Treatment of Compartment Syndrome of the Thigh Associated With Acute Renal Failure After the Wenchuan Earthquake

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abstract

Compartment syndrome of the thigh is a rare emergency often treated operatively. The purpose of this study was to evaluate the effects of nonoperative treatment for compartment syndrome of the thigh associated with acute renal failure after the 2008 Wenchuan earthquake. Nonoperative treatment, which primarily involves continuous renal replacement therapy, was performed in 6 patients (3 men and 3 women) who presented with compartment syndrome of the thigh associated with acute renal failure. The mean mangled extremity severity score (MESS) and laboratory data regarding renal function were analyzed before and after treatment, and the clinical outcome was evaluated at 17-month follow-up. Laboratory data regarding renal function showed improvements. All 6 patients survived with the affected lower limbs intact after nonoperative treatment. Follow-up revealed active knee range of motion and increased muscle strength, as well as a recovery of sensation. A positive linear correlation was found between MESS and the time required to achieve a reduction in swelling, as well as the time required for the recovery of sensation and knee range of motion ($r$=0.8; $P<.05$). Satisfactory clinical outcomes were obtained in patients with compartment syndrome of the thigh associated with acute renal failure.

Urine alkalization, electrolyte and water balance, and continuous renal replacement therapy have played an important role in saving lives and extremities. Nonoperative treatment should be considered in the treatment of compartment syndrome of the thigh associated with acute renal failure.

Figure: Photograph of an 11-year-old boy with noncontact compartment syndrome of the left thigh showing the affected lower limb with massive swelling in the ipsilateral thigh, leg, pudendum, and inguinal region on admission.

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Compartment syndrome of the thigh exhibits variability in terms of clinical features and outcome due to the contributions of multiple etiologies. Common events leading to increased compartmental pressures in the thigh include femoral fractures, bleeding in the thigh in the presence of vascular injury and muscular exertion, motor vehicle crashes, crush injury and edema caused by contusion of the thigh, or prolonged extremity displacement. These causes account for 70% of blunt trauma, including crush injury and contusion. The myoglobin released following rhabdomyolysis after compartment syndrome damages renal cells and tubules, which contributes to the development of acute renal failure. Satisfactory clinical outcome correlates with early operative treatment. Early fasciotomy has routinely been recommended before the formation of acute renal failure. Symptoms largely resolve following fasciotomy and decompression, but high complication rates have been described. However, the technique was frequently reported to be related to a high rate of infection and mortality. Amputation is performed in patients whose lives are at risk after systematic evaluation. Few authors advocate nonoperative treatment in this situation.

The purpose of this study was to evaluate the effects of nonoperative treatment of compartment syndrome of the thigh associated with acute renal failure after the 2008 Wenchuan earthquake.

**Materials and Methods**

The study group comprised 3 men and 3 women with compartment syndrome of the thigh associated with acute renal failure after the 2008 Wenchuan earthquake, which measured an 8 on the Richter scale. Average patient age was 23.33 years. No patient exhibited limb necrosis. A single thigh was affected in 4 patients, and both thighs were affected in 2 patients. Average duration of depressed renal function was 8.16±8.01 hours, and average time to initial treatment was 43.66±35.24 hours after injury. Average time to admission after injury was 133±134.85 hours.

All patients were injured by collapsing buildings, remained awake the entire time, and did not sustain multiple injuries. Blood pressure was 113 to 140/78 to 97 mm Hg, and pain and paresthesias was present in all patients. Ipsilateral dorsalis pedis pulses were weak in 5 patients, but limb necrosis was not present. Anuria presented in all patients. Massive swelling in the ipsilateral thigh, leg, pudendum, gluteal, and inguinal regions was observed in all patients. Sensation beyond the affected thigh decreased in all patients, and the affected muscles were tense. No patient presented a large area of ecchymosis. In all patients, the muscle strength of the extensor and flexor of the knee was classified as grade 0-1 and grade 0-2, respectively, according to Lovett and Martin’s manual for muscle testing, which uses a scale of 0 to 5. Femoral fractures were not observed on radiographs, and major vascular injury and thrombosis were not detected by Doppler imaging. The mangled extremity severity score (MESS) was 4 to 5 points (mean, 4.5±0.54). Acute renal failure was defined as creatinine >26.4 mmol/L or a reduction in urine output (documented oliguria of <0.5 mL/kg per hour for >6 hours), according to the RIFLE (increasing severity classes [Risk, Injury, and Failure] and outcome classes [Loss and End-stage kidney disease]) criteria for acute renal failure, which were revised in 2004. The measurement of intracompartamental pressure is the most reliable clue for diagnosis, but this measurement could not be performed.

