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CHARLES UNIVERSITY IN PRAGUE,
FACULTY OF PHYSICAL EDUCATION AND SPORT,
DEPARTMENT OF ANATOMY AND BIOMECHANICS

# THE CARDIAC RUPTURE DUE TO THE BLUNT CHEST TRAUMA AND THE CAUSING MECHANISMS – PHYSICAL ATTACK CASE STUDY

ONDŘEJ FANTA, DANIEL HADRABA, PETR KUBOVÝ, KAREL JELEN

## SUMMARY

Biomechanical analysis of injuries to the area of the thorax caused by a sudden impact of a blunt object is a world-wide accepted topic, which is mainly related to passive car safety features, prevention of industrial injuries, and physical assaults. This case study discusses the biomechanical aspects of an incident in which a 32 year-old man, 180 cm, and 76 kg was beaten to death. Cardiopulmonary resuscitation (CPR) was unsuccessfully applied for 20 minutes after the rescuers arrival. Cardiac tamponade due to a rupture of the left atria auricle was listed as the cause of death.

The potential origins of the caused damage are elaborated in detail and compared with an extensive critical review, video analysis of the attack, and the autopsy report. After interpreting all the aforementioned information, an experimental observation was executed to specify physical values of the critical attack on the thorax, respectively, determine the force exerted on the thorax by a powerful stamp. The Kistler measuring device was used to identify the force of a stamp during the experimental part.

The under-mentioned findings are applicable to all sorts of activities where a blunt chest injury trauma may occur as the injury mechanisms for physical assault, and occupational or leisure activities (sport, transport, etc.) are almost identical.

**Key words:** aorta, biomechanics, chest injury, Kistler, trauma, heart, rupture, blunt.

## INTRODUCTION

Thoracic trauma is a frequent cause of reduced mobility and according to Aghabadian (2005) it is considered as a primary cause of death (25% cases), and furthermore a secondary cause of death (another 25–50%).

Considering the fact of the complexity and importance of the thoracic organs, thoracic injuries are classified as injuries which represent a direct danger to vital functions. A wide range of classifications and categories exist and are defined such as open vs. blunt, inner vs. outer, etc.

On the occasion of an international conference (Asian Intensive Care – Chest Injuries, 2009) a new scale of classification was adopted and published, hence traumatic mechanisms of thoracic injuries are divided into several groups (blunt injuries, crush injuries, penetrating injuries, inhalation burns, aspiration of foreign bodies).

According to the above mentioned injuries, the blunt trauma is the most frequent followed by penetrating injuries (Shnyder, 2000).

Firstly, blunt trauma arises when an object directly impacts on a chest and causes a massive deformation of the thorax, e.g. car accidents, falls from height, sport injuries, physical assaults, or as stated by Black, Busuttil, and Robertson (2004) a result of enormous cardiopulmonary resuscitation (CPR). Secondly, blunt injuries are also caused by deceleration of thorax, when due to relative differences between moments of inertia a rupture or more serious damage of inner organs may occur (Besson, 1983). The level of severity and extent of injuries is mainly determined by properties of an impacting object, thorax, and ambient conditions. As Bronzino & Peterson (2011) pointed out, the key aspects influencing a collision are a profile, stiffness, mass density and weight of the colliding objects as well as acceleration, its orientation, and the features of contact areas of colliding objects. According to the viscoelastic characteristics of the thorax, it is evident that the pectoral wall is able to cope with substantial forces.

Blunt chest trauma is typically caused in three main directions: anteroposterior, lateral, and transdiaphragmatic. Due to the function and anatomical organization of the organs in the thorax, the most serious injuries happen in the areas of a heart, aorta, lungs and ribs depending on the direction and location of the impact.

Anteroposterior deformities of the heart are mainly caused by its relative movement forward. The aorta is strained under shear stress due to deceleration of the outer structures and a consequential rupture can appear distal from ligamentum arteriosum (Williams, 1994). On the other hand deceleration as a result of back falls rarely leads to serious interthoracic injuries.

