mechanical) forces. The direct piezoelectric effect allows the device to perceive a reflected echo signal resulting from reflection from the interface of tissues with different acoustic impedances.

- For the propagation of ultrasound, a material substrate (substance) is required,in this case, vibrations are transmitted from one particle of matter to another, i.e. energy transfer occurs.
- In ultrasound diagnostics, so-called longitudinal acoustic waves are used, in which the direction of displacement of individual particles of the medium is parallel to the direction of propagation of the waves.

Main characteristics of ultrasonic wave:

- Frequency
- Period
- Wavelength
- Spread speed
- Amplitude
- Acoustic impedance

The main physical effects of the interaction of ultrasound with particles of matter

- Refraction
- Scattering
- Absorption
- Interference
- Diffraction
- Reflection

Ultrasonic wave reflection

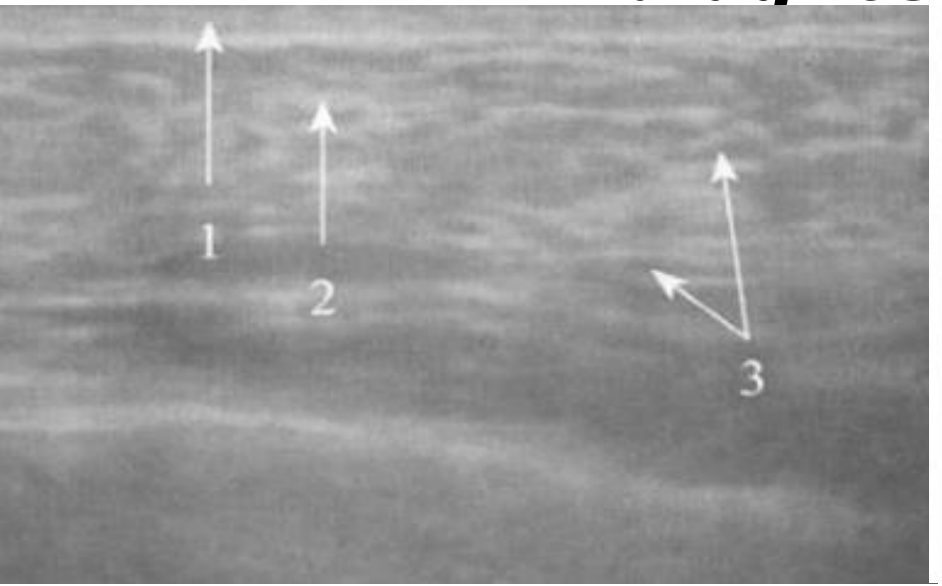
- **Reflection** –***changing the direction of propagation of an ultrasonic wave at the interface between media to the opposite. It is this property that underlies the principle of obtaining ultrasound images.***
- The nature of changes in ultrasound propagation has a significant influence ***acoustic impedance*** environment.
- The ratio of the part of the energy (intensity) reflected from the interface to the energy (intensity) of the incident ultrasonic flow is called ***reflection coefficient.***

- How *greater difference in acoustic characteristics* environments, the greater the reflection at their interface.
- The reflection coefficient depends only on the difference in the acoustic resistance of the media.
- Higher reflectance at the interface of fatty tissues with other soft tissues.
- Reflections from the soft tissue–bone tissue boundary depend on the type of bone tissue.
- *At the interface between air and soft tissue, the ultrasonic wave is reflected almost completely.*

