Differences in Cardiac Rupture and Hemopericardium Caused by Blunt Chest Injury, Acute Myocardial Infarct, Aortic Dissection and CPR

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Article

Keywords: cardiac rupture, blunt violence, AMI, aortic dissection, CPR, hemopericardium

Posted Date: February 27th, 2023

DOI: https://doi.org/10.21203/rs.3.rs-2581119/v1

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Abstract

Objective

In this study, the hemopericardium volume and pathological characteristics associated with cardiac ruptures caused by blunt violence, AMI, aortic dissection and CPR have been analyzed. The findings might provide reference and data support for deciphering the cause of heart rupture in forensic pathology.

Method

Pericardial water-injection tests were conducted in 22 noncardiac death subjects. Other study groups included 9 cases of myocardial infarction, 20 cases of aortic dissection rupture, 11 cases of cardiac rupture caused by trauma and 4 cases of cardiac rupture by CPR. The volume of hemopericardium and the pathological features were analyzed for each group.

Result

The hemopericardium volume in myocardial infarction and dissecting aneurysm rupture were significantly higher than the pericardial injection test in noncardiac subjects (p-value < 0.01). The traumatic cardiac rupture cases had a large range in hemopericardium volume and no significant difference was observed with respect to non-cardiac death cases (p-value > 0.05). The volume of hemopericardium in CPR-induced cardiac rupture had no difference with non-cardiac rupture and it was significantly lower than the pericardial injection test (p-value < 0.01).

Conclusion

Differences in the volume of hemopericardium induced by different causes of cardiac rupture were observed. It may be related to the state of the cardiac systolic functions during an event of a rupture. The volume of hemopericardium can be used as reference data to determine the mechanism of the rupture. This could also be beneficial in cases of cardiac rupture with similar morphological and pathological features such as severe blunt chest injury and CPR.

Highlights

1. Survival time may be one of the significant factors of hemopericardium volume.
2. Different volume of hemopericardium in cardiac rupture events is related to pumping functions.
3. Cardiac rupture caused by CPR is usually with less hemopericardium.
4. In blunt violence cases, the volume of hemopericardium is in a large span.
1. Background

Death because of cardiac rupture occurs through acute circulatory failure. It is induced by a rapid entry of blood into the pericardial cavity leading to a pericardial tamponade limiting the return of blood to the heart and the pumping function of the heart is suppressed. In forensic pathology, trauma, heart diseases, and CPR are considered as the main factors behind cardiac rupture. The traumatic cardiac rupture is of two types, first one occurs due to direct force from sharp objects or firearms making the damage and rupture of the heart through the thoracic wall. In this case usually, the morphological characteristics of the wound can provide a basis for judgment. The second type occurs due to a severe blunt force in the chest leading to complications such as arrhythmias, myocardial rupture, myocardial infarction, followed by valvular or papillary rupture, pericardium or coronary artery lacerations(1-4). This is more common during traffic accidents or falling(5). Blunt traumatic rupture of the heart has a very high mortality rate(6, 7). The heart lacerations may involve the right and left atria or ventricles, the atrial septum, the interventricular septum, the intrapericardial portion of the superior or inferior vena cava, the pulmonary veins, the atrioventricular valves, and their chordae tendineae or contusion of the conduction system. Autopsy studies had demonstrated that the right ventricle is most frequently ruptured, followed by the left ventricle, right atrium, intraventricular septum, left atrium and intra-atrial septum(8, 9). The cardiac and great vessels lesions are very rare during the CPR(10). Chest compressions could also lead to complications such as a rib or sternal fractures. Further, insufficient skills or preexisting myocardial damage might also cause cardiac rupture(11, 12).

The heart rupture caused by cardiac diseases mainly involves AMI. Research has shown that the most common rupture site during AMI is the left ventricular free wall, followed by the ventricular septum, papillary muscle (13, 14). Factors distinguishing the cardiac rupture cases from non-rupture cases during acute myocardial infarction (from autopsy studies) include coronary arterial narrowing by a plaque, left ventricular scars, size of the acute infarct and subepicardial adipose tissue(14, 15).

Distinguishing between heart ruptures caused by trauma, heart disease or CPR, especially when they occurred simultaneously or successively is a difficult task. Also, minimum data focusing on the comparison of the heart rupture caused by the above-mentioned methods are available. In the present study, we have analyzed the pathological characteristics and the variation in the hemopericardium volume in cardiac rupture associated with different causes. Findings of the study can serve a valuable reference source for distinguishing the type of heart injury.

