Blunt Traumatic Cardiac Rupture: Single-Institution Experiences over 14 Years

Jeong Hee Yun, M.D.1, Joung Hun Byun, M.D.2, Sung Hwan Kim, M.D.2, Sung Ho Moon, M.D.2, Hyun Oh Park, M.D.2, Sang Won Hwang, M.D.2, Yong Hwan Kim, M.D.4

1Department of Thoracic and Cardiovascular Surgery, Samsung Medical Center, Sungkyunkwan University School of Medicine, 2Department of Thoracic and Cardiovascular Surgery, Gyeongsang National University Changwon Hospital, Gyeongsang National University School of Medicine, Departments of 3Thoracic and Cardiovascular Surgery and 4Emergency Medicine, Samsung Changwon Hospital, Sungkyunkwan University School of Medicine

Background: Blunt traumatic cardiac rupture is rare. However, such cardiac ruptures carry a high mortality rate. This study reviews our experience treating blunt traumatic cardiac rupture. Methods: This retrospective study included 21 patients who experienced blunt traumatic cardiac rupture from 1999 to 2015. Every patient underwent surgery. Several variables were compared between survivors and fatalities. Results: Sixteen of the 21 patients survived, and 5 (24%) died. No instances of intraoperative mortality occurred. The most common cause of injury was a traffic accident (81%). The right atrium was the most common location of injury (43%). Ten of the 21 patients were suspected to have cardiac tamponade. Significant differences were found in preoperative creatine kinase-myocardial band (CK-MB) levels (p=0.042) and platelet counts (p=0.004) between the survivors and fatalities. The patients who died had higher preoperative Glasgow Coma Scale scores (p=0.007), worse Trauma and Injury Severity Scores (p=0.007), and higher Injury Severity Scores (p=0.004) than those who survived. Conclusion: We found that elevated CK-MB levels, a low platelet count, and multi-organ traumatic injury were prognostic factors predicting poor outcomes of blunt cardiac rupture. If a patient with blunt traumatic cardiac rupture has these factors, clinicians should be especially attentive and respond promptly in order to save the patient’s life.

Key words: 1. Cardiac tamponade 2. Trauma 3. Rupture

Introduction

Blunt traumatic cardiac rupture is rare but highly fatal [1-3]. The incidence of blunt cardiac rupture among hospital admissions for trauma is only approximately 0.16%–2% [4-6]. However, the actual incidence may be higher because many victims may die before arrival at the hospital. With advances in traumatology, several studies have investigated the prognostic factors associated with traumatic cardiac rupture [1,7]. In this study, we attempted to find factors affecting the prognosis of patients with blunt traumatic cardiac rupture.
Table 1. Patient characteristics

| Characteristic                    | Value   |
|----------------------------------|---------|
| Age (yr)                         | 48 (17–95) |
| Gender                           |         |
| Male                             | 13 (62) |
| Female                           | 8 (38)  |
| Cause of trauma                  |         |
| Fall                             | 2 (9.7) |
| Motor vehicle accident           |         |
| Inside car                       | 11 (52.0) |
| Pedestrian                       | 4 (19.0) |
| Motorcycle                       | 2 (9.7)  |
| Industrial accident              | 2 (9.7)  |
| Injury location                  |         |
| Left atrium                      | 2 (9.7) |
| RA                               | 9 (43.0) |
| RA/superior vena cava            | 2 (9.7)  |
| RA/IVC                           | 1 (4.8)  |
| RV/IVC                           | 1 (4.8)  |
| Left ventricle                   | 3 (14.0) |
| RV                               | 3 (14.0) |
| Diagnostic method                |         |
| Chest CT                         | 10 (48.0) |
| Echocardiography                 | 7 (33.0) |
| CT/echocardiography              | 4 (19.0) |
| Cardiopulmonary bypass           | 4 (19.0) |
| Cardiopulmonary resuscitation    | 2 (9.7)  |
| Ventilator care time (hr)        | 111±318.8 |
| Hospital stay duration (day)     | 36±35.9 |
| Intensive care unit stay duration (day) | 17±29.3 |

Values are presented as median (range), number (%), or mean±standard deviation. RA, right atrium; IVC, inferior vena cava; RV, right ventricle; CT, computed tomography.