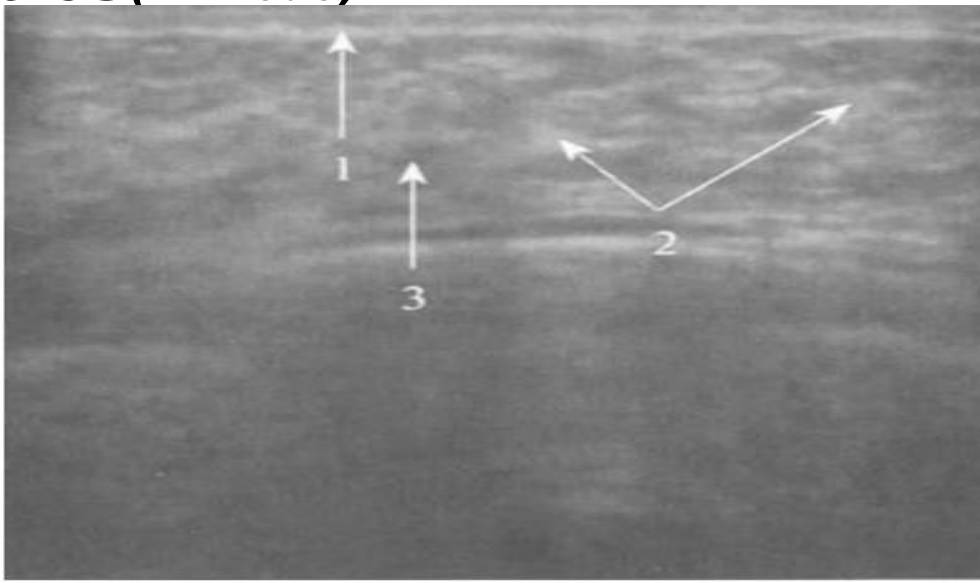
Ultrasonic wave frequency

- ***High frequencies***give a more detailed image, higher resolution, but less penetrating power.
- ***Low Frequencies***penetrate deeper, but have less resolution.

Ultrasound methods of radiation diagnostics(B-mode)

