Application of damage control orthopedics in 41 patients with severe multiple injuries

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Objective: To probe the feasibility and efficacy of damage control orthopedics (DCO) in treating severe multiple injuries.

Methods: A retrospective analysis was made on the clinical data of 41 patients (31 males and 10 females, aged 18-71 years, mean: 36.4) with multiple injuries admitted to our department and treated by DCO from January 1995 to December 2005.

Results: As a first-stage therapy, devascularization of internal iliac arteries was performed in 29 patients with pelvic fractures combined with massive bleeding, including ligation of bilateral internal iliac arteries in 21 patients and embolization of bilateral internal iliac arteries in 8. And early external fixation of pelvis was performed in 10 patients. Ten patients with severe multiple injuries combined with femoral fractures were managed with primary debridement and temporal external fixation and 2 patients with spinal fractures combined with spinal cord compression received simple laminectomy. Thirty-one patients received definite internal fixation after resuscitation in intensive care unit. The overall mortality rate was 12.1% (5/41) with an average injury severity score of 41.4. The main causes of death were hemorrhagic shock and associated injuries. Complications occurred in 7 patients including acute respiratory distress syndrome in 3 cases, thrombosis of right common iliac artery in 1, subphrenic abscess in 2 and infection of deep wound in lower extremity in 1. After treatment, all the patients got cured.

Conclusions: Prompt diagnosis and integrated treatment are keys to higher survival rate in patients with severe multiple injuries. In this condition, DCO is an effective and safe option.

Key words: Wounds and injuries; Orthopedic procedures; Damage control surgery; Multiple injuries

METHODS

General data

The clinical data of 41 patients (31 males and 10 females, aged 18-71 years, mean: 36.4) with multiple injuries admitted to our hospital and treated by DCO from January 1995 to December 2005 were studied retrospectively in this article. Injury causes included traffic injury in 28 patients, fall injury in 10, and crush injury in 3. On admission, there were 36 patients (87.8%) with shock, of whom 10 patients were in moribund state (no detectable blood pressure was measured). Twenty-eight patients received blood transfusion for over 2500 ml. Abbreviated injury scale (AIS) was over 4 in 29 patients with pelvic fracture, over 3 in 10 patients with femoral fractures and over 4 in 2 patients with spinal fractures, with the mean injury severity score (ISS) of 37.1.

DCO was employed to treat 29 patients with severe
multiple injuries combined with pelvic fractures, 10 with femoral fractures, and 2 with spinal fractures, respectively. In this study, pelvic fractures in 29 patients were unstable pelvic ring fractures, of which 20 patients were dealt with secondary internal fixation. Femoral fractures in 10 patients were open fractures, and spinal fractures in 2 patients were L₁ burst fractures combined with spinal compression.

**Injury and treatment**

Based on theory of DCO, the treatment was divided into three different stages. In the first stage, fatal hemorrhage was controlled, early and temporary external fixation, and decompression by using pelvic bracket and simple laminectomy were performed. In the second stage, resuscitation and optimization of physiological functions in intensive care unit (ICU) were made. And in the third stage, if the physiological function was good enough, delayed definite reduction and internal fixation were done for fractures.

**Treatment of first stage** For the treatment in the first stage, it was important to control hemorrhage and prevent secondary injury when treating fractures. In the 29 patients with pelvic fractures, the massive hemorrhage was treated with devascularization of the iliac artery, including ligation of bilateral internal iliac arteries in 21 patients and embolization of bilateral internal iliac arteries in 8 patients. External fixation with pelvic bracket was used in 10 patients at the early stage. Bone traction was performed in 8 cases for the associated acetabulum fracture or sacro-iliac articulation dislocation. Injuries of organs adjacent to the pelvis included vesical rupture in 6 patients and posterior urethral injury in 4 (2 with both vesical rupture and posterior urethral injury), of whom 8 were treated by cystostomy and 4 by late urethral reconstruction, extraperitoneal rectum injury in 2, of whom 1 was treated by proximal sigmoid colostomy plus presacral drainage and 1 with stage I repair of nonstoma, and intraperitoneal colorectal injury in 4 patients, of whom 3 were treated by initial repair or resection plus anastomosis and 1 by colostomy and later return. Besides, there were remote organ injuries including spleen injury in 3 patients, liver injury in 1, kidney injury in 1, small intestine injury in 6 and pancreatic injury in 1, which were managed by surgical repair or resection. Associated extra-abdominal injuries included craniocerebral injury in 8 patients, thoracic injury in 10 and extremity injury in 12, and all of them received corresponding treatment.

