Penetrating injury to the cardiac box

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BACKGROUND: A penetrating injury to the "cardiac box" is thought to be predictive of an injury to the heart; however, there is very little evidence available to support this association. This study aims to evaluate the relationship between penetrating trauma to the cardiac box and a clinically significant injury.

METHODS: All patients presenting to a Level I trauma center from January 2009 to June 2015 who sustained a penetrating injury isolated to the thorax were retrospectively identified. Patients were categorized according to the location of injury: within or outside the historical cardiac box. Patients with concurrent injuries both inside and outside the cardiac box were excluded. Clinical demographics, injuries, procedures, and outcomes were compared.

RESULTS: During this 7-year period, 330 patients (92% male; median age, 28 years) sustained penetrating injuries isolated to the thorax: 138 (42%) within the cardiac box and 192 (58%) outside the cardiac box. By mechanism, 105 (76%) were stab wounds (SW) and 33 (24%) were gunshot wounds (GSW) inside the cardiac box, and 125 (65%) SW and 67 (35%) GSW outside the cardiac box. The overall rate of thoracotomy or sternotomy (35/138 [25.4%] vs. 15/192 [7.8%], $p < 0.001$) and the incidence of cardiac injury (18/138 [13%] vs. 5/192 [2.6%], $p < 0.001$) were significantly higher in patients with penetrating trauma within the cardiac box. This was, however, dependent on mechanism with SW demonstrating a higher incidence of cardiac injury (15/105 [14.3%] vs. 3/125 [2.4%], $p = 0.001$) and GSW showing no significant difference (3/33 [9.1%] vs. 2/67 [3%], $p = 0.328$]. There was no difference in overall mortality (9/138 [6.5%] vs. 6/192 [3.1%], $p = 0.144$).

CONCLUSION: The role of the cardiac box in the clinical evaluation of a patient with a penetrating injury to the thorax has remained unclear. In this analysis, mechanism is important. Stab wounds to the cardiac box were associated with a higher risk of cardiac injury. However, for GSW, injury to the cardiac box was not associated with a higher incidence of injury. The diagnostic interaction between clinical examination and ultrasound, for the diagnosis of clinically significant cardiac injuries, warrants further investigation. (*J Trauma Acute Care Surg.* 2020;89: 482–487. Copyright © 2020 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Prognostic study, Level IV, Therapeutic V.

KEY WORDS: Cardiac box; penetrating trauma; cardiac injury; sternotomy; thoracotomy.

Classically, a penetrating injury to the "cardiac box" has been thought to be predictive of an injury to the heart. This box is defined as being bordered by the sternal notch superiorly, the xiphoid process inferiorly, and the nipples laterally. The origin of these anatomic borders is unclear, and there is a paucity of evidence available to support this contention. Recently, a retrospective autopsy study by Jhunjhunwala et al.[1] specifically addressed the concept of the cardiac box by creating a circumferential grid system around the thorax. They analyzed the anatomic location of gunshot wounds (GSWs). The relative risk of a cardiac injury when the wound was in the cardiac box along with different combinations of thoracic regions were calculated, and they concluded that GSWs to regions not traditionally included in the cardiac box actually had a higher likelihood of a cardiac injury.

The clinical suspicion for cardiac injury after penetrating trauma to the precordial region is high based on simple anatomy. However, as it is also very possible for a penetrating injury to thoracic regions outside the historical cardiac box to cause an injury,[1–3] the clinical significance of the cardiac box remains unclear. Unless there is a disproportionately greater likelihood of a clinically significant injury from a wound to the box, all thoracic injuries should be treated the same. The purpose of this study was, therefore, to further evaluate the relationship between penetrating trauma and the cardiac box in predicting cardiac injury. We hypothesize that in penetrating trauma, injury to the cardiac box is not a predictor of cardiac injury and need for intervention.

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METHODS

Patient Selection

The institutional review board of the University of Southern California approved this project. This single-center retrospective study identified all trauma patients who were transported with signs of life to our Level I trauma center with penetrating trauma between January 1, 2009, and June 31, 2015. Information regarding patients who expired in the field were not included in this study. Patients with penetrating wounds isolated to the thorax were included. The study population was then categorized according to the location of their injury: within the historical cardiac box, outside the cardiac box, or both. The cardiac box was defined as being bordered by the sternal notch superiorly, the xiphoid process inferiorly, and the nipples laterally. External wounds were documented as inside the box if within the borders overlying the anterior chest and outside the box for wounds elsewhere on the thorax beyond the margins. Patients with concurrent penetrating injuries both within and outside the cardiac box were excluded as it could not be determined retrospectively for which injury an intervention, if any, was performed.

