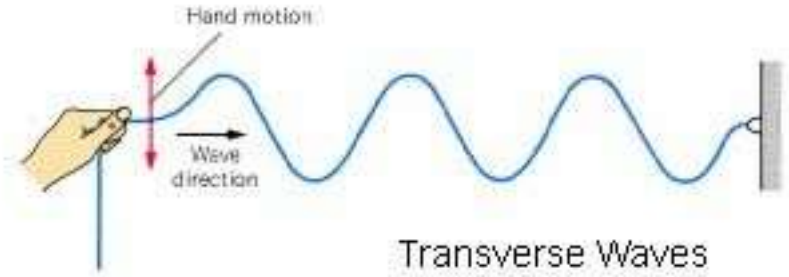
Application of ultrasound and electric pulses

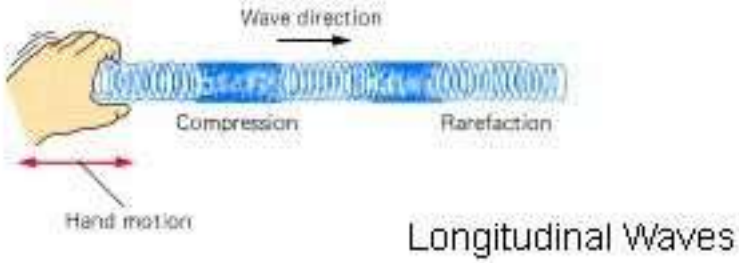
Dr. István Voszka

Semmelweis University, Department of Biophysics and Radiation Biology

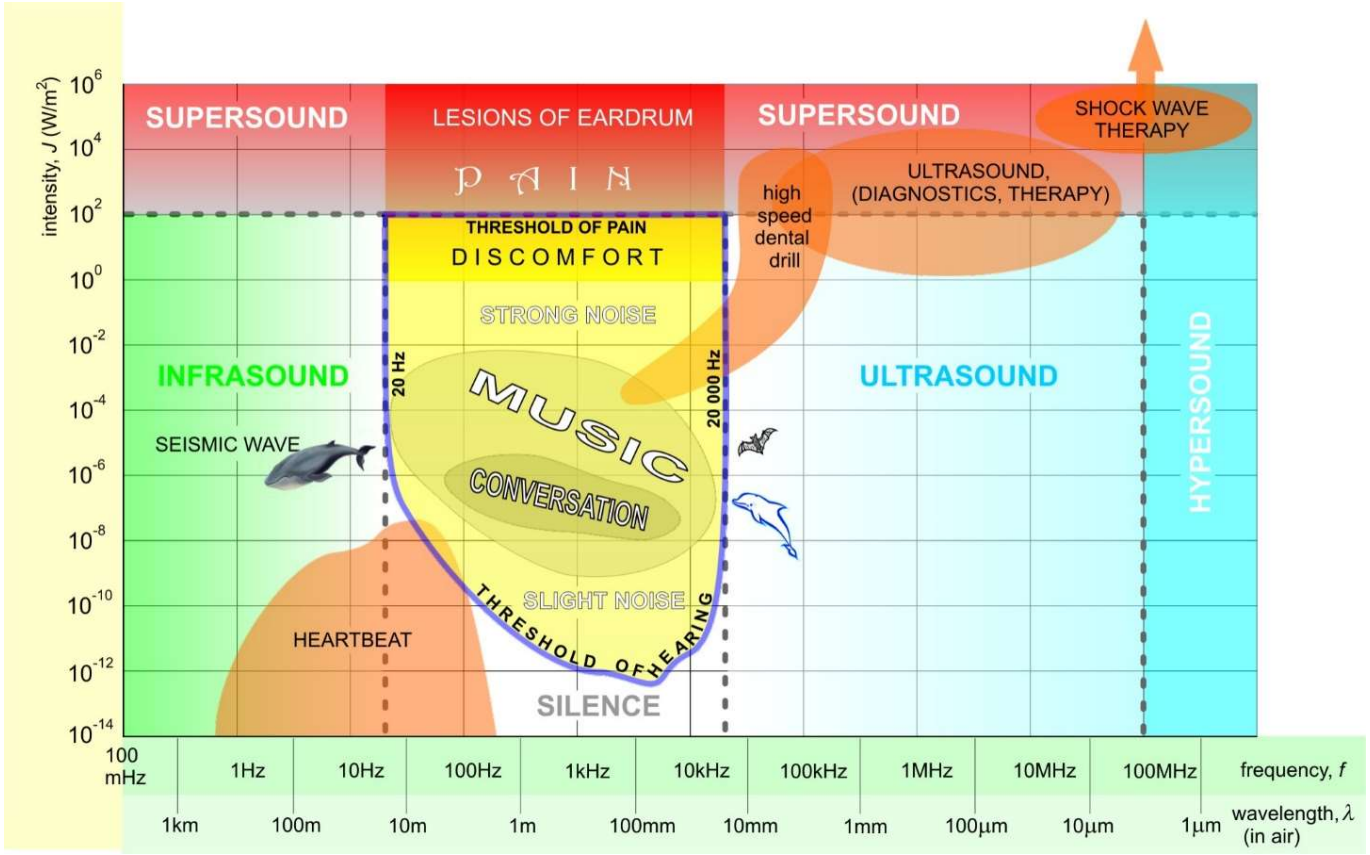
SEMMELWEIS
UNIVERSITY 1769

Ultrasound: mechanical wave, f > 20 kHz.
Mechanical waves (sound, ultrasound) require medium for spreading.





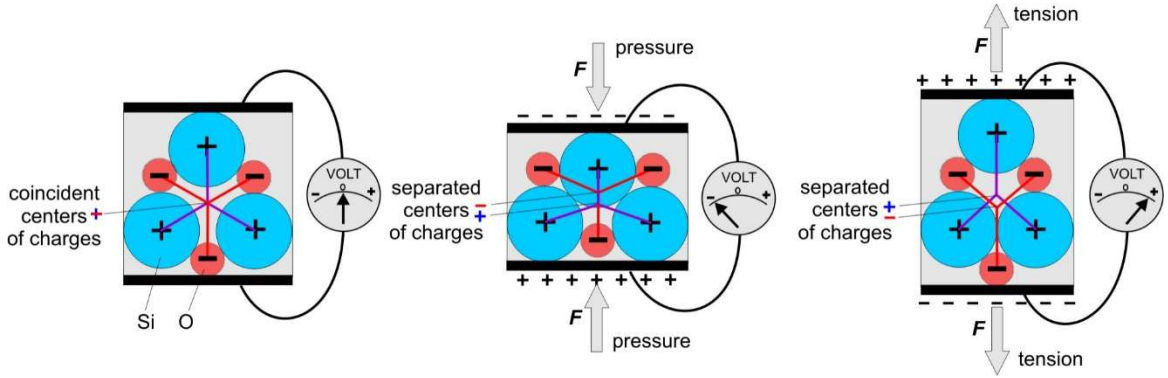
Frequency and intensity ranges of mechanical waves

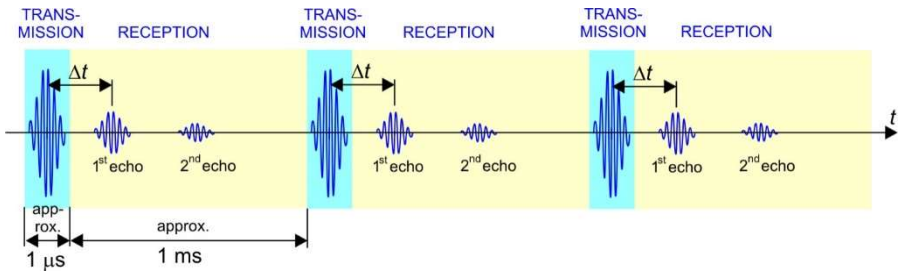


Production by piezoelectric crystal

- Direct piezoelectric effect: charge separation due to mechanical effect. – detection of ultrasound

- Inverse piezoelectric effect: putting alternating voltage on the crystal it starts mechanical vibration. – production of ultrasound





Medical application:

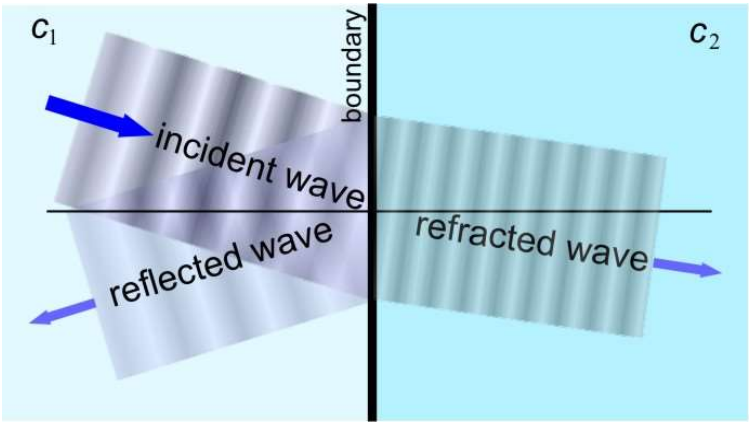
- Diagnostics: f = 1 – 10 MHz, in ophthalmology and for short distance 20 MHz,
  J ~ mW/cm^2

- Therapy: f = 0,8 – 1,2 MHz, J ~ W/cm^2

Basis of diagnostic application is the reflection of ultrasound from boundaries of different media

$$R = \frac{J_{back}}{J_{in}}$$

$$R = \left(\frac{\rho_1 c_1 - \rho_2 c_2}{\rho_1 c_1 + \rho_2 c_2} \right)^2$$



$\rho c = Z$ (acoustic impedance)

Total reflection on solid/gas or liquid/gas boundaries (because of this coupling medium (e.g. contact gel) is applied)

The absorption of ultrasound is also important

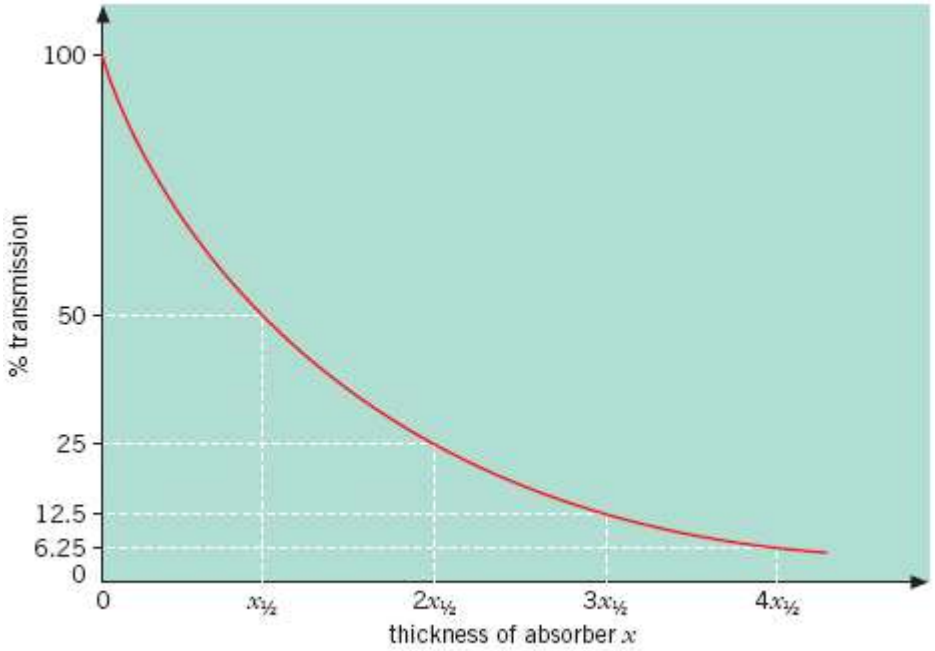


Figure 14.6 The percentage transmission of ultrasound in a medium

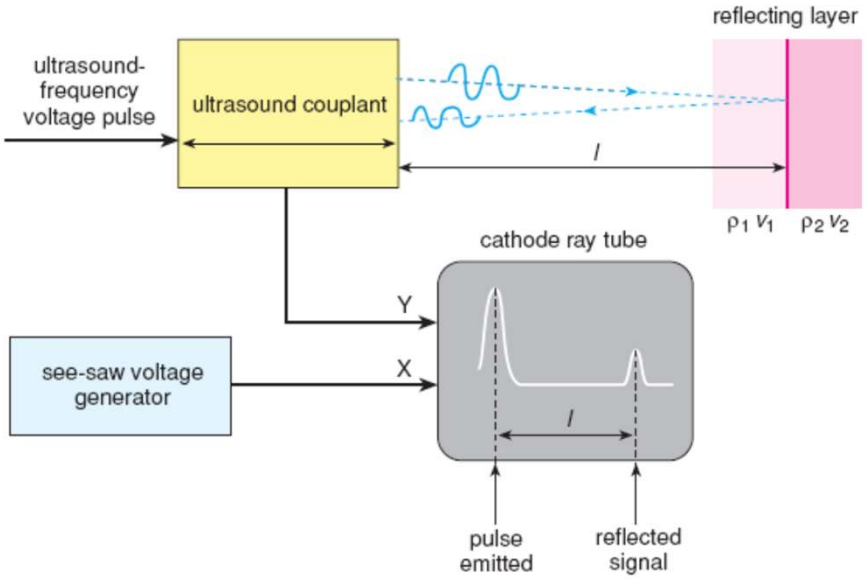
The law of attenuation is valid.

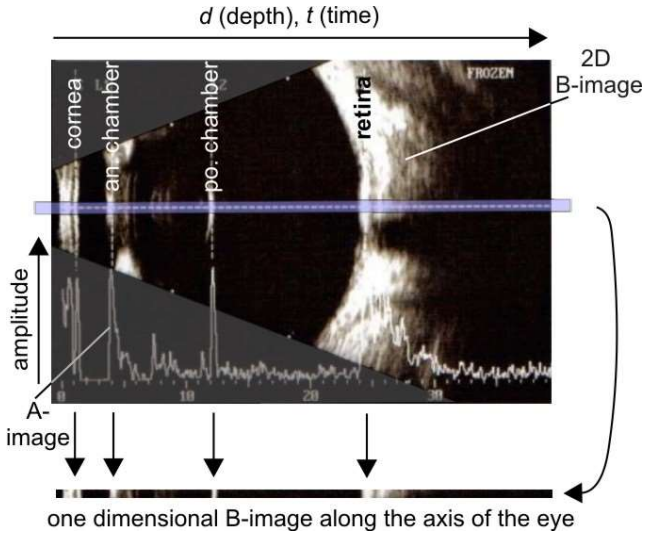
In the frequency range of diagnostics the absorption is directly proportional to the frequency

Higher frequency: - better resolution
- shorter effective range

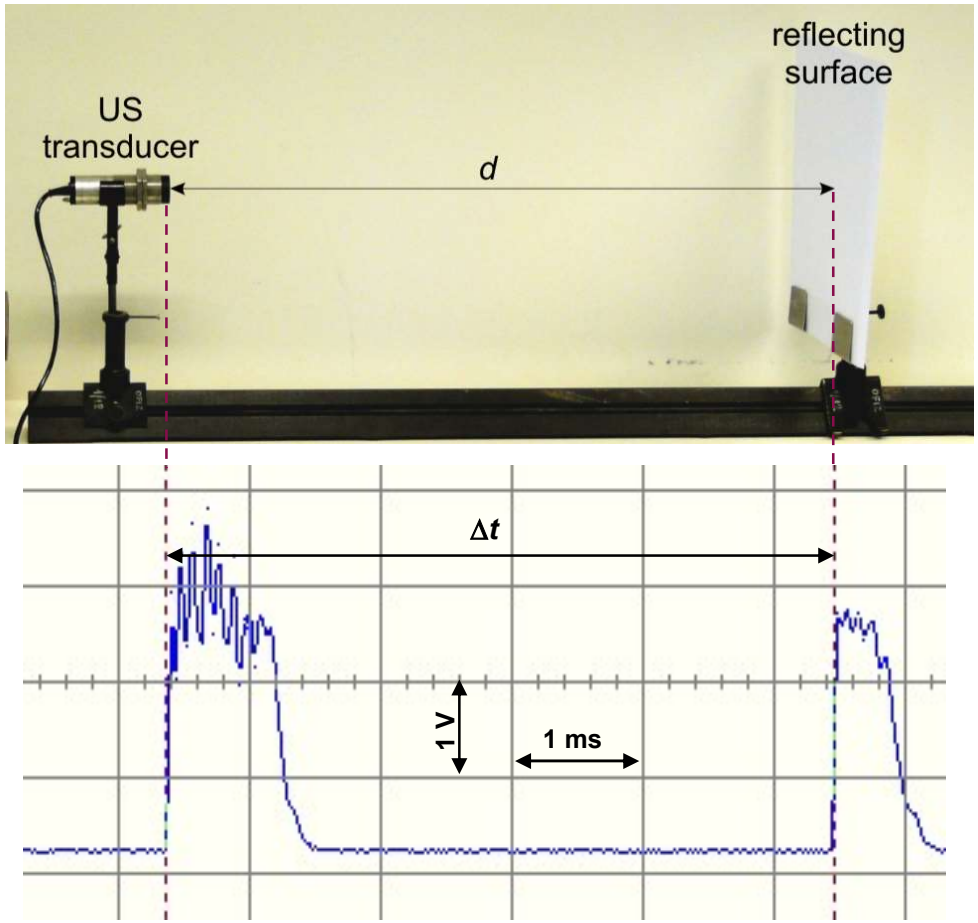
A-image (amplitude image)

