Cardiac rupture during cardio-pulmonary resuscitation
Case presentation and literature data

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Abstract: Cardio-pulmonary resuscitation (CPR) is, without doubt, a life-saving procedure which proved its efficiency many times. However, CPR even correctly performed may determine iatrogenic injuries which by themselves may endanger the patient's health or life. In this paper the authors present a case in which a traumatized patient sustained a prolonged CPR of about 105 minutes. The prolongation of CPR was at least in part motivated by the pressure from the members of the patient's family who witnessed the CPR. The post-mortem examination of the body revealed, besides the traumatic injuries, important cardiac injuries due to the CPR. The authors analyze this case in the context of the literature data emphasizing the possible detrimental effects of the family members witnessing CPR and the need for resuscitation duration and technique to be established based on the patient's medical condition.

Key Words: CPR, cardiac rupture, technique, duration, family.

Cardio-pulmonary resuscitation by external cardiac massage (ECM) proved its efficiency and its crucial importance many times, since its beginnings the technique being gradually improved. In cardiac arrest situations it is important to restore the blood flow to the heart and brain [1], and to provide an adequate blood circulation during the circulatory standstill [2]. Even minimum blood quantities at the level of these organs, together with mouth-to-mouth ventilation could be enough in the first minutes after collapse [3]. However, being itself a trauma to the body [4], the chest compressions – whether they are performed by trained medical personnel or by bystanders, in hospital or outside of it – can cause injuries, starting from the most simple and mild to serious or even fatal, the latter being though very rarely encountered. General incidence of the resuscitation-related injuries vary between 21 and more than 65% [3, 5, 6] and, despite the quasi-permanent improvement of the techniques and the special attention paid to their application, post-resuscitation injuries cannot be completely avoided [1, 3, 7].

CPR complications are often encountered during the medico-legal postmortem examination [6, 8] and they may raise difficult issues concerning their potential contribution to death [6, 9]. There are situations when the forensic pathologist has to differentiate them based on their etiology [9], regarding both pathologic features with similar morphology [9] or other type of trauma, such as accidents or assaults- for instance in many situations the etiology of the fractures of the thoracic cage needs to be carefully assessed in this respect [6]. In some circumstances, in the survivors a post-resuscitation injury can go unnoticed, leading to impairment of the patient's health or, worse, to his/her death [5], this being also a reason for clinical procedures to involve the systematic searching for CPR-related injuries in successfully resuscitated patients [10]. Finally, CPR can generate unusual lesions which must be recognized by the forensic...
pathologist in order to avoid their misinterpretation [1]. More, the patients suffering from thoracic trauma have an increased risk in worsening the lesions produced by chest compressions and an increased mortality rate due to these injuries [3].

Ribs and sternal fractures are the most frequent internal thoracic injuries produced during CPR [1, 4, 6, 8, 11, 12]. Cardio-vascular injuries are some of the most severe complications of this medical procedure [1] and comprise a multitude of clinical entities, such as: hemopericardium, epicardial hematoma, myocardial contusion, hemorrhages and injuries of large vessels, such as rupture of the vena cava close to its junction with the right atrium [1, 13] and myocardial rupture [3, 11], the latter being also the rarest [1, 8, 11, 14].

In this paper the authors present a case of cardiac rupture during the resuscitation procedures and analyze it in the context of the current literature data.

**CASE PRESENTATION**

A 47 years old male, with no relevant past medical history, was admitted in the emergency room after being stabbed with a knife in his left hemithorax and hit with a brick in the left side of his forehead during a conflict with a neighbor. Upon arrival in the emergency unit vital parameters recorded the following values: GCS=15, respiratory rate=20/min, heart rate=109/min, systolic arterial pressure=180 mmHg. Clinical examination showed the two wounds, thoracic and frontal respectively, bulging of the left hemithorax, bone crepitus at that level, tachycardia, tachypnea and a diminished vesicular murmur on the left side. Laboratory analyses performed immediately upon arrival in the emergency unit showed anemia (suggested by the low number of erythrocytes, low hemoglobin and hematocrit).

