Communication

Correct and incorrect reporting of the principles of focused and radial extracorporeal shock wave therapy (fESWT and rESWT)

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Correct and Incorrect Reporting of the Principles of Focused and Radial Extracorporeal Shock Wave Therapy (fESWT and rESWT)

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Abstract: This article is a commentary on the publication Guo J, Hai H, Ma Y. Application of extracorporeal shock wave therapy in nervous system diseases: A review. *Front Neurol.* (2022) 13:963849. doi: 10.3389/fneur.2022.963849 (1). In the opinion of the authors of this commentary the information provided in the Section "Principles of ESWT" in (1) is partly incorrect and misleading. This is due to the fact that important, published knowledge regarding focused extracorporeal shock wave therapy (fESWT) and radial extracorporeal shock wave therapy (rESWT) was disregarded in (1).

Keywords: extracorporeal shock wave therapy; focused extracorporeal shock waves; radial extracorporeal shock waves; ESWT; rESWT; fESWT

Introduction

We became aware of the article "Application of extracorporeal shock wave therapy (ESWT) in nervous system diseases: A review" by Guo et al. (1) published in *Frontiers in Neurology*. Unfortunately the information provided in the Section "Principles of ESWT" in (1) is partly incorrect and misleading. The first author of this commentary (LJ) suffers from an extreme disability (tetraplegia from C4), is regularly treated with radial ESWT because of his spasticity, has not needed any related medication since then, particularly no injection of BTX-A, and therefore has a special interest in correct reporting about ESWT in the literature. All authors are actively involved in ESWT research (2-5).

Both focused extracorporeal shock waves (fESWs) and radial extracorporeal shock waves (rESWs) used in ESWT have phases of positive and negative pressure and can generate cavitation

Figure 1A of this commentary shows the waveforms provided in Figure 1 in Guo et al. (1); Figure 1B,C show real waveforms of fESWs published in the literature (3,6); and Figure 1D shows real waveforms of rESWs published in the literature (7). These published waveforms differ from the illustrations in Guo et al. (1). Specifically, after an initial phase of positive pressure (black arrows in Figure 1A-D) followed by a phase of negative pressure (red arrows in Figure 1A-D) both fESWs and rESWs can show a second phase of positive pressure (green arrows in Figure 1B-D) followed by a second phase of negative pressure (blue arrows in Figure 1C,D). Of particular note, both fESWs and rESWs can generate cavitation as a consequence of the negative pressure. This is shown for fESWs in Figure 1E taken from (4) and for rESWs in Figure 1F taken from (5); both publications (4,5) are from the senior author of this commentary (CS). In contrast, the illustration of the waveform of rESWs provided by Guo et al. (1) (Figure 1A) does not show any negative pressure, which would prevent the formation of cavitation bubbles. Furthermore, the rise time of shock waves is defined as the time interval between 10% of the maximum positive pressure (P_{max}) and 90% of P_{max} during the initial phase of positive pressure (4), which is different from the illustration provided by Guo et al. (1) (Figure 1A).

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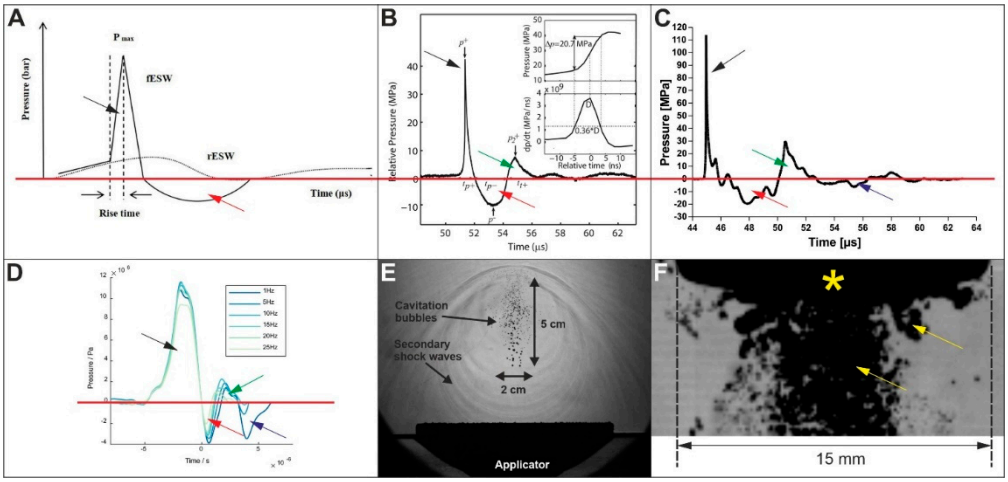

Figure 1. Waveform characteristics of focused and radial extracorporeal shock waves as illustrated in (1) (A) and published in (3,6,7) (B-D), as well as cavitation fields generated by focused (E) and radial (F) extracorporeal shock waves (4,5). Details are in the text. Panel A was taken from (1) published under the CC-BY license; Panel B was taken from (6) with permission from the publisher (8); and Panels C / D / E / F were taken from (3) / (7) / (4) / (5) published under the CC-BY license (3), the CC BY 2.0 license (4) or the CC BY 4.0 license (5,7), respectively. The publications (3-5) are from the senior author of this commentary (CS).

