FORENSIC ASPECTS OF SKYDIVING-RELATED DEATHS AND INJURIES

Dana Doroftei1, *, Carmen Corina Radu1, Cosmin Carașca1, Cătălin Negrea2, Levente Csok3, Codrin Horea Rebeleanu4, Costel Siserman4

1“George Emil Palade” University of Medicine, Pharmacy, Science and Technology, Department of Forensic Pathology, Târgu Mureș, 2“Babes Bolyai” University, Cluj Napoca, 3“Elie Carafoli” Territorial Aeroclub, Târgu Mureș, 4“Iuliu Hațieganu”University of Medicine and Pharmacy, Department of Forensic Pathology, Cluj-Napoca, Romania

Abstract. Skydiving incidents during flight are common, a decisive factor in what concerns the traumatic injuries severity being represented by special techniques- to prevent the conversion of incidents into accidents. The injury pattern is revealing a polymorphism related to every single incident. In rare cases these incidents conclude with severe bodily injuries or even death. In this paper, two cases of skydiving accidents will be reviewed, one concluded with the survival of the skydiver, and the other with the person’s death, by analyzing the operational procedures, their usage, the severity of the traumatic injuries and other skydiving accidents from international literature.

Keywords: Traumatic injuries, skydiving accidents, operational procedures, parachuting accidents.

INTRODUCTION

Skydiving is an extreme sport, practiced on a large scale globally. Felix Baumgartner, an Austrian skydiver and BASE jumper, gained notoriety on October 14, 2012, when he descended to Earth from a helium balloon in the stratosphere. He did this while skydiving an estimated 39 kilometers and attaining an estimated top speed of 1,357.64 kilometers per hour. While descending, he broke the sound barrier for the first time without the assistance of a vehicle [1].

The rate of skydiving deaths and accidents is very rare, the estimated prevalence being approximately 0.5-0.8 deaths/100,000 jumps [2-4]. In order to understand the circumstances in which these accidents occur, it is necessary to know the development phases of parachute jumps: leaving the aircraft, free fall, opening the main parachute and landing. In aeronautical nomenclature, the occurrence of these accidents are called special cases, which are generally determined by three main causes: a faulty position of the body at the moment of opening the parachute, equipment failures, improper folding of the parachute, to which negligence can also be added, which can lead to accidents due to not mastering the equipment/release techniques. Apart from the possible malfunctions of the equipment, which cannot be predicted in all cases, all the other determining causes of skydiving accidents reside in human error.

During the skydiving courses, in addition to technical and procedural details, emphasis is placed on various incidents that can appear often in any of the jump phases, but which have methods of resolution and ensure a safe landing. These incidents are very frequent, but rarely result in the injury or death of the skydiver, precisely due to the fact that the operational procedures in special situations lead to solving these problems during the dive, within the safety altitude (800 m) and ensure the landing in optimal conditions - any hesitation or ignorance of these techniques can turn a frequent, minor incident that can be resolved into severe accidents or even death.

MATERIALS AND METHODS

In this article, we will evaluate 2 cases of skydiving accidents, one resulting in the parachutist’s serious injury, but his survival, and the second one resulting in the person’s death. In both cases, the evaluation of the injuries was made from a medico-legal point of view correlated with the occurrence circumstances of these accidents, from a technical point of view and the existing operational procedures by
using the technical investigation reports from the civil aviation accidents and incidents centralizer “In these cases, the cause of death is usually easily identified but the events leading up to death are usually a matter for investigation” [4].

**CASE REPORT 1**

28-year-old male, licensed parachutist with a 365 jumps experience, suffers a fatal accident during a parachute jump. From the final investigation report on the safety of civil aviation, it appears that, during the flight, upon reaching the established height of 3000 m necessary for the jump, from the analysis of the recordings made with the GoPro cameras, the accidental opening of the reserve parachute occurred inside the aircraft (Fig. 1).

The parachutist, for a short time, remained attached to the plane, thus blocking the thruster and giving the aircraft a pronounced dive with an inclination to the left side (Figs 2-4).

