6th International Anthropological Congress of Dr. Ales Hrdlicka 150TH anniversary of birth.
"All mankind is of one origin"

PIEZOELECTRIC EFFECT IN BONE DURING EXTRACORPOREAL SHOCK WAVE THERAPY IN EXPERIMENT.

S.Vasilevich, MD, PhD.
A.Arsenev, MD, PhD.
S. Kurchenko MD.
M.Dudin, MD, PhD. Sc.D. Prof.
A. Falinskii MD, PhD.

Children's Rehabilitation Center of Orthopaedics and Traumatology "Ogonyok", St. Petersburg, Russia.

HUMPOLEC
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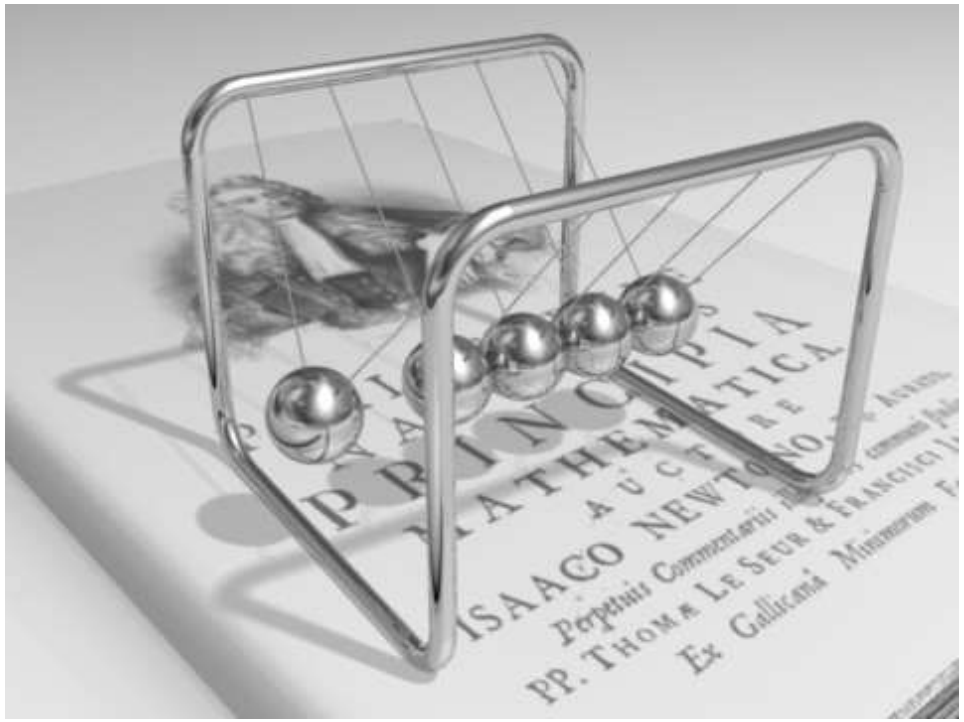
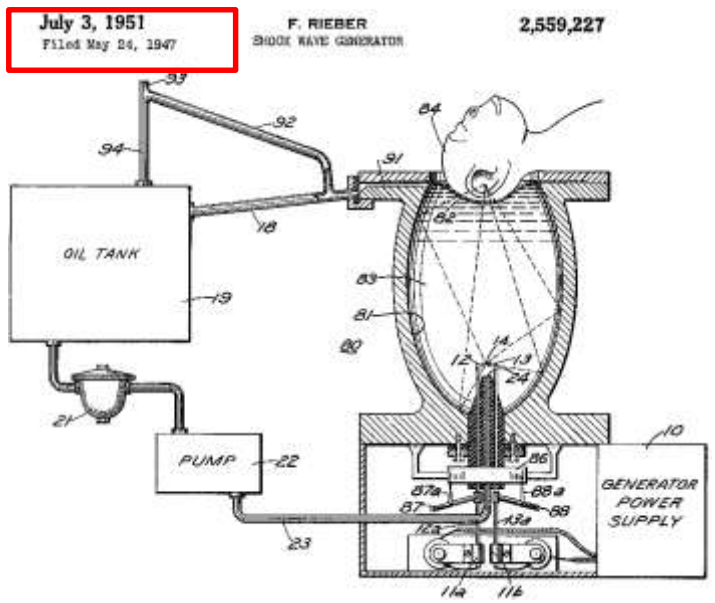
Harvard school of medicine defines extracorporeal shock wave therapy (ESWT) as a non-invasive treatment, which is the delivery of shock waves, low or high energy, through a device to a specific place inside the body. The shock wave occurs as a result of micro explosions inside the device and with the help of a special device is transmitted to the body at different depths, positively or destructively affecting the tissues of a living organism (depending on the chosen power of exposure).



History of the method



In the early 1950ˢ, American scientist Frank Rieber invented the first shock wave generator. The idea of this generator was to create focused pressure pulses (shock waves) with their subsequent transmission to the depths of the human body - offered using shock waves to treat brain tumors without surgery