Methods

1) Patients

This retrospective study was reviewed and approved by the institutional ethics committee of our institution (Ethical Committee of Sungkyunkwan University of Samsung Changwon Hospital, approval number 2015-SCMC-037-00). Between 1999 and 2015, a total of 107,657 patients were admitted to our hospital due to trauma. We selected 47 patients who were diagnosed with traumatic cardiac rupture. We excluded patients with penetrating or iatrogenic cardiac rupture. Ultimately, we analyzed 21 patients who were diagnosed with blunt traumatic cardiac rupture and required emergency surgery. In our analysis of these 21 patients, we identified several prognostic factors.

2) Surgery

All operations were performed via median sternotomy. In each case, cardiopulmonary bypass (CPB) or extracorporeal membrane oxygenation was prepared as a precaution. If the patient was hemodynamically unstable, 2 cardiovascular surgeons operated together to perform the median sternotomy and femoral cannulation simultaneously. After the sternotomy, surgeons opened the pericardium for prompt decompression of the heart, rapidly removed the hematoma, and attempted to find the injury site. The injury sites were primarily repaired using double-arm monofilament stitches with pledgeted, interrupted sutures. After the injury sites were primarily repaired, we weaned the patients from CPB as soon as possible.

3) Statistical analysis

All data are expressed as mean±standard deviations. Continuous variables were compared using the Mann-Whitney U-test. Categorical variables were compared using the chi-square test or the Fisher exact test. All p-values < 0.05 were considered to indicate statistical significance. Data were analyzed using IBM SPSS ver. 21.0 (IBM Co., Armonk, NY, USA).

Results

The patients’ clinical characteristics are presented in Table 1. Most blunt traumatic cardiac injuries resulted from traffic accidents (81%), and most patients had combined trauma. The combined trauma included liver laceration, spleen injury, pelvic bone fracture, spinal fracture, and fractures of the extremities (Table 2). The mean Injury Severity Score (ISS) was 28±17.4 (range, 16 to 97).

Among the 21 patients, 10 were suspected to have cardiac tamponade, 3 of whom died after surgery. The mean central venous pressure (CVP) and systolic blood pressure of the 3 patients who died were 28 cm H₂O and 67 mm Hg, respectively. In contrast, the mean CVP and systolic blood pressure of the 7 surviving patients were 26 cm H₂O and 81 mm Hg, respectively.