Of 10 patients with open femoral fractures, 4 were combined with craniocerebral injuries and 2 received intracranial decompression. Associated thoracic injuries included multiple rib fractures in 8 patients, floating chest wall in 2 (treated by suspensive traction of the rib), and hemopneumothorax in 8 (treated by thoracic close drainage). The other injuries included pulmonary contusion in 5 patients, intrapulmonary hematoma in 1 and blunt myocardial contusion in 2. Associated injuries in abdomen included splenic rupture in 4 patients (treated by splenectomy), hepatorrhexis in 3 (2 were treated by ligation of the hepatic artery and 1 by debriding hepatectomy), duodenal rupture in 1 (treated by duodenal diverticulum operation) and enterorrhexis in 1 (treated by intestinal resection and anastomosis). Six patients combined with extremity fractures were treated by simple fixation. Open femoral fracture was treated by debridement and simple external fixation. Among the patients who were treated by simple external fixation, 6 received external fixator and 4 received bone traction immobilization. None of them was treated by internal fixation with reamed intramedullary nails at the first stage.

Two patients with spinal fractures plus back spinal cord compression were combined with abdominal injuries. One had hepatorrhexis and splenic rupture, who was treated by splenectomy and debriding hepatectomy; the other had stomach and intestine rupture combined with left hemopneumothorax and left lung contusion, who was treated by simple posterior vertebral plate decompression.

**Treatment of second stage** For the treatment at the second stage, all the patients were admitted to ICU for resuscitation therapy, including retrieve of coagulopathy, hypothermy, acidosis, relief of ventilation dysfunction and necessary respiratory support. The aim of treatment of this stage was to rectify acidosis, and to reach the standards of an hemoglobin greater than 100 g/L, an hematocrit greater than 35/L, a platelet count greater than 90 000/L, a serum lactate less than 2.5 nmol/L, and normal coagulation function. For those with severe pelvic fractures, definitive operation was performed within 2 weeks in condition that the above indicators approximately arrived such standards,
because of collateral circulation following internal iliac artery devascularization would form after 2 weeks, which would increase the hemorrhage. For those with femoral fractures, definitive operation was made when all indicators were observed.

**Treatment of third stage** For treatment at the third stage, definite internal fixation was performed after improvement of the physiological functions. Pelvic fractures combined with acetabular fractures in 6 patients, anterior horn and anterior wall fractures in 2, posterior horn and posterior wall fractures in 3, and dual column fracture and type T fracture in 1, were treated by internal fixation with curve pelvic bone plate. Diastasis or combined pubis fracture of the symphysis pubis in 8 patients was treated with anatomic plate internal fixation, while comminuted ilium wing fractures in 5 patients were treated with curve plate internal fixation. Out of the 29 patients with pelvic fractures, 20 underwent definitive procedures. Femoral fractures were treated by interlocking bone nailing in 6 patients, dynamic hip fixation in 2 and dynamic condylar fixation in 1. Spinal fractures were treated by anterior bone graft of lumbar vertebrae and Z-plate self-lock plate fixation in 2 patients.

**RESULTS**

The mortality rate was 12.1% (5/41). Of 5 deaths, 3 died during operation or 24 hours after operation due to hemorrhagic shock, 1 died of thoracic injury combined with acute respiratory distress syndrome (ARDS) and 1 died of postoperative multiorgan dysfunction syndrome (MODS), with mean ISS of 41.4.

Postoperative complications included ARDS in 3 patients who recovered after use of respirator, thrombogenesis after ilium fractures combined with right common iliac artery contusion in 1 patient who recovered after forced amputation surgery because of failed embolectomy, subphrenic abscess in 2 patients who recovered after subphrenic drainage, and deep infection of lower extremity in 1 patient who got recovery after debridement and correct drainage.

All the patients were followed up for 6 months to 2 years. After late reconstruction of the urethra in 4 patients, 1 patient had urethral stricture and recovered after repeated distention. There was no anischuria or sexual disturbance. In 2 patients with spinal fractures combined with back spinal cord injury, the muscle strength of both lower extremities was Grade IV, without abnormality of sensory function or sphincter dysfunction. All patients obtained bone union.

