

A Severe Hemorrhagic Shock Leads to Delayed Fracture Healing and Biomechanical Instability in a Murine Model

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Purpose: In patients with multiple trauma, a delayed fracture healing is often diagnosed, whereas the pathomechanisms are not well known today. The purpose of the study is to evaluate the effect of a severe hemorrhagic shock on fracture healing in a murine model.

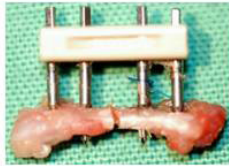
Methods: 10 male C57BL/6N mice per group (Fx, THFx, Sham) and time point were used in this experiment. The Fx group received an osteotomy after an external fixator was fixed to the right femur. The THFx group additionally received a pressure-controlled hemorrhagic shock (TH) with a mean arterial blood pressure of 35 mm Hg over a period of 90 minutes. Afterwards, resuscitation with 4 times the shed blood volume of Ringer solution was performed. Animals of the Sham group received both the implantation of a catheter and an external fixator but neither a blood loss nor an osteotomy was performed. After 1, 2, 3, 4, or 6 weeks, the animals were sacrificed. Afterwards the bones were radiographed, analyzed by micro computed tomography (μ CT) and underwent a 3-point bending test. Statistical analysis was performed using SPSS 22 (IBM). Statistical significance was set at $P < 0.05$. Comparisons between groups were performed using the Mann-Whitney U test.

femura after explantation

Fx 2 weeks



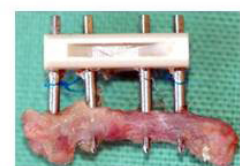
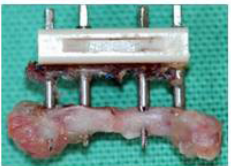
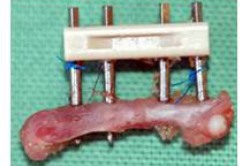
THFx 2 weeks



Fx 3 weeks

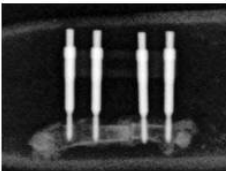


THFx 3 weeks

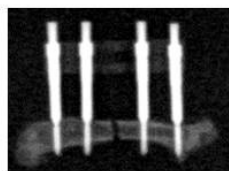


X-rays

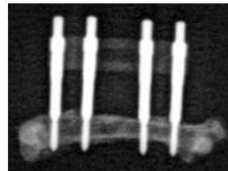
Fx 2 weeks



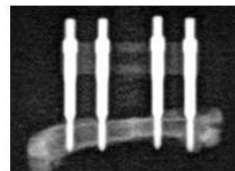
THFx 2 weeks



Fx 3 weeks



THFx 3 weeks



Results: One week after surgery the bones of the Fx and the THFx mice were macroscopically instable. After 2 weeks, the Fx group showed a stable bridging of the fracture analyzed by radiograph and μ CT, whereas the bones of the THFx group were instable in 50% of the cases (see figure). Interestingly, the 2-week THFx mice showed a stable bridging with a blood loss under 30% of the whole blood volume. In contrast, animals with a blood loss higher than 30% of the whole blood volume showed an unstable fracture. 3 weeks after surgery, the bones of both groups were bridged. First results of the 3-point bending tests showed a reduced tensile strength of the THFx group after 2 and 3 weeks in comparison to the Fx group.

Conclusion: A hemorrhagic shock has a negative effect on fracture healing. In this context, the amount of the removed blood in terms of a “30% threshold” plays a decisive role.