ORIGINAL ARTICLE

Factors affecting mortality caused by falls from height

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ABSTRACT

BACKGROUND: Falls from height are among the most common trauma cases presenting to emergency departments and often cause mortality and morbidity. In the present study, we aimed to determine the factors that effectively reduce mortality caused by falls from height.

METHODS: Data from 2252 trauma patients who presented to Dicle University Emergency Service between January 2005 and December 2008 due to falling from height in the Southeastern Anatolia region were retrospectively analyzed. We analyzed the parameters that are considered to have a positive effect on mortality, which included the following: month of fall; age; gender; etiology; place of fall; type of ground on which the patient fell; height of fall; intubation; hypotension; tachycardia; neck, head, thoracal, abdominal, pelvic, and extremity injuries; Glasgow Coma Score (GCS); Injury Severity Score (ISS); and Revised Trauma Score (RTS).

RESULTS: There were 1435 males (63.7%) and 817 females (36.3%) included in the study. Two thousand thirty-one (94.6%) patients survived the fall while 121(5.4%) died. The mean age of the surviving patients was 15.55±18.60 years, while the patients who died had a mean age of 29.59±28.93 years. The mean height of the fall of the survivors' was 3.09 meters, and the mean height of the fall for those that died was 6.61±5.73 meters ($p<0.001$).

CONCLUSION: The mean fatal height of the fall in falls from height is 6.61 m. Age, attempted suicide, height of fall, type of ground on which the patient fell, place of fall, and head, thoracic, and abdominal trauma are the primary factors affecting mortality caused by falls from height.

Key words: Fall from height; height of fall; hemopneumothorax; mortality; subarachnoid hemorrhage.

INTRODUCTION

Falls from height are a leading cause of traumas, second only to traffic accidents. They are the most common cause of trauma in childhood, and are responsible for 5.90% of all deaths during childhood in developed countries.[1] In addition, falls rank first among admissions to emergency services related to trauma and injuries,[2] and account for 25-34% of admissions to the emergency room in the United States of America.[3] Falls from height cause blunt body trauma. Many factors can affect the prognosis, such as age, fall height, cause of fall, type of ground on which the patient fell, the injured body parts, and organ injury. In this study, we aimed to examine the factors affecting mortality caused by falls from height.

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MATERIALS AND METHODS

Data from 2252 trauma patients who presented to Dicle University Emergency Service between January 2005 and December 2008 due to falling from height in the Southeastern Anatolia region were retrospectively analyzed. Patients were consecutively enrolled. All patients were examined by emergency services. All patients were resuscitated according to the ATLS (Advanced Trauma Life Support) program and were diagnosed and treated in compliance with available protocols. Detailed information about the trauma was obtained from the patient, the patient's family, paramedics, police records, or witnesses. Patient data were recorded on standard forms. Patients with incomplete or missing data or those having trauma from simple falls, falls from moving vehicles (cars, bicycle, horse-donkey), electric shock, or those who were dead at presentation were excluded from the study.

To assess mortality rate, patients were divided into the following two groups: survivors and those that died. We examined parameters considered important for mortality as follows: month of fall; age; gender; cause of fall (workplace accident, suicide, other accidents); place of fall (fall off the roof, balcony, window, stairs, tree, domestic furniture, construction scaffold, hammock, lap); other types of fall (fall into

a hole, stairwell, elevator shaft, well, fall off the wall, cliffs); type of ground on which the patient fell; fall height; intubation; hypotension; tachycardia; neck, head, thoracic, pelvic, abdominal, and extremity injuries; GCS; ISS; and RTS.

Univariate analyses were performed using the Chi-Square test (X^2) for categorical variables and the Student's t test for continuous variables. Multivariate logistic regression analysis (Backward-Wald Step-Wise Model) was used to detect risk factors for mortality. Continuous variables are presented as Mean ± SD (Standard Deviation). A *p* value less than 0.05 was considered statistically significant.

RESULTS

Among the 2252 trauma patients presenting with fall from height, 1435 (63.70%) were male and 817 (36.30%) were female. Two thousand one hundred and thirty-one (94.60%) patients survived and 121 (5.40%) died. Among those who died, 84 (69.40%) were male and 37 (30.60%) were female (Table 2).

The patients ranged in age from 1 month to 95 years, with 48% between 4-15 years of age. The greatest number of presentations occurred in August, and the most common mode of fall was falling off the roof. Table 1 presents the patient distribution in terms of age, season, place, cause, and type of ground on which the falls occurred.

