Does hemopericardium after chest trauma mandate sternotomy?

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BACKGROUND: Recently, three patients with hemopericardium after severe chest trauma were successfully managed nonoperatively at our institution. This prompted the question whether these were rare or common events. Therefore, we reviewed our experience with similar injuries to test the hypothesis that trauma-induced hemopericardium mandates sternotomy.

METHOD: Records were retrospectively reviewed for all patients at a Level I trauma center (December 1996 to November 2011) who sustained chest trauma with pericardial window (PCW, n = 377) and/or median sternotomy (n = 110).

RESULTS: Fifty-five (15%) patients with positive PCW proceeded to sternotomy. Penetrating injury was the dominant mechanism (n = 49, 89%). Nineteen (35%) were hypotensive on arrival or during initial resuscitation. Most received surgeon-performed focused cardiac ultrasound examinations (n = 43, 78%) with positive results (n = 25, 58%). Ventricular injuries were most common, with equivalent numbers occurring on the right (n = 16, 29%) and left (n = 15, 27%). Six (11%) with positive PCW had isolated pericardial lacerations, but 21 (38%) had no repairable cardiac or great vessel injury. Those with therapeutic versus non-therapeutic sternotomies were similar with respect to age, mechanisms of injury, injury severity scores, presenting laboratory values, resuscitation fluids, and vital signs. Multiple logistic regression revealed that penetrating trauma (odds ratio: 13.3) and hemodynamic instability (odds ratio: 7.8) were independent predictors of therapeutic sternotomy.

CONCLUSION: Hemopericardium per se may be overly sensitive for diagnosing cardiac or great vessel injuries after chest trauma. Some stable blunt or penetrating trauma patients without continuing intrapericardial bleeding had nontherapeutic sternotomies, suggesting that this intervention could be avoided in selected cases. (*J Trauma Acute Care Surg*. 2012;72: 1518–1525. Copyright © 2012 by Lippincott Williams & Wilkins)

LEVEL OF EVIDENCE: Therapeutic study, level III.

KEY WORDS: Cardiac injury; pericardial window; sonography.

Mortality for penetrating cardiac trauma is 60% to 80% prehospital[1,2] and remains high (48–71%) for those alive long enough to reach a hospital.[3] Survival depends on rapid diagnosis and treatment. Clinical presentation varies from hemodynamic stability to cardiopulmonary arrest; even in stable patients, rapid decompensation is common. In the moribund patient with cardiovascular collapse, emergency department thoracotomy is warranted after penetrating trauma[4] and in those with witnessed loss of vital signs after blunt mechanisms.[5] Surgeon-performed focused assessment with sonography for trauma (FAST) has a clearly defined role after either blunt or penetrating trauma,[4,5] with high sensitivity and specificity.[6,7]

Pericardial window (PCW) after trauma was first described 40 years ago.[8,9] Its use has declined during recent times, but some important indications remain. Subxiphoid pericardial window (SPW) is recommended if the FAST is equivocal or negative in the presence of significant hemothorax.[4,10] In contrast to FAST, PCW allows the surgeon to distinguish hemopericardium from benign pericardial effusion. The transdiaphragmatic pericardial window (TPW) may also be used in cases of combined thoracoabdominal trauma for patients undergoing exploratory laparotomy.[11,12]

Recently at our institution, three hemodynamically stable patients after chest trauma with positive PCWs were successfully managed without sternotomy. All received mediastinal tube drainage and close monitoring in the operating room. This prompted the question whether these were rare or common events, so we evaluated our experience with all sternotomies performed in patients with positive PCW. We tested the hypothesis that trauma-induced hemopericardium mandates sternotomy.

METHODS

Patients admitted to a Level I trauma center from December 1996 to November 2011 who sustained chest trauma with PCW and median sternotomy were identified from a registry. Medical records were reviewed for demographics, injury factors, hemodynamic status, diagnostic workup, operative data, and outcomes. The University of Miami Institutional Review Board approved this retrospective review with waiver of consent.

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Patients who proceeded immediately to sternotomy were not included in the analysis. The diagnostic algorithms used for suspected cardiac injury are similar to recent textbook descriptions for penetrating injury[4] and blunt injury.[5] Briefly, patients with cardiopulmonary arrest after penetrating chest trauma receive emergency department thoracotomy. FAST is performed by the surgical resident, trauma fellow, or attending surgeon for all patients. Patients with obvious cardiac tamponade or severe hemodynamic instability proceed immediately to sternotomy. SPWs may be performed as a confirmatory test before median sternotomy for those with FASTs that are positive, negative with a large hemothorax, or inconclusive. SPWs are also performed due to clinical suspicion in patients based on mechanism/trajectory, at attending discretion. TPW is used during exploratory laparotomy if hemodynamics do not improve after addressing intra-abdominal sources of bleeding or due to trajectory.

