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Original article

FALL FROM HEIGHT INJURIES

Pavlovski Goran, Stankov Aleksandar, Jakjovski Zlatko, Bitoljanu Natasha, Belakaposka Srpanova Viktorija, Chakar Ljupco, Ivceva Ana, Poposka Verica

Institute of Forensic Medicine, Criminalistic and Medical Deontology, Faculty of Medicine, Ss. Cyril and Methodius University in Skopje, Republic of North Macedonia
e-mail:goran.pavlovski@medf.ukim.edu.mk

Abstract

The type of injuries sustained from fall from heights depends primarily on the fall height, the part of the body that suffered the first impact when hit the ground-primary contact, the age and weight of the victim's body, clothes worn and the body composition.

This study encompassed 60 casualties - bodies of victims of fatal falls from height, divided in three groups: fall from less than 7 meters (m), from 7 to 25 m, more than 25 m. The study analysed brain injuries, thoracic and abdominal organs, skull fractures, limb fractures, ribs and spine, as well as fractures of scapular and clavicular bones (analysed jointly). The study was focused on determining the frequency of the occurrence of different injuries, analysed one with other, that correlation depending on the height of the fall.

The analysis on the number and severity of the injuries in correlation to the height of the fall showed that fractures of the hipbone and limbs were mostly present in the victims who had fallen from 7 to 25 m height. In the victims who had fallen from 7 m height, the most common injuries were fractures of the ribs and spine. In falls from height above 25 m, all organs were equally damaged. In all analysed cases, the most frequent cause of death was trauma shock, followed by cerebral contusion.

Our data have shown that assessing only the pathological characteristics is not sufficient to determine the cause of death in fatal falls from heights.

Keywords: fall from height, type of injury, accident

Introduction

Falls from height are a significant problem in the clinical and forensic medicine. Depending on the country in which the analysis was done, falls from height are the third, in some cases even the second leading cause of accidental or suicidal death, mainly a phenomenon of urban environments. Falls from height result in different injuries, mainly conditioned by many factors, such as: height of the fall, age, the position of the body of the victim and the characteristics of the surface in which the victim hit. The fall from height normally involves multiple organs trauma. In relation to the manner of death, the falls from height may be accidental, homicidal and mostly suicidal[1,2]. As suicidal intention, compared to other methods, falls are relatively rare and usually preferred by the elderly[1,3,4]. Accidental falls mainly occur in specific working environments, as a result of negligence - for e.g., working on a construction site, working on rooftops, cleaning of windows in high buildings, but also in sport activities and hiking[2,5]. Falls from height have been rarely encountered in homicides. In those cases, other additional injuries have been seen that cannot be related to

the fall; however sometimes it is difficult to differentiate them from those caused by the fall. If the victim has been caught by surprise, or has been significantly weaker than the attacker or has been using medications, additional injuries may be absent. In the case of death caused by fall from height, the forensic doctor should determine whether it is a homicide, suicide or an accident. In the assessment, the forensic pathologist should gather all beneficial information, which can be collected independently, including those from the prosecution, police and victim's family. Successful resolution of every case requires a detailed analysis of the place of death, psychiatric history of the victim, analysis of the type of injuries, determination of the cause of death and toxicological analysis.

The aim of this study was to assess the manner of death and the degree of injuries sustained by the victims of falls from heights in relation to the height of the fall.

Material and methods

The study was performed on 60 bodies of victims of falls from different heights, who were brought for forensic-medical autopsy at the Institute for Forensic Medicine and Criminalistics in Skopje in the period from 2014 to 2017. The heights of the falls were divided in three groups: less than 7 m, from 7 to 25 m, more than 25 m. Each of the victims underwent a standard forensic medical autopsy. For each victim, information about gender, age, type of injuries, body height and presence of alcohol and other toxic substances in the bloodstream was registered. The analysis included injuries of the brain, thoracic and abdominal organs, skull fractures, fractures of the limbs, ribs and spine, as well as fractures of the scapular, clavicular bones and sternum (observed jointly). The study was focused on determination of the frequency in the occurrence of different injuries analysed one with other, that correlation and depending on the height of the fall.