Lateral compression of the thorax affects mainly the lower parts of ribs (fracture, multiple fractures) more over, the liver, spleen, and kidneys are jeopardized. Although the probability of extensive harm inside the thorax is reasonably minimal when a lateral force, compression is applied, contusions and lacerated wounds may follow (lung parenchyma).

## The mechanism of the injuries and its results

- ***Traumatic rupture of aorta***

Horizontal deceleration concentrates shifting forces by the aortic isthmus which is situated between the fairly flexible aortic arch and the fixed descending part of aorta. As Banning and Pillai (1997), Schmitt (2004) noted, the aforementioned region is the most common place of aortic injuries. Vertical deceleration causes a displacement of the heart and the ascending elements of the aorta caudally into the left pleural cavity. These parts are simultaneously fixed with ligamentary and venous components, thus the descending part of the aorta or even the aortic arch can be ruptured (Howells, 1998).

The mechanisms of the aortic injuries:

a) Rapid deceleration (acceleration) – the heart is situated relatively loosely in the chest cavity. Despite the fact that the heart moves quite freely, the descending part of the

aorta is adhered to the thoracic structures, thus a rupture may occur when shear stress is presented. The chance of trauma is much higher during strong deceleration
b) Direct contact – applying great pressure against the thorax in anteroposterior direction causes compression of the aorta and resulting ruptures.
c) Excess pressure in the aorta – it is usually caused by increasing pressure on the lower extremities, the abdominal area, and the zone of the thorax.

The above mentioned information appears to be supported by Mlčoch (2008), who states that the most common location of aortic injuries is just in the boundary of the aortic arch and the descending aorta, right where the subclavian artery springs. On the one hand the relatively free and moveable features in the area of the aortic arch, but on the other hand the firm spinal connections of the thoracic aorta are recognized as the main reason of the aortic injuries, therefore, in this place a sectional or total rupture of the aorta appears after thoracic trauma. The acute traumatic aortic transection is problematic to diagnose due to polytrauma of other organs (fractures of upper extremities, head injuries, abdominal and thoracic injuries, etc.) The main symptoms after blunt thoracic injuries are acute chest pain, varieties of shock conditions, and signs of internal haemorrhage eventually. As blood flow in the aorta is interrupted ischemia affects the lower part of the body and sometimes it leads to paraplegia.

Brohi (2007) also notes that most of the impacts generate blunt aortic trauma in the area of the proximal part of the thorax, furthermore the proximal part of the descending aorta, where the relatively loose aortic arch moves against the firmly attached descending aorta (ligamentum arteriousm), is highly in danger due to deceleration forces acting on the inner organs, however, all parts of the aorta are under serious threat.

The danger of a rupture of the aorta dramatically increases in lateral impacts and falls from height. The other common mechanisms of the aortic injuries involve compression of the heart between the sternum and the spine and/or a rapid increase of intra-aortic pressure at the moment of impact. The most destructive direction of the impact for aortic injuries seems to be anteroposterior deceleration, as mentioned above, however Katyal et al. (1997) proved in their study that impact in lateral direction is also a frequent cause of an aortic rupture. It was published that 97 patients (81 registered with coroner database and 16 with traumatic unit) suffered permanent ruptures of thoracic aorta. The forty-eight cases (49.5%) were caused by lateral impact (22 drivers were injured by impact into the driver's side and 6 by contralateral impact) and the aortic ruptures appeared in 91 cases (94%) in peri-isthmic region.

The physical – numerical parameters of thoracic injuries were obtained, analysed, and processed by the technique of Finite Element Method (FEM) (Siegel, Belwadi, Smith, Shah, and Yang, 2010). The dynamic computer simulation shows increased stress in the aortic isthmus. It was published on the basis of the simulations that the aortic pressure increased from 100 mm/Hg pre-crash to over 1322 mm/Hg, i.e. thirteen times. The maximum stress diagnosed at the aortic isthmus was between 1.1 MPa and 3.2 MPa.