Cardio-thoracic surgeon performed a minimal pleurotomy on the left side followed by evacuation of one liter of air and 1500 mL blood, 700 mL of which were auto-transfused. With a steady hemodynamic status in the beginning, shortly after the patient went into cardiac arrest and the medical personnel started the CPR maneuvers, which were continued also during the CT examination of the thorax which revealed the following lesions: hemothorax, pneumothorax, soft tissues emphysema, ribs and sternal fractures, laceration of the lower pulmonary lobe on the left side and hemopericardium. During the CT examination the patient was clouded, agitated, with bradypnea and bradycardia. He was given repeated doses of Adrenaline and Dopamine each 3-5 minutes. Vigorous ECM was continued unsuccessfully for about 105 minutes, but the absence of the central pulse and recording of asystolia on the monitor, unresponsive to resuscitation maneuvers led to their end and pronouncement of death.

As mentioned in the medical file the members of the patient’s family were present throughout the CPR and they insisted for the continuation of the procedure despite the lack of any improvement in the patient’s condition.

The cause of death established in the hospital was “Multiple contusions. Stabbed wound on the left scapular region measuring about 2 cm. Superficial laceration on the frontal region. Acute closed head trauma. 105 minutes resuscitated cardiac arrest. Left hemotherax.”

A medico-legal autopsy was performed 24 hours later. External examination of the body revealed the following: pale pink lividities, parchment abrasion of about 6/2 cm in the middle part of the sternum, frontal laceration of about 3.5/1.5 cm, left subcapular stabbed wound measuring about 2/0.5 cm through which liquid blood was purging out, and subcutaneous emphysema on the left hemithorax. Internal examination of the head showed no traumatic findings. The internal examination of the thorax revealed the canal of the stabbed wound with an oblique orientation downwards to the right side, passing through the thoracic wall, transfixing the left inferior pulmonary lobe to the vertebral insertion of the 9th rib, with a total length of about 16 cm. Thoracic cage examination revealed furthermore multiple rib fractures as follows: on the left side, fractures of the 2nd to 5th ribs on the medial clavicle line, 3rd rib on the parasternal line and 3rd to 5th ribs on the medial scapular line; on the right side, fractures of the 2nd and 3rd ribs on the medial clavicle line, 4th rib on the parasternal line, 7th to 9th ribs on the medial axillary line and the 3rd rib on the medial scapular line. Also a transverse fracture on the sternal body was identified between the 3rd and 4th segments. The examination of the heart showed the following injuries: pericardial rupture on the anterior side, hematoma in the pericardial anterior and lateral walls; hemopericardium of about 150 mL of liquid blood mixed with blood clots; at the level of the right ventricle, on its anterior, basal and lateral septal side, all along its thickness, a rupture with irregular margins, measuring 4/2 cm circa at the epicardial surface and 1/1 cm circa at the endocardial surface. It was concluded that death was determined by the external and internal hemorrhage due to the stabbed thoracic wound, penetrating and transfixing the left inferior pulmonary lobe. This conclusion was motivated by the important blood loss due to the thoracic stabbed wound (1500 mL of blood were evacuated by left pleurotomy) which caused cardiac arrest and required the initiation of the CPR.

In this case, given the seriousness of the lesions and the cardio-pulmonary arrest, CPR maneuvers had been performed with a high intensity, for a long time, even during the CT examination, in order to maintain an adequate blood flow to the heart and brain. The pressure by the members of the patient’s family also contributed to the prolongation of the CPR. The prolonged CPR maneuvers resulted in sternal and multiple ribs fractures and pericardial and cardiac lacerations.
CARDIAC RUPTURE DURING CPR

Cardiac rupture following chest compressions during CPR is a rare but serious injury [11], being reported only few cases worldwide [8, 12, 14, 15]. The cardiac rupture may be the result of either an open or a close mechanism.

