# Fatal falls from great height in Sousse (Tunisia): Study of 141 medicolegal autopsy cases

## Les chutes mortelles de grande hauteur dans la région de Sousse (Tunisie): Etude autopsique de 141 cas

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**Abstract**

**Introduction:** Falls from great heights constitute a violent trauma that can lead to death. This represents a suspicious death, leading to initiate legal proceedings with in particular the practice of an autopsy.

**Aims:** to determine the features of victims of falls from height and relations between medico-legal form of the death, the height of the fall and the nature of traumatic injuries

**Methods:** A retrospective study about 141 cases of death after fall from great height. Data were collected at the Legal Medicine Department of the Farhat Hached University Hospital in Sousse (Tunisia) over a period of 14 years from 2007 to 2020.

**Results:** The average age of the victims was 37±12.8 years with a sex ratio of 6.05. Half of them were day laborers. The majority had no history of psychiatric illness (91.5%). The majority of victims (41.8%) fell from a height of 3 to 6 meters. Regarding injuries, rib fractures (52.4) were predominant, especially on the right side followed by skull fractures (31.2%). A significant difference in the prevalence of rib cage lesions in the groups over 9 meters in height ($p<0.05$) was found. The lesions of the lower limbs were proportional to the increase in the height of the fall. Deaths were accidental in 80.8% and suicides in 13.5%.

**Conclusion:** In cases of high falls, a forensic autopsy is essential to make a complete evaluation of the injuries, to search a correlation between severity of injuries and height of the fall and finally to orientate towards the medico legal form of the fall.

**Key words:** fall from height, trauma, autopsy, death, forensic form

**Résumé**

**Introduction:** Les chutes de grande hauteur constituent des traumatismes violents pouvant entraîner la mort. Il s'agit de mort suspecte et la pratique d'une autopsie est souvent nécessaire.

**Objectifs:** Identifier les liens entre la forme médico-légale du décès, la hauteur de la chute et la nature des lésions traumatiques.

**Méthodes:** Etude rétrospective portant sur 141 cas de décès par chute de grande hauteur. Les données ont été recueillies au service de médecine légale du CHU Farhat Hached de Sousse (Tunisie) sur une période de 14 ans allant de 2007 à 2020.

**Résultats:** L'âge moyen des victimes était de 37±12,8 ans avec un sexe ratio de 6,05. La moitié des victimes étaient des journaliers. La majorité n'avait aucun antécédent de maladie psychiatrique (91,5%). Pour la majorité des victimes (41,8%) l'hauteur de précipitation était de 3 à 6 mètres.

Concernant les blessures, les fractures des côtes prédominaient (52,4%), surtout du côté droit suivies des fractures du crâne (31,2%). Une différence significative dans la prévalence des lésions de la cage thoracique dans les groupes de chute de plus de 9 mètres de hauteur ($p<0,05$) a été trouvée. Les lésions des membres inférieurs étaient proportionnelles à l'augmentation de la hauteur de chute. Les décès étaient accidentels dans 80,8% et suicidaires dans 13,5%.

**Conclusion:** Lors chutes mortelle de grande hauteur, une autopsie est indispensable. Elle permet un inventaire complet des blessures, et d'orienter vers la forme médico-légale de la mort

**Mots clés:** chute de hauteur, traumatisme, autopsie, décès, forme médico-légale

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## INTRODUCTION

A fall from height occurs when a person lands on the ground or other surface that is lower than the level at which he or she was previously standing. This may include falls from stairs, ladders, roofs, trees, etc. It can be caused by accidents, suicides or even an act of homicide (1). Fall from great heights represent a frequent cause of injuries, especially in urban areas. This is a high-energy trauma with a typical mechanism of deceleration injury. Itcan provide a severe form of injury and constitute a high cause of mortality (2).

Several studies were interested in the fall from great heights, but the characteristics of the victims, the type of injuries resulting from this trauma and the evolution of the affected patients were rarely documented (3).

In case of death following a fall from a great height the forensic autopsy is always required in order to make a complete assessment of the injuries however it is not always evident to the forensic expert to identify if the injuries were caused by a fall from a height or by another blunt trauma (1). That has prompted us to conduct this study

The aim of our study was to determine the features of victims of falls from height and to determine relations between medico-legal form of the death, the height of the fall and the nature of traumatic injuries.