- Distance measurement (applied mainly in ophthalmology)





The pulse echo principle



During the time of Δt the US pulse propagates a distance of $2d$, thus the distance d is given by:

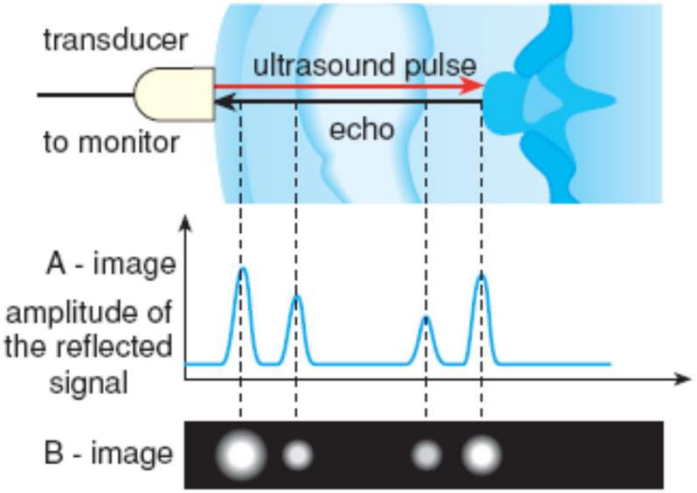
$$d = \frac{c \cdot \Delta t}{2}$$

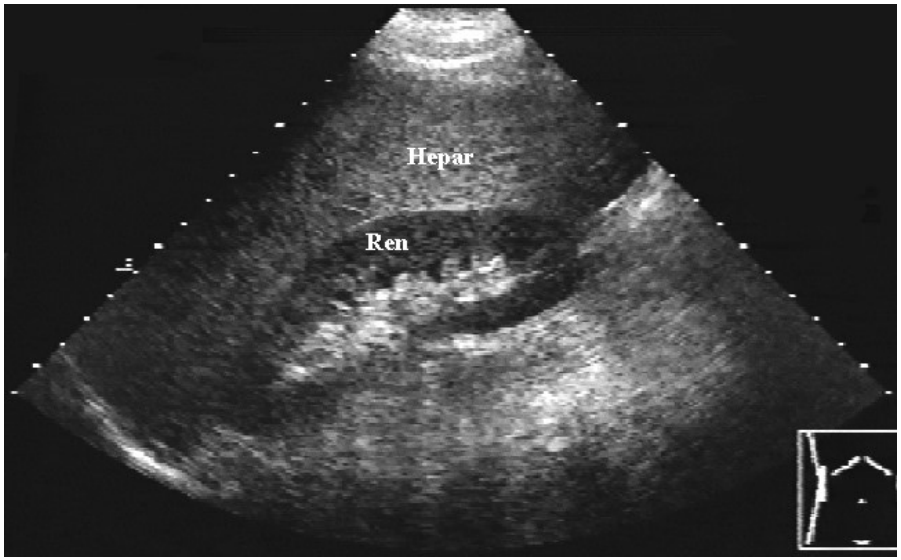
Medium	Speed of sound, c (m/s)
Air (20 °C)	343
Water (20 °C)	1482
Soft tissue	1540

From a special transducer a part of ultrasound can be conducted to air.

B-image (brightness)

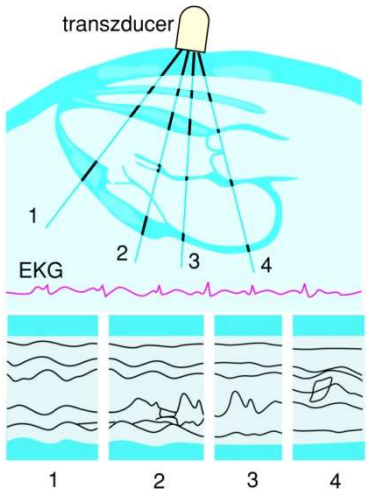
- Brightness of the image point depends on the reflection

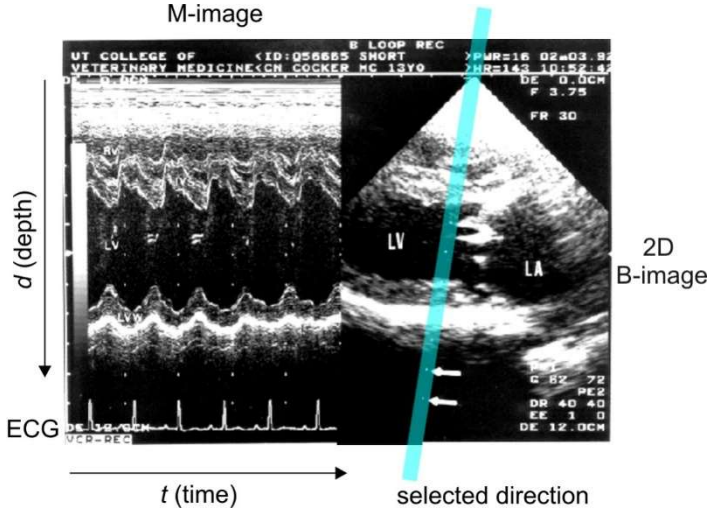




M-image (motion) – TM-image (time motion)

- The position of reflecting surface changes in time (echocardiography)
  change of one-dimensional B image in the function of time

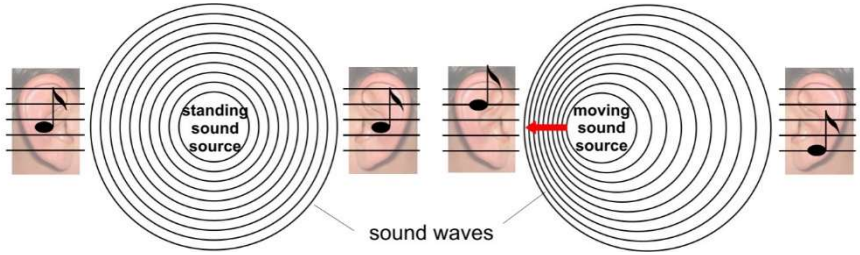




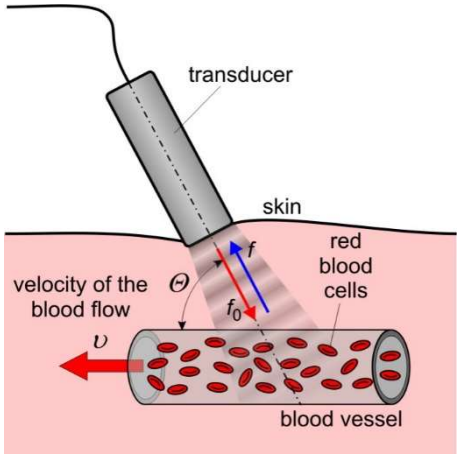
Examination of motion on the basis of Doppler principle

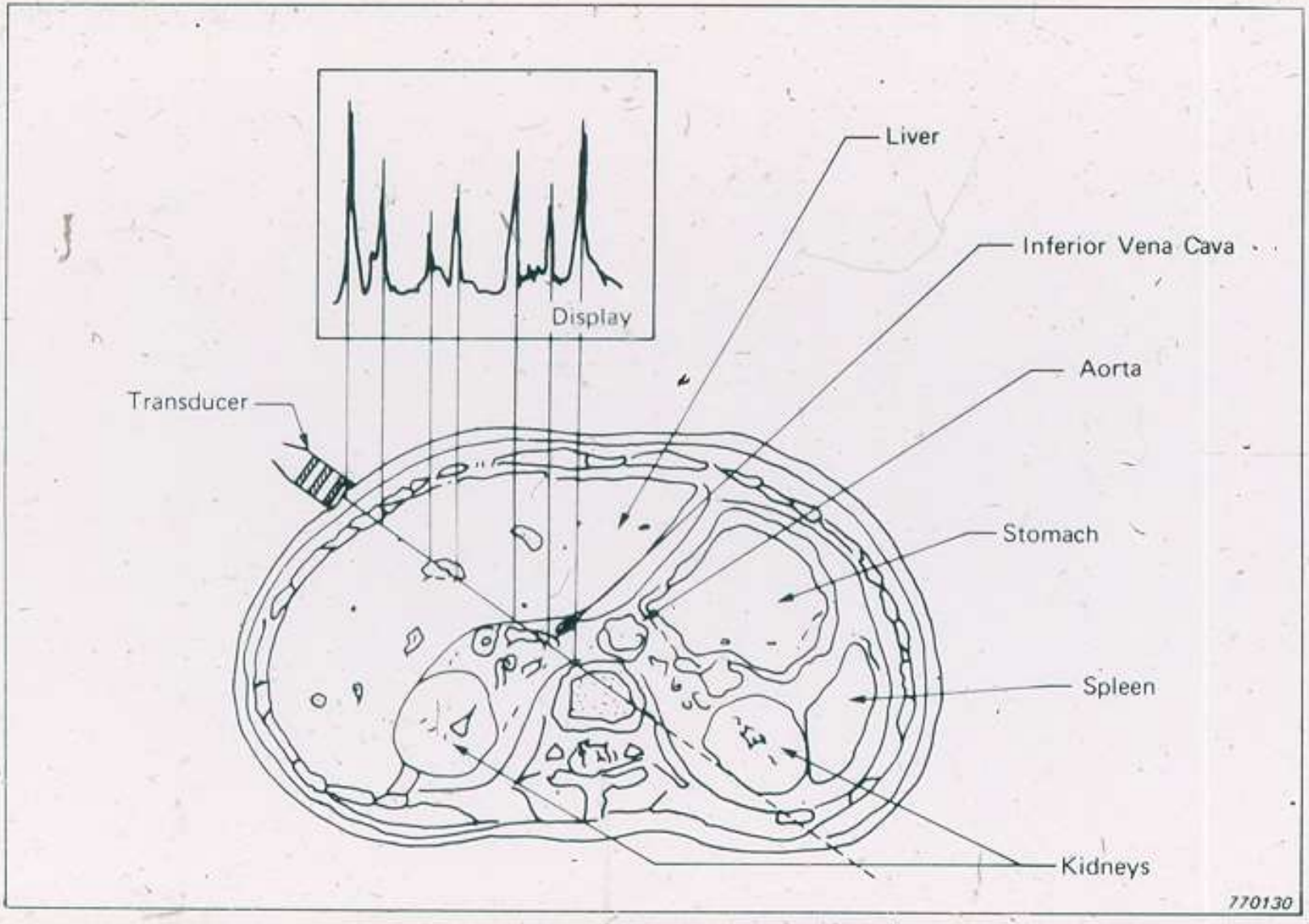
- Frequency of sound (ultrasound) changes, if the sound source or reflecting surface is moving.

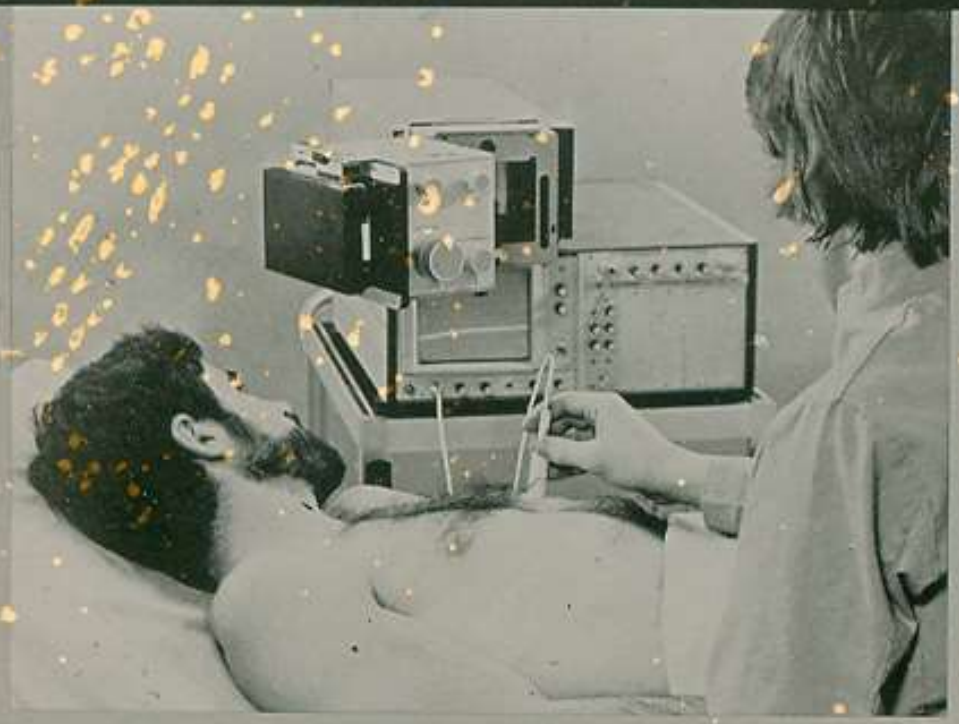
$$f = f_0\left(1 \pm \frac{2v}{c}\right)$$



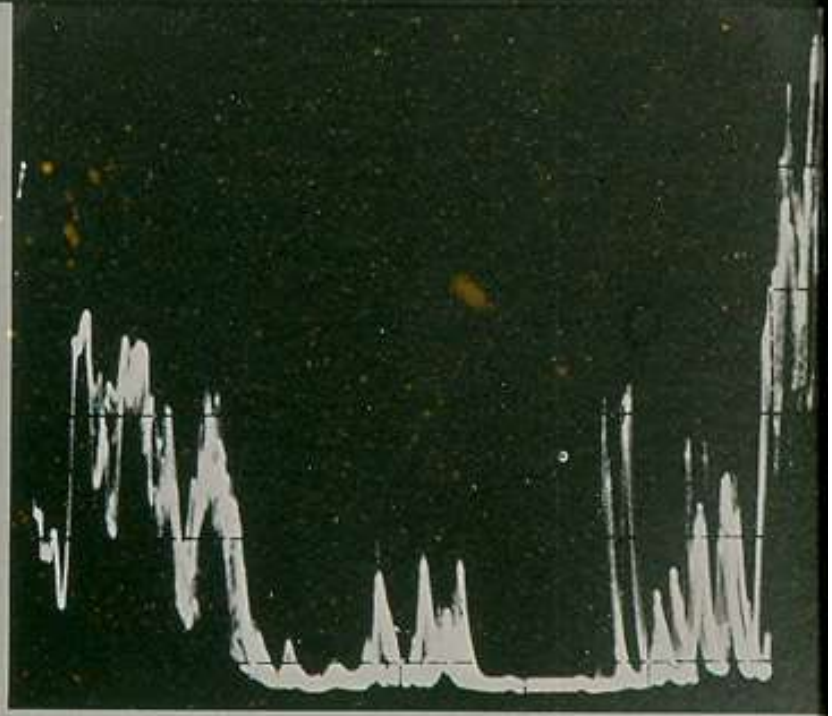
The difference between the original and reflected frequency is in the audible sound range – the sound of motion can be heard when we put it to headphone or loudspeaker (examination of blood flow in blood vessels and examination of fetal heart)