Results

The study analyzed 60 bodies of victims of fatal falls from different heights in the period of three years. A standard forensic medical autopsy was performed in all of the victims. Of the total number of victims, 53 were men and seven women. The mean age of victims was 49.7 years (from 20 to 80). Majority of victims were aged 50 to 60 years (Figure 1).

Fig. 1. Victims' age range

According to the manner of death, the cases were dividied into suicides, accidents and unresolved causes (Figure 2).

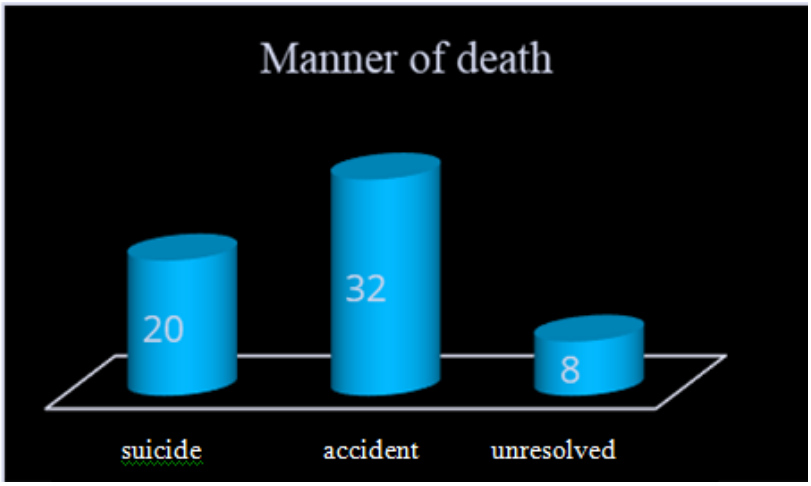

Fig. 2. Distribution according to manner of death

The height of the falls was divided in three groups: less than 7 m, from 7 to 25 m, more than 25 m. The distribution of the victims according to the type of injuries in relation to the height of the fall is presented in Table 1.

Table 1. Distribution of victims according to type of injuries in relation to height of the fall

Height of fall	Number of victims	Type of injuries
<7m	22	Cerebral contusion and skull fractures
7-25 m	30	Fractures of the ribs, lacerations of the liver and spleen
>20m	8	Fractures of the ribs and spine, laceration of the lungs and aortal rupture

The results obtained in this study about the number and severity of the injuries in relation to the height of the fall showed that fractures of the hipbones and limbs were commonly present in victims who had fallen from 7 to 25 m height. In victims who had fallen from 7 m, the most frequent injuries were those on the ribs and spine. In the falls from over 30 m, all organs were equally damaged (Figures 3 and 4).

