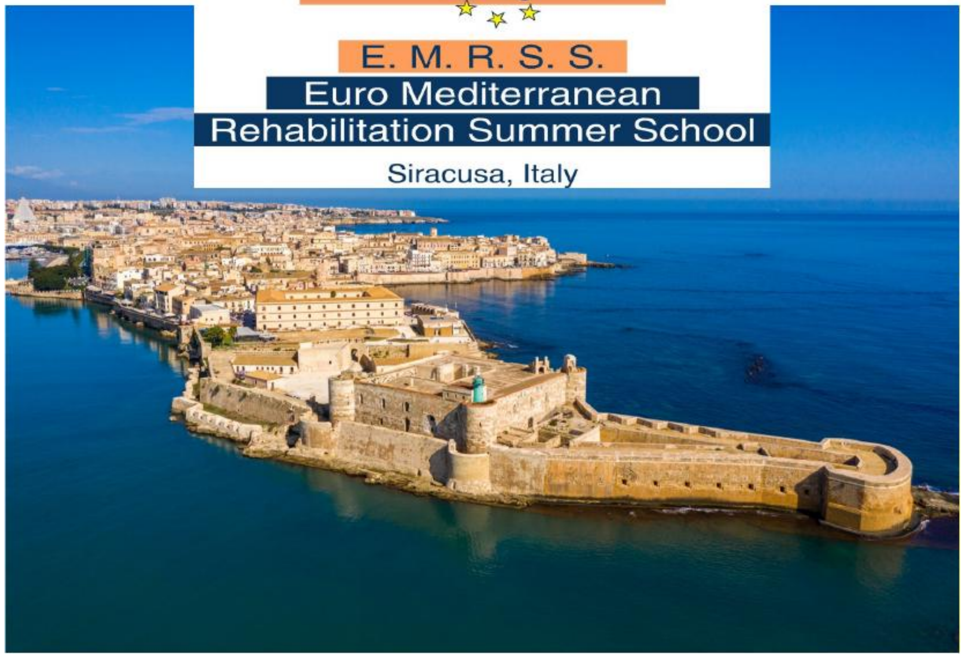
E. M. R. S. S.
Euro Mediterranean
Rehabilitation Summer School
Siracusa, Italy



20th EDITION

REHABILITATION
Yesterday – Today – Tomorrow

Syracuse 16 – 19 October 2025

Physical Therapy..
..in Rehabilitation

AN OVERVIEW OF METHODS, GOALS AND BENEFIT

Valeria Coco, MD

Introduction

- Physical Therapy, also known as physiotherapy, plays a crucial role in rehabilitation.
- It focused on restoring movement, reducing pain and improving the functional capacity of individuals affected by injury, illness or disability

Goals of Physical Therapy

- Relieve pain and inflammation
- Restore joint mobility and muscle strength
- Improve coordination and balance
- Prevent future injuries

Therapeutic Indications

- Orthopaedic conditions (fractures, sprains, arthritis, back pain, ecc..)
- Neurological disorders (stroke, multiple sclerosis, paralysis)
- Rheumatic and inflammatory diseases
- Post surgical and post-traumatic rehabilitation

Main types of Phyisical Therapy

- Electrotherapy – electrical stimulation for pain or muscle recovery
- Thermotherapy – any form of therapy that uses heat for therapeutic purposes
- Ultrasound Therapy- sound waves fot tissue healing
- Laser and Magnetic therapy- promote tissue regeneration
- ....

Analgesic electrotherapy

- These currents are able to reduce pain sensitivity through the removal of algogenic substances from the area where pain occurs, the release of endorphins or through the peripheral and/or spinal block of nociceptive inputs.
- Interferential Current, TENS, High Voltage Current, Horizontal Therapy

Analgesic electrotherapy. Interferential current

- Bidirectional current at low frequency (1-100 Hz) and modulated in intensity

The modulation of F, intensity and duration of the pulse ensures that the nerve does not get used to the stimulus delivered.

Biological effects: F <50 Hz excitomotor effect (1-10 F),

- F > 50 Hz vasodilatation with analgesia (by block of
- sympathetic fibers, modulation of nociceptive afferents)

Analgesic electrotherapy. T.E.N.S.

- Rectangular low frequency current

F: 1-125 Hz, Intensity: 1-80mA, Pulse duration: 30 – 400 μsec

Analgesic effect on spinal block of nociceptive afferents and/or activation of the endorphin system

- Techniques:
- A) high frequency low intensity: rapid analgesia, short duration (2 hours);
- B) Low Frequency High Intensity: late analgesia, long duration (2 days).

Analgesic electrotherapy.
High Voltage

- Direct current with micropulses, double impulses from 1 to 100 per second with pulse duration of a few microseconds (μ)
- Short and Fixed Lifetime: 100μsec; High intensity: 1500-2000 mA;
- Analgesic effect on spinal block of nociceptive afferents and/or activation of the endorphin system

Thermotherapy

- Exogenous Thermotherapy: heat is transmitted from an external medium to the body
- Endogenous Thermotherapy: heat is generated inside the body, with the use of electromagnetic waves
- Effects on muscle tissue: increased vascularity, reduced tone
- Effects on bone tissue: arteriovenous network hyperemia, increased bone trophism
- Effects on tendon tissue: increases collagen elasticity

Hyperthermia TCR: Capacitive and Resistive Energy Transfer (TECAR)®

- Joule effect from movement of ionic charges: thermal energy is not delivered from the outside, but generated directly in the tissue by ionic currents
- Capacitive mode, target muscles and subcutaneous soft tissues by heat transfer from the active ceramic electrode
- Resistive Mode, Target Bone, Periosteum, Tendons, Ligaments, Aponeurosis, Capsule

TCR Hyperthermia: Capacitive and Resistive Energy Transfer (TECAR®) – Biological Effects

- Analgesic: direct action on receptors and increased endorphins secretion
- Reduction of joint contractures and stiffness
- Increased elasticity of the connective tissue
- Increased cellular metabolism
- Stimulation of the immune system
- Deep hyperemia (O2 increase, wash out, edema resorption and effusions)

Hyperthermia TCR: Capacitive and Resistive Energy Transfer (TECAR)® – Energy Level of Treatment

- LOW (50-100 W) biostimulation, hypoalgesic, poor thermic effect
- MEDIUM (100-200 W) biostimulation, initial thermic effect, increased metabolism, microhyperemia
- HIGH (200-300 W) marked thermal effect, poor biostimulation effect, marked hyperemia, increased venous and lymphatic drainage

LASER (Light Amplifiation by Stimulated Emission of Radiation)

It consists of 3 fundamental elements:

- **Active material** that, once excited, is able to emit its own energy source and characteristic of the wavelength of the material itself
- **The external energy source**, which has the function of stimulating the active material,
- **The optical resonance chamber**, which consists of two parallel mirrors that determine the amplification of energy
- They are distinguished according to the Power or the Source.
- Power: Low Level (<1 W/cm2)(He-Ne, semiconductor), High Level (> 1 W/cm2)(Nd-Yag)
- Source: semiconductor (diode), helium-neon, carbon anhydride, neodymium-Yag

LASER (Light Amplifiation by Stimulated Emission of Radiation)

- **THERAPEUTIC EFFECTS**
- Anti-Inflammatory Effect (they create active hyperemia with a wash out effect on pro-inflammatory substances, they activate phagocytes that remove harmful substances)
- Analgesic effect: induces blockade of the action potential in nociceptive endings, interact with large-caliber myelin fibers, increase endorphin synthesis
- Biostimulant effect; increase ATP synthesis, a process that promotes cellular energy processes, promotes cell replication and protein synthesis, facilitating reparative processes

PENS. Percutaneous Electrical nerve Stimulation

- PENS is a mini-invasive neuromodulation technique that alters nerve impulses at the subcutaneous level and might be effective in chronic and refractory pain management

MECHANISM of ACTION

Positive effects in neuropathic pain management involve the physiological gate control theory,

The gate control regulation theory indicates that inhibitory interneurons at the spinal level are the keys that might open or close “the gate” to the painful sensation.

