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Point of Care Cardiac Ultrasound and New Injury Severity Score for Diagnosis of Hemorrhagic Pericardial Effusion after Penetrating Thoracic Trauma

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Abstract

Background: Ultrasound is used for trauma patients for rapid detection and assessment, permitting early treatment intervention. Its use in the recognition of pericardial effusion [PCE] hemopericardium in penetrating chest trauma gained attention in recent years to prevent rapid deterioration of hemodynamics of these patients.

Aim of the study: This study aimed to evaluate the diagnostic power of ultrasound for PCE hemopericardium after penetrating cardiac trauma.

Patients and Methods: This was a retrospective study included patients presented with penetrating chest trauma and suspected PCE hemopericardium. The collected data included personal characteristics, admission hemodynamic data, new injury severity score [NISS], Glasgow Coma Scale [GCS], mechanism of injury, results of ultrasound, duration of hospital stay, and in-hospital mortality. The results of ultrasound were compared to the results of intraoperative data [as the gold-standard diagnostic method].

Results: The PCE hemopericardium was confirmed for 42 patient [65.6%]. Patients with PCE hemopericardium had significantly higher NISS, duration of hospital stay, and in-hospital mortality and significantly lower GCS at admission. Duration of stay ranged between 6-15 days, and in-hospital mortality was reported for 7 patients [10.9%], all were from those who developed PCE hemopericardium. The ultrasound detected 45 patients with PCE hemopericardium, 42 of them were confirmed intraoperatively [True positive] and it detected 19 patients without PCE hemopericardium, all were confirmed intraoperatively. Thus, the sensitivity, specificity, PPV and NPV were 93.3%, 100.0%, 100.0%, 86.4% successively. At a cutoff value > 25, the NISS had a 64.29% and 90.91% sensitivity and specificity respectively. Older age, lower admission blood pressure, higher injury severity score are associated with in-hospital mortality.

Conclusion*:* Ultrasound can be considered as a reliable diagnostic tool for the rapid recognition of pericardial effusion hemopericardium in penetrating chest trauma. Thus, permitting early intervention and prevent hemodynamic deterioration.

Keywords: Penetrating trauma; Thoracic; Pericardial Effusion hemopericardium; New Injury Severity Score; Mortality.

INTRODUCTION

Mortality in the first four decades of life are highly related to trauma and thoracic injuries account for high percentages of death due to trauma [10 to 50%]. Thus, rapid diagnosis of thoracic injury is crucial to reduce thoracic trauma-associated mortality. Computed tomography is the gold-standard diagnostic tool. However, it is not suitable for hemodynamically unstable patients and associated with exposure to high risk of radiation. Chest x-ray is cost-effective with low exposure to radiation. However, the sensitivity is low [1-3].

During recent years, the detection of traumatic pericardial effusion was increased. This was attributed to the available teams for trauma care [e.g., cardiac surgeons, trauma surgeons and cardiologists], diagnostic methods [e.g., Focused ultrasound, echocardiography, and computed tomography]. Traumatic pericardial effusion is associated with higher mortality if neglected. Thus, rapid detection and diagnosis is of utmost importance for proper treatment [4-6]. In addition, the penetrating cardiac injury is associated with higher mortality rate. However, patients who survive cardiac injury, they usually have an excellent long-term function of the heart [7-10].

The potential cause of mortality in penetrating cardiac trauma is usually due to hemorrhagic shock or cardiac tamponade [77.5% and 22.5% respectively] [11]. The deceleration trauma is the most common cause of cardiac injury in the blunt cardiac trauma. It usually related to motor-care accidents [12]. In cardiac trauma, hemorrhagic PCE is a common occurrence that may lead to reduction of cardiac volume and decreased stroke volume leading to tamponade. It may be developed very rapidly in cases of trauma. Thus, rapid diagnosis is crucial and rapid intervention is life-saving. Ultrasound can be used to diagnose hemorrhagic PCE with different sensitivities and specificities [13]. The use of ultrasonography has become increasingly used. It had the advantages of being readily available, inexpensive and non-invasive. The ultrasonographic scan showing hemorrhagic PCE early in clinical course can lead to prompt surgical treatment for cardiac injury. Other imaging modalities can be used to confirm diagnosis if required [e.g., computed tomography [CT], and transthoracic echocardiography [TTE]]. In clinical sittings, intraoperative surgically created pericardial window is the gold-standard for detection for the presence of hemopericardium [14].