Baseline patient characteristics including age, sex, admission systolic blood pressure (SBP), heart rate (HR), Glasgow Coma Scale (GCS), and Injury Severity Score (ISS) were collected from the trauma registry. Hypotension was defined as SBP less than 90 mm Hg and tachycardia defined as HR greater than 120 bpm. The location of the penetrating wound was obtained from the trauma consult form, which contains a detailed description and drawing of all external wounds for the trauma patients who arrive to Los Angeles County + University of

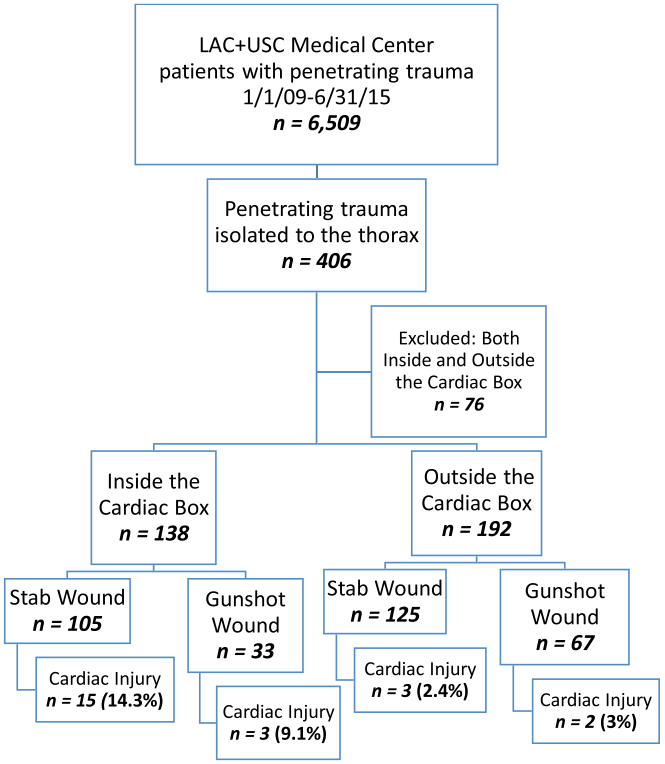

Figure 1. Study outline.

Southern California (LAC+USC) Medical Center. The trauma registry and patients' charts were then reviewed to abstract operative findings, imaging results, and clinical outcomes.

Statistical Analysis

Demographics and clinical characteristics were compared using univariate analysis. Fisher's exact or χ^2 tests were used for categorical variables, and Student's *t* test or Mann-Whitney *U* test were used for continuous variables. To detect independent factors associated with the need for intervention and the risk of sustaining a cardiac injury, a stepwise binary logistic regression analysis using Nagelkerke R^2 to assess the accuracy of the model was performed. Significant *p* values in the univariate analysis and variables determined by the model performance measure were included in the multivariate analysis. Adjusted odds ratios (ORs) with 95% confidence intervals (CIs) were derived from the logistic regression. All statistical analyses were performed using IBM SPSS Statics version 23.0 (SPSS INC., Armonk, NY). Continuous variables were expressed as median (interquartile range) and categorical variables presented as n (%).

RESULTS

From January 2009 to June 2015, 6,509 patients presented to LAC+USC Medical Center with penetrating trauma. Of these, 406 patients met inclusion criteria with injuries isolated to the thorax: 138 patients with single or multiple wounds within the cardiac box and 192 patients with single or multiple wounds outside the box. Excluded were 76 patients with wounds both within and outside the box. For the 138 patients classified as inside the cardiac box, 105 (76%) patients presented secondary to stab wounds (SW) and 33 (24%) patients to GSWs. For the 192 patients with injuries outside the box, 125 (65%) patients presented after SWs and 67 (35%) patients after GSWs (Fig. 1).

