JTI
JOURNAL OF
TRAUMA AND INJURY

ORIGINAL ARTICLE
J Trauma Inj 2017;30(4):166-172
http://doi.org/10.20408/jti.2017.30.4.166

Emergency Surgical Management of Traumatic Cardiac Injury in Single Institution for Three Years

Seok Joo, M.D., Dae Sung Ma, M.D., Yang Bin Jeon, M.D., Sung Youl Hyun, M.D.

Department of Trauma Surgery, Regional Trauma Center, Gachon University Gil Hospital, Incheon, Korea

Received: November 7, 2017
Revised: December 14, 2017
Accepted: December 18, 2017

Correspondence to
Dae Sung Ma, M.D.
Department of Trauma Surgery, Regional Trauma Center, Gachon University Gil Hospital, 21 Namdong-daero 774beon-gil, Namdong-gu, Incheon 21565, Korea
Tel: +82-32-460-3010
Fax: +82-32-460-3019
E-mail: pegamu@gilhospital.com

Purpose: Thoracic traumas represent 10-15% of all traumas and are responsible for 25% of all trauma mortalities. Traumatic cardiac injury (TCI) is one of the major causes of death in trauma patients, rarely present in living patients who are transferred to the hospital. TCI is a challenge for trauma surgeons as it provides a short therapeutic window and the management is often dictated by the underlying mechanism and hemodynamic status. This study is to describe our experiences about emergency cardiac surgery in TCI.

Methods: This is a retrospective clinical analysis of patients who had undergone emergency cardiac surgery in our trauma center from January 2014 to December 2016. Demographics, physiologic data, mechanism of injuries, the timing of surgical interventions, surgical approaches and outcomes were reviewed.

Results: The number of trauma patients who arrived at our hospital during the study period was 9,501. Among them, 884 had chest injuries, 434 patients were evaluated to have over 3 abbreviated injury scale (AIS) about the chest. Cardiac surgeries were performed in 18 patients, and 13 (72.2%) of them were male. The median age was 47.0 years (quartiles 35.0, 55.3). Eleven patients (61.1%) had penetrating traumas. Prehospital cardiopulmonary resuscitations (CPR) were performed in 4 patients (22.2%). All of them had undergone emergency department thoracotomy (EDT), and they were transferred to the operating room for definitive repair of the cardiac injury, but all of them expired in the intensive care unit. Most commonly performed surgical incision was median sternotomy (n=13, 72.2%). The majority site of injury was right ventricle (n=11, 61.1%). The mortality rate was 22.2% (n=4).

Conclusions: This study suggests that penetrating cardiac injuries are more often than blunt cardiac injury in TCI, and the majority site of injury is right ventricle. Also, it suggests prehospital CPR and EDT are significantly responsible for high mortality in TCI.

Keywords: Trauma; Heart injuries; Cardiac surgery

http://www.jtraumainj.org
eISSN 2287-1683
pISSN 1738-8767

Copyright © 2017 The Korean Society of Trauma
This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (http://creativecommons.org/licenses/by-nc/4.0/) which permits unrestricted noncommercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

INTRODUCTION

Thoracic traumas represent 10-15% of all traumas and are responsible for 25% of all trauma mortalities [1]. Traumatic cardiac injury (TCI) is one of the major causes of death in trauma patients, rarely present in living patients who are transferred to the hospital. TCI is a challenge for trauma surgeons as it provides a short therapeutic window and the management is often dictated by the underlying mechanism and hemodynamic status [2]. Due to the improved transfer system in trauma, patients with TCI who survive to reach the hospital have increased.

This study is to describe our experiences about emergency cardiac surgery in TCI.

METHODS

This study is a retrospective clinical analysis of patients who had undergone emergency cardiac surgery in our trauma center from January 2014 to December 2016. Demographics, physiologic data, mechanism of injuries, the timing of surgical interventions, surgical approaches, and outcomes were reviewed.

Inclusion criteria were 1) the patients who underwent trauma and 2) the presence of surgically confirmed cardiac injury. The patients were excluded; who underwent emergency department thoracotomy (EDT) but had not surgically confirmed the cardiac injury.