SPWs are performed in the operating room under general anesthesia using the technique described by Arom et al.[13] TPWs are performed during exploratory laparotomy as explained by Garrison et al.[12] In either case, to avoid false-positive results, meticulous hemostasis is ensured before opening the pericardium. PCW was defined as "positive" if there was blood or clot in the pericardial cavity. "Non-therapeutic" sternotomy was defined as no identifiable injury or minor non-bleeding injury for which no surgical repair was performed. "Therapeutic" sternotomy was defined as any injury that required surgical repair.

Using PASW statistical software version 19.0 (PASW, Chicago, IL), categorical data were compared using χ^2 test or Fisher's exact test. Group data with a normal distribution were compared using the Student's *t* test, and nonparametric data were compared with a Mann-Whitney *U* test. Multiple logistic regression was used to identify predictors of therapeutic sternotomy. Values are expressed as mean ± standard deviation, median (interquartile range), or number (percentage) as appropriate. Significance was assessed at $p < 0.05$.

RESULTS

Case 1

A 29-year-old male motorcycle crash victim presented with a systolic blood pressure (SBP) of 62 mm Hg, heart rate (HR) 126 bpm, and disorientation/altered mental status. The patient was immediately intubated, fluid resuscitated, and a left chest tube returned 300 mL of hemothorax. Hemodynamic status improved. FAST within 3 minutes of arrival was negative, and portable chest X-ray revealed prominent cardiac silhouette with multiple rib fractures. After stabilization, a contrast-enhanced computed tomography (CT) scan revealed extensive pneumocephalus causing mass effect, grade I liver and splenic lacerations, and hemopericardium (12.5 mm thickness). While in observation, the patient had another episode of hypotension with continued tachycardia and was taken for SPW. Starting vitals were SBP 95 mm Hg and HR 115 bpm, prompting transfusion of packed red blood cells. SPW released 100 mL of blood, and vital signs improved. Intraoperative transesophageal echocardiogram (ECHO) showed no evidence of residual hemopericardium. Mediastinal tubes were placed, and the patient was transferred to the trauma intensive care unit (ICU). Three follow-up ECHOs during the first week were normal. The patient had a complicated ICU stay with severe acute respiratory distress syndrome (requiring nitric oxide and oscillatory ventilation), sepsis (requiring multiple vasopressors), and died on hospital day 13.

Case 2

The patient was a 27-year-old female pedestrian struck by car who presented with loss of consciousness at the scene and stable hemodynamics. FAST examination (7 minutes after arrival) was negative in all windows, but chest X-ray showed widened mediastinum. One episode of hypotension (SBP, 87 mm Hg) within 10 minutes of arrival responded to fluid. The CT revealed bilateral pulmonary contusions, small occult pneumothoraces, grade I liver laceration, pelvic fracture, right internal carotid artery dissection, and hemopericardium (15 mm thickness). Subsequently, a 12-lead electrocardiogram showed nonspecific voltage changes. A formal 2-D transthoracic ECHO showed hemopericardium but no evidence of cardiac tamponade. In consultation with the cardiothoracic surgery service, it was decided to take the patient for SPW, which produced 200 mL of hemopericardium. Irrigation was performed until the pericardium was cleared. An intraoperative transesophageal ECHO was normal. After a 20-minute observation, mediastinal tubes were placed, and the patient was transferred to the trauma ICU. An ECHO on postoperative day 1 was normal. The patient had a prolonged hospital course due to refusal of operative treatment for a lower extremity fracture but was eventually discharged home without complications.

Case 3

A 49-year-old man presented after thoracoabdominal stab wound. Hemodynamics were SBP=108 mm Hg, HR=91 bpm, FAST examination was inconclusive, and chest X-ray revealed left hemothorax. The left chest tube produced 500 mL blood. SPW produced 30 to 50 mL blood. After 5 minutes of observation, a choledochoscope was used to investigate the pericardial space revealing no injuries or continued bleeding. Diagnostic laparoscopy excluded intraperitoneal injury. Postoperative ECHO showed trace pericardial effusion. The patient was discharged on hospital day 6 after an uncomplicated recovery.

Retrospective Cohort

During the 15-year study period, there were 377 PCW performed after chest trauma. Fifty-five (15%) patients had a positive PCW and proceeded to immediate sternotomy. Penetrating injury was seen in 49 (89%), with 33 stab wounds (60%) and 16 gunshot wounds (30%). The other six patients suffered blunt injury (motor vehicle collisions [n = 4, 7%], motorcycle crash [n = 1, 2%], and fall [n = 1, 2%]).