2. Material And Methods

In the present study, all experimental protocols were approved by Medical Ethics committee of Nanfang Hospital of Southern Medical University (Guangzhou, China). All autopsy procedures were conducted according to public safety industry standard of the People's Republic of China: Forensic Autopsy GA/T 147–1996 with the informed consent obtained from the deceased's family.
2.1 Cases

A total of sixty-six cases were accrued in this study. All cases were from autopsy cases conducted by the Forensic Science Center of Southern Medical University. This included 9 patients with cardiac rupture induced by myocardial infarction and 11 patients by blunt violence on the chest, respectively. Four patients had cardiac rupture via CPR, 20 had aortic dissection rupture and 22 deaths not due to cardiac rupture (the causes of death not involve the heart). Age, gender, heart weight, the volume of hemopericardium, pathological findings and postmortem intervals were recorded. Autopsy and material evaluation were carried out by experienced forensic pathologists in our center.

2.2 Pericardial infusion test

Twenty-two (22) noncardiac rupture death subjects (Male/Female = 13/9) without any history of heart disease were analyzed to measure the potential volume of the pericardial space. The process of pericardial infusion test was as following:

Step 1: Make a 2cm incision in the pericardium at the root of the aorta,

Step 2: Draw out the pericardial effusion with a 50ml syringe.

Step 3: In the absence of external pressure, inject water through the incision into the pericardial cavity until the water flows out from the incision. Record the volume of water injection.

Step 4: The average value of three repeated measurements was calculated for analysis.

2.3 Statistical analysis

The volume of hemopericardium in different cases was analyzed. The statistics also included age, gender, and heart weight. Data were presented as mean ± SD. A value of $p \leq 0.05$ was considered statistically significant. One-way ANOVA was used for comparisons across different groups.

3. Results

3.1 Variation in hemopericardium volume

A total of 66 subjects were analyzed. This included death cases with noncardiac rupture (22), myocardial infarction (9), aortic dissection rupture (20), blunt chest injuries (11), and CPR-induced cardiac rupture (4). Heart weight and volume of the hemopericardium were analyzed. Findings suggest that the hemopericardium volume in 9 cases of heart rupture caused by AMI and 20 cases of acute dissecting aneurysm rupture were significantly higher than maximum volume obtained from pericardial injection test ($p$-value < 0.01). Even though effusion volume in cardiac rupture cases caused by blunt chest injury...
had a large variation it was not statistically significantly different from the pericardial injection test (p-value > 0.05). CPR induced cardiac rupture had a significantly lower volume of hemopericardium than the pericardial injection test (p-value < 0.01), Table 1, Fig. 1.

Table 1
Volume of pericardial effusion and weights of hearts in different causes of death

<table>
<thead>
<tr>
<th>Cause of Death</th>
<th>AMI</th>
<th>Trauma</th>
<th>CPR</th>
<th>AD</th>
<th>Non-Cardiac Rupture</th>
<th>Pericardial Infusion Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (M/F)</td>
<td>5/4</td>
<td>10/1</td>
<td>3/1</td>
<td>19/1</td>
<td>13/9</td>
<td>13/9</td>
</tr>
<tr>
<td>Age (y)</td>
<td>59.0 ± 9.3</td>
<td>38.6 ± 12.8</td>
<td>62.3 ± 22.4</td>
<td>41.8 ± 10.3</td>
<td>33 ± 13.5</td>
<td>33 ± 13.5</td>
</tr>
<tr>
<td>Weight of Heart (g)</td>
<td>392.8 ± 31.4</td>
<td>304.6 ± 70.6</td>
<td>382.5 ± 43.5</td>
<td>456.9 ± 126.7</td>
<td>271.9 ± 63.6</td>
<td>271.9 ± 63.6</td>
</tr>
<tr>
<td>Pericardial Effusion (ml)</td>
<td>380.0 ± 144.4</td>
<td>183.0 ± 112.8</td>
<td>41.3 ± 30.1</td>
<td>556.5 ± 238.2</td>
<td>3.6 ± 2.9</td>
<td>145.3 ± 33.0</td>
</tr>
</tbody>
</table>

AMI = acute myocardial infarction CPR = cardiopulmonary resuscitation AD = aortic dissection

3.2 Cardiac rupture caused by a blunt chest injury

Eleven blunt chest injury-induced death cases had traffic accident (n = 7) and falling injury (n = 3) and unknown cause (n = 1).