Due to the limited medical resources available after the catastrophe, 6 patients were forced to receive nonoperative treatment, including alkalization of urine, electrolyte and water balance, nutritional support, and continuous renal replacement therapy. Laboratory data, including myoglobin, creatine kinase, potassium, blood urea nitrogen, and creatinine, were analyzed with the Wilcoxon signed rank test. Pearson’s correlation coefficient was used to determine correlations among clinical data, laboratory data, and MESS. The follow-up period was 17 months. Clinical data and laboratory data are presented as mean±SD; statistical significance was assumed at P<.05. A commercially available statistical software program (SPSS 15.0; SPSS, Inc, Chicago, Illinois) was used for the statistical analysis.

**Results**

All patients survived with the affected lower limbs intact after nonoperative treatment, with normal urine output (range, 1500-2500 mL/24 hours). Swelling of the affected lower limb had completely disappeared by 16.16±3.43 days after injury. On average, the recovery of sensation was experienced at 12.66±2.58 days postinjury, which suggested slight hypoesthesia 17 months postinjury. Active knee joint range of motion (ROM) (<40°) was first recovered an average of 18.17±2.23 days postinjury. All patients had completely recovered active knee ROM at 17 months postinjury. Pain relief and dorsalis pedis pulse recovery were achieved within 4 weeks. Muscle strength of the extensor and flexor of the knee increased to grade 1-2 and 1-3, respectively, 4 weeks postinjury; these values increased to grade 3-5 and 4-5, respectively, at 17-month follow-up (Figure).

Laboratory data regarding renal function showed improvements: myoglobin, creatine kinase, potassium, blood urea nitrogen, and creatinine decreased significantly after treatment (P<.05) (Table 1). Neither MESS nor time of initial treatment correlated with myoglobin, creatine kinase, potassium, blood urea nitrogen, or creatinine (Table 2). A positive linear correlation was found between MESS and the time required to achieve a reduction in swelling, as well as the time required for the recovery of sensation and knee ROM (r>0.8; P<.05) (Table 3). Furthermore, the time to initial treatment correlated
with the time required for a reduction in swelling and the initial recovery of sensation \((r > 0.8; P < 0.05)\), but not with the time required for the recovery of knee ROM (Tables 2, 3).

**DISCUSSION**

Compartment syndrome is caused by increased pressure in a closed osseofascial compartment, causing microcirculatory changes and ischemia. In our series, increased pressure was caused by muscle necrosis and tissue swelling after crush injury. In previous studies, fasciotomy was observed in the early stages of compartment syndrome, \(40 \text{ mm Hg} \) delta pressure (difference between mean arterial pressure and intracompartmental pressure).

Nonoperative treatment has not been implemented to treat compartment syndrome of the thigh. In our study, patients who suffered from compartment syndrome with acute renal failure recovered sensation and most functions after nonoperative treatment.

Nonoperative treatment was effective for compartment syndrome for many reasons. The thigh is a unique location for the occurrence of compartment syndrome. Anatomically, the large-volume compartments of the thigh provide a space for the potential increase in propensity of edema and hemorrhage to occur along the muscle attachment of the thigh to the hip and knee due to the presence of relatively elastic fascia. This allows the contents of the thigh to escape proximally into the ipsilateral pudendum, inguinal, or gluteal region and distally into the leg. The available space allows the intracompartmental pressure to increase to a higher level without endangering the circulation. In our patients, the leg, pudendum, and gluteal and inguinal regions were swollen in addition to the thigh. All patients were rescued 43.66 ± 35.24 hours after injury, but limb necrosis was not identified. The thighs of all patients tolerated the compartment syndrome.