For the 330 patients included in the study, the median age was 28 years (IQR, 19 years; range, 4–75 years) and 91.5% were male. The median initial SBP (129 mm Hg [33] vs. 130 mm Hg [28], $p = 0.476$) and initial HR (97 bpm [35] vs. 100 bpm [32], $p = 0.746$) were similar for the patients with injuries within and outside the cardiac box. Patients presenting with hypotension (14/138 [10.4%] vs. 13/192 [6.8%], $p = 0.256$), in cardiac arrest (3/138 [2.2%] vs. 4/192 [2.1%], $p = 0.955$), and with tachycardia

TABLE 1. Patient Demographics

	Total	Inside the BOX	Outside the BOX	
	N = 330	n = 138	n = 192	$p < 0.05$
Demographics				
Age	28 (19)	30 (21)	27 (19)	0.226
Sex				0.278
Female	28 (8.5%)	9 (6.5%)	19 (9.9%)	
Male	302 (91.5%)	129 (93.5%)	173 (90.1%)	
Clinical findings				
Initial SBP	130 (30)	129 (33)	130 (28)	0.476
Hypotension	27 (8.3%)	14 (10.4%)	13 (6.8%)	0.256
Cardiac arrest	7 (2.1%)	3 (2.2%)	4 (2.1%)	0.955
Initial HR	99 (33)	97 (35)	100 (32)	0.746
Tachycardia	65 (19.7%)	31 (22.5%)	34 (17.7%)	0.284
GCS score	15 (0)	15 (0)	15 (0)	0.001
GCS score < 8	22 (6.7%)	15 (10.9%)	7 (3.6%)	0.009
ISS	9 (8)	9 (8)	9 (8)	0.909
ISS > 15	65 (19.7%)	33 (23.9%)	32 (16.7%)	0.103

Continuous variables: median (interquartile range). Categorical variables: n (%).
Hypotension: SBP <90 mm Hg.
Tachycardia: HR >120 bpm.

(31/138 [22.5%] vs. 34/192 [17.7%], $p = 0.284$) were also similar between the two groups. The presenting GCS was equivalent for both groups (15 [0] vs. 15 [0], $p = 0.001$). Patients with wounds within the cardiac box were more likely to present with altered mental status defined as GCS score less than 8 (15/138 [10.9%] vs. 7/192 [3.6%], $p = 0.009$). The median ISS was also equivalent (9 [8] vs. 9 [8], $p = 0.909$), and there was no statistically significant difference in the number of patients with ISS greater than 15 (33/138 [23.9%] vs. 32/192 [16.7%]; $p = 0.103$) (Table 1).

The injury characteristics, procedures, and outcomes are presented in Table 2. The operative procedures analyzed in this study included laparotomy, thoracotomy, and sternotomy. The laparotomy rate (22/138 [15.9%] vs. 31/192 [16.1%], $p = 0.960$) and chest tube insertion rate (59/138 [42.8%] vs. 83/192 [43.2%], $p = 0.931$) did not differ between the two groups. However, the rate of thoracotomy and sternotomy (35/138 [25.4%] vs. 15/192 [7.8%], $p < 0.001$) and the incidence of cardiac injury (18/138 [13%] vs. 5/192 [2.6%], $p < 0.001$) were statistically significantly higher in patients who sustained penetrating trauma within the cardiac box. Patients with wounds identified within the cardiac box did not have a significantly higher overall mortality rate (9/138 [6.5%] vs. 6/192 [3.1%], $p = 0.144$) and had similar hospital lengths of stay regardless of the location of injury (3 days [6] vs. 3 days [4], $p = 0.153$).

Because the mechanism of penetrating injury was significantly different in the overall univariate analysis ($p = 0.032$), subgroup analyses were conducted for SWs and GSWs within and outside the cardiac box (Table 3). For patients with SWs, the incidence of cardiac injury (15/105 [14.3%] vs. 3/125 [2.4%], $p = 0.001$) and the rate of thoracotomy or sternotomy (23/105 [21.9%] vs. 8/125 [6.4%], $p = 0.001$) were significantly higher in patients with wounds within the cardiac box while the mortality rate (2/105 [1.9%] vs. 2/125 [1.6%], $p = 1.000$) was not statistically different. For patients sustaining GSWs, the incidence of cardiac injury was not statistically different when comparing wounds inside and outside the box (3/33 [9.1%] vs. 2/67 [3%], $p = 0.328$). However, the rate of thoracotomy or sternotomy (12/33 [36.4%] vs. 7/67 [10.4%], $p = 0.002$) and mortality rate (7/33 [21.2%] vs. 4/67 [6%], $p = 0.038$) were statistically significantly higher inside the cardiac box.

