

# Penetrating cardiac trauma in stab wounds: A study of diagnostic accuracy of the cardiac area

 Jorge Hernan Montenegro Muñoz, M.D.,<sup>1</sup>  Oscar Dussan, M.D.,<sup>2</sup>  Francisco Ruiz, M.D.,<sup>3</sup>  
 Andres M. Rubiano, M.D.,<sup>4</sup>  Juan C. Puyana, M.D.<sup>5</sup>

<sup>1</sup>Meditech Foundation, Clinical Research Group, Neiva-Colombia

<sup>2</sup>Department of General Surgery, South Colombian University, Neiva-Colombia

<sup>3</sup>Department of General Surgery, South Colombian University/Hernando Moncaleano Hospital, Neiva-Colombia

<sup>4</sup>Meditech Foundation / El Bosque University, Neurosciences Institute, Bogota-Colombia

<sup>5</sup>Department of Surgery, Division of Trauma, University of Pittsburgh, Pittsburgh-USA

## ABSTRACT

**BACKGROUND:** Stab wounds (SW) to the thorax raises suspicion for cardiac injuries; however, the topographic description is variable. The present study aims to evaluate different topographical descriptions within the thorax and establish their diagnostic value in penetrating cardiac trauma by SW.

**METHODS:** Medical records of all patients admitted to our center with thoracic SW from January 2013 to June 2016 were included in this study. Diagnostic value potential was measured using different areas of the thorax described in the literature.

**RESULTS:** In this study, we analyzed 306 cases. Thirty-eight (12.4%) patients had a cardiac injury managed surgically. Death by cardiac injury occurred in seven (18.4%) patients. The cardiac area defined between the right mid-clavicle line until the left anterior axillary line, and between 2<sup>nd</sup> and 6<sup>th</sup> intercostal spaces was the more accurate. It has sensitivity of 97.3%, specificity 72%, positive predictive value 33%, negative predictive value 99.4% and accuracy 75.1% for penetrating cardiac trauma. ROC was 0.894 IC 95% (0.760–0.901).

**CONCLUSION:** Among the thoracic areas, topographical limits between the right mid-clavicle line and the left anterior axillary line, and between 2<sup>nd</sup> and 6<sup>th</sup> intercostal spaces are the more accurate and are highly indicative of cardiac injury in patients with SW to the thorax.

**Keywords:** Diagnosis; penetrating cardiac trauma; stab wound; trauma.

## INTRODUCTION

Penetrating cardiac trauma remains an injury with high mortality but can be salvageable. Despite immense progress in the area of trauma care, more than 90% of patients may die before reaching the emergency room.<sup>[1,2]</sup> Due to the low frequency of these cases and thus the difficulty in acquiring sufficient experience in their management, it can be easy to miss a diagnosis of cardiac injury. Penetrating cardiac injuries represent around 0.1% of all trauma admissions, representing less than 10 cases per year for the majority of hospitals in many regions of the world.<sup>[3,4]</sup>

During the last two decades, the advent of real-time ultrasound and the use of echocardiography mode B or M in emergency departments has revolutionized management and algorithms for thoracic injuries, in particular those corresponding to the anterior wall of the chest.<sup>[5]</sup> The use of Focused Assessment with Sonography for Trauma (FAST) and subxiphoid pericardial window (SPV) was introduced and led to significant changes in the timing for surgical approach, especially in centers where the initial diagnosis was routinely performed clinically.<sup>[6]</sup> In countries with a high incidence of violence like Colombia, early case series noted that 85% of the penetrating injuries were stab wounds (SW) and 12%

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Address for correspondence: Jorge Hernan Montenegro Muñoz, M.D.

Calle 7A#44-95 760036 Cali - Colombia

Tel: +573006154775 E-mail: jorgehmontenegrom@gmail.com

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were from firearms.<sup>[5,7]</sup> However, in studies performed, more recently, 47% of the wounds were SVW and 42% from a firearm, with mortality levels from a firearm being the highest.<sup>[8]</sup>

Publications from countries with low volumes of chest trauma have been published, including numbers like 14 cases over 20 years, highlighting that cardiac injuries are relatively rare, but with high mortality, requesting the application of clear guidelines with the aim of improving the survival of the patients.<sup>[9]</sup> However, there is not yet a statistically validated definition for the different “Cardiac areas” or “Cardiac Box” found in the literature, making it difficult to design diagnostic and management protocols for penetrating stab wounds in cardiac trauma. The present study aims to evaluate different topographic descriptions of the thorax and cardiac area and establish their diagnostic value for cardiac injury in penetrating trauma.

