Case Review

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Delayed Cardiac Rupture Induced by Traumatic Myocardial Infarction: Consequence of a 45-Magnum Blast Injury; A Comprehensive Case Review

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ABSTRACT

A penetrating chest trauma, a myocardial contusion or a myocardial infarction can lead to a cardiac rupture, which is linked to an extreme high death rate. Only few cases with delayed perforation of the myocardium have been reported in literature. We report about a penetrating gunshot injury, which led to a myocardial contusion with secondary delayed rupture of the left ventricle and the left inferior lobe of the lung. The leakage of the lesion in the left ventricle could be sealed sufficiently with fibrin-coated collagen fleeces after adapting stitches with Prolene 2-0. For additional stabilization of the vulnerable myocardium area, a bovine patch has been placed on the damaged ventricle. Fibrin fleeces are used successfully in cardiac surgery, as in our case, to seal the leakage of the lesion in the left ventricle. The implantation of a bovine patch in the pericardium could prevent a cardiac compartment syndrome with a fatal pericardial tamponade. To prohibit a thoracic compartment syndrome a modified Bogota bag could be sewed in for temporarily closure of the chest. In most cases penetrating cardiac injuries can be treated without heart-lung-machines. An immediate transfer to a cardio-surgical center is, due to the acute situation, not possible. If a surgeon with thoraco-surgical expertise is present a transfer is not absolutely necessary,

Keywords: Shotgun; Myocardial infarction; Delayed cardiac rupture; Damage control; Thoracic compartment syndrome.

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Introduction

A penetrating chest trauma, a myocardial contusion or a myocardial infarction can lead to a cardiac rupture, which is linked to an extreme high death rate [1-4]. We report about an extremely rare case of a delayed cardiac rupture with additionally rupture of several segments of the left lung in consequence of a blast injury from a penetrating gunshot wound of a large-caliber gun (Magnum 45; v=370 m/s). Normally an immediate hit from a bullet with such high kinetic energy (E=1228 Joule) would have led to a complete cardiac rupture with immediate exitus letalis. Most of the patients with blunt and penetrating cardiac trauma die at the accident site [3]. The "Janus-faced" pericardial tamponade requires immediate action to

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prevent a cardiac-output-syndrome [5-8]. There have been reported only a handful of cases with delayed perforation of the myocardium in literature [2,4,9-15] (Table 1).

Case Report

A 49-year-old man shot himself with a 45-magnum-revolver into the anterior chest wall in order to commit suicide. He was brought to our hospital by a friend in his private car. Anamnestic the patient was member of the gun club and suffers from depression. In the clinical examination a 2 cm entry wound below the left mammilla, as well as a 1 cm exit wound on the left back, was found (Figure 1). The patient was fully oriented (Glasgow Coma Scale=15), suffered from moderate pain, was hemodynamically stable and showed no signs of a tension pneumothorax. The sonography of the abdomen (FAST) showed no significant disease. The essential laboratory parameters were within normal limits. After fluid resuscitation a CT scan of the chest was made under the strong suspicion of the left lung being injured. The CT scan showed emphysema of the lateral chest wall, a fracture of the 10th rib with fragments of the bullet, as well as a hemothorax with a massive bleeding of the lung parenchyma starting from the lingula and the left inferior lobe (Figure 2). Due to the progressive instability of the vital signs the patient was immediately transferred to the operating room for an emergency antero-lateral thoracotomy in the 5th intercostal space. Because of the severe injury of the lingula and the left inferior lobe, the pleural cavity was filled with fresh blood (>1000 ml) and blood clots. The bleeding was quickly controlled by placing hemostatic forceps. The bulging, but extrinsically intact, pericardium was immediately opened by a longitudinal incision parallel to the phrenic nerve. After the incision, light red blood drained explosively. After that no active bleeding could be detected temporarily. A 3-cm contusion lesion with a small bleeding perforation (3-4 mm) in the left ventricle (dorsal of the ramus interventricularis anterior of the left coronary artery) was suspicious. Suddenly, distinct ST- elevations appeared and shortly afterwards the rupture of the contusion lesion followed.