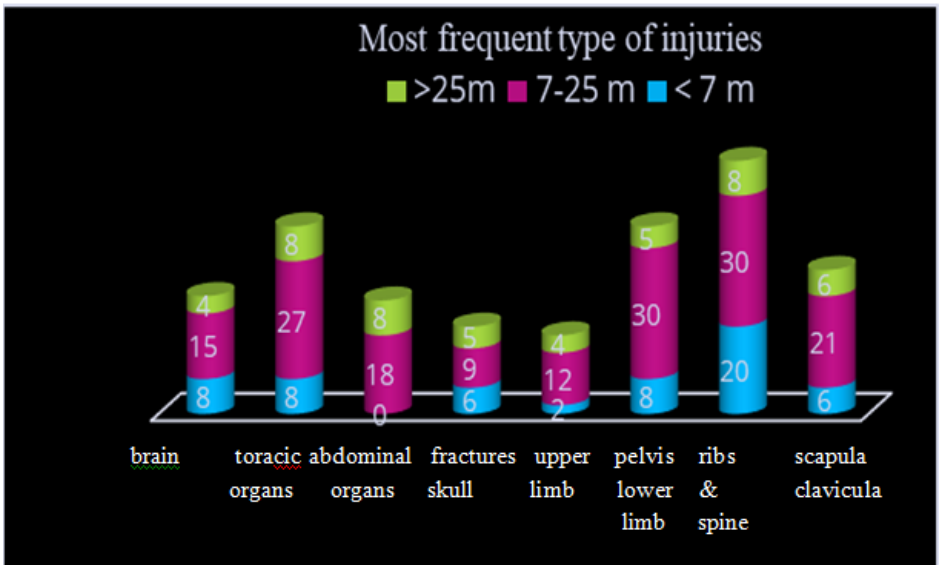

Fig. 3. Most frequent injures depending on the type of fall

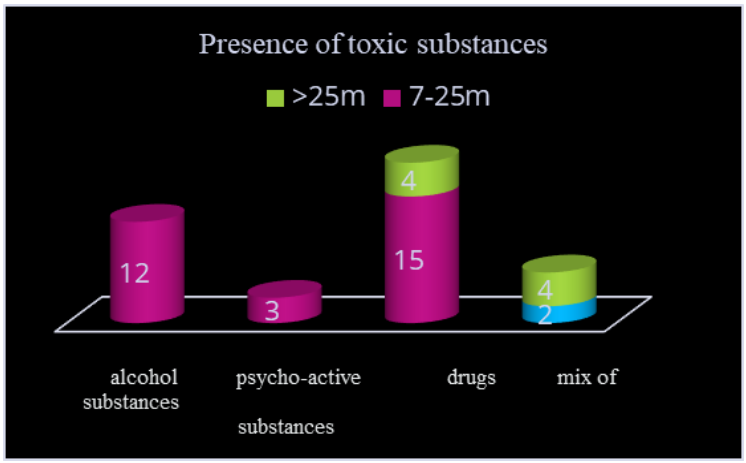

Fig. 4. Presence of toxic substances in the victims' blood**.** In all analyzed cases, the most frequent cause of death was traumatic shock (38 of victims), followed by cerebral contusion (15 of victims)

Discussion

The crime scene of the death carries important information in determining the cause of the fall from height. When the falls happen in places where people normally do not go, such as rooftops and bridges intended for vehicles only, we should think of a suicide[6,7]. Falls from high buildings and victims' homes, medical ward (psychiatry) and absence of sings of fight and resistance, are suspected of suicide. If there is a barrier to prevent the fall, in the suicide scenery, then there will also be objects, which would help the victim to overcome that barrier, such as chair or ladders. Suicides are more likely to happen at night. Compared to the other types of suicides, suicide note is rarely seen (10-25%) in those performed by fall from height[1,6,8]. Bigger distance from the place of the fallen body and the exact jumping spot, most commonly indicates an active jump in a suicide attempt; however, sometimes people do not jump, but rather allow their body to passively fall down[1,9]. The largest number of those victims are already death when found. The accidental falls from heights are most common in specific working places and environments during working hours, through a closed window or smaller heights. However, we should always have in mind a possible homicide[2,5]. Some of these victims somehow stay alive. The presence of medications and drugs shows an accidental fall from heights caused by the effects of the drugs, while the presence of signs of a fight always indicates homicide. In our study, we confirmed 32 accidental falls and 20 suicidal falls. The suicidal falls from height are very often accompanied by facts about psychiatric background or diagnosis, such as depression, schizophrenia, personality disorders. Alcohol consumption and drug abuse increase the probability of an accidental fall, under their influence[6,8,10]. The type of injuries caused by falls from heights depends largely on the height of the fall, the part of the body that hit the ground first, age and weight of the victim, clothes and body composition [1,11-14]. In our study, the injuries were grouped according to their joint correlation and the height of the fall. In falls from a height less than 7 m, cerebral contusion and skull fractures were prevalent (22 victims). In falls from 7-20 m height, the most frequent injuries were ribs fractures, as wells as liver and spleen lacerations (20 victims), whereas in falls form height over 20 m, predominant were ribs and spine fractures, lungs laceration and aortal rupture.

