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The use of computed tomography for penetrating heart injury screening.

O uso da tomografia computadorizada na triagem da lesão cardíaca penetrante.

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A B S T R A C T

Objective: to determine if computed tomography represents a safe option for penetrating heart injury screening. **Methods:** retrospective transversal study which confronted tomographic findings with the ones detected in surgical exploration in patients that had undergone surgery because of suspected cardiac trauma from January, 2016 to January, 2018. **Results:** seventy-two cases were analysed; 97.2% of them were males, and the most prevalent age range was 20 to 29 years; 56.9% of them presented injuries caused by firearm shots and 43.1% by cutting weapons. In 20 cases, computed tomography suggested heart injury, confirmed in 13 cases during surgery. Sensitivity of computed tomography was 56.5%, reaching a specificity of 85.7%. **Conclusion:** computed tomography must not be adopted as a routine for the screening of penetrating heart injuries.

Keywords: Heart. Wounds and Injuries. Heart Injuries. Tomography. Diagnosis.

INTRODUCTION

The first successful repair of cardiac trauma was performed by Dr. Ludwig Rehn, from Frankfurt, Germany, in 1896, who operated on a right ventricle injury of a 22-year-old man that had suffered a penetrating injury in the fourth left intercostal space[1]. Presently, improvement on the pre-hospital and hospital care increase the survival rate of patients with penetrating heart injuries, allowing for a greater possibility of exams and diagnostic procedures and continued improvement in treatment[2-5].

Clinical characteristics of the patients depend on the nature of the injury mechanism: blunt or penetrating[3]. Penetrating injuries are the most serious and represent one of the main morbidity and mortality causes related to thoracic trauma[3,6,7]. These penetrating injuries are more frequent in young men, and cutting weapon and firearm wounds are the main mechanisms[7]. Due to its anatomical position, the right ventricle, which accounts for most of the anterior surface of the heart (sternocostal), is classically described as the most vulnerable cardiac chamber, and death occurs mainly due to hypovolemic shock and to cardiac tamponade. A penetrating heart injury requires a precise diagnosis and immediate treatment[2,3,6].

In spite of the evolution seen in imaging methods, it is not always possible to identify heart injury by means of non-invasive techniques. The pericardial window is considered to be easily performed, with high sensitivity and low morbidity, and it remains the gold standard for diagnosing heart injury due to its capability of direct visualization of the pericardial sac. Nonetheless, it is less and less performed due to its invasive character[3,4]. In better equipped centers, the pericardial window can be substituted by less invasive methods, like FAST (Focused Assessment with Sonography for Trauma)[3,8].

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However, this ultrasonographic examination requires appropriate equipment and trained doctors, who are not always available[9].

Axial computed tomography (CT) is usually performed to assess penetrating injuries in the thorax and, although many authors argue that this exam can be used to diagnose heart injuries, there are no guidelines suggesting this exam for this objective, nor references that quantify its sensitivity to detect heart injuries[3,9-12].

The objective of this study is to determine if CT represents a safe option to screen penetrating heart injuries.

METHODS

Retrospective transversal study, based on the analysis of medical records of patients operated on suspicion of penetrating cardiac trauma admitted to the Metropolitan Hospital of Urgencies and Emergencies of Pará (HMUE) between January 1st, 2016 and December 31st, 2017.

Inclusion criteria: patients of both genders and at any age who suffered penetrating injuries and who, after undergoing an axial computed tomography (CT) have undergone surgical exploration of the pericardial sac through subxiphoid pericardiotomy (pericardial window) or thoracotomy.

Exclusion criteria: inability to retrieve, in the database, the imaging of tomographies and/ or non-identification in the medical record of the description of the operating act or inability to identify in this document terms that would allow a confrontation of the radiologic suspicion of penetrating heart injury with the surgical finding.

An electronic search in the medical records of suspected cases was performed using the terms "pericardiotomy", "pericardial window", "cardiac suture", "atrium", "ventricle" and "thoracotomy".

The following epidemiologic variables were researched: date and time of medical care, sex, age in years (classified by age ranges: <20, 20 to 29, 30 to 39, 40 to 49 and ≥50), trauma mechanism (classified as white gun, firearm or other mechanisms), injured intrapericardial structure (cardiac chambers classified in right/left atriums and right/left ventricles and intrapericardial portion of base vessels).

Tomographies were assessed by a radiologist doctor and were found to suggest heart injury when one or more of the following findings was described: pneumomediastinum, pneumopericardium, mediastinal hematoma, hemopericardium, pericardial effusion, mediastinal hemorrhage, or in case terms like "compatible with heart injury" have been used to describe a finding.

Operatory findings of heart injury were hemopericardium, solution of continuity in the pericardium and direct identification in one of the cardiac chambers or in the intrapericardial portion of the base vessels.