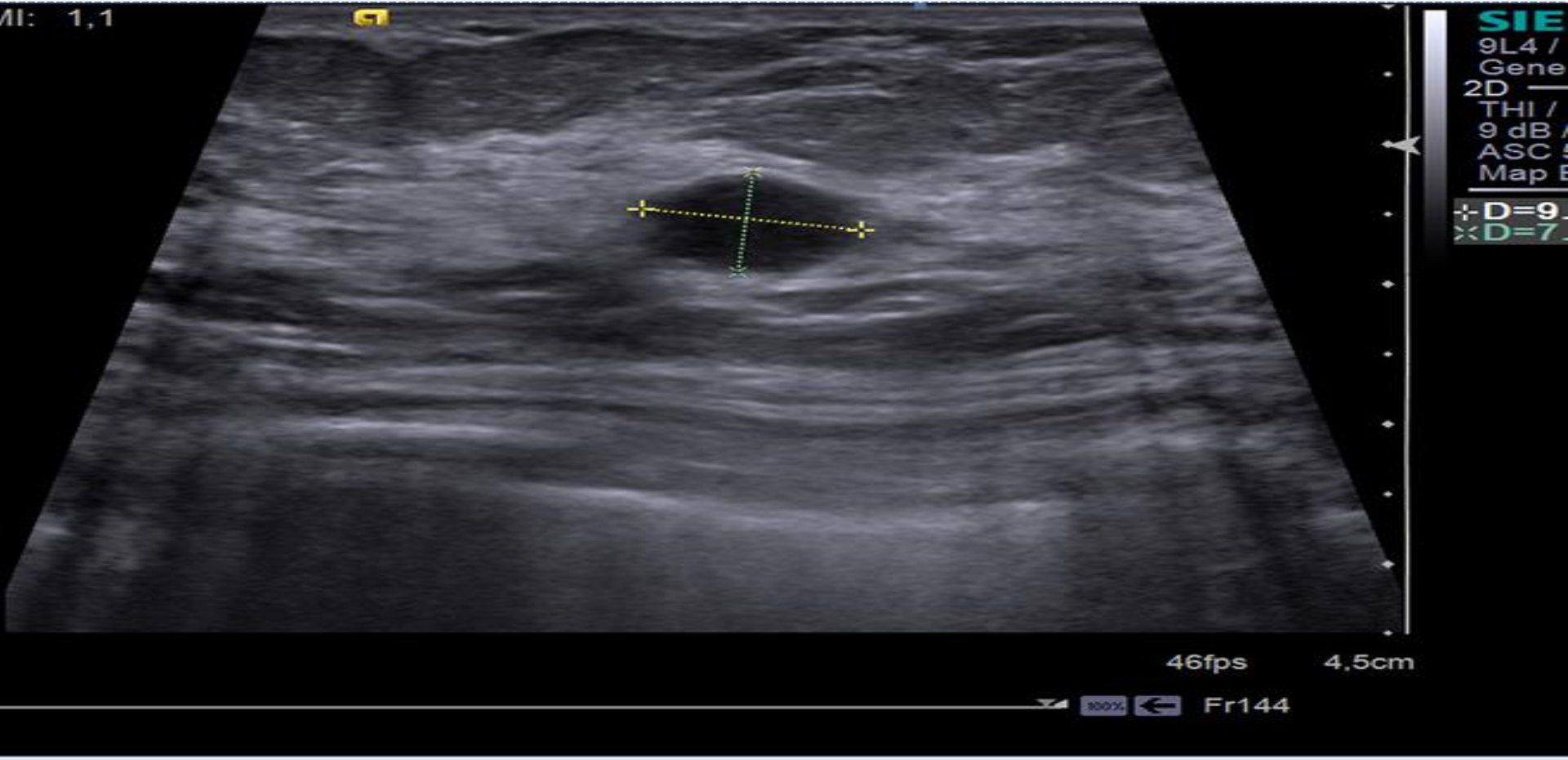


Sonogram of the breast without pathology: 1- skin 2- glandular tissue 3- milk ducts