A large heterogeneity of interneurons has been identified, both excitatory (pain facilitation) and inhibitory (pain inhibition).

It has been hypothesized that specific anterograde signals might play a crucial role in gate control regulation.

The precise mechanisms underpinning inhibitory interneurons spinal circuits are far from being fully understood

PENS. Percutaneous Electrical nerve Stimulation

MECHANISM of ACTION

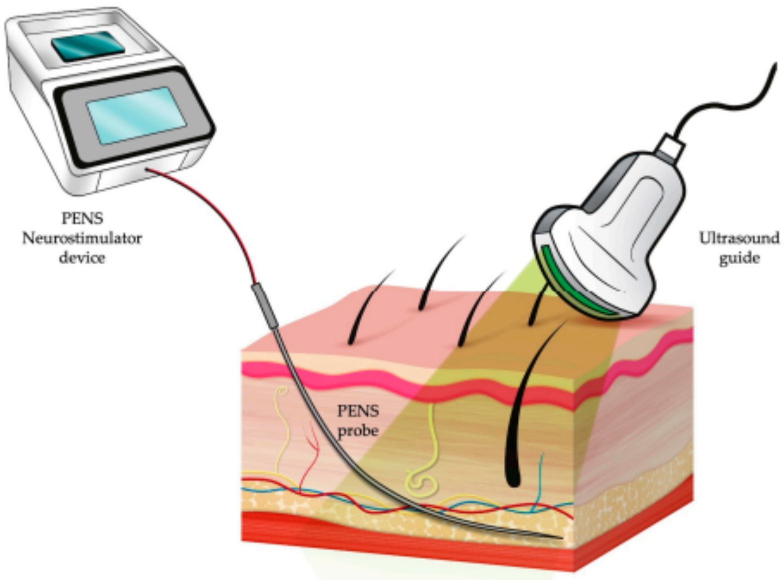
Pain relief induced by PENS treatment is mediated by both Aβ fibers modulation and the local release of biochemical mediators such as neurotransmitters and endorphins,

An orthodromic stimulus applied on non-nociceptive Aβ nerve fibers activates respective dorsal horn interneurons and transmits the nociceptive information to peripheral Aβ and C fibers .

According to this neurophysiological dynamic, a nonpainful stimulus applied in a peripheral nerve territory can generate a decrease in pain signals.

PENS. Percutaneous Electrical nerve Stimulation

- PENS consists of a subcutaneous neuromodulation of nerve structures, through 21gauge 5 to 20 cm length modellable needle-electrode monopolar probes, inserted in the skin; then, the probe is tunneled percutaneously through the use of an ultrasound guide along the major axis of the painful area, within the subcutaneous tissue at a depth ranging from 0.5 to 3 cm



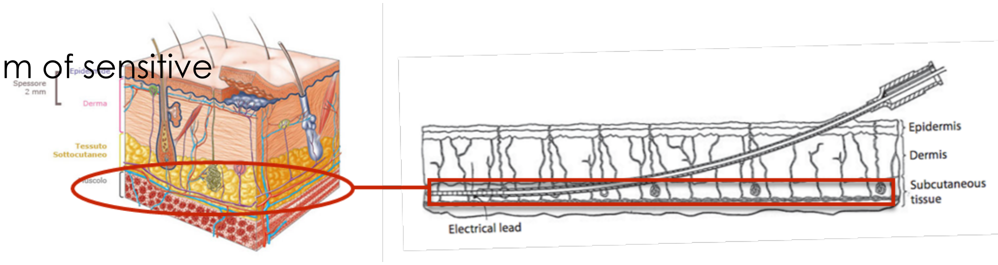
PENS. Percutaneous Electrical nerve Stimulation

MATERIAL

ELECTRODE:

Available in various lengths with a 21G diameter.
Atraumatic tip (pencil-shaped).
The electrodes are flexible and malleable, allowing them to be shaped to adapt to the different anatomical structures being treated.
Depending on the size of the area to be treated, it may be necessary to use a short electrode, or for larger areas, a longer one, or even two electrodes simultaneously.
Any bending does not compromise functionality

The probe is connected to a neurostimulator device with a program of sensitive stimulation at 100 Hz.



PENS. Percutaneous Electrical nerve Stimulation

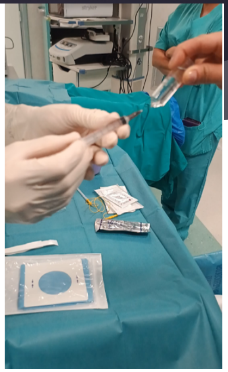
Therapeutic indications

- Occipital neuralgia and occipital pain
- Supraorbital neuralgia
- Trigeminal and facial neuralgia
- Cervicobrachialgia
- Chronic post-surgical pain
- Intractable headaches
- Surgical scar (lumbar, inguinal, occipital)
- Shoulder neuropathy

- Post-traumatic cervical pain
- Post-surgical dorsal pain
- Paravertebral dorsal pain
- Stump pain
- Localized low back pain
- Pain following hernia surgery
- Pain following mastectomy
- Presacral and inguinoscrotal pain

PROCEDURE

- Preparation of the sterile field.
- Anesthetic wheal.
- Use an 18G needle to facilitate electrode insertion.
- Ultrasound-guided percutaneous insertion of the electrode along the center of the target area, according to the chosen trajectory.
- Connection of the electrode to the Stimulator.
- Start of treatment: increase the intensity until the optimal level is reached.
- Treatment duration: 25 minutes.
- End of treatment and electrode removal.



ADVERSE EVENTS and CONTROINDICATION

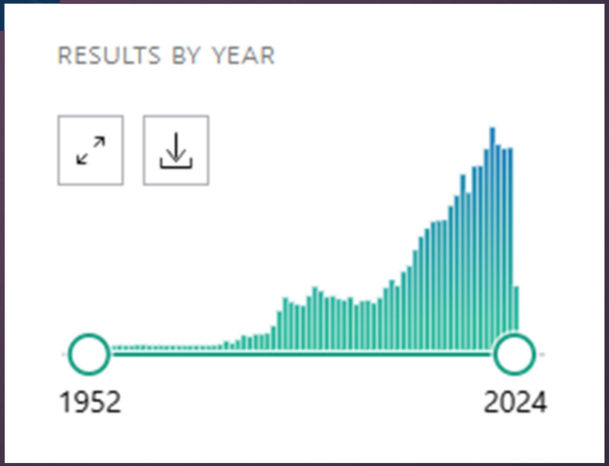
The most common adverse event was a mild discomfort during the probe implantation and/or Withdrawal

PENS is not devoid of contraindications that are mainly related to the infective risk

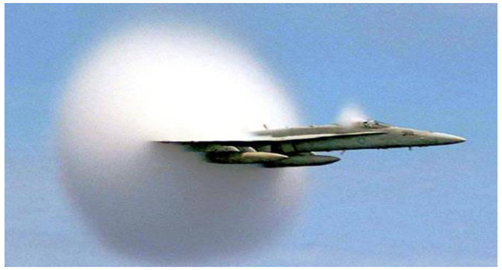
An implanted pacemaker/defibrillator or neurostimulator is considered a common contraindication