197th years

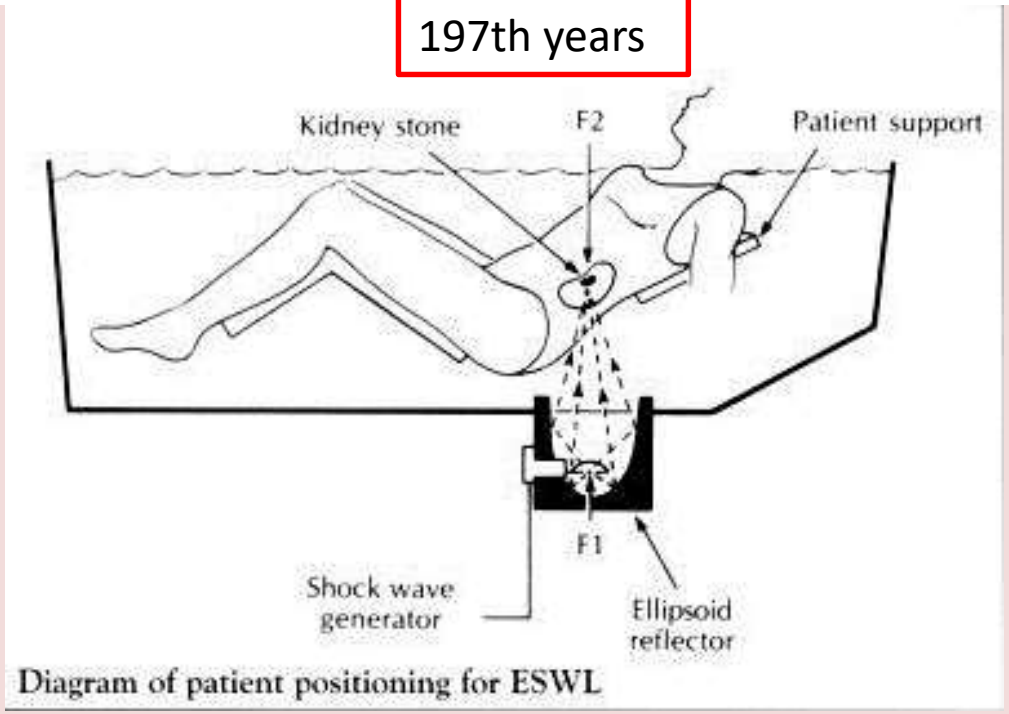


Diagram of patient positioning for ESWL

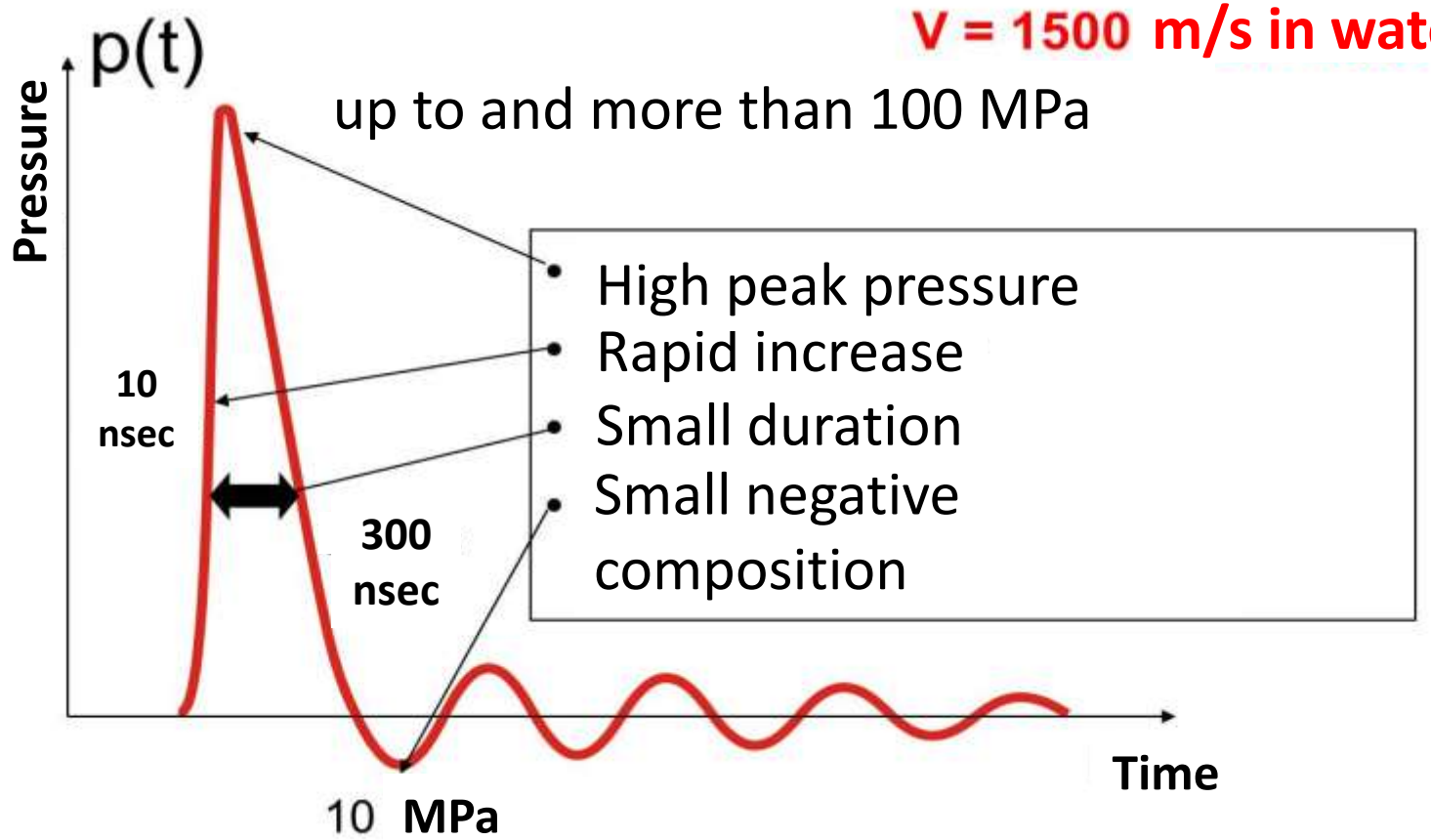
In 1971ˢᵗ, it was reported about the successful destruction of the kidney stone by shock waves.
(F. Eisenberger, C. Chaussy, B. Forssmann).

Shock waves were first used in 1986 to stimulate healing processes. The effect of superficial wounds of pigs on wound healing was assessed , and osteogenic (bone-forming) effect was observed. It is believed that low-energy shock waves stimulate healing processes, while high – energy shock waves do not (Law Arndt-Schulz, 1883).

