

Postdischarge Complications After Penetrating Cardiac Injury

A Survivable Injury With a High Postdischarge Complication Rate

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Hypothesis: A significant rate of postdischarge complications is associated with penetrating cardiac injuries.

Design: Retrospective trauma registry review.

Setting: Level I trauma center.

Patients: All patients sustaining penetrating cardiac injuries between January 2000 and June 2010. Patient demographics, clinical data, operative findings, outpatient follow-up, echocardiogram results, and outcomes were extracted.

Main Outcome Measures: Cardiac-related complications and mortality.

Results: During the 10.5-year study period, 406 of 4076 trauma admissions (1.0%) sustained penetrating cardiac injury. One hundred nine (26.9%) survived to hospital discharge. The survivors were predominantly male (94.4%), with a mean (SD) age of 30.8 (11.7) years, and 74.3% sustained a stab wound. Signs of life were present on admission in 92.6%. Cardiac chambers involved were the right

ventricle (45.9%), left ventricle (40.3%), right atrium (10.1%), left atrium (0.9%), and combined (2.8%). In-hospital follow-up was available for a mean (SD) of 11.0 (9.8) days (median, 8 days; range, 3-65 days) and outpatient follow-up was available in 46 patients (42.2%) for a mean (SD) of 1.9 (4.1) months (median, 0.9 months; range, 0.2-12 months). Abnormal echocardiograms demonstrated pericardial effusions (9), abnormal wall motion (8), decreased ejection fraction (<45%) (8), intramural thrombus (4), valve injury (4), cardiac enlargement (2), conduction abnormality (2), pseudoaneurysm (1), aneurysm (1), and septal defect (1). No operative intervention was required for the complications. The 1-year and 9-year survival rates were 97% and 88%, respectively.

Conclusions: Penetrating cardiac injuries remain highly lethal. A significant rate of cardiac complications can be expected and follow-up echocardiographic evaluation is warranted prior to discharge. The majority of these, however, can be managed without the need for surgical intervention.

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DESPITE ADVANCES IN EMERGENCY medical care, penetrating cardiac injuries continue to carry a high on-scene and immediate postinjury mortality. In an urban population-based study by Rhee et al,¹ the overall survival rate following penetrating cardiac injury was 19.3%, with rates of 9.7% for gunshot wounds and 32.6% for stab

See Invited Critique at end of article

wounds. In a large review of survival after emergency department thoracotomy (EDT) by Rhee et al,² 1058 EDTs performed for penetrating cardiac injuries were included. The overall survival rate after penetrating trauma to the heart was 19.4%. A more recent examination from South Africa

included 109 patients with survival rates of 84.4% and 19.0% for stab wounds and gunshot wounds, respectively.³

Poor outpatient compliance with follow-up in the trauma population is a well-recognized phenomenon.^{4,5} Consequently, for those who survive these penetrating cardiac injuries, the incidence and natural history of complications are poorly understood. To date, there have only been small case series examining the posttraumatic sequelae after penetrating cardiac injuries.⁶⁻¹¹ Reported complications include atrial and ventricular septal defects, valvular incompetence, vascular-cardiac fistulas, ventricular aneurysms, conduction abnormalities, ventricular dysfunction, dilatation or hypertrophy, intramural thrombus, endocarditis, and pericarditis.⁶⁻¹¹ These studies are limited by their sample size, wide patient inclusion criteria, and lack of stan-

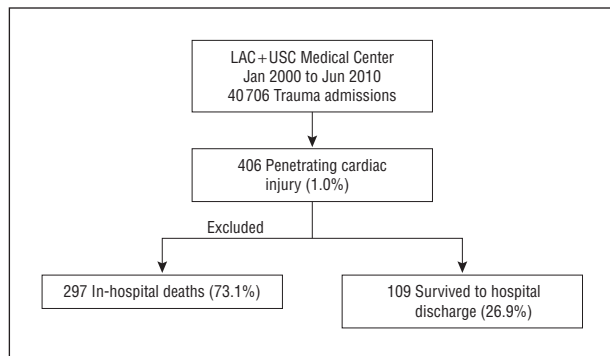


Figure. Study outline. LAC indicates Los Angeles County; USC, University of Southern California.

standardization in imaging studies used for screening. The purpose of this study was therefore to evaluate the outcomes after penetrating injuries to the heart through a protocolized follow-up regimen. We hypothesized that a significant rate of postdischarge complications was associated with these injuries.