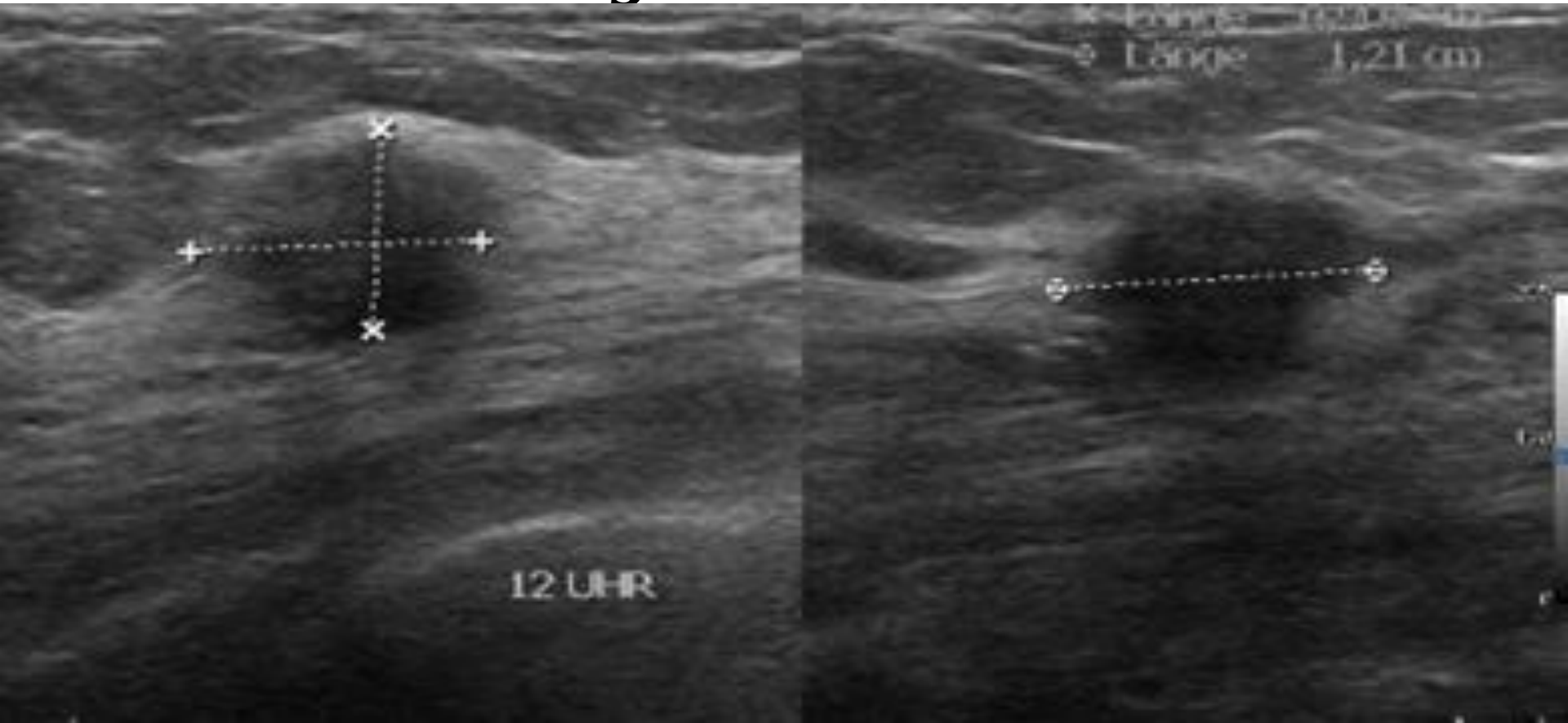


Sonogram of the mammary gland without pathology (post-pubertal period): 1- skin 2- glandular tissue 3- fat lobule

Ultrasound methods of radiation diagnostics (B-mode)



Ultrasound methods of radiation diagnostics(B-mode)