By considering surgical exploration as the "gold standard" for diagnosing heart injuries, operatory findings were confronted with the ones of tomographies. Sensitivity, specificity, positive and negative predictive values (PPV and NPV, respectively) of CT were calculated to identify heart injuries in penetrating trauma. Patients were classified into four groups: Group A- positive tomographic and surgical findings; Group B- positive tomographic finding and negative surgical finding; Group C- negative tomographic finding and positive surgical finding; and Group D- negative tomographic and surgical findings.

Sensitivity and specificity of the pericardial window were also calculated by confronting the results of the positive windows with the findings of thoracotomy and comparing to the ones obtained for CT through the ROC curve.

The research was approved by the Research Ethics Committee (REC) from the University Center of Pará (CESUPA) - register: 3.054.905.

RESULTS

Within the period set up as the study interval, 97 patients fulfilling the inclusion criteria; 25 patients were excluded from the study due to the impossibility of recovering the tomographic images, resulting in a casuistry of 72 cases.

Epidemiologic variables: 70 male patients (97.2%; p<0.0001; G adherence test) and the most prevalent age range was 20 to 29 years (37.5%; p=0.0018; Chi-square adherence) (Table 1).

As to the injury mechanism, 41 patients (56.9%) presented wounds caused by firearms (GSW) and 31(43.1%) by cutting weapons (p=0.2888; X^2 test).

Twenty-three cases were identified with operatory findings of heart injury (hemopericardium, solution of continuity in the pericardium or identification of a wound in one of the cardiac chambers), and in 17 (23.6%) patients injuries were found in at least one cardiac chamber, while in six patients (8.3%), although solutions of continuity have been identified in the pericardium or hemopericardium have been detected, the exploration did not identify heart or intrapericardial vessels injuries. Sensitivity of the pericardial window was 100%, and specifity was 87.8%.

The most injured cardiac chambers were the ventricles, appearing in 12 out of 17 patients (70.6%) (six patients showing injuries only in the left ventricle, four of them in the right ventricle, and two patients had injuries in both ventricles). The distribution of heart injuries according to the affected chamber can be found in table 2.

Tomographic and surgical findings: Group A- positive tomographic and surgical findings: 13 patients (18.1%); Group B- positive tomographic finding and negative surgical finding: 7 patients (9.7%); Group C- negative tomographic finding and positive surgical finding: 10 patients (13.9%); and Group D- negative tomographic and surgical findings: 42 patients (58.3%).

Among patients with positive tomographic findings (groups A+B=20 patients), surgical exploration did not confirm positive findings in seven patients, therefore, the PPV of the CT was 65%.

Among patients with negative tomographic findings (groups C+D=52 patients), surgical exploration confirmed positive findings in 10 of them, therefore, the NPV of the TC was 80.7%.

Table 1. *Sample characterization according to gender and age, in years.*

Sample characterization	n	% (n=72)	p-value
Gender			<0.0001*
Female	2	2.8%	
Male*	70	97.2%	
Age range			0.0018**
<20	13	18.1%	
20 to 29*	27	37.5%	
30 to 39	16	22.2%	
40 to 49	9	12.5%	
≥50	7	9.7%	

*Source: Metropolitan Hospital for Urgencies and Emergencies. *G adherence test; **X^2 test.*

When applying diagnostic tests, the sensibility obtained for CT was 56.5% and a specificity of 85.7% in relation to findings suggesting heart injuries. The pericardial window in this study showed 100% sensibility and 87.8% specificity, as shown in table 3.

In order to assess the accuracy of the diagnostic methods used (computed tomography and pericardial window) a ROC curve was drawn to compare the area corresponding to the sensitivity and the specificity of each method, in comparison to the parameter found by Mantovani *et al*.[13], that considers a 97.4% sensitivity and 100% specificity for the pericardial window. The area of the curve representing the CT accuracy showed some distance in relation to the ideal sensitivity of 0.46 (#A), the pericardial window of 0.12 (#B) and the reference considered of 0.03 (#C), indicating poor accuracy of the CT and a considerable approximation of the pericardial window of the study to the parameter considered as golden for a comparison (Figure 1).