Four cases had sternal fractures (36.4%), 8 had rib fractures (72.7%), 5 had pericardial rupture (45.5). Four (36.4%) cases had rupture spots located in the right atrial appendage. Three (27.2%) cases were located in the right anterior ventricular wall. (see Table 2).
### Table 2
Cardiac rupture caused by blunt violence in chest

<table>
<thead>
<tr>
<th>No.</th>
<th>Gender</th>
<th>Age (y)</th>
<th>Cause of Injury</th>
<th>Sternal Fracture</th>
<th>Rib Fracture(s)</th>
<th>Hemopericardium (ml)</th>
<th>Rupture Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>43</td>
<td>T.A.</td>
<td>Yes</td>
<td>Yes</td>
<td>160</td>
<td>RAA</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>49</td>
<td>T.A.</td>
<td>Yes</td>
<td>Yes</td>
<td>250</td>
<td>RAA</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>58</td>
<td>T.A.</td>
<td>No</td>
<td>Yes</td>
<td>250</td>
<td>LAVW*</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>50</td>
<td>T.A.</td>
<td>No</td>
<td>Yes</td>
<td>135</td>
<td>Ventricular septum</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>30</td>
<td>T.A.</td>
<td>No</td>
<td>No</td>
<td>170</td>
<td>RAVW*</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>53</td>
<td>T.A.</td>
<td>No</td>
<td>Yes</td>
<td>150</td>
<td>Auricular dextra</td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td>18</td>
<td>T.A.</td>
<td>Yes</td>
<td>No</td>
<td>300</td>
<td>RAVW</td>
</tr>
<tr>
<td>8</td>
<td>M</td>
<td>25</td>
<td>Falling</td>
<td>No</td>
<td>Yes</td>
<td>220</td>
<td>Multiple</td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>30</td>
<td>Falling</td>
<td>No</td>
<td>Yes</td>
<td>5</td>
<td>LAA</td>
</tr>
<tr>
<td>10</td>
<td>M</td>
<td>37</td>
<td>Falling</td>
<td>Yes</td>
<td>Yes</td>
<td>3</td>
<td>RAA</td>
</tr>
<tr>
<td>11</td>
<td>M</td>
<td>32</td>
<td>Others</td>
<td>No</td>
<td>No</td>
<td>370</td>
<td>RAVW</td>
</tr>
</tbody>
</table>

T.A. = traffic accident, LAVW = left anterior ventricular wall, RAVW = right anterior ventricular wall RAA = right atrial appendage LAA = left atrial appendage

Pathological findings suggest adipose tissue bleeding, myocardium eosinophilic staining and contraction bands necrosis around the ruptured areas.

### 3.3 Cardiac ruptures caused by AMI

Nine cases of ventricular wall rupture caused by myocardial infarction were consist of 5 males and 4 female subjects with an average age of 59 years (50–65 year).

Pathological changes such as cardiac hypertrophy and arteriolar thickenings in multiple organs (brain, lung, spleen, and kidney), transmural infarction, blood in the pericardial cavity accompanied by clots were observed. The ruptures transfix the ventricle walls from the epicardium to the endocardium with ambient myocardial necrosis, inflammatory cell infiltration, mural thrombus as well as pulmonary congestion and edema. Seven cases (87.5%) had coronary atherosclerosis with stenosis (grade to ). One subject had heart rupture after valve replacement. The cardiac rupture was localized to the left ventricular walls among all subjects. Specifically, 5 cases had rupture in the left ventricular anterior wall, 2 in the posterior wall of the left ventricle, and 1 at the left ventricular lateral wall, Table 3.
Table 3
Cardiac rupture caused by AMI

<table>
<thead>
<tr>
<th>No.</th>
<th>Gender</th>
<th>Age</th>
<th>Sternum/Rib Fracture</th>
<th>Rupture Site</th>
<th>Hemopericardium (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>65</td>
<td>Yes</td>
<td>PLV</td>
<td>350</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>57</td>
<td>Yes</td>
<td>LLVW</td>
<td>180</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>50</td>
<td>No</td>
<td>LAVW</td>
<td>320</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>65</td>
<td>No</td>
<td>LAVW</td>
<td>550</td>
</tr>
<tr>
<td>5</td>
<td>F</td>
<td>57</td>
<td>No</td>
<td>LAVW</td>
<td>430</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>51</td>
<td>No</td>
<td>LAVW</td>
<td>600</td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td>51</td>
<td>No</td>
<td>PLV</td>
<td>480</td>
</tr>
<tr>
<td>8</td>
<td>M</td>
<td>79</td>
<td>Yes</td>
<td>PLV</td>
<td>230</td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>56</td>
<td>Yes</td>
<td>PLV</td>
<td>280</td>
</tr>
</tbody>
</table>

PLV = posterior left ventricle, LLVW = left lateral ventricular wall, LAVW = left anterior ventricular wall

3.4 Cardiac rupture caused by CPR

All 4 cases of cardiac rupture caused by CPR had sternal and/or rib fractures. Among these, 3 subjects had coronary artery disease or hypertension. The longitudinal ruptures transfixed the right ventricle anterior wall about 2 cm into the cardiac apex with the intact pericardium. There was less effusion in the pericardial cavity. Ambient myocardial rupture and scattered eosinophilic staining were observed without bleeding, necrosis or fibrosis (Table 4).