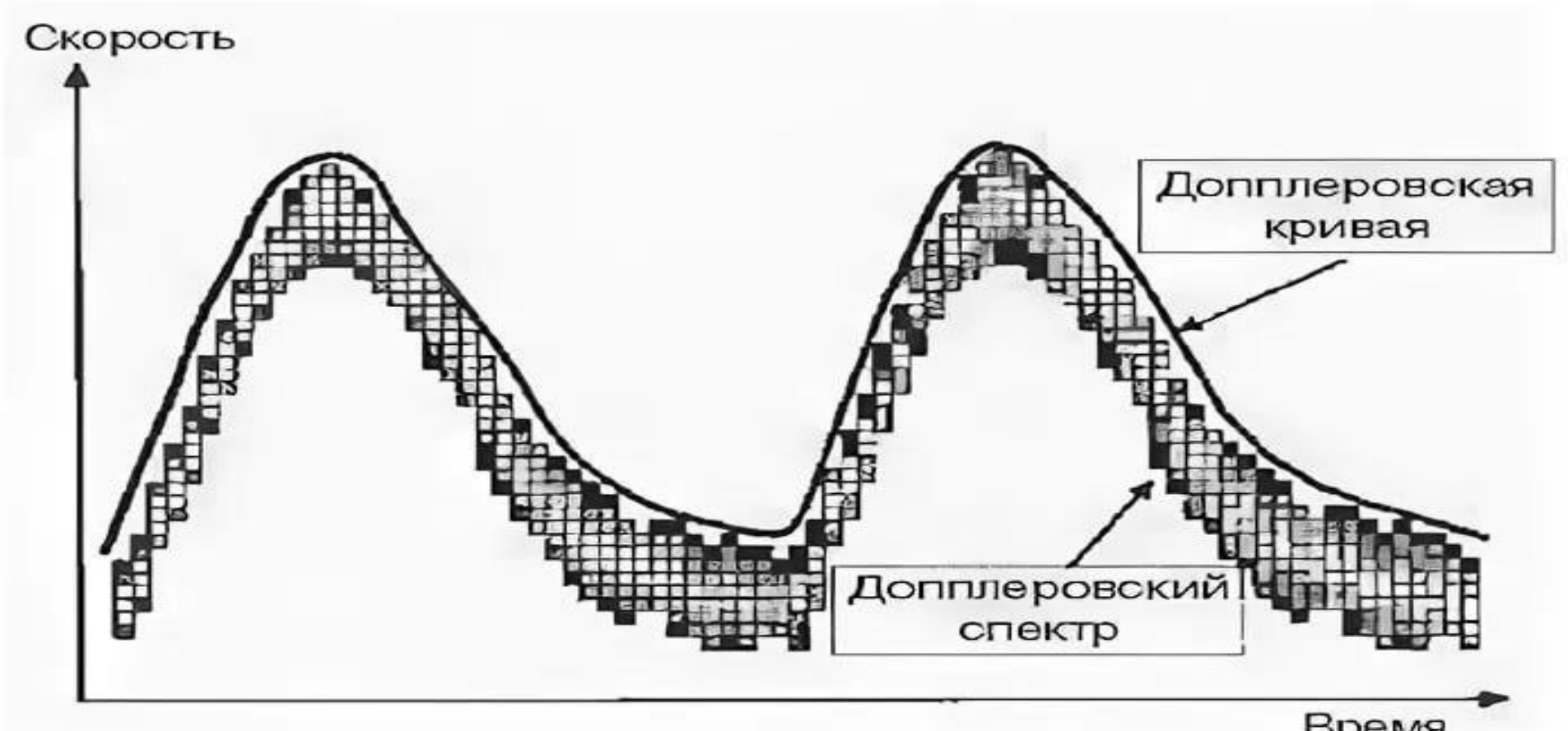
Doppler effect

- Doppler effectconsists in changing the frequency of the ultrasonic signal when reflected from moving objects compared to the original frequency of the sent signal (Doppler frequency shift).
- ***Doppler frequency shift (Δf) depends on:***
- Travel speeds***(v)***red blood cells (reflector).
- Angle between the red blood cell velocity vector in the ultrasound beam vector***(α)***With
- Speed of sound propagation in the medium (s).
- Emitter frequencies***(f0)***.

By type of information displayed

- **Spectral** (as a Doppler spectrum or Doppler curve).
- **Color Doppler mapping**(coding) CDC.
- *Color flow of Doppler frequency shift (velocity).*
- *Color flow diagram of the “energy” of the Doppler spectrum.*

Doppler spectrum and Doppler curve



Using the Doppler method allows you to determine:

- Nature of the flow (laminar or turbulent).
- Flow direction (relative to sensor).
- Flow rate.