## MATERIALS AND METHODS

This study was approved by the local Ethics Committee and conformed to the principles of the Declaration of Helsinki.

### Study Design

A cross-sectional retrospective study was conducted reviewing medical records of patients admitted to Neiva University Hospital with SW, which caused the thoracic penetrating injury (TPI) during the period from 2013 to 2016. This was defined as an injury that penetrates the pleural or pericardial cavity.

#### Inclusion criteria

1. Patient with an SW in the anterior or posterior region of the thorax.
2. Age older than 14 years.
3. Admission during the period of evaluation.

#### Exclusion criteria

1. Tangential or superficial SW.
2. Patients who arrived without signs of life.
3. Incomplete information in physical and electronic medical records.
4. Pregnancy

### Test Methods

A review of the literature was conducted to determine the different topographical areas of the thorax that were described when attempting to determine the possibility of cardiac injury from an SVW. We found two different descriptions that were used by different national and international studies. These areas were identified for this study as A, B and C. A new area identified as D was also proposed from the pilot test carried out at the start of this research. The limits of topographical area A (the Cardiac Box<sup>[10]</sup>) are between the superior aspect of the clavicles and inferior costal margin,

including the epigastrium, and between the two mid-clavicular lines. Topographical area B (the Cambridge-anatomical area<sup>[11]</sup>) is located from the 3rd to the 6th intercostal space on the right sternal edge and the left from the 2nd intercostal space 2 cm lateral to the sternal border until the 5th intercostal space in the midclavicular line. Topographical area C (Cardiac Zone<sup>[12]</sup>) is located from right anterior axillary line anteriorly across the precordium to the posterior left chest ending in the midline at the spinous processes, with the superior margin being the supraclavicular areas and the inferior margin being the costal margins, including the upper epigastrium. Topographical area D (proposed area) is located from the 2nd to the 6th intercostal space between the right midclavicular line and the left anterior axillary line.

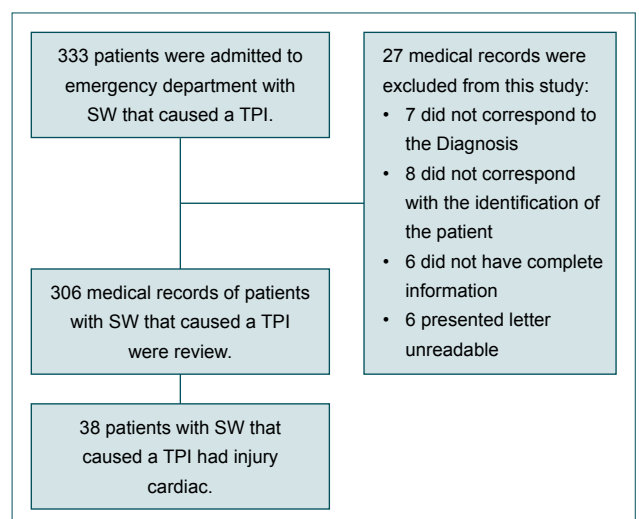
The gold standard for confirmation of cardiac injury was surgical findings. In those patients who had no cardiac injury, this was confirmed by Echocardiogram, FAST, SPW or chest x-ray in order to give satisfactory confirmation of the absence of injury. This information was confirmed through the medical records, imaging studies and surgical reports.

### Statistical Analysis

Data were expressed as the mean value and its standard deviation. The diagnostic value for cardiac injury of each topographical thoracic area was calculated using sensitivity, specificity, accuracy, positive predictive value, negative predictive value, positive likelihood ratio, negative likelihood ratio and ROC with 95% CI. SPSS software (SPSS version 19, Chicago, IL, United States) was applied for statistical analyses.

## RESULTS

After reviewing the medical record of the 306 patients, 38 patients were found with cardiac injury diagnosed during the surgical intervention to be included in this study (Fig. 1).