On arrival, SBP (mean ± standard deviation) was 108 ± 29 mm Hg, HR 107 ± 24 bpm, base deficit −8 ± 7 mEq/L, and hematocrit 36 ± 7. Fourteen (26%) patients were hypotensive (SBP < 90 mm Hg) on arrival, and 19 (35%) were hypotensive during initial resuscitation. Two had cardiac arrest in the resuscitation bay. One sustained a motor vehicle crash and had immediate return of vital signs after chest tube placement. The other suffered a gunshot wound to the chest and head, developed fixed/dilated pupils with alternating tachycardia and bradycardia, and had return of vital signs after Advanced Trauma Life Support protocol.

Diagnostic Workup

As a component of their workup, 45 (82%) patients received a portable chest X-ray. Most examinations were abnormal (n = 34, 76%) with the most common findings being hemothorax (n = 16, 47%), pneumothorax (n = 12, 35%), widened mediastinum (n = 5, 15%), foreign body (n = 4, 12%), rib fractures (n = 4, 12%), and pulmonary contusion (n = 3, 8%). The majority of patients received cardiac FAST (n = 43, 78%) with 25 (58%) positive and 3 (7%) inconclusive examinations. Three hemodynamically stable patients with positive FAST had confirmatory formal ECHO, all revealing hemopericardium.

The indication for operative intervention was positive FAST (n = 26, 47%), negative FAST with associated hemothorax (n = 8, 15%), inconclusive FAST with symptoms or trajectory (n = 2, 4%), or clinical signs/symptoms with penetrating chest trauma (n = 7, 13%). Other indications were continued hemodynamic instability during laparotomy after control of bleeding (n = 8, 15%) or trajectory to clear the pericardium after laparotomy (n = 4, 7%).

General Operative Data

The median (interquartile range) time from arrival to beginning of surgical procedure was 25 (30) minutes. Thirty-one (56%) PCWs were performed through the SPW route, with 19 (35%) patients undergoing SPW followed by sternotomy alone. The remainder had SPW and sternotomy followed by either a laparotomy (n = 11, 20%) or thoracotomy (n = 1, 2%). Twenty-four (44%) patients had TPW performed during exploratory laparotomy.

The most common source of hemopericardium was a ventricular injury (right [n = 16, 29%] and left [n = 15, 27%]). Additional injuries are listed in Table 1. Six (11%) patients with positive PCW had isolated pericardial lacerations, and four (7%) had no identifiable injury.

Nontherapeutic Sternotomies

Table 2 presents 21 (38%) patients with hemopericardium identified on PCW that had no identifiable or repaired cardiac/great vessel injury on sternotomy. Seventeen (81%) patients sustained penetrating, and three (19%) suffered blunt trauma. There were 12 (57%) who received SPW and 9 (43%) with TPW. Four patients in this group died, all in the perioperative period. Patient 7 sustained a fall from a cherry picker, which subsequently fell on his thoracoabdominal area resulting in liver/mesenteric lacerations, multiple fractures, and cardiac contusion. The remaining three patients had traumatic brain injuries and died either intraoperatively (patients 8 and 17) or postoperatively (patient 4 coded during postoperative CT brain). Two patients had in-hospital complications. One sustained an iatrogenic pulmonary injury during sternal closure and developed an infected pericardial effusion on hospital day 21. The other developed an empyema at the chest tube site. Both recovered to discharge.

TABLE 1. Location and Frequency of Cardiac Injury

	n (%)
Right ventricle	16 (29)
Left ventricle	15 (27)
Right atrium	7 (13)
Vena cava	4 (7)
Aorta	2 (4)
Internal mammary artery	2 (4)
Left atrium	1 (2)
Innominate vein	1 (2)
Phrenic vein	1 (2)
Pulmonary vein	1 (2)
Pericardium only	6 (11)
No injury	4 (7)

Table 3 shows that patients with therapeutic versus nontherapeutic sternotomies were virtually identical in most categories, except more patients in the therapeutic group developed hypotension (62% vs. 29%, $p = 0.017$).

Hemodynamic Stability

Patients with a SBP < 90 mm Hg for >5 minutes were defined as hemodynamically unstable. By this criteria, 29 patients (53%) were considered unstable, whereas 26 (47%) were stable. In unstable versus stable, there were more blunt injuries, Injury Severity Score (ISS) was higher, more patients received exploratory laparotomies, and there were more TPW (Table 4). Unstable patients also received more fluid/blood products and had higher estimated blood loss. More patients in the unstable cohort (77% vs. 46%, $p = 0.024$) had therapeutic sternotomies. All deaths (four intraoperative and three additional in-hospital) were in hemodynamically unstable patients.