METHODS

After institutional review board approval, all patients sustaining penetrating cardiac injuries between January 2000 and June 2010 were identified through the trauma registry at the Los Angeles County + University of Southern California Medical Center. The patient demographics, admission clinical data, operative findings, and hospital course were extracted from the institutional trauma registry and intensive care unit electronic database. Outpatient follow-up data were obtained through medical record reviews. All patients underwent a postoperative transthoracic echocardiogram performed by the Cardiology Service. A second echocardiogram was performed 1 month after discharge. The final reading by an attending radiologist or cardiologist was used for the analysis.

Patient variables abstracted included age, sex, penetrating injury mechanism (gunshot wound including shotgun injury and stab wound); the presence of signs of life (pupillary response, spontaneous ventilation, carotid pulse, or blood pressure) in the field, during transport, and on arrival to the emergency department (ED); cardiac focused assessment with sonography for trauma results; cardiopulmonary resuscitation and its duration when performed; admission vital signs in the ED; Glasgow Coma Scale score; Injury Severity Score (ISS); Abbreviated Injury Scale score; location of cardiac injury; intensive care unit length of stay; hospital length of stay; and in-hospital mortality.

Long-term cardiac-specific complications collected included decreased ejection fraction (<45%), pericardial effusions, wall motion abnormalities, intramural thrombus, cardiac dilation, cardiac pseudoaneurysm, and aneurysm. Long-term survival for each patient was obtained using the Social Security Death Index¹² to a closing date of November 14, 2010. The standardized mortality ratio was calculated for the study population.¹³ The standardized mortality ratio is the ratio of observed deaths to expected deaths according to a specific outcome in a particular population.

Data were entered into a computerized spreadsheet (Microsoft Excel 2003; Microsoft Corporation, Redmond, Washington) and analyzed using SPSS for Windows, version 12.0 (IBM SPSS, Chicago, Illinois). Continuous variables were dichotomized using the following clinically relevant cut points: age (≥ 55 vs <55 years), systolic blood pressure at admission (<90 vs ≥ 90 mm Hg), Glasgow Coma Scale score at admission (≤ 8 vs >8), and ISS (≥ 16 vs <16).

Table 1. Demographic, Clinical, and Injury Data of Study Population

	No. (%) (n=109)
Demographics	
Age, y, mean (SD)	30.8 (11.7)
Age ≥ 55 y	5 (4.6)
Male	103 (94.4)
SW	81 (74.3)
GSW	25 (22.9)
Shotgun injury	3 (2.8)
Clinical data	
Signs of life in the ED	
Lost vital signs on scene	3 (2.8)
Lost vital signs en route	1 (0.9)
Lost vital signs in the ED	4 (3.7)
Time at scene + transport time, min, mean (SD) ^a	4.2 (10.2)
Intubated on admission	16 (14.7)
SBP on admission, mm Hg, mean (SD)	108.7 (41.1)
SBP on admission <90 mm Hg	18 (16.5)
GCS on admission ≤ 8	11 (10.1)
ISS, mean (SD)	26.1 (19.1)
ISS ≥ 16	71 (65.1)
Positive cardiac FAST or intrapericardial blood at pericardiotomy	109 (100.0)
Injury data	
RA	11 (10.1)
RV	50 (45.9)
LA	1 (0.9)
LV	44 (40.3)
Cardiac injury involving multiple chambers	3 (2.8)
Isolated cardiac injury	68 (62.4)
Associated major vessel, ie, aorta, IVC, SVC	4 (3.7)

Abbreviations: ED, emergency department; FAST, focused assessment with sonography for trauma; GCS, Glasgow Coma Scale score; GSW, gunshot wound; ISS, Injury Severity Score; IVC, inferior vena cava; LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle; SBP, systolic blood pressure; SVC, superior vena cava; SW, stab wound.