Initially, the intraventricular defect was only manageable through the insertion of two fingers. In order to reduce the excessive tachycardia (>150/min) and to facilitate the suture conditions, 24 mg of adenosine were applied intravenously. Because the cardiac frequency did not decelerate, the heart was additionally cooled by iced water. No visible effect was shown either. Only with the help of a Fogarty catheter, blocked with saline solution, which was inserted into the defect, the perforation could be occluded temporarily (Figure 3). Multiple non-absorbable sutures sheathed with Teflon plates (Prolene 2-0) were pre-applied on

Table 1. Reported cases of Delayed Cardiac Rupture

Author	Journal and Year of publication	Diagnosis postmortem	Successful repair
Lassus J et al.	Injury, 2001	-	+
Vohra HA et al.	J Cardiothorac Surg, 2006	-	+
Pooniya S et al.	Med Sci Law. 2016	+	-
Pollak S et al.	Forensic Med Pathol, 1991	+	-
Kanchan T et al.	J Forensic Leg Med, 2012	+	-
Ueda S et al.	Gen Thorac Cardiovasc Surg, 2011	-	+
Tomioka Y et al.	Nihon Kyukyu Igakukai Zasshi, 2014	-	+
Eisenman A et al.	Eur J Trauma, 2006	-	+
Greene CF et al.	Ann Thorac Surg, 2016	-	+
Total	9	3	6

Fig. 1. Patient with 2 cm entry wound below the left mammilla.

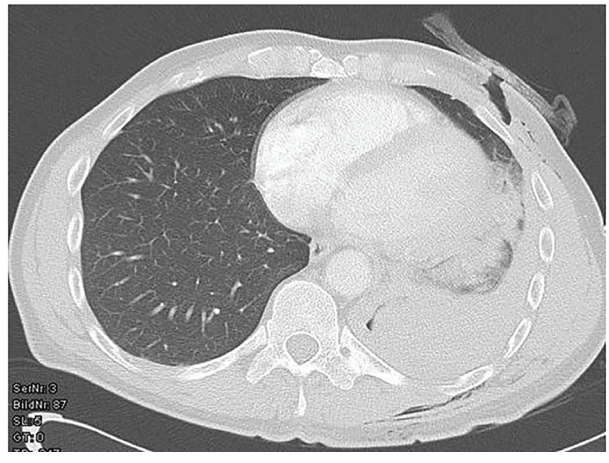

Fig. 2. CT scan: emphysema of the lateral chest wall, fracture of the 10th rib with fragments of the bullet, hemothorax.

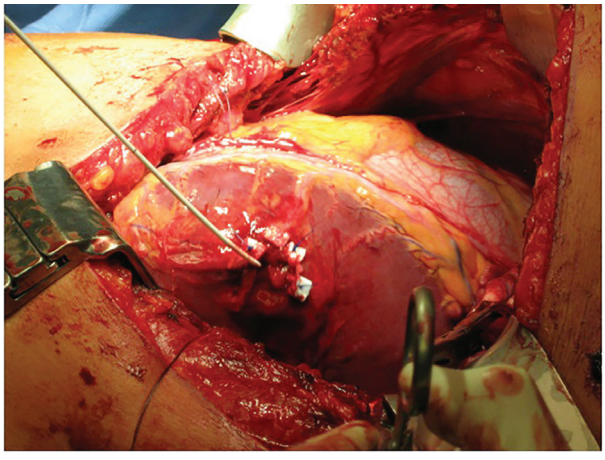

Fig. 3. Inserted blocked Fogarty catheter.