External examination

Examination of victims' clothes can give initial information about the fall. Feet are first affected by the fall; in the inguinal region most commonly we witness tear of the trousers in length (longitudinal). Basically, there is a smaller number of externally seen injuries

compared to internal ones, which are determined after the autopsy of the victim's body[6,7]. Livor mortis may be less present due to the high blood loss. Since the feet sustain the first impact of the fall, there may be opened fractures of the ankle joint and calcaneus, hemorrhages in the perineal region (these may be mixed with sexual harassment before the fall). Skin lacerations on the palms, open hand or knee joint fractures may be signs of attempts of the victim to cushion the impact. Blunt injuries, such as abrasion and hematoma on the site of the primary impact are a casual finding. If the victim tried to hold on to or stroke protruding objects on the way and during the fall, there may also be injuries such as peeling abrasions and hematoma on the palms (rope kick). Depending on the density and the body composition, parts of the body may be torn[1,6,10]. Old and fresh signs of the attempt wounds in the victim may also be present, which indicate previous suicide attempt (scars from wrist incision - "hesitation marks"). Bruising on the volar (inner) side of the upper wrist area indicate involvement of a second person[1,6,10].

Internal examination

There have been many mathematical models exploring the connection between the conditions under which the fall happened and the severity of the internal injuries. It has been concluded that the fall height and the victim's age are the main determinants about the size and severity of the internal injuries. Although the fall from heights causes multiple and intensive injuries, not always can the injuries' severity indicate the height of the fall[1,6,10,15-18]. When there is the feet-first impact, the trauma caused from the vertical deceleration is the cause of characteristic injuries, such as aortal laceration, ring-like fractures of the skull base[6,8,9,19].

Head injuries - are often findings in falls from height and they involve subarachnoid, subdural and epidural hemorrhage, intracerebral hemorrhage, brain contusions, partial or full loss of cerebral tissue. In falls in water, we rarely witness heavy head injuries[1,6,10]. When there is head-first impact, it is expected that the head would suffer the most serious injuries such as: open skull fractures and splattering of the brain tissue in the wide surrounding area, while the other organs are less affected, especially in falls from heights less than 25 m[1,6,20-23]. When there is feet-first impact, the prevalent injuries to the brainstem (lacerations, contusion and transections) are accompanied by ring fracture of the skull base. Conflicting opinions exist about the influence of the height on head injuries. While some authors find it proportional, others believe that falls from less than 10 m height and over 25 m cause more severe head trauma, compared to falls from 10-25 m heights[1,6,10]. In our study, head injuries were most frequent in falls from less than 7 m height.

Neck injuries - blunt neck injuries are found in about 33% and involve mild to severe hemorrhage in subcutaneous and muscular layer, thyroid hematomas and fractures of the hyoid bone and thyroid cartilage fractures[24-26].

Injuries of the thorax - in the analysis of the thoracic cavity, injuries to its walls, the heart, large blood vessels and the lungs are included[6-8,10]. In the walls of the thoracic cavity, most common are abrasions and bruises of the chest and multiple rib fractures. In falls from heights above 25 m, multiple fractures of the entire thoracic cavity, including the sternum, thoracic spine and vertebrae, are found. In falls into water, the injuries are slightly lower, but still present. Penetrating rib fractures can cause secondary injuries to the thoracic organs or may result in pneumothorax and/or hemothorax[1,10]. The frequency and intensity of the heart injuries increase with the increase of the height of the fall. Blunt heart injuries have been witnessed in 54% of the cases in falls from heights, while 79% of them are multiple[10,27]. In the largest number of cases, there are pericardial and epicardial tears. Pericardial tears are most likely to be found in the right posterior part and can be of longitudinal orientation. Epicardial tears and hemorrhage are frequent around the ostium of the lower *vena cava* and