Assessing the patient mortality in terms of age revealed that those patients between 7-15 years and 4-6 years had the lowest mortality (2.35%, p=0.001; 3.45%, p=0.015, respectively) while patients aged 55 years or greater had the highest mortality (19.20%, p=0.001). Suicidal falls had the highest mortality (20.50%, p=0.001). Furthermore, 79.50% of suicidal falls were from greater than 7 meters and 46.20% were from more than 10 meters. Mortality rates in terms of place of fall, in descending order, were falls from roofs, balcony/windows, and construction scaffolds (p=0.001, p=0.018, and p=0.023, respectively). Also, the outcomes of patients falling on solid grounds compared to those falling on soft grounds were statistically significant (p<0.001). The effects of fall height were also statistically significant, with mortality increasing as fall height increases. Among the 71 patients already intubated at admission, 24 (33.80%) survived and 47 (66.20%) died. Forty-eight (65.80%) of the 73 patients who presented with hypotension survived while 25 (34.20%) died. Among 264 tachycardic patients, 191 (72.30%) survived and 73 (27.70%) died. Mortality was higher among intubated, hypotensive, and tachycardic patients (p<0.001). Clinical and demographic data of the patients that died and those that survived are presented in Table 2.

The ratios of system injuries in surviving and dying patients are presented in Table 3. The effect of head, thoracic, abdominal, and maxillofacial trauma on mortality was statistically significant (p<0.001, p=0.003). Among pathologies related to head trauma, neurologic deficit, cerebral edema, cranial fracture, epidural hematoma (EDH), subdural hematoma (SDH), subarachnoid hemorrhage (SAH), intracerebral hematoma (ICH), cerebral contusion, and pneumocephalus had a statistically significant effect on mortality. (p=0.008, p<0.001, p=0.006,

Table 1. Demographic characteristics of cases with fall from height

	n	%
Age distribution (years)		
0-3	495	22
4-6	521	23
7-15	552	25
16-25	204	9
26-54	303	13
≥55	177	8
Seasonal distribution		
January	82	3.64
February	71	3.15
March	121	5.37
April	164	7.28
May	189	8.39
June	272	12.07
July	336	14.96
August	386	17.14
September	244	10.83
October	191	8.48
November	81	3.59
December	115	5.10
Cause of fall		
Workplace accident	153	7
Suicide	39	2
Other accidents	2060	91
Place of fall		
Roof	1056	46.90
Balcony/window	98	4.35
Stairs	162	7.19
Tree	104	4.61
Domestic furniture	78	3.46
Construction scaffold	103	4.57
Hammock	20	0.90
Lap	21	0.90
Others	608	27
Ground of fall		
Soft	493	21.90
Hard	1759	78.10

Table 2. Clinical and demographic data of patients that died and those that survived

	Survived		Died		Total		*p*
	n	%	n	%	n	%	
Gender distribution							
Male	1351	94.10	84	5.90	1435	100	
Female	780	95.50	37	4.50	817	100	0.206
Total	2131	94.60	121	5.40	2252	100	
Age distribution (years)							
0-3	468	94.55	27	5.45	495	100	0.501
4-6	503	96.55	18	3.45	521	100	0.015
7-15	539	97.65	13	2.35	552	100	0.001
16-25	193	94.60	11	5.40	204	100	0.544
26-54	285	94.05	18	5.95	303	100	0.359
≥55	143	80.80	34	19.20	177	100	0.001
Cause of fall							
Workplace accident	140	91.50	13	8.50	153	100	0.091
Suicide	31	79.50	8	20.50	39	100	0.001
Others	1960	95.10	100	4.90	2060	100	0.001
Place of fall							
Roof	981	92.90	75	7.10	1056	100	0.001
Balcony/window	87	88.80	11	11.20	98	100	0.018
Stairs	156	96.30	6	3.70	162	100	0.467
Tree	103	99	1	1	104	100	0.041
Domestic furniture	77	98.70	1	1.30	78	100	0.124
Construction scaffold	92	89.30	11	10.70	103	100	0.023
Hammock	18	90	2	10	20	100	0.292
Lap	21	100	0	0	21	100	0.625
Others	594	97.70	14	2.30	608	100	<0.001
Ground of fall							
Soft	491	99.60	2	0.40	493	100	<0.001
Hard	1640	93.20	119	6.80	1759	100	
Fall height							
3 m or lower	1663	97.70	39	2.30	1702	100	<0.001
3.1-6 m	345	88.70	44	11.30	389	100	<0.001
6.1-9.9 m	57	85	10	15	67	100	0.003
10 m or higher	66	70.20	28	29.80	94	100	<0.001
Intubation	24	33.80	47	66.20	71	100	<0.001
Hypotension	48	65.80	25	34.20	73	100	<0.001
Tachycardia	191	72.30	73	27.70	264	100	<0.001

p=0.002, p=0.001). The effect of orbital fracture in maxillofacial trauma on mortality was statistically significant (p=0.021). Among thoracic injuries, rib fracture, pneumothorax, lung contusion, and hemopneumothorax had a statistically significant effect on mortality (p<0.001). Intraabdominal free fluid presence in abdominal trauma was significantly associated with mortality (p<0.001). The effect of pelvic fracture in extremity traumas on mortality was also significant (p<0.05).