Table 4
Cardiac rupture caused by CPR

<table>
<thead>
<tr>
<th>No.</th>
<th>Gender</th>
<th>Age (y)</th>
<th>Sternum/Rib Fracture</th>
<th>Rupture Site</th>
<th>Hemopericardium (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>89</td>
<td>Yes</td>
<td>RAVW</td>
<td>50</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>35</td>
<td>Yes</td>
<td>RAVW</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>58</td>
<td>Yes</td>
<td>RAVW</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>67</td>
<td>Yes</td>
<td>RAVW</td>
<td>80</td>
</tr>
</tbody>
</table>

RAVW = right anterior ventricular wall
4. Discussion

Pericardial effusion is the pathological accumulation of fluid in the pericardial cavity, which may compress heart chambers causing hemodynamic impairment (15). A large amount of hemopericardium can cause acute cardiac tamponade where the accumulation of fluid suppresses the heart function (16). However, in our practical experience, we have noticed variations in the hemopericardium level associated with different causes of heart rupture. In the present study, we compared the volume of hemopericardium in different cardiac rupture death cases caused by AMI, blunt chest injury, aortic dissection (Stanford A) and CPR. The pericardial perfusion test was performed in noncardiac death cases to have an estimate of the maximum postmortem pericardial volume. The statistical analysis suggested that the volume of hemopericardium in cardiac ruptures linked with myocardial infarction and aortic dissection were significantly higher than pericardial perfusion test. No statistically significant difference in the volume of hemopericardium between cardiac rupture caused by CPR and in non-cardiac rupture death was observed. The findings implied that the differences in the hemopericardium during cardiac rupture might be related to cardiac systolic-diastolic functions. In contrast to the rupture caused by AMI or aortic dissection, in CPR the heart usually has impaired pumping functions and therefore the blood flow from the cardiac to the pericardial cavity is minimized. More hemopericardium was seen in MI and aortic dissection deaths since these patients had systemic pressure forcing blood into the pericardial sac. CPR patients were nearly or completely dead, so had no blood pressure. Trauma death victims almost always had other severe or fatal injuries and thus their survival time would have been limited compared to AMI or aortic dissection patients. In our study, the volume of hemopericardium in blunt chest injury has relatively large variation (3ml to 370 ml). which is consistent with the above explanation. In other words, in traumatic death, there is a potential correlation between survival time and the volume of hemopericardium. The low volume associated with CPR and some blunt force trauma cases indicates lack of tamponade and thus not significant in causing death. If low volume due to CPR overlaps with some blunt force cases, we should consider a rapidly fatal lesion elsewhere in the body to account for the lack of bleeding into the pericardium from an antemortem heart rupture.

Cardiac rupture is the most fatal complication of AMI with a fatality rate of around 80%: the blood flows into the pericardium after the rupture leading to a pericardial tamponade(17). Myocardial necrosis depresses the cardiac pumping function. In aortic dissection rupture, if the ruptured aneurysm is located at the root of the aorta the contraction of the myocardium forces a large amount of blood into the pericardial cavity(18, 19). In contrast to AMI, the cardiac pumping function is relatively normal at the beginning of acute aortic dissection rupture. These statements seem to explain that the volume of hemopericardium in aortic dissection rupture was significantly higher than in AMI. The pumping function of the heart is potentially related to the volume of hemopericardium: the reduction of pumping function caused by partial myocardial necrosis could be responsible for the difference between AMI and aortic dissection.

Although investigating on the volume of hemopericardium cannot be used as a direct basis for the identification of the cause of death, it can be a corroborating evidence and supplement to the existing evidence.
Abbreviations

AMI=acute myocardial infarction  CPR= cardiopulmonary resuscitation

Declarations

Conflict of interest

The authors declare that they have no conflict of interest.

Data availability

All data generated or analysed during this study are included in this published article

References


**Figures**
Figure 1

Volume of hemopericardium in different causes of death and pericardial infusion test. The hemopericardium volume in myocardial infarction and dissecting aneurysm rupture were significantly higher than the pericardial injection test in noncardiac subjects (p-value<0.01). The traumatic cardiac rupture cases had a large range in hemopericardium volume and no significant difference was observed with respect to non-cardiac death cases (p-value>0.05).