A summary of injuries categorized by external wound location and mechanism for the 50 patients who underwent a sternotomy or thoracotomy are presented in Table 4. Twenty-three (46%) patients sustained a cardiac injury. Of these, 19 patients (19/50, 38%) sustained a cardiac injury only, and four patients (4/50, 8%) sustained a combination of a cardiac and a great vessel (aorta, inferior vena cava, or subclavian vein) or pulmonary injury. The second most common isolated organ injury was the lung (14/50 patients, 28%). Four patients (8%) underwent a nontherapeutic thoracotomy.

Finally, Table 5 presents the independent predictors of the need for a thoracotomy or sternotomy and risk of sustaining a cardiac injury determined by stepwise logistic regression analysis. A wound location within the cardiac box was associated with a threefold increased risk of requiring a thoracotomy or sternotomy (adj $p = 0.012$; OR, 3.095; 95% CI, 1.278–7.493) and a sevenfold increased risk of sustaining a cardiac injury (adj $p = 0.012$; OR, 6.429; 95% CI, 1.496–27.630). When predicting the risk for cardiac injury, the risk with GSW compared with SW was lower (adj $p = 0.007$; OR, 0.046; 95% CI, 0.005–0.427).

DISCUSSION

The dogma of having a high index of suspicion for cardiac injury after penetrating trauma to the "cardiac box" is well known. The exact origin of the contemporary borders of this cardiac box is unclear. In 1967, Sauer and Murdock[4] described a thoracic "danger zone" overlying the topographical area of the heart and great vessels after reviewing 13 cases of penetrating injuries to the thorax. The borders of this area consisted of zone 1 of the neck superiorly, laterally from the vertical line intersecting the medial third of the right clavicle to the left midclavicular line, and the level of the midsubcostal regions inferiorly. All 13 wounds were within these boundaries. In the

TABLE 2. Injury Characteristics, Procedures, and Outcomes

	Total	Inside the BOX	Outside the BOX	
	N = 330	n = 138	n = 192	$p < 0.05$
Injury characteristics				
Mechanism				0.032
SW	230 (69.7%)	105 (76.1%)	125 (65.1%)	
GSW	100 (30.3%)	33 (23.9%)	67 (34.9%)	
Procedures				
No procedure	154 (46.7%)	58 (42%)	96 (50%)	0.152
Chest tube	142 (43%)	59 (42.8%)	83 (43.2%)	0.931
Laparotomy	53 (16.1%)	22 (15.9%)	31 (16.1%)	0.960
Thoracotomy or sternotomy	50 (15.2%)	35 (25.4%)	15 (7.8%)	<0.001
Cardiac injury	23 (7%)	18 (13%)	5 (2.6%)	<0.001
Outcomes				
Hospital LOS	3 (5)	3 (6)	3 (4)	0.153
Mortality	15 (4.5%)	9 (6.5%)	6 (3.1%)	0.144

Continuous variables: median (interquartile range). Categorical variables: n (%).
LOS, length of stay (days).

TABLE 3. Subgroup Analyses of SWs and GSWs

	SWs			Gunshot Wounds		
	Inside the BOX	Outside the BOX		Inside the BOX	Outside the BOX	
	n = 105	n = 125	$p < 0.05$	n = 33	n = 67	$p < 0.05$
Demographics						
Age	31 (22)	27 (18)	0.168	22 (12)	24 (16)	0.458
Sex			0.322			0.854
Female	5 (4.8%)	10 (8%)		4 (12.1%)	9 (13.4%)	
Male	100 (95.2%)	115 (92%)		29 (87.9%)	58 (86.6%)	
Clinical findings						
Hypotensive	9 (8.7%)	7 (5.6%)	0.367	5 (16.1%)	6 (9.2%)	0.321
Cardiac arrest	2 (1.9%)	1 (0.8%)	0.593	1 (3%)	3 (4.5%)	1.000
Tachycardia	21 (20%)	18 (14.4%)	0.260	10 (30.3%)	16 (23.9%)	0.491
GCS score < 8	8 (7.6%)	1 (0.8%)	0.013	7 (21.2%)	6 (9%)	0.087
ISS > 15	19 (18.1%)	15 (12%)	0.195	14 (42.4%)	17 (25.4%)	0.083
Procedures						
No procedure	47 (44.8%)	65 (52%)	0.274	11 (33.3%)	31 (46.3%)	0.218
Chest tube	42 (40%)	53 (42.4%)	0.713	17 (51.5%)	30 (44.8%)	0.525
Laparotomy	12 (11.4%)	17 (13.6%)	0.621	10 (30.3%)	14 (20.9%)	0.300
Thoracotomy or sternotomy	23 (21.9%)	8 (6.4%)	0.001	12 (36.4%)	7 (10.4%)	0.002
Cardiac injury	15 (14.3%)	3 (2.4%)	0.001	3 (9.1%)	2 (3%)	0.328
Outcomes						
Hospital LOS	3 (5)	2 (3)	0.020	4 (13)	4 (7)	0.886
Mortality	2 (1.9%)	2 (1.6%)	1.000	7 (21.2%)	4 (6%)	0.038