^aTime at scene + transport time to our institution for patients arriving to the ED in cardiopulmonary arrest.

Descriptive analysis was used to report demographic, clinical, and outcome data. The Kaplan-Meier method was used for survival analysis. Values are reported as means and standard deviations for continuous variables and as percentages for categorical variables. All analyses were performed using SPSS for Mac, version 18.0 (IBM SPSS).

RESULTS

During the 10.5-year study period, 406 (1.0%) of the 40 706 trauma admissions sustained penetrating cardiac injuries. Of these, 109 (26.9%) survived to hospital discharge (**Figure**). The survivors were predominantly male (94.4%), with a mean (SD) age of 30.8 (11.7) years, and 74.3% sustained stab wounds. Signs of life were present on admission to the ED in 92.6% of patients, 14.7% required endotracheal intubation on admission, and 16.5% had hypotension. The mean (SD) ISS was 26.1 (19.1) and 65.1% had an ISS of 16 or more.

All injuries were diagnosed with abnormal results of cardiac focused assessment with sonography for trauma on admission or evidence of intrapericardial blood on pericardiotomy performed in the operating room (**Table 1**).

The cardiac chambers involved were the right ventricle (45.9%), left ventricle (40.3%), right atrium (10.1%), left atrium (0.9%), and multiple (2.8%); 62.4% sustained isolated penetrating injuries to the heart whereas 3.7% sustained an associated major vascular injury including the aorta, inferior vena cava, and superior vena cava (Table 1).

The mean (SD) number of units of packed red blood cells transfused per patient during the first 6 hours of hospital admission and during the total hospital stay were 3.0 (4.1) and 4.6 (6.7), respectively. The mean (SD) number of units of plasma transfused per patient during the first 6 hours of hospital admission and during the total hospital stay were 1.4 (2.8) and 2.6 (6.7), respectively. For surgical procedures, 7.3% required an ED thoracotomy and 20.2%, an operating room thoracotomy. Two of these patients underwent an EDT followed by a right thoracotomy in the operating room. Slightly more than 74% required median sternotomy, all of which were performed in the operating room, and 29.4% required exploratory laparotomy. The mean (SD) intensive care unit length of stay and hospital length of stay were 6.2 (6.7) and 11.0 (9.8) days, respectively (**Table 2**).

In-hospital clinical follow-up was available for a mean (SD) of 11.0 (9.8) days (median, 8 days; range, 3-65 days). Outpatient follow-up was available in 46 patients (42.2%), for a mean (SD) of 1.9 (4.1) months (median, 0.9 months; range, 0.2-12 months). An abnormal echocardiogram was identified in 19 patients (17.4%), including pericardial effusions (9), abnormal wall motion (8), decreased ejection fraction (<45%) (8), intramural thrombus (4), valve injury (4), cardiac enlargement (2), conduction abnormality (2), pseudoaneurysm (1), aneurysm (1), and septal defect (1). All abnormalities were detected on the initial in-hospital echocardiogram. The description of these patients is presented in **Table 3**. As of November 14, 2010, 2 of 19 patients who developed complications were dead (patients 5 and 14). The causes of death are unknown.

The 1-year and 9-year survival rates were 97% and 88%, respectively. The standardized mortality ratio (increase in death above US normative data) was 9.3 (95% confidence interval, 3.8-19.5) at 9 years.