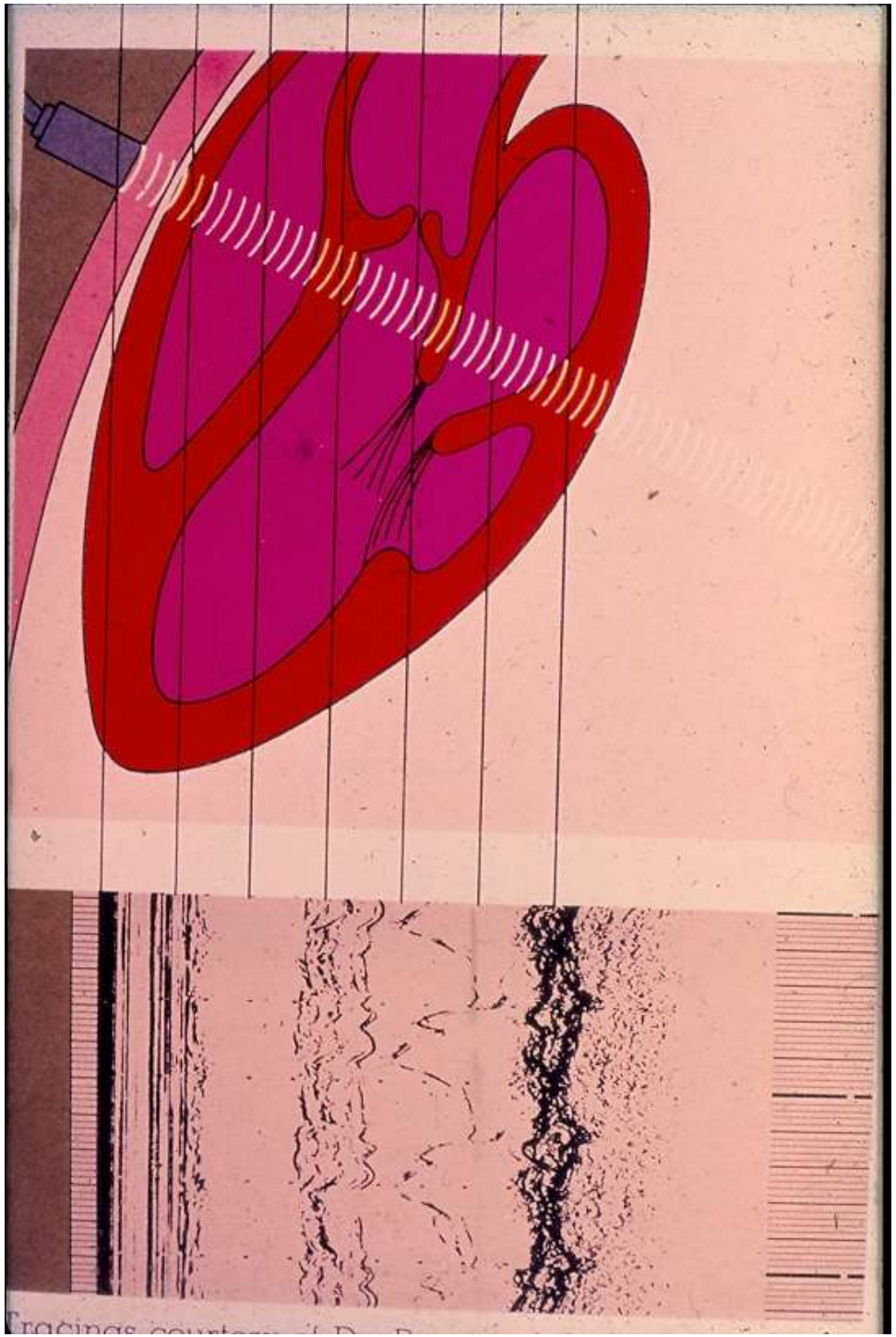

Display
Liver
Inferior Vena Cava
Aorta
Transducer
Stomach
Spleen
Kidneys
770130

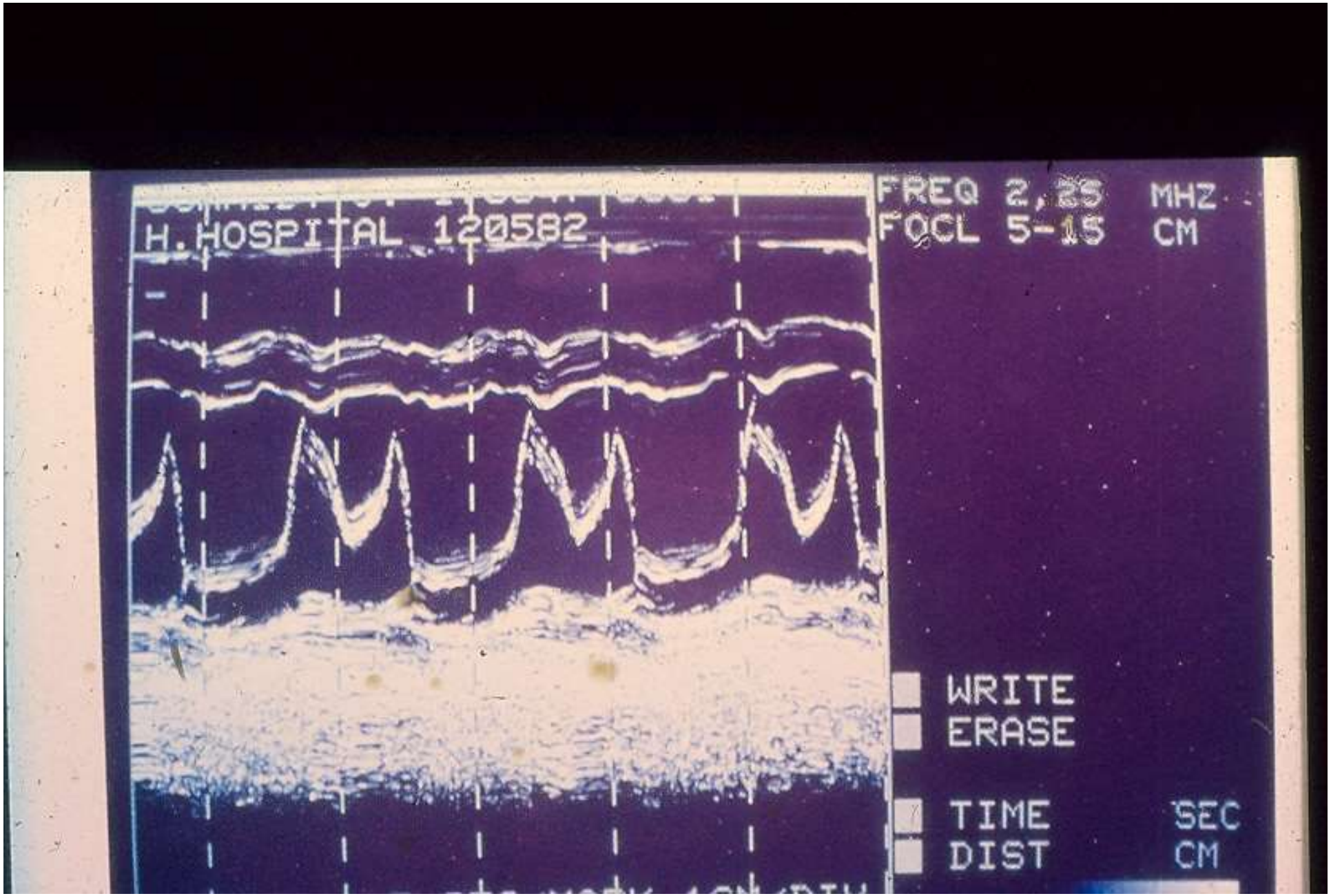


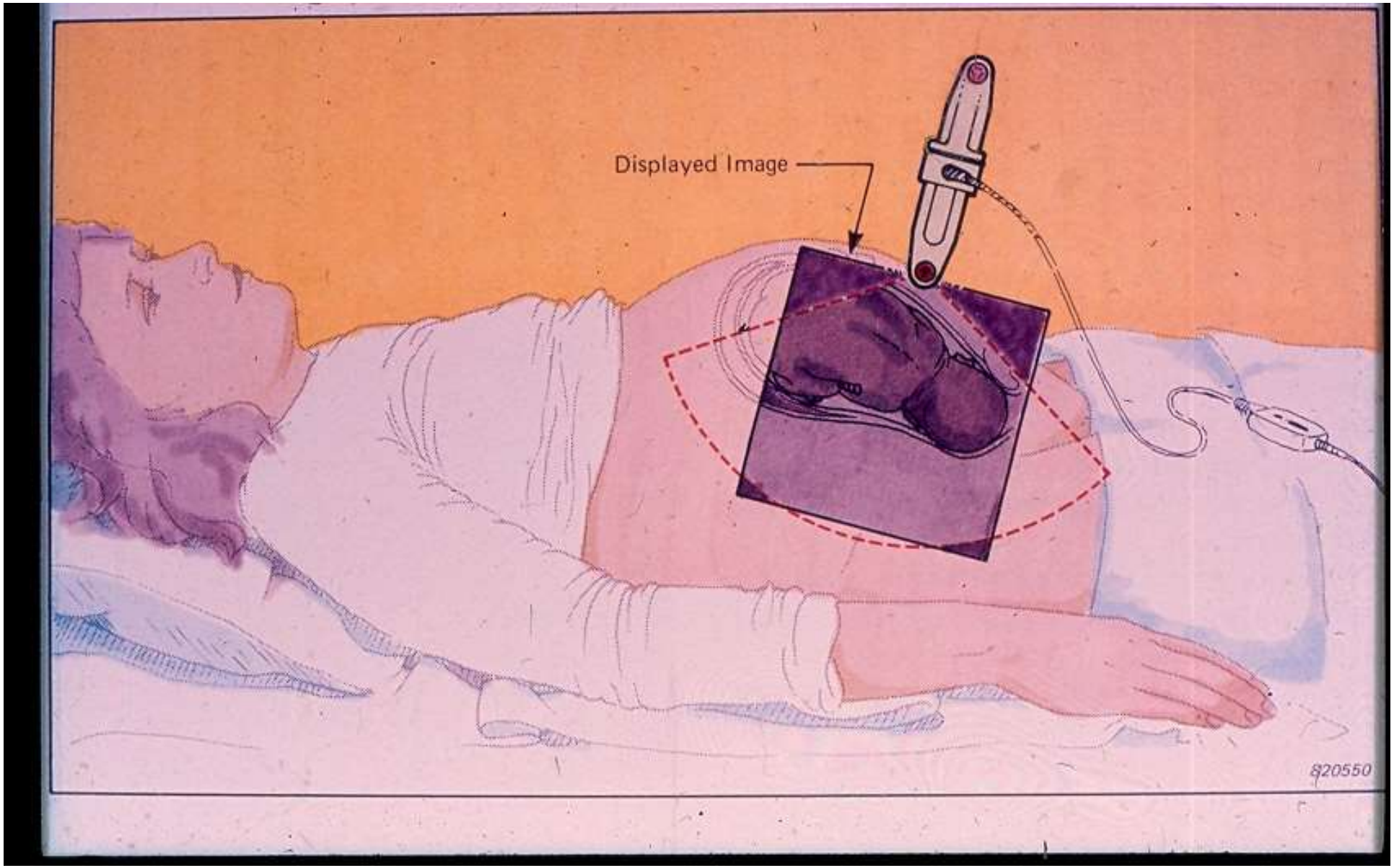
Cardiac System in clinical use

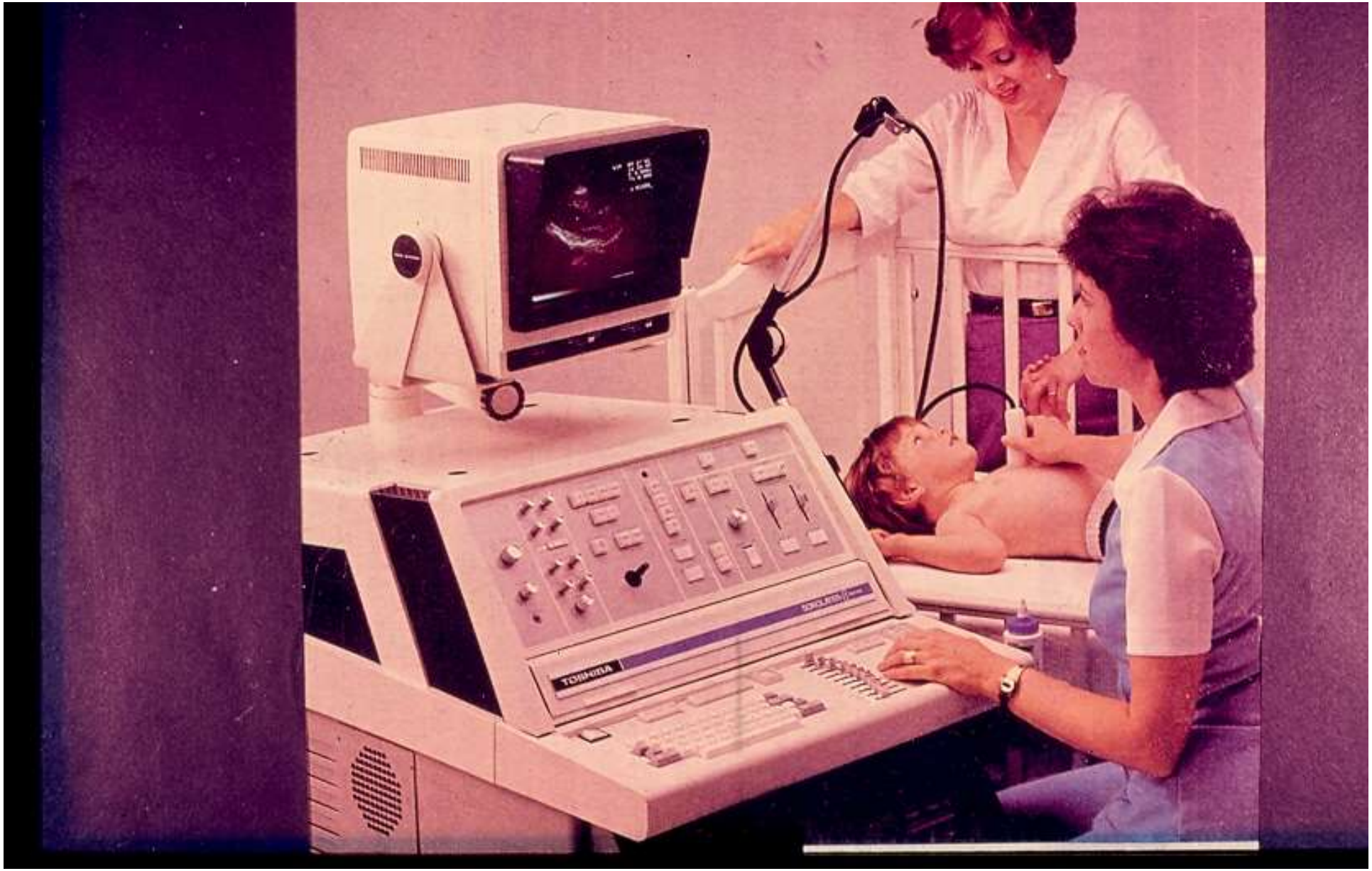


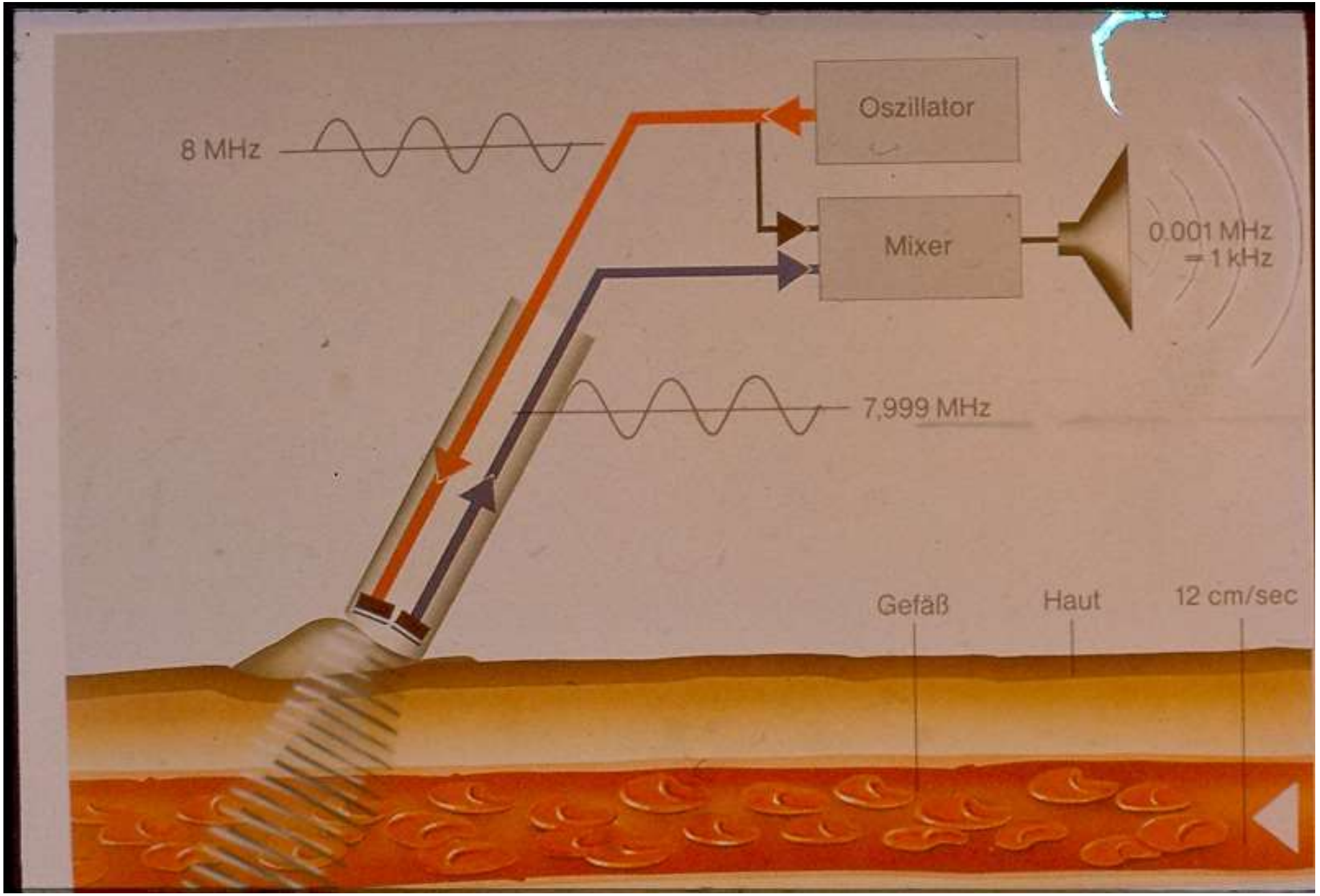
A-mode display of the mitral valve

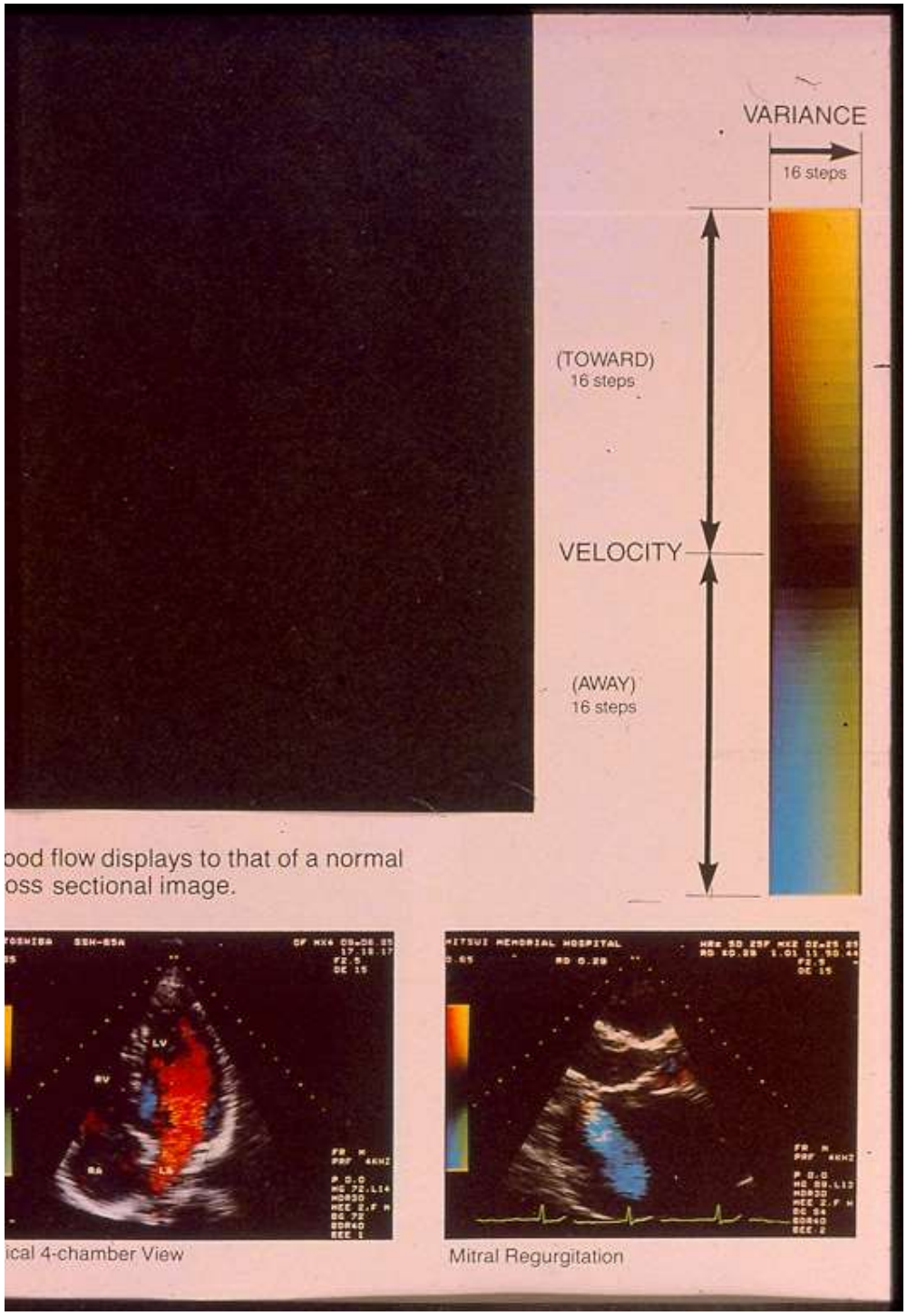



H.HOSPITAL 120582
FREQ 2,25 MHZ
FOCL 5-15 CM
WRITE
ERASE
TIME SEC
DIST CM


Displayed Image
820550


TOSHIBA

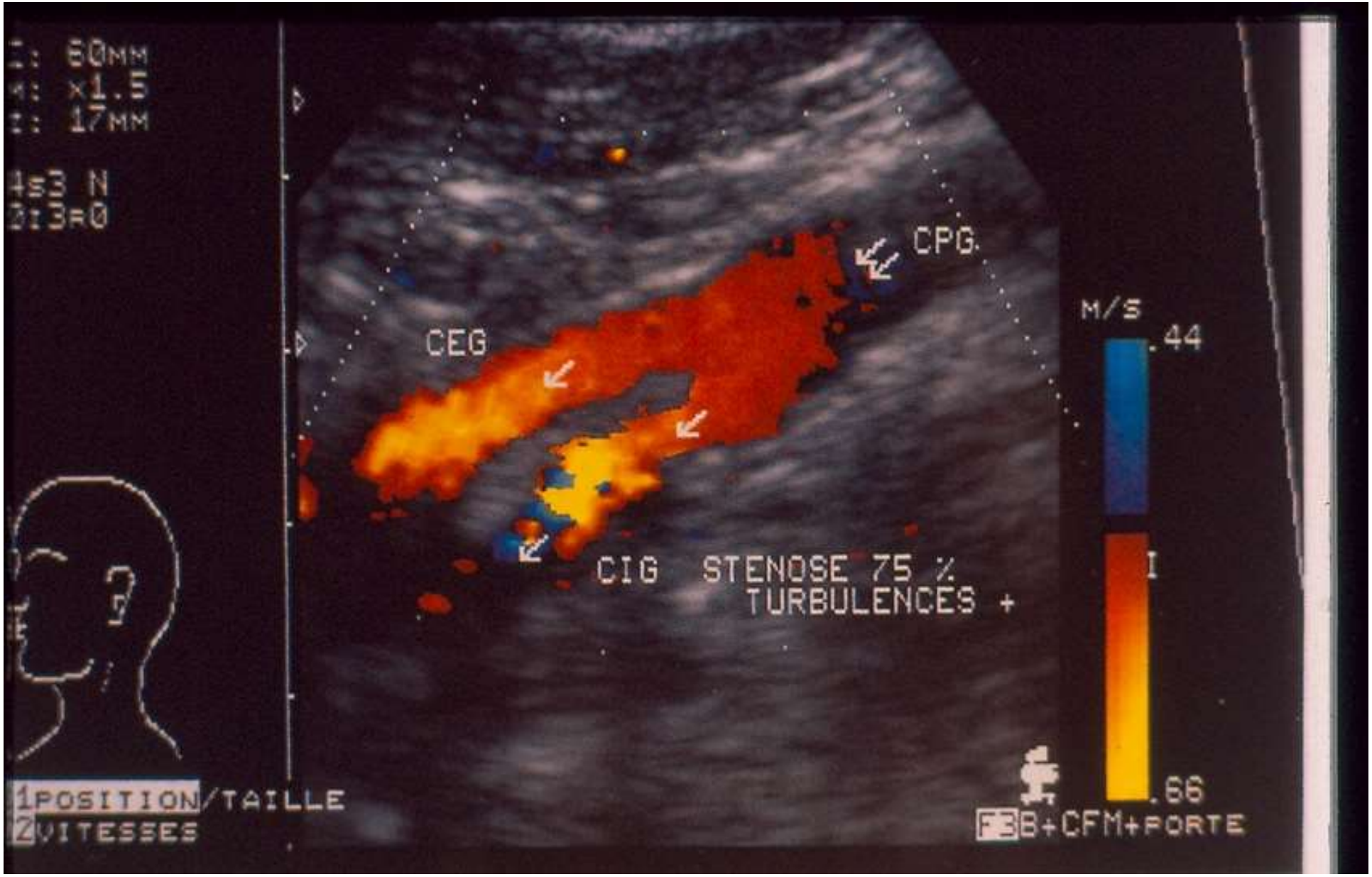

Oszillator
8 MHz
Mixer
0.001 MHz
= 1 kHz
7,999 MHz
Gefäß
Haut
12 cm/sec



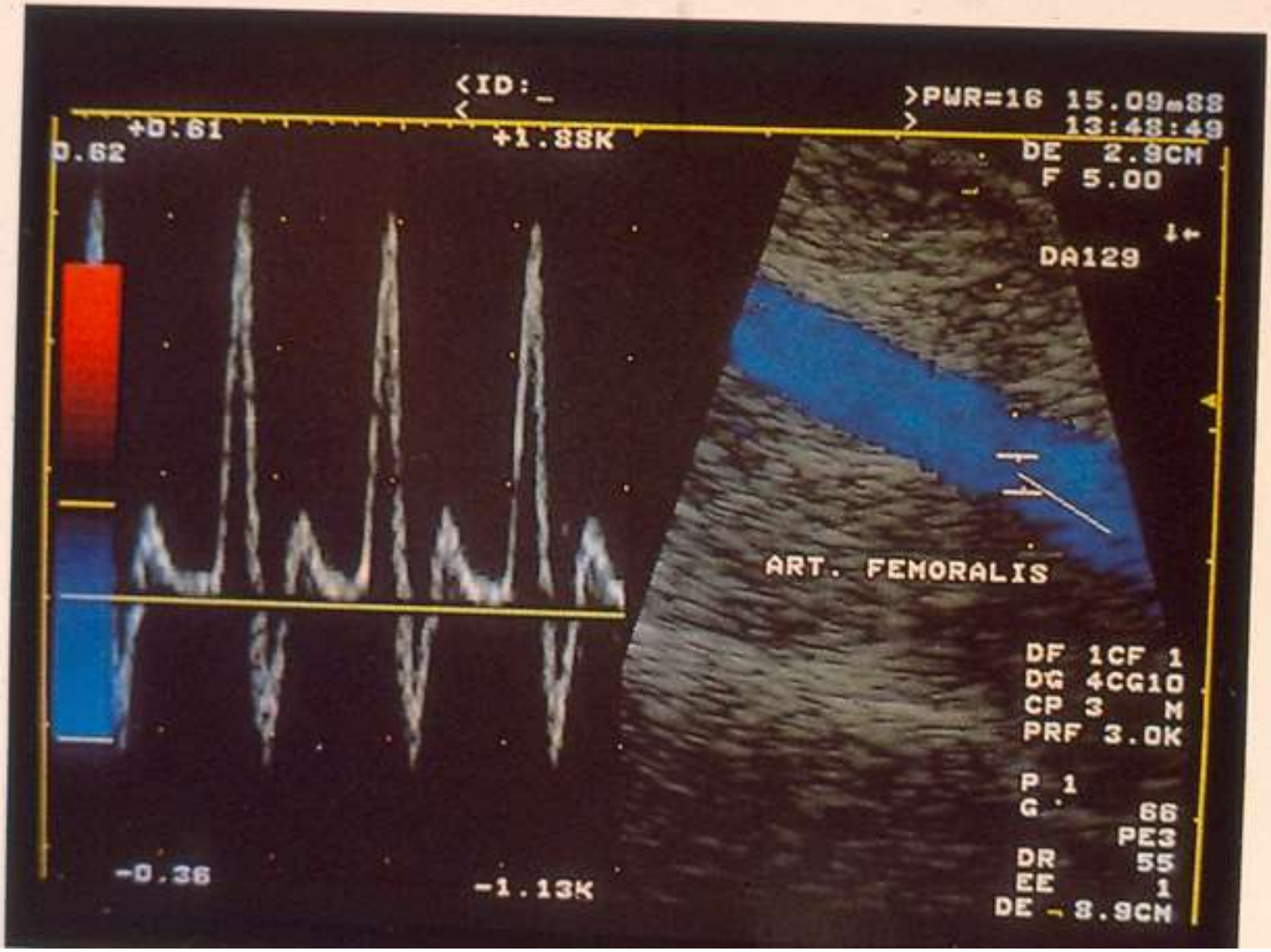
ood flow displays to that of a normal
oss sectional image.

ical 4-chamber View

Mitral Regurgitation