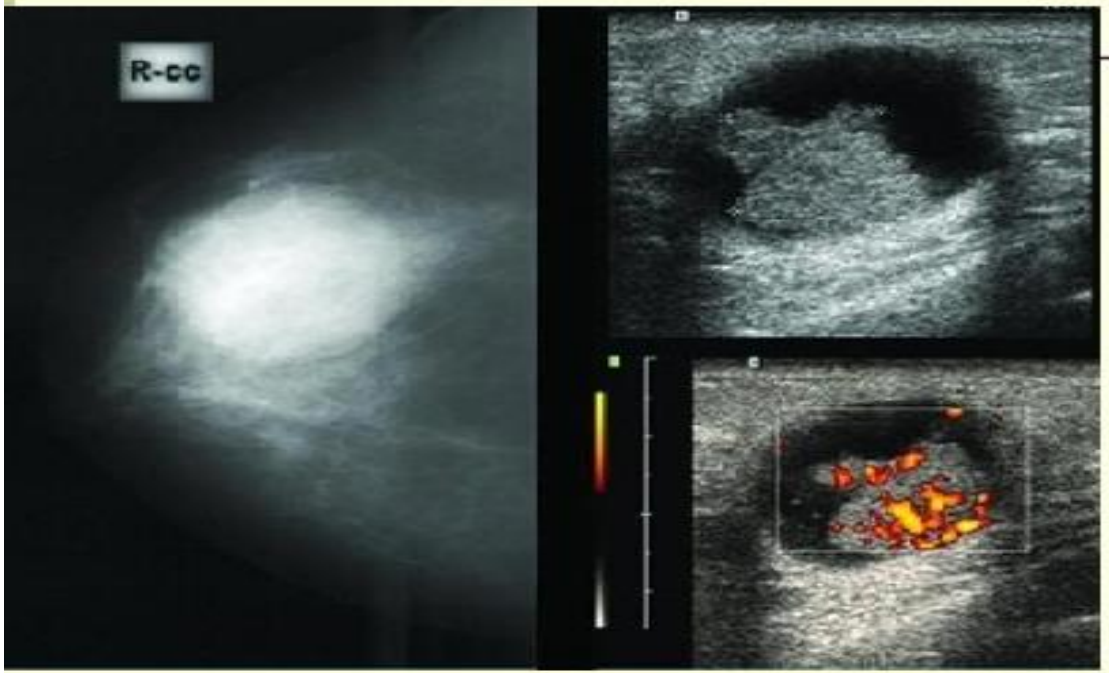
Duplex studies

- ***Duplex ultrasound scanning***
- Includes simultaneous use of two image modes.
- Usually this is a black and white two-dimensional image and spectral or color Doppler.
- This scanning mode allows you to see blood flows in the vascular bed.

triplex studies

- ***Triplex ultrasound scanning*** includes simultaneous use of three image modes.
- This is usually one-dimensional, black-and-white two-dimensional imaging and spectral or color Doppler.

Кисты и рак молочной железы



Рак в кисте

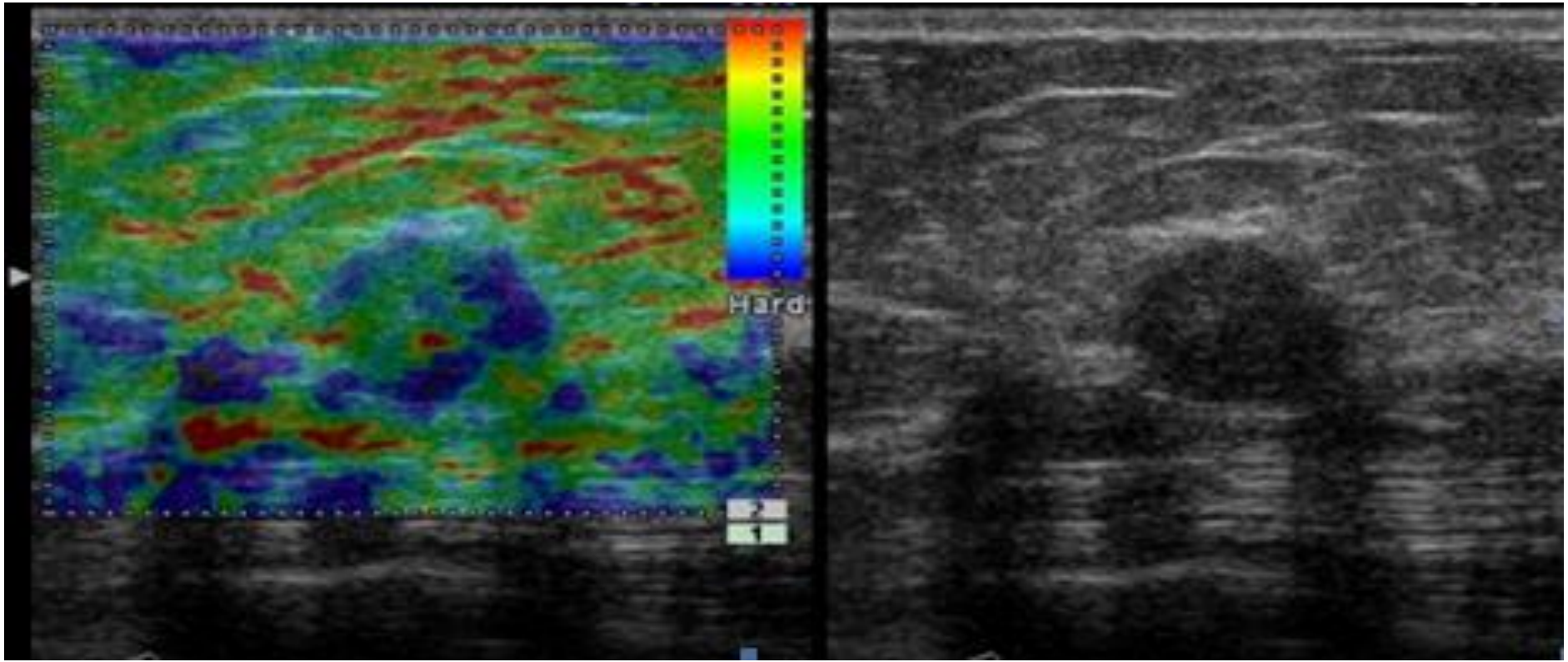
- Не менее информативным, не конкурирующим с маммографией методом диагностики заболеваний молочных желёз считают УЗИ
- Данный метод позволяет более чётко определить размеры первичной опухоли, контуры, структуру, наличие интенсивного кровоснабжения опухоли, что наиболее важно, состояние регионарных лимфатических узлов, что наряду с вышеперечисленными данными позволяет установить более точный диагноз.