## METHODS

Our work is a descriptive retrospective study about 141 cases of death after a fall from a great height collected at the Department of legal Medicine Department of Farhat Hached University Hospital in Sousse (Tunisia) during a period of 14 years from 2007 to 2020. Based on data from the literature (1-3), and given the lack of consensus, the notion of “great height” was arbitrarily conferred by the authors on falls of more than three meters.

We included in this study all deaths that occurred as a result of a fall from height of more than 3 meters and that were autopsied in the Department of legal Medicine of Farhat Hached University Hospital in Sousse (Tunisia) during the period of the study.

Data were collected from the registers of the Legal Medicine Department and from the autopsy files which contained data from the examination and autopsy carried out by forensic doctors, medical data from the treatment of the victims as well as data from the initial judicial investigations

The victims characteristics (age, sex, origin, marital status, profession, psychiatric history…), the fall circumstances (date and time, place of death, height of the fall, landing surface…), the injury assessment (regions affected, bone injuries, visceral injuries, toxicological assessment when was done …), cause of death and the medico-legal form of death were collected.

Data was analyzed using SPSS 21 (statistical Package for the Social Sciences software). Means, medians and range for the quantitative variables and the frequencies and percentages for the qualitative variables were calculated. The associations between the injuries and height of fall were carried out using Chi-square test and in case of non-validity, Fisher test was used.

## RESULTS

### Characteristics of the study population

A total of 141 subjects were collected with a male predominance (85.6%). Mean age was 37±12.8 years and the most affected age group (42.5%) was 19–31 years. Majority of the victims (42.5%) was from the city of Sousse, more than the half lived alone (54.6%) and was day laborers. Most of them (91.5%) had no history of psychiatric illness, however 7% had a history of suicide and 3.5 % had mental disorders history (Table 1).

**Table 1.** Socio-demographic characteristics of the study population

| Socio-demographic Characteristics | | N | % |
|---|---|---|---|
| **Sex** | Male | 121 | 85.8 |
| | Female | 20 | 14.2 |
| **Age (years)** | 0-18 | 11 | 7.8 |
| | 19-31 | 60 | 42.5 |
| | 32-47 | 46 | 32.7 |
| | 48-63 | 15 | 10.7 |
| | 64-79 | 5 | 3.5 |
| | 80-95 | 4 | 2.8 |
| **city of origin** | Sousse | 60 | 42.5 |
| | Kairouan | 41 | 29.4 |
| | Others | 40 | 28. 4 |
| **Marital status** | Single | 75 | 53.2 |
| | Married | 59 | 41.8 |
| | Widow (er) | 7 | 5 |
| **Living situation** | Living alone | 77 | 54.6 |
| | Not Living alone | 64 | 45.4 |
| **Occupation** | Day laborer | 71 | 50.4 |
| | Unemployed | 26 | 18.4 |
| | Others | 44 | 31.2 |
| **Psychiatric history** | Suicide attempt | 7 | 5 |
| | Other mental disorders | 8 | 5.6 |
| | No history of mental disorders | 126 | 89.4 |

### Circumstances of the fall from height

From 2007 to 2020, the highest number of deaths was recorded in 2007 (11.3%) and in summer (34.1%) with two frequency peak of 13.5% in June and July. In 19.1% of cases, the falls happened at the beginning of the week (Monday). The time of the fall was most frequently (32.6%) between 9 pm and midnight. Majority of victims (41.8%) fell from a height of 3-6 meters followed by over 15 meters (21.3%), 9-12 m (17%), 12-15 m (15.5%) and 6-9 m (6.4%). Most of them landed on the ground (73.3%)and 20.6% at the bottom of wells (Table 2).