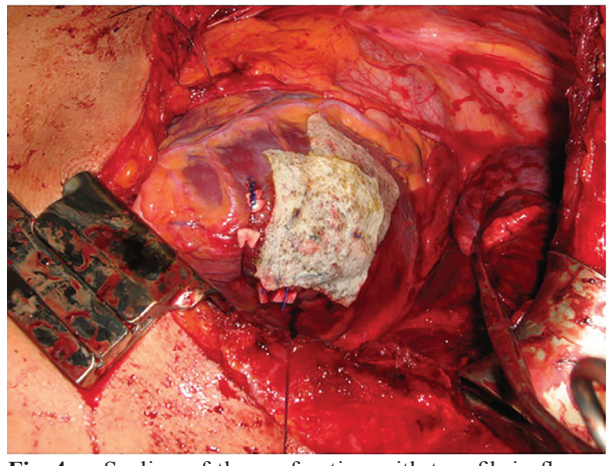

Fig. 4. Sealing of the perforation with two fibrin fleeces (Tachosil®).

the wound and pulled tight after the extraction of the forgaty catheter. Because of the ischemic myocardium the stitches could only be adapted. Therefore blood was still seeping into the area of the stitch canals and the perforation fissure. The leakage was sealed sufficiently with two fibrin fleeces (Figure 4). For additional stabilization of the vulnerable myocardium a bovine patch was placed (Tutomesh®) (Figure 5).

Because of an obvious edema of the myocardium, a primary occlusion of the pericardium could not be reached. That is why a second bovine patch was placed on the pericardial margins to prevent an iatrogen pericardial tamponade (Tutomesh®) (Figure 5). The destroyed inferior left lobes (8 and 9) and the ruptured lingula were extracted by wedge resection with the linear cutter. A sagittal penetrating gunshot wound in the inferior lobe was treated by tractotomy with the help of the linear cutter. At this time the patient showed the "lethal triad" [clinical signs of coagulopathy, acidosis (pH=7.2) and hypothermia (34.5°C)].

The thoracic cavity was packed with abdominal swabs. When a primary closure of the chest was performed, the patient reacted with dropping blood pressure and an increase of the ventilation parameters. Because of this thoracic compartment syndrome an ordinary operating polythene sheet (modified "Bogota bag") was sewed into skin (Figure 6). Therefore the lung was enabled to expand itself. Before closing the polythene sheet, a 28 Charrière thoracic drainage (without suction) was placed as an overflow valve. Intraoperative a transesophageal echocardiography was performed in order to exclude intracardial lesions. After blood transfusion and further volume loading the patient was transferred hemodynamically stable to the Intensive Care Unit. After 24 hours and a correction of the acid-base equilibrium and normothermia, the reoperation was performed with extraction of the tamponade under blood-dry conditions. In addition, a necrotic area in segment 10 (2 cm) had to be extracted atypically. After placing a second drainage, the chest could be closed easily. However, the healing process was complicated by a hypercapnic respiratory insufficiency. The patient was in need of an extracorporeal elimination of CO^2 with ILA ("interventional lung assist"). Three weeks later the patient was able to be weaned off the respirator. Later he was discharged into psychiatric care. Two years later the patient is fully restored.