Two patients received cardiopulmonary resuscitation (CPR) prior to surgery. One of them died during postoperative care due to pneumonia and the
| No. | Age (yr) | Sex | Mechanism | Injury location | Combined injury | Injury Severity Score | Shock \( i \) | Cardiopulmonary resuscitation | Cardiopulmonary bypass | Hospital day (day) | Intensive care unit stay day (day) | Cause of death | Outcome |
|-----|----------|-----|-----------|-----------------|-----------------|----------------------|-----------|---------------------------|----------------------|----------------|-----------------------------|---------------|---------|
| 1   | 39       | F   | MVA       | RA-SVC          | Pneumothorax, Rt. patella fracture | 21       | No         | 0.65                     | No                   | No            | 15       | 8               | Alive         |
| 2   | 25       | M   | Pedestrian | RA              | Diffuse axonal injury, Lt. renal contusion, liver contusion, Lt. hip fracture | 24       | No         | 2.5          | No                   | No            | 92       | 42             | Alive         |
| 3   | 35       | F   | MVA       | RA-SVC          | Rt. radius fracture, intrahepatic hematoma | 24       | No         | 0.86                     | No                   | No            | 18       | 4               | Alive         |
| 4   | 19       | M   | MVA       | RA              | No                       | 16       | Yes        | 2.26                     | No                   | No            | 13       | 4               | Alive         |
| 5   | 59       | M   | Industrial | RV              | No                       | 16       | Yes        | 0.9                      | No                   | No            | 37       | 4               | Alive         |
| 6   | 67       | M   | Motorcycle | RA              | Hemopneumothorax (both), Rt. patella fracture, Rt. acetabular fracture | 21       | No         | 0.9          | No                   | No            | 99       | 55             | Alive         |
| 7   | 17       | M   | Motorcycle | RA              | Liver laceration, Rt. renal injury, Rt. pubic bone fracture, Lt. facial bone fracture, cerebral contusion, | 26       | No         | 2.7          | Yes                  | No            | 28       | 7              | Alive         |
| 8   | 30       | F   | MVA       | RA              | Hypoxic brain damage, liver contusion, Rt. ankle fracture | 21       | Yes        | 1.14                     | No                   | No            | 21       | 8               | Alive         |
| 9   | 50       | M   | Industrial | RV-IVC          | Rt. wrist fracture | 20       | Yes        | 1.13                     | No                   | No            | 26       | 5               | Alive         |
| 10  | 39       | F   | MVA       | RA              | Liver laceration, cerebral concussion | 26       | No         | 1.51                     | No                   | No            | 15       | 9               | Alive         |
| 11  | 52       | F   | Pedestrian | RA              | Spleen laceration | 24       | Yes        | 1.56                     | No                   | No            | 28       | 3               | Alive         |
| 12  | 47       | M   | MVA       | RV              | No                       | 16       | Yes        | 1.61                     | No                   | No            | 10       | 2               | Alive         |
| 13  | 75       | F   | MVA       | RA-IVC          | Lt. humerus mid shaft fracture, facial laceration | 21       | No         | 1.16                     | No                   | Yes           | 82       | 8              | Alive         |
| 14  | 48       | M   | MVA       | LV              | Cerebral hemorrhage, panperitonitis, liver contusion, Rt. patellar fracture | 34       | No         | 0.94                     | No                   | No            | 70       | 27             | Alive         |
| 15  | 73       | M   | MVA       | LA              | Pelvic bone fracture | 20       | No         | 0.78                     | No                   | No            | 16       | 4               | Alive         |
| 16  | 48       | M   | Fall down | LA              | Distal jejunum mesenteric tearing | 34       | Yes        | 1.33                     | No                   | Yes           | 23       | 5               | Alive         |

(Continued to the next page)
Table 2. Continued

| No. | Age (yr) | Sex | Mechanism | Location | Combined Injury | Injury Severity Score | Shock Index | Cardiopulmonary resuscitation | Cardiopulmonary bypass | Hospital day (day) | Intensive care unit stay day (day) | Cause of death | Outcome |
|-----|----------|-----|------------|----------|-----------------|----------------------|-------------|-------------------------------|-----------------------|----------------|-------------------------------|--------------|---------|
| 17  | 27       | M   | Pedestrian | RA       | L-spine dislocation, paraplegia, hemopneumothorax, hemoperitoneum, liver contusion, GI bleeding | 42         | No                      | 1.44       | No                          | No                    | 31             | 30                           | GI bleeding due to gastric ulcer, ARF | Dead     |
| 18  | 36       | M   | MVA        | RA       | Hypoxic brain damage, Rt. pneumothorax | 97         | Yes                     | 1.73       | Yes                         | No                    | 128            | 128                          | Pneumonia, brain death                  | Dead     |
| 19  | 48       | M   | MVA        | LV       | Rt. femur fracture | 20         | Yes                     | 2.46       | No                          | No                    | 2              | 1                            | Low cardiac output, brain death          | Dead     |
| 20  | 31       | F   | Fall down  | LV       | Pelvic bone fracture, spleen laceration, both internal iliac artery rupture | 41         | No                      | 1.65       | No                          | Yes                   | 2              | 2                            | Hypovolemic shock, DIC, ARF             | Dead     |
| 21  | 95       | F   | Pedestrian | RV       | Multiple rib fracture, Lt. fibular fracture, Lt. pubic bone fracture | 24         | Yes                     | 0.97       | No                          | Yes                   | 1              | 1                            | DIC, hypovolemic shock                  | Dead     |

F, female; MVA, motor vehicle accident; RA, right atrium; SVC, superior vena cava; Rt., right; M, male; Lt., left; RV, right ventricle; IVC, inferior vena cava; LV, left ventricle; LA, left atrium; GI, gastrointestinal; ARF, acute renal failure; DIC, disseminated intravascular coagulation.