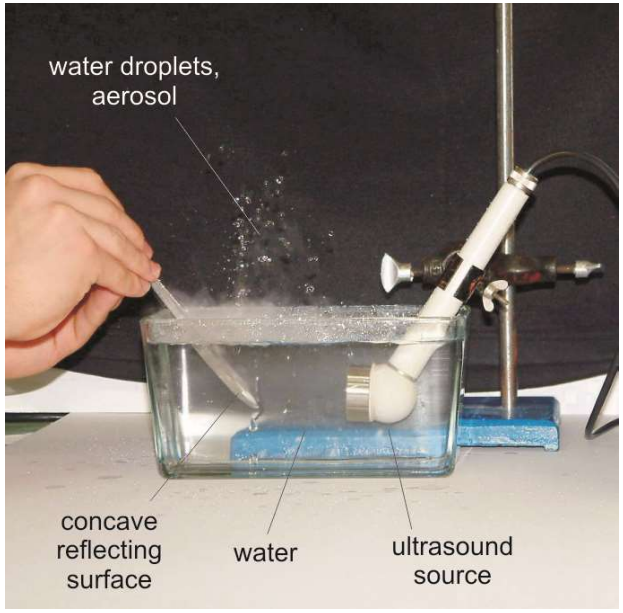

60MM
x1.5
17MM
4s3 N
2i3r0
CPG
CEG
CIG STENOSE 75 %
TURBULENCES +
M/S
.44
I
.66
1POSITION/TAILLE
2VITESSES
F3B+CFM+PORTE

20. Femoral artery

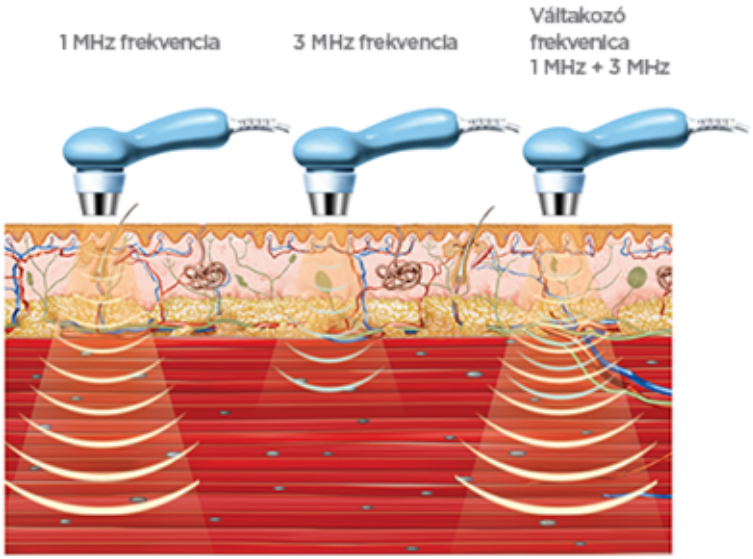


Ultrasound therapy (f = 0.8 – 1.2 MHz, most frequently 0.8 MHz)

- The heat effect and micromassage effect is applied – e.g. treatment of arthrosis.
- Due to high intensities even ionization is possible.

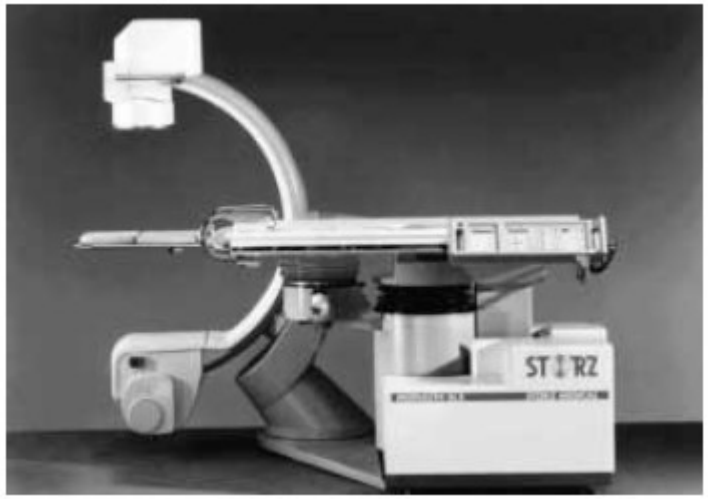


Muscle relaxation, pain killer and vasodilator effect.
Low dose enhances the cell metabolism,
Medium and high dose inhibits it.

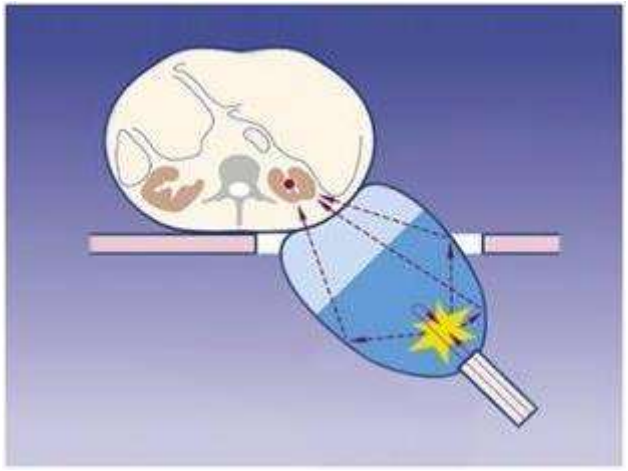


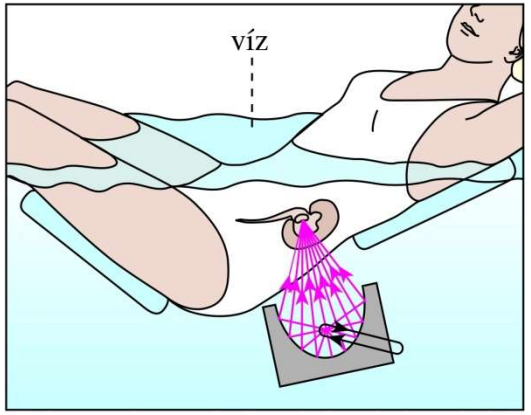
Shock wave therapy (destruction of stones)

Extrakorporális lökéshullám (ESWL) kőzúzó berendezés.