COMMENT

Despite advances in prehospital transport, and the availability and accuracy of ultrasonography for rapid diagnosis, penetrating cardiac injuries remain highly lethal. In a population-based study of 212 patients with penetrating cardiac injuries, Rhee et al¹ reported that 45% of patients were brought to the trauma center with at least 1 sign of life. The overall survival rate was 19.3%, 9.7% for gunshot wounds and 32.6% for stab wounds. Two years later, Rhee et al² conducted the largest examination to date on survival after EDT. This review included 1058 EDTs performed for penetrating cardiac injuries. The overall survival rate after penetrating trauma to the heart was 19.4%. In our hospital-based study of penetrating cardiac injuries from January 2000 to June 2010, we report an overall survival rate of 26.9%, with 50.3% for stab wounds and 11.5% for gunshot wounds. Emer-

Table 2. Transfusion Requirements, Procedures, and In-Hospital Outcomes

	Mean (SD) (n=108)
Transfusion requirements	
Units of PRBCs received	
0-6 h	3.0 (4.1)
Total	4.6 (6.7)
Units of plasma received	
0-6 h	1.4 (2.8)
Total	2.6 (6.7)
Units of platelets received	0.3 (1.0)
Procedures, No. (%)	
ED thoracotomy	8 (7.3)
OR thoracotomy	22 (20.2)
Median sternotomy	81 (74.3)
Exploratory laparotomy	32 (29.4)
Outcomes	
ICU LOS, d	6.2 (6.7)
Hospital LOS, d	11.0 (9.8)

Abbreviations: ED, emergency department; ICU, intensive care unit; LOS, length of stay; OR, operating room; PRBCs, packed red blood cells.

gency department thoracotomy was performed in 285 patients (70.2% of total study population) and in 8 of the 109 survivors (7.3%). These data are similar to a 2-year prospective study from our institution performed between 1994 and 1996, in which Asensio et al¹⁴ reported an overall survival rate of 33% (stab wound, 65% and gunshot wound, 16%). The observed lack of improvement in survival over time may in part be due to patients with a higher injury burden being transported alive to the hospital because of the efficient prehospital care system in place within the Los Angeles, California, metropolitan area. The mean (SD) ISS in our study was 26.1 (19.1), with 65.1% of patients having an ISS of 16 or more. Thirty-two patients of the 109 survivors (29.4%) underwent exploratory laparotomy in addition to the cardiorrhaphy.

The time lapsed between injury and definitive care is one of the most important predictors of survival for penetrating cardiac injuries. In one of the largest series, including 1198 patients, it was estimated that 18% of deaths are potentially salvageable because of isolated cardiac wounds with tamponade.¹⁵ The same study also identified higher survival rates for patients who had surgery within a 30-minute window. Of the 109 survivors in our study, 7.4% had lost vital signs at the scene, en route, or in the ED. Not surprisingly, the mean (SD) time from the scene to the hospital in cardiopulmonary arrest was much shorter in those who survived to hospital discharge when compared with those who died (4.2 [10.2] minutes vs 21.5 [28.0] minutes, respectively; $P < .001$).

The right ventricle composes the majority of the anterior surface of the heart and is most vulnerable to penetrating injuries. The left atrium is the least likely injured cardiac chamber because of its small size and well-protected posterior location. In our study, ventricular wounds composed 86.5% of all injuries. Demetriades et al⁶ reported that the location of cardiac injury correlated with survival, with right ventricular injuries having the best prognosis. The theoretical advantage is that the right ventricle is rela-