Viano (1983) presented the results of lateral crash tests (1610) in which no damage was caused to the aorta. Moreover, a new series of test were executed and the aorta was torn as the force reached 10 000 N. In addition, Chung (1999) tested lateral impact (velocity 20 km/h) on six objects and discovered that there was no damage to the aorta. The tested force in this experiment was from 3200 to 3800 N.

- ***Rib trauma***

Isolated rib injuries are not critical and no medical intervention is necessary to cure the injury. On the other hand complication may arrive due to multiple fractures Schmitt (2004). Compound fractures may damage the inner, outer pleura – pneumothorax, collapse of lungs, or infection.

According to Wanek and Mayberry (2004), the most vulnerable region on the thorax is located sixty degrees from the sternum. In this area, the ribs are narrowed and the muscles provide poor support, thus lateral impact on the thorax frequently causes a double rib fracture. When more ribs are broken, a medical condition named flail chest induce extensive respiratory problems. Porzionato (2004) assumes that a one rib fracture is mostly caused by impact in the sagittal plane. On the contrary, a multiple rib fracture is caused by impact in the coronal plane. The fracture usually happens at the point of maximum curvature or at the point of the force application and it is strongly affected by the shape of the impacting object.

In most cases the fourth to ninth rib(s) are broken (a fracture of the first – second rib(s) is commonly accompanied by the injury of great blood vessels and a fracture of the ninth to twelfth rib(s) often leads to the injury of the spleen, liver, and kidneys) (Sirmali, 2003). The essential information on rib fractures, thoracic structure in the view of an impacting object are carefully analysed in the under mentioned studies (Parreira et al., 2010; Pieter, 1995; Porzionato, 2004; Serina & Lieu, 1991; Viano, 2011).

A complex paper was publish by Viano (2011), eleven unembalmed cadavers (body weight 61.8 ± 11.9 kg, height 166.6 ± 15.6 cm) were hit (impacting speed 8.6–14.9 m/s) by the impacting object (24–34 kg) and the impact force was measured (9.65 ± 2.45 kN). The impact caused a large deformation, compression (52.8 ± 5.4%) of the thorax and the accelerations at the spine were measured (.5 ± 105.4 g – T1, 141.3 ± 80.5 g – T8 a 89.3 ± 39.1 g – T12). The impact led to a multiple rib fracture and serious thoracic trauma – AIS 4.2 ± 1.0 (maximum AIS 6). A rupture of the aorta was reported in four cases and a transection of the ascending aorta 20 mm form cusp of the aortic valve was diagnosed. This sort of aortic trauma would have caused death within an hour. The compression of the heart and the following hydrodynamic effect produce increased pressure within the aorta which may cause a rupture of the cardiac vessels, cardiac muscle. The hydrodynamic pressure inside the aorta provides only 20–30 % of stress which is needed for an aortic rupture.

Considering the objectives of this paper, it is highly relevant to mention the physical values and details of kicks, punches into the thoracic region. Pieter (1995) found that the highest speed was achieved while executing a round kick, and the greatest impact force while performing a spinning back kick. The results and the variance of the values showed that the applied force significantly vary from the mean (up to 25%). The absolute speed of the kicks among the women and men is displayed in Table 1. There was found to be no statistical significance between the body weight and the measured kick speed ($p < .05$).

**Table 1.** Mean values (± SD) of speed (m/s) in selected taekwondo techniques

| | MEN | | WOMEN | |
|---|---|---|---|---|
| | **Right (n = 5)** | **Left (n = 6)** | **Right (n = 8)** | **Left (n = 8)** |
| SIDE KICK | 6.87 ± 0.43 | 6.32 ± 1.54 | 6.00 ± 1.81 | 5.2 ± 0.60 |
| ROUND KICK | 15.51 ± 2.27 | 16.26 ± 1.32 | 13.79 ± 1.56* | 12.84 ± 2.52 |
| SPINNING BACK KICK | 9.14 ± 1.49 | 8.73 ± 1.72 | 7.47 ± 0.95 | 6.71 ± 0.86 |
| REVERSE PUNCH | 11.38 ± 3.68 | 10.05 ± 0.79 | 8.97 ± 1.46 | 8.41 ± 0.62 |

* n = 7

The impact force was measured in different taekwondo techniques and is displayed in Table 2.