Focused assessment with sonography for trauma (FAST) was conducted in all patients. No preoperative echocardiography was done. Preoperative chest computed tomography (CT) scan was performed by each surgeon's assessment considering the medical condition of the patient. EDT was performed on the patients who were in extremis, or who lost their vital signs in transport or the trauma bay. All the operative procedures were conducted by four cardiothoracic surgeons with expertise in trauma management. Patients were operated upon under general anesthesia with single lumen endotracheal tube. The heart-lung machine was not used in any of the patients.

The bleeding from cardiac injuries was primarily controlled by applying digital pressure. And then the cardiac injuries were repaired using double-armed monofilament stitches with or without pledgets as interrupted or running sutures by the operating surgeon's preference. All the patients were admitted and managed in the intensive care unit (ICU) in the postoperative period.

Statistical analyses

All descriptive statistics were expressed as the median and interquartile range for continuous variables. Categorical data were analyzed with Fisher exact test. Continuous data were compared using the Mann-Whitney *U* test. Differences were considered to be statistically significant with p values <0.05. Statistical analyses were performed using SPSS statistical software version 22.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

The number of trauma patients who arrived at our hospital during the study period was 9,501. Among them, 884 had chest injuries, 434 patients were evaluated to have over 3 abbreviated injury scale (AIS) about the chest. Cardiac surgeries were performed in 18 patients.

Clinical characteristics of patients are listed in Table 1. Thirteen (72.2%) patients were male. The median age was 47.0 years (quartiles 35.0, 55.3). Eleven patients (61.1%) had penetrating traumas. Prehospital cardiopulmonary resuscitations (CPR) were performed in 4 patients (22.2%). All of them had undergone EDT, and they were transferred to the operating room for definitive repair of the cardiac injury, but all of them expired in the ICU. Nine patients (50.0%) were evaluated by chest CT before the operation.

Perioperative variables of patients are listed in Table 2. Most commonly performed surgical incision was median sternotomy (n=13, 72.2%). The majority site of injury was right ventricle (n=11, 61.1%), three at right atrium, three at pericardium and one at left atrium, respectively. Concomitant procedures were performed in 8 patients (44.4%), especially pulmonary repairs were performed in 4 patients. Only two cases were known to have the cardiac problem on postoperative echocardiography. Mortality rate was 22.2% (n=4). The causes of deaths were two hem-

http://doi.org/10.20408/jti.2017.30.4.166

Table 1. Clinical characteristics of patients

Case	Sex	Age (years)	Mechanism	Severity of trauma	PCPR	Time F to TB (min)	Consciousness	ISS	RTS	TRISS	AIS chest	GCS	SBP (mmHg)	EDT	CT
1	M	36	Stab injury	Cardiac tamponade, tension hemopneumothorax	N	66	Verbal	10	7.108	89.1	5	14	80	N	N
2	M	63	Stab injury	Cardiac tamponade, liver laceration	N	73	Painful	26	6.904	67.1	5	9	112	N	N
3	F	32	Stab injury	Cardiac tamponade	N	117	Painful	26	6.904	93.3	5	9	122	N	Outside
4	F	40	Stab injury	Hemopericardium	N	136	Alert	34	7.841	99.0	3	15	93	N	N
5	M	54	Stab injury	Cardiac tamponade	N	37	Verbal	38	5.439	76.4	5	12	50	N	N
6	M	64	Occupant TA	Massive hemothorax right, cardiac tamponade	N	165	Painful	24	5.235	46.7	5	7	86	N	Outside
7	M	30	Stab injury	Cardiac arrest	Y	56	unresponse	34	0	0.8	5	7	0	Y	N
8	F	25	Pedestrian TA	Cardiac tamponade	N	25	Painful	20	3.479	30.8	5	7	49	Pericardiocentesis	Y
9	M	60	Occupant TA	Cardiac tamponade	N	180	Verbal	10	7.841	89.5	4	15	130	N	Y
10	F	36	Stab injury	Cardiac arrest, IVC laceration, liver laceration	Y	33	Unresponse	26	3.600	0.9	5	3	0	Y	N
11	M	51	Occupant TA	Hemopericardium, hemothorax, multiple rib fracture	N	386	Painful	26	3.565	68.2	4	5	64	N	Y
12	M	19	Stab injury	Hemopericardium	N	100	Alert	9	7.841	99.1	3	15	108	N	Y
13	F	59	Stab injury	Hemopericardium	N	61	Alert	27	7.550	88.8	5	15	101	N	Outside
14	M	50	Pedestrian TA	Hemopericardium	N	45	Verbal	33	6.376	83.9	5	14	65	N	Y
15	M	50	Occupant TA	Hemopericardium	N	31	Painful	29	5.676	77.1	5	7	103	N	Y
16	M	47	Pedestrian TA	Cardiac tamponade, cardiac arrest	Y	111	Unresponse	75	1.163	0.3	6	3	0	N	N
17	M	45	Stab injury	Right ventricle perforation, left upper lobe perforation	Y	29	Unresponse	25	0	1.5	5	3	0	Y	N
18	M	47	Stab injury	Hemothorax left, left lung injury	N	54	Alert	10	7.841	99.0	3	15	139	N	Y

