**Extracorporeal shock wave therapy for the treatment of chronic bone infections**

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**Introduction:** Extracorporeal shock wave therapy (ESWT) has been well-established in orthopaedics, and is currently applied successfully to various bone and soft tissue pathologies, such as non-unions and enthesopathies [1,2]. In spite of the generally minor side effects of ESWT, local infections are still regarded as a contraindication due to an assumed risk of bacterial spreading with bacteraemia and secondary infections. Nevertheless, bacterial spreading after ESWT of infected sites has not been investigated in a controlled experiment, and proven benefits of ESWT like neovascularization and the induction of bone remodeling might even support the healing of chronic inflammatory and infectious bone pathologies. Furthermore, antibacterial effects have been reported for shock waves in vitro. Since many patients with chronic osteomyelitis have compromised soft tissue coverage, a non-invasive alternative for the treatment of chronic bone infections, e.g. by ESWT, would be extremely promising.

The aim of the present study was first to investigate the effects of shock waves on bacteria under different growth conditions. In a second part, interactions of ESWT with the antibacterial activity of gentamicin were evaluated. Finally, we yielded to assess the safety and effectiveness of ESWT in vivo in a rabbit model of chronic osteomyelitis.

**Materials and Methods:** In vitro experiment:

Standardized suspensions of Staphylococcus aureus were exposed to 1,000 to 6,000 shock wave impulses of various energy flux densities (EFD 0.00-0.96 mJ/mm²), both at 37°C in growth medium and at 20°C in normal saline. Bacterial viability of treatment groups and untreated control samples were quantified after plating and incubation for 48 hours.

In the second part of the in vitro experiments, MICs of gentamicin against shock wave-treat ed and untreated suspensions of S. aureus were compared. Furthermore, suspensions of S. aureus containing graded concentrations of gentamicin were exposed to ESWT, and bacterial growth was assessed.

In vivo experiment:

Chronic osteomyelitis was induced by injecting sodium morrhuate and S. aureus into the proximal tibia of 12 female New Zealand white rabbits (3.5 - 4.5 kg). Four and five weeks after the initial operation, ESWT was applied twice to the infected areas. Treatment of Chronic Calcifying Tendonitis of the Rotator Cuff. JAMA 1997;277:1175-1181.

**Results:** In vitro experiment:

Significant antibacterial effects of ESWT were demonstrated with killing rates up to 99.5% on bacteria suspended in normal saline (20°C; P=0.008). A minimum threshold of more than 1,000 impulses and an EFD of at least 0.59 mJ/mm² was necessary to induce bacterial killing.

Bacteria suspended in growth medium and treated at 37°C were less sensitive to ESWT and even demonstrated significantly increased proliferation (P=0.009) after treatment with shock waves of lower EFD (0.59 mJ/mm²). At higher EFD, a significant reduction of bacterial growth was also observed for bacteria suspended in growth medium (P=0.009).

The MIC of gentamicin against S. aureus was not altered by prior shock wave application. Furthermore, the combination of gentamicin and ESWT did not affect gentamicin activity (P=0.05). Nevertheless, a growth-promoting effect of lower energy ESWT (EFD 0.59 mJ/mm²) was demonstrated despite simultaneous gentamicin administration.

**Discussion:** This is the first study reporting both energy-dependent killing as well as stimulation of bacterial growth by ESWT. This energy-dependent effect is extremely important for a potential application of shock waves in the treatment of chronic infections. Likewise important, ESWT did not alter activity of gentamicin against S. aureus. Based on these results, systemic antibiotic prophylaxis can be recommended during shock wave treatment of infected sites to prevent bacterial spreading.

The effects of ESWT applied to infected target areas have not been studied previously. Our data indicate that ESWT of infected bone does neither induce bacterial spreading nor worsening of local infection. The results even suggest ESWT to be beneficial in the treatment of chronic bone infections, although evidence is limited to the histological score.

Apart from the direct bactericidal activity, biological shock wave effects like local hyperemia, neovascularization, new bone formation and remodeling of sclerotic bone might improve the presentation of systemic antibiotics and immune defence at the site of infection. A combined administration of ESWT and antibiotics might further increase the effectiveness of ESWT in chronic bone infections.

**References:**


**Table 1:** Histological scores and soft tissue abscess formation in hind limbs of ESWT-treated and control animals at sacrifice (8 weeks)

<table>
<thead>
<tr>
<th>Soft tissue abscesses</th>
<th>Histological scoring according to Smeltzer et al. [3]</th>
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<tbody>
<tr>
<td></td>
<td>Intraosseous acute inflammation</td>
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<tr>
<td>ESWT (treated)</td>
<td>0.25±0.4</td>
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<tr>
<td>Control (untreated)</td>
<td>1.5±1.4</td>
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<tr>
<td>p-value</td>
<td>&lt;0.001*</td>
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*Mann-Whitney test; *Fisher exact test, SD = standard deviation