The current work aimed to evaluate the sensitivity of ultrasound in diagnosis of hemorrhagic PCE after penetrating cardiac trauma. We believe that, it will help physicians provide healthcare for those patients to intervene early with proper decision making.

PATIENTS AND METHODS

This retrospective cohort study was conducted in a tertiary hospitals [Al-Azhar University Hospitals]. Patients presented to the emergency department with penetrating thoracic trauma and suspected hemorrhagic pericardial effusion between January 2019 and January 2024 were included. An administration consent to collect data was included from the administration principal manager, and data was used only for the purpose of research and patient anonymity was guaranteed [through coding of data]. The collected data included personal characteristics, admission hemodynamic data, new injury severity score [NISS], Glasgow Coma Scale [GCS], mechanism of injury, results of ultrasound [figures 1-3], duration of hospital stay, and in-hospital mortality. The results of ultrasound were compared to the results of intraoperative data [as the gold-standard diagnostic method].

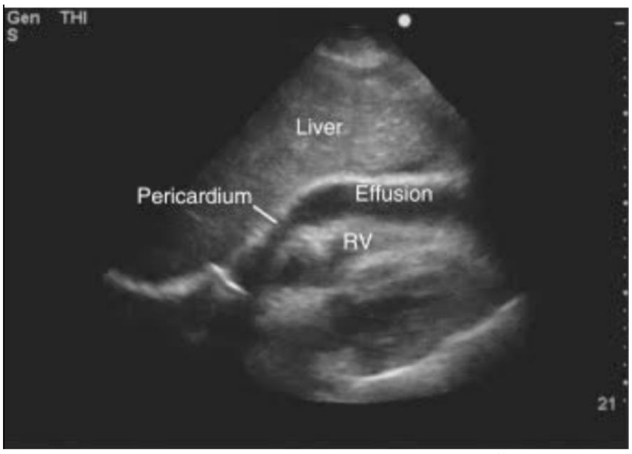

Figure [1]: Ultrasound image showing mild pericardial effusion.

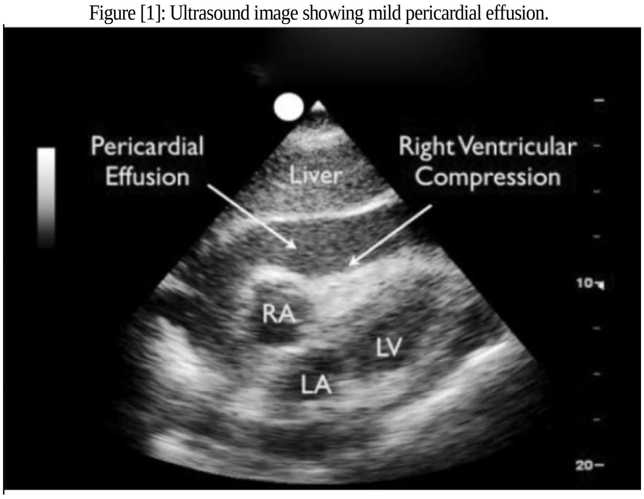

Figure [2]: Ultrasound Image Showing Pericardial Effusion with right Ventricular Compression.

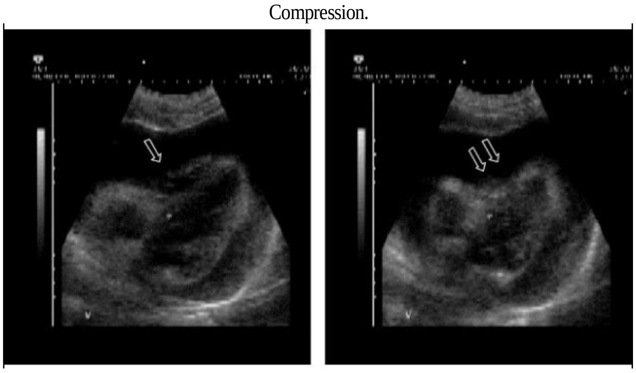
Figure [3]: Ultrasound Image Showing Marked Pericardial Effusion with Ventricular Compression [Tamponade].