Table 3. Description of Patients Who Developed Cardiac Complications^a

Patient No./ Age, y	Injury Mechanism	Heart Injury	Signs of Life in ED	Initial Management	Definitive Management	HLOS, d	Timing of Follow-up	Complication	Management
1/18	SW	LV	Yes, lost vital signs in the ED	EDT + OR	OR: LV repair	9	16 d; 3 mo	LV thrombus; hypokinesia of the distal septal wall	Anticoagulation
2/20	SW	RV	Yes	OR	Sternotomy; RV repair	7	5 d	RV thrombus; pericardial effusion	Anticoagulation
3/29	SW	LV	Yes	OR	Sternotomy; LV repair	7	1 d	LA thrombus; pericardial effusion	Anticoagulation
4/50	SW	LV	Yes	OR	Sternotomy; LV repair	6	1.5 mo	LV enlargement; decreased ejection fraction; severe mitral regurgitation	None
5/19	GSW	LV	Yes, lost vital signs in the ED	EDT + OR	OR: LV repair	18	5 d; 2 mo	LA enlargement; pericardial effusion; pulmonary valve insufficiency	None
6/58	SW	LV	Yes	OR	Sternotomy; LV repair	30	1 d; 28 d	Atrial fibrillation; pericardial effusion	Cardioversion
7/17	GSW	RV	Yes	OR	OR: RV repair	6	2 d	First-degree AV block	Medical management
8/44	SW	RV	Yes	OR	Sternotomy; RV repair	11	6 d; 21 d	RV aneurysm; R EF decreased; pericarditis	Medical management
9/38	SW	LV	Yes, lost vital signs in the ED	EDT + OR	OR: thoracotomy; LV repair	43	5 d; 17 d; 6 mo; 1 y	LV pseudoaneurysm; pericardial effusion; LV moderate hypokinesia	None
10/24	SW	RV	Yes	OR	Sternotomy; RV repair	8	1 d; 1 mo	Severe RV hypokinesia; decreased EF	Medical management
11/27	SW	RV	Yes	OR	Sternotomy; RV repair	5	2 d	RV akinesia; decreased EF; pericardial effusion	Medical management
12/22	GSW	LV	Yes	OR	Sternotomy; LV repair	7	4 d	LV apical hypokinesia	Medical management
13/18	SW	RV	Yes	OR	Sternotomy; RV repair	7	2 d	RV hypokinesia	Medical management
14/20	SW	RV	Yes	OR	Sternotomy; RV repair	9	3 d	RV EF reduced	Medical management
15/31	SW	RA	Yes	OR	Sternotomy; RA repair	11	2 d	Patent foramen ovale; RA embolism; CVA	Anticoagulation
16/21	SW	RV	Yes	OR	Sternotomy; RV repair	5	Unknown	RV decreased EF	Medical management
17/44	SW	LV	Yes	OR	Sternotomy; LV repair	7	4 d; 28 d	LV mild hypokinesia	None
18/46	SW	RV	Yes	OR	Sternotomy; RV repair	9	5 d; 21 d	Tricuspid valve insufficiency; severe RV hypokinesia; decreased EF; pericardial effusion	Medical management
19/29	SW	RV	Yes	OR	Sternotomy; RV repair	11	3 d; 33 d	Severe tricuspid valve insufficiency; RV decreased EF; ASD; pericardial effusion	Medical management

Abbreviations: ASD, atrial septal defect; AV, atrioventricular; CVA, cerebrovascular accident; ED, emergency department; EDT, emergency department thoracotomy; EF, ejection fraction; GSW, gunshot wound; HLOS, hospital length of stay; LA, left atrium; LV, left ventricle; NOM, nonoperative management; OR, operating room; R, right; RA, right atrium; RV, right ventricle; SW, stab wound.

^aAll patients were male. As of November 20, 2010, patients 5 and 14 were dead.

tively low pressure, yet with a muscular wall that can lead to effective containment of free hemorrhage. In our study, patients sustaining a right ventricular wound had a survival rate of 31.5%; left ventricle, 26.1%; right atrium, 20.5%; and left atrium, 5.9% ($P < .001$). Patients with atrial injuries had a high incidence of associated injuries with other cardiac chambers and great vessels. Two hundred two patients (49.8%) had isolated cardiac injuries; of those, 93.1%

had a single cardiac chamber injury, with a survival rate of 46.6%. The mortality for patients with multiple chamber cardiac injury was 95.6%.