After the canopy got ripped, the parachutist, in uncontrolled free fall, wrongly believing that the main parachute had opened in the plane, released the main parachute and opened the reserve [6]. The investigation commission analyzed the parachute and found that an improper folding/preparation of the parachute was present, determining the accidental opening of the reserve parachute inside the plane [6].

The skydiver, who initially opposed exiting the plane, was forced out of the plane due to air currents, ending in an uncontrolled free fall; the only possibility to resolve the situation would have been to open the main parachute. At the moment when the release/cutaway command of the main parachute was activated, the parachutist no longer had any options available (Figs 5, 6)[6].

From the medico-legal autopsy report carried out, multiple excoriations were found at the cephalic level (Fig. 8), at the level of the upper limbs, pathological mobility associated with bone fractures at the level of the lower right limb, right occipital epicranial blood effusions, meningeal hemorrhage, posterior thoracic blood effusions – massive, with hemothorax and associated rib fractures, multiple continuity solutions and pulmonary contusions, pericardial and myocardial continuity solution corresponding to the left auricle with associated hemopericardium, aortic rupture,
liver continuity solutions with blood effusions and hemoperitoneum (Figs 9-13). The traumatic injuries plead for a landing on the dorsal side, a fact confirmed by the disposition of the traumatic injuries and the on-site investigation (Fig. 7).

The death was due to acute cardio-respiratory insufficiency following multi-visceral ruptures and fractures produced as part of a poly-traumatism. The traumatic injuries could have been caused by falling from a great height in the conditions of an aeronautical sports accident. The blood alcohol level and the general toxicological examination of the urine were negative for the usual classes of drugs, drugs and ethanol.

The terminal velocity of the human body is
approximately 200 km/h [7]. In the present case we can consider the speed of the parachutist in falling close to the speed of free fall, the reserve parachute being torn and the remaining parts unable to provide speed attenuation.

**CASE REPORT 2**

A 20-year-old male, performing the 17th jump during a skydiving course, suffered an accident resulting in serious bodily injury. The preliminary analysis report reveals that, according to the statements of the ground instructors, the deployment of the main parachute was performed correctly, but 2-3 seconds after its opening, a rotational movement began.

Due to the incomplete release of the main parachute, its lines became entangled in the lines of the reserve parachute, which opened only partially. In these conditions, the victim suffered a rapid, uncontrolled fall, with rotational movements, resulting in a hard landing in which the victim suffered serious bodily injuries (Fig. 14).

According to the reports of the emergency crew that arrived at the scene, he was taken with a Glasgow score of 9 pt., his respiratory system deteriorated rapidly and required intubation and mechanical ventilation. The poly-trauma could be caused by a fall from a height (1200m) and resulted in left brachial hemiparesis, bitemporal hemianopsia, left hemopneumothorax and right pneumothorax. The brain CT examination revealed cervical posterior dislocation at C5-6 level, with damage to the spinal canal at this level and possible spinal cord damage. Cervical vertebra C6 exceeded posteriorly by 6 mm, posterior lamination of vertebra C6 compared to C5 and posterior dislocation C5-C6, distance between spinous processes C5 C6 increased to 11 mm. spinal canal traumatically affected

![Figure 11. Posterior thoracic blood effusion](image1)

![Figure 12. Hepatic rupture.](image2)

![Figure 13. Aortic rupture](image3)

![Figure 14. Parachute entanglement](image4)
at C5-C6, possible spinal contusion at this level. The thoracic and abdominal CT examination revealed fluid pneumothorax, multiple lung parenchyma contusions, moderate pneumomediastinum, perirectal and presacral reticular effusions, lower retroperitoneal hemorrhagic effusions, sternal and coccygeal fracture.

The patient is transferred to the intensive care unit, being in critical condition, hemodynamically and respiratory unstable, which is why the surgical intervention is delayed. The cranio-vertebral CT examination reveals: hypodense lesions with an ischemic vascular character, at the cerebellar, bilateral occipital, thalamic and right frontal level, posterior listhesis grade 1 C6-C5, sternal fractures and coccyx. Following the neurosurgical evaluation, the patient is put on hemofiltration. Surgical intervention is performed by practicing C5-C6 anterior radix fusion with anterior fixation system, C5 disectomy, cervical cage installation - evolution is favorable, with patient extubation. The patient has tetraparesis: grade 4/5 superior and inferior right limbs, grade 3/5 left superior limb, grade 2/5 left inferior limb, with bilateral Babinski sign positive. Later, due to the remissive nature of the paresis, the victim is transferred to a recovery center in order to perform physical therapy.