Continuous variables: median (interquartile range). Categorical variables: n (%).
Hypotension: SBP <90 mm Hg.
Tachycardia: HR >120 bpm.

early 1970s, Siemens et al.[5] sought to determine which patients would benefit from an immediate thoracotomy with or without cardiorrhaphy after penetrating thoracic trauma in the absence of signs of hemorrhagic shock or cardiac tamponade. They concluded that one indication for immediate operative intervention was the "location of the entrance wound in the upper mediastinum, a location associated with heart injury more often than other wounds." A figure of the anterior thorax provided in the study showed that the upper mediastinum was comprised of the thoracic region medial to the bilateral midclavicular lines and cephalad to the level of bilateral nipples. Patients who required operative intervention (70%) had wounds in the upper mediastinum. Similarly, Evans et al.[6] in 1979 examined 46 patients with cardiac trauma and presented the anatomic locations of the external wounds. Overall, 85% of these wounds were within a rectangular-shaped area over the anterior thorax bordered by the clavicles superiorly, nipples laterally, and midsubcostal regions inferiorly. Jhunjhunwala et al. analyzed autopsy reports of patients sustaining GSWs to the torso to assess the predictive value of a cardiac injury with a GSW within the traditionally described cardiac box. Analysis of the likelihood of a cardiac injury from a GSW to the cardiac box compared with other thoracic regions resulted in a RR 0.96 (95% CI, 0.68–1.40; $p = 0.82$; sensitivity, 85%; specificity, 16%; positive predictive value, 35%; negative predictive value, 68%), thus, invalidating the concept that the highest risk of cardiac injury is when a penetrating GSW is within the cardiac box. The logistic regression instead showed that the region that is most predictive of a cardiac injury is a GSW to the region from the anterior to posterior midline of the left thorax. This includes the left lateral chest, an area outside the traditional box.

TABLE 4. Injury Summary

		Inside the BOX		Outside the BOX	
	Total	SW	GSW	SW	GSW
No. thoracotomy or sternotomy	N = 50	n = 23	n = 12	n = 8	n = 7
Cardiac injury only	19 (38%)	14	2	2	1
Cardiac injury + great vessel*	1 (2%)	0	1	0	0
Cardiac injury + pulmonary	3 (6%)	1	0	1	1
Great vessel injury only	4 (8%)	1	2	0	1
Great vessel + pulmonary	1 (2%)	0	1	0	0
Pulmonary injury only	14 (28%)	1	5	4	4
Other artery**	4 (8%)	3	0	1	0
No injury	4 (8%)	3	1	0	0

* Aorta, inferior vena cava, or subclavian vein.
** Internal mammary, intercostal, or superior thoracic artery.

The results of this current study demonstrate that, overall, there is a higher risk of cardiac injury from a penetrating injury to the cardiac box but that it also depends on the mechanism. It is not surprising that there is a better correlation between external wound location and cardiac injury for SWs as a knife has a fixed length. An SW directly over the cardiac silhouette is very different from one to the right lateral thorax. In contrast to an SW,

TABLE 5. Independent Predictors of Thoracotomy or Sternotomy and Cardiac Injury

	Thoracotomy or Sternotomy		
	*p**	OR	95% CI
SBP	<0.001	0.965	0.950–0.980
ISS	<0.001	1.124	1.064–1.187
GCS score	0.003	0.808	0.702–0.931
Injury inside the cardiac box	0.012	3.095	1.278–7.493
	Cardiac injury		
	*p**	OR	95% CI
SBP	0.003	0.971	0.952–0.990
ISS	<0.001	1.157	1.077–1.243
Mechanism**	0.007	0.046	0.005–0.427
Injury inside the cardiac box	0.012	6.429	1.496–27.630

* Adjusted *p* value for multifactorial analysis.
** Risk of injury with GSW compared with SW.

