Evaluation of the Outcome of Traumatic Thoracic Aortic Rupture in Patients in a Trauma and Critical Care Center

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Objectives: Multiple injuries may lead to traumatic thoracic aortic rupture (TTAR), which can be fatal. We evaluated the relationship between the clinical findings and outcomes of 26 patients with TTAR who were treated at our institution.

Methods: A total of 26 patients (men, 21; women, 5; average age, 45.8 ± 19.6 years) with a diagnosis of TTAR received from 1999 to 2009 were studied. We categorized patients into groups based on the outcome (survival or death) and investigated the relationship between the outcome and the following factors: injury mechanism, vital signs, other combined injuries, injury severity score (ISS), revised trauma score, and probability of survival (Ps).

Results: Of the 26 TTAR patients, 7 underwent emergency operations, 5 underwent delayed operations, 1 received conservative treatment, and 13 suffered cardiopulmonary arrest immediately after consultation and died. Of the 13 patients who died, 11 died within 2 hours after injury because of bleeding. Two of the 7 patients who underwent emergency operations died within 1 day of consultation, whereas all those who underwent delayed operations survived. Patients who underwent TTAR repair had a relatively favorable outcome. Analysis of the relationship between the clinical data and outcome showed that a young age was significantly correlated with survival, and that the Glasgow coma scale (GCS), heart rate, respiratory rate, or occurrence of shock were not significantly related to the outcome. The abbreviated injury scale (AIS) was used to score the severity of multiple injuries, and ISS was calculated from the AIS score. ISS was significantly higher in the death group (P = 0.007). ISS did not significantly differ among body parts (P = 0.077), but ISS of the extremities was higher than those of other parts. Pelvic fractures were frequent in the death group. Our strategy, whereby the patient initially underwent pelvic external fixation followed by TTAR repair was found to be very effective. The P-values calculated by the trauma and injury severity score method were significantly higher in the survival group (both, P = 0.007).

Conclusion: To treat TTAR, it is important to accurately evaluate the damage due to multiple injuries and apply an appropriate treatment strategy. Immediate repair of TTAR after bleeding due to combined injury improves the outcome. (English Translation of Jpn J Vasc Surg 2012; 21:5-9)

Keywords: aortic rupture, multiple trauma, vascular surgery

INTRODUCTION

Traumatic thoracic aortic rupture (TTAR) is a fatal injury, mostly leading to death within 24 hours if untreated,1) and requires immediate treatment. Patients with TTAR are frequently transported to emergency and critical care centers as tertiary emergency medical facilities. When TTAR is complicated by severe injuries in other areas, each injury even as a single complication markedly affects survival. Therefore, in addition to the
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SubjectS and MethodS

