Conversion from External Fixator to Intramedullary Nail Impairs Fracture Healing Particularly After a Severe Trauma

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ABSTRACT INTRODUCTION:
In polytraumatic patients second hits, e.g. second surgical interventions, are known to potentiate the posttraumatic systemic inflammatory response, thus increasing the risk of multi-organ dysfunction. Generally, in severely injured patients fractures of the extremities are initially treated with an external fixator, which is replaced by an intramedullary nail in a second surgical intervention as soon as the immunological status of the patient is considered as stable. Recently, we demonstrated that a severe trauma impaired the healing of fractures, which were stabilized by an external fixator during the entire healing period. The question arises, whether the switch to an intramedul lary nail increases the posttraumatic systemic inflammatory response in terms of a second hit and leads to a further impairment of bone healing.

METHODS:
42 male Wistar rats received an osteotomy of the right femur, which was initially stabilized by an external fixator (FX). At the same time, half of the animals underwent a blunt chest trauma (TX). After 4 days the external fixator was replaced by an intramedullary locking nail (IMN; Fig. 1) in a second surgical intervention in half of the animals of the two groups. The animals were harvested 40 and 47 days after the first operative procedure. The groups were divided as follows: (A) FX, 40 days (n=8); (B) FX+IMN, 40 days (n=5); (C) FX+TX, 40 days (n=7); (D) FX+TX+IMN, 40 days (n=7); (E) FX+IMN, 47 days (n=7); (F) FX+TX+IMN, 47 days (n=8) (Table 1). Blood was taken from the animals in order to measure the systemic inflammatory response by analyzing the C5a serum level 0, 6, 24, and 72h after the fist surgery and 6, 24, and 72h after the second surgery. The fracture healing outcome was determined by biomechanical testing (three-point-bending test) of the healed femora and by μCT analysis. The animal experiment was performed according to international regulations for the care and use of laboratory animals, and approved by the local ethical committee (Regierungspräsidium Tübingen, Germany). Statistics: Student’s t-test. Level of significance: p<0.05.

Table 1: Experimental design

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
<th>Group D</th>
<th>Group E</th>
<th>Group F</th>
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</thead>
<tbody>
<tr>
<td>External Fixator</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<tr>
<td>Blunt chest trauma</td>
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<tr>
<td>Conversion to intramedullary locking nail</td>
<td>x</td>
<td>x</td>
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<tr>
<td>40 days</td>
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<td>40 days</td>
<td>47 days</td>
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RESULTS SECTION:

The C5a serum levels were significantly increased 6 and 24h after the first surgery and decreased to pre-operative values after 72h with no significant differences between the groups with and without thoracic trauma (groups B, D). However, the blunt chest trauma significantly increased C5a concentrations 6 (p=0.02), 24 (p=0.02) and 72h (p=0.04) after the second surgical intervention (groups B, D; Fig. 2). Whereas the fracture calli of the rats treated with an external fixator during the entire healing time (groups A, C) almost attained the stiffness of the contralateral intact femur, the switch to the intramedullary nail 4d after the first surgery (groups B, D) decreased the bending stiffness considerably, with no significant differences between animals that had a thoracic trauma nor between those without after 40 days (Fig. 3). After 47 days flexural rigidity was still reduced in group E compared to group A, demonstrating the negative influence of the second operation on fracture healing. In the rats with a severe trauma, the second intervention (group F) slightly decreased the bending stiffness in comparison to rats without a thoracic trauma (Group E; Fig. 3). μCT measurements confirmed the biomechanical results, indicating inferior callus quality in animals subjected to a second surgical intervention, particularly in combination with the blunt chest trauma (results not shown).

DISCUSSION:

This study showed that after a severe trauma the conversion of the fracture fixation from an external fixator to an intramedullary nail could provoke a second hit as demonstrated by significantly increased C5a serum concentrations up to 3 days after the second surgical intervention. Furthermore, the switch to an intramedullary nail 4 days after the first surgery led to considerable impairment of the fracture healing outcome 40 days after the first surgery. Even 7 days later after a healing time of 47 days, fracture healing in animals subjected to a conversion from external fixator to secondary intramedullary nail was still delayed, particularly in combination with the blunt chest trauma, indicating that the accumulation of second hits after multi injury could lead to a further aggravation of the fracture healing outcome.

ACKNOWLEDGEMENTS:

This study was kindly supported by the German Research Foundation (DFG, No. KFO200). None of the authors have any conflicts of interest.