Table 2. *Distribution of heart injuries according to affected chambers.*

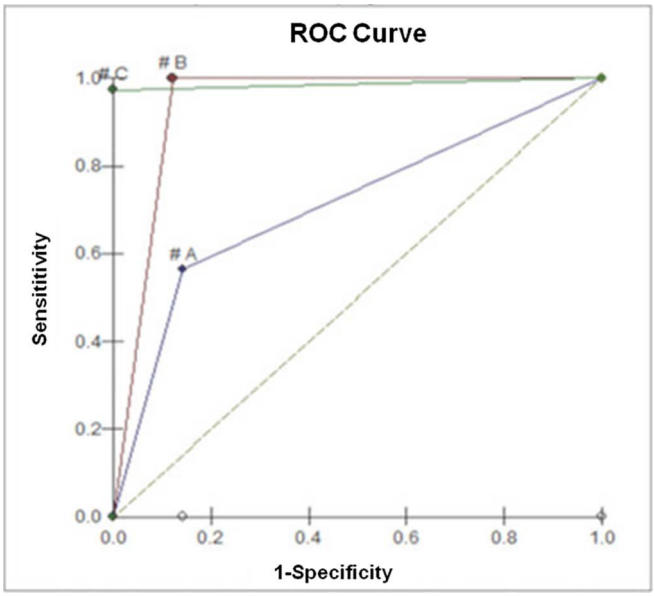
Heart injuries	Frequency	% (N=72)
Cardiac chamber		
Injuried	17	23.6%
Uninjuried	55	76.4%
Site of the heart injury		n=17
Left ventricle	6	35.3%
Right ventricle	4	23.5%
Right and left ventricles	2	11.8%
Left atrium	2	11.8%
Right atrium	1	5.9%
Right and left atriums	1	5.9%
Intrapericardial vessel	1	5.9%

Source: Metropolitan Hospital for Urgencies and Emergencies.

Table 3. *Diagnostic tests to identify cardiac trauma.*

Exam performed	Cardiac Trauma			
	Presence		Abscence	
Computed tomography (n=72)				
Positive	13	18.1%	7	9.7%
Negative	10	13.9%	42	58.3%
Sensitivity: 56.5%; Specificity: 85.7%; PPV: 65%; NPV: 80.8%				
Pericardial window (n=63)				
Positive	15	23.8%	5	7.9%
Negative	0	0.0%	43	68.3%
Sensitivity: 100%; Specificity: 87.8%; PPV: 100%; NPV: 92.1%				

Source: Metropolitan Hospital for Urgencies and Emergencies.



Source: Metropolitan Hospital for Urgencies and Emergencies. #A: computed tomography; #B: pericardial window; #C: gold standard in the literature.

Figure 1. *ROC curve of the results obtained by computed tomographies, pericardial window of the study and of the comparison gold standard.*

DISCUSSION

Penetrating heart injuries represent a significant mortality cause, and can be challenging either from the therapeutic or the diagnostic point of view, since they can be asymptomatic or oligosymptomatic for a variable period after a trauma occurs[6,11,14]. Most studies show that young men are the most struck by penetrating heart injuries, which is in consonance with our outcomes[5,7,8,14-18].

The most frequent mechanism among patients operated due to penetrating heart traumatism is stab wounds, in a proportion ranging from 39% to 81.4%[3,7,8,15]. Necropsy research suggests that firearm wounds (GSW) are the most frequent[2] ones. This disagreement is probably due to the fact that firearm wounds (GSW) cause greater solutions of continuity in the pericardium and wider myocardial wounds, leading to profuse bleeding uncontrolled by the pericardium which evolve quickly to death by hypovolemia; as the majority of such patients would evolve to death before surgery, the operated population would tend to be predominantly victims of stab wounds[2,5,6,10].

It is interesting to point out that among the 23 cases where operatory findings were classified as compatible with heart injury, in six patients there was hemopericadium, but no injury to any cardiac chamber or intrapericardial vessel was found (five cases went through pericardial window followed by thoracotomy, and in one case no pericardial window was performed). This finding of blood inside the pericardium, without detecting intrapericardial structure injury is described as a false positive result of the pericardial window, and this can happen in 18% to 30% of the cases[8,19]. According to the casuistry of the present study, this happened in 25% of the pericardial windows. Causes may include an insufficient hemostasis during dieresis (allowing the blood to mingle with the pericardial liquid and hindering interpretation) or the pericardial injury, causing bleeding into the pericardial sac without affecting the cardiac chambers; this mechanism is classically described when the pericardiophrenic artery is affected by the injury[6].

The right ventricle is often described as the most affected cardiac chamber in penetrating injuries, because it accounts for most of the anterior surface of the heart (sternocostal), with predominance ranging from 30% to 48%[3,8,13,19-21]. This study identified a non-significant prevalence of injuries in the left ventricle, amounting to eight cases (47.1%), followed by the right ventricle in six cases (35.3%), a distribution similar to the ones detected by other authors[2,6].

Diagnosis of penetrating heart injuries can be based on clinical data and complementary exams. Any diagnostic method (FAST, CT or pericardial window) must be performed only in stable patients. Patients in shock must be submitted to surgery immediately[10,12].

The literature points out FAST as an important complementary exam, which can be performed in the emergency room, and repeated whenever necessary, however it has a bias of being operator dependent.