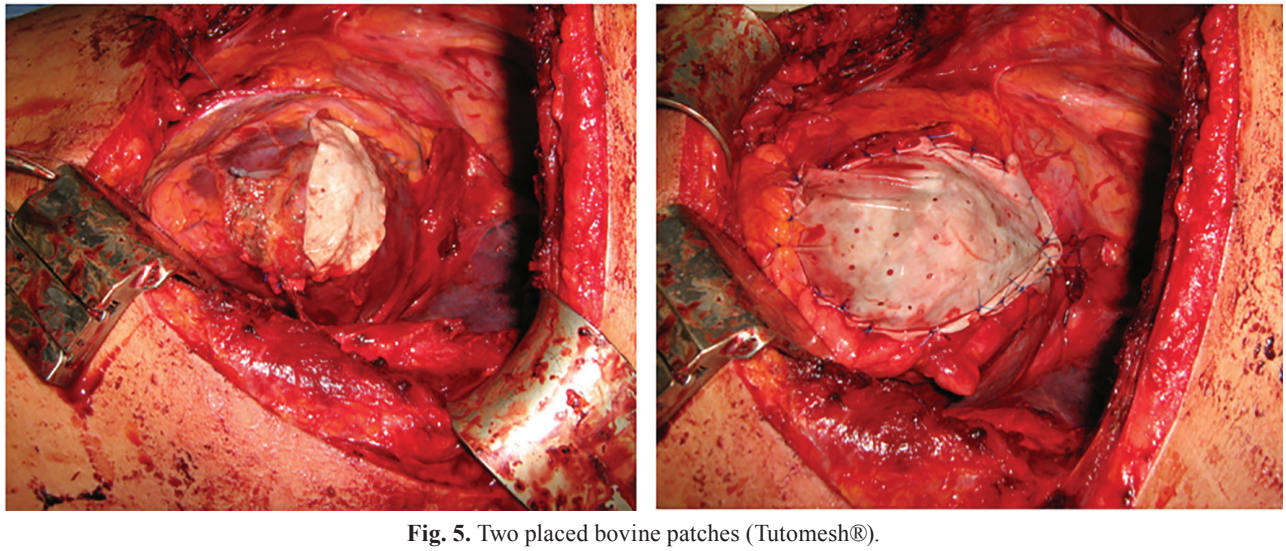

Fig. 5. Two placed bovine patches (Tutomesh®).

Fig. 6. Polythene sheet to prevent thoracic compartement syndrome

Discussion

Literature Review

Pooniva et al. reported about a two-year-old child who was hit by a car. There were no external injuries present over the body except two small abrasions on the occipital region of head. He was discharged from the hospital apparently well without pathological findings. The child was absolutely asymptomatic for a week, after which he suddenly died while playing at home. Autopsy revealed left ventricular free wall rupture and pericardial hematoma [9]. Pollak *et al*. described a case of a 7-year-old boy who fell from a 2.5-m height and suffered contusion of the thorax with hematoma in the soft tissues of the lateral chest wall. On day 8 after the trauma, the child suddenly died during school lesson. Autopsy revealed a full-thickness rupture of the left ventricle with resultant cardiac tamponade [10]. Kanchan *et al*. referred about a case of delayed cardiac rupture in an elderly person who sustained blunt chest trauma following a fall into a roadside ditch. The patient deteriorated suddenly due to a delayed rupture of the right ventricle that was diagnosed postmortem [11].

There have been reported successfully repair of delayed cardiac rupture either:

Vohra reported about a left ventricular free wall rupture after myocardial infarction. A sutureless technique with Gelatine-Resorcin-Formalin glue and bovine pericardial patches has been described [4]. Lassus *et al*. reported also about a case of myocardial contusion as a cause of delayed cardiac rupture [2]. Ueda *et al*. reported about a case of blunt chest trauma. The cardiac rupture occurred 74 days after the trauma. A coin-sized pericardial defect and cardiac rupture on the left ventricle was found to be close to a fractured rib, which was thought to have induced the myocardial degeneration. The cardiac rupture did induce hemothorax, which could be successfully treated [12]. Tomioka et al. described also effective repair in a case of a fall from a 1.5-m high fence. In this case, there was no pericardial effusion on admission. A 10-mm rupture to the left ventricle was discovered, which was repaired by inserting felt strips and pledgeted mattress sutures, thus restoring hemostasis. The authors believe that although the fractured rib caused the hemorrhage, it did not penetrate the pericardium; but as it was in contact with the heart for a long period, it led to a delayed cardiac rupture [13]. Eisenman et al. reported about an unusual case who sought medical help one month after having been stabbed in his chest. An investigation revealed a perforation of the myocardium and a pericardial tamponade. The patient survived thanks to a large organized clot that plugged the perforation [14]. Greene *et al*. reported about a female patient who was found to have an enlarging pericardial effusion 10 days after a 40-foot fall. Ten days after presentation she developed hemodynamic compromise and chest computed tomography was concerning for cardiac rupture. The patient survived thanks to surgery [15].