LITERATURE EVIDENCE

PubMed.gov



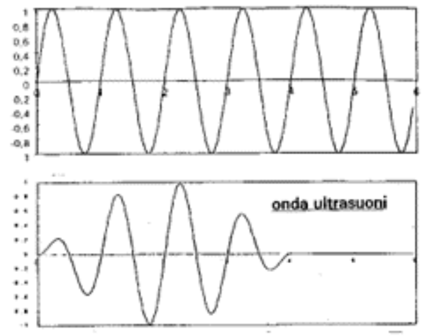
Shock waves are in nature or caused by humans

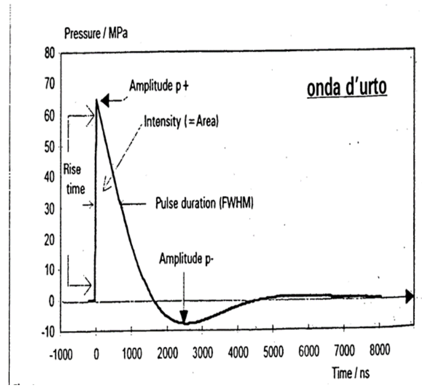


Pulses of mechanical pressure that propagate as acoustic waves

Focused Shock Waves

- Shock waves are acoustic pulses characterised by high positive pressure amplitude and a steep pressure increase compared to the ambient pressure.
- They are capable of temporarily transmitting energy from the point of generation to remote regions
- Despite their similarity to ultrasound, shock waves have substantially higher pressure amplitude than ultrasound waves. In addition us waves are periodic oscillations with a limited bandwidth. SW on the other hand,are characterised by a single, mostly positive pressure pulse, which is followed by a comparatively small tensile wave component (negative pressure pulse)

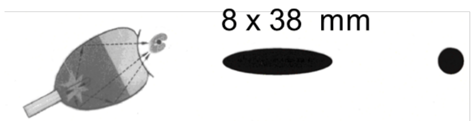




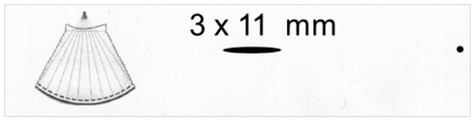
Generation of focused shock waves

- Focused shock waves can be generated by means of electro-hydraulic, piezoelectric or electromagnetic generators. Electro-hydraulic systems produces shock waves directly at the source of generation. The other two generators create shock waves as a result of wave steepening and superposition, which means that the shock waves only forms in the focus. The fact that shock waves produced by different types of generators have differently sized focal zones plays a key role from the medical point of view.
- SW generated with a piezoelectric generator have the smallest focus, while those generated by electro-hydraulic have the largest focus. From this it is concluded that the SW dose required for a specific treatment partly depends on the type of generator used

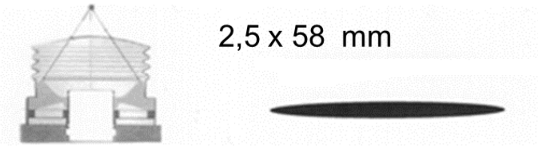
Generation of focused shock waves



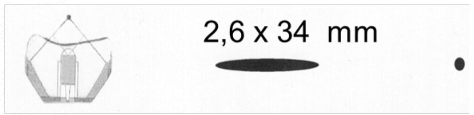
Electrohydraulic



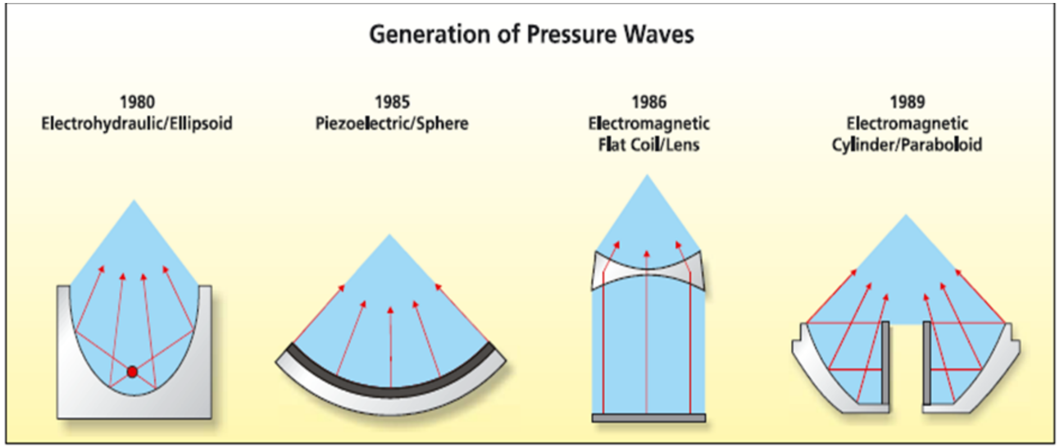
Piezoelectric



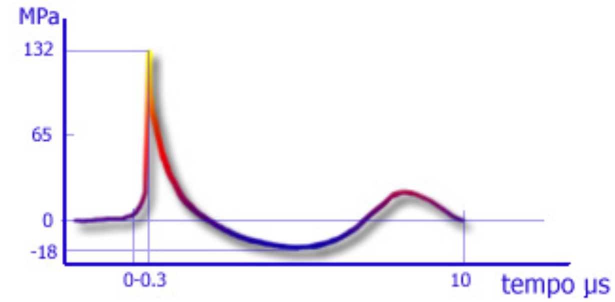
Electromagnetic,
flat coil



Electromagnetic,
cylindrical coil



Extracorporeal Shock Wave Therapy



Therapeutic shock waves were defined by the

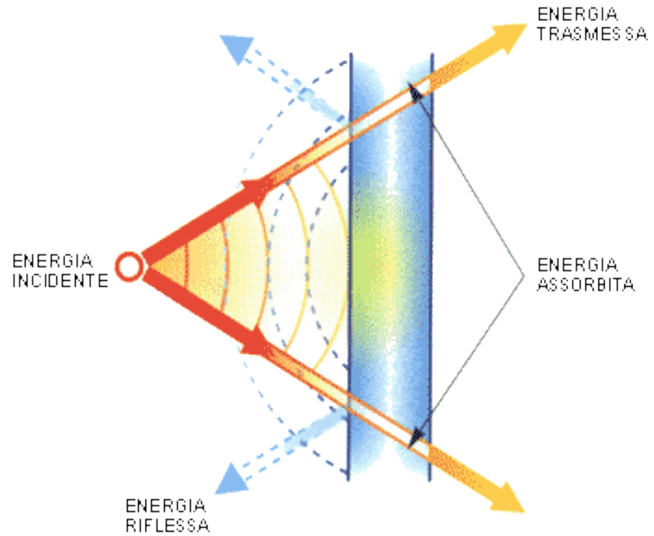
- Shock Wave Therapy Consensus Group (1997)
- and the ISMST Consensus Statement (2011) that
- have fixed its physical parameters as superposition waves
- to those used for lithotripsy (E.S.W.T. = E.S.W.L.)

A shock wave is an acoustic wave, characterized by
Rapid pressure rise (< 10 ns)
High peak pressure (> 500 bar = 50 MPa)
Short duration (< 10 µs)
It can also be defined as an impulse wave

ISMST

Shock Wave in the body

In the passage of tissues with different densities,
Shock Wave is:
TRANSMITTED – ABSORBED – REFLECTED – REFRACTED



In the human body, therefore, it can undergo
significant changes in its progress
from the outside to the target point of its application

The therapeutic protocol ...

… It depends on focal dimension of the wave generated and the number of shots to be administered depends on the target to be treated in consideration of the type of generator used.