Surviving patients (n=2131) had a mean age of 15.55±18.60 years, a mean fall height of 3.09 meters, a mean RTS of 11.90±0.46, a mean ISS of 8.76±7.63, and a mean GCS of

Table 3. Distribution of patients that died and those that survived by system injuries

	Survived		Died		Total		*p*
	n	%	n	%	n	%	
Head trauma	505	85	89	15	594	100	<0.001
Neurologic deficit	19	79.20	5	20.80	24	100	0.008
Diffuse axonal injury	2	67.70	1	33.30	3	100	0.153
Cerebral edema	140	79.10	37	20.90	177	100	<0.001
Cranial fracture	372	86.30	59	13.70	431	100	<0.001
Epidural hematoma (EDH)	66	86.80	10	13.20	76	100	0.006
Subdural hematoma (SDH)	54	68.40	25	31.60	79	100	<0.001
Subarachnoid hemorrhage (SAH)	22	37.90	36	62.10	58	100	<0.001
Intracerebral hematoma (ICH)	19	76	6	24	25	100	0.002
Cerebral contusion	61	84.70	11	15.30	72	100	0.001
Pneumocephalus	56	77.80	16	22.20	72	100	<0.001
Maxillofacial trauma	114	92.70	9	7.30	123	100	0.003
Maxillar fracture	26	86.70	4	13.30	30	100	0.074
Mandibular fracture	25	92.60	2	7.40	27	100	0.654
Orbital fracture	46	86.80	7	13.20	53	100	0.021
Nasal fracture	28	96.60	1	3.40	29	100	1
Thoracic trauma	92	76.70	28	23.30	120	100	<0.001
Rib fracture	42	75	14	25	56	100	<0.001
Sternal fracture	0	0	1	100	1	100	0.054
Hemothorax	27	81.80	6	18.20	33	100	0.070
Pneumothorax	25	69.40	11	30.60	36	100	<0.001
Lung contusion	25	71.40	10	28.60	35	100	<0.001
Hemopneumothorax	8	61.50	5	38.50	13	100	<0.001
Abdominal trauma	300	89.30	36	10.70	336	100	<0.001
Intraabdominal free fluid	281	89.50	33	10.50	314	100	<0.001
Hepatic injury	34	87.20	5	12.80	39	100	0.055
Splenic injury	53	91.40	5	8.60	58	100	0.237
Retroperitoneal hematoma	2	66.70	1	33.30	3	100	0.153
Renal injury	22	91.70	2	8.30	24	100	0.373
Urinary bladder injury	1	50	1	50	2	100	0.105
Extremity trauma	563	95.30	28	4.70	591	100	0.459
Cervical vertebral fracture	10	83.30	2	16.70	12	100	0.133
Thoracic vertebral fracture	46	93.90	3	6.10	49	100	0.745
Lumbal vertebral fracture	81	94.20	5	5.80	86	100	0.806
Sacral vertebral fracture	6	100	0	0	6	100	1
Scapular fracture	16	18.80	3	81.20	16	100	0.051
Clavicular fracture	21	84	4	16	25	100	0.042
Humeral fracture	111	94.10	7	5.90	118	100	0.678
Radial fracture	153	96.20	6	3.80	159	100	0.465
Ulnar fracture	92	95.80	4	4.20	96	100	0.816
Femoral fracture	165	93.20	12	6.80	177	100	0.384
Tibial fracture	56	94.90	3	5.10	59	100	1
Fibular fracture	40	95.20	2	4.80	42	100	1
Metacarpal fracture	6	100	0	0	6	100	1
Metatarsal fracture	5	100	0	0	5	100	1
Calcaneal fracture	51	91.10	5	8.90	56	100	0.223
Pelvic fracture	79	88.80	10	11.20	89	100	0.026

Table 4. Mean values of age, fall height, and trauma scores

	Result	n	Mean	SD*	p
Age	Died	121	29.59	28.93	<0.001
	Survived	2131	15.55	18.60	
Fall height (m)	Died	121	6.61	5.73	<0.001
	Survived	2131	3.09	2.77	
RTS	Died	121	8.14	3.55	<0.001
	Survived	2131	11.90	0.46	
ISS	Died	121	24.72	9.13	<0.001
	Survived	2131	8.76	7.63	
GCS	Died	121	7.74	4.29	<0.001
	Survived	2131	14.37	1.82	

SD: Standard deviation.