The hemorrhagic PCE was exclusively treated by surgical drainage through anterior thoracotomy followed by pericardiotomy, and evacuation of the hemopericardium and cardiac exploration was performed and cardiac injury was repaired. An interrupted or running, double armed, 3/0 nonabsorbable, monofilament sutures with pledgets enforcement were used to perform Cardiorrhaphy. In cases with extensive rupture, cardio-pulmonary bypass was performed aiming to decompress the heart and facilitate the repair. All patients, regardless of the treatment option, were admitted to intensive care unit [ICU] for at least 48 hours. This aimed to monitor for delayed cardiac rupture, conduction block or ventricular arrhythmia.

Data analysis: collected data were treated by statistical package for social sciences. Continuous normally distributed data were summarized by their means and standard deviations [SDs], while qualitative data were summarized by their relative frequency and percentages. Diagnostic accuracy measures of ultrasound included sensitivity [the ability to diagnose positive cases], specificity [the ability to exclude negative cases], positive predictive value [PPV], and negative predictive value [NPV]. These were calculated by the following equations. Sensitivity = true positive [TP] / [TP + false negative [FN]], specificity = true negative [TN] / [TN + false positive [FP]], PPV = TP / [TP+ FP], NPV = [TN / [TN+FN]. Finally, the value of NISS score for prediction of hemorrhagic PCE was calculated from the receiver operation characteristic [ROC] curve. Finally, to test associated factors with the development of hemorrhagic PCE, and mortality, patients were categorized to positive and negative for hemorrhagic PCE and live or died. P value< 0.05 was considered significant.

RESULTS

The current work included 64 patients with penetrating chest trauma and clinically suspected hemorrhagic pericardial effusion [HPCE] [cardiac tamponade]. The gold standard for diagnosis of hemorrhagic pericardial effusion was the intraoperative findings. Cases were assigned as positive or negative for HPCE. The final results showed that, 42 patient [65.6%] had HPCE and the others were negative. Both cases with and without HPCE were comparable regarding patient gender, age and admission hemodynamics. However, patients with HPCE had significantly higher NISS, duration of hospital stay, and in hospital mortality. However, patients with HPCE had significantly lower GCS at admission. Duration of stay ranged between 6-15 days, and in-hospital mortality was reported for 7 patients [10.9%], all were from those who developed HPCE [Table 1].

The ultrasound detected 45 patients with HPCE, 42 of them were confirmed intraoperatively [True positive], while 3 patients were intraoperatively negative [False negative]. On the other side, ultrasound detected 19 patients without HPCE, all were confirmed intraoperatively [True negative], none of them reported positive results [FP=0]. Thus, the sensitivity, specificity, PPV and NPV were 93.3%, 100.0%, 100.0%, 86.4% successively [Table 2].

At a cutoff value > 25, the NISS can be considered as a good screening test of HPCE in penetrating chest trauma [AUC was 0.823]. It had a 64.29% and 90.91% sensitivity and specificity respectively [Table 3 and figure 4]. Factors associated with in-hospital mortality included older age, lower admission systolic blood pressure, higher NISS and longer duration of hospital stay [Table 4].

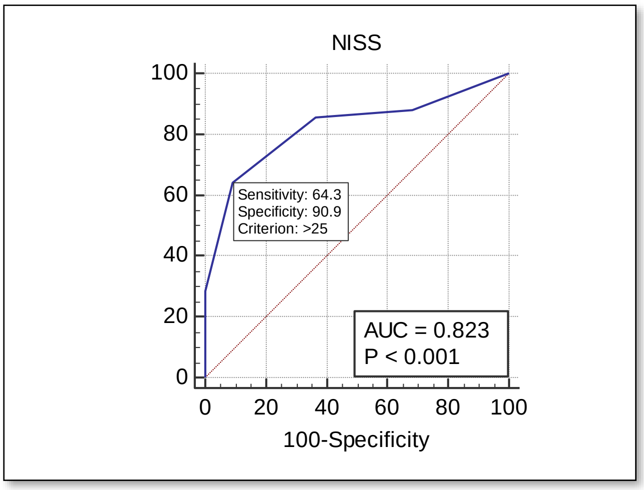

Figure [4]: ROC curve for NISS in prediction of HPCE.