In our case the bullet fortunately struck a rib. As a result, the energy potential was reduced significantly and the bullet was diverted from the heart. The bullet-determined blast-injury probably led to a small myocardial lesion with an emission of blood into the pericardial sac and in consequence to a pericardial tamponade. The perforation was occluded through the muscle tonus of the left ventricle and a blood clot [14,16,17]. The contusion led to an interrupted blood circulation and to a necrosis of the affected myocardial area. The following transmural infarction caused the delayed free rupture [2,18-20].

Emergency Diagnostics

The most important examination concerning penetrating chest traumata is the transthoracic echocardiography. The detection of haematoma indicates surgery. Any time delay triggers a cardiac arrest. Patients with cardiovascular activity have better chances to survive because every reanimation squeezes out larger amounts of blood due to compression. If the patient reaches the hospital alive the pericardial tamponade is almost always or at least temporarily the life-saving component. Later the filling of the ventricle compromises and the cardiac output fails. Due to that an immediate intervention after detection of pericardial haematoma is important. In our lucky case the rupture of the left ventricle appeared after the pericardial tamponade. We think, the enormous pressure wave (E=1228 Joule) triggered the myocardial ischemia which provoked the infarction of the left ventricle and consecutive the rupture. If there is no noticeable finding or only a small pericardial haematoma by a hemodynamically stable patient a CT scan of thorax and abdomen must be performed. The abdominal CT scan is necessary to detect ricochets or bone fragments due to ricochets. Suspicious changes in the ECG (ST-elevations) appeared relatively late - just before perforation [18,20]. In general, indicating changes in the ECG are rarely utilizable as early

warning signs [2, 21-23].

Emergency Surgery

To prevent bleeding to death, major cardiac and pulmonary bleeding requires damage-control-measures in an acute situation [24,25]. A leakage in the ventricular wall was initially occluded digitally - also to get an overview of the injury patterns. Blind sewing-over (without safe sight!) can lead to an extension of the defect or to an accidental closure of a coronary artery. In two of our other cases with penetrating cardiac trauma, the heart could be shut down with a bolus- injection of adenosine to achieve a safe primary closure [26,27]. In our current case the injection of adenosine did not lead to the desired reaction. In special cardiac injury patterns the bolus-injection of adenosine is a therapeutic option [26-29]. Alternatively, a Forgaty- or a Foley-catheter can be placed for temporary defect occlusion [30-34].

The perforation is sewed over with non-absorbable stitches sheathed with Teflon plates (Prolene 2-0, 3-0) [3,29,31]. The stitches should only be adapted, as they could cause a cut-through-phenomenon [4,18,19,35-37] in the ischemic area of the myocardium. Moreover, blood was seeping into the area of the stitch canals and the perforation fissure, which could lead to another pericardial tamponade, especially in cases of coagulation diseases [18,38,39]. With the help of fibrin-coated collagen fleeces the leakage was sealed sufficiently. To ensure a better hold, the fibrin fleece should be placed over the margin of the infarction zone. Fibrin fleeces are used successfully in cardiac surgeries [18,19,36,38-42].