Ultrasound methods of radiation diagnostics

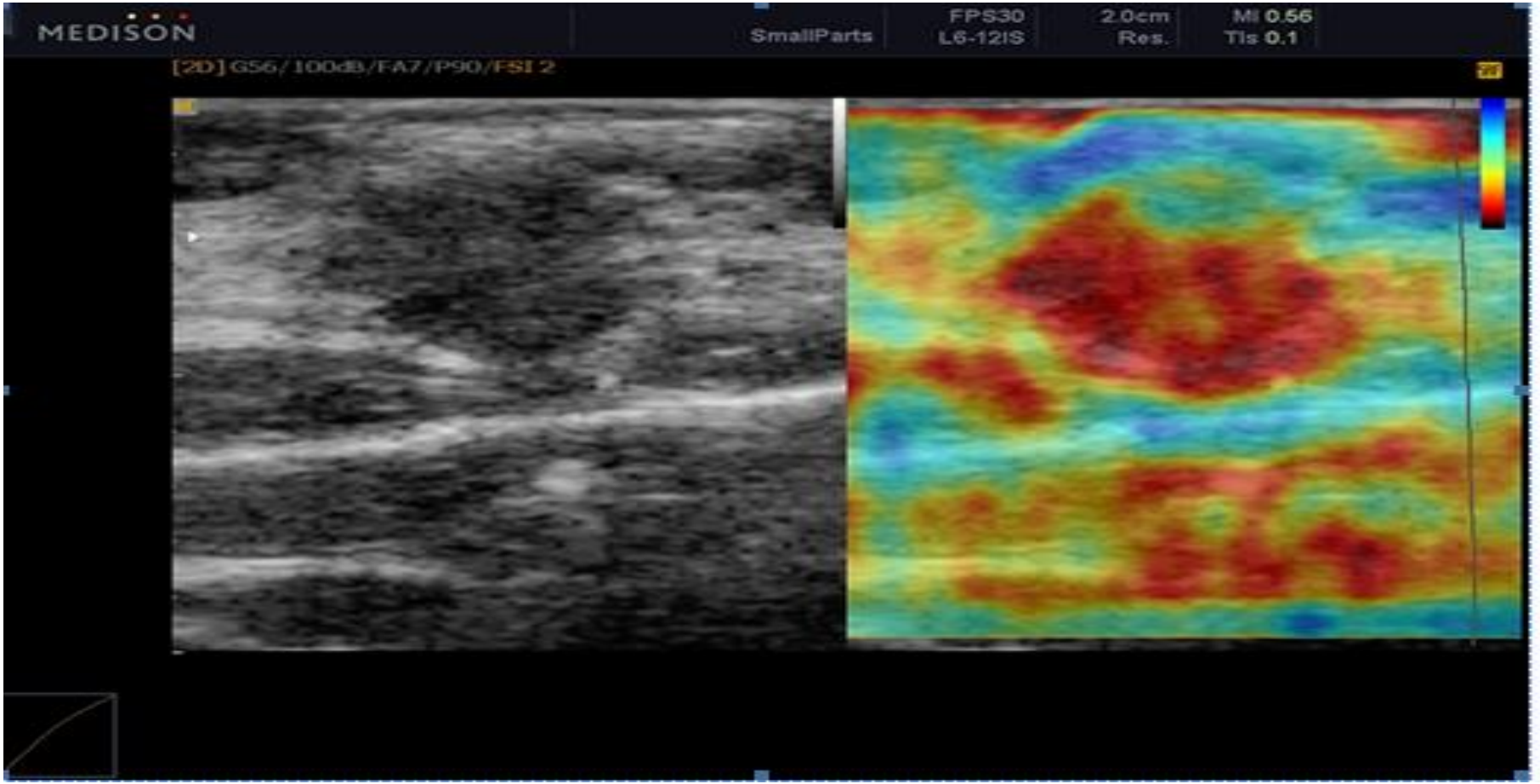
Elastics– elastography

- ***ElastoScanTM(elastography)***– technology for improving the visualization of soft tissue inhomogeneities based on their shear elastic characteristics.
- Applying pressure.
- Manual vibration (by hand or sensor) or automatic vibrator (special attachment).

Ultrasound methods of radiation diagnostics



Ultrasound methods of radiation diagnostics (elastography)



- The image quality and diagnostic information content of ultrasound devices depend on its hardware capabilities and are determined by a number of technical characteristics.

Spatial resolution

- Ability to distinguish small objects and structures that are close to each other.
- As a measure of resolution, the minimum distance between two small reflective objects is taken, at which, when observing the image on the screen, you can see them separately, i.e. decide on the presence of two elements

- A)longitudinal resolutions, when point reflectors are located on the same ultrasonic beam and their relative position changes along the beam (one after another).
- High frequency sensors provide higher resolution.

- b)lateral resolution, when point reflectors are located at the same depth or on a line perpendicular to the axes of the ultrasonic beams.
- Transverse resolution is determined by the distance between the beams and deteriorates as this distance increases; placing the beams closer to each other during the scanning process, i.e. By increasing the beam density, the lateral resolution improves.
- Transverse resolution is, as a rule, worse than longitudinal and deteriorates with depth.

Operating frequency of the sensor, MHz	Longitudinal resolution, mm	Transverse resolution, mm	Maximum working depth, mm
3.5	0.8	2.5	200
5	0.6	1.5	130
7.5	0.4	0.8	70
10	0.3	0.4	40

- Two quantities - transverse and longitudinal resolution characterize**spatial resolution**, which is directly related to such a concept as*graininess of the image*.