Multiple logistic regression was performed on demographics (age, gender, and mechanism), ISS, type of PCW (SPW or TPW), cardiac FAST findings, and hemodynamic stability. Penetrating trauma (odds ratio: 13.3) and hemodynamic instability (odds ratio: 7.8) were independent predictors of therapeutic sternotomy.

DISCUSSION

This study demonstrates that in patients after chest trauma, even with hemopericardium confirmed by direct visualization, there is a significant proportion (38%) with no treatable cardiac or great vessel injury. Hemodynamic instability and injuries sustained after penetrating trauma were independent predictors of therapeutic sternotomy. In addition, successful nonoperative management of hemopericardium identified on PCW was performed in three hemodynamically stable patients, two after blunt trauma and one after penetrating trauma.

In 1829, Larrey[14] described a “new surgical procedure to open the pericardium in the case of fluid in the cavity.” However, it was not until 1970 that Fontenelle et al.[8] coined the term “subxyphoid pericardial window.” In 1974, Trinkle et al.[9] compared pericardiocentesis and SPW in a series of 45 patients suffering penetrating trauma, then later confirmed

TABLE 2. Patients With Nontherapeutic Sternotomies

No.	Demographics	Mechanism	OR Indication	OR	Sternotomy Findings	Outcome
1	28 M	GSW	FAST (+)	SPW	Superficial laceration of RA/RV	Discharge
2	21 M	SW	Hypotension	SPW	Pericardial laceration	Discharge
3	39 M	SW	Trajectory/evisceration	TPW	No injury or blood	Discharge
4	27 M	MVC	FAST (+)	SPW	LV contusion	Death
5	33 M	SW	Trajectory/DPL+	TPW	Epicardial contusion/laceration	Discharge
6	35 M	SW	FAST inconclusive	SPW	LA laceration	Discharge
7	30 M	Fall	Hypotension	TPW	Blood in pericardium	OR death
8	19 M	MCC	FAST (+)	TPW	LV epicardial laceration	OR death
9	25 M	SW	FAST (+)	SPW	LV epicardial laceration	Empyema
10	34 M	SW	Location/symptoms	SPW	LV epicardial laceration	Discharge
11	43 M	SW	FAST (+)	SPW	RV contusion	Discharge
12	34 M	SW	FAST (+)	SPW	Pericardial laceration	Discharge
13	32 M	GSW	Hypotension in OR	TPW	Apical hematoma	Rehab
14	19 M	GSW	FAST (−) with HTX	SPW	RV contusion	Discharge
15	47 M	SW	FAST (+)	SPW	Pericardial laceration	Discharge
16	33 M	SW	FAST (−) with HTX	SPW	Pericardial laceration	Iatrogenic
17	19 M	GSW	FAST (−) with HTX	TPW	No injury or blood	OR Death
18	23 M	SW	Trajectory	TPW	RV epicardial laceration	Discharge
19	44 M	MCC	Hypotension in OR	TPW	RV hematoma	Discharge
20	24 M	SW	Hypotension	SPW	Pericardial hematoma	Discharge
21	30 M	GSW	Trajectory	TPW	Apical contusion	Discharge

M, male; GSW, gunshot wound; SW, stab wound; MVC, motor vehicle crash; RA, right atrium; RV, right ventricle; LV, left ventricle; LA, left atrium.

TABLE 3. Comparisons of Therapeutic and Nontherapeutic Sternotomies

	Therapeutic (n = 34)	Nontherapeutic (n = 21)	*P*
Age, yr	36 ± 17	30 ± 8	0.102
Gender, n (%) male	28 (82)	21 (100)	0.072
Mechanism, n (%) pen	32 (94)	17 (81)	0.188
ISS	26 (9)	25 (13)	0.166
Base deficit mEq/L	−7 ± 6	−9 ± 10	0.386
Hematocrit, %	36 ± 7	38 ± 7	0.351
Fluids in resuscitation bay + operating room			
Crystalloid, mL	6,925 (4,538)	6,000 (6,976)	0.921
PRBC, units	7 ± 7	10 ± 13	0.461
FFP, units	3 ± 5	6 ± 8	0.303
Hemodynamics in resuscitation bay			
SBP, mm Hg	108 ± 22	109 ± 39	0.900
HR, bpm	104 ± 25	112 ± 20	0.270
Minimum SBP, mm Hg	90 ± 27	99 ± 43	0.490
Maximum HR, bpm	115 ± 23	118 ± 21	0.702
BP < 90 mm Hg, n (%)	13 (38)	6 (29)	0.464
Hemodynamics in operating room			
SBP, mm Hg	120 (30)	120 (40)	0.479
HR, bpm	97 ± 17	100 ± 24	0.600
Minimum SBP, mm Hg	77 ± 22	73 ± 42	0.733
Maximum HR, bpm	115 (20)	115 (20)	0.903
Time BP <90, min	30 ± 34	16 ± 24	0.143
BP < 90 mm Hg, n (%)	21 (62)	6 (29)	0.017