Extracorporeal shock wave lithotripsy (ESWL) machine



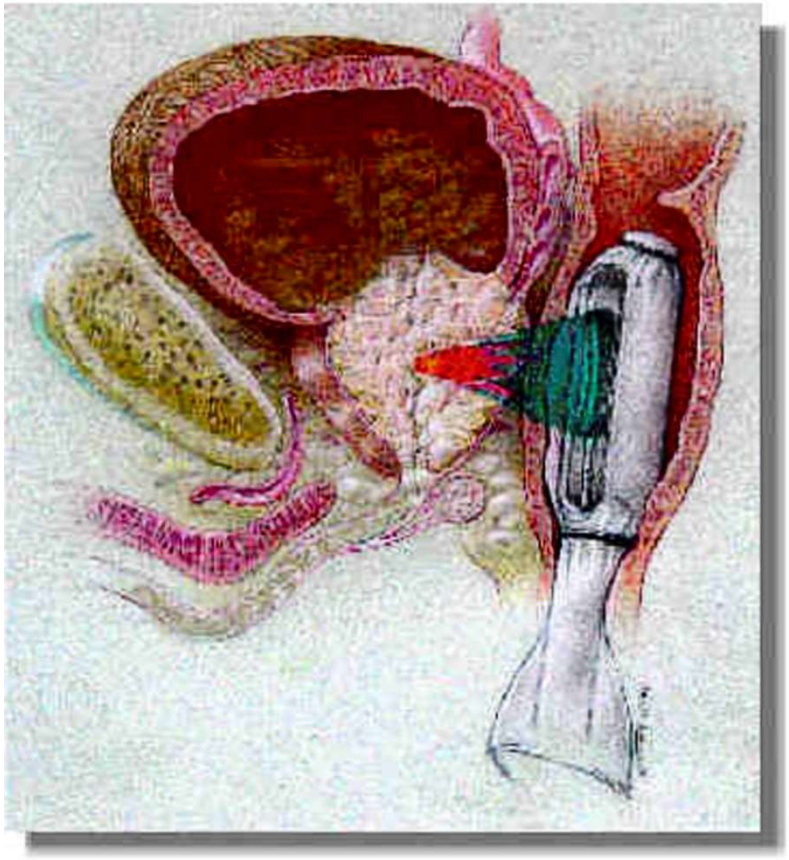


Due to high intensity focused shock wave the bile or kidney stones are destroyed.

Removal of odontolith by ultrasound

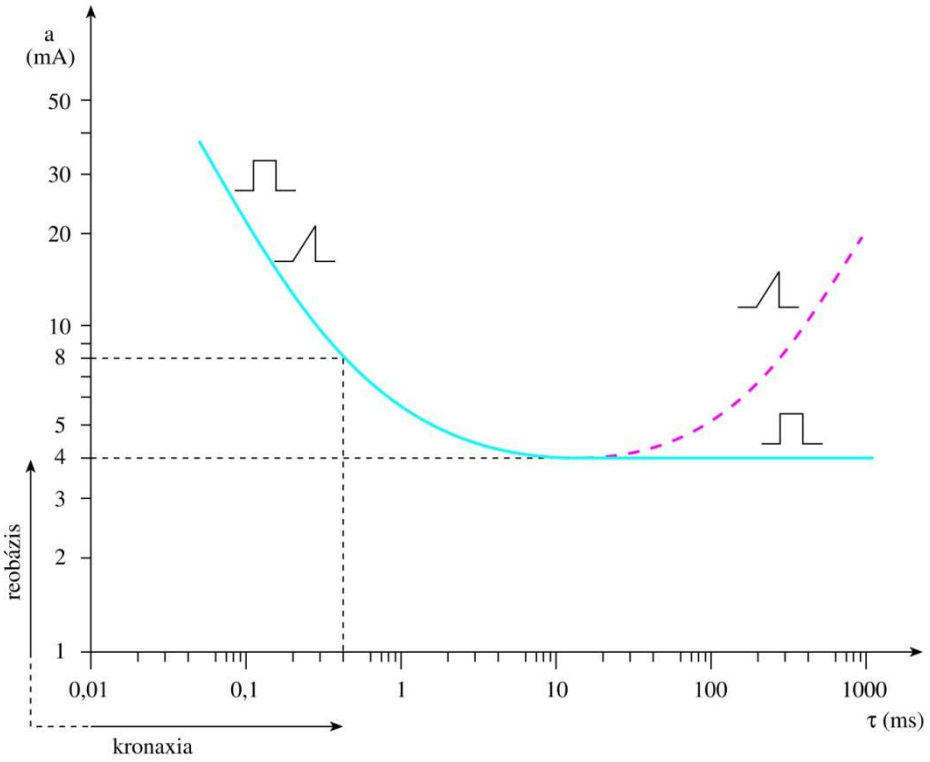
HIFU (high intensity focused ultrasound)

- treatment of prostate cancer by ultrasound

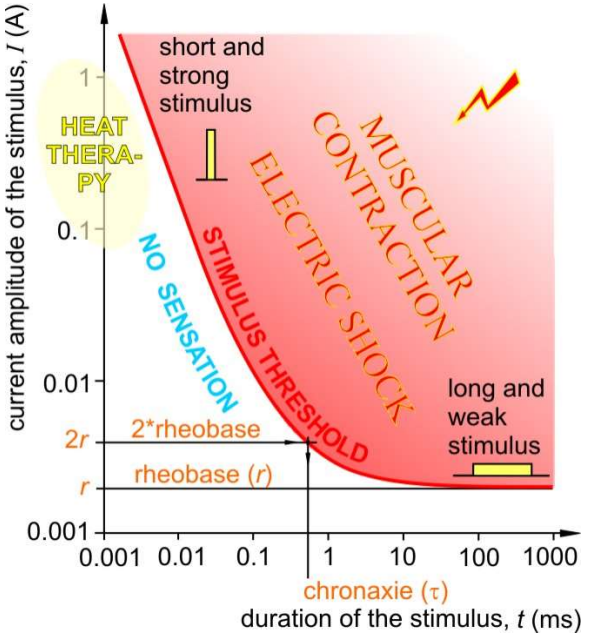


- face lifting

Effects of electric current (stimulus characteristics curve)

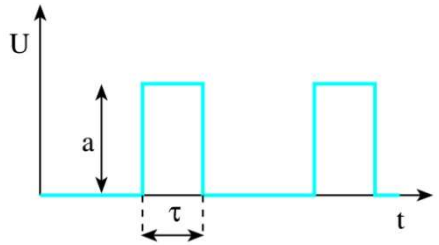


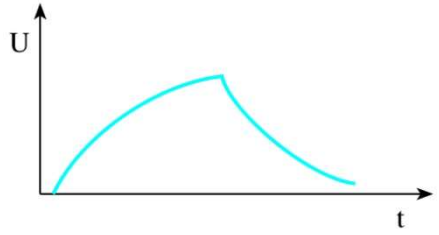
- Difference between the effect of triangle and square pulses (only in case of healthy muscles) – **selective treatment of injured muscles**.
- In case of short pulse duration time (high frequency) the threshold is very high
– no stimulation effect, only heat effect
– **high frequency heat therapy**. (f > 100 kHz)



Electric pulses can be produced as single pulses or in pulse series.

- characteristics of single pulses:
  - pulse duration time (τ)
  - amplitude (a)





Single pulse can be used:

- for stimulation of heart muscle(defibrillator)
- for stimulation of striated muscles (in case of muscle or nerve injury – also selectively, e.g. by exponential pulses)

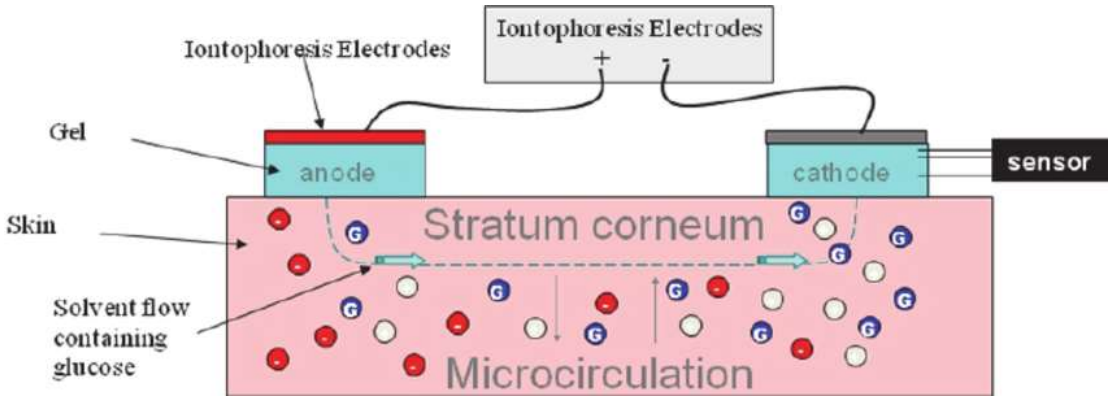
Pulse series

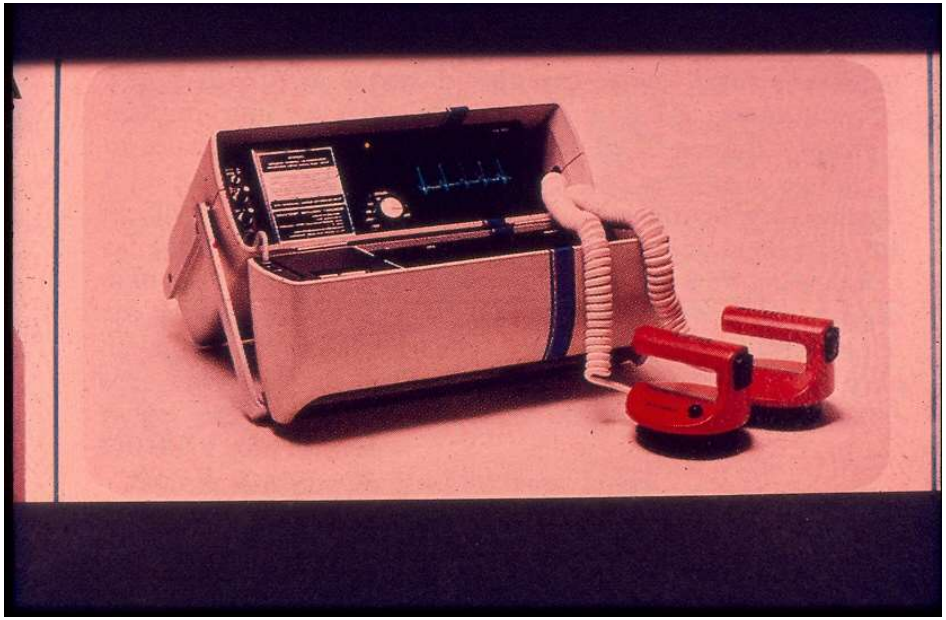
- further characteristics over pulse duration time and amplitude:
    - period time (T) pulse duration time + duration of the break between two pulses
    - frequency (f): reciprocal of period time
    - duty ratio (τ/T)
- application
    - stimulation of heart muscle (pacemaker)
    - stimulation of striated muscles (in case of muscle or nerve injury) – TENS (transcutaneous electro neuro stimulator -it can be used also for pain killing)

Galvanic treatment: direct current of constant intensity is applied

- effects:
  - pain killing
  - metabolism enhancement
  - vasodilation
  - enhances the excitability of motoneurons

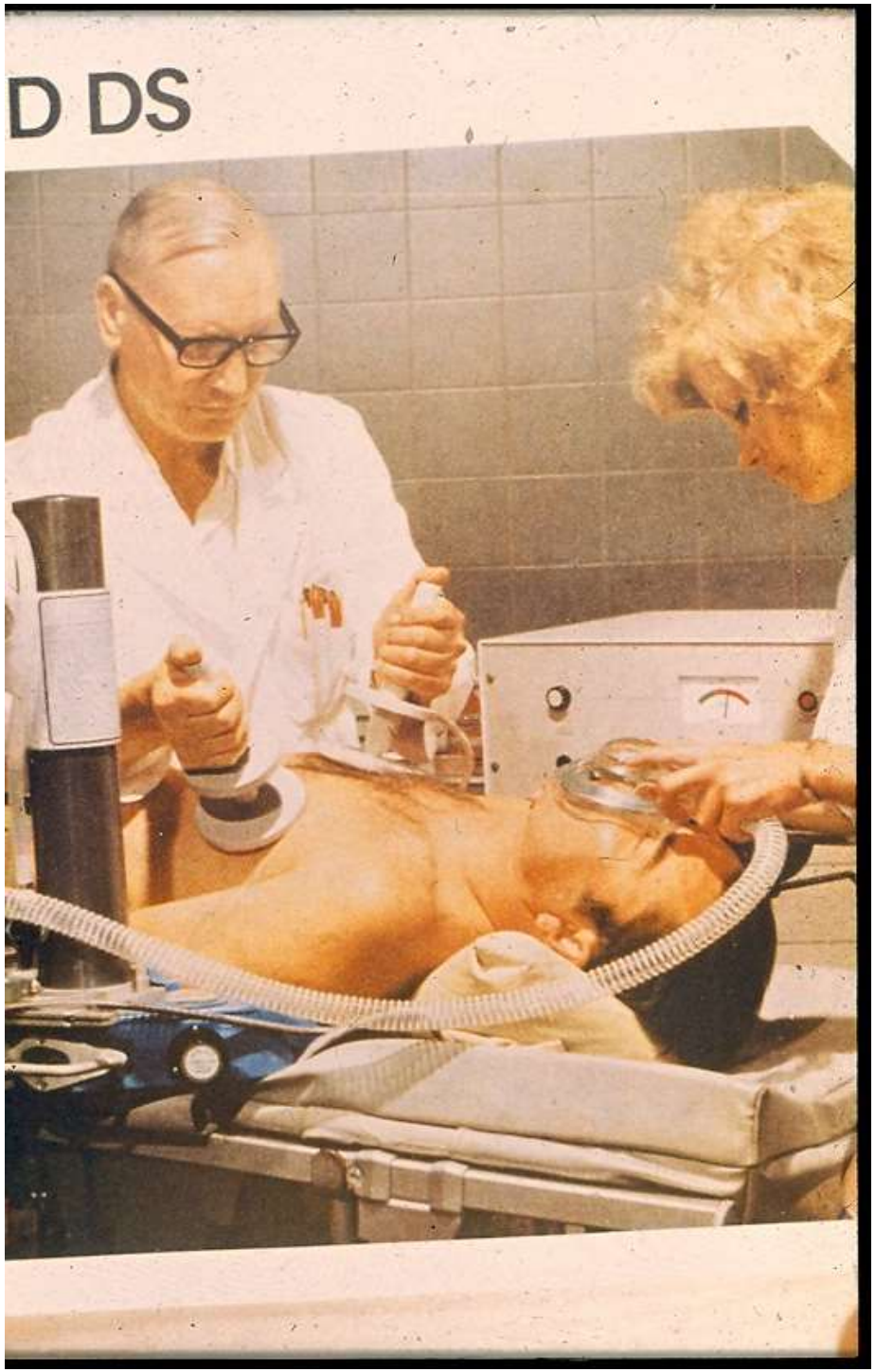
Iontophoresis: ionic drugs can be targeted to the organ between the two electrodes by direct current.
(pain killers, antiinflammatory drugs, vasodilators, etc.)

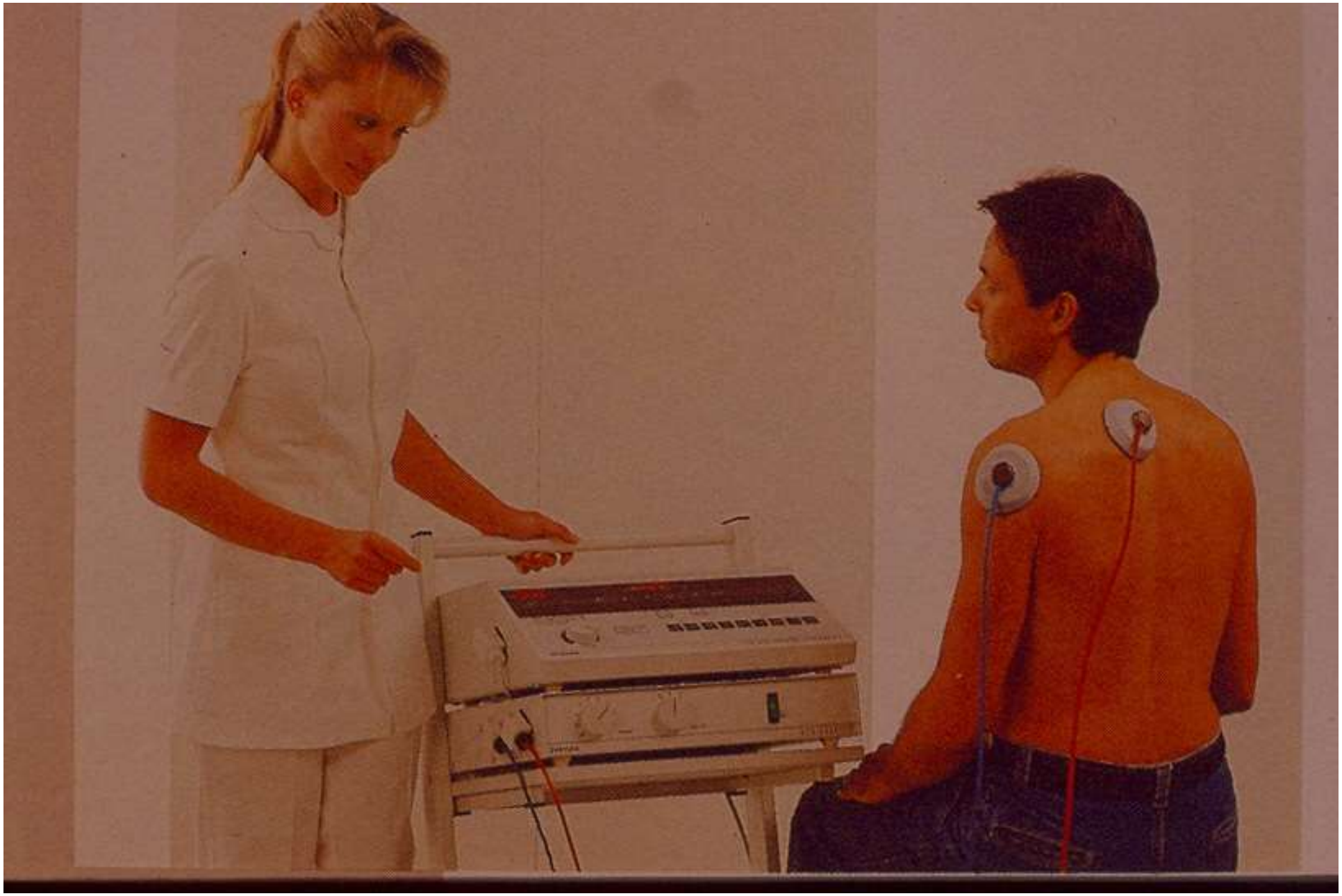




RESCUE
LIFE
ECG

D DS





Indikationsbeispiele aus unserem Therapieheft:

Periarthritis humeroscapularis

Arthrosis (Kniegelenk)

Distorsion

Cervikalsyndrom
Migräne cervikalen Ursprungs

Lumbago, Ischialgie usw.