Survival after stab wounds to the heart was 50.3% as opposed to 11.5% for gunshot wounds. This finding is consistent with the published literature demonstrating survival rates up to 5-fold higher for stab wounds compared with gunshot wounds.^{3,14,16}

In our series of 109 survivors of 406 penetrating cardiac injuries, the mean (SD) overall in-hospital follow-up was 11.0 (9.8) days. Outpatient follow-up was available in 46 patients for a mean (SD) of 1.9 (4.1) months. Our standard protocol for evaluation after cardiac injury included electrocardiography and 2-dimensional echocardiogram with Doppler performed postoperatively while the patient was still in the hospital and at 1-month follow-up. All abnormalities, however, were detected on the initial postoperative echocardiogram and there was no added benefit in this study from repeated imaging at 1 month. Nineteen patients (17.4%) were found to have an abnormal echocardiogram, including pericardial effusion in 9 patients, abnormal wall motion in 8, decreased ejection fraction in 8, intramural thrombus in 4, valve injury in 4, cardiac enlargement in 2, conduction abnormality in 2, and pseudoaneurysm, aneurysm, and septal defect in 1 each. None of these patients required surgical correction. The 4 patients with intramural thrombus required anticoagulation. Three of the 4 patients had thrombi form in the cardiac chambers corresponding to the site of injury (right ventricle, left ventricle, and right atrium). The fourth patient had a stab wound to the left ventricle but developed a left atrial thrombus. The valve injury in 3 of 4 cases correlated with the chamber of injury, including mitral valve insufficiency and tricuspid valve insufficiency.² In 1 case with a left ventricular injury, pulmonary valve insufficiency was noted. This was a gunshot wound and likely not a direct valvular injury due to the missile itself. All were treated nonoperatively and followed up closely by the Cardiac Surgery Service.

For the pseudoaneurysm, a 38-year-old man with a single stab wound to the left ventricle was resuscitated with an EDT. On hospital day 24, an echocardiogram was obtained revealing findings consistent with a pseudoaneurysm of the left ventricle, measuring 1.0×1.6 cm, confirmed on magnetic resonance imaging. A second magnetic resonance image obtained 16 days later demonstrated stabilization of the lesion. The patient was discharged home without intervention. Six-month follow-up echocardiogram confirmed normal cardiac function and there was no evidence of progression or leakage from the pseudoaneurysm. One-year follow-up magnetic resonance imaging showed a significant decrease in the size of the pseudoaneurysm. Echocardiogram showed an overall ejection fraction of 55% to 60% with moderate hypokinesia of the anterolateral wall of the left ventricle.¹⁷

Similarly, for the aneurysm, a 44-year-old man with a stab wound to the right ventricle underwent repair through a median sternotomy. On hospital day 6, an echocardiogram was obtained demonstrating an aneurysm of the right ventricle, subsequently confirmed on magnetic resonance imaging. The patient was discharged home without intervention and a subsequent follow-up echocardiogram performed 15 days after the initial injury demonstrated no progression of the lesion.

The incidence and natural history of posttraumatic cardiac sequelae are not well established. Reported complications include atrial and ventricular septal defects, valvular incompetence, vascular-cardiac fistulas, ventricular aneurysms, conduction abnormalities, ventricular dysfunc-

tion, dilatation or hypertrophy, intramural thrombus, endocarditis, and pericarditis.⁶⁻¹¹ In our study, the rate of anatomic defects was low. One explanation for this is that small intracardiac lesions such as septal defects may not be apparent in the initial postoperative period because of tissue edema, occluding coagulum plug, or a nondilated cardiac chamber.⁶ In many patients, only a single postoperative echocardiogram was performed during the initial hospital stay. These may have been performed too early to detect injury. It is unlikely, however, that these would have been clinically significant injuries. In both human and experimental models, small ventricular septal defects have been seen to heal spontaneously.^{18,19}

