Epidemiological, Clinical and Hematological Findings in Feline High Rise Syndrome in Israel: A Retrospective Case-Controlled Study of 107 Cats

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ABSTRACT

Feline high rise syndrome (HRS) is commonly observed in cats in Israel. This retrospective case-controlled study characterizes HRS in Israel, and describes, to the best of the authors' knowledge, for the first time, the hematological findings and their prognostic value in HRS. The study included 107 cats with HRS, 482 ill negative controls and 59 healthy, blood donor cats. Cats with HRS were younger when compared to the ill negative controls. Orthopedic injuries occurred in 48% of cats, most frequently involving the hind limbs. Respiratory system injuries were significantly associated with falls from floor three to six, while head injuries mostly occurred in falls from lower floors. Survival was negatively associated with the height of the fall. Shock was associated with longer hospitalization. Cats with HRS had a significantly lower leukocyte counts compared to controls, and a higher proportion of band neutrophils. The frequency of monocytosis was significantly higher in survivors when compared to non-survivors. It would appear that the hematological findings and differential count dissimilarities between surviving and non-surviving cats with HRS have no prognostic value. Mortality was associated with subcutaneous emphysema, hypothermia, abdominal and spinal injuries. The overall survival rate was 83% (89/107 cats), however, when euthanized cases (12 cats) were excluded, the survival rate was 93.7%% (89/95 cats).

Key Words: Pneumothorax, head trauma, fracture, orthopedic, complete blood count, leukocyte.

INTRODUCTION

The combination of injuries sustained by cats falling or jumping from heights exceeding 8 meters (24 feet, or 2 floors) is known as high rise syndrome (HRS) (1, 2). It was initially described as a triad of presenting clinical signs, including epistaxis, cleft palate, and pneumothorax (1), however, the clinical signs associated with HRS are not limited to this classic triad of injuries. Mandibular symphysis fracture, temporomandibular joint (TMJ) luxation and pulmonary contusion have also been recognized as common signs in HRS (1). More recently, it has been reported that orthopedic injuries of the extremities occur more frequently in HRS than the classic triad of injuries (3).These findings have led to a broader definition of the common characteristic injuries associated with HRS (3).

The epidemiology of feline HRS has been previously described in several reports (2-7). Most cats with HRS are young, with cats younger than one year of age comprising a third to a half of the cases, with no differences between the sexes (2, 4, 6, 7). The discrepancy in the reported proportions of intact versus neutered cats with HRS is likely due to cultural differences and variations in the feline population control regulations (2-4, 6). Seasonal variation have also been reported, with increased incidence when environmental temperatures are comfortable (1, 3, 4, 6).

The association between the number of injuries and the height of fall has been described as curvilinear (2, 6), and linear (5). Two studies have recorded that an increase in the height of the fall beyond a certain threshold was not associated with a proportional increase in the number of injuries (2, 6). In another study, in contrast, the number of thoracic injuries have been reported to increase with the increasing height of the fall (5).In spite of the multi-traumatic nature of feline HRS, survival rates are high, ranging from 88% to 97.3% (2-7).

In human medicine, significant associations have been reported between clinical signs and hematological parameters in trauma patients (9). Trends in the leucogram have been investigated to explore their prognostic value in human patients with severe blunt trauma. It has been reported that during the first two hours post injury, neutrophil numbers increase above the reference interval (RI). The lymphocyte count increases during the first hour post trauma, and later decreases, over the following two hours (8). Both lymphocytosis and lymphopenia were predictive for a poor prognosis following blunt trauma, probably due to changes in lymphocyte numbers over time (8). A study evaluating early leukocytosis in human trauma patients concluded that variations in white cell count (WCC) are associated with race and the severity of injury, but such changes were not useful for predicting the need for IV fluid volume resuscitation, transfusion, or surgery (9). Additionally, changes in neutrophil morphology were noted in trauma patients, such as an increase in band neutrophil numbers, even when infection was absent (10). No information regarding the hematology of cats with HRS in general, and particularly on the leucogram, is available in the literature. In contrast with the human medicine literature, there is paucity of reports of the associations of leucogram changes due to mechanical trauma in veterinary trauma patients of any species.

The aims of this retrospective study were to characterize feline HRS in Israel, and to compare some characteristics of cats with HRS to negative control populations, of ill, hospitalized cats and healthy cats. In addition, the hematological findings in HRS cats were characterized, compared to the control populations and their predictive value was evaluated.

MATERIALS AND METHODS

Selection of cats and collection of data

The medical records of the Hebrew University Veterinary Teaching Hospital, from 1999 to 2009 were reviewed retrospectively. Cats presented with HRS were included in the study if they fell from a height of the first floor or above (4 m or above, as most apartment buildings in Israel are built on pillars), had no other concurrent disease unrelated to the fall based on the history, physical examination and other tests performed, and presented to the HUVTH within 24 hours of the fall. Data were retrieved from their medical records. Non-survivors included cats that died due to the injuries sustained or other disease processes, as well as euthanized cases.

The HRS population was compared to two control populations. One comprised of 482 ill cats, presented to the HUVTH during the study period, and diagnosed with diseases other than HRS. These served solely to compare the signalment with the HRS group. The second control group comprised of 59 healthy cats presented for blood donation, to the HUVTH Blood Bank. This group was used to compare the WCC and leukocyte differential count with the HRS group. These cats were deemed healthy based on a normal physical examination and negative serological tests for feline immunodeficiency virus and feline leukemia virus.

Laboratory methods

Samples for CBC were collected in potassium-ethylenediamineteteraacetic acid and analyzed within 30 minutes from collection using automatic impedance hematology analyzers (Abacus or Arcus, Diatron, Wien, Austria). A100-cell differential leukocyte count (WCC) was performed manually in modified Wright's-stained blood smears by a single clinician (IA), blinded to the clinical data of the cats. The WCC was corrected for the number of nucleated red blood cells. Total plasma protein (TPP) was measured on plasma from centrifuged blood collected in heparin-containing capillary tubes using a standard clinical refractometer, calibrated weekly with distilled water.

Definitions of complications and types of injuries

Cats presenting with the following concurrent clinical signs were considered to be in shock; tachycardia (> 140 beats/minute), tachypnea (> 40 breaths/minute), weak femoral pulse, pale mucous membranes, hypothermia (rectal temperature < 37°C) and cold extremities. Pneumothorax was diagnosed based on physical examination findings as well as either the presence of free air in the chest cavity upon thoracocenthesis or compatible radiographic findings when