**Table 2.** Mean values (± SD) of force (N) in selected taekwondo techniques

| | MEN | | WOMEN | |
|---|---|---|---|---|
| | **Right (n = 5)** | **Left (n = 6)** | **Right (n = 8)** | **Left (n = 8)** |
| SIDE KICK | 461.8 ± 100.7 | 456.7 ± 94.8 | 408.4 ± 66.4 | 390.7 ± 47.6 |
| ROUND KICK | 518.7 ± 96.3 | 510.5 ± 96.3 | 406.6 ± 89.5* | 404.1 ± 78.4 |
| SPINNING BACK KICK | 606.9 ± 94.6 | 661.9 ± 52.7 | 584.2 ± 91.0 | 500.9 ± 96.9 |
| REVERSE PUNCH | 560.5 ± 139.2 | 457.4 ± 113.1 | 391.7 ± 56.4 | 341.8 ± 44.9 |

* n = 7

Serina and Lieu (1991) also analyzed taekwondo kicks while using high-speed film cameras. In this paper were performed two types of kicks. A speed reached in the swing kick was 15 m/s and the calculated energy 200 J. On the other hand, a speed in the thrust kick was about 45% lower but the calculated energy for 28% higher.

Several case studies handle the problem of physical assault and only insufficient numbers of related articles have been published. For example, Porzionato (2004) issued a case study that analyses a beating of an eighty-year-old woman. The woman suffered bilateral fractures of the second to eighth ribs (bilateral hemothorax), and several cardiac ruptures (the cause of death). It was said that the heart injuries were probably caused by direct impacts into the thorax, the heart compression in terms of bidirectional forces, deceleration, rapid rotation with the fixation of the great blood vessels, or the transfer of hydrodynamic pressure in the vessels and the subsequent compression of the abdomen and the peripheries of the body.

- ***The rupture of myocardium***

A wide range of heart injuries, including the cardiac contusion or a rupture might be caused by an object impacting the thorax, especially in the area of the sternum, and the related compression. It was reported that the speed of 15–20 m/s negatively affects the electromechanical cardiac signal transduction through the heart wall. According to Porzionato (2004), blunt chest trauma may cause injuries of the great vessels, the heart –

including the pericardium, the coronary arteries, the valves as well as disorders of cardiac rhythm and conductivity, furthermore, a massive CRP is sometimes reason for a cardiac rupture.

The frequency of ruptures diminishes from the right ventricle, the left ventricle, then the right atrium, and left atrium. In case of extensive impact, the roof of the atria and/or the apex of the heart are damaged. If the cardiac ruptures are caused by increasing hydrostatic pressure in ventricles (usually not in contact with the damaged tissue) the orientation of the ruptures is from inside out from the endocardium at the end of diastole. The atriums are more vulnerable during the systole when the amount of the returned blood reaches maximum. The atrium rupture is more probable among individuals with a pliable thorax (children, women) together with rib fractures (increased the mobility of the thorax). A heart injury caused by a broken rib(s) can be easily excluded in reference to the anatomical position of the rib(s) and the injury. The atrium injuries mainly occur under the compression between the sternum and the spine. In addition, ruptures are not located at the frontal surface of the ventricles but at the area of the atriums that are closer to the spine and are often involved in the bilateral pressure mechanism.

It was detected that 90% of cardiac ruptures are caused by car accidents Nan (2009). In addition, it was confirmed that the most possible mechanism for a cardiac rupture is the precordial compression when the heart is squeezed between the sternum and the spine. As mentioned above, the effect of compression is the most destructive when the heart is full of blood and maximally distended (the end of diastole). The other possible mechanism of heart injuries includes the exposition to rapid deceleration with a resulting rupture at the area of the atrium and its connection to the vena cava, pulmonary veins. The location of a rupture was mostly situated in the superior vena cava (36.4%, 4 cases), the left ventricle (36.4%, 4 cases), and the right atrium auricle (1 case). Fulda et al. (1991) localized the ruptures mostly in the right atrium, and then the right ventricle, and after that the left atrium, and the right ventricle. Alternative studies show that the most common is a cardiac rupture to the right ventricle followed by the left ventricle, the right atrium, the intraventricular septum, the left atrium, and the intra-atrial septum. Banning and Pillai (1997) reported the contusion of the cardiac ventricles in 20 cases due to blunt chest trauma, moroever, the contusion right behind the sternum is more frequent. The example of a traumatic myocardial rupture in a car accident was published by Degiannis (2001). The rupture resulted from acute deceleration, and forceful anteroposterior compression. A one-centimetre wound at the right atria auricle was found and 200 ml of blood was drained from the pericardium.

