SHOCK WAVE THERAPY IN PRACTICE

MULTIDISCIPLINARY MEDICAL APPLICATIONS

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LEVEL10

CONTENTS

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PHYSICS: F-SW AND R-SW

BASIC INFORMATION ON FOCUSED AND RADIAL SHOCK WAVE PHYSICS

/ Pavel Novak

ABSTRACT

In modern medical practice, both focused shock waves and radial pressure waves are used. Though not correct in physical terms, radial pressure waves are often referred to as radial shock waves. Shock waves and pressure waves differ not only in regard to their mode of generation and physical properties, but also in terms of the magnitude of the standard parameters used and the tissue penetration depths. Planar shock waves, also referred to as defocused shock waves, are a special type of focused shock waves. They act superficially, similarly to radial pressure waves, but cause only very little pain. In principle, shock and pressure waves as well as ultrasound are acoustic waves.

Focused and defocused shock waves and radial pressure waves are not identical.

FOCUSED SHOCK WAVES

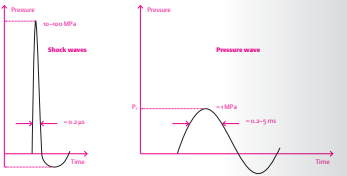
WHAT ARE SHOCK WAVES?

Shock waves occur in the atmosphere during explosive events, for example during lightning strokes, or when aeroplanes break through the sound barrier. Shock waves are acoustic pulses characterised by high positive pressure amplitudes and a steep pressure increase compared to the ambient pressure.

Shock and pressure waves are pulses, while ultrasound is a continuous oscillation.

They are capable of temporarily transmitting energy from the point of generation to remote regions and cause window panes to shatter, for instance. Despite their similarity to ultrasound, shock waves have substantially higher pressure amplitudes than ultrasound waves. For this reason, steepening effects resulting from non-linearities in the propagation medium (water, human tissue) have to be taken into consideration. In addition, ultrasound waves are periodic oscillations with a limited bandwidth (Fig. 1). Shock waves, 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) (Fig. 2). Such a pulse contains frequencies that may range from a few kilohertz to over 10 megahertz.[22, 23, 24]

TYPICAL PARAMETERS OF FOCUSED SHOCK WAVES AND RADIAL PRESSURE WAVES[2] | Fig. 13



p_+ and p_- are the maximum positive and negative pressure. The amplitude p_+ of shock and pressure waves differs by a factor of 10–100.

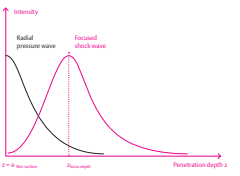
The collision of the projectile with the impact body also generates a higher-frequency acoustic wave (solid-borne sound) in the impact body. Owing to the great difference between the two acoustic impedances (metal, water), only a small portion (about 10 %) of this oscillation energy is transmitted to the tissue or water. The energy contained in the high-frequency acoustic oscillation (not shown in diagram Fig. 13) is substantially smaller than the energy of the low-frequency pressure pulse.[21]

The therapeutic effectiveness of radial pressure waves reaches a depth of z to 5 cm, but it is strongest on the body surface.

PROPAGATION OF PRESSURE WAVES

Pressure waves as described here originate from the application point of the impact body and travel radially into the adjacent tissue.[2] The energy density of the induced pressure wave rapidly drops with increasing distance from the application point (by a proportion of $1/r^2$) so that the strongest effect is at the application point of the impact body,in other words on the skin surface (Fig. 14).

DIFFERENCES IN THE INTENSITY PROFILE OF FOCUSED SHOCK WAVES AND RADIAL WAVES WITH RESPECT TO THE DEPTH WITHIN THE HUMAN BODY | Fig. 14



The shock waves have the maximum intensity in the focus (in the depth). The radial pressure waves have the maximum intensity at the point of entry (skin surface).

PRESSURE WAVE PARAMETERS/PRESSURE WAVE MEASUREMENT

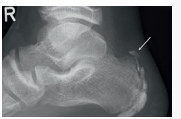
Due to the significantly longer pulse duration and lower pressure amplitude of pressure waves compared to shock waves, pressure (MPa) measurements and calculation of the energy flux density (mJ/mm²) do not provide suitable methods for identifying the characteristics of pressure waves. The EFD expressed in mJ/mm² is usually calculated on behalf of the low intensity high-frequency (in the range of 100 kHz) oscillations. The contribution of these low intensity oscillations to the therapeutic effect is questionable, because their penetration depth is in the range of millimetres only.[1]

More accurate information can be obtained by measuring the excursion of the impact body (Fig. 15) and the force transmitted to a viscoelastic tissue phantom. However, since these parameters are decisively determined by the type of impact body (transmitter) used, the intensity parameter commonly quoted is the pressure (bar) that drives and accelerates the projectile. This approach is similar to using voltage (kV) in the case of focused shock waves.

PATIENT SATISFACTION

Four out of five patients graded the shock wave therapy as successful, while one patient graded the shock wave treatment as unsuccessful. In this specific case, the young football player underwent surgery three months after the last radial shock wave treatment session. At that time, he had an avulsion fracture of the proximal calcaneal apophysis and an accompanying (fracture-related) retrocalcaneal bursitis (Fig. 1).

AVULSION FRACTURE (PROXIMAL PART) OF THE PROXIMAL CALCANEAL APOPHYSIS (ARROW) | *Fig. 1*



All five patients were satisfied at the follow-up telephone interview. Three out of five patients returned to their pre-injury sport at the same intensity. The remaining two patients returned to sports, but on a lower level. In one of these cases the reduced activity was a consequence of a spine and knee injury. In the other case personal reasons unrelated to the orthopaedic disorders were specified.

ANKLE ACTIVITY SCORE

Before the injury, the patients' median ankle activity score was 9 (range 5-9). At follow-up, the median ankle activity score was 7 (range 4-9).

COMPLICATION RATE

No negative rESWT side effects have been documented in the analysis of the patients' medical records and at the telephone follow-up.

PATIENT CHARACTERISTICS AND TREATMENT RESULTS (PT = PHYSIOTHERAPY, US = THERAPEUTIC ULTRASOUND) | *Table 1*

Patient No.	1	2	3	4	5
Age (years)	12	9	12	12	12
Sex	Male	Female	Female	Male	Female
Affected leg	Right	Left	Left	Right	Right
Conservative treatments before	PT, US, insoles, sport reduction	PT, US, taping, in-soles, sport reduction	PT, sport rest	Sport rest, injections	PT, insoles, sport reduction
Time between advent of symptoms and shock wave treatment (months)	4	12	3	5	36
Sport before Sever's disease	Football	Trampoline	Triathlon	Football	Gymnastics, athletics
Sport at follow-up	Football	Martial arts	Triathlon	Football	Modern dance
Follow-up (years)	7	8	1	3	8
VISA-A-G score at follow-up	100	100	100	100	100
Patient satisfaction at follow-up	Yes	Yes	Yes	Yes	Yes
ESWT related complications	No	No	No	No	No