GSWs result in further penetration generally, and can have a trajectory that crosses the heart, likely more important than the location of the external wound itself. The GSW subgroup analysis from this study, similar to the results from the Jhunjhunwala study, did not show an increased risk of a cardiac injury from a GSW to the box compared with outside the box. However, compared with SWs, patients with GSWs resulted in more severe injuries to other thoracic structures and organs. Whether inside or outside the box, GSW victims had a significantly higher burden of overall injury. The increased risk of mortality for patients sustaining GSWs inside the cardiac box despite not having a significantly higher rate of cardiac injury may be attributed to this higher severity of injuries. These associations are important as they can give trauma care providers advanced warning that there may be an injury. Certainly, the closer the injury is to the heart, the higher the likelihood that there will be an injury; however, the important take-home message is that all wounds potentially put the heart at risk.

Finally, for contemporary trauma management, we now have Focused Assessment with Sonography for Trauma to help rapidly and noninvasively assess for a cardiac injury. This allows for point of care, real time diagnosis of a cardiac injury with a high degree of sensitivity (57–100%) and specificity (74–97%).[7–11] Practically, this is more important for clinical decision making than the location of injury.

This is a retrospective study from a single center's trauma registry data and is inherently limited by the study design. There is also recognition that patients sustaining GSWs may have expired in the field, and thus, the GSW population may be under-represented in this study. Despite this limitation, this study provides a contemporary analysis of penetrating thoracic wounds to the cardiac box in predicting a clinically significant cardiac injury and the need for operative intervention with a thoracotomy or sternotomy. Penetrating injuries to the box, and SWs in particular, are associated with an increased likelihood of a cardiac injury. While the potential for cardiac injury based on the location of the wound was more important in the past, in the modern era all penetrating thoracic injuries put the heart at risk and the heart should be assessed by ultrasound to exclude an injury.

AUTHORSHIP

K.I. and J.B.H. provided the study concept. J.S.K. provided the literature search. J.S.K., L.A.L., and C.R. performed the data collection. L.A.L. and J.S.K. performed the data analysis. J.S.K. and K.I. performed the data interpretation. J.S.K., K.I., J.B.H., J.S.D., V.A.S., and D.D. participated in the writing and critically reviewing the final article.

DISCLOSURE

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REFERENCES

1. Jhunjhunwala R, Mina MJ, Roger EI, et al. Reassessing the cardiac box: a comprehensive evaluation of the relationship between thoracic gunshot wounds and cardiac injury. *J Trauma Acute Care Surg*. 2017;83(3):379–355.
2. Degiannis E, Loogna P, Doll D, Bonanno F, Bowley DM, Smith MD. Penetrating cardiac injuries: recent experience in South Africa. *World J Surg*. 2006;30(7):1258–1264.
3. Claassen CW, O'Connor JV, Gens D, Sikorski R, Scalea TM. Penetrating cardiac injury: think outside the box. *J Trauma*. 2010;68(3):E71–E73.
4. Sauer PE, Murdock CE Jr. Immediate surgery for cardiac and great vessel wounds. *Arch Surg*. 1967;95(1):7–11.
5. Siemens R, Polk HC Jr., Gray LA Jr., Fulton RL. Indications for thoracotomy following penetrating thoracic injury. *J Trauma*. 1977;17(7):493–500.
6. Evans J, Gray LA Jr., Rayner A, Fulton RL. Principles for the Management of Penetrating Cardiac Wounds. *Ann Surg*. 1979;189(6):777–784.
7. Rozycki GS, Feliciano DV, Ochsner MG, et al. The role of ultrasound in patients with possible penetrating cardiac wounds: a prospective multicenter study. *J Trauma*. 1999;46(4):543–551.
8. Ball CG, Williams BH, Wyrzykowski AD, Nicholas JM, Rozycki GS, Feliciano DV. A caveat to the performance of pericardial ultrasound in patients with penetrating cardiac wounds. *J Trauma*. 2009;67(5):1123–1124.
9. Inaba K, Chouliaras K, Zakaluzny S, et al. FAST ultrasound examination as a predictor of outcomes after resuscitative thoracotomy: a prospective evaluation. *Ann Surg*. 2015;262(3):512–518.
10. Stranch EW, Zarzaur BL, Savage SA. Thinking outside the box: re-evaluating the approach to penetrating cardiac injuries. *Eur J Trauma Emerg Surg*. 2017;43(5):617–622.
11. Matsushima K, Khor D, Berona K, Antoku D, Dollbaum R, Khan M, Demetriades D. Double jeopardy in penetrating trauma: get FAST, get it right. *World J Surg*. 2018;42(1):99–106.