In almost all diagnosed cases, it is crucial to reveal the suffered injury promptly. The first sign of the blunt chest injury, in case of no evident trauma (pneumothorax, hemothorax, brain injuries, etc.), is usually hypotension (abnormally low blood pressure). Cardiac ruptures are associated with a high rate of mortality as the pericardium plays the function of a sack that accumulates the out-flowing blood (the pericardial tamponade). In a case study by Plooy (2008) is analysed a physical attack on a man which resulted in 300 ml of clotted blood in the man's pericardium. More about heart injuries caused by blunt chest trauma can be found in older publications, for instance, in the paper of Parmley (1958).

## MATERIAL AND METHODS

- ***Video analysis***

The aforementioned physical attack happened in a fully video-monitored room. The available tapes were closely analysed and each impact (kick, punch, etc.) was listed and associated with a possible injury. The whole physical attack lasted for four minutes and thirty-two seconds but the most important period regarding the intensity continued for one minute and twenty-eight seconds. The victim seemed to be apathetic and did not defend himself. On the other hand the aggressor was taught in martial arts.

- ***Autopsy repost***

The autopsy report was critically studied and the revealed injures were analytically bound with the impact during the attack.

- ***Stamp reconstruction using the dynamic force platform – Kistler***

On the one hand an overview of current studies provides useful information about impact properties of kicks and punches, but on the other hand physical properties of a stamp hasn't been fully detected. According to this case study, the force exerted on the thorax while doing a stamp is essential, therefore a simple pre-experiment was designed and conducted in the laboratory of the extreme loading at the department of Anatomy and Biomechanics, Faculty of Sport and Physical Education, Charles University.

The 3D dynamic force platform Kistler was used to conduct the experiment. The platform was placed 20 cm above to surface to imitate the thickness of the average male thorax. The participants (n = 3) were all males, age 32 (±3) years, body weight 75 (±5) kg, body height 180 (±5) cm. The participants had a dominant right leg which had been demanded due to the case study. The participants were asked to stamp on the platform as forcefully as possible with the dominant leg during the period of 20 seconds. The vectors of force in the vertical direction (Z axis) and the horizontal direction (forward – X axis) were scanned, and the measured vector components of force were expressed as vector product.

Although the stamping patterns or certain techniques were not prescript, the supporting leg (the left leg) had to stay in contact with the surface throughout the experiment (see the stamp in the video analyse) and the stamping leg moved up, and then down towards the platform Kistler. Five, six stamps were recorded for the each participant and evaluated.

## RESULTS

- ***Confrontation between the video analysis and the autopsy report***

Firstly, the victim sat on a sofa, wearing a hood, was hit five times (left and right hooks and downward elbow strike). The hits were performed in the transversal plane and the arms were stretched up to 90° from the medial plane. Then the victim lay down on the right side, still wearing a hood on the head. The second set of three hits is directed into the head (left hook, left elbow) and the ribs (right hook). After that the victim sat back on the sofa and hid the face into the hands, suddenly the third set of two hits (right forearm, right elbow) is aimed into the nape of the neck. According to the autopsy report, the aforementioned hits caused multiple scratches a centimeter in diameter and related bruises especially at the forehead and suborbital area, an abrasion on the nose (0.3 × 0.1 cm) and an abrasion behind the right earlobe. The skeletal segments of the skull were unchanged, however, a light sign of bleeding in the area of the nostrils was examined, and both valval – orbital conjunctiva were bloodshot. The soft tissue of the head was undamaged and the temporal muscles did not showed a sign of bleeding. The brain weighed 1680 g, the brain grooves disappeared, the tissue was saturated with oedema fluid. Furthermore, both the pericellular and the perivascular oedema were found. In addition to the first phase of the attack, a neck injury was reported (a bruise 5 × 1 cm).