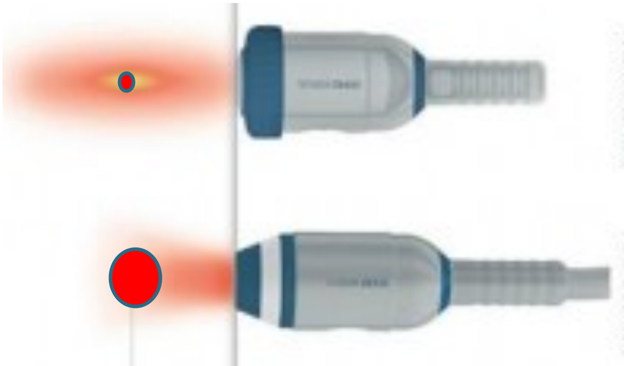
The number of therapeutic SW in relation to the characteristic focal size of each device can be schematized as follows

- *Electro-hydraulic 1*
  Electromagnetic 1.5/2
  Piezoelectric 2 / 2.5

Focused and defocused shock waves

FOCUSED

DEFOCUSED



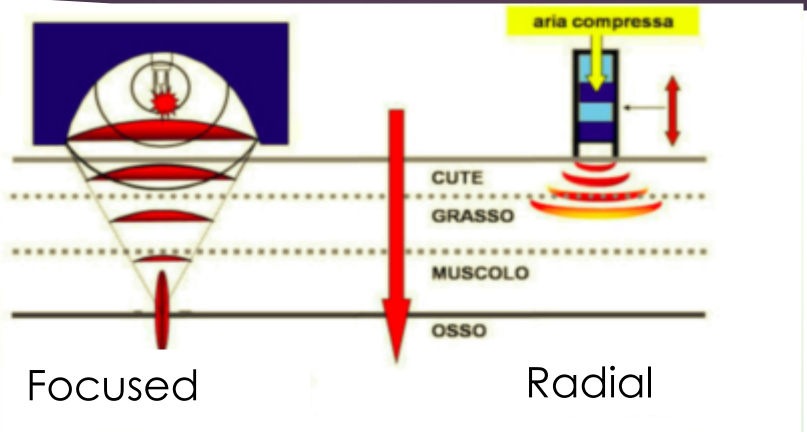
Energy density: 0.05 to >0.25 mJ/mm2

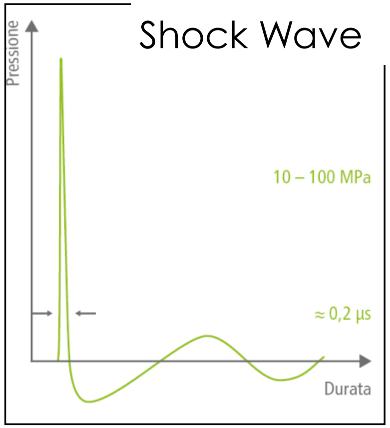
Energy density: 0.01 to <0.18 mJ/mm2

↓ Increased Focal Section

↓ Decreased Energy FD

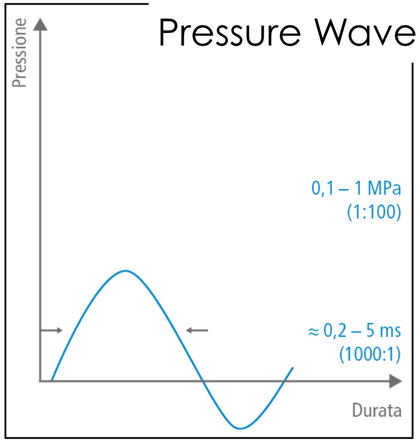
Differences between Shock Waves and Radial Waves





< 10 µs	Pulse duration	1000 µsec
< 10 ns	t Peak pressure	500 µsec
> 500 bar	Pressure	1–5 bar

They cannot be considered shock waves
International Consensus Conference - 1999



How do these phenomena of transformation of an acoustic stimulus into activation of biological processes occur?

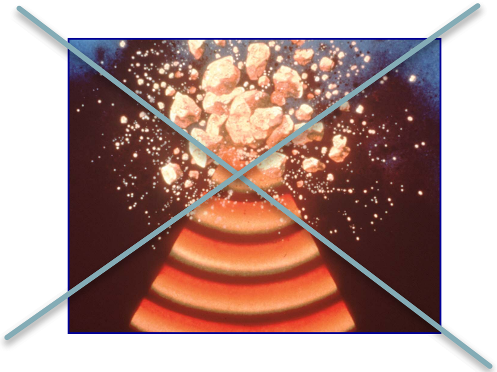
The hypothesis is that the transduction of acoustic energy to biological tissues occurs through the phenomenon of mechanotransduction

Limitations of the Mechanical Model

- The mechanical model is questioned when Schaden et al. (2001) show that with fewer shocks and a lower energy per pulse (therefore less total amount of energy) they are more effective in the treatment of pseudarthrosis
- Maier et al. (2002) demonstrate a greater osteostimulation response in the rat femur with energy levels below the reference levels for cellular mechanical damage
- Martini et al. (2003) verify on osteoblastic cell lines a different response of activation of cellular biological mechanisms and cell damage in relation to the intensity of energy flow used

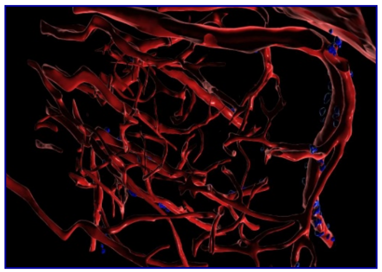
From the mechanical to the biological model

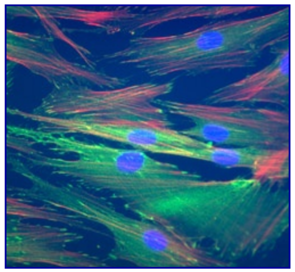
The **mechanical** interpretive model explained the tissue reaction as a response to shock wave-induced micro-injuries with a consequent activation of cellular repair mechanisms

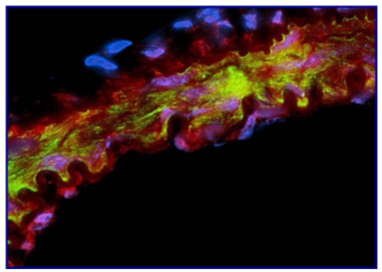


Biological Model

Several AA. (Neuland, Gerdesmeyer, Suzuki, Frairia, Russo, d'Agostino, Wang) have testified to the biological effects of the reactions provoked at the cellular level by shock wave stimulation







Mechanotransduction

It consists of a biological response on an electrochemical basis of cellular structures to the acoustic stimulus (analogous to how electrical variations induce an acoustic phenomenon)

Immediate function response

Tissue plasticity including structural and functional adaptations

The target of stimulation is both active and passive structures

Muscle tissue

Endothelial tissue

Epithelial tissue

Connective tissue

Jaalouk and Lammerding, Nature 2009

Table 1. Main therapeutic effects of extracorporeal shock wave therapy.

Therapeutic Effects	Biological Effects
Analgesic effect	Decreased substance P in the area of application [9]
	Selective loss of unmyelinated nerve fibers [10]
	Decreased expression of calcitonin-related peptide in dorsal root ganglia [11]
	Activation of the serotonergic system [12]
Tissue repair effect	Proliferation of tenocytes [13]
	Activation of catabolic processes leading to the elimination of damaged matrix constituents [14]
	Microdisruption of avascular or poorly vascularized tissues [15]
	Increased tissue neovascularization [16]
	Enhanced collagen synthesis, maturation and characteristics [17]
	Regulation in proliferation, activation and differentiation of keratinocytes originating from scar tissue (antifibrosis) [18]
Osteogenic effect	Osteoblast growth through osteogenic transcription factors such as vascular endothelial growth factor-A (VEGF-A) and hypoxia-inducible factor-1α [19]
	Regulation and stimulation of chondrogenesis and bone regeneration through mesenchymal stem cell metabolism [20]
	Enhancement of Pdia-3 expression involved in the 1α,25-Dihydroxyvitamin D 3 Rapid Membrane Signaling Pathway, related to calcium homeostasis [21]
	Stimulation of the periosteum with decreased osteoclast activity [22]
	Osteoblast proliferation and differentiation through regulation of nitric oxide (NO), protein kinase B (PKB), bone morphogenetic protein-2 (BMP-2) and transforming growth factor-beta 1 (TGF-β1) levels [23]

Biological effects of Shock Waves

Modification of the permeability of cell membranes

Anti-inflammatory effect

Stimulation of the production of NO (Nitric Oxide)

Stimulation of the production of growth factors (VEGF, BMP´s, OP´s, etc.)