Pen, penetrating; ISS, injury severity score; PRBC, packed red blood cells; FFP, fresh frozen plasma.

the reliability of this procedure and described the modern version of the technique in 50 penetrating trauma patients.[13] By 1979, Trinkle et al.[15] had clearly established the value of SPW for evaluating cardiac injuries and recommended abandoning pericardiocentesis.

Since then, surgeon-performed cardiac FAST has emerged as the first-line diagnostic tool for rapidly identifying

TABLE 4. Comparisons of Patients by Hemodynamic Status

	Stable (n = 26)	Unstable (n = 29)	*P*
Age, yr	30 ± 9	37 ± 17	0.068
Gender, n (%) male	25 (96)	24 (83)	0.197
Mechanism, n (%) blunt	0	6 (21)	0.024
ISS	18 (14)	30 (18)	<0.001
FAST positive, n (%)	18 (69)	25 (86)	0.128
Laparotomy, n (%)	9 (35)	23 (79)	0.001
TPW, n (%)	5 (19)	19 (66)	0.001
Fluids in resuscitation bay + operating room			
Crystalloid, mL	5,500 (5,113)	7,475 (6,450)	0.039
PRBC, units	2 ± 3	11 ± 10	<0.001
FFP, units	1 ± 2	5 ± 7	0.006
EBL, mL	972 ± 888	2,771 ± 3,009	0.005
Outcomes			
Therapeutic, n (%)	12 (46)	22 (77)	0.024
Mortality, n (%)	0	7 (24)	0.011

EBL, estimated blood loss.
Unstable, SBP < 90 mm Hg for >5 min during initial resuscitation or in the OR.

hemopericardium. In a prospective multicenter study, Rozycki et al.[6] reported a sensitivity = 100%, specificity = 97%, and accuracy = 97% for detecting hemopericardium. Subsequently, Ball et al.[10] concluded that false negatives may occur if there is decompression into the thoracic cavity and that patients with residual hemothorax or high output after chest tube placement should undergo SPW as a confirmatory test. This present study evaluated all patients who proceeded to sternotomy with hemopericardium confirmed by PCW (n = 55). The majority also received cardiac FAST (n = 43, 78%). We did not evaluate patients who proceeded to sternotomy based on FAST alone.

ECHO is also useful in the initial evaluation of these patients. Jimenez et al.[16] used this technique in 73 patients with stable vital signs after penetrating chest trauma (sensitivity, specificity, and accuracy > 90%). Freshman et al.[17] identified four stable patients with positive ECHO, and only one required cardiac repair. Meyer et al.[18] found SPW to be more sensitive than ECHO, with the latter missing four significant injuries. In patients without hemothorax, however, the sensitivity, specificity, and accuracy were comparable between SPW and ECHO. In this study, we used ECHO to confirm hemopericardium detected by FAST in three hemodynamically stable patients. This technique is limited by the inability to rapidly obtain images in hemodynamically unstable patients and by inaccessibility after-hours in many urban centers.

Regardless of the technique used to diagnose hemopericardium (FAST, ECHO, or PCW), false positives are expected. Table 5 compares results from this study on the use of SPW in context with previous studies, in terms of number of cases, true positives, false positives, and nontherapeutic rate. The false-positive rate is likely underestimated, as specific treatment of identified injuries is not always discussed. If cardiac injuries were described, repair was assumed unless otherwise stated. The false-positive rate ranges from 0% to 30% (compared with 5.6% in this study). The nontherapeutic rate was determined by dividing the number of false-positive examinations by the total number of positive examinations and ranges from 5% to 67% (compared with 38% in this study). The wide variations in false-positive and nontherapeutic rates may be due to inclusion/exclusion criteria, cohort of patients examined, and institutional practices.

On the basis of their experience with four patients treated for cardiac tamponade with pericardiocentesis, Blalock and Ravitch[19] recommended nonoperative management if there was no continued bleeding. Subsequently, Cooley et al.[2] observed a fivefold mortality increase for patients treated with cardiorrhaphy versus pericardiocentesis. In 1968, because of the high mortality experienced with pericardiocentesis (36%), Sugg et al.[1] advocated early thoracotomy, resulting in a mortality decrease to 7%. With this landmark study, the pendulum swung back toward more aggressive treatment of suspected cardiac wounds.