Secondly, the victim was caught in a headlock, forced to stand, rotated for 180° around the vertical axis and thrown on the floor. During the direct fall the body parts hit the floor in this order: the buttock, the lower back, the right side of the thorax at the same time with the right arm, and then the head (without the rebound from the solid floor). The victim lay on the floor still (on the back, bent legs and with the arms on the floor close to the body). The aggressor was approaching and while moving performed a powerful stamp on the victim's thorax (the aggressor's supporting leg never left the floor). The autopsy report listed that there was no pulpable damage on the thorax or chest. However, multiple scratches and bruises in the area of the thorax – above the ala ossis illi, the buttocks, and in the posterior inter-thoracic region. The internal injuries contained partially cracked ribs on the right side (the 7.–9. ribs). The signs of bleeding were detected under the right part of the pleura. The centre of the contusion (7 × 4 × 1.5 cm) was located at the top of the posterior lobe. The heart was analysed and a presence of bleeding found on the anterior side of the pericardium sack (10 × 6 cm). The pericardium was highly stretched and after the slitting, 500 ml of partially gore flowed out. At the top of the left atria auricle was discovered a rupture (0.8 cm) penetrating into the left atria auricle cavity – this injury was marked as the cause of death. Another superficial rupture was found in the upper part of the liver. A significant number of small scratches, bruises were localized on the upper and lower extremities. The victim moved into the half-sitting position on the left hip, touching the ground with the left hand. At that moment the victim received a low kick into the left part of the head (it was impossible to match the kick whit a specific injury – it had to be one of the mentioned above). A little while after these two attacks (the stamp and kick) the signs of life were almost zero. It was again manipulated with the victim and the body was removed from the room after 20 minutes and one second after the start of the attack.

- ***Stamping on the dynamic force platform Kistler***

The first participant generated maximum force of 10002 N. The lowest measured value of force was 4985 N and the mean value 7044 N. The second participant generated maximal force of 10665 N, minimum force of 5325 N, and the mean value 7700 N. The third participant generated maximum force of 7775 N, minimum force of 4038 N, and the mean value 5808 N. The mean value of maximum force for all the participants was 9481N and the mean value of all the measured values was 6851 N.

**Table 3.** The values measured in the camping experiment

| Force (N) | Stamp 1 | | Stamp 2 | | Stamp 3 | | Stamp 4 | | Stamp 5 | | Stamp 6 | | MAX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Z-axes | Z-axes | X-axes | Z-axes | X-axes | Z-axes | X-axes | Z-axes | X-axes | Z-axes | X-axes | Z-axes | |
| Participant 1 | 1 641 | 4 707 | 2 818 | 9 597 | 2 212 | 5 419 | 2 557 | 5 942 | 1 169 | 7 825 | | | |
| V. product | | **4 985** | | **10 002** | | **5 853** | | **6 469** | | **7 912** | | | **10 002** |
| Participant 2 | 2 477 | 6 368 | 2 276 | 7 780 | 3 183 | 8 281 | 3 201 | 5 544 | 1 554 | 5 094 | 1 513 | 10 557 | |
| V. product | | **6 833** | | **8 106** | | **8 872** | | **6 402** | | **5 325** | | **10 665** | **10 665** |
| Participant 3 | 1 430 | 5 824 | 907 | 6 841 | 647 | 5 481 | 557 | 4 000 | 233 | 4 612 | 648 | 7 748 | |
| V. product | | **5 997** | | **6 901** | | **5 519** | | **4 038** | | **4 618** | | **7 775** | **7 775** |