Stimulation of mitochondrial activity and increase of presence of ATP

Effect of neo-angiogenesis and neo-vasculogenesis

Mobilization, Migration and Differentation of Stem Cells

At Energy Flux Density Levels ≥ 0.30 mJ/mm² onset of damage phenomena of cellular structures
Martini et al. 2003

In case of ……

- Tendonitis, Tendinopathy
- Calcific tendonitis
- Plantar fasciitis
- Epicondylitis, epitrochleitis,
- Pseudoarthrosis
- ………………

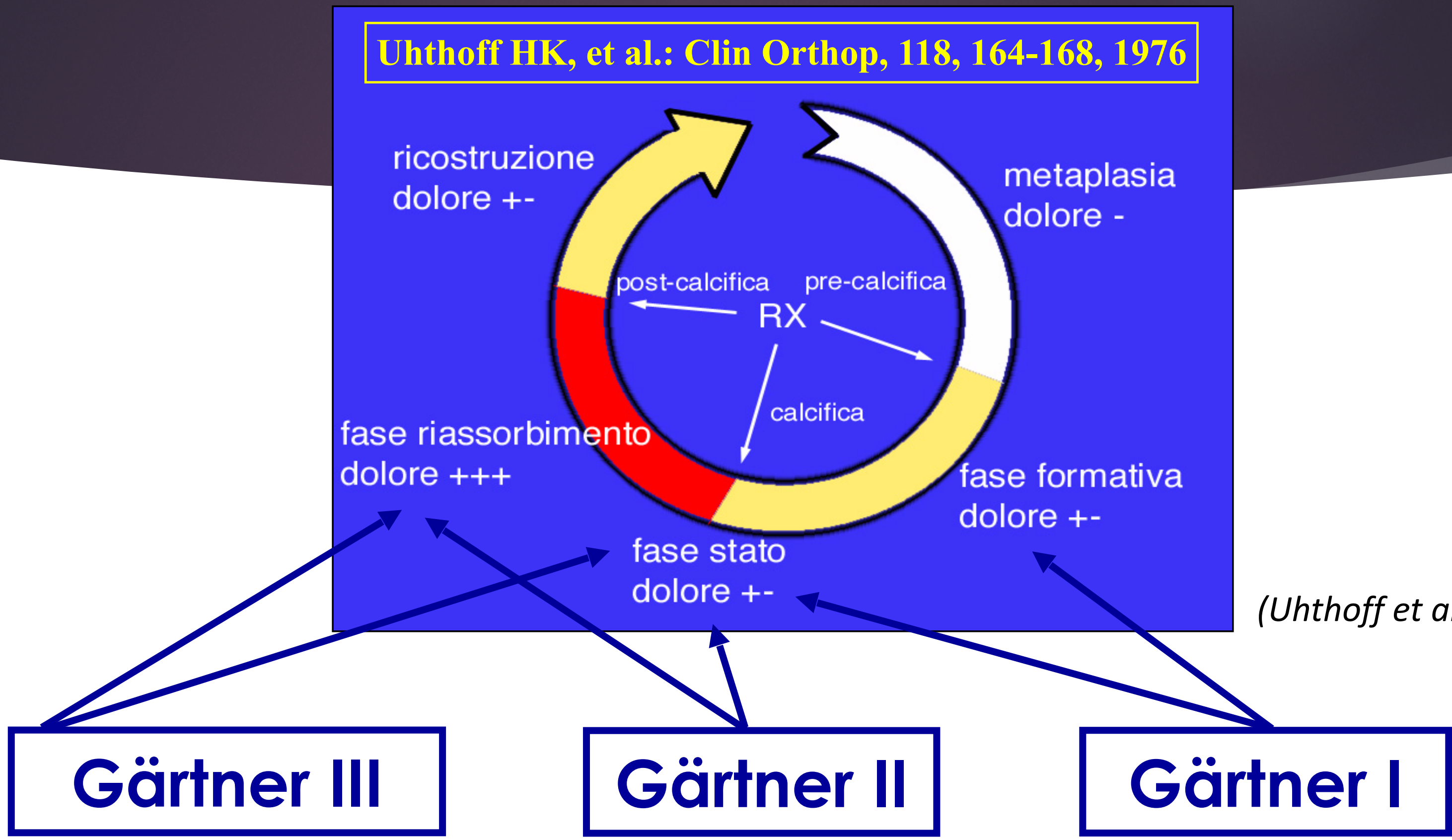
Etiology of tendinopathies

- Impingement syndrome resulting in vascular damage, ischemia, tenocyte apoptosis, tendinopathy and frictional tendon damage (Harrison and Flatow, 2011)
- Overloads and repeated movements - hyperabduction and extrarotation - (Burkhart et al., 2003, Rudzki et al., 2008)
- Mechanical damage due to overuse (Greenberg, 2014)
- Post -Traumatic (Weiss et al., 2018)

Etiology of tendinopathies

- Physiological age-related degeneration of tendon structures with alteration of the orientation of collagen fibers and myxoid degenerationof bone structures due to arthritic alteration (Longo et al., 2007)
- Genetic, hormonal and metabolic factors (Abate et al., 2013, Harvie et al., 2017)
- Smoking, alcohol and lifestyle (Zabrzynsky et al., 2021)
- Psycho-social factors (Wong et al., 2020)

Evolution of calcification



(Uhthoff et al, 1976)