Since the 2000ˢ, the market presents a portable shock wave therapy device with extensive technical capabilities.

Graph of shock wave propagation in the medium

V = 1500 m/s in water

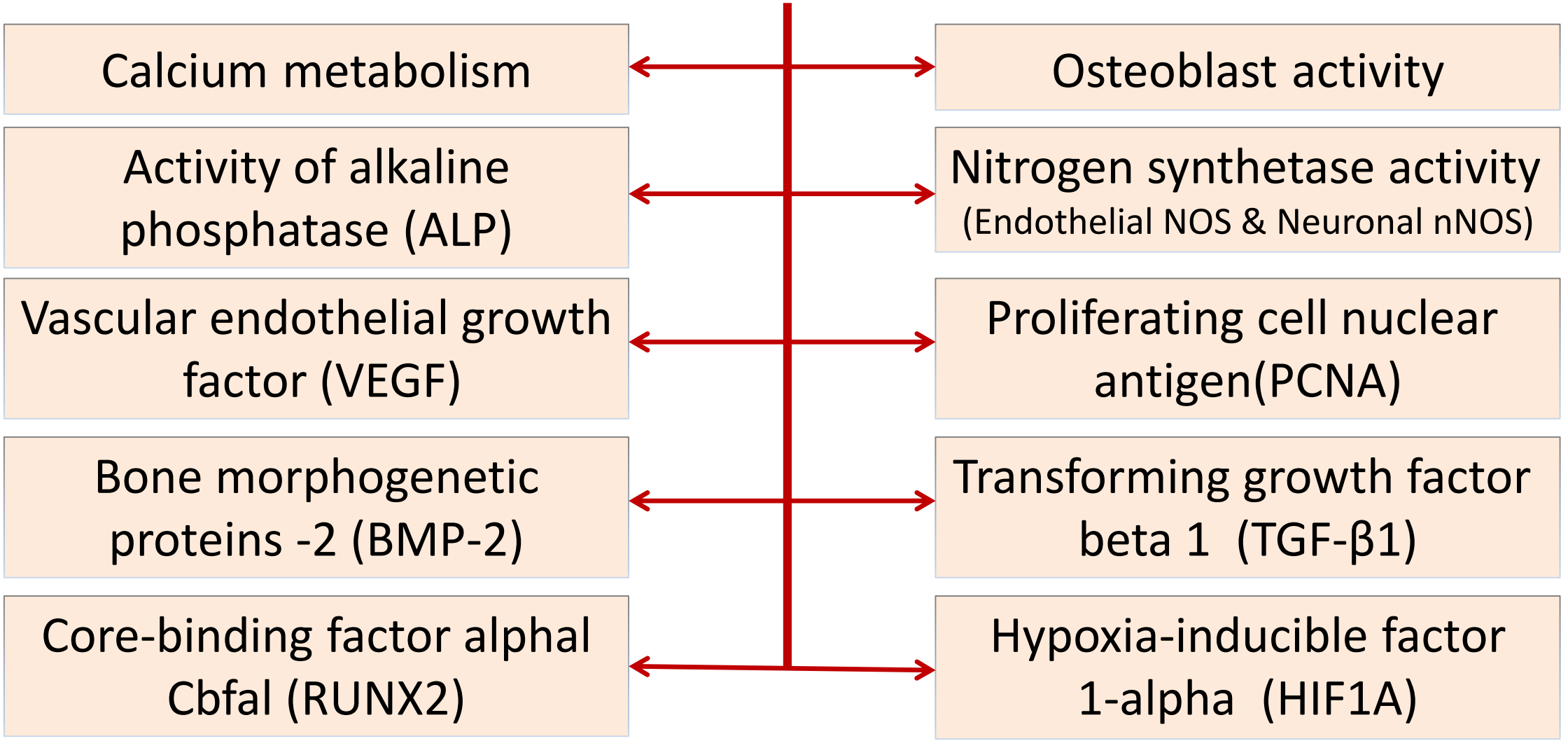


The shock wave can be divided into two pnases.

First phases – positive pressure phase.

Second phases – negative pressure phase.

Mechanism of action



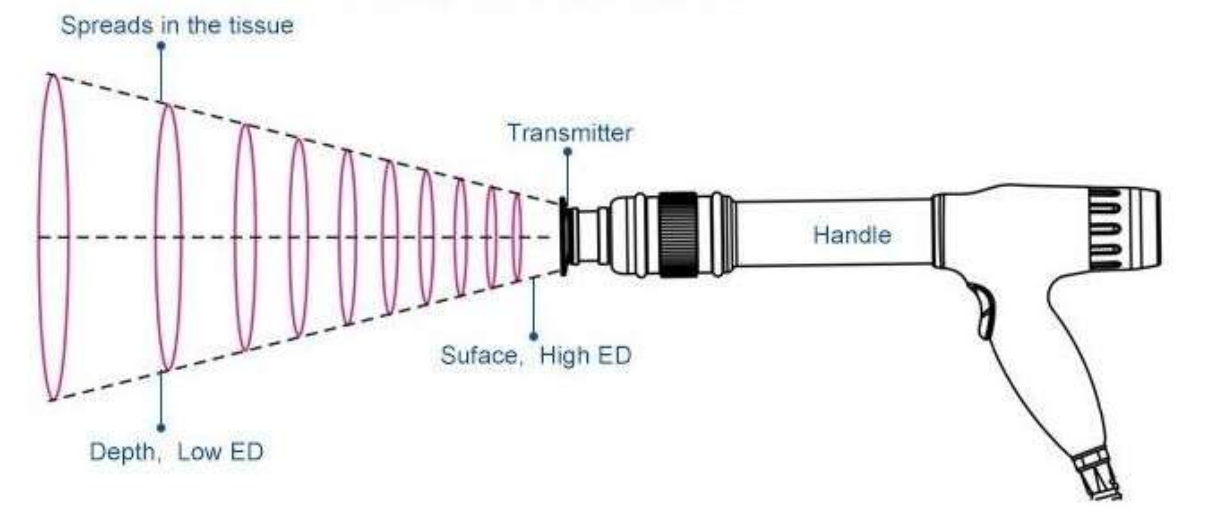
Jai-Hong Cheng, Ching-Jen Wang. Review: Biological mechanism of shockwave in bone. International Journal of Surgery , Volume 24, Part B, December 2015, Pages 143-146