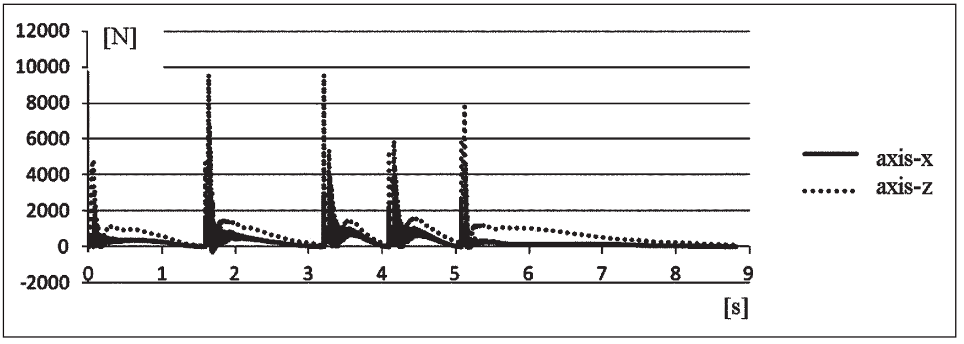


**Figure 1.** Participant 1 stamps – generated force.

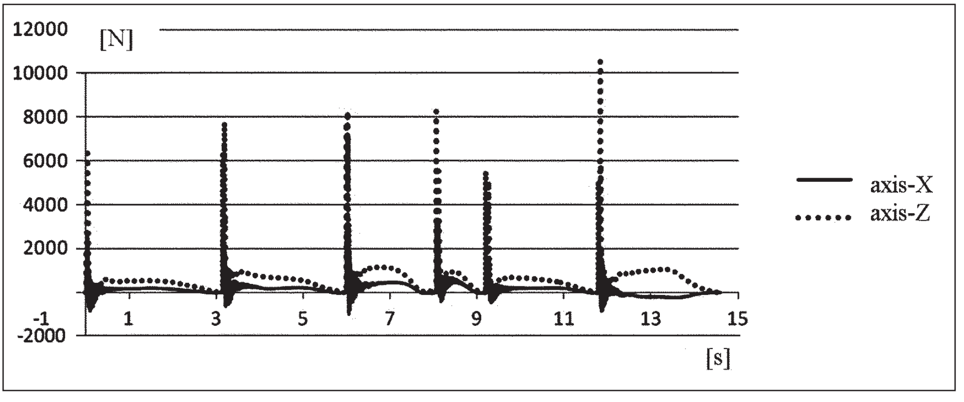


**Figure 2.** Participant 2 stamps – generated force

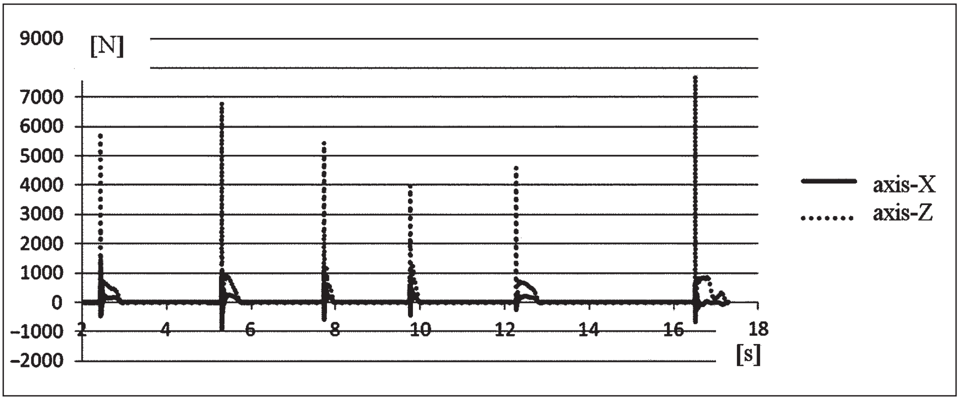


**Figure 3.** Participant 3 stamps – generated force

## DISCUSSION

### Aortic injury

According to the mechanism of thoracic trauma, the aorta is an important segment of the cardiovascular system which can be affected by blunt impact. The aorta originates cranially at the left ventricle and then turns left to form the arch of the aorta. Although the descending aorta is firmly attached to the ligaments of the spine, the relatively mobile ascending aorta arises from the heart (the passing is a common place of a rupture).