*aHeart rate/systolic blood pressure.*
Table 3. Mean preoperative measures

| Variable                        | Value       |
|---------------------------------|-------------|
| Creatine kinase-myocardial band isoenzyme (ng/mL) | 13.4±9.2    |
| Troponin I (ng/dL)              | 1.69±2.2    |
| Hematocrit (g/dL)               | 37.1±5.1    |
| Platelet count (10^3/mL)        | 189.2±7.2   |
| Creatinine (mg/dL)              | 1.1±0.3     |
| Systolic blood pressure (mm Hg) | 80.9±21.9   |
| Central venous pressure (cm H2O)| 19.2±8.8    |
| Elapsed time from arrival to surgery (min) | 74.4±71.4  |

Values are presented as mean±standard deviation.

Table 4. Comparison between survivors and fatalities

| Variable                        | Survivors (n=16) | Fatalities (n=5) | p-value |
|---------------------------------|------------------|------------------|---------|
| Age (yr)                        | 50.3±15.3        | 50.2±31          | 0.842   |
| Lactate (mmol/L)                | 5.3±3.2          | 7.8±0.22         | 0.212   |
| Creatine kinase–myocardial band isoenzyme (ng/mL) | 22.7±28.7       | 78.5±110.4      | 0.042   |
| Troponin I (ng/dL)              | 2.2±4.1          | 2.8±2.1          | 0.133   |
| Creatinine (mg/dL)              | 1.1±0.3          | 1.1±0.2          | 0.495   |
| Hematocrit (g/dL)               | 38.3±4.2         | 34.8±6.0         | 0.109   |
| Platelet count (10^3/mL)        | 196.8±53         | 144.8±46         | 0.004   |
| Central venous pressure (cm H2O)| 18.3±5.9         | 17.3±12.5        | 0.905   |
| Elapsed time to surgery (min)   | 66.1±62.4        | 112.3±104.4      | 0.445   |
| SBP (mm Hg)                     | 87±22.1          | 75±19.1          | 0.354   |
| Ventilator care (hr)            | 65.4±141.3       | 11.9±12.9        | 0.842   |
| Hospital days (day)             | 38.6±30.9        | 9.0±14.7         | 0.313   |
| Intensive care unit stay duration (day) | 11.4±12.9   | 8.5±14.3         | 0.445   |
| Injury Severity Score           | 23.2±6.5         | 33.5±9.3         | 0.004   |
| Glasgow Coma Scale              | 13.7±2.5         | 6.8±4.6          | 0.007   |
| Trauma and Injury Severity Score| 99.2±1.8         | 87.1±13.2        | 0.007   |
| Blood transfusion (packs)       | 6.4±2.98         | 9.8±9.7          | 0.900   |
| Shock index (heart rate/SBP)    | 1.3±0.56         | 1.65±0.54        | 0.186   |

Diagnostic method

- Chest CT: 8 (50.0) / 2 (40.0) 0.696
- Echocardiography: 4 (25.0) / 3 (60.0) 0.147
- CT and echocardiography: 4 (25.0) / 0 0.214

Injury location

- Left atrium: 2 (12.5) / 0
- RA: 7 (43.8) / 2 (40.0)
- RA-superior vena cava: 2 (12.5) / 0
- RA-IVC: 1 (6.3) / 0
- RV-IVC: 1 (6.3) / 0
- Left ventricle: 1 (6.3) / 2 (40.0)
- RV: 2 (12.5) / 1 (20.0)
- Cardiopulmonary bypass: 2 (12.5) / 2 (40.0) 0.182
- Cardiopulmonary resuscitation: 1 (6.3) / 1 (20.0) 0.372

Values are presented as mean±standard deviation or number (%), unless otherwise stated.

SBP, systolic blood pressure; CT, computed tomography; RA, right atrium; IVC, inferior vena cava; RV, right ventricle.
tinine levels (1.1±0.3 mg/dL) were nearly normal in all patients. The time from hospital arrival to surgery ranged from 10 to 260 minutes. In addition, the mean blood transfusion amount in survivors was 6.3 units, as compared to 9 units in fatalities (p=0.900).