The close mechanism, produced in the absence of ribs or sternal fractures, is attributed on the one hand to the hydrostatic effect as a result of increased pressure [16] by applying compressions over an incompressible fluid [1], blood being trapped in the right ventricle, in case of obstruction of the outflow tract and a closed tricuspid valve by the pressure applied [16]. Ruptures are more frequent in the areas where the wall is thinner, such as the right atrium and right ventricle. Hence, right ventricle wall rupture emerges when the pressure inside the right heart is elevated (e.g. when cardiac blood outflow is obstructed by a pulmonary thromboembolism or when compressed pulmonary valves impede blood flow during cardiac massage [6]) or as a consequence of a technical deficiency- such as placing the hands above the recommended level with the consequent closure of the tricuspid valve by pressure [1, 6, 11, 16]. Massive bilateral pulmonary embolism may be a cause for cardiac rupture during chest compression by reducing the pulmonary arteries caliper, hence interfering with the blood flow from the right ventricle [11, 14]. Added to this is the increased pressure by the blood accumulating in the pericardial sac [8, 14], which compresses and fastens the heart, hence focusing the mechanical trauma at its basal region [14]. This is also the case when, failing the ribs or sternal fractures, the pericardium could tear, by its nature being otherwise resistant to chest compressions; but when the pressure inside the pericardial sac is increased by blood accumulation, the additional pressure by ECM leads to its creeping and rupture [8]. On the other hand, when blood shortage occurs in the cardiac ventricles (i.e. in the absence of high pressure inside the heart), heart might get strongly compressed between the thoracic anterior wall and vertebral column, causing its rupture [6].

The open mechanism involves fractured bones piercing or tearing the pericardial sac and subsequent myocardium [12]. The action of the fractured bone tips is considered as the causal mechanism especially when the lesion depiction is very extensive, involving the pericardium and the heart (atriums and/or ventricles) but also the great vessels emerging from its base [14]. After the first fractures occurred, continued chest compressions lead to fractured bone ends movement inward, injuring all they meet on the trail: heart, pleura, lungs or vessels, leading to further injuries [12] and their consequences – massive, life-threatening blood/air accumulation inside the cavities [5, 7]. According to Krischer, post-resuscitation injuries coupled with myocardial contusions seem to have a worst prognosis compared to those without accompanying myocardial injuries since they lead to hypertension, arrhythmia, hypoxia etc. [17].

Risk factors for the cardiac rupture during CPR are partly common to the resuscitation-induced injuries in general and partly peculiar to this complication. Preexisting heart pathology, such as atherosclerotic calcifications [1] or myocardial infarction [18] decreases heart resistance to pressure both by myocardial weakening given by a previous infarction in the patient medical history [18] and by facilitating outflow obstruction in stenosis or rupture of the vessels already embritted by atherosclerosis. Other risk factors that significantly contribute to the occurrence of cardiac complications are the large number of rib fractures [4] by increasing the risk directly proportional and prolonged resuscitation. Respiratory pathology deforming the thorax (e.g. barrel-shaped thorax) favors the occurrence of rib fractures by decreasing thoracic cage resistance during chest compressions. Old age is another risk factor both in the light of thoracic elasticity loss [4] and unsuccessful resuscitation which increases proportionally [5].

The above-mentioned risk factors are interconnected with determinative causes. Mainly, excessive pressure, incorrect anatomic placement of the resuscitation effort [4, 13] compression between the sternum and vertebral column and trauma produced by fractured bones [11] are the main causes leading to complications. The force needed for the correct placement of these manoeuvres is influenced by two factors: thoracic cage anatomy and the intensity of the chest compressions [13]. Technical deficiency by wrong hands placement means in this case, as mentioned above, hands placement higher than recommended, contributing to right ventricle outflow obstruction and closing tricuspid valve by pressure [11].

In our case, we appreciated that heart and pericardial injuries occurred by a direct/open mechanism by fractured sternum fragments, fracture focus being adjacent to myocardial and pericardial laceration area. Severe revealed injuries were the repercussion of the prolonged CPR, in particular, most probably improper conditions, generated by continuous chest compressions while performing CT examination. During the autopsy we did not identify any preexisting pathological factors that could favor the occurrence of the severe cardio-pericardial injuries.