The incidence of delayed sequelae of cardiac injuries varies widely in different series depending on the patient criteria used for further investigation and the methods used for imaging. In a small study using symptoms and physical findings as a screening tool for cardiac evaluation, 8 of 20 patients (40%) were found to have secondary lesions. The authors of the study adopted a policy of detailed evaluation consisting of serial electrocardiography, echocardiogram, and cardiac catheterizations for all survivors of penetrating cardiac injuries. Subsequently, 7 of 9 patients (78%) were found to have secondary lesions.⁹ In a series of 48 survivors of 71 with penetrating cardiac injuries, Cha et al²⁰ found 11 patients (23%) to have surgically correctable lesions within 2 months of the initial operation by using a Swan-Ganz catheter, 2-dimensional echocardiogram, electrocardiography, and cardiac catheterization.

Of the 19 patients in our study with abnormal echocardiograms, only 15 were symptomatic. All asymptomatic patients had a mild reduction in cardiac ejection fraction or mild ventricular wall hypokinesia. Demetriades et al⁷ reported a similar finding of inadequacies in the history and physical examination for diagnosing post-traumatic cardiorrhaphy complications. In their series of 54 survivors of penetrating cardiac injuries followed up for a mean of 23 months, history alone was suggestive of complications in only 6% of patients; clinical examination alone, in 11%; and both combined, in 17%.

The 1-year and 9-year survival rates were 97% and 88%, respectively. The standardized mortality ratio (increase in death above US normative data) was 9.3 (95% confidence interval, 3.8-19.5) at 9 years. The cause of death was not known because survival was obtained using the Social Security Death Index. Multiple factors are conjectured to explain the high comparative mortality including trauma-related disease processes, socioeconomically based limited access to care, and lifestyle choices.

In conclusion, penetrating cardiac injuries remain highly lethal with an overall survival rate of 26.9% and standardized mortality ratio of 9.3 at 9 years. A significant rate of cardiac complications can be expected and a postoperative echocardiographic evaluation is warranted prior to discharge. The majority of these, however, can be managed medically without the need for surgical intervention.

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INVITED CRITIQUE

Hole in the Heart

Is an Echocardiogram Really Indicated 1 Month Later?

Tang and colleagues¹ performed a 10-year retrospective review of their patients who sustained penetrating cardiac injuries. They have shown that signs of life on admission, normal blood pressure, and a stab wound mechanism predict survival. Survival to discharge was 26.9% and postdischarge follow-up was available in 46 patients for a mean of 1.9 months. Based on the Social Security Death Index, surviving patients were more likely to die over the 9-year course of the study than age-matched comparators. They also evaluated long-term complications in survivors using a standardized protocol that includes a postoperative echocardiogram and an echocardiogram obtained 1 month after discharge. They found abnormalities in 17% of patients but all of the abnormalities seen in follow-up were present on the postoperative echocardiogram and none of the abnormalities required surgical intervention.

This study is significantly limited by the fact that less than 50% of surviving patients were available for fol-

low-up and follow-up in surviving patients was brief. Use of the Social Security Death Index only partially ameliorates this problem because many patients may have had unknown complications and survived. This is quite typical of trauma studies but the results of the study must be interpreted with this in mind.

This study is unusual in that there were almost as many left ventricular wounds as right ventricular wounds sustained. As Tang and colleagues point out in their article, right ventricular wounds are generally much more common than left ventricular wounds because the right ventricle is situated anteriorly. Also, survival was similar between patients with left ventricular (26%) and right ventricular (31%) wounds. Previous studies, including one from Tang and colleagues' Los Angeles County + University of Southern California Medical Center, report higher survival rates in patients with right ventricular wounds.

Finally, Tang and colleagues continue to advocate for their standardized penetrating cardiac injury follow-up