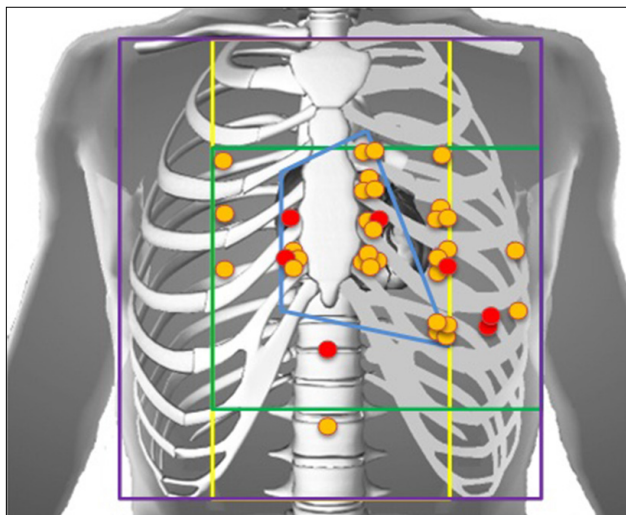
**Figure 1.** Flow of participants in this study. SW: Stab wounds; TPI: Thoracic penetrating injury.

**Table 1.** Distribution of the patient with penetrating cardiac injury

Variable	Survivor n (%)=31	Die n (%)=7	Total n (%)=38
<b>Admission data</b>			
Age (year)	29.7±9.7	41.1±18.6	31.8±11.5
Sex (male/female)	30/1	5/2	35/3
Systolic pressure blood (mmHg)	86.1±25.5	40.5±41	77.7±33.5
Heart rate (bpm)	101±23.8	76.8±53.9	96.5±32
Shock index	1.3	2.9	1.4
Injury Severity Score	18±8.5	44±15.2	30±12.3
<b>Diagnosis, n (%)</b>			
Surgery	19 (61.3)	7 (100)	26 (68.4)
Focused assessment with sonography for trauma	6 (19.4)	0	6 (15.8)
Subxiphoid pericardial window	5 (16.1)	0	5 (13.2)
Echocardiogram	1 (3.2)	0	1 (2.6)
<b>Cardiac injury, n (%)</b>			
Right atrium	4 (12.9)	1 (14.3)	5 (13.2)
Right ventricle	20 (64.5)	4 (57.1)	24 (63.2)
Left atrium	1 (3.2)	0	1 (2.6)
Left ventricle	6 (19.4)	2 (28.6)	8 (21.1)
Size of cardiac lesion (mm)	15.5±10.1	31.7±16.5	18.9±12.2

The majority of patients were male [292 (95.4%)] the average age was 30.4±11.6 years, a median of 28 years, the minimum age was 15 and maximum of 75 years. 38 (12.4%) of the patients were identified with cardiac injury, all injuries being located in the anterior wall of the thorax; the average age of these patients was 31.8±11.5 years, minimum age of 15 and maximum of 60 years and 35 (92.1%) were men. At

admission to the emergency department, systolic blood pressures mean (SBP) was 77.7±33.5 mmHg and the mean heart rate (HR) was 96.5±32 beats per minute; the shock index (SI) average was 1.4. The location of the lesions to the heart was in 24 (63.2%) cases the right ventricle, five (13.2%) cases in the right atrium, 8 (21.1%) in the left ventricle and 1 (3.3%) in the left atrium. The average size of the cardiac lesions was 18.9±12.2 mm. In-hospital mortality rate was 7 (18.4%) cases; 4 (57.1%) had a lesion to the right ventricle, 2 (28.5%) to the left ventricle and 1 (14.2%) to the right atrium (Table 1). The following table shows an analysis of the patients within the study, their injuries and outcomes (Fig. 2).



**Figure 2.** Relationship between areas evaluated and the topographical location of the lesions in the thorax. Non mortal Injuries (yellow points) and mortal injuries (red points). Area A (yellow box), area B (blue box), area C (orange box) and area D (green box).

The diagnostic value for cardiac injury of each topographical thoracic areas evaluated is described in the following Table (Table 2).