- Experts often use this concept when comparatively assessing the image quality of various devices.(subjective assessment).

Sensitivity.

- Sensitivityis the ability to detect and observe small structural elements against the background of interfering signals (interference) and the system’s own noise.
- Sensitivity determines the maximum operating depth of the device, i.e. the depth at which the required level of sensitivity associated with the set threshold is ensured.
- The sensitivity of the device is especially important at great depths, where the level of useful signals decreases due to attenuation in biological tissues.

Dynamic range

- **Dynamic range**– characterizes the system's ability to simultaneously display very small and large signals, conveying the difference in their level.
- Dynamic range is quantified by the ratio of the maximum to minimum signal displayed by the system.

- The greater the dynamic range of the system, the more information about various structures can be displayed on the monitor screen.
- *Related to dynamic range is the concept* ***contrast resolution****, which determines the ability of the device to transmit small differences in signal levels.*

Temporal resolution

- –characterizes the system’s ability to perceive and display with sufficient speed changes in the acoustic characteristics of biological structures over time.
- *Temporal resolution*determines the ability to obtain information about moving structures in real time.
- This ability is especially important when studying the functioning of the heart and blood vessels in dynamics.

- limitations in the operation of the ultrasonic device are associated with possible***the occurrence of biological effects.***

- The need to increase transmission power arises in cases where better insolation of objects in obese patients is required.
- An increase in radiation power is realized through an increase in the amplitude of the emitted signal. Increases far-field penetration and resolution

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