It presents 100% sensitivity and 96.9% specificity[13]. In this study, no patient went through FAST due to unavailability of the device at the emergency room of the service[3,6,10].

Many authors still consider the pericardial window as the gold standard due to its 97% sensitivity and 100% specificity[3,4,8,14]; it is an invasive surgical procedure with low complication rates reported of up to 2.6%[4,6,13].

Other exams can be performed for a better assessment of patients who were victims of thoracic trauma. A study performed by Melo *et al.*[10], in 2016, shows that patients who suffered penetrating thoracic traumas who were submitted to CT had findings related to mediastinal alterations in 20% of the exams. Other studies claim that CT has high sensitivity and specificity to detect penetrating heart injuries, associated to findings like pericardial pericardial effusion and pneumopericardium; however, such papers do not assign values to the exam sensitivity[9,10,21].

Although less specific radiological alterations, like a voluminous hemothorax, may be associated to a heart injury, only findings of pneumomediastinum, pneumopericardium, mediastinal hematoma, hemopericardium, pericardium effusion, mediastinal hemorrhage were considered as suggestive of heart injure on CT images because these are the findings classically described in the literature[9,10,21]. In spite of this, alterations like pneumodiastinum or mediastinal hematoma can occur in patients with injuries in other structures than the heart.

In this study, CT sensitivity was 56.5% and its specificity was 85.7%, way below the FAST ones, which has an approximate sensitivity of 100% and a specificity of 96%[8,22]. Besides, just like among the 72 tomographies, 20 patients (27.8%) presented findings suggesting heart injury and, among such patients, in only 13 of them (18%) surgical findings were compatible, the Positive Predictive Value of CT was 65%, that is, in 35% of the cases, patients with tomographic findings suggesting heart injury do not present an actual injury.

On the other hand, in patients whose tomographies showed no findings suggesting heart injury (52 patients, or 72.2%), in only ten of them (13.9%) surgical findings compatible with heart injury were detected. Thus, a negative predictive value of 80.7% is obtained, that is, in 80.7% cases of patients with no tomographic evidence suggesting heart injury, this was not detected during surgery.

In practical terms, it is possible to notice that, in hospitals where FAST is not available, tomographies are more and more requested for screening heart injuries. In the casuistry of the study, 68.2% of the patients submitted to the pericardial window after tomography obtained a negative result in the pericardial window, that is, if CT presented an accuracy which is enough for screening, approximately 70% of patients would be undergoing the pericardial window unnecessarily. It is as if patients were submitted do surgical exploration regardless of the CT findings.

Among the limitations of this study is the relatively small sample, although superior to some of the articles published on CT findings in thoracic trauma, and the fact that the CT were performed using 16 channels CT scanners. Many hospitals own a CT scanner that is annexed or close to the emergency room, which makes it faster to get exams done and for the therapeutic decision making. More modern CT scanners produce finer cuts, increasing image definition, which is obtained within seconds[23]. However, the worldwide and national reality is heterogeneous regarding availability and quality of the exams and training of surgeons and radiologists to interpret suggestive findings of penetrating heart injury[3,6].

Considering that the literature indicates an approximate sensitivity of 97% and an approximate specificity of 100%, either for the FAST or for the pericardial window[3,6,8,9,21], the sensitivity and specificity values of the computed tomography obtained in this study indicate that this diagnostic modality must not be recommended as a routine for the screening of penetrating heart injuries; in services where an ultrasonographic assessment of the pericardial sac cannot be urgently performed, a subxiphoid pericardiotomy remains an appropriate option.

R E S U M O

Objetivo: *determinar se a tomografia computadorizada representa uma opção segura para triagem de lesões cardíacas penetrantes.* **Métodos:** *estudo transversal retrospectivo, que confrontou os achados tomográficos com os detectados na exploração cirúrgica em pacientes operados por suspeita de trauma cardíaco no período de janeiro de 2016 a janeiro de 2018.* **Resultados:** *setenta e dois casos foram analisados; 97,2% eram do sexo masculino e a faixa etária mais prevalente foi de 20 a 29 anos; 56,9% apresentaram ferimentos por projéteis de arma de fogo e 43,1% por arma branca. Em 20 casos, a tomografia computadorizada foi sugestiva de lesão cardíaca, confirmada em 13 casos durante a cirurgia. A sensibilidade da tomografia computadorizada foi de 56,5% e a especificidade de 85,7%.* **Conclusão:** *a tomografia computadorizada não deve ser adotada rotineiramente para triagem de ferimentos cardíacos penetrantes.*

Descritores: *Coração. Ferimentos Penetrantes. Traumatismos Cardíacos. Tomografia. Diagnóstico.*

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