PCPR: prehospital cardiopulmonary resuscitation, F to TB (min): field to trauma bay (minutes), ISS: Injury severity score, RTS: revised trauma score, TRISS: trauma and injury severity score, AIS: abbreviated Injury scale, GCS: Glascow coma scale, SBP: systemic blood pressure at trauma bay, EDT: emergency department thoracotomy, CT: computed tomography, N: no, TA: traffic accident, Y: yes, IVC: inferior vena cava.

Table 2. Perioperative variables of patients

Case	Time TB to OR (min)	Time F to OR (min)	Incision	Cardiac repair	Concomitant procedure	OP time (min)	Ventilator (days)	ICU stay (days)	Post OP echo finding	Outcome	Cause of death
1	84	150	Median sternotomy	Right ventricle	Pulmonary repair: left upper lobe	140	1	5	RWMA at LAD territory, depressed LV systolic function (EF: 47%)	2nd OP discharge	
2	37	110	Median sternotomy	Right ventricle	Laparotomy (liver, omental laceration)	145	1	5		Discharge	
3	33	150	Median sternotomy	Right ventricle		205	0	2	Normal	Discharge	
4	59	195	Median sternotomy	Right ventricle		110	0	0[a]		Transfer	
5	38	75	Median sternotomy	Right ventricle	LIMA ligation	105	0	3	Normal	Discharge	
6	70	235	Median sternotomy	Left atrium		180	5	8	Postoperative constrictive physiology, reduced LV systolic function(EF:35~45), moderate global hypokinesia	Transfer	
7	64	120	EDT	Right ventricle	Pulmonary repair: left upper lobe, Laparotomy (colon laceration)	230	0	0[a]		Expire	DIC
8	117	142	Median sternotomy	Right atrium		135	1	3	Normal	Discharge	
9	67	241	Median sternotomy	Pericardium		130	1	2	Normal	Discharge	
10	47	80	EDT, clamshell	Right ventricle	Pulmonary repair: right lower lobe Laparotomy (IVC laceration)	185	0	1		Expire	Hemorrhagic shock
11	74	460	Median sternotomy	Pericardium		130	10	18	Normal	Transfer	
12	113	213	Left anterior thoracotomy	Pericardium		75	0	2	Normal	Discharge	
13	59	120	Median sternotomy	Right ventricle		170	0	1	Normal	Transfer	
14	65	110	Median sternotomy	Right atrium		135	0	3		Transfer	
15	49	80	Median sternotomy	Right atrium		105	1	2		Discharge	
16	35	146	EDT, Median sternotomy	Right ventricle	Peritoneal pelvic packing	182	0	0[a]		Expire	Cardiac tamponade
17	46	75	EDT, clamshell	Right ventricle	Wedge resection: left upper lobe, primary repair: right upper lobe	167	1	1		Expire	Hemorrhagic shock
18	81	135	Left thoracotomy	Right ventricle	Pulmonary repair: left upper lobe, left arm repair	210	0	2		Discharge	

TB to OR (min): field to operation room (minutes), F to OR (min): field to operation room (minutes), OP: operation, ICU: intensive care unit, RWMA: regional wall motion abnormality, LAD: left anterior descending coronary artery, LV: left ventricle, EF: ejection fraction, LIMA: left internal mammary artery, EDT: emergency department thoracotomy, DIC: disseminated intravascular coagulation, IVC: inferior vena cava.