**Ethical and psychological issues related to the family presence during resuscitation procedures**

As we showed above the members of the patient's family were present throughout the CPR and they insisted for the continuation of the chest compressions.

Currently the opportunity of the presence of family members during CPR is the subject of an ongoing debate. Some studies revealed the psychological effects of
being present during a CPR and the short-term and long-term impact on grief among the family members.

A study conducted by Jabre et al. in order to evaluate the psychological consequences for family members who were given the opportunity to assist during the CPR of a relative, compared with those not usually offered the option proved that one year after the event, there are a lot of psychological benefits for family members who witnessed the CPR of a relative [19]. Many researches proved that benefits are developed on long-term, especially when it is about children undergoing CPR. Studies reported lower level of anxiety and depression among family members who assisted CPR being provided to their relatives.

The opinions sustaining the utility of the presence of the family members during CPR mention also the patient's right for autonomy and his/her right to have the family's support in order to pass through difficult situations. Also, some families want to have an active role in end-of-life decision-making. However, the preference for the presence of the family members during CPR varies across cultures and is influenced by social and religious factors, believes about death, ethnicity etc.

For instance, studies show that Roma culture is characterized by solidarity so that a life-threatening condition to one individual is perceived as a common harm for the others and engages the whole group which forms a support network for the dying [20]. Fulfilling family role obligations are very important [21] and the family gathering when a member of the community is ill represents one of the strongest values in the Roma culture. More the family assumes a position of ascendance over individual interests. Based on this belief some of the Roma consider that the decision to withdraw the life support from an unconscious Roma patient belongs solely to the family. However, the medical team performing CPR should be guided solely by the patient's medical condition to one individual is perceived as a common harm for the others and engages the whole group which forms a support network for the dying [20].

The presence of the family members during CPR may have a negative impact to the activity of the medical team because the relatives may interfere with the health professional's efforts or they could have difficulty in facing trauma that usually occurs during CPR. On the other hand the medical team might be obliged to take care for the relatives who act or feel strange or even collapse [28, 29].

The most frequent behaviours identified in the witnesses of CPR performed on a relative are: communicating with the health-care-team (67%), being in tears (33%), asking for explanation (30%), being frozen (29%) and touching the patient (13%) [30].

However, due to the positive effects on the family members' emotional health, existing policies are encouraging the presence of relatives during these critical events. Such policies should also include staff education and specific protocols [31].

Currently, there are no clear prognostic criteria for the CPR. However, in the hospital the physician in charge with the case is the only one who can take the decision to stop the CPR according to the patient's condition, circumstances of the cardiac arrest and prognosis factors for resuscitation such as: time till the initiation of the CPR, time till defibrillation, co-morbidities, the condition before the cardiac arrest etc. The duration of CPR is acknowledged as the most important factor associated with unfavourable evolution of this procedure in the sense that the probability of neurological damages increases directly proportional with the duration of CPR. Studies showed that the CPR can be withdrawn after 30 minutes of advanced cardiac life support if the spontaneous circulation cannot be restored [32].

CONCLUSIONS

Correct CPR implementation in terms of both topography and compression force, could lead to decreased, if not complete avoidance of its complications. The utility of the ECM resides in the application of the smallest force in the right place and the smallest excursion required in order to provide palpable pulsations in the carotid, femoral or brachial arteries accompanied by decrease in pupillary dilation associated with the cardiac asystole [13].

Even though during CPR physician must always grant priority to life-threatening condition, in some situations resuscitation procedures imply massive manipulations presenting a high risk of injuring the patient, risk that physicians should be aware of, in order to avoid an additional danger to the patient [5]. In cases as the one discussed in this paper the iatrogenic injuries following the CPR may be as severe as the initial injury itself, adding significantly to the gravity of the life-threatening situation which imposed the initiation of CPR.

In this case the patient sustained prolonged CPR which was, at least in part, motivated by the pressure of the family. However, the medical team performing CPR should be guided solely by the patient's medical condition so that the iatrogenic injuries produced by prolonged and vigorous CPR are avoided.

Conflict of interest. The authors declare that they have no conflict of interest concerning this article.
References