## DISCUSSION

A high clinical suspicion of cardiac injury (CI), which occurs in the 6.4% stab wounds to the chest,<sup>[13]</sup> is important due to the high mortality and the increase in survival rates if intervention comes early. In low and middle-income countries centers without access to radiological studies are still the primary location for the diagnosis and management of these injuries.<sup>[14,15]</sup> The cardiac area has an important clinical significance due to its ability to help in the development of management algorithms with or without the use of technologies for imag-

**Table 2.** Description of the diagnostic value for CI of each topographical thoracic area evaluated

Area evaluated	SEN (%)	SPE (%)	VPP (%)	VPN (%)	Accuracy (%)	LR +	LR -	AUC ROC	IC 95%
Area A	89.4	66.4	27.4	97.8	69.2	2.6	0.1	0.779	0.710–0.849
Area B	55.2	86.5	36.8	93.1	82.6	4.1	0.5	0.709	0.610–0.808
Area C	100	17.9	14.7	100	28.1	1.2	0	0.590	0.505–0.674
Area D	97.3	72	33	99.4	75.1	3.47	0.03	0.847	0.797–0.897

SEN: Sensitivity; SPE: Specificity; PPV: Positive predictive value; NPV: Negative predictive value; LR+: Positive likelihood ratio; LR-: Negative likelihood ratio; AUC ROC: Area under curve ROC.

ing (FAST, SPW, thoracoscopy). Given that decision-making should be done quickly to reduce mortality in this type of injury, it is important to define the limits of this area as a diagnostic screening test. In a review of the literature, studies evaluating their diagnostic value are not easy to find. The area has been previously referred to as the “cardiac proximity”,<sup>[16]</sup> “cardiac box”,<sup>[10]</sup> “heart silhouette”,<sup>[17]</sup> “precordium” and “cardiac zone”,<sup>[12]</sup> terms all used to describe an area of the thorax in which the penetrating wounds are at risk of causing injury to the heart.<sup>[18]</sup>

The population in this study is similar to the population described in other studies, being mostly male and of an economically active age.<sup>[9,10,12,14]</sup> The site more affected in the heart is the right ventricle by its previous position with similar frequency to the literature (62%), followed by the left ventricle that causes high mortality.<sup>[19–21]</sup> Mortality reported in studies of CI secondary to stab wounds is on average 21.9% (range 8–22%) which is higher than the mortality found in our study (18.4%) and higher than other mortality described in other Colombian trauma centers (8.8%).<sup>[14]</sup> Most of the patients in our study reached the hospital in a haemodynamically unstable state and with a CI greater than 30 mm.

Different methods diagnostics (creatinase kinase (CK)-MB or CKMB ratio, troponin I and troponin T, electrocardiogram) have been evaluated remain limited to its value diagnosis and applied with greater frequency in patients with blunt cardiac injuries and hemodynamically stable.<sup>[22–24]</sup> Focused assessment with sonography for trauma patients (FAST) and the Focused cardiac ultrasound (FOCUS) have been associated with a decrease of mortality as it leads to early diagnosis and timely management.<sup>[6,25]</sup> Most of these studies have been conducted to evaluate ultrasound methods and include multiples types of injuries like knives and firearms. According to these studies, two-thirds of the patients with a CI have entry wounds into the skin between the left anterior axillary line and the left sternal edge.<sup>[26]</sup> Another study shows the highest mortality from cardiac injury by stab wounds outside of the precordial region (25%), in contrast, to stab wounds located in the cardiac area (4%). In these studies, they recommend a re-thinking of the actual cardiac areas described in the thorax to improve the index of suspicion

for the detection of CI and recommend a new “Cardiac zone”.<sup>[12,27]</sup>

On assessing the diagnostic value of the three areas, it was shown that the cardiac area described as the Cambridge anatomical area (Area B) had lower sensitivity but a higher specificity (86.5%) than the other areas. Nicol et al.<sup>[12]</sup> proposes an area (Area C) that was evaluated with sensitivity and negative predictive value perfect (100%), despite which would exclude the wound outside the thorax as possible cardiac injury should be considered a small area with similar value diagnosis to suspect a cardiac injury taking considerations about the trauma mechanism as described the literature. In two cases reported, the lesions are located lateral to the right mid-clavicular line and another superior to the left clavicle suggesting that CI should be anticipated even when a wound is not in the cardiac area.<sup>[28]</sup>

This type of injury requires that the defined cardiac area has adequate sensitivity and NPV to guide the management. In comparison with the previously defined areas, the area described by the new proposal (area D) was found to have a sensitivity of 97.3%, a VPN of 99.4%, and an improved area under the curve ROC (0.847 CI 95% 0.797–0.897). It is believed that this proposed “Cardiac area” can better guide the process of identifying cardiac injury in those patients with penetrating trauma to the thorax.

### Limitations

The main limitation of this study is the small sample size. There is not analysis for excluded patients with incomplete data in the medical record. Further studies are required to validate our findings in a bigger population.