are witnessed in falls from heights less than 15 m. Endocardial tears are characteristic in falls from greater heights, which also frequently involve rupture of the entire heart wall. In the examination of the heart septum, more frequently we witness tears of the interatrial septum than interventricular septal tears. Myocardial hematoma is more frequently found in the left heart[27]. In falls from greater heights, we witness tears of the coronal blood vessels, but also possible is the heart torn off from the bigger blood vessels[27,29]. Less often we witness rupture of the papillary muscles of the heart and the valves. A correlation between the fractures of the sternum and the intensity of the injury of the heart has not been detected. Sometimes, minor changes are present that may contribute to fatal outcome. It is important to diagnose a possible contusion in the survived, in which case the use of troponin is recommended[30,31]. Aortal rupture is most frequent in the injuries of the thoracic blood vessels, commonly followed by mediastinal bleeding. The rupture edges are smooth, which appear, as sharp transection and sometimes it can be multiple. The frequency of aortic rupture increases in falls from greater heights. Pulmonary artery and venous ruptures are seen less frequent[6,8,10,15]. Minor or major contusions of the lungs can be found in almost all fatal falls from height, with severity increasing in falling from greater heights, when also complete pulmonary ruptures or hilus ruptures can be detected. Very often, additional injuries are witnessed, caused by penetrating rib fractures[6,10]. Diaphragm ruptures are relatively rare; however, the injury may be associated with displacement of the abdominal organs into the thorax[1]. In our study, the predominant finding in the thoracic injuries were rib fractures (in falls from 7 to 20 m) and spine trauma, lung laceration and aortal rupture (falls from over 20 m).

Abdominal injuries - liver rupture is found in 52-68% of the falls from height. The right lobe is damaged more often. Tears are often irregular in their nature, but relatively parallel in their orientation. In falls from greater heights, complete disruption of the liver, vascular avulsion and hilar rupture are often encountered. Findings also show that even in the most extensive ruptures, the accompanied abdominal bleeding is minimal[6,10,32,22]. Spleen ruptures are a common finding in falls from height and often they are multiple[1,10]. Also, in falls from height, ruptures and hemorrhage of the mesenteries are commonly found. Traumatic ruptures of the oesophagus, the stomach and intestines are relatively rare, which is due to their elasticity and mobility. In the retroperitoneal space, the most common finding is rupture of the abdominal aorta, which is less frequent than rupture of the thoracic aorta. According to some authors, retroperitoneal bleeding is rare, while according to others, it is relatively often[1]. Adrenal, renal and renal hills ruptures are commonly found. Renal injuries can be extensive and can influence on the fatal outcome. The connection/correlation between the renal damage and the height of the fall has not been determined, while there is a connection between the part of the body which takes the first impact. The most severe injuries are found in victims falling and laying on the sides. Regarding abdominal organ injuries, our study found predominant lacerations of the liver and spleen. The results about the number and severity of injuries in relation to the height of the fall showed that the hipbone and limb fractures were most commonly present in victims falling from 7 to 25 m. In victims who had fallen from 7 m, the most common injuries were ribs and spine fractures. In falls above 30 m, all organs were equally damaged.

Cause of death

Most of the victims of falls from heights die at the scene of the fall, immediately or after couple of minutes[1,35,36]. The survived most often die during the reanimation attempts at the intensive care units, in a relatively short time after admission, while only a small number survive from four hours to couple of days[1,6]. The cause of immediate death is most commonly polytrauma, accompanied by head injuries and internal bleeding. In victims who

have managed to survive from four hours to couple of days, the most common cause of death is head trauma[6]. After several days, the most common cause of death is also pulmonary embolism and systemic failure of the internal organs caused by sepsis. In falls in water, the most common cause of death is drowning[7,8]. In all analyzed cases in our study, the most common cause of death was traumatic shock (38 of all victims), followed by cerebral contusion (15 of the total number).

Toxicology findings

Ethanol is found in 15-35% of the cases of fall from height. It is equally present in suicide attempts and accidental falls, whereas the alcohol concentration is normally higher in the suicide attempts. High concentration of medications, especially psychiatric (benzodiazepines and antidepressants), is a common finding in suicides, however not in lethal doses[1,6,10,37]. In our study, in the blood of the victims who have fallen from 7 to 25 m height, alcohol was found in 12 victims, psychoactive substances in 3 victims and medications in 15 victims.

Conclusion

Our data and findings show that the sole assessment of the pathological characteristics is insufficient to assess the mode of death in the fatal falls from height. Each case should be separately considered and assessed, in the frames of the history of the victim and related to the findings about the place of death and toxicology results.

Conflict of interest statement. None declared.

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