Table [1]: Comparison between patients with and without intraoperative HPCE

Variable		HPCE [42]	Non HPCE [22]	Total [64]	Test	P
Sex [n,%]	Male	34[81.0%]	21[95.5%]	55 [85.9%]	2.51	0.11
	Female	8 [19.0%]	1 [4.5%]	9 [14.1%]		
Age [years]	Mean±SD; [Min.-Max.]	37.67±11.99; [21-63]	33.73±10.82; [18-56]	36.31±11.67; [18-63]	1.29	0.20
Admission SBP [mmHg]	Mean±SD; [Min.-Max.]	101.67±7.70; [90-155]	103.18±7.80; [90-120]	102.19±7.71; [90-120]	0.74	0.46
Admission HR [beat/minute]	Mean±SD; [Min.-Max.]	94.31±8.0; [79-110]	93.18±7.71; [85-112]	93.92±7.86; [79-112]	0.54	0.59
Admission Temperature [^{O}C]	Mean±SD; [Min.-Max.]	36.83±0.16; [36.39-37.10]	36.89±0.14 [36.60-37.10]	36.85±0.16 [36.39-37.10]	1.58	0.12
Admission O2 Saturation [%]	Mean±SD; [Min.-Max.]	94.36±1.08 [93-97]	94.59±1.14 [93-97]	94.44±1.10 [93-97]	0.81	0.42
Admission RR [cycle/minute]	Mean±SD; [Min.-Max.]	20.05±1.25 [18-24]	20.00±0.98 [18-22]	20.03±1.15 [18-24]	0.15	0.87
NISS	Mean±SD; [Min.-Max.]	31.83±8.69 [16-43]	21.36±5.40 [16-34]	28.23±9.16 [16-43]	***5.14***	***<0.001****
GCS	Mean±SD; [Min.-Max.]	12.26±0.83 [11-14]	12.91±0.53 [12-14]	12.48±0.80 [11-14]	***3.32***	***0.001****
Duration of stay	Mean±SD; [Min.-Max.]	11.88±2.05 [8-15]	8.32±2.01 [6-14]	10.66±2.64 [6-15]	***6.64***	***<0.001****
Ultrasound results For PCE [n, %]	Positive	42[100.0%]	3 [13.6%]	45 [70.3%]	***51.58***	***<0.001****
	Negative	0 [0.0%]	19 [86.4%]	19 [29.7%]		
In hospital Mortality [n, %]	Positive	7 [16.7%]	0 [0.0%]	7 [10.9%]	***4.11***	***0.042****
	Negative	35 [83.3%]	22 [100.0%]	57 [89.1%]		

Table [2]: Sensitivity, Specificity, PPV, NPV and overall accuracy of ultrasound for diagnosis of HPCE associated with penetrating chest trauma.

		Ultrasound	
		Positive for HPCE	Negative for HPCE
Intraoperative	Positive	TP = 42	FP= 0
	Negative	FN= 3	TN= 19
Sensitivity		TP/TP+FN = 42/ [42+3] = 93.3%,	
Specificity		TN/TN+FP = 19/ [19+0] = 100.0%,	
PPV		TP/[TP+FP] = 42/42+0= 100.0%,	
NPV		TN/ [TN+FN] = 19 / [19+3] = 86.4%.	
Overall accuracy			

Table [3]: Predictive value of NISS for diagnosis of PCE

	Value
AUC	0.823
Cutoff value	>25
Sensitivity	64.29
Specificity	90.91

Table [4]: Factors associated with in-hospital mortality

	Died		Survived		Test	p
	Mean	SD	Mean	SD		
Age	47.00	9.80	35.00	11.26	***2.69***	***0.009****
Admission SBP	96.43	7.48	102.89	7.50	***2.15***	***0.035****
Admission HR	97.29	8.26	93.51	7.79	1.20	0.233
Admission temperature	36.83	0.22	36.85	0.15	0.37	0.710
Admission O2 saturation	93.14	0.90	93.47	1.12	0.75	0.456
Admission RR	20.57	1.13	19.96	1.15	1.32	0.192
NISS	42.14	1.07	26.53	8.20	***4.99***	***< 0.001****
GCS	12.57	0.98	12.47	0.78	0.30	0.762
Duration of stay	12.71	1.98	10.40	2.62	***2.25***	***0.028****