The severity of traumatic injuries from a medico-legal point of view falls within 45-50 days of medical care. The complications related to the trauma, respectively the need for blood transfusions, place the current case under the notion of life endangerment.

The traumatic injuries occurred through a complex mechanism, associating hyperflexion/hyperextension (C5-C6 cervical dislocation), hitting hard surfaces (hemopneumothorax, pneumomediastinum, multiple lung parenchyma contusions, sternal, coccygeal fracture), by falling from heights in an aeronautical sports accident.

Concerning the dynamic of the accident, we can state that most likely the victim tried to perform a hard landing procedure - rolling during the impact with the ground, a fact revealed by the disposition of the traumatic injuries found.

**DISCUSSION**

Vincent L. Ball *et al.*, highlights a predominance of lower extremity injuries, which represent 65% of all injuries found, followed by 22% cranial injuries, and 22% cervical and thoracic injuries, 19% superior limb injuries [8].

Stephan C Craig *et al.* found, in a 20-month evaluation, that 27% of all injuries in skydiving accidents are found in the lower limbs, 19.3% in the axial skeleton (thoracic and cervical dislocations), 18.4% closed cranial injuries [9].

Knut Magne Ekerhovd *et al.*, highlights the dominant causes of deaths in parachute jumps, these being due to the failure of performing special techniques during the dive, 40% of these deaths being avoidable [10]. In 17 of the 32 fatalities, the jumper mishandled, or completely neglected their emergency procedure. All 17 of these fatalities may have been avoided if the emergency protocol had been followed appropriately and at a high enough altitude [10,4].

Anton Westman and Ulf Björnstig, evaluated the data on all reported injury events (n=257) in Swedish skydiving 1999–2003: the prevalence of non-fatal injuries was 48/100 000 jumps. The most common areas of injury were the spine, shoulders and lower extremities [12]. “No injury is specific enough to be called a typical parachute lesion”[13].

**In conclusion**, skydiving incidents are often encountered, but thanks to the implementation of special techniques-operational procedures, these incidents are mostly resolved and ensure the safe landing of the parachutist, the accidents being predominantly due to human error.

- Evaluating the actual operational procedures, it is recommended to leave the plane as quickly as possible in case of accidental deployment of the parachute. In the first case, the parachutist tried to stay inside the plane for 6 seconds until the force of the air currents threw him out, and he voluntarily released the main parachute due to the erroneous assessment of the situation. In the second case, the error highlighted during the application of the special techniques residing in the incorrect release of the main parachute, entangling with the lines of the reserve parachute, leading to a partial opening of the canopy, both cases involving human errors.

- The traumatic injuries encountered in such cases reveal the serious but predominantly internal nature of these types of trauma, the external correspondent being predominantly due to the land on which the landing is made and the protective equipment used (helmet, glasses, suit).

- Traumatic aspects in case of deaths during parachute jumps include lacerations of lungs, rupture of heart, lacerations of brain, rupture of aorta, and fractures of spine. Death is instantaneous in these cases (first case presentation—rupture of the aorta). The peculiarity and rarity of the second case is that despite...
the fact that the parachutist fell from a considerable height (1200 m), and suffered serious traumatic injuries, without considerable attenuation of free-fall speed from the partially open parachutes, this accident resulted only in serious bodily injury of the victim, without permanent disability, the victim displaying a quick recovery, with the remission of tetraplegia.

- The toxicological analysis performed on biological samples of the skydivers generally has a negative result, both from the general toxicological point of view and the alcohol level.

- In the evaluation of injuries caused by skydiving accidents, an interdisciplinary collaboration is necessary to elucidate the occurrence circumstances of the traumatic injuries. In these cases, the corroboration of the data obtained from the full medico-legal autopsy and the data of the technical analysis / possible recordings made available to the forensic pathologist to determine the mechanism and dynamics of the accident.

Conflict of interest
The authors declare no conflict of interest.

References