cloudy at the margins
not well defined

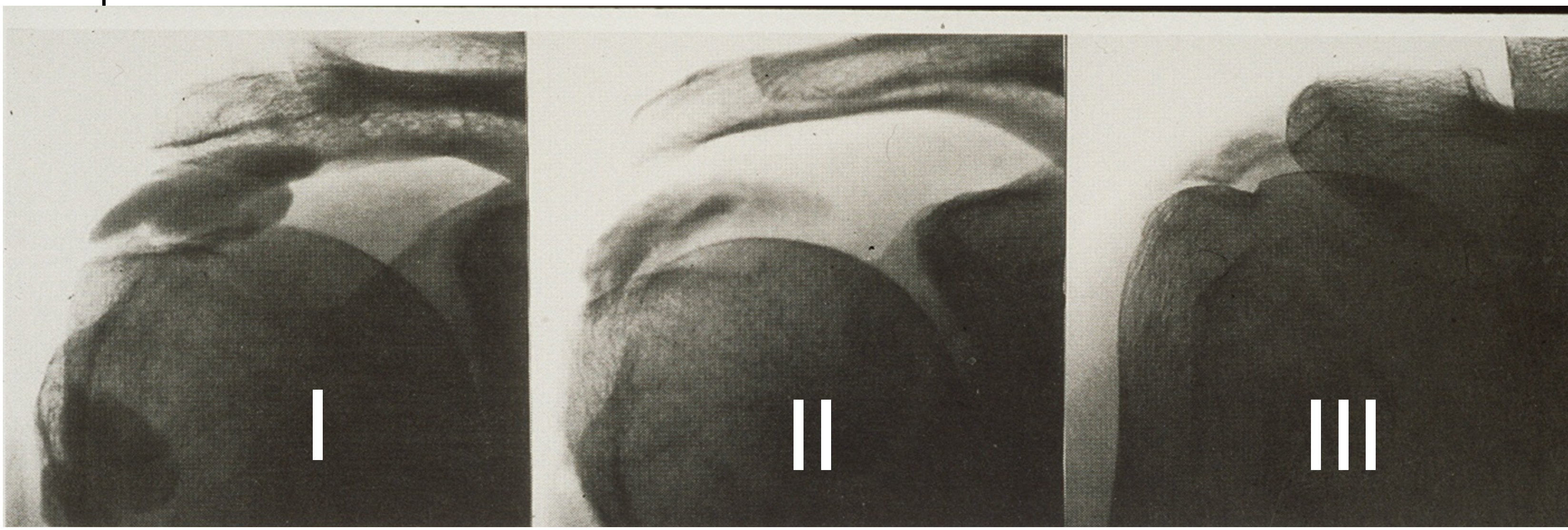
intermediate

dense and at the edges
well defined

Characteristics of calcification

Gärtner I: Defined margins, homogeneous structure
Gärtner II: Defined margins, inhomogeneous structure
Gärnter III: Undefined margins, inhomogeneous structure

(Gärtner, 1993)



Symptoms

- Shoulder pain often referred to the deltoid, present at night and during the day in specific movements (intrarotation and retroposition)

Painful functional limitation in one or more planes of motion

Progressive worsening of pain and function with reduced movement

What happens to calcifications

- The data varies for the different authors

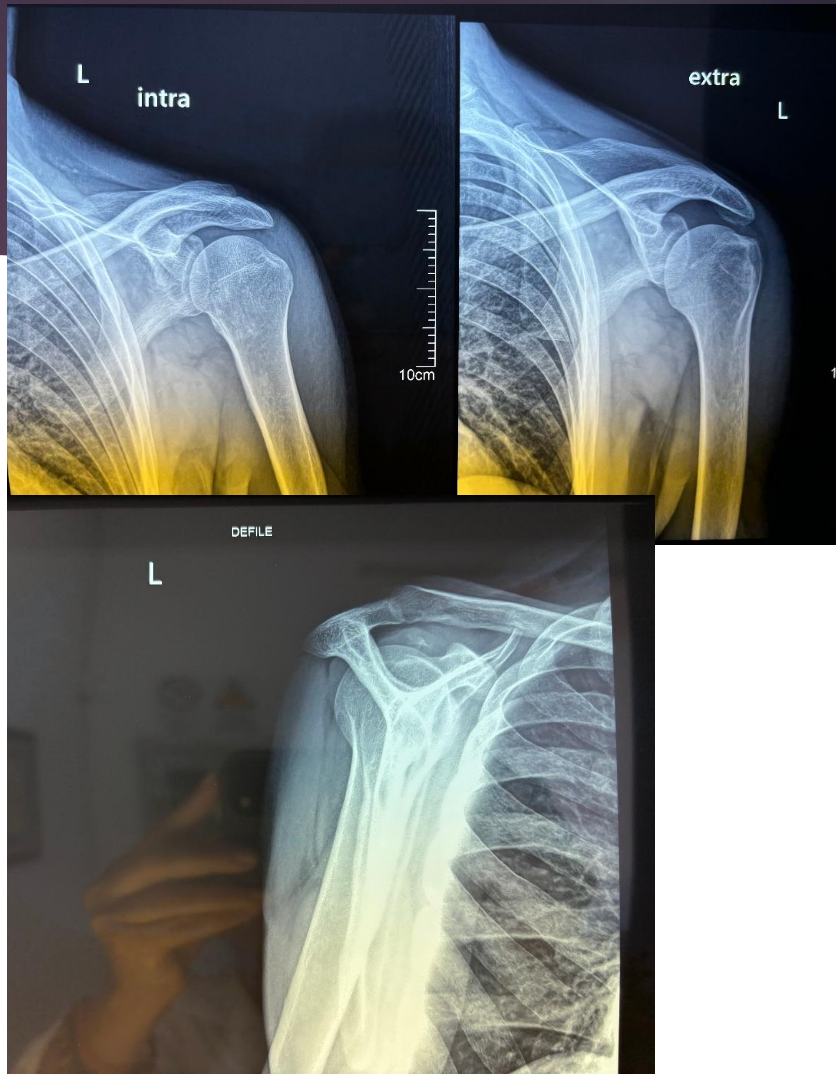
about 1/3 of cases are completely reabsorbed

about 1/3 of cases change

about 1/3 of cases remain unchanged

The figure does not appear to be closely related to the trend of the clinical picture


intra
L
10cm
L
extra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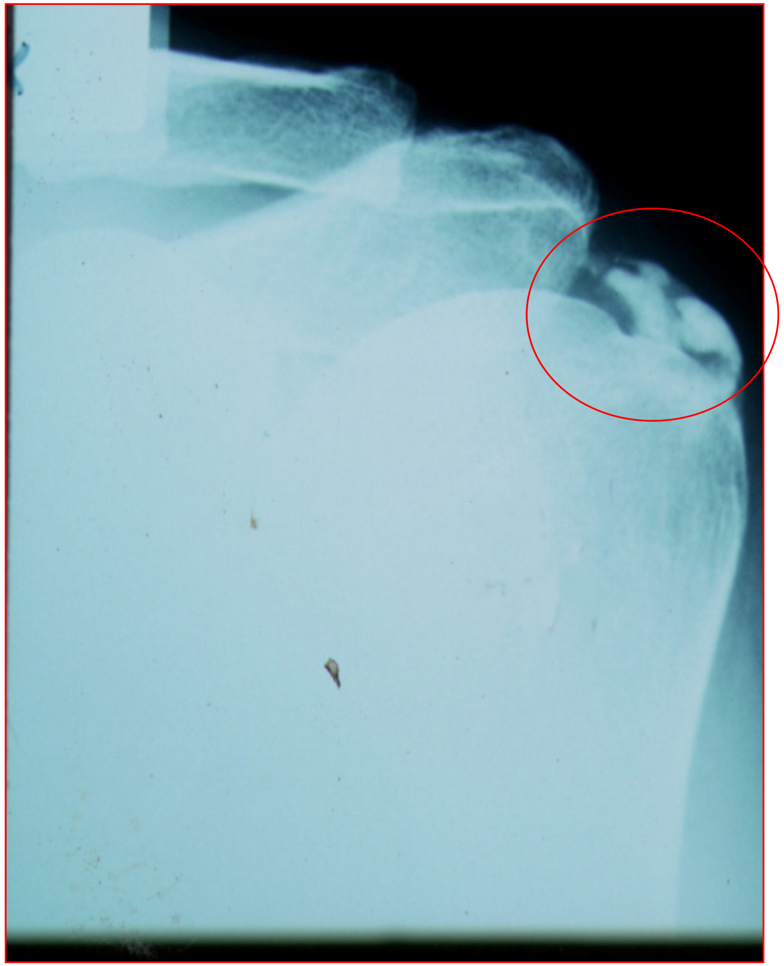
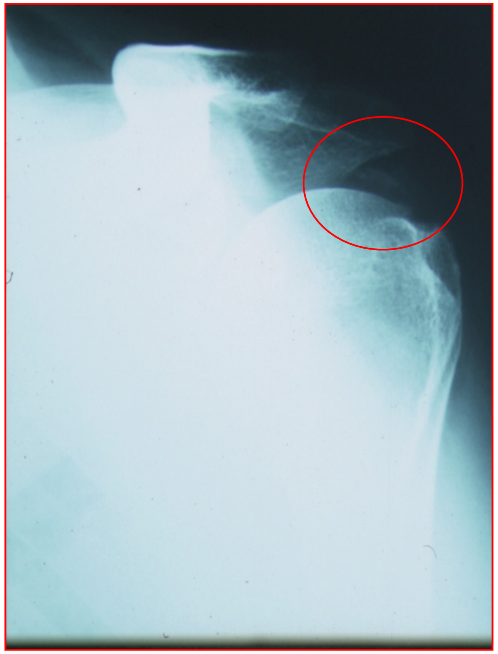