A comparison between the survivors and fatalities is presented in Table 4. There were 16 survivors and 5 fatalities. No instances of intraoperative mortality occurred, but the in-hospital mortality rate was 24% (5 of 21). The causes of death included pneumonia (1), inadequate myocardial protection-related low cardiac output (1), and massive bleeding-related disseminated intravascular coagulation (3). All fatalities showed liver and renal failure, and 2 of them showed brain death. The clinical characteristics of each patient are presented in Table 2.

Significant differences were found in preoperative CK-MB levels (p=0.042) and platelet counts (p=0.004) between the survivors and fatalities. In addition, the preoperative Glasgow Coma Scale score (p=0.007), Trauma and Injury Severity Score (p=0.007), and ISS were significantly worse in the fatalities than in the survivors (p=0.004). No significant differences were found between the two groups in preoperative creatinine levels (p=0.495) or elapsed time to surgery (p=0.445). Similarly, no significant differences were found in injury location (p=0.437), CPR history (p=0.372), use of CPB (p=0.182), amount of blood transfusion (p=0.900), or shock index (p=0.186) between the two groups.

**Discussion**

Most patients who experience blunt traumatic cardiac rupture die before arrival to the hospital. According to one Japanese study, 91% of patients with blunt traumatic cardiac rupture died within 30 minutes of the accident [7]. We analyzed 21 patients who experienced blunt traumatic cardiac rupture and compared our results with those of previous studies.

Most of our results are consistent with those of previous papers. Traffic accidents were the most common cause of blunt traumatic cardiac rupture (80%), and the most common site of injury was the right atrium (43%) [2,5,7-9]. However, some of our results were different from those of previous studies.

When a patient arrived at the hospital, we first focused on the vital signs, peripheral circulation, presence of an open wound, neck vein distension, and facial plethora. If cardiac rupture was suspected, we performed chest computed tomography, focused assessment with sonography for trauma, or thoracic echocardiography as soon as possible. If patients had unstable vital signs, we performed intubation and transfusion, using intravenous inotropics as needed. If patients had hemopneumothorax, we inserted a chest tube at the emergency department and then rapidly transferred the patients to the operating room.

Ten of the 21 patients were suspected to have cardiac tamponade because they had hypotension, high CVP, and echocardiographic signs of tamponade (the presence of pericardial effusion, diastolic collapse of the right ventricle, IVC dilatation, etc.). When we suspected cardiac tamponade, we rapidly moved the patient to the operating room rather than trying to insert a pericardial catheter in the emergency room, because it takes almost the same time to perform a pericardial catheter insertion as to prepare the operating room in our hospital. The average elapsed door-to-surgery time in patients with cardiac tamponade was 29 minutes. In contrast, when cardiac tamponade was not suspected, further evaluations were performed prior to surgery.

If a patient’s vital signs are unstable, we consider an emergency department thoracotomy to have several advantages, including the prompt decompression of pericardial pressure and the rapid restoration of hemodynamics. However, our emergency room had no facilities available for emergency department thoracotomies.

All cases were performed via median sternotomy. CPB was applied in 4 patients with left ventricular rupture, and in 1 patient with an RA/IVC junction injury.

Sixteen (75%) of the 21 patients survived. The overall survival rate was similar to that of a prior study, which found that 70%-80% of patients who were transferred to trauma centers survived after blunt cardiac injury [8].

Several discrepancies are present between our results and those of Nan et al. [4]. They found significant differences between survivors and fatalities in preoperative creatinine levels, but no differences in preoperative CK-MB or platelet count [4]. In contrast, we found no significant difference in preope-
Blunt Cardiac Rupture

Fig. 1. Elevated CL-MB, a low platelet count, and multi-organ traumatic injuries were associated with a poor prognosis after blunt traumatic cardiac injury. CK-MB, creatine kinase–myocardial band isoenzyme.

Elevated preoperative CK-MB may be associated with a poor prognosis. This enzyme is not specific for cardiac injury, but can reflect severe muscle injury and potentially predict rhabdomyolysis. According to a 1998 study by Swaanenburg et al. [10], among 38 patients with thoracic injuries, 18–30 had increased CK-MB levels, increased CK-MB activity, an elevated ratio of CK-MB activity to total CK, or an elevated ratio of CK-MB mass to total CK upon admission. Although elevated CK-MB levels are not specific for cardiac injury, they can be indicative of severe combined injuries and be associated with a poor prognosis.