In 1995, Nagy et al.[20] instituted a protocol for immediate ECHO in hemodynamically stable patients with injuries in the "cardiac box." If the examination is positive or equivocal for pericardial effusion, a SPW is performed as a

TABLE 5. Literature on Pericardial Windows

Author	No. of Cases (SPW/TPW)	True Positive	False Positive	Nontherapeutic Rate	Description of Nontherapeutic Cases
This study	377	34 (9%)	21 (5.6%)	21/55 (38%)	See text
Smith et al.[23]	38[a]	5 (13%)	1 (2.6%)	1/6 (17%)	Contusion
Huang et al.[22]	31	16 (52%)	NA	NA	Nonoperative management (n = 15)
Fraga et al.[11]	245 (207/38)	44 (18%)	8 (3.3%)	8/52 (15%) 14/52 (25%)[b]	Not discussed
Navsaria and Nicol[21]	21	4 (19%)	NA	NA	Nonoperative management (n = 17)
Patel et al.[24]	26	20 (77%)	1 (3.8%)	1/20 (5%)	RV lac
Valentine and East[25]	11	4 (36%)	1 (9%)	1/5 (20%)	Not discussed
Nagy et al.[20]	31	9 (29%)	7 (23%)	7/16 (44%)	Nonoperative management (n = 4), pericardial lac (n = 3)
Meyer et al.[18]	105	9 (8.6%)	8 (7.6%)	8/17 (47%)	Pericardial lac (n = 3), epicardial lac (n = 2), contusion (n = 1), no injury (n = 1)
Johnson et al.[26]	53	50 (94%)	3 (5.7%)	3/53 (5.6%)	Epicardial lac (n = 3)
Grewal et al.[27]	122	24 (20%)	2 (1.6%)	2/26 (7.7%)	Pericardial lac
Andrade-Alegre and Mon[28]	76	16 (21%)	0	NA	
Jimenez et al.[16]	73	3 (4.1%)	6 (8.2%)	6/9 (67%)	No repair (n = 4), pericardial lac (n = 2)
Mayor-Davies and Britz[29]	10	3 (30%)	3 (30%)	3/6 (50%)	Pericardial lac (n = 2), contusion (n = 1)
Duncan et al.[30]	51	12 (23%)	0	NA	Nonbleeding, but repaired (n = 2)
Brewster et al.[31]	108 (69/39)	30 (28%)	9 (8.3%)	9/39 (23%)	Pericardial lac (n = 5), no injury (n = 2), no repair (n = 2)
Miller et al.[32]	104 (88/16)	19 (18%)	3 (2.9%)	3/22 (14%)	Pericardial lac (n = 2), no injury (n = 1)
Garrison et al.[12]	60 (0/60)	16 (32%)	3 (3.3%)	3/19 (16%)	Pericardial lac (n = 2), contusion (n = 1)
Trinkle et al.[15]	54	49 (91%)	NA	NA	Not discussed
Arom et al.[13]	50	43 (86%)	3 (6%)	3/46 (6.5%)	Pericardium only

True positive, PCW showed hemopericardium with repairable injury; false positive, PCW showed hemopericardium with no repairable injury; nontherapeutic rate, calculated by dividing false-positive/all positive examinations; lac, laceration; NA, not applicable.
[a] Laparoscopic technique.
[b] Six additional patients had grade I injuries.

confirmatory test. If bloody fluid is encountered on entering the pericardium, the site is irrigated with warm saline. If gross blood is present, or the bloody fluid persists with irrigation, median sternotomy is performed. When pericardial blood clears with irrigation, mediastinal drains are placed, and the patient is observed. The protocol resulted in 4 of 16 (25%) patients with SPW treated with irrigation/drainage alone. In 2005 in South Africa, Navsaria and Nicol[21] used drainage and observed seven patients after penetrating trauma, and 10 of 14 additional patients had nontherapeutic sternotomies for low-grade injuries. A limitation of widespread acceptance of their protocol is the delayed presentation of their population (mean: 48 hours postinjury). A group from Taiwan[22] treated nearly half of traumatic pericardial effusions (15/31, 48%) with nonoperative management. Their cohort was mostly blunt injury (94%), and all patients treated with nonoperative management sustained blunt injuries. In this present study, three patients (two blunt and one penetrating) were successfully managed nonoperatively.