Types of shock waves

Radial (defocused)

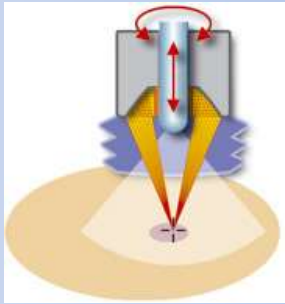
low-pressure therapy

THE MECHANICAL SHOCK WAVE GENERATOR
(pneumatic or electromagnetic drive)



Focused
(high pressure therapy)

ELECTROMAGNETIC GENERATOR SHOCK WAVE



PIEZOELECTRIC SHOCK WAVE GENERATOR

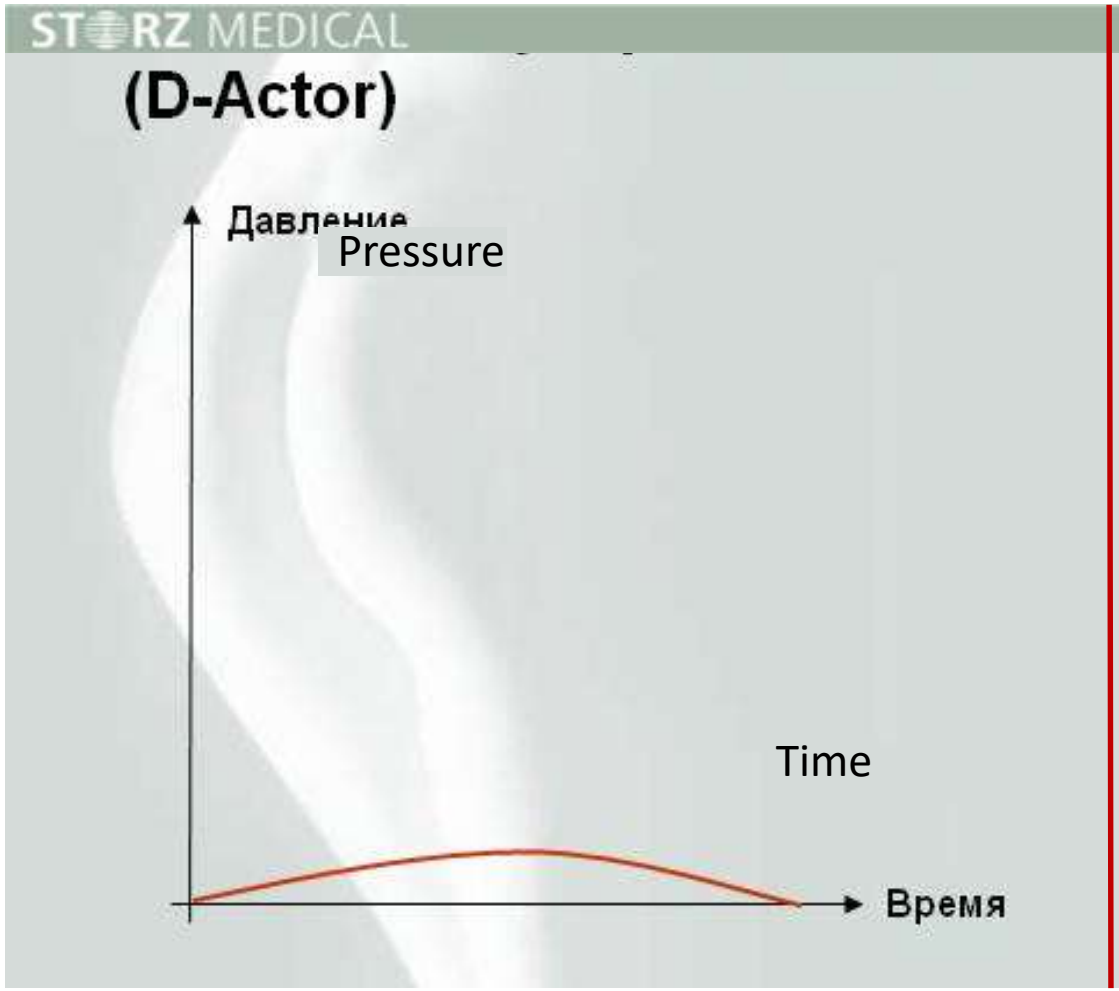
ELECTROHYDRAULIC SHOCK WAVE GENERATOR

COMPARATIVE CHARACTERISTICS OF THE FOCUSED AND RADIAL SHOCK WAVES

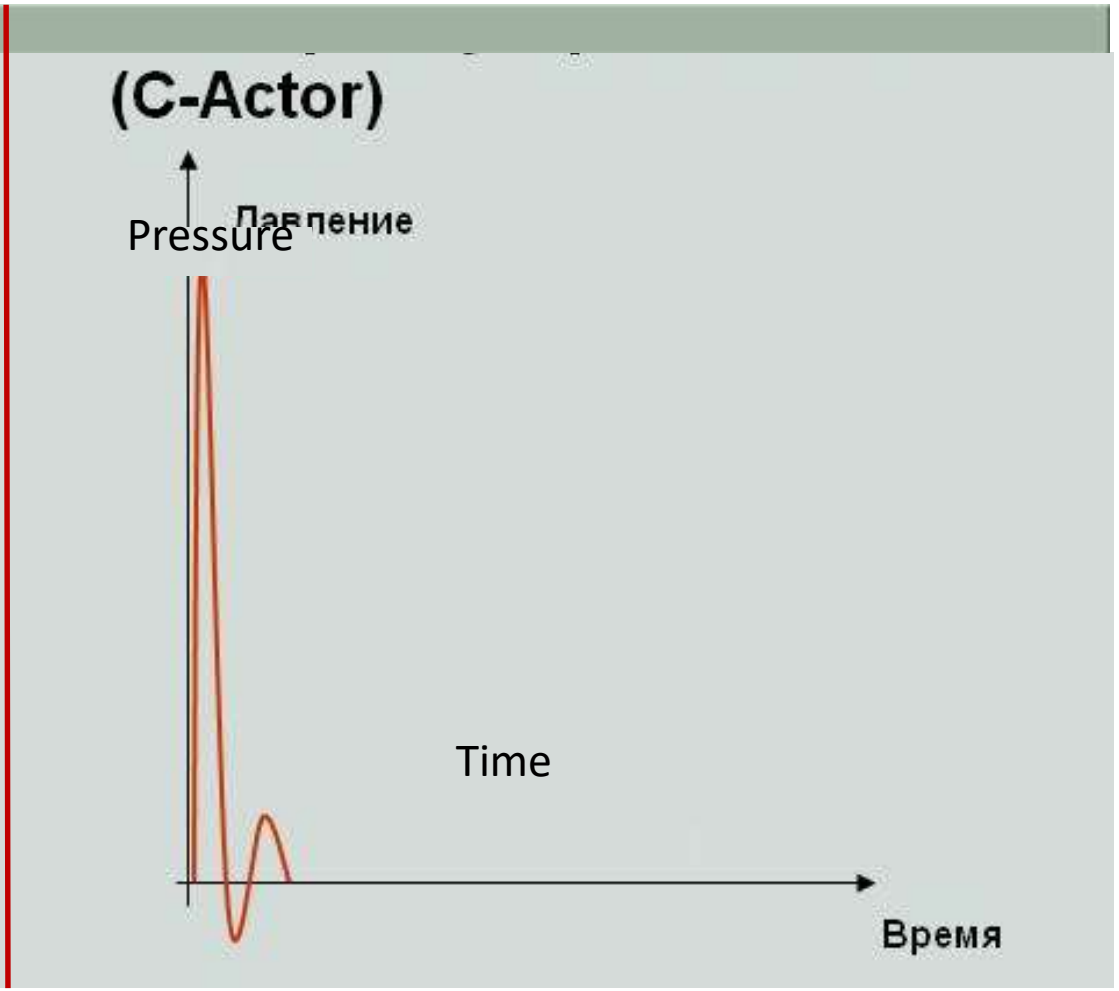
Property	Radial shock waves	Focused shock waves
THE AREA OF INFLUENCE	Large area	Very small point
ENERGY	A maximum of 0.3 MJ/sq. mm at the skin surface	Maximum 1.5 MJ/sq cm in the body (in the focus area)
POSITIVE PRESSURE PEAK	0-10 MPa	0-100 MPa
COMPRESSION PULSE DURATION	200-2000 nanoseconds	0,3 nanoseconds
PENETRATION DEPTH	0-3 cm, depending on the type and shape of the acoustic head	0-12 cm
NAVIGATION, ACCURATE AIMING METHOD	No need at all, under the control of the eye	Needs to be accompanied (x-ray or ultrasound devices)
USERS	Physiotherapists, cosmetologist, orthopedist	Urologists, cardiologists, orthopedists

SHOCK WAVE PROPAGATION DIAGRAM

Radial shock waves



Focused shock waves



Applications of shock wave therapy

ORTHOPEDICS

- ✓enthesopathy;
- ✓fasciitis;
- ✓delayed fracture healing,
- ✓arthrosis;
- ✓sports injury;