[a]Expired on admission day.

orrhagic shocks, a DIC and a cardiac tamponade.

Comparison between survival group and fatality group is presented in Table 3. The median age was 50.0 years (quartiles 35.0, 59.3) in the survival group, 40.5 years (quartiles 31.6, 46.5) in fatality group, respectively (p=0.202). The median injury severity score (ISS) was 26.00 (quartiles 10.00, 30.00) in the survival group, 30.00 (quartiles 25.25, 64.75) in the fatality group, respectively (p=0.199). The median RTS was higher in the survival group than in the fatality group (6.904 [quartiles 5.389, 7.841] vs. 0.582 [quartiles 0, 2.991]; p=0.005). The median TRISS was higher in the survival group than in the fatality group (86.350 [quartiles 67.925, 94.725] vs. 0.850 [quartiles 0.425, 1.350]; p=0.003). The median AIS chest was 5.00 (quartiles 3.75, 5.00) in the survival group and 5.00 (quartiles 5.00, 5.75) in the fatality group, respectively (p=0.066). The median Gglasgow coma scale (GCS) was higher in the survival group than in the fatality group (13.0 [quartiles 7.0, 15.0] vs. 3 [quartiles: 3.0, 6.0]; p=0.006). In the survival group, the patients had higher initial systolic blood pressure than in the fatal group (97.00 [quartiles 64.75, 114.50] vs. 0; p=0.003). Regarding the time lag, the median time from field to operation room was 66.00 minutes (quartiles 46.25, 81.75) in the survival group, 46.50 minutes (quartiles 37.75, 59.75) in fatality group, respectively (p=0.111). And the median time from field to operation room was 146.00 minutes (quartiles 110.00, 218.50) in the survival group, 100.00 minutes (quartiles 76.25, 139.50) in fatality group, respectively (p=0.123). The median operation time was 135.00 minutes (quartiles 108.75, 172.50) in the survival group 183.50 minutes (quartiles 170.75, 218.75) in the fatality group, respectively (p=0.033).

Table 3. Comparison between survival group and fatality group

Variables	Total (n=18, 100%)	Survival (n=14, 77.778%)	Fatality (n=4, 22.222%)	*p*-value
Sex				1.000
Male	13 (72.2%)	10 (71.4%)	3 (75.0%)	
Female	5 (27.8%)	4 (28.6%)	1 (25.0%)	
Age (years)	47.0 (35.0, 55.3)	50.0 (35.0, 59.3)	40.5 (31.6, 46.5)	0.202
Mechanism				1.000
Blunt	7 (38.9%)	6 (42.9%)	1 (25.0%)	
Penetrating	11 (61.1%)	8 (57.1%)	3 (75.0%)	
Prehospital CPR	4 (22.2%)	0	4 (100%)	<0.001
ISS	26.00 (17.50, 33.25)	26.00 (10.00, 30.00)	30.00 (25.25, 64.75)	0.199
RTS	6.026 (3.544, 7.623)	6.904 (5.389, 7.841)	0.582(0, 2.991)	0.005
TRISS	76.750 (23.475, 90.450)	86.350 (67.925, 94.725)	0.850 (0.425, 1.350)	0.003
AIS chest	5.00 (4.00, 5.00)	5.00 (3.75, 5.00)	5.00 (5.00, 5.75)	0.066
GCS	9.0 (6.5, 15.0)	13.0 (7.0, 15.0)	3.0 (3.0, 6.0)	0.006
ISBP at TB (mmHg)	83.00 (36.75, 109.00)	97.00 (64.75, 114.50)	0	0.003
EDT	4 (22.2%)	0	4 (100%)	<0.001
Pericardiocentesis	1 (5.6%)	1 (7.1%)	0	1.000
Time F to TB (min)	63.50 (36.00, 121.75)	69.50 (43.00, 143.25)	44.50 (30.00, 97.25)	0.243
Time TB to OR (min)	61.50 (44.00, 75.75)	66.00 (46.25, 81.75)	46.50 (37.75, 59.75)	0.111
Time F to OR (min)	138.50 (102.50, 199.50)	146.00 (110.00, 218.50)	100.00 (76.25, 139.50)	0.123
OP time (min)	142.50 (125.00, 182.75)	135.00 (108.75, 172.50)	183.50 (170.75, 218.75)	0.033