The subjects consisted of 26 patients (21 males and 5 females) aged 45.8 ± 19.6 years who were transported to the emergency center of our hospital between 1999 and 2009 and diagnosed with TTAR after excluding patients with cardiopulmonary arrest (CPA) on arrival. The mechanism of injury was a traffic accident in 14 patients and fall in 12 (industrial, 5 patients; self-inflicted, 7). The site of aortic injury was the aortic isthmus (Is) according to the classification by the Japanese Association for the Surgery of Trauma in 23 patients (88.5%). Concerning the clinical course, treatment for multiple injuries could be completed in 13 patients and could not be completed due to the development of CPA early after arrival at the emergency center in 13. All the latter 13 patients died. Of the former 13 patients in whom treatment could be completed, 12 underwent aortic repair (emergency operation, 7 patients; elective operation, 5) and the other 1 was observed, receiving conservative treatment. Of the 7 patients who underwent an emergency operation, 5 survived to discharge, but the other 2 died of multiple organ failure and hemorrhage, respectively, after the operation. All 5 patients who underwent elective operations survived to discharge. Of the 13 patients in whom treatment could not be completed, 3 underwent aortic repair with resuscitation, but all patients died. The outcomes of the patients who did not develop CPA and underwent aortic repair were relatively favorable. In the patients who developed CPA, the mean duration from injury to CPA was 2.1 ± 3.9 hours; the duration was 2 hours or less in 11 patients (84.6%). The mean duration from consultation to aortic repair was 3.4 ± 1.2 hours in the patients who underwent an emergency operation and 82.6 ± 122.9 days (3–300 days) in those who underwent an elective operation. In the patients who survived to discharge, the mean ICU stay was 22.8 ± 14.2 days (6–42 days) in the patients who underwent an emergency operation and 27.4 ± 11.5 days (13–40 days) in those who underwent a delayed operation, while the mean hospitalization period was 78.4 ± 23.8 days (23–145 days) in the former and 115.4 ± 31.1 days (51–226 days) in the latter. As the repair technique for aortic injury, graft replacement of the descending aorta was performed in 12 patients and direct suturing in 3. Postoperative paraplegia was not observed in any patient. As circulatory support during aortic repair, partial extracorporeal circulation using a percutaneous cardiopulmonary support system (PCPS) was performed in 11 patients, and complete extracorporeal circulation in 1 (combined with hypothermia-induced circulatory arrest with perfusion of the descending aorta and drainage from the femoral vein). In 2 patients, since circulation could not be maintained, perfusion of both the cardiac apex and femoral artery was performed. In 1 patient, the clamp and sew technique was used for repair.

As accompanying injuries (including multiple injuries) in the head, brain contusion was present in 8 patients, skull fracture in 7, traumatic subarachnoid hemorrhage in 3, and acute epidural hematoma in 1 (preoperative CPA). As injuries in the extremity, spine, and pelvis, upper limb fracture was observed in 3 patients, femoral fracture in 6, lower leg fracture in 6, pelvic fracture in 11, and vertebral fracture in 7. As visceral organ injuries in the trunk, rupture of the bladder was observed in 1 patient, renal injury in 2, hepatic injury in 3, and small intestine injury in 2. As treatment for each accompanying injury, open reduction · internal fixation involving the extremity was performed in 5 patients, lumbar spinal fusion in 2, pelvic external fixation in 3, laparotomy in 3, and IVR in 3. Among these procedures, those performed prior to aortic repair were pelvic external fixation and laparotomic ligation of the right hepatic artery in 2 and 1 patient, respectively, who underwent an emergency operation, and internal fixation of the femur, posterior lumbar spinal fusion, and hepatic arterial embolization in 2, 1, and 1 patient, respectively, who underwent an elective operation. The patients were classified into those who survived to discharge (survivor group) and those who died (non-survivor group), and the age, sex, mechanism of injury (traffic accident/fall), Glasgow coma scale (GCS) at the time of consultation, systolic blood pressure, respiratory rate, cardiac rate, and fibrinogen, fibrin degradation product (FDP), and Creatine Kinase MB (CK-MB) levels were compared between the two groups. As a parameter for the evaluation of multiple injuries, the injury severity score (ISS) was calculated according to each body area using the abbreviated injury scale (AIS-90) as an injury severity scale for the anatomical evaluation of multiple injuries. As a parameter for the physiological severity of injury,
the revised trauma score (RTS)\(^3\) obtained from the respiratory rate, systolic blood pressure, and GCS was calculated. In addition, the probability of survival (Ps)\(^4\) in patients with multiple injuries obtained from ISS, RTS, and the patient’s age was calculated using the trauma and injury severity score (TRISS) that was developed by Champion, et al. to objectively evaluate preventable trauma deaths. Ps was compared with the outcome in the 26 patients, and the clinical findings and strategies for the treatment of trauma were evaluated.

All measurement values in this study are expressed as the mean ± standard error (SEM). For statistical analysis, Stat View for Windows ver. 5.0 was used, and the χ\(^2\) test, Student’s t-test, and Man-Whitney’s U test were performed. P <0.05 was regarded as significant.