Altogether, these provocative data suggest re-examination of the treatment of hemopericardium in select cases. In the moribund patient with cardiovascular collapse, emergency department thoracotomy is warranted after penetrating trauma or with witnessed loss of vital signs after blunt injury. With gross hemodynamic instability and a clear cardiac source, sternotomy should be performed immediately. In contrast, in hemodynamically stable patients, we propose that hemopericardium per se may be overly sensitive for diagnosing repairable cardiac or great vessel injuries after chest trauma. In stable patients, or those with transient responses to crystalloid or blood product resuscitation, SPW allows direct visual clearance of the pericardial cavity in patients with hemopericardium detected by other means. A positive examination without continued active intrapericardial bleeding may be amenable to watchful waiting; sternotomy may be selectively applied, sparing the patient a nontherapeutic sternotomy with its associated morbidity.

There are several limitations in our study that must be considered before recommending a selective management approach for widespread use. Obviously, this interpretation is based on a retrospective review from a single center, and there is a relatively small sample size. There were no long-term outcome data due to patient noncompliance with follow-up clinic appointments. Additionally, these injuries are relatively rare; more than 15 years were required to accumulate 55 patients undergoing sternotomy after positive PCW, and as stated earlier, we did not analyze those who received sternotomy after positive cardiac FAST. Finally, although meticulous hemostasis is generally ensured, it is conceivable that some PCW could have been contaminated with blood from the operative field.

This study may be the beginning of a journey similar to the one that occurred 20 years ago at the beginning of nonoperative management of solid organ injuries (i.e., liver, spleen, and kidney). At that time, the standard was a positive diagnostic peritoneal lavage followed by mandatory laparotomy. Many of those laparotomies were nontherapeutic. Subsequently, new criteria were developed that led to the successful nonoperative management of many solid organ injuries in the current era. Analogous to this study, in hemodynamically unstable patients or patients with active bleeding, surgical intervention is, of course, still mandated. Although no broad conclusions can be drawn from a retrospective review of 55 patients, it might give us pause to at least begin to examine the possibility of an algorithm ending with observation for the stable patient with an initially positive PCW but no continued bleeding.

AUTHORSHIP

C.M.T. is directly responsible for this study and participated in the collection, analysis, and interpretation of data and drafting and revision of the manuscript, figures, and tables; N.N., E.G., T.A.S. and C.I.S. were medically responsible for a fraction of the patients in this study; treatments were administered at their discretion; and participated in the revision of the manuscript, figures, and tables; R.V.H. and G.G. participated in the collection of data and revision of the manuscript, figures, and tables; A.S.L. participated in the analysis and interpretation of the data and revision of the manuscript, figures, and tables; and K.G.P. had overall responsibility for the study including conception and experimental design; analysis and interpretation of data; drafting and revision of the manuscript, figures, and tables; statistical expertise and evaluation; obtaining funding for this project; and supervision.

DISCLOSURE

The authors declare no conflict of interest.

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DISCUSSION

Dr. David V. Feliciano (Atlanta, Georgia): This provocative paper is a retrospective review of a 12-year experience with subxiphoid pericardial windows at the Ryder Trauma Center.

The authors' hypothesis, as you heard, is that the presence of a hemopericardium does not mandate sternotomy in all patients.

Based on two patients with blunt trauma with negative pericardial FAST exams and positive CT scans for pericardial fluid, the authors reviewed forty-plus injured patients with a hemopericardium on a subxiphoid pericardial window and found, interestingly enough, that only 20 had cardiac or great vessel injuries requiring repair. Hence their hypothesis.

I have a number of comments and questions. First, you state in your discussion that, quote "subxiphoid pericardial window has remained the standard for evaluation of cardiac injuries."

Second, what is your denominator here? How many other patients over the past 12 years had sternotomies or thoracotomies for cardiac injuries based on the classic symptoms and signs or a positive surgeon performed ultrasound?

In other words, in this exotic group of 44 patients with all these negative taps, were these some kind of difficult diagnostic problems?

Third and a related question, what are your indications for a subxiphoid pericardial window at the Ryder Trauma Center? There is no clear-cut description of your indications in the manuscript. And just to give you some comparative data, in the last 19 years at Grady we have performed 0.7 windows per year.

Fourth, you applied the AAST Cardiac Injury Organ Scale retrospectively. How were you able to distinguish Grade II injuries - as defined, those without tamponade - from Grady III injuries - those with tamponade - from the op notes alone, particularly with the systolic blood pressures in the therapeutic and non-therapeutic groups were exactly the same on admission? By definition tamponade has to have hemodynamic changes.

Fifth, as clearly stated by the presenter there is no follow-up in the manuscript whatsoever nor any description of your policy on post-sternotomy or post-cardiorrhaphy use of TTEs or TEEs.

Did you crosscheck the records of the cardiac surgery service during the same time to see if any injured patients returned with pseudoaneurysms of the ventricular wall, VSDs, intracardiac fistulas, etc.?