Periphere Lähmungen

Kontraktion

Bipolare Reizung der volaren Unterarmmuskulatur

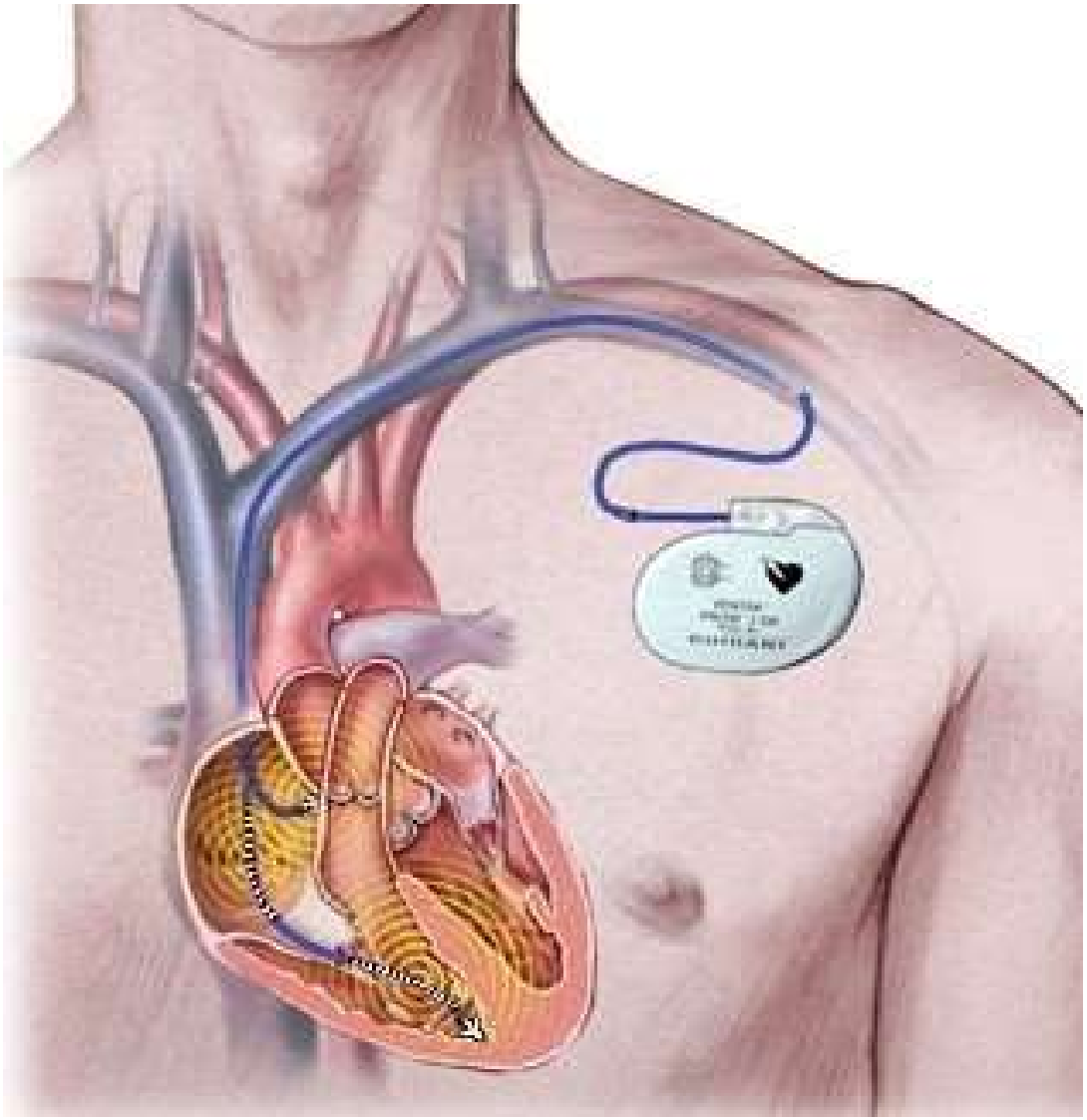
Monopolare Reizung der Daumenballenmuskulatur.

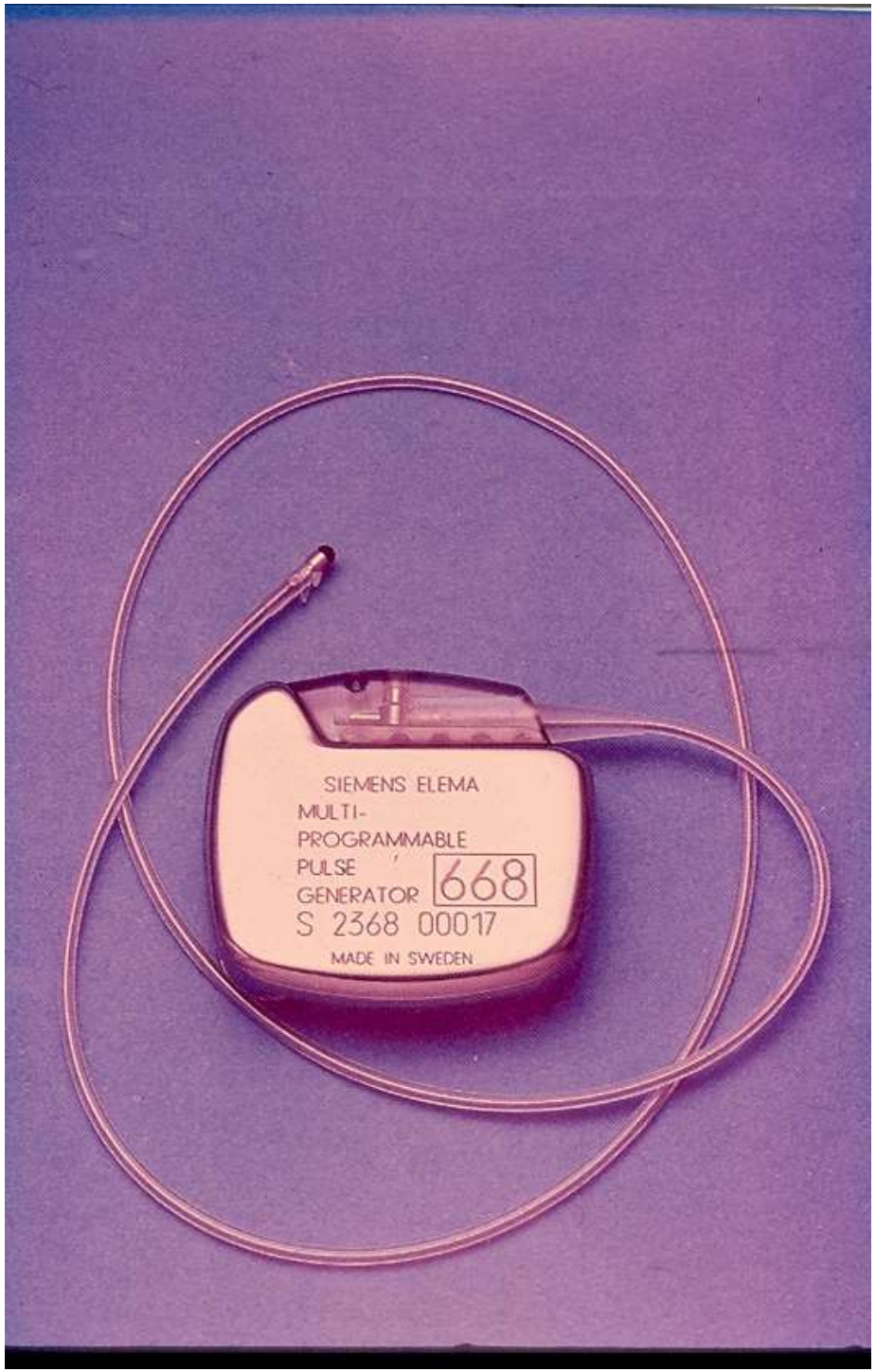
Bipolare Reizung der dorsalen Unterarmmuskulatur (Radialisgruppe). Die Patientin wird in die Verwendung der Fernsteuerung für Intentionsübungen eingewiesen.

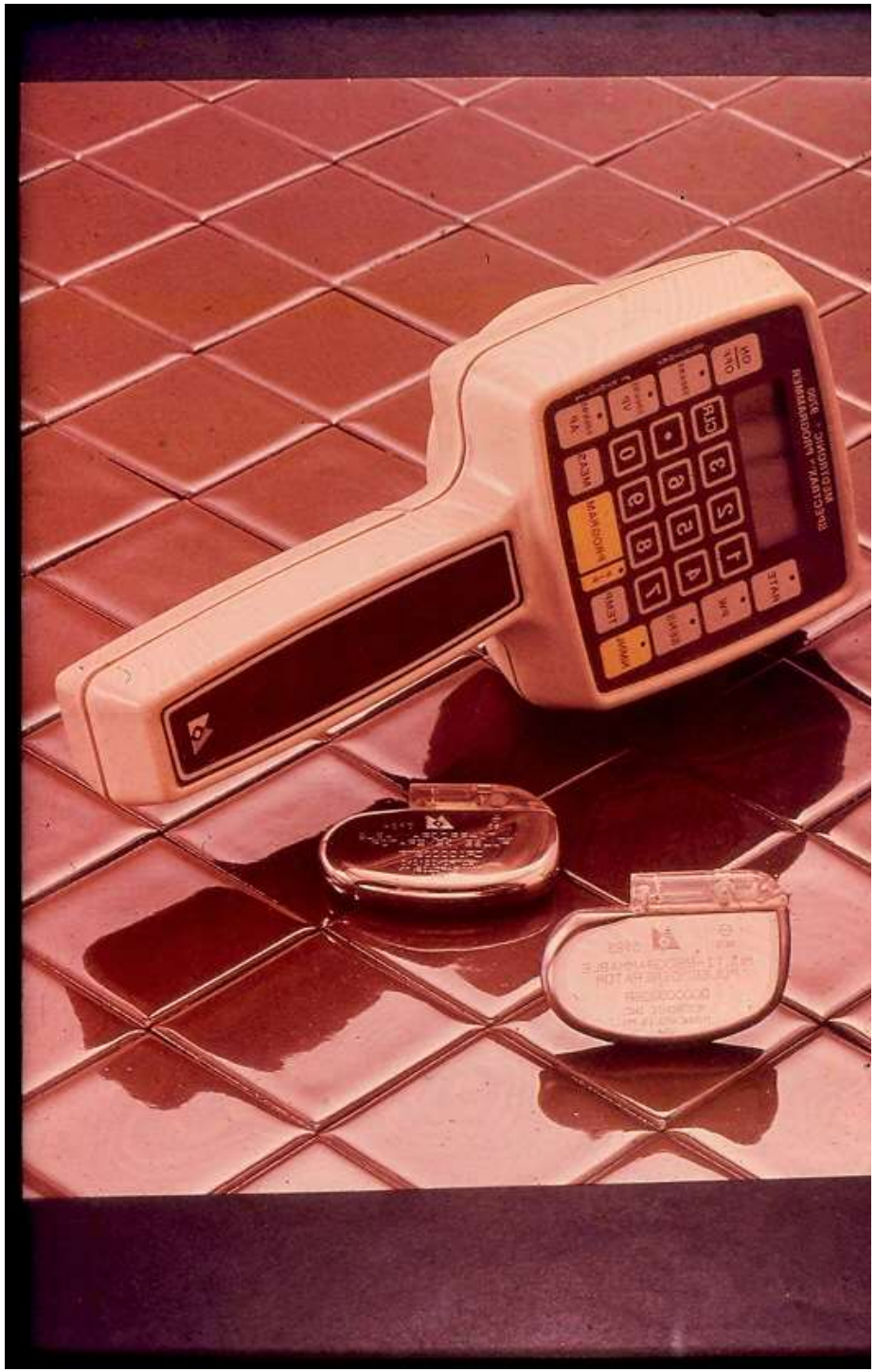
Interference current therapy:

- Some 1000 frequency current is give on both electrode pairs. The frequency difference between them is low (approx. 100 Hz). With proper positioning of the electrode pairs the difference frequency appears in the required area (e.g. in the injured muscle.)

Tetrapolare Interferenzstrombehandlung eines Schultergelenkes.

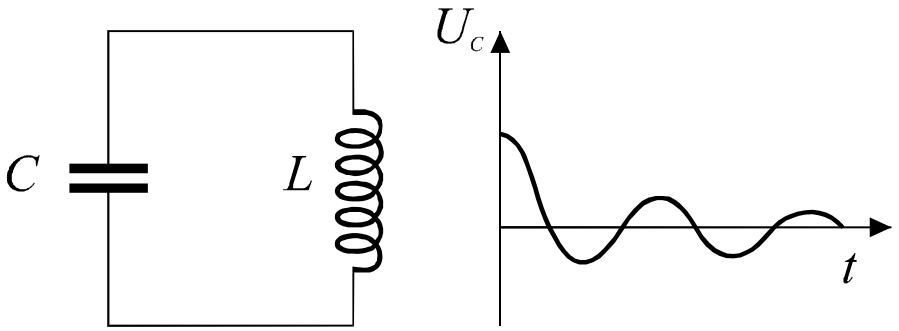



SIEMENS ELEMA
MULTI-
PROGRAMMABLE
PULSE
GENERATOR 668
S 2368 00017
MADE IN SWEDEN



High-frequency heat therapy

Production of high-frequency sine waves:
by feedback oscillator circuit (LC-circuit)



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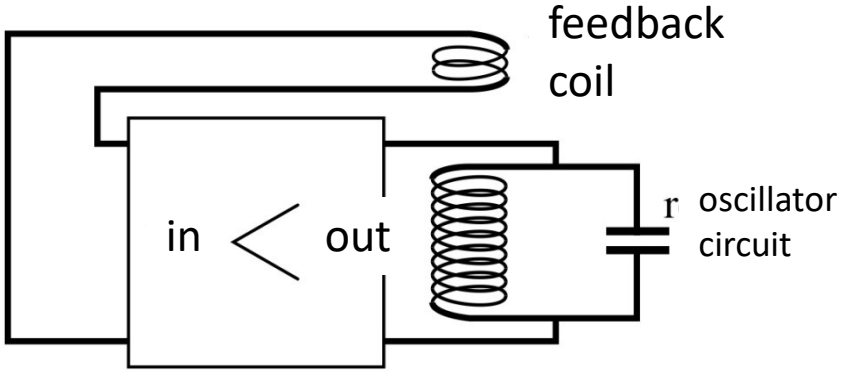
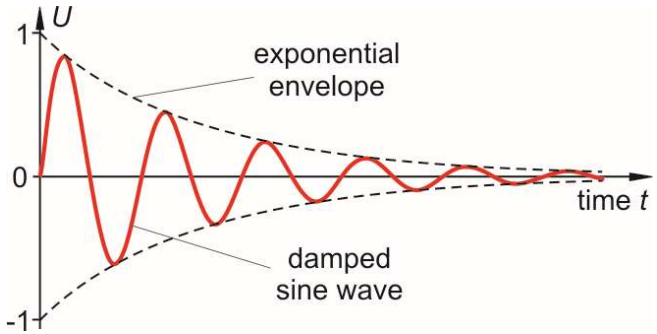
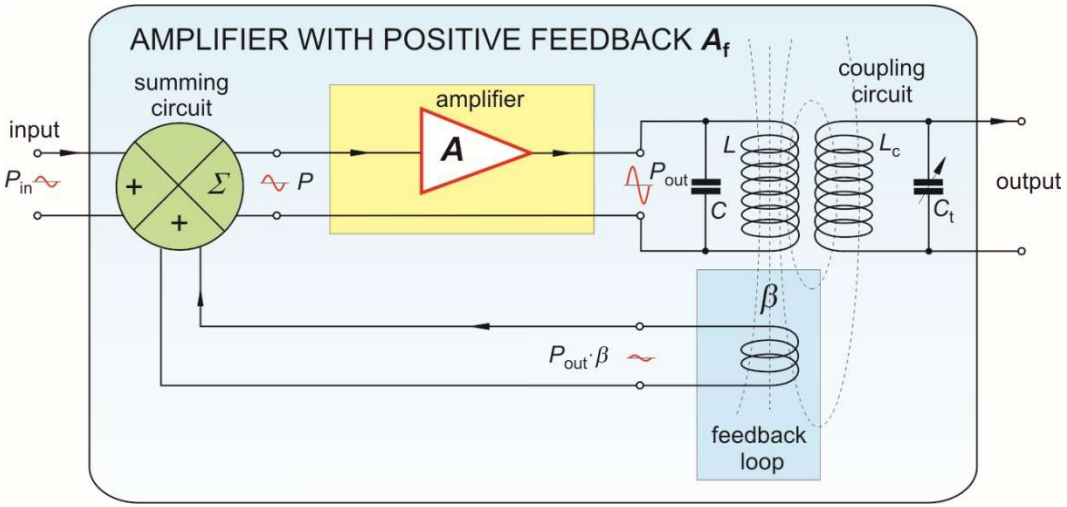