**Table 2.** Circumstances of the fall

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Year** | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
| **n (%)** | 16 (11.3) | 12 (8.5) | 8 (5.7) | 8 (5.7) | 10 (7.1) | 10 (7.7) | 8 (5.7) |
| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
| | 9 (6.4) | 12 (8.5) | 9 (6.4) | 9 (6.4) | 8 (5.7) | 10 (7.7) | 12 (8.5) |
| **Month** | January | February | March | April | May | June | July |
| **n (%)** | 6 (4.2) | 10 (7.1) | 15 (10.7) | 13 (9.2) | 15 (10.7) | 19 (13.5) | 19 (13.5) |
| | August | September | October | November | December | | |
| | 10 (7.1) | 12 (8.5) | 9 (6.3) | 2 (1.4) | 11 (7.8) | | |
| **Day** | Monday | Tuesday | Wednesday | Thursday | Friday | Saturday | Sunday |
| **n (%)** | 27 (19.1) | 20 (14.2) | 17 (12.1) | 14 (9.9) | 24 (17) | 18 (12.8) | 21 (14.9) |
| **Hour *** | 0-3h | 3-6h | 6-12h | 12-15h | 15-18h | 18-21h | 21-0h |
| **n (%)** | 7 (5) | 11 (7.8) | 15 (10.6) | 15 (10.6) | 24 (17) | 5 (3.6) | 46 (32.6) |
| **Height** | 3-6 m | 6-9 m | 9-12 m | 12-15 m | >15 m | | |
| **n (%)** | 59 (41.8) | 9 (6.4) | 24 (17) | 19 (13.5) | 30 (21,3) | | |
| **Receiving surface** | Ground | Wells | | | Others | | |
| **n (%)** | 109 (77.3) | 29 (20.6) | | | 3 (2.1) | | |

* Not specified:18 (12.8%)

In most cases (90.8%), the fall occurred without any intoxication, however 7.8% of the victims were on alcohol and 1.4% on psychotropic drugs

### Patients' Injury

The most affected region by orthopedic injuries were the thorax (68.9%) followed by the head/neck (43.7%), the pelvis (17.7%), the inferior member (23.4%) and the superior member (17%). Regarding orthopedic injuries, the costal fractures were predominant (52.4), particularly on the right side followed by skull fractures (31.2%), dorsa lumbar spine fractures (16.3%) and cervical spine fractures (12.7%). The distribution and frequency of orthopedic injuries were studied according to different height categories (between 3 and 9 meters, between 9 and 15 meters, and more than 15 meters) (Table 3).

Frequency of damage to thoracic region and the head or the neck increased proportionally with height of fall and was statistically significant above 9 meters ($p<0.05$). For visceral injuries, majority was intracranial injuries (43.2%) and liver was the most frequently affected intra-abdominal organ (41.1%), while heart and lungs were the least involved (16.3% and 11.3% respectively).

**Table 3.** Distribution of the body parts affected by orthopedic injuries according to the height of the fall

| Orthopedic injuries | Height of the fall | | | Total | |
|---|---|---|---|---|---|
| | 3-9 m ( n=68) | 9-15 m ( n=43) | >15 m ( n=30) | N (n=141) | (%) |
| Head/Neck (n, %) | 6 (8.8) | 29 (67.4) | 26 (86.6) | 61 | 43.2 |
| Thorax | 35 (51.8) | 32 (74.4) | 30 (100) | 97 | 68.8 |
| Pelvis | 7 (10.3) | 12 (27.9) | 6 (20) | 25 | 17.7 |
| Superior member | 14 (20.6) | 4 (9.3) | 6 (20) | 24 | 17 |
| Inferior member | 8 (11.7) | 12 (27.9) | 13 (43.3) | 33 | 23.4 |

### Cause and medico-legal forms of death

Majority of deaths (61%) was caused by polytrauma followed by cranial injuries (24.8%), thoracic injuries (4.9%), hemorrhagic shock (6.3%), and other causes in 2.8% (Table 4).

Most victims (80.8%) died as a result of an accidental fall. 19 victims (13.5%) committed suicide by jumping. Only in tow case (1.4%) there was a suspicion of homicide, and in 4.2% of cases, the medico legal form of the death was not determined.

**Table 4.** Distribution of victims according to cause of death

| Cause of death | N (%) |
|---|---|
| Polytrauma | 86 (61.0) |
| Cranial trauma | 35 (24.8) |
| Thoracic trauma | 7 (4.9) |
| Hemorrhagic shock | 9 (6.3) |
| Other | 4 (2.8) |

For accidental deaths, the majority (90.3%) was male, the most concerned age group (39.4%) was between 19 and 31 years. Two thirds of the accidental falls (75.4%) occurred in the context of work-related accidents, 16.7% of the falls happened at home and 7.9% werein other locations (Table 5).