14.37±1.82. The 121 patients that died had a mean age of 29.59±28.93 years, a mean fall height of 6.61±5.73 meters, a mean RTS of 8.14±3.55, a mean ISS of 24.72±9.13, and a mean GCS of 7.74±4.29. Fall height, age, RTS, ISS, and GCS had statistically significant effects on mortality (p<0.001) (Table 4).

All variables shown in univariate analyses to be effective on mortality (p<0.05) were included in logistic regression. In multivariate analysis, hemopneumothorax (95% confidence interval=9.621-939.915, Odds Ratio=9509.23, p=0.009), and SAH (95% confidence interval=4.747-157.928, Odds Ratio=2737.96, p=0.015) were the most significant independent variables affecting mortality.

DISCUSSION

Falls from height constitute a large number of trauma patients presenting to emergency services. The factors affecting mortality in falls are very complex.

Injuries due to falls from height are usually severe multi-organ injuries related to the skeletal muscles and solid organs.[4] The mortality risk is affected by the fall height, the body part hitting the ground, and the type of ground on which the fall occurred.[5] Mortality and morbidity of trauma in falls from height depend on impact velocity, the injured organ(s), and the resulting pathologies.[6-8] Deaths due to falls from height result from multiple blunt traumas, especially head trauma.[9]

Al et al.[10] reported a mortality rate of 2.20% due to falls from height. That study included all cases presenting with trauma due to a fall, as did our current study. Falls from higher heights often have greater mortality than those that are from lower heights. Liu et al.[11] reported a mortality rate of 22.70% due to falls from above 6 m, while Lapostolle et al.[12] reported a mortality rate of 33.80% due to falls from above 3 m. In our study, the mortality rate due to falls from above 10 m was similar to the figures derived from those studies.

In the study by Yagmur et al.[13] 67 of 1220 patients died from falls from height, and 29 of these patients were older than 15 years. Goren et al.[14] studied 484 postmortem cases, and found that their mean age was 27.05 years (range 4-100 years). Agalar et al.[15] reported that age was one of the important prognostic factors affecting the severity of the trauma after vertical free fall. Lapostolle et al.[12] found that age was one of the independent prognostic variables in those who died from falls from height. Another study reported that children younger than 3 years sustained fewer injuries than did older children falling from the same height. The authors hypothesized that this is because the younger children have more fat and cartilage and a lesser amount of muscular tissue, which leads to a better transfer of energy.[16] Driscoll et al.[17] reported that 44% of patients older than 75 years had fatal falls from height and that the mortality risk increased as age increased above 55 years. We also found that mortality was the highest in those older than 55 years, while the mortality rates were significantly lower in those patients between 4-6 years and 7-15 years. We believe that the anatomic and physiologic differences between children and the elderly may cause the significant differences in mortality between these groups.

In the study by Goren et al.,[14] of the 484 postmortem cases examined, 431 were related to accidents while 53 were related to suicide attempts. In the study by Lapostolle et al.,[12] 123 of 287 cases were due to suicide and 45.50% of them died. In our study, the rate of mortality in suicide cases was lower than that reported by Laposotlle et al. This is most likely because the patients in that study fell from a height ≥ 3 m. We speculate that the increased fall height was an important factor for the relationship between the suicide cases and mortality.

Yagmur et al.[13] reported a mortality rate of 5.80% in 1643 cases that fell off the roof. Goren et al.[14] found that the majority of deaths due to falls were due to falls from the roof

(56, 36.7%), balcony (108, 25.1%), and stairs (57, 13.2%). Falls off the rooftops, balcony/windows, and construction scaffolds are most likely more fatal since they often occur from an increased fall height, land on a solid ground, and lead to a higher rate of life-threatening injuries such as head, thoracic, and abdominal injuries.

The type of ground on which the fall occurs, the mode of the fall, and the general health status of the victim are the most important factors influencing the severity of the injury.[12,18] In our study, falling on solid ground increased severity of trauma and organ damage, and therefore we determined that it was a major factor affecting mortality.