In addition, a low preoperative platelet count may also be associated with a poor prognosis. Nijboer et al. [11] recently reported that the early-stage platelet count was independently related to mortality in blunt trauma patients. A low platelet count reflects increased platelet consumption as well as massive blood loss and hemodilution. Increased platelet consumption can lead to a systemic inflammatory response or disseminated intravascular coagulation [11]. Early platelet consumption can be explained based on the fact that platelet aggregation and blood clot formation begins within 15–20 seconds of a major vessel rupture [12].

We did not find any significant difference in elapsed time from hospital arrival to surgery between fatalities and survivors. Disease severity may have acted as a suppressor variable. For instance, when a patient was suspected to have cardiac tamponade, surgery was promptly performed within 30 minutes. In contrast, surgery was delayed more in hemodynamically stable patients.

1) Study limitations
This was a case-control study, and case-control studies are prone to bias and confounding. The small, heterogeneous study population is a major limitation of this study. Although we were able to identify some characteristics of survivors, we were not able to clearly confirm causality. Given this limitation, we attempted to identify factors associated with a poor prognosis. Larger studies in the future are needed to substantiate our findings.

2) Conclusion
Few prior studies have investigated blunt traumatic cardiac rupture due to the rarity of such cases. This study analyzed factors associated with a poor prognosis of blunt traumatic cardiac rupture. We found that elevated CK-MB levels, a low platelet count, and multi-organ traumatic injury were associated with a poor prognosis (Fig. 1). If a patient with blunt traumatic cardiac rupture exhibits these factors, clinicians should be especially attentive and respond promptly to save the patient’s life.

Conflict of interest
No potential conflict of interest relevant to this article was reported.

Acknowledgments
This study was supported by a Grant of the Samsung Vein Clinic Network (Daejeon, Anyang,
References

1. Bright EF, Beck CS. Nonpenetrating wounds of the heart: a clinical and experimental study. Am Heart J 1935;10: 293-321.
2. Brathwaite CE, Rodriguez A, Turney SZ, Dunham CM, Cowley R. Blunt traumatic cardiac rupture: a 5-year experience. Ann Surg 1990;212:701-4.
3. Kang JK, Yoon YS, Kim HT, Park ID, Soh DM, Lee CJ. Surgical management of traumatic cardiac injury. Korean J Thorac Cardiovasc Surg 2004;37:335-41.
4. Nan YY, Lu MS, Liu KS, et al. Blunt traumatic cardiac rupture: therapeutic options and outcomes. Injury 2009;40: 938-45.
5. Martin TD, Flynn TC, Rowlands BJ, Ward RE, Fischer RP. Blunt cardiac rupture. J Trauma 1984;24:287-90.
6. Perchinsky MJ, Long WB, Hill JG. Blunt cardiac rupture: the Emanuel Trauma Center experience. Arch Surg 1995; 130:852-6.
7. Namai A, Sakurai M, Fujiwara H. Five cases of blunt traumatic cardiac rupture: success and failure in surgical management. Gen Thorac Cardiovasc Surg 2007;55:200-4.
8. Fitzgerald M, Spencer J, Johnson F, Marasco S, Atkin C, Kossmann T. Definitive management of acute cardiac tamponade secondary to blunt trauma. Emerg Med Australas 2005;17:494-9.
9. Fulda G, Brathwaite CE, Rodriguez A, Turney SZ, Dunham CM, Cowley RA. Blunt traumatic rupture of the heart and pericardium: a ten-year experience (1979-1989). J Trauma 1991;31:167-72.
10. Swaanenburg JC, Klaase JM, DeJongste MJ, Zimmerman KW, ten Duis HJ. Troponin I, troponin T, CKMB-activity and CKMB-mass as markers for the detection of myocardial contusion in patients who experienced blunt trauma. Clin Chim Acta 1998;272:171-81.
11. Nijboer JM. New insights in outcome after major trauma. Groningen: University Library Groningen; 2009.
12. Guyton AC, Hall JE. Textbook of medical physiology. Philadelphia (PA): Saunders; 2000.