Before

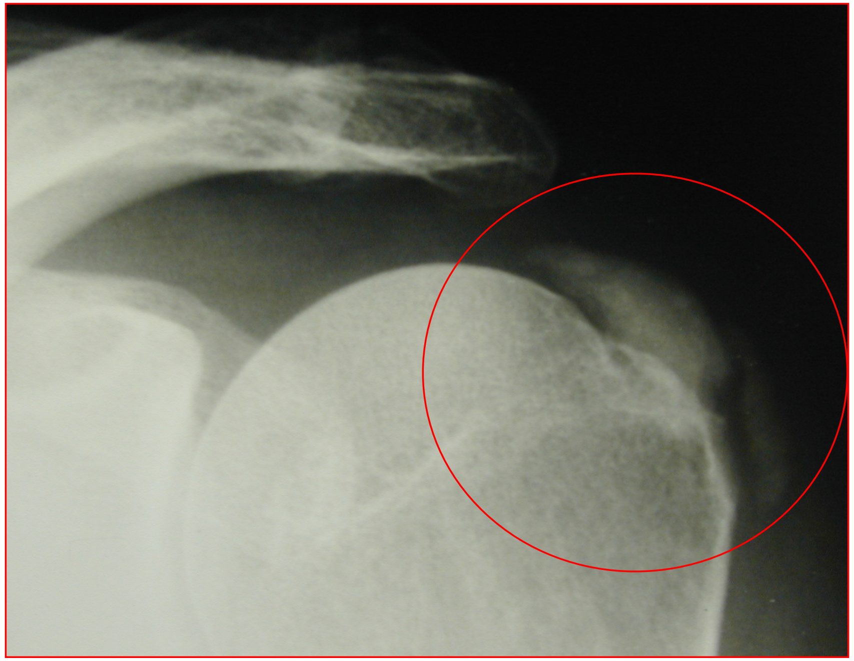
Follow up 6 m.

Before

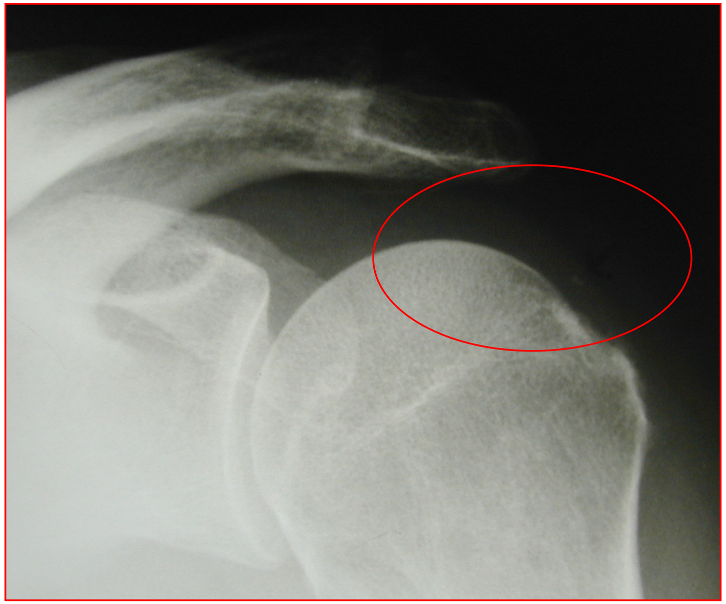


Post.1° t.

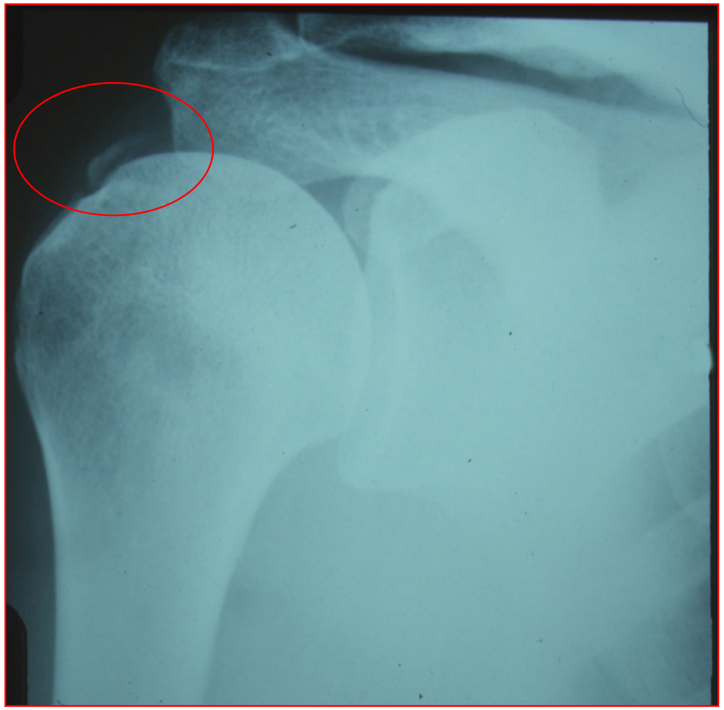
Follow up 6 m.



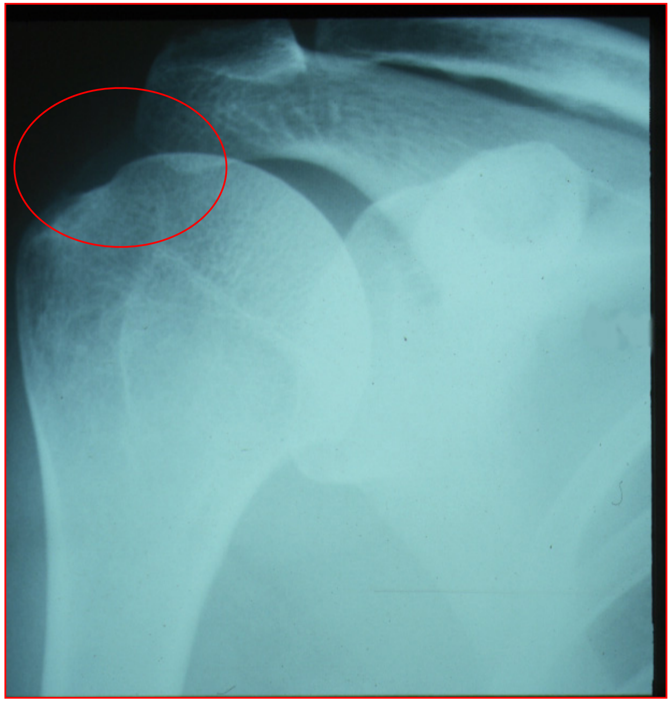
Before



Post



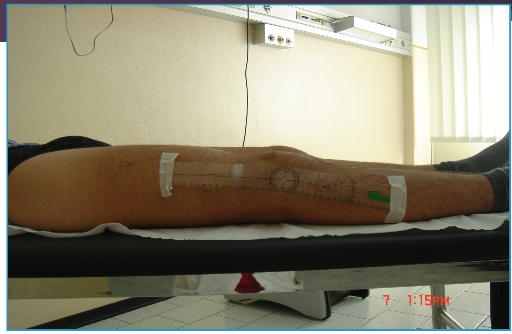
Before



Post

IN PSEUDOARTRHOSIS

Myositis Ossificans



Before

After 1 m.