In this studied case, the aorta was not damaged and it is assumed that no significant deceleration, injury mechanism was applied or caused a direct contact with impact force of 5000–10000 N, furthermore no signs of massive compression of the abdominal or thoracic area were discovered, therefore excess pressure in the aorta is highly unlikely.

### Rib injury

The fracture of the ribs is usually located at the point of the maximum curving or at the place of the force application.

In this case no kicks are defined in the files (the video analysis) which could cause the rupture of the left atria auricle without serious damage to the thorax or skeletal elements. On the other side there are well known cases where an intensive CPR resuscitation causes an injury of the thoracic component (mostly cracked – broken ribs, heart, and great vessels). There is no literary evidence of the cracked or broken ribs by a powerful stamp on the frontal thorax.

### Cardiac Injury

According to the extensive review, the impact loading on the thorax is usually not causing a serious cardiac injury since force does not exceed the value of 7200 N. In contrast, force about 10000 N cases a serious injury of the heart. In the view of the experiment the measured upper values could cause a rupture of the heart.

A rupture of the atria auricle is hidden behind the series of more probable trauma. Even a great number of documented heart injuries due to the blunt trauma are known, the atria auricle is not frequently affected. It is almost impossible to specify the character of the rupture only by the autopsy report. A possible cause was not considered at the autopsy report, thus the chance of specifying the mechanism is very limited. A description of the rupture would help to identify the injury mechanism, for example growing hydrostatic pressure (rupture from inside out from the endocardium at the end of diastolic) or compression between the sternum and the spine. It is obvious that a cardiac rupture may be caused by a massive stamp as well as intensive CPR.

## CONCLUSION

According to the nature of the injuries, autopsy report, video analysis, results from the experiments is possible to state that a rupture of the atria auricle and resulting cardiac tamponade, which leads to the heart failure, may be caused by a forceful stamp (10000 N) under certain circumstances (damage of the thoracic skeletal components, amount of blood in the heart, etc.)

On the other hand one cannot eliminate the fact that massive CPR may cause similar heart injuries. This case study opens the field of stamps as a forceful destructive technique in physical attacks and increases the amount of information related to forensic biomechanics.

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## TLAKOVÉ ÚČINKY DOPADU TUPÉHO TĚLESA DO OBLASTI HRUDNÍKU S NÁSLEDKEM SRDEČNÍHO PORANĚNÍ – CASE STUDY

ONDŘEJ FANTA, DANIEL HADRABA, PETR KUBOVÝ, KAREL JELEN

SOUHRN

Biomechanika poranění způsobená dopadem tupého tělesa do oblasti hrudníku je celosvětově akcentovanou problematikou spojovanou zejména s pasivní bezpečností vozidel, pracovními úrazy a fyzickými napadeními. V této studii jsou rozebrány biomechanické aspekty ubití muže, 32 let, 180 cm, 76 kg, který byl po napadení neúspěšně oživován po dobu 20 minut (kardiopulmonální resuscitace) a za smrt byla označena trhlina levého ouška síně srdeční s následnou tamponádou srdce. Rešeršním způsobem jsou detailně rozebrány možnosti vzniku poranění, dále byla provedena videoanalýza, která byla srovnána s pitevním protokolem a výsledky experimentálně porovnány s fyzikální podstatou útoku na hrudní část lidského těla, resp. dupnutí na hrudní část těla. Součástí experimentu bylo měření síly dupnutí na Kistleru.

Získané poznatky lze aplikovat ve všech činnostech, při kterých dochází k tupému nárazu do hrudníku. Mechanismy odpovídají „injury“ problematice při napadení, v pracovních i volnočasových aktivitách např. v dopravě, sportu apod.

**Klíčová slova:** aorta, biomechanika, poranění hrudníku, Kistler, trauma, srdce, ruptura, tupá poranění

Ondřej Fanta
fantao@seznam.cz