**Table 5.** Characteristics of the victims dying as a result of accidental falls

| Characteristics | | N | (%) |
|---|---|---|---|
| **Sex** | Male | 103 | 90.3 |
| | Female | 11 | 9.7 |
| **Age range** | 0-18 | 5 | 7.9 |
| | 19-31 | 25 | 39.4 |
| | 32-47 | 14 | 32.6 |
| | 48-63 | 8 | 14 |
| | 64-79 | 3 | 3.5 |
| | 80-95 | 2 | 2.3 |
| **Location of accidental falls** | Accident at work | 38 | 75.4 |
| | Home accident | 11 | 16.7 |
| | Others | 8 | 7.9 |

Among those who died by suicide, the majority (68.4%) was male, the most concerned age group (76.9%) was between 32 and 47 years. The majority of suicidal fall victims (68.4%) had psychiatric history. (Table 6).

**Table 6.** Characteristics of the victims who committed suicide by jumping

| | | | |
|---|---|---|---|
| **Sex** | Male | 13 | 68.4 |
| | Female | 6 | 31.6 |
| **Age range** | 0-18 | 1 | 5.2 |
| | 19-31 | 6 | 31.6 |
| | 32-47 | 7 | 36.9 |
| | 48-63 | 2 | 10.5 |
| | 64-79 | 1 | 5.2 |
| | 80-95 | 2 | 10.5 |
| **Psychiatric history** | Suicide attempt | 5 | 26.3 |
| | Other mental disorders | 8 | 42.1 |
| | Not specified | 6 | 31.6 |
| **Intoxication associated** | Alcohol | 3 | 15.8 |
| | Psychotropic drugs | 2 | 10.5 |
| | Not intoxicated | 14 | 76.7 |

## DISCUSSION

Our study showed a male predominance with a sex ratio at 6.05. Similar results were found in international series on falls from great heights (3,4).This can be explained by the fact that jobs with a higher risk of falling, such as building construction, are mainly occupied by men (5).

The age range most found in our series was 19-31 years (42.5%).Two studies were conducted in India and Benin have also considered the young working population to be the most vulnerable to falls (1,6).However, other studies have shown that the mortality rate increased significantly with advancing age (6,7). Indeed, human anatomy and physiology change with age affecting the type and severity of injuries (8,9).

Psychiatric disorders are commonly associated with traumatic falls (10,11).A Taiwanese studyfound that people with mental disorders have significant morbidity and mortality related to falls (12). These disorders can also lead to suicide among adolescents (13). In our study, it was 10.6% of cases.

The most common seasons of deathswere spring and summer with 36,1% and 31,9% of cases respectively and the most common time of falls (36,1%) were between 21h and midnight.This can be explained by the fact of sleeping in balconies and on the roofs of houses during the hot seasons (1,14).

Several studies showed that severity and typology of injuries resulting from great heights fallsdepend on the fall height as well as the landing surface. Furthermore the survival chance decreased significantly beyond five floors (9,15).

The majority of cases in our series (41.8%) had fallen from 3 to 6 meters this was similar to the results in an Iranian study (62.9% of cases) (1). In addition to that, majority (77.3%) had

fallen on hard surfaces (concrete, ground...) which are considered, in biophysical terms, to be more severe and to have a greater impact on the injury record (16).

Injuries secondary to falls constitute a specific type of blunt trauma produced by fast vertical deceleration and impact forces (17). The final shape and extent of these injuries are particularly influenced by the height of the fall and the landing surface (18,19).

The most susceptible area for fractures during falls from great height was the rib cage (1,20), followed by cranial fractures (20)and limb fractures (1). It was similar in our study, which there was a predominance of rib fractures (52.4%) followed by cranial fractures (31.2%).

The number of affected areas was significantly higher as the height of the fall increased (20), which is inconsistent with our study, where the average number of affected areas was almost constant regardless of the height of the fall. Bony injuries predominated in the cranium (75%) and the rib cage (72,2%). these results were concordant with that of Venkatesh et al (21).Although certain series concluded that cranial fractures were predominant during falls regardless of the height of fall (22), others found that they predominated under 10 meters and over 30 meters (23,24)or only during low falls with the absence of a concomitant increase with higher heights (25). In our study, we found no statistically significant difference between the frequency of cranial fractures and the fall height. Nevertheless, frequency of rib cage injury increased proportionally with the height of the fall, and we also noted a statistically significant difference for falls above 9 meters ($p<0,05$). Several studies have also found this increase in the frequency of rib cage injury proportional to the increase in the height of fall (20–22).We also found a statistically significant difference between frequency of lower limb damage and height of the fall. Other series have also confirmed the significant increase in bone injuries in the limbs with increasing fall height (21,22). In addition, a Croatian studydescribed a statistically significant difference between the frequency of pelvic fracture and the height of the fall (20), but this was disproved by our series.