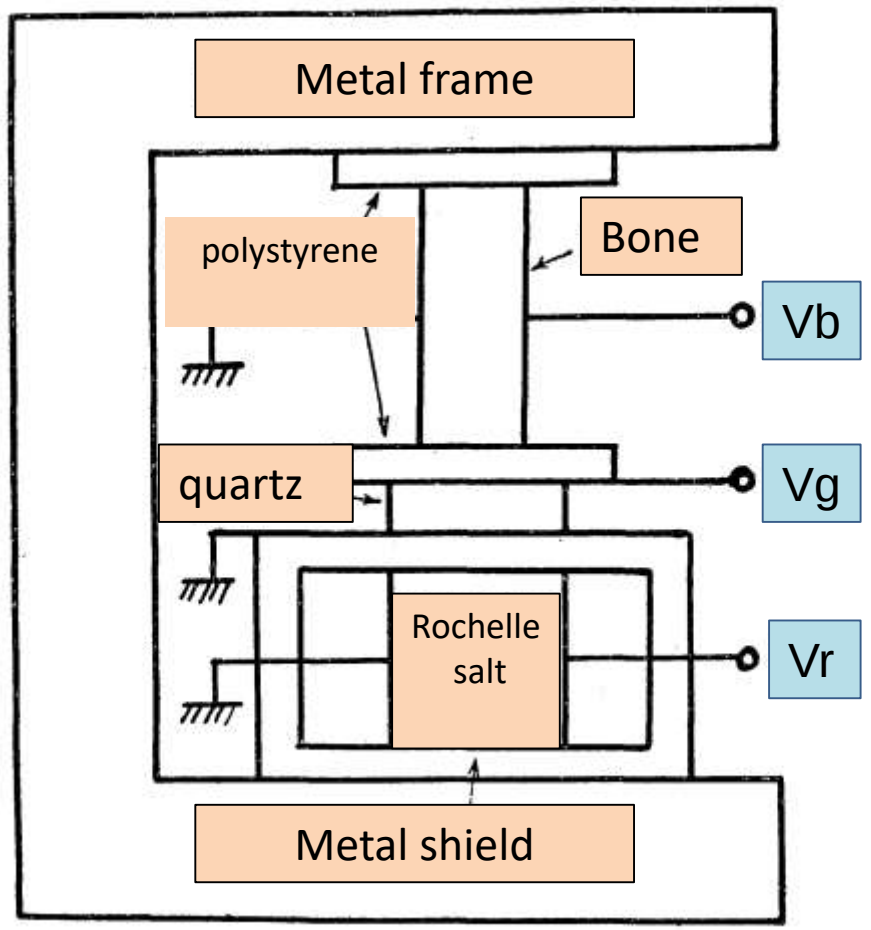
IN OTHER MEDICAL AREAS

- ✓urolithiasis;
- ✓in veterinary medicine (treating orthopedic problems in horses);
- ✓treatment of diabetic foot or non-healing wounds;
- ✓increased blood supply to the heart during angina pectoris and after heart attacks;
- ✓improvement of erection of organic origin and treatment of chronic prostatitis;
- ✓improve the elasticity of the skin with cellulite.

Contraindications to the use of shock wave therapy:

- **EPIPHYSEAL ZONES IN ADOLESCENTS,**
- **THE BODIES OF THE VERTEBRAE**
- in the ribs area,
- bones of the skull,
- large vessels (risk of thrombosis),
- nerve trunks,
- bowel and lung tissue.

Electrical properties of bone tissue



Schematic diagram of measuring device.

Mechanical deformation of the bone is directly related to the electrical potentials of the bone.

An unambiguous connection between the electrical potentials of the bone and its compression was established in 1957. (Fukada E., Yasuda I.).

Previously, it was observed the emergence of electrical potentials in the formation of bone calluses.

(Yasuda I., Noguchi K., Sata T. 1955).

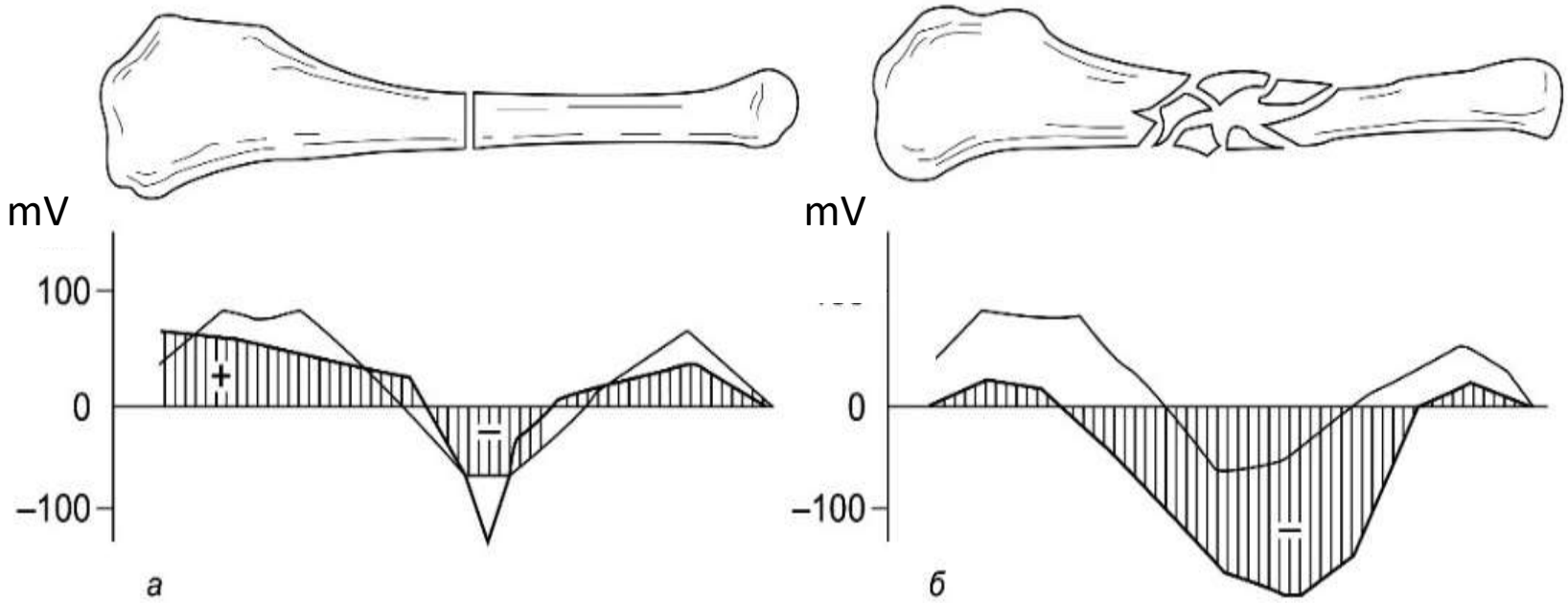
Andrew C. and co-authors hypothesized that the appearance of electrical potentials of bone is a consequence of an adaptive reaction to its compression (1962).

These electrical potentials have a relationship with bone remodeling (Shamos MH., and Lavine LS. 1964).

The reverse piezoelectric effect was also found in the bone.

Fukada E., Yasuda I. On the Piezoelectric Effect of Bone.// J. Phys. Soc. Japan, vol. 12, pp. 1l58-1162, 1957.

Diagrams of longitudinal and transverse distribution of extracortical (on the outer surface of the bone) static electrical potentials (SEP) of the dog's tibia in transverse osteotomy and gunshot fracture



The violation of physiological distribution SEP at the transverse osteotomy (a) and gunshot fracture (б) in the experiment (Tkachenko S., Rutskii V. Electrical stimulation osteoreparation.// L.: Medicine, 1989. – 207c).