**RESULTS**

The patient-related parameters were compared between the survivor and non-survivor groups (Table 1). The patients in the survivor group were significantly younger than those in the non-survivor group (p = 0.025). The sex (male/female) or mechanism of injury (traffic-accident/fall) did not differ between the two groups. The GCS, heart rate, or respiratory rate at the time of consultation did not significantly differ between the two groups. The blood pressure at consultation was significantly lower in the non-survivor group. Blood examination showed no significant difference in CK-MB or FDP between the two groups but a significantly lower fibrinogen level in the non-survivor group (p = 0.038). ISS as a parameter for multiple injuries was significantly higher in the non-survivor group (p = 0.007). According to injured areas, ISS for injuries of the four extremities · spine · pelvis was 1.273 ± 0.499 in the survivor group and 2.500 ± 0.489 in the non-survivor group (p = 0.077). Although there was no significant difference between the two groups, ISS in this area was higher than that in the other areas, and pelvic fracture was frequently observed in the non-survivor group, suggesting that it tends to aggravate the outcome (Table 2). Among patients with head injury as a complication, 3 patients in the acute stage, in whom head computed tomography (CT) at consultation showed relatively extensive brain contusion, bleeding, and cranial base fracture not requiring emergency craniotomy, underwent emergency aortic repair using PCPS, and were ambulant at discharge without the aggravation of brain injury (Table 3). RTS did not significantly differ between the two groups. Ps was strongly correlated with the outcome (p = 0.007) in our patients. Ps was slightly lower (p = 0.19) in the 7 patients who underwent an emergency operation excluding those with preoperative CPA (48.6 ± 14.6%) than in the 5 who underwent an elective operation (73.9 ± 16.3%), showing that the emergency operation group tended to have severe multiple injuries.

The evaluation of treatment results in terms of Ps showed Ps >0.5 (preventable death) in 2 patients. These patients were encountered in the early period of this study, and showed no shock at consultation, but died of acute bleeding due to TTAR during the course. Both patients also had pelvic fracture. Since CT at consultation revealed no massive hemothorax or mediastinal hematoma associated with TTAR, an elective operation was planned, other areas were treated, and the course of head injury was observed. Of 12 patients with Ps <0.25 (non-preventable death), 3 could survive to discharge. Of the 3 patients, 2 underwent an emergency operation (2 and 2.5 hours, respectively, after injury), and the other underwent a delayed operation (31 days after injury). At consultation, shock was observed in 2 of the 3 patients, and the GCS score was ≤8 (coma) in all 3. All the 3 patients had an accompanying head injury and organ injury involving the trunk, but underwent TTAR repair after the control of bleeding due to the accompanying injuries, showed improvement in disturbed consciousness after the operation, and were discharged.
TTAR is still a fatal thoracic injury even though about half a century has passed since the first report by Parmley, et al.\(^1\) in 1958. Only 20% of patients with TTAR survive for 4 hours or more after injury. However, due to recent improvements in the emergency medical care system in urban areas, transportation to emergency and critical care centers in a short time after injury has become possible. The transportation of patients with severe multiple injuries, who might have died at the site of injury under the conventional emergency system, is expected to increase the detection rate of TTAR. In the Trauma and Critical Care Center of our hospital, about 600 patients with severe multiple injuries are annually treated. Von Oppell, et al.\(^5\) reported that the mean number of patients with TTAR encountered in trauma centers specializing in multiple injuries in Western countries is 2.6/year, which is similar to the number in our center. Concerning the cause of injury, Hunt, et al.\(^6\) reported traffic accidents in most patients. In our patients, the cause of injury was a fall in almost 50% of the patients, which may have been associated with high-rise buildings specific to urban areas in our medical care zone. The site of aortic injury was reported to be the proximal descending aorta including Is in most patients transported to medical institutions.\(^7\) In our study, a similar result was obtained. This may be because of the anatomical characteristic of Is being fixed by the arterial ligament.