For additional stabilization of the vulnerable myocardium area, a bovine patch was placed (Tutomesh®) on the damaged ventricle, which should also prevent the formation of a pseudoaneurysm [4,18,35,37,40,43]. Because of the migration of fibroblasts into the patch and the angioneogenesis the patch was replaced through a collagen tissue. Ischemia, disseminated intravascular coagulation and hypothermia (lethal triad) could cause a myocardial edema or rather a dilatation of the ventricle [30,44-47]. Due to this a primary closure of the pericardium is impossible. An iatrogenic tamponade would lead to a fatal decrease of cardiac output [30,47-50]. The implantation of a bovine patch [51,52] could prevent the cardiac compartment syndrome. The ischemia of the pulmonary structures [48], especially the non-cardiac swelling of the lung [49], could lead to low blood pressure [44-47,50] and an increase of the ventilation parameters when the chest is closed initially. Leaving the pericardium open is equally dangerous, as it could lead to a potentially life-threatening cardiac herniation [53-55].

The thoracic compartment syndrome can be prevented through an open-chest-procedure [44-46,50,56,57]. A modified "Bogota bag" [48,58] (ordinary polythene sheet sewed into skin) could extend the ventral expansion volume of the lung. That is why the pleural cavity can be packed generously in case of a blood leakage without provoking a compression of the lung or the big vessels [58]. This "packing" is an essential and vital damage-control-procedure [30,46,50,56,57,59-65].

Collateral Lung Injuries

In case of collateral lung injury, the bleeding has to be controlled first, for example through disconnecting the lung hilum [30,31,64,66] or through a so called pulmonary twist [67]. This procedure reduces the risk of an air embolism [30,31,66-68]. However, the risk of a right heart failure [48,66] has to be taken into account, in case of central disconnection. Therefore only the traumatic damaged pulmonary segments should be disconnected specifically. Because of the direct correlation with the lethality rate the dimension of pulmonary resection should be strictly limited [25,50,57,66,69,70]. Sagittal perforations are provided by a so called " Tractotomy", which means the perforation canal is opened by a linear cutter to sew selectively opened bronchial tubes and blood vessels [25,30,57,69,70]. Sewing over the entry- and exit wound has to be avoided. An intrapulmonal hematoma could extend and lead to a secondary pulmonary rupture. Also an air embolism can occur caused by a fistula between bronchial tubes and pulmonary vessels [30]. After surgical treatment of potentially life-threatening injuries, the postoperative admission to an intensive care unit for up to two days is urgent to correct the acid-base-balance, the coagulopathy and for efficient temperature raising to a normal range [25,44,64].

Further Measures

To exclude intracardial lesions (perimembranous interventricular septum anomaly, heart valve vitium), and to decide about a secondary transfer in a cardio-surgical centre [71], a transthoracic or transesophageal echocardiography should be performed [3,19,28,45,51]. When insufficient oxygenation or hypercapnic respiratory insufficiency is detected, early extracorporeal oxygenation procedures, like ECMO (extracorporeal membrane oxygenation) or ILA (intervential lung assist) should be performed [60,72]. Usually after 24 to 48 hours a re-operation is performed. Then the tamponades can be extracted and the chest can be closed after placing a large-lumen drainage [4,29,30,36,44,46,50,51].

Conclusions

In most cases penetrating cardiac injuries can be treated without heart-lung-machines. The patients who do not undergo surgery with extracorporeal circulation have a better prognosis as no systemically heparinisation is required. Furthermore, an immediate transfer to a cardio-surgical centre is not possible due to the acute situation (pericardial

tamponade). Moreover, a transfer is not absolutely necessary, if a surgeon with thoracosurgical (expert knowledge) expertise is present. The factor of time is also very important, because the initially live-saving tamponade (occlusion of the perforation with clots) finally leads to a rapid decrease in heart-beat volume. In case of a penetrating (pericardial) chest injury the sonographic detection of intracardial hematoma is enough for indication for immediate thoracotomy. In this constellation a CT-scan is not necessary and may even be dangerous, because of the decompensation of circulation, which can appear within a matter of seconds. Like in our case, the attending physicians should not be mistaken by the obvious good vital signs, the existing consciousness and the missing tamponade signs.

Conflicts of Interest: None declared.

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