DISCUSSION

Patients who developed HPCE had higher NISS, lower GCS, longer duration of stay, and higher in hospital mortality. The ultrasound yield showed that, the sensitivity was 93.3%, specificity 100.0%, PPV 100.0% and NPV 86.3%. NISS can be used a screening test, as the AUC was 0.823 denoting good diagnostic power, with sensitivity of 64.29%, specificity of 90.91% at a cutoff point > 25 [it is more specific than sensitive]. Mortality was significantly associated with older age, lower systolic blood pressure at admission, higher NISS and longer duration of hospital stay.

These results are comparable to those reported by **De Mond *et al.*** [14] who reported that, with its high specificity and reasonable sensitivity, ultrasound is a useful rapid bedside examination tool for early diagnosis of HPCE in penetrating cardiac trauma. The positive results ultrasound advocates the transfer of the patient directly to operation room before any further imaging modalities to guard against hemodynamic deterioration.

Other previous studies provided a comparable results to the current work. For example, a previous meta-analysis demonstrated a pooled specificity of 94% and sensitivity of 91.0% for a sum of 1031 patients [13]. The better sensitivity and specificity observed in the current work may be attributed to the advancement of ultrasound devices and to the experiences of sonographers in this work [senior staffs].

Results of the current work also comparable to those reported with **Huang *et al.*** [5] who concluded that, the precise diagnosis of traumatic HPCE is a challenge. The use ultrasound can discover it with comparable results to cardiac echocardiography and computed tomography. The value of these diagnostic methods based on the increased number of patients with traumatic HPCE needing surgical intervention. However, the treatment protocol or surgical intervention methods did not impact the survival. However, the early diagnosis and drainage with cardiac repair if required as associated with better outcome.

An interesting study comparing CT to ultrasound for traumatic thoracic injuries concluded that, ultrasound is highly specific than sensitive for detection of thoracic injuries [1]. Considering advantages of ultrasound over CT, being readily available, may be portable, and inexpensive reflected the value of ultrasound in these conditions.

Furthermore, **Hoch *et al.*** [15] in a retrospective study showed that, ultrasound was associated with earlier intervention than those who not submitted to ultrasound [21.6 vs 34.6 hours, respectively] regardless any other variables [e.g.., patient age, anticoagulation or hemodynamic state]. In addition, the use of imaging modality for diagnosis of HPCE was associated with a reduction of the 28—day mortality [9.7% vs. 26.0%]. Thus, they concluded that, the use of ultrasound was associated with earlier intervention for HPCE with reduced rate of mortality than those who do not submitted to ultrasound or any other imaging modality.

Furthermore, **Tayal *et al.*** [16] concluded that, in patients submitted to penetrating trauma of the anterior chest, the ultrasound examination was sensitive and specific for identification of traumatic HPCE and intraperitoneal fluid. Thus, helping for early or emergent surgical intervention.

Comparable results are reported by **Alpert *et al.*** **[17]**. They concluded that, point of care ultrasound [POCUS] effectively recognized HPCE and guide proper treatment. This led to a reduced time to pericardiocentesis and reduced the length of hospital stay.

Finally, **Li H and Ma Y-F** **[18]** evaluated the value of NISS for prediction of outcome in cardiac trauma in comparison to ISS. They concluded that, NISS is better than ISS in the prediction of outcomes and can be essential for evaluation of those patients. It is more convenient in calculation.

Conclusion: Ultrasound can be considered as a reliable diagnostic tool for the rapid recognition of HPCE in penetrating chest trauma. Thus, permitting early intervention and prevent hemodynamic deterioration. However, the retrospective nature and small number of patients included in this work are two limiting steps preventing the globalization of results. However, results of the current work advocates the use of ultrasound as a screening tool in patients with penetrating chest trauma.

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