Regarding visceral injuries, we found that 43.2% of cases had intracranial lesions. The liver was the most frequently affected intra-abdominal organ (41.1%), followed by the spleen (20,6%).The brutal deceleration of the body caused injuries that affect mainly the intra-thoracic organs and the upper part of the abdominal organs (26) in fact it projected violently the organs, especially the full and heavy ones, in the direction of the fall, which acquired an immense kinetic energy during the impact (2). Therefore, the large surface area of the liver and the high mobility of the spleen could explain our results.The heart and lungs were the least involved, in only 16.3% and 11.3% of cases respectively. Indeed the thoracic cage protect these organs, particularly for falls of low height (1). In contrast, an Italian study found that the heart and lungs were frequently affected during falls from great heights. This was explained by the large surface area of the lungs as well as the significant risk of injury from fractured ribs or «rib danger» (26). Concerning the kidneys, no case was described in our series. This could be explained by their location and their small dimension (1). Other studies have found that as the height of the fall increased, the incidence of intra-thoracic and intra-abdominal organ injury also increased (22,24).

In our series, only 7.8% of the cases had alcohol intoxication and 1.4% were on psychotropic drugs. Several studies have reported the influence of intoxication on the injury outcome during falls from great heights (25). Indeed, alcohol consumption causes orthostatic hypotension, which is highly predictive of falls (27). Other series have disproved this influence (28).

Cranial trauma was found to be the leading cause of death in falls from great heights (1,2).It was also the leading cause of death among children who fell from heights (29). Although,we found that the majority of deaths (61%) were secondary to polytrauma and only 24.8% to isolated cranial trauma.

Medico-legal forms of falls were accidental, suicidal and criminal falls.For accidental falls we found that 42.5% of the victims belonged to the young working population aged between 19 and 31 years and 85.8% of the victims were male. These findings were similar by the majority of series (9,14,30). Indeed, the curious and adventurous behavior of young male individuals, as well as their impulsiveness, could explain the frequency of this type of accident among them.More than two thirds of the falls from height of accidental origin (75.4%) were in the context of accidents at work, related to the construction of buildings. In fact, the construction field was among the most accident generating fields in the world (31), it was responsible for the highest rate of fatal accidents (32). Suicide by jumping is the third most common method of suicide in Europe, after intoxication and hanging (33), particularly among young people (34). However, in our work, it was found in only 13.5% of cases. The majority (36,4%) of suicide patients were aged between 19 and 31 years. This was supported by most series where suicidal jumping was seen in younger patients (33,35). We also found a male predominance (68.4%) as in other series (35). But, some authors have found that suicidal jumping is more common among females (14,27,33,36), especially those who are single (14).In our work, more than half of suicidal subjects had a psychiatric history (54,5%). People with mental illness were more likely to use suicide by jumping as a suicide modality (37), especially those suffering from schizophrenia (33,36).Falls due to criminal cause were considered to be rare or absent (5,9,14,27). This was confirmed by our series where only tow case with strong suspicion of homicide was described (1,4%). It is difficult for the forensic physician to identify whether a fall from a great height was accidental, voluntary, or due to a pushing accident particularly for an initial launch speed of less than 2 meters per second (38). Although, an initial launch speed higher than 2,7 meters per second indicates a suicidal origin (39).

## CONCLUSION

Falls from great heights mainly concern the young male. The majority of the victims fell from a height between 3 and 6 meters, on a solid surface. Costal fractures were predominant inbone injuries, the frequency of rib cage injury increased proportionally with the height of the fall and there was a statistically significant difference in the prevalence of rib cage injury when comparing the two groups of less than and more than 9 meters. The cause of death was related to polytrauma in most cases and concerning the medical-legal form of death, we noted a predominance of deaths from accidental falls from height due to work-related accidents.

In cases of high falls, a forensic autopsy is essential to make a complete evaluation of the injuries, to search for a correlation between the severity of the injuries and the height of the fall and to orientate towards the medico legal form of the fall.

Finally, we would also like to suggest some safety measures to prevent these falls, in particular awareness campaigns should be launched to make people more aware of the risks of falls at home but also in the workplace.

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