Analysis of patient-associated parameters at consultation suggested the influences of the age, blood pressure, and presence/absence of coagulopathy on outcomes. These parameters are also important when the management of multiple injuries is performed. In patients with poor prognostic factors, more immediate treatment with a consideration of invasiveness may be necessary. To reduce invasiveness, the usefulness of partial extracorporeal circulation using PCPS during TTAR repair has been reported.\(^8\) Our experience of its use in patients with a brain contusion also suggested that this method is minimally invasive and useful in patients with brain injury in the acute stage. In recent years, minimally invasive stent grafting has become the first choice for TTAR repair in overseas countries.\(^9\) The spread of this technique is also awaited in Japan.

The timing of TTAR repair in patients with multiple injuries has been controversial: some studies have recommended emergency surgery\(^10\) while others have recommended an elective operation in all patients irrespective of the presence or absence of injuries to other organs.\(^11\) Most patients who died had developed CPA due to bleeding within 2 hours after injury. Patients who survived to TTAR repair showed relatively favorable outcomes. Therefore, in our department, TTAR repair as soon as possible after the diagnosis is the basic principle for TTAR treatment. However, when TTAR is complicated by other severe injuries, treatment for TTAR first is not always appropriate, and determination of the order of priority and the selection of treatment methods with a consideration of the balance between the required time and effects are important keys to determine success or failure. The treatment strategy for TTAR complicated by other injuries in our department is shown (Fig. 1). When continuous bleeding from TTAR is marked, and vital signs are unstable, a highly emergent operation for TTAR (transportation directly from the CT room to the operating room) is performed. However, since TTAR
The evaluation of invasiveness using Ps is very useful. Based on experience of preventable deaths in our patients and a patient with a low Ps who was ambulant at discharge, it is important to complete TTAR repair as soon as possible while being aware that TTAR is a condition that constantly jeopardizes the patient’s life and does not allow a moment’s delay.

**Conclusions**

TTAR is a fatal thoracic injury with an extremely high risk of death due to bleeding early after injury, and should be repaired as soon as possible. To formulate its treatment strategy, the evaluation of invasiveness using ISS and Ps as parameters for the assessment of injury was useful. For improvement in the outcome, it may be useful to control bleeding from accompanying injuries first using a method giving consideration to the balance between the required treatment time and effects, followed by TTAR repair.

**References**

4) Boyd CR, Tolson MA, Copes WS. Evaluating trauma repair requires the “systemic administration of heparin” and “use of extracorporeal circulation”, which promotes bleeding from other injuries, aggravating the patient’s condition, when vital signs are stable, we consider that the control of bleeding from other injuries is necessary before TTAR repair. However, as described above, since the risk of bleeding due to TTAR increases with time, the time for the treatment of injuries in other areas should be as short as possible, and the damage control concept[12] is necessary. Damage control was originally a term used in the navy, meaning emergency procedures for returning ships damaged due to battles to the nearest naval port, keeping them from sinking. This meaning has changed to mean treatment strategies for trauma to save life. We use this concept. In particular, since comparison of ISS suggested that accompanying injuries in the limbs, spine, and pelvis aggravate the outcome, in patients with pelvic fracture showing instability at the fracture site and retroperitoneal bleeding, external fixation, which can be performed in a short time in the operating room and have marked effects on bleeding, is performed first, followed by TTAR repair. When further postoperative hemostasis is necessary, pelvic TAE is added. We also encountered a patient with accompanying hepatic injury who underwent ligation of the injured hepatic artery to stop bleeding through a small incision, followed by TTAR repair, who showed a favorable course, and was discharged.[13] As damage control, the following strategy was useful: Bleeding from accompanying injuries is stopped first, followed by TTAR repair, and a hemostatic procedure is added after the operation when necessary.

Fig. 1 Therapeutic strategy of traumatic thoracic aortic rupture (TTAR) and other traumatic injury.