Laws of bone growth

Law Hueter-Volkmann (1862)

(Carl Hueter (1838 – 1882) and Richard von Volkmann (1830 – 1889).

compressive load leads to a slowdown in skeletal growth, and stretching, on the contrary, to its acceleration.

Law J. Wolff

(Julius **Wolff,** 1836–1902)

the bone of a healthy person or animal adapts to the loads to which it is subjected, rearranging the orientation of the bone beams.

The Ilizarov effect (1970)

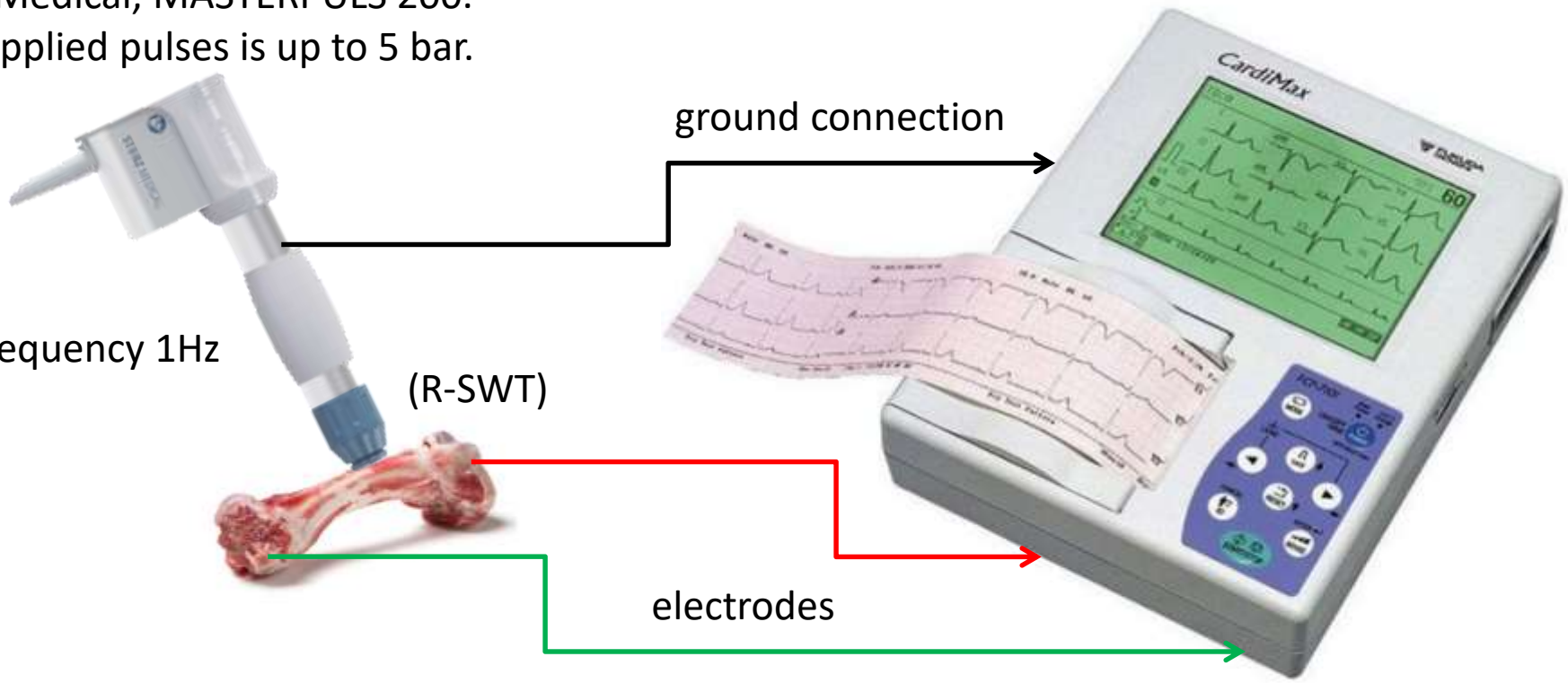
(Gavriil Ilizarov 1921-1992)

is a general biological property of tissues to react to the dosed stresses arising in them, mainly due to tensile stresses leading to growth and regeneration caused by stimulation of biosynthesis processes in tissues