### Conclusion

Among the thoracic areas evaluated, the topographical limits between the right midclavicular line and the left anterior axillary line and between 2<sup>nd</sup> and 6<sup>th</sup> intercostal spaces are the most accurate and highly indicative of cardiac injury in patients with stab wounds to the thorax.

**Ethics Committee Approval:** Approved by the local ethics committee.

**Peer-review:** Internally peer-reviewed.

**Authorship Contributions:** Concept: J.H.M.M., O.D., A.M.R.; Design: J.H.M.M., O.D., A.M.R., F.R., J.C.P.; Supervision: A.M.R., F.R., J.C.P.; Materials: J.H.M.M., O.D., A.M.R., F.R., J.C.P.; Data: J.H.M.M., O.D., A.M.R., F.R., J.C.P.; Analysis: J.H.M.M., A.O., A.M.R.; Literature search: J.H.M.M., O.D., A.M.R., F.R., J.C.P.; Writing: J.H.M.M., O.D., A.M.R., F.R., J.C.P.; Critical revision: J.H.M.M., O.D., A.M.R., F.R., J.C.P.

**Conflict of Interest:** None declared.

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ORIJİNAL ÇALIŞMA - ÖZET

## Kesici-delici alet yaralanmalarında penetran kardiyak travma: Kardiyak bölgenin doğru tanısına ilişkin bir çalışma

Dr. Jorge Hernan Montenegro Muñoz,<sup>1</sup> Dr. Oscar Dussan,<sup>2</sup> Dr. Francisco Ruiz,<sup>3</sup>  
Dr. Andres M Rubiano,<sup>4</sup> Dr. Juan C. Puyana<sup>5</sup>

<sup>1</sup>Meditech Vakfı, Klinik Araştırma Grubu, Neiva-Kolombiya

<sup>2</sup>Güney Kolombiya Üniversitesi, Genel Cerrahi Anabilim Dalı, Neiva-Kolombiya

<sup>3</sup>Güney Kolombiya Üniversitesi / Hernando Moncaleano Hastanesi, Genel Cerrahi Anabilim Dalı, Neiva-Kolombiya

<sup>4</sup>Meditech Vakfı / El Bosque Üniversitesi, Nörobilim Enstitüsü, Bogota-Kolombiya

<sup>5</sup>Pittsburgh Üniversitesi, Cerrahi Anabilim Dalı, Travma Bölümü, Pittsburgh-ABD

**AMAÇ:** Torakstaki kesici ve delici alet yaralanmaları (SW) kardiyak yaralanma şüphesini akla getirmekle beraber bunlara ilişkin tomografik açıklamalar değışkenlik gösterir. Bu çalışma, toraks içindeki farklı tomografik tanımlamaları değerlendirilmesi ve SW'nin penetran kardiyak travmasındaki tanı değerlerinin saptanması amaçlanmaktadır.

**GEREÇ VE YÖNTEM:** Ocak 2013 - Haziran 2016 tarihleri arasında merkezimize torasik SW ile başvuran tüm hastaların tıbbi kayıtları bu çalışmaya alındı. Bunların tanı değeri potansiyelleri literatürde açıklanan farklı torasik alanları kullanılarak ölçüldü.

**BULGULAR:** Üç yüz altı olgu analiz edildi. Otuz sekiz (%12.4) hastada cerrahi olarak yönetilen kalp yaralanması vardı. Kardiyak yaralanma nedeniyle ölüm 7 (%18.4) hastada meydana geldi. Sağ ön klavikula çizgisi ile sol ön aksiller çizgiye kadar, 2. ve 6. interkostal boşluklar arasında tanımlanan kalp alanı daha doğrudu. Penetran kardiyak travmada %97.3, özgüllük %72, pozitif prediktif değer %33, negatif prediktif değer %99.4 ve %75.1 hassasiyete sahiptir. ROC 0.894 IC %95 (0.760–0.901) idi.

**TARTIŞMA:** Torasik bölgeler arasında, sağ orta klavikula çizgisi ile sol ön aksiller çizgisi ve 2. ve 6. interkostal boşluklar arasındaki topografik sınırlamalar daha kesindir ve toraks ile SW hastalarında kalp yaralanmasının yüksek göstergesidir.

**Anahtar sözcükler:** Penetran kalp travması; stab yara; tanı; travma.

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