CPR: cardiopulmonary resuscitation, ISS: injury severity scale, RTS: revised trauma score, TRISS: trauma and injury severity score, AIS: abbreviated Injury scale, GCS: Glascow coma scale, ISBP: initial systolic blood pressure, TB: trauma bay, EDT: emergency department thoracotomy, F to TB (min): field to trauma bay (minutes), TB to OR: trauma bay to operation room, F to OR: field to operation room, OP: operation.

 http://doi.org/10.20408/jti.2017.30.4.166

DISCUSSION

TCI is an uncommon occurrence following chest trauma, which is a significant cause of mortality in trauma victims [2]. Patients with traumatic cardiac injury rarely survive, and most die at the scene or soon in the emergency room before the cardiac lesions are diagnosed [3].

The prevalence of TCI depends on the amount of violence in society, the volume of motor vehicle crashes, and access to the medical facility. Mishra et al. [2] reported that the incidence of TCI was 1.168% (21/1798) in traumatic chest injury. In our study, the incidence of TCI was 2.036% (18/884).

Survival rate following TCI has been reported from 19% to 74% in the literature [3,4]. In this study, survival rate following TCI was 77.8% (14/18), the Survival rate of blunt cardiac injury was 85.7% (6/7), and the survival rate of penetrating cardiac injury was 72.7% (8/11).

Hypotension at presentation in trauma bay was significantly related to high mortality [2]. In our study, all mortality cases had uncheckable blood pressure. Physiologic indices such as the RTS and GCS were statistically significant as predictors of outcomes [5]. We reported the median RTS was higher in the survival group than in the fatality group (6.904 [quartiles 5.389, 7.841] vs. 0.582 [quartiles 0, 2.991]; p=0.005). Also, the median GCS was higher in the survival group than in the fatality group (13.0 [quartiles 7.0, 15.0] vs. 3.0 [quartiles 3.0, 6.0]; p=0.006).

Associated injuries were more often seen with blunt injury than in penetrating injury [2]. Multi-organ traumatic injury, especially neurological insult, may adversely impact the survival even with timely repair of heart damage [3]. But we could not perform in depth evaluation of other organ injuries, especially in fatality group, because of the disastrous situation and the urgency of preparing for the emergency operation. Thus the possibility of the result being influenced by undetected or occult injuries is the limitation of this study.

Administration of intravenous fluids may be more harmful in TCI patients as it may precipitate tamponade. Meticulous examination by FAST and early intervention could improve the overall outcome [2]. If pericardial tamponade was detected, emergency thoracotomy and repair of underlying cardiac injury by trauma surgeon could improve the survival rate.

Definitive surgical procedure to manage TCI is surgical drainage of pericardial blood and repair of underlying cardiac injury. Clinical features depend on the type of mechanism of injury (blunt or penetrating), and the size of the wound in the heart or the pericardium [2]. Patients with TCI who survive to reach the hospital usually have sustained injuries limited to one cardiac chamber that can be repaired by trauma surgeons without cardiopulmonary bypass [2]. Rhee et al. [6] reported the number of chambers injured in an individual was predictive of outcome and single-chamber injuries (61%) were more common than multi-chamber injuries. In our study, all patients had single chamber injury and most frequently injured cardiac chamber was right ventricle (n=11, 61.1%).

When cardiac lesions are first identified on exploratory thoracotomy for a massive hemothorax, shifting to median sternotomy should be performed without hesitation if the visualization is limited and surgical assistance is difficult [3]. Use of the median sternotomy was a strong predictor of favorable outcomes; probably it is used in patients that present with lesser degrees of hemodynamic stability and who are able to reach the operation room [6]. In our study, most commonly performed surgical incision was median sternotomy (n=13, 72.2%).