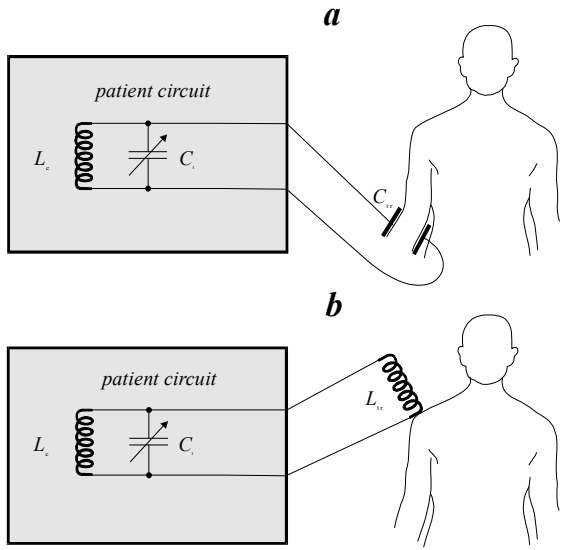


$$f = \frac{1}{2\pi\sqrt{LC}}$$

The amount of produced heat is different in different tissues and in different methods of treatment.
(methods of treatment: capacitor field, coil field, radiation field)

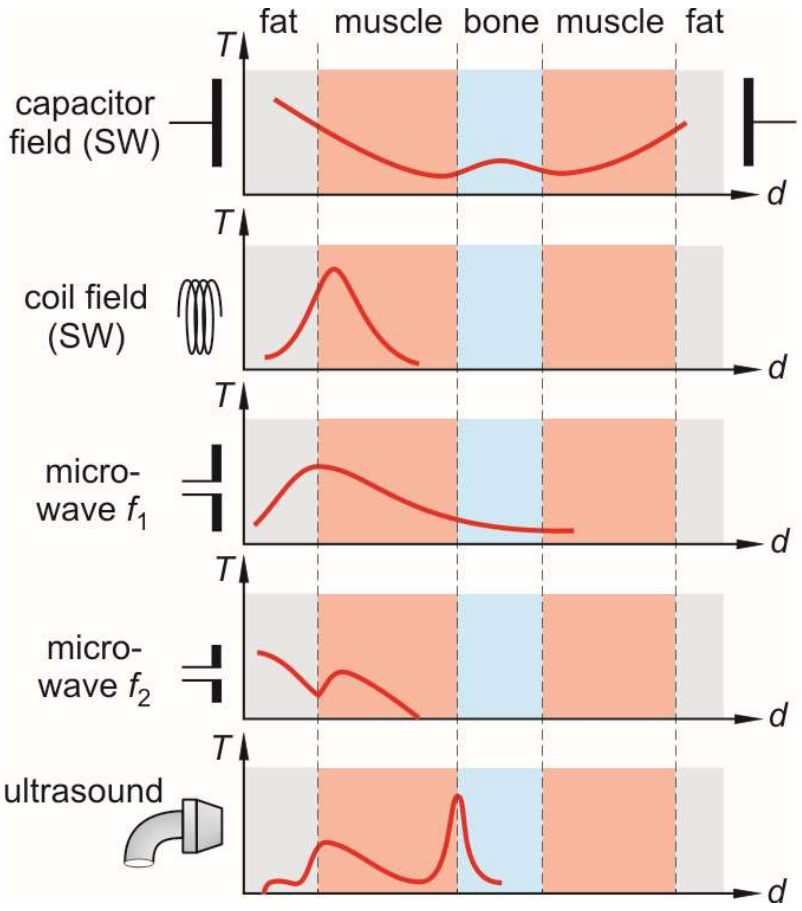
Optimal coupling between patient circuit and oscillatory circuit: in case of resonance: the LC product value is the same for both circuits.





The applied frequency and wavelength ranges:

- Short wave (f ~ 30 MHz - λ~10 m)
- Decimeter wave (f ~ 0,5 GHz - λ~0,6 m)
- Microwave (f ~ 2,5 GHz - λ~12 cm)



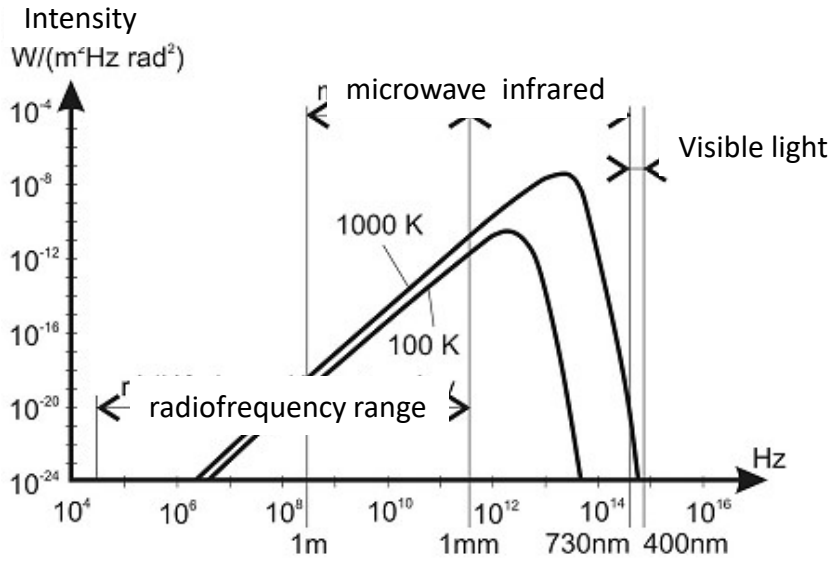
e.g. in case of capacitor field method:

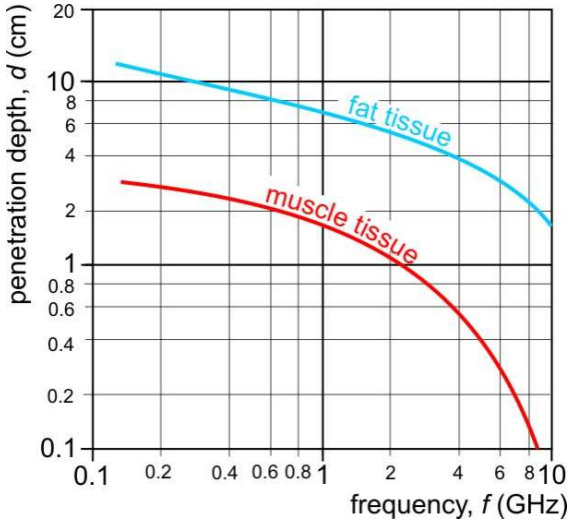
$$Q = \frac{U^2}{R}t = \frac{U^2 A}{\rho l}t = \sigma\frac{U^2}{l^2}Alt = \sigma E^2 Vt$$

frequency	σ_{fat} **[mS/cm]**	σ_{muscle} **[mS/cm]**
300 MHz	2,7	9,0-9,9
1000 MHz	3,6	13,0-14,5

Medical applications of microwaves:

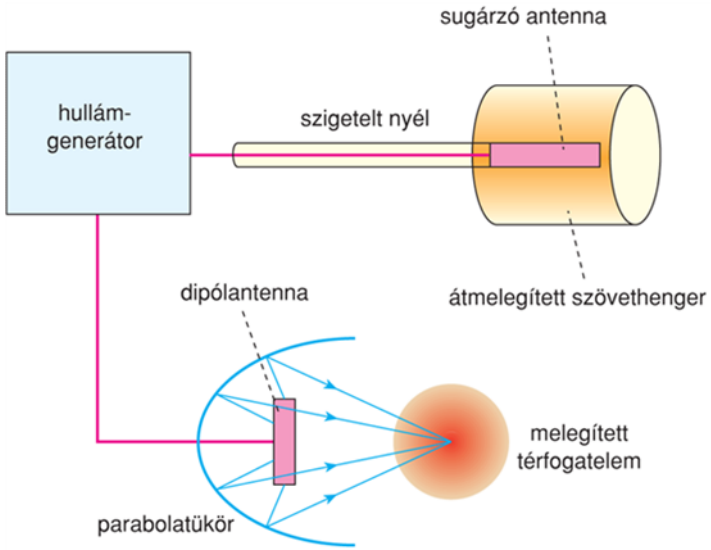
Diagnostics: **microwave thermography** – mostly for detection of breast cancer. The intensity is much lower, than in infrared region, but the penetration depth is much higher. Tumor in higher depth can also be detected.





frequency	Penetration depth [cm]	
	fat tissue	muscle tissue
100 MHz	30	4
10 GHz	3	0.2

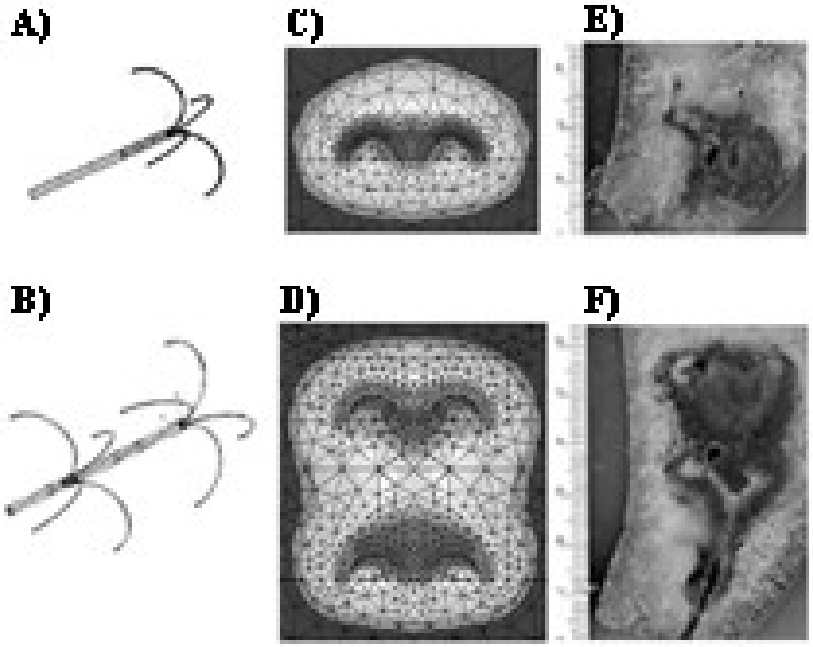
Therapy: - heat therapy (microwave hyperthermia)
- Treatment of rheumatic joint diseases
- Skin disorders (eczema, wart, psoriasis, angioma)
- Tumor therapy – optimal: 42 – 43,5 °C tumor temperature. (Tumor cells are destroyed, but the surrounding healthy cells are not injured.) It can be combined with radio-, or chemotherapy. Optimal power density: 200 mW/cm^2.

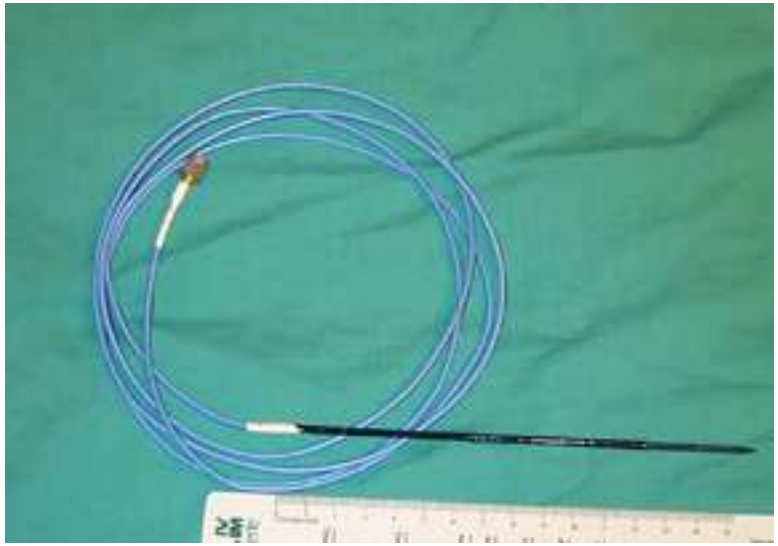


- MBA (microwave balloon angioplasty)

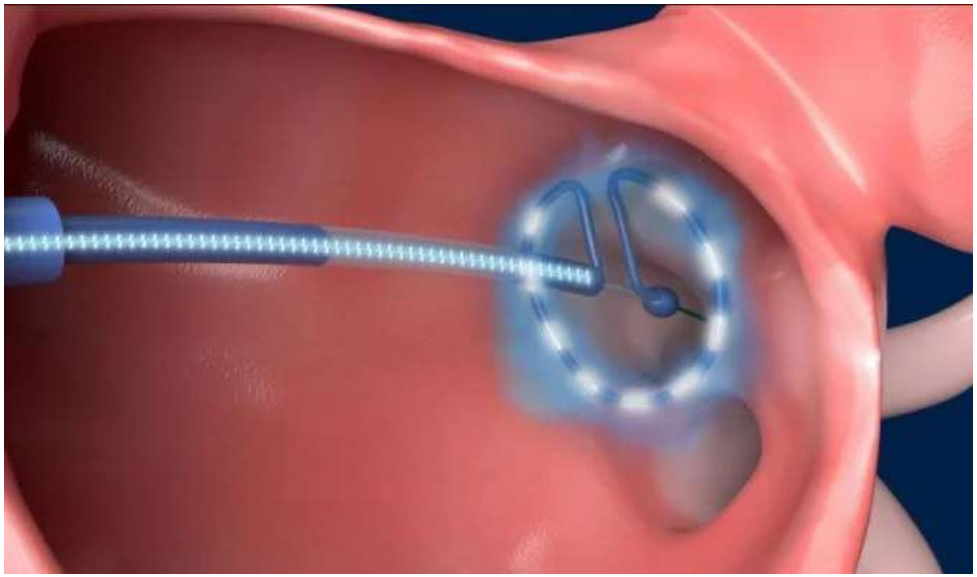
advantages: - lower chance for restenosis
- welding of vessel injuries
- lower probability for thrombosis

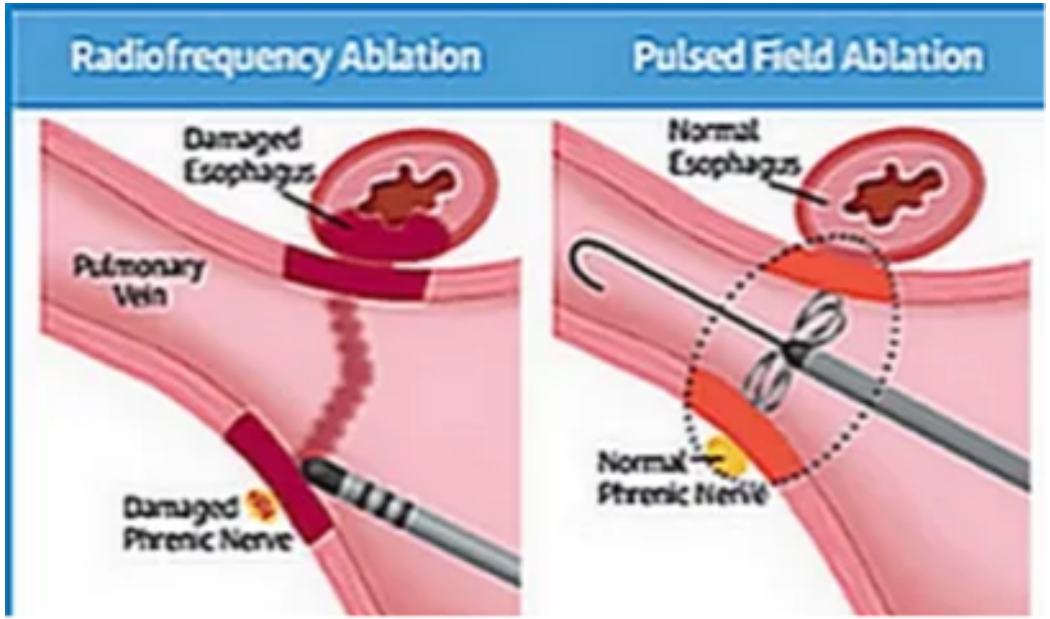
- Treatment of some types of arrhythmia with catheter ablation – cutting of anomal bundles for stimulus conduction