Some fESWT devices used in contemporary ESWT generate true shock waves, whereas others do not

Guo et al. (1) stated that "as an acoustic wave, fESW is characterized by its high pressure of more than 1,000 bar (100 MPa), an extremely short rise time (<10 ns), a short duration (<10 ms), and a broad frequency spectrum (16–20 MHz)". This definition of fESWs was established in 2001 by Ogden et al. (9). The waveform shown in Figure 1C of the piezoelectric fESWT applicator F10G4 (Richard Wolf, Knittlingen, Germany) operated at highest machine settings is in line with this definition, whereas the waveform shown in Figure 1B of the electromagnetic fESWT device Duolith SD1 (Storz Medical, Tägerwillen, Switzerland) operated at highest machine settings is not. Figure 1C in Guo et al. (1) shows the focused handpiece of the Duolith SD1 device (Storz Medical). Of note, the same illustration of this handpiece was already used e.g. in 2019 in (10) (Figure 1 therein) and therefore was most probably not created by Guo et al. (1) themselves. Waveform characteristics of the fESWs generated by the Duolith SD1 device (Storz Medical) were reported in 2007 in (6) as follows: maximum pressure 42.7 MPa, rise time 8 to 500 ns, no formation of true shock waves for any machine settings.

Like fESWs, rESWs can possess non-linearity

Guo et al. (1) stated that "unlike fESW, radial extracorporeal shock wave (rESW) does not possess the shock wave characteristics of a short rise time, a high peak pressure, and non-linearity". Contrary to this description Cleveland et al. (11) demonstrated already in 2007 nonlinear distortion of the rESWs generated using the rESWT device Swiss DolorClast (Electro Medical Systems, Nyon, Switzerland) (Figure 1D). However, the nonlinear distortion was not strong enough to result in a shock front. Of note, this is different from the description by Guo et al. (1) that rESWs do not possess non-linearity. Furthermore, Cleveland et al. (11) reported a rise time of 800 ns of the rESWs generated by the Swiss DolorClast (Electro Medical Systems), which is not too different from the 500 ns reported in (6) for the Duolith SD1 (Storz Medical) at low machine settings.

A scientifically correct classification of shock waves used in contemporary ESWT would have to distinguish between focused shock waves, focused pressure waves and radial pressure waves

Guo et al. (1) stated that "some scholars even call “rESW” “radial pressure waves” because rESW uses the energy generated from compressed gas to drive the bullet body to the treated tissue area in a pulsed manner". In this regard it is of note that Cleveland et al. (11) reported that piezoelectric and electromagnetic fESWT sources (such as the F10G4 device from Richard Wolf and the Duolith SD1 device from Storz Medical) use focusing but do not generate shock waves at the source. Rather, they "rely on nonlinear propagation distortion to produce a shock along the path to the focus. For mid and high-amplitude settings, the waveforms are shocked and the peak amplitudes and rise times are comparable to those of electrohydraulic sources" (11) (as shown in Figure 1C for the F10G4 device

from Richard Wolf). However, "at low-amplitude settings the waveforms do not contain shocks" (11), as demonstrated in (2) for the Duolith SD1 (Storz Medical) at any machine settings (Figure 1B). Therefore it would be correct to distinguish between true focused shock waves (Figure 1C), focused pressure waves (Figure 1B) and radial pressure waves (Figure 1D). However, for several good reasons this is not done in the literature. One of these reasons is that differences in molecular and cellular mechanisms of action between focused shock waves and focused pressure waves have not been reported in the literature.

Discussion

It is beyond the scope of this commentary to discuss to what extent the incorrect and misleading description of the principles of ESWT in (1) had influence on the other sections of the latter article. In our opinion researchers and users of fESWT and rESWT should be informed that the principles of ESWT are different than outlined in (1), and the molecular and cellular mechanisms of action of fESWs and rESWs on nervous tissue presented in (1) are incomplete (for a comprehensive review see (2)).

Conflict of Interest: CS served as consultant for Electro Medical Systems (Nyon, Switzerland) until December 2017, and has received funding from Electro Medical Systems for conducting basic research into rESWT at his lab. However, Electro Medical Systems had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results. No other conflicts of interest are reported.

Author Contributions: LJ, TW and CS conceived and wrote the article. All authors contributed to the article and approved the submitted version.

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