Conducting experiments

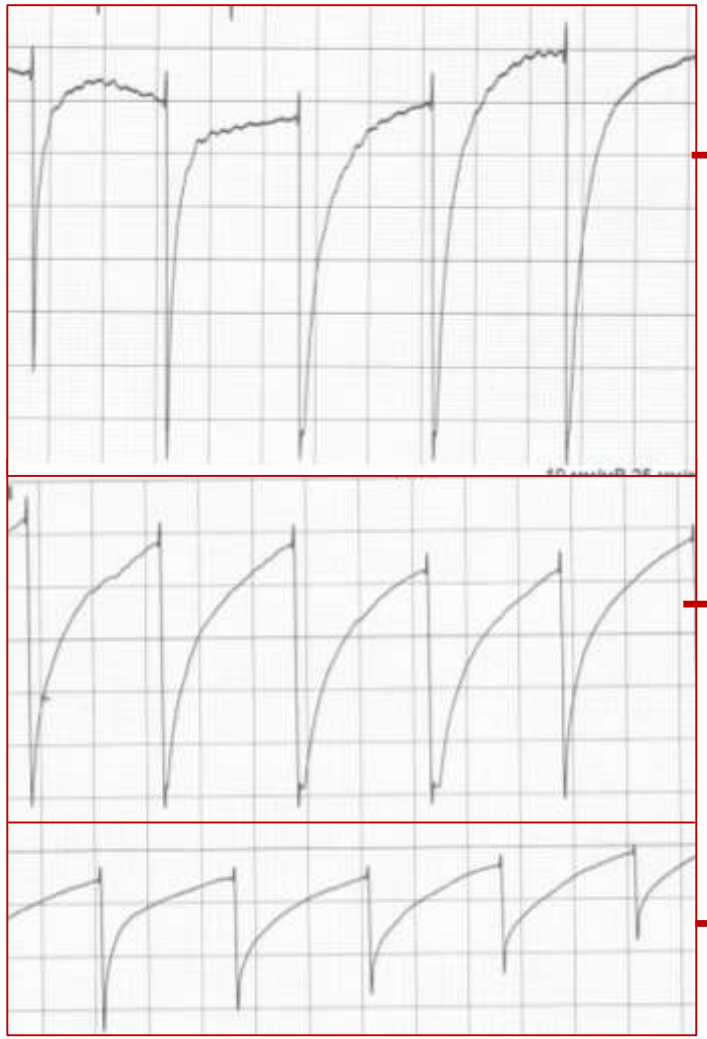
OUR ORIGINAL EXPERIMENT

Storz Medical, MASTERPULS 200.
The pressure of the applied pulses is up to 5 bar.



Analog-to-digital Converter from
the electrocardiograph "Valenta"

Diagrams of electrical signals from the bone when exposed to a shock wave (results of the experiment)



Diaphysis zone, maximum electrical potentials when exposed to bone (up to 40 mV)

Area metaepiphysis, intermediate amplitude electrical potentials under the influence (up to 25 mV)

The area of the epiphysis of the bone, a minimum amount of electric potentials under the influence (up to 15 mV)

NOTE. When exposed to a shock wave into the tendon tissue – potentials have not been registered.

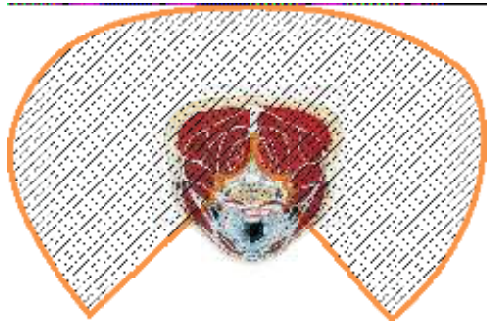
Revealed regularity:

- The higher bone mineral density, the higher piezoelectric charge resulting from the impacting shock wave (the maximum value on the diaphysis, intermediate on the metaepiphyses, the smallest on the epiphysis).
- The piezoelectric discharge decreases exponentially when the source of the radial shock wave is removed from the bone or when the angle of incidence of the shock wave on the bone deviates from 90 degrees.
- The absence of piezoelectric discharges on the tendon can be explained by the insufficient absorption of the shock wave by the tendon tissue due to the difference in the acoustic density of the bone and tendon.

Navigation and zones of application of shock waves to the spine (among our patients are dominated by children with lesions and injuries of the spine)

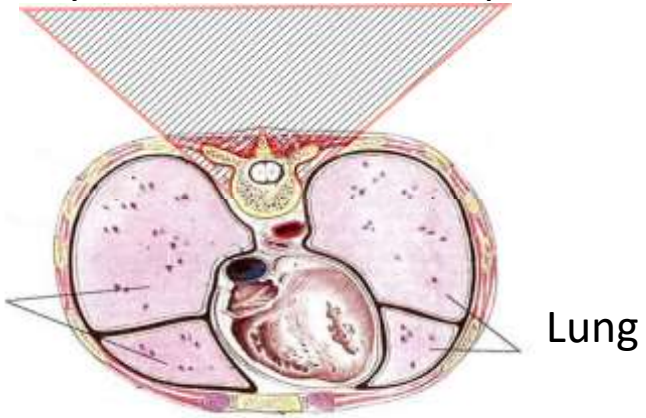
It is advisable to use ultrasonic navigation

Wide area of access to the spine



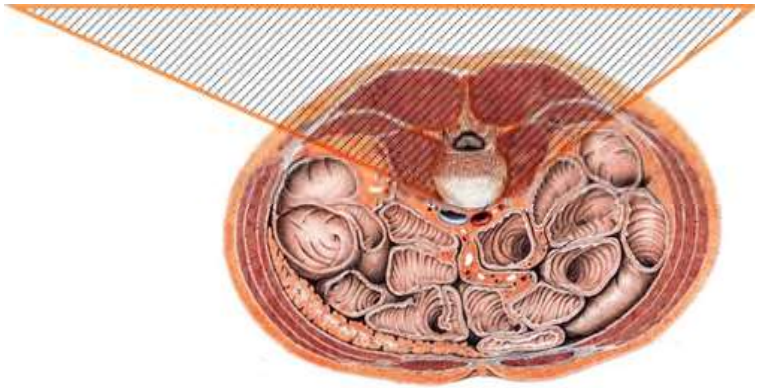
Cervical spine

Only back access to the spine



Thoracic

Back and lateral access to the spine



Lumbar spine

The possibility of a shock wave

- Focused shock-wave therapy will create at any point of the body shock-wave effect of the specified parameters.
- Radial shock wave is advisable to use if possible to create a close contact with the impact zone.

Summary:

- The shock wave causes piezoelectric effects in bone tissue, which may be related to the regulation of bone metabolism and bone growth activity.
- The use of shock waves should be considered as a promising direction for the regulation of the imbalance of bone growth with the aim of treating patients with different types of scoliosis, Scheuermann's disease, exposition of the lower extremities.
- The main point of impact from the shock wave will be the most acoustically dense tissue (with the highest content of calcium hydroxyapatite). For example, in the areas of growth of the skeleton - the area of calcification of dying cartilage, in which it is replaced by a new bone tissue.
- The intensity of the biological effects of the shock wave will also depend on the angle of incidence of the shock wave on the impact zone.

DĚKUJI ZA POZORNOST!

Thank you for your attention

svasilevich@mail.ru