To summarize, the authors have described a troubling incidence of a clinical entity that is extraordinarily uncommon in the literature short with the exception of the two papers mentioned. In addition, they have used a technique that has almost disappeared in most urban trauma centers.

So I suggest before we all return to the Blalock-Ravitch approach of 1943 or the Cooley-DeBakey approach of 1955, I would encourage the authors to switch to surgeon- performed pericardial ultrasound, stop doing CTs in hemodynamically stable patients after blunt trauma with a normal chest x-ray and perhaps to study their use of windows in a prospective manner.

I thank Dr. Vu for the timely arrival of the manuscript and the Association for the privilege of discussing it. Thank you.

Dr. David P. Blake (Centerville, Ohio): Like Dr. Feliciano, I was questioning why you went from a positive FAST to another sort of diagnostic study with no real intervention, perhaps that of the subxiphoid pericardial window.

The second part of that question, though, is that you kept using the phrase "to determine whether or not they are stable and they don't have any more ongoing bleeding." You didn't describe how you were trying to do that and I'm curious: did you insert a catheter and leave it in?

And why did you need to sit in an operating room to do that if all you were going to do was a percutaneous procedure? I'm not sure that observation in an operating room is going to be financially and logistically feasible, especially in a busy trauma center. Thank you.

Dr. Carl J. Hauser (Boston, Massachusetts): I rise to congratulate the authors for putting on a paper where they knew they were going to be vilified. Surgeons have been vilified for non-operative management of splenic injuries, use of CTs to triage penetrating flank injuries, and a variety of other things which have since become the standard of care.

I have on occasion done sternotomies for penetrating injuries where the only findings were a little blood in the pericardium and a wound in the heart that had now stopped bleeding. You're then faced with a resident across the table who really wants to put one #4-0 prolene and call it a therapeutic sternotomy.

Well, the reality is there are some patients who don't necessarily come in rock stable but can still be watched. And there will now be a group that have penetrating injuries "in the box" and who are hemodynamically "rock stable" but have a positive FAST.

So the question is what are we going to do with this new information? These are people with a hemo-pericardium that we would not have found a while back and went home happy. Do they all deserve sternotomies?

So I think that the point that the authors bring up is a very good one. We do need to be thoughtful about it, I agree with David Feliciano about that. But I think we can stratify the group. We need to look for instance, at mechanism of injury. Wounds made with sharpened bicycle spokes and ice picks are very different from a penetrating injury due to a bullet.

Again, I think we have to look at these issues prospectively and the wounds are rare enough that they're likely best studied through a registry.

But I applaud the authors for taking the first step and saying out loud that maybe some of these people don't need an operation. At least they're thinking outside of "the box."

Dr. Thai Vu (Miami, Florida): Thank you, Dr. Feliciano and the audience for the excellent questions and comments.

First of all, the question of the subxiphoid window is a standard of care - no, it is not. The modern standard of care is ultrasounds; subxiphoid window, however, remains a standard adjunct. We will make sure this is clear in the manuscript.

I do not have the number of patients who have sternotomies or thoracotomies, but I do know the number of pericardial windows performed. It was only 28 in this 12-year period. We will add the components you suggest to the manuscript.

The question regarding the indication for pericardial window really gets to the crux of the matter.

We are all familiar with the clot indications but as we analyze this data we have come to the conclusion that over the decade the indications must have been liberalized as much as the interpretation of positive leading to often non-therapeutic sternotomies.

We are clearly not alone in this phenomena as we have cited two papers with a similar experience.

The questions regarding retrospective scoring of the cardiac injuries, this was very difficult. It was clearly a very important limitation in our study. We applied this information from the records as best as we could. However, this ultimately does not change our findings over a very large number of non-therapeutic sternotomies.

As for the question regarding follow-up: we have an EMR that is clearly incomplete. Those patients who presented over the past five years would have records found if they were presented to our cardiac surgery clinic or the emergency room. Prior to that, we would have relied on paper records. We will go back and specifically search for these patients that you mentioned.

We do use pericardial ultrasound and we have been doing it since the early '90s. However, subxiphoid window has not become obsolete. As you well know, in this retrospective review we cannot tell you why a patient went on to subxiphoid window. It would make an interesting prospective study to evaluate why surgeons go on to perform subxiphoid window in the age of the pericardial ultrasound.

In response to Dr. Blake's question of what do we do regarding why we're in the OR, actually we observe the patient with tube drainage. Therefore, the question of a pericardiocentesis is probably not what we use at Ryder Trauma Center at all. Those drains classically do always clot up, and we actually don't get the idea that the patient is still bleeding or not.

Thank you, Dr. Hauser, for your kind comments. And I really thank the American Association for the Surgery of Trauma again for the privilege of the podium. Thank you.