Rapid and early diagnosis, multidisciplinary approach and prompt transfer to the operating room are the cornerstones in the management of TCI patient [1,2,5-7]. And speedy and optimal surgery is essential to improve outcome, the delay can adversely affect the outcome regarding both morbidity and mortality [7].

Fatimi et al. [7] reported, the average time lag between injury and arrival to the hospital was 2.17 hours, and the time lag between arrival to the hospital and incision time was 32.13 minutes. In our cases, the median time from field to trauma bay was 63.50 minutes (quartiles 36.00, 121.75). The median time from trauma bay to operation room was 61.50 minutes (quartiles 44, 75.75). The median time from field to operation room was 138.50 (quartiles 102.50, 199.50). The median operation time was 142.50 minutes (quartiles 125.00, 182.75). We need to shorten the time lag because rapid transfer and early diagnosis and approach are essential to improve outcome. We should educate about prehospital trauma care and transfer. It

is necessary to review the processes of managing TCI patients, and then, revise and improve the management protocol in the trauma bay. Although the operation time was thought to be affected by the surgical situation and concomitant operative procedure for other organs, it took too much time. We need to practice operative skills to shorten the operation time and to improve the outcomes.

Our study had several limitations. First, it was limited to a small number of patients. A lot of variables did not reach statistical significance presumably due to the small number. Second, it was a retrospective study, and all cohort is under the emergency situation. We could not include more detailed information regarding the variables (comorbidity, concomitant injury, medical history, etc.), especially in fatality group. Third, heterogeneity of the cohort is a kind of limitations of this investigation. To further validate our results, prospective collection of data through TCI registry and a larger group of patients are needed. Further multi-institutional studies may provide further information regarding the optimal protocols and prognostic factors in TCI patients.

CONCLUSION

We have detailed our experiences about emergency cardiac surgery in TCI. This study suggests that penetrating cardiac injuries are more common than blunt cardiac injury in TCI and the majority site of injury is right ventricle. Also, it suggests prehospital CPR and EDT are significantly responsible for high mortality in TCI.

ACKNOWLEDGEMENTS

This article was presented at the 25th Annual Meeting of the Asian Society for Cardiovascular and Thoracic surgery, Seoul, Korea from 23-26 March, 2017.

REFERENCES

1. Demirhan R, Onan B, Oz K, Halezeroglu S. Comprehensive analysis of 4205 patients with chest trauma: a 10-year experience. Interact Cardiovasc Thorac Surg 2009;9:450-3.
2. Mishra B, Gupta A, Sagar S, Singhal M, Kumar S. Traumatic cardiac injury: Experience from a level-1 trauma centre. Chin J Traumatol 2016;19:333-6.
3. Nan YY, Lu MS, Liu KS, Huang YK, Tsai FC, Chu JJ, et al. Blunt traumatic cardiac rupture: therapeutic options and outcomes. Injury 2009;40:938-45.
4. Rodrigues AJ, Furlanetti LL, Faidiga GB, Scarpelini S, Barbosa Evora PR, de Andrade Vicente WV. Penetrating cardiac injuries: a 13-year retrospective evaluation from a Brazilian trauma center. Interact Cardiovasc Thorac Surg 2005;4:212-5.
5. Asensio JA, Murray J, Demetriades D, Berne J, Cornwell E, Velmahos G, et al. Penetrating cardiac injuries: a prospective study of variables predicting outcomes. J Am Coll Surg 1998;186:24-34.
6. Rhee PM, Foy H, Kaufmann C, Areola C, Boyle E, Maier RV, et al. Penetrating cardiac injuries: a population-based study. J Trauma 1998;45:366-70.
7. Fatimi SH, Hanif HM, Awais A, Shamsi G, Muzaffar M. Major thoracic vessels and cardiac trauma: case series from a center in a developing country. Ulus Travma Acil Cerrahi Derg 2012;18:490-4.

 http://doi.org/10.20408/jti.2017.30.4.166