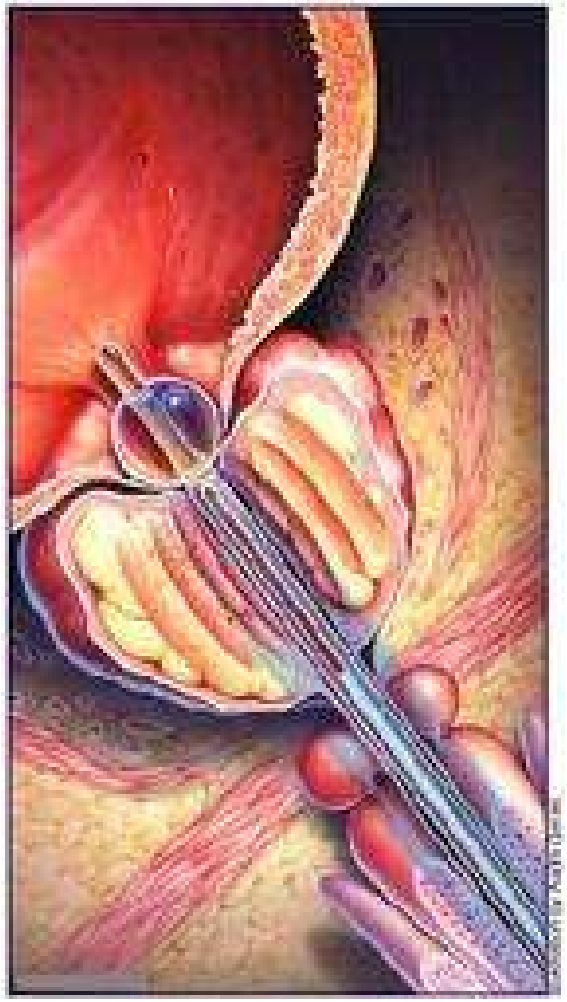


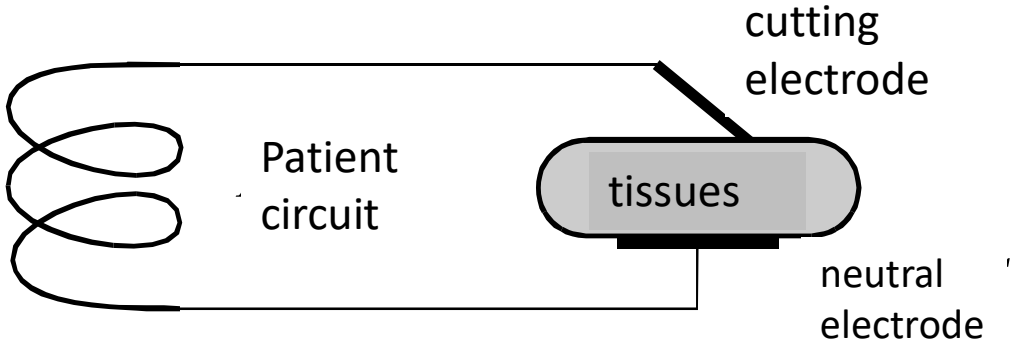
Pulse field ablation treatment of atrial fibrillation

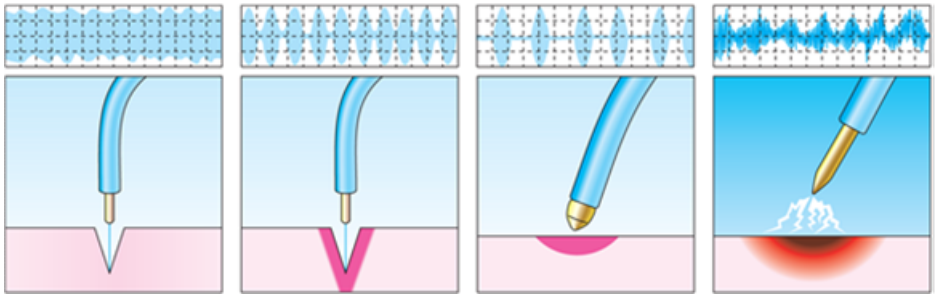




- Treatment of prostatic hyperplasia
- Microwave surgery – mainly in endoscopic operations





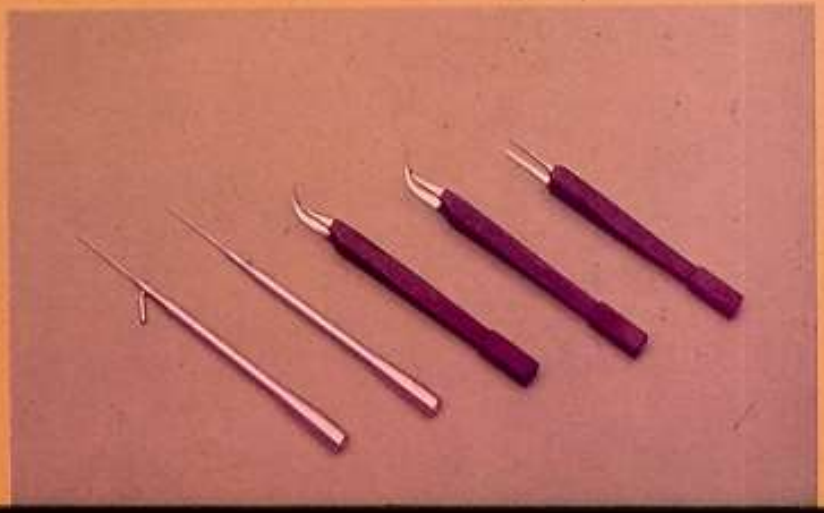


Ophthalmobipolar

Ophthalmobipolar for bipolar „wet-field"-coagulation in ophthalmic surgery

The Ophthalmobipolar is equiped with a special socket for bipolar electrodes which is fully isolated from line and ground potentials. The RF power of the bipolar output is provided with a continuous and finely reproducible adjustment up to a maximum of 30 watts with dosage settings for the most delicate bipolar coagulations with fine coagulation forceps, as well as for bipolar endodiathermy.

The Ophthalmobipolar conforms to VDE and IEC regulations for electromedical equipment.



Technic

Power supply

Lead current in conductor

Power consump

RF power bipo

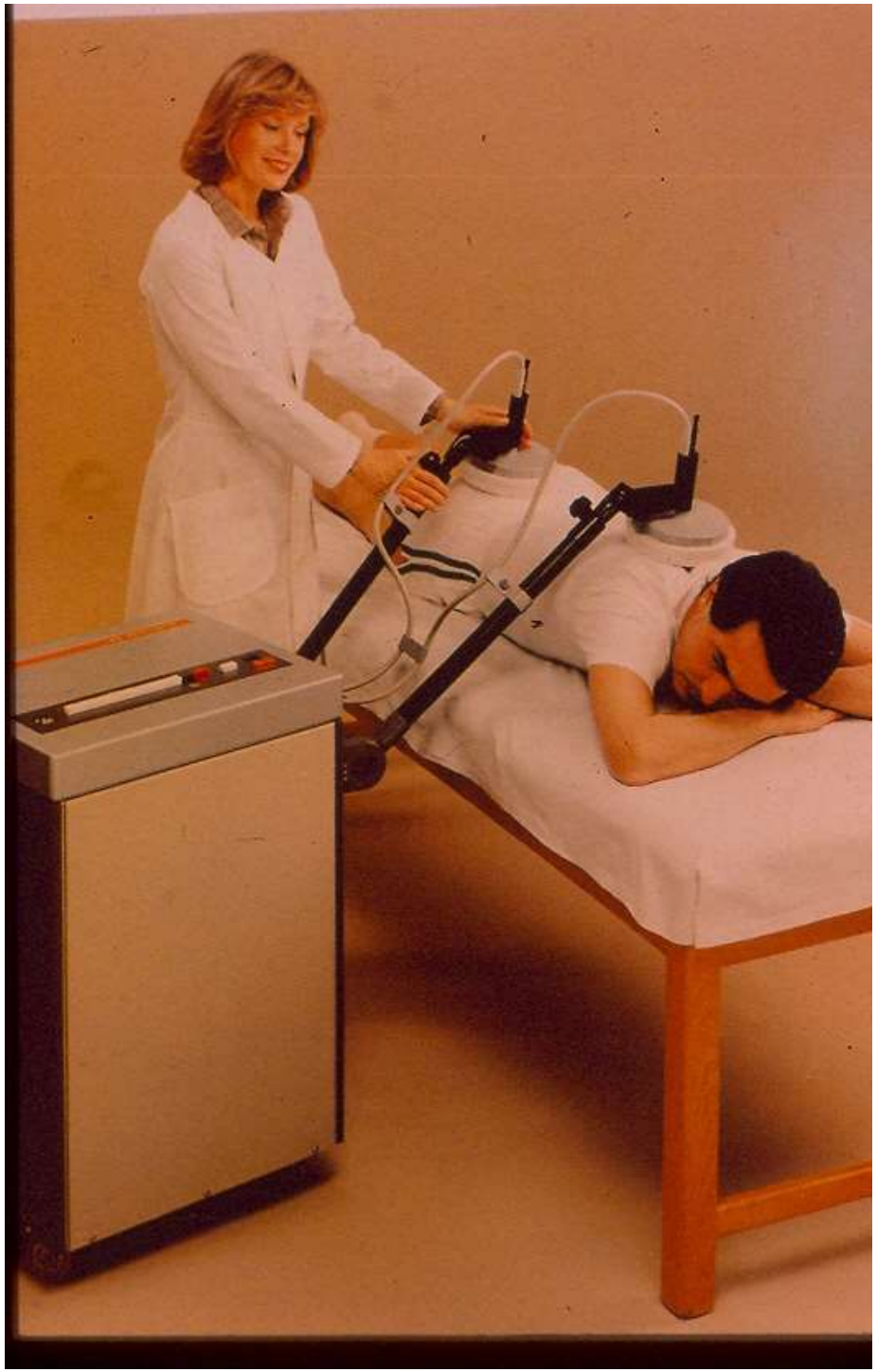
Operating freq

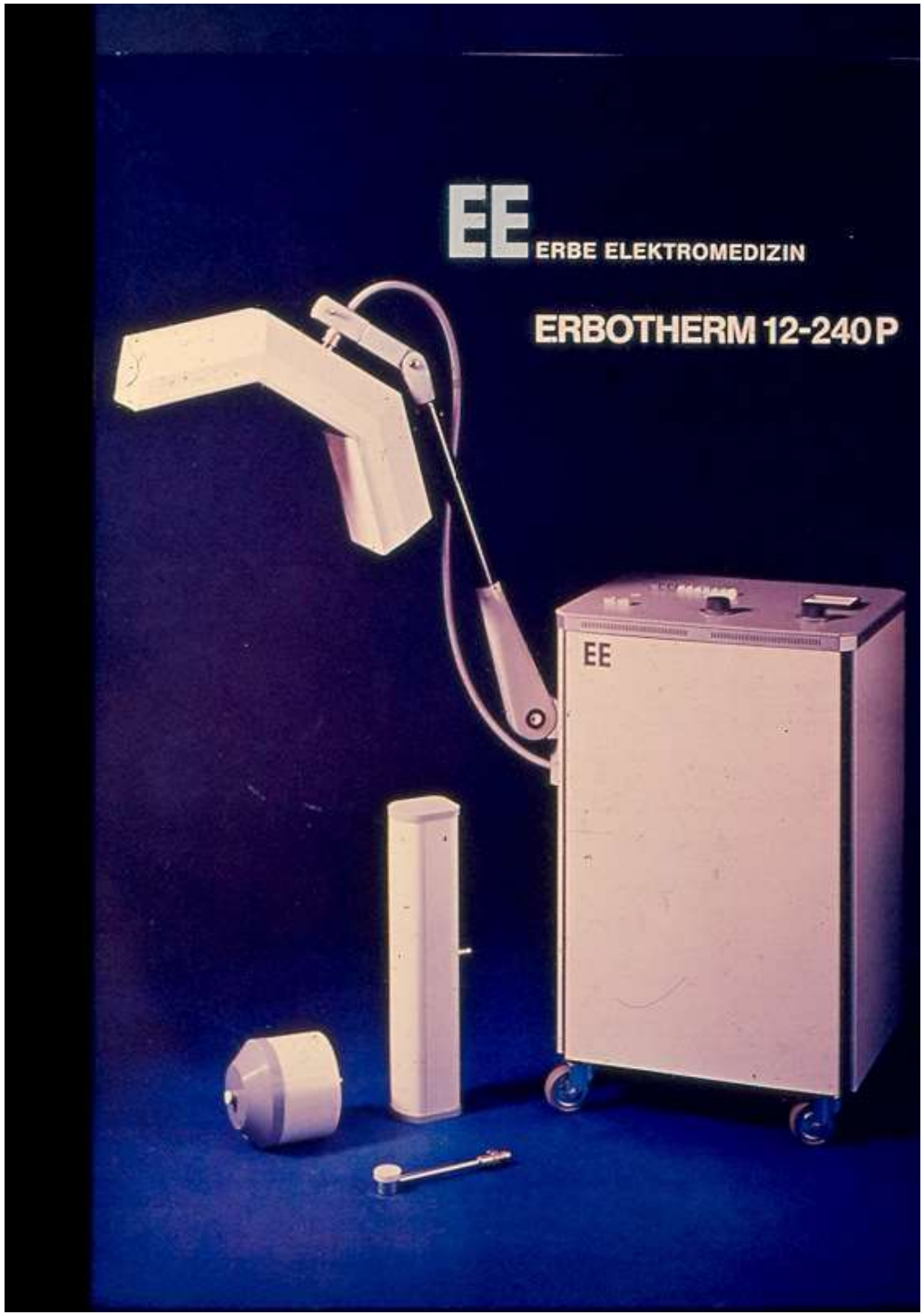
Protection clas

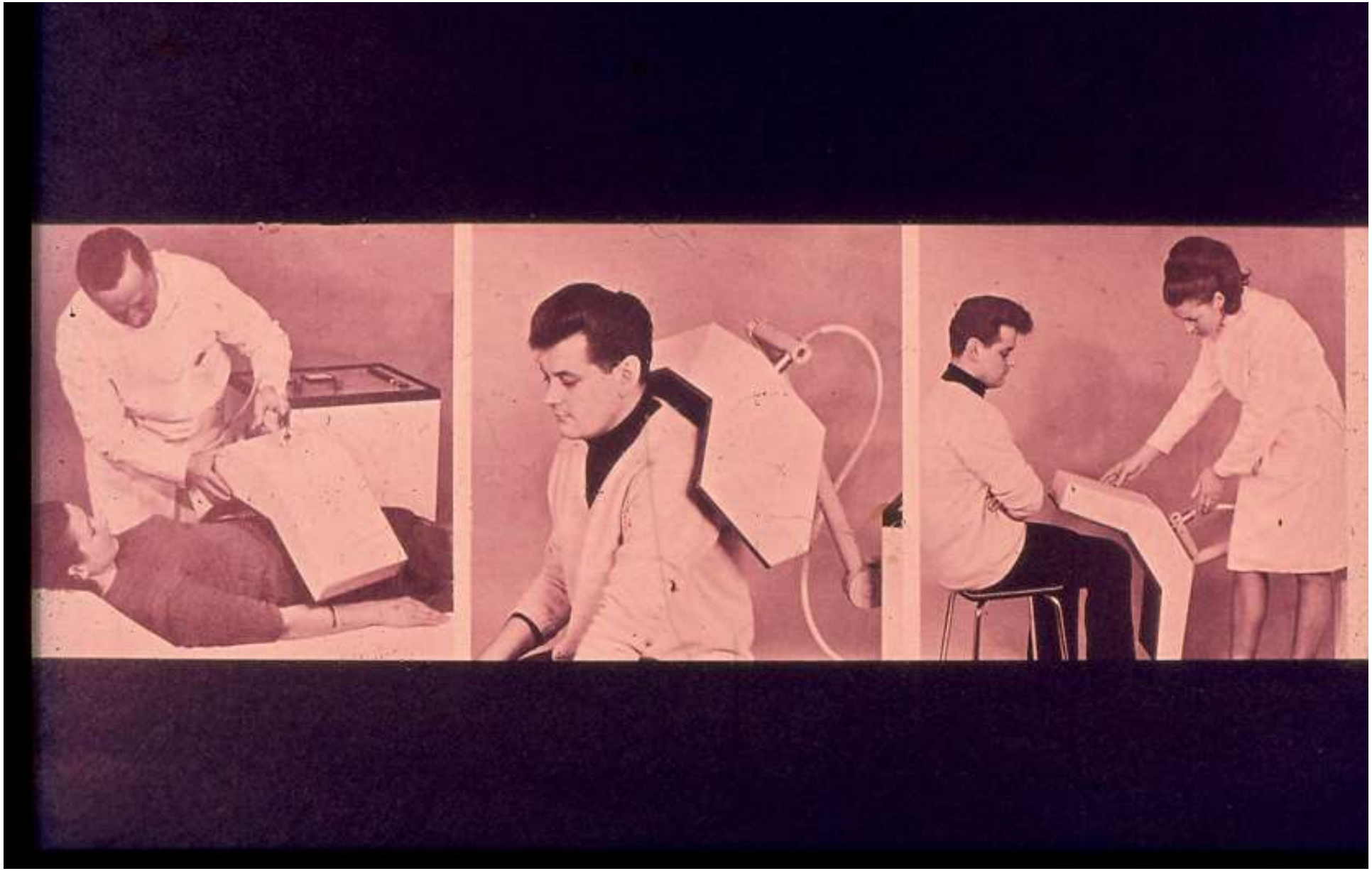
Dimensions

Weight

Guarantee




EE
ERBE ELEKTROMEDIZIN
ERBOTHERM 12-240 P
EE



1 Treatment of a furuncle of the neck with the round-field director

2 Microwave treatment of sinusitis with the focus electrode

1

2

Thank you for your attention

Dr. István Voszka

SEMMELWEIS
UNIVERSITY 1769