**DISCUSSION**

Many lives have been saved since Stone and his cooperatators employed simplified operation, resuscitation and secondary definitive operation in treating patients with severe trauma and introduced concept of damage control surgery (DCS) in 1983. In recent years, the application of DCS has gradually changed from primary abdominal injuries to orthopedics and cardiothoracic surgery, especially severe multiple injuries. DCO is employed to minimize the damage to patients so as to enhance the survival rate of patients with severe multiple injuries. Nevertheless, reasonable choice of DCO is still a difficult problem.

In the present study, auxiliary examination and shift should be avoided because the patients with severe multiple injuries are mostly combined with severe shock. A fast diagnosis mainly relies on the history of injury, physical signs and simple thoracoabdominal puncturation. If possible, X-ray photographs of the thorax and the pelvis should be taken and routine urinary catheter should be placed, which are helpful to find bladder and urethral injuries and are also a way for monitoring shock. The main cause of early death of patients with severe pelvic fractures is uncontrollable hemorrhage, and the cause of late death is MODS, which is induced by infection of associated injuries. Therefore, early control of hemorrhage is the most important measure for pelvic fractures. In all the 29 patients with pelvic fractures, diagnostic abdominal puncturation was made with a positive result in 21 patients (72.4%). In these 21 cases, dilatant hematoma caused by pelvic fractures and hemorrhage due to rupture of hematoma were proved by operation in 9 and 12 cases, respectively, which were treated by ligation of bilateral internal iliac artery. At the same time, the abdomen was examined so as to deal with combined abdominal injuries. Therefore, for severe open pelvic fractures (AIS=4) combined with shock, severe brain, thoracic or abdominal injuries, DCO should be considered to control the lethal hemorrhage so as to elevate the survival rate. Selective ce-
iliac arteriography and bilateral internal iliac arterial embolization could be used for ceasing the hemorrhage from severe pelvic fractures. When injuries of other organs need operative treatment, fluid expansion to retrieve hemodynamics and bilateral internal iliac arterial embolization are still safe for shock patients.

To deal with the patients with femoral fractures associated with severe multiple injuries, especially those combined with thoracic and abdominal injuries, simple external fixation should be made primarily, then definite internal fixation (for example, bone nailing) be made after stabilization of systemic function, which can decrease the risk of inducing ARDS and MODS postoperatively. DCO is safe for patients with unstable conditions such as unconsciousness, low body temperature, coagulative dysfunction, poor circulation, respiratory distress, and disorder of acid-base balance. Patients with femoral fractures in this study were all combined with severe cranio-cerebral injuries, thoracic, or abdominal injuries with mean ISS of 30 and needed urgent treatment. We suggest that the indications of choosing DCO for femoral fractures combined with severe multiple injuries are as follows: (1) combined with cranio-cerebral injury (AIS=3) or thoracic or abdominal injuries (AIS=4), (2) blood transfusion >2500 ml, (3) urinary volume less than 80 ml/h after resuscitation, and (4) having a tendency of consumptive coagulopathy, with the platelet count less than $9 \times 10^4/L$. When severe multiple injuries occur, spinal fractures involve many systems or sites and can easily cause severe physiological disturbance. Therefore, for such kind of patients, critically severe injury should be managed first, at the same time, attention should be paid to the characteristics of the spine and back spinal cord injuries needing early treatment. In this study, there were two patients with spinal fractures combined with thoracoabdominal injuries, who were treated only by posterior plate de-compression at stage I, and anterior bone graft plus Z-plate self-lock plate fixation was performed later.

In this study, the patients were all sent to ICU after primary management. In ICU, they were treated by recovering blood volume, keeping stable hemodynamics, and transfusing whole blood to keep hematocrit at over 0.35. For such patients, fresh blood is more helpful for recovery of blood volume and retrieval of coagulopathy. If coagulation disorder exists, fresh plasma and platelets should be transfused, with active retrieve of metabolic acidosis. The body temperature should be recovered and ambitransfusion equipment be used to recover the thermal balance of the patients. If there is presymptom of ARDS, breathing mechanical ventilation should be employed actively for resuscitation, thereafter definitive operation can be planned after improvement of the physiological function.

REFERENCES


(Received August 31, 2007) Edited by LIU Yang-e