In addition, continuous renal replacement therapy had a significant effect on the patients enrolled in this study. Continuous renal replacement therapy has some advantages: it is possible to remove fluid in special circumstances and to remove pro-inflammatory mediators of inflammation, such as interleukins 1, 6, and 8, and tumor necrosis factor \(\alpha\). Continuous renal replacement therapy can reduce the inflammation induced by necrotized muscle or ischemia tissues; moreover, it can directly reduce swelling by the removal of fluid from edematous tissue. In our study, con-

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**Table 1**

<table>
<thead>
<tr>
<th>Data</th>
<th>CK, IU/L</th>
<th>MYO, ng/mL</th>
<th>BUN, µmol/L</th>
<th>CREA, µmol/L</th>
<th>K+, mmol/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before treatment</td>
<td>96894.5±78085.7</td>
<td>3900.6±2854.5</td>
<td>21.9±10.6</td>
<td>435.88±176.99</td>
<td>5.72±1.65</td>
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<tr>
<td>After treatment</td>
<td>794±166.8</td>
<td>320±245.6</td>
<td>10.68±6.26</td>
<td>227.11±117.73</td>
<td>3.37±0.30</td>
</tr>
<tr>
<td>(z)</td>
<td>-2.201</td>
<td>-2.201</td>
<td>-1.992</td>
<td>-1.992</td>
<td>-1.992</td>
</tr>
<tr>
<td>(p)</td>
<td>.028</td>
<td>.028</td>
<td>.046</td>
<td>.046</td>
<td>.046</td>
</tr>
</tbody>
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*Abbreviations: BUN, blood urea nitrogen; CK, creatine kinase; CREA, creatinine; K+, potassium; MYO, myoglobin.*

*Wilcoxon signed rank test.*

**Figure:** Photograph of an 11-year-old boy with noncontact compartment syndrome of the left thigh showing the affected lower limb with massive swelling in the ipsilateral thigh, leg, pudendum, and inguinal region on admission (A). Radiograph demonstrating the absence of a femoral fracture (B). Photographs showing complete recovery of extensor (C) and flexor (D) muscle strength in the left thigh 17 months postinjury.
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Continuous renal replacement therapy was used to manage compartment syndrome of the thigh. The limbs were ultimately saved. More than 70% of acute kidney injuries require renal replacement therapy, including slow, extended daily dialysis, peritoneal dialysis, intermittent hemodialysis, or continuous renal replacement therapy. In our study, 6 patients received continuous renal replacement therapy after admission. Continuous renal replacement therapy is considered the most promising and effective option for treating acute renal failure in critically ill patients with no major problems or complications. The technique allows for a compound of extremely high molecular weight, such as myoglobin, to be eliminated easily through the larger holes in the filtration membrane. In our study, continuous renal replacement therapy was used in patients with acute renal failure with high serum myoglobin levels following compartment syndrome. Renal function, especially myoglobin, decreased significantly after treatment.

Acute renal failure followed by compartment syndrome with a high myoglobin level was associated with a mortality rate of 86%, and amputation was sometimes necessary to save the patient’s life, depending on the severity of the soft tissue injury. Amputation is recommended when the MESS is >7 points; however, the mortality rate did not markedly decrease when amputation was performed. In our study, a low MESS score was demonstrated in all patients. Six patients sustained low-energy blunt trauma, as determined by slight ecchymosis of the thigh and the absence of femoral fracture and vascular injury. It is difficult to prevent muscle necrosis and heal the limb and kidney using urgent fasciotomy, which is recommended only in patients lacking a distal pulse, excluding those who have suffered from major artery injury and hypotension within 6 hours of the development of compartment syndrome. In our series, the average time to initial treatment was 43.66 ± 35.24 hours after injury. Compartment syndrome developed in our patients over the course of 6 hours. The muscle appeared to be partially ischemic without limb necrosis, but acute renal failure was observed. However, mean MESS score was 4.5 ± 0.54, and amputation was not recommended. Nonoperative treatment was elected due to the limited medication available, and good clinical results were achieved in the patients.

Our study was based on an accident compounded by limited medical conditions. Study limitations include (1) an insufficient number of patients enrolled, (2) the study’s retrospective nature, (3) a short follow-up duration, and (4) the inclusion of only young patients. Due to the lack of theoretical support, basic research should be performed in the future to establish a theoretical foundation for this treatment. Animal models have demonstrated that nonoperative treatment is effective in treating patients with acute compartment syndrome with acute renal failure. A large, prospective, controlled clinical trial should be completed to confirm our results.

**Conclusion**

Satisfactory clinical outcomes were obtained in patients with compartment syndrome of the thigh associated with acute renal failure. Urine alkalization, electrolyte and water balance, and continuous renal replacement therapy play an important role in saving lives and extremities. Nonoperative treatment should be
considered for young patients with compartment syndrome of the thigh with lower MESS scores.

REFERENCES