The severity of the injury is typically proportional to the fall height.[19] Most childhood fatalities from falls occur from floor 3 or above.[20,21] Scalea et al.[22] reported a mortality rate of 4.90% in patients falling from 3 meters or above. In a retrospective study, Liu et al.[11] reported a mortality rate of 22.70% in 66 patients falling from 6 meters or above. Hawley et al.[23] reported a significantly increased mortality in patients falling from 6 meters and reported a threshold of 6 meters for fatal fall heights for individuals below 15 years of age. In our study, compared with mortality of falls from 3 m or below, the mortality rates associated with falls from 3-6 m, 6-10 m, and 10 m and above were increased 5, 6.50, and 13 times, respectively (Table 2). Based on this data, we predict a lower mortality in falls from 3 m or below but expect a higher mortality in falls from 6-10 m and above.

An association between hypotension and tachycardia, which are important symptoms of blood loss in major trauma, and mortality has been reported in literature.[24] Many studies have reported an increased mortality in intubated patients.[25-27] The mortality rates of patients in our study who arrived intubated, hypotensive, and tachycardic were consistent with the literature findings.

Goren et al.[14] found that the most frequently affected body part was the head (91%) in 484 postmortem cases that had fallen or jumped from height. The other effected body parts, in descending order, were thorax (54%), abdomen (37%), extremities (36%), and neck (17%). A study from India that autopsied 80 patients who died from falls from height reported that head traumas were associated with the highest mortality.[28] Multiple organ failure and brain injury were the most common causes of death in another study examining falls from height.[29] Consistent with the literature, in our study, the patients who died most commonly had head trauma.

Goodacre et al.[30] reported head trauma as a factor affecting mortality. Lapostolle et al.[12] identified age, fall height, ground of fall, and the first body part hitting the ground as the independent prognostic factors affecting mortality in cases falling from above 3 m. Liu et al.[11] reported head trauma and chest trauma as mortality factors, and reported severe head trauma as an independent prognostic mortality factor. These studies reported an association between the affected body part and mortality, but did not report a relationship between the clinical diagnosis at the affected part and mortality. We examined both the affected body part and the relationship between the clinical diagnoses and mortality and found that SAH and hemopneumothorax were independent prognostic factors affecting mortality.

In conclusion, the mean fatal height in falls from height is 6.61 m. Age, suicide, fall height, type of ground on which the fall took place, place of fall, as well as head, thoracic, and abdominal trauma affect mortality. Hemopneumothorax and SAH were the most important independent factors affecting mortality in our study.

Conflict of interest: None declared.

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KLİNİK ÇALIŞMA - *ÖZET*

Yüksekten düşmelerde mortaliteyi etkileyen faktörler

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AMAÇ: Acil servislere başvuran travma hastaları içinde yüksekten düşmeler ilk sırada yer alır ve önemli oranlarda morbidite ve mortaliteye neden olur. Çalışmamızda yüksekten düşmelerde mortalite üzerine etkili faktörleri araştırmayı amaçladık.

GEREÇ VE YÖNTEM: Bu çalışmada Ocak 2005 ile Aralık 2008 tarihleri arasında Güneydoğu Anadolu bölgesinde yüksekten düşme ile gelen ve Dicle Üniversitesi Hastanesi Acil Servisinde tedavi edilen 2252 travmalı hastaya ait veriler geriye dönük olarak analiz edildi. Mortalite üzerinde etkili olabileceğini düşündüğümüz; düşmenin olduğu ay, yaş, cinsiyet, düşme nedeni, düşme yeri, düşme zemini, düşme yüksekliği, entübasyon, hipotansiyon, taşikardi, baş boyun, göğüs, karın, pelvis, ekstremite yaralanması, Glasgow Koma Skalası (GKS), Injury Severity Score (ISS) ve Revize Travma Skoru'nu (RTS) içeren parametreleri inceledik.

BULGULAR: Çalışmaya alınan hastaların 1435'i (%63.7) erkek, 817'si (%36.3) kadındı. Hastaların 2131'i (%94.6) yaşadı, 121'i (%5.4) öldü. Yaşayan hastaların yaş ortalaması 15.55±18.60 yıl, düşme yüksekliği ortalaması 3.09 metre iken, ölen hastaların yaş ortalaması 29.59±28.93 yıl, düşme yüksekliği ortalaması 6.61±5.73 metre idi ($p<0.001$).

TARTIŞMA: Yüksekten düşmelerde ölümcül düşme yüksekliği ortalaması 6.61 m'dir. Yaş, intihar, düşme yüksekliği, düşme zemini, düşme yeri, kafa travması, göğüs travması ve karın travması mortaliteyi etkileyen faktörlerdir.

Anahtar sözcükler: Yüksekten düşme; düşme yüksekliği; hemopnomotoraks; mortalite; subaraknoid kanama.

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