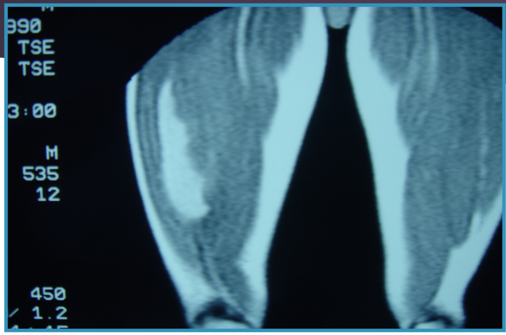
9 m

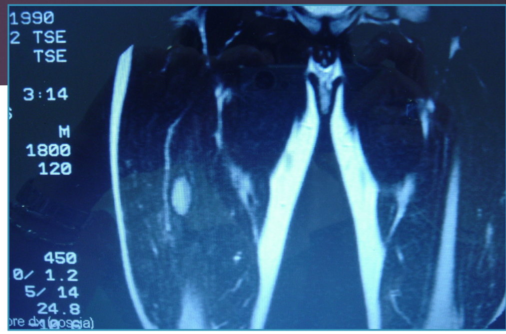
X Ray

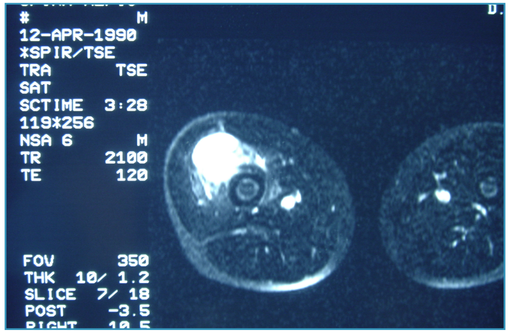
Before eswt

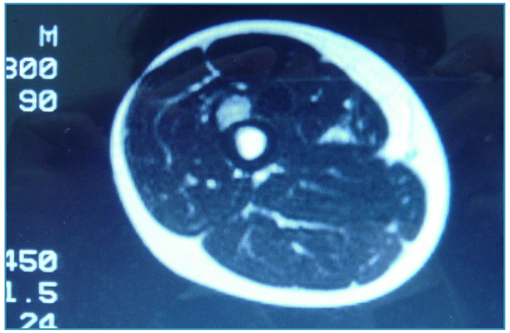
F. up 9° m.

M.N.R.









Before eswt

F. up 9° m.

Shock waves in the treatment of skin lesions

From mechanical stimulus to biological effect = MECCANO - TRANSDUCTION

RIDUZIONE DEL BIOFILM

STIMOLAZIONE DELLA RIGENERAZIONE TISSUTALE

BMC Musculoskeletal Disorders

BioMed Central

2009

Research article

Open Access

The management of neuropathic ulcers of the foot in diabetes by shock wave therapy

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- stimulation of physiological angiogenesis thanks to the release of NO and vascular growth factors at the ulcer site

stimulation of the early expression of angiogenic growth factors (eNOS, VEGF and PCNA)

improves local blood supply, increases cell proliferation and accelerates tissue regeneration and ulcer healing

Possible mechanisms of action of EWSTs

• They stimulate the reorganization of the endothelium and stimulate the processes of epithelialization
Increase the release of endogenous angiogenic factors from endothelial cells and fibroblasts and local growth factors
Call appropriate stem cells in the target area
Stimulate revascularization

accelerate the healing process of chronic wounds

Fioramonti et al., Ann Ital Chir **2012**

Volume 20, Issue 4, pages 456–465, July-August 2012

Wound Repair and Regeneration

Extracorporeal shock wave therapy (ESWT) for wound healing: Technology, mechanisms, and clinical efficacy

Rainer Mittermayr, MD[1,2]; Vlado Antonic, MS[5,6]; Joachim Hartinger[1]; Hanna Kaufmann, MD[3]; Heinz Redl, PhD[1]; Luc Téot, MD, PhD[4]; Alexander Stojadinovic, MD[5]; Wolfgang Schaden, MD[2]

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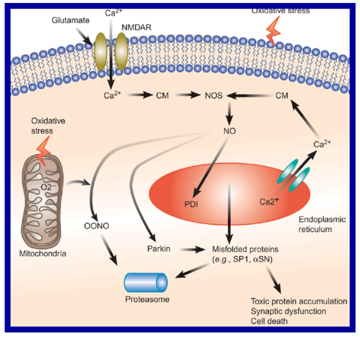
4. Burns Unit, Wound Healing Unit, Lapeyronie Hospital, Montpellier University Hospital, Montpellier, France,
5. Combat Wound Initiative Program, Washington, DC, and
6. Henry M Jackson Foundation for the Advancement of Military Medicine, Bethesda, Maryland

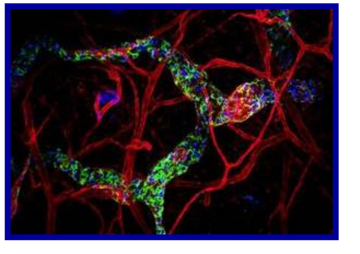
2012

Nitric oxide (NO) plays a vital role in improving blood flow and reducing local tissue inflammation

Nitric oxide (NO) in combination with VeGF has an important action in modulating the different processes of angiogenesis



it was shown that the physical properties of shock waves are translated to complex biological responses including release of factors, cytokine, and chemokines involved in enhanced tissue perfusion and angiogenesis, both essential for the wound healing cascade.



Therapeutic effects on skin lesions

Injuries from systemic diseases

diabetic ulcer

ulcer due to alteration of nutritional status

(hypoalbuminemia, dysproteinemia)

Schaden et al., J Surg Res 2007

2005

Dermatology Times

The Leading Newsmagazine for Dermatologists www.dermatologytimes.com Vol. 26, No. 9 September 2005

Study shows shock wave therapy helps heal various skin lesions

By Lisette Hilton
Staff Correspondent

Vienna, Austria — A new study suggests that extracorporeal shock wave therapy (ESWT) is highly effective in treating patients with several types of skin lesions, including venous ulcers and burns.

Researchers presented their findings at the 8th International Congress on Shock Wave Therapy in Vienna.

Lead author Wolfgang Schaden, M.D., a trauma surgeon working in the Trauma Center, Meidling, Vienna, reported on the study of 104 participants, 44 with post-traumatic lesions, 25 with venous ulcers, 15 with arterial ulcers, and the others with postoperative healing disorders, decubital ulcers or burns.

The study

Researchers in Vienna and Berlin treated participants' skin lesions with ESWT between September 2004 and January 2005. They used low energy flow densities — depending on the defect size, with the number of impulses varying from a few hundred to several thousand. No anesthesia was necessary, because they used a defocused shock wave.

"We did not use anesthesia, antibiotics (unless participants were already taking them) or debridement," Dr. Schaden says.

Figure 1 shows the forefoot of a 47-year-old male patient injured by a rotating ship's propeller just before the first shock wave treatment.

Figure 2 shows same patient three weeks later, before the third shock wave treatment.

Figure 3 shows the lesion three weeks later, before the fourth treatment.

Figure 4 shows the healing status after a total of six shock wave treatments (total time 15 minutes), 11 weeks after starting the therapy.

Photos: Wolfgang Schaden, M.D.

Injury following an open fracture

52 year old man
(1 treatment every 15 days, total 12 treatments)

Before

After 6 m

Injury in diabetes
82-year-old woman
(insulin dependent, CKD)
(1 treatment every 15 days)

pre ESWT

4 weeks later ESWT

2 years later

Man
28 years old
Paraplegia
Sacral pressure ulcer

1° Treatment

After 7 days

After 3 m.

O. U. in skin regeneration pathologies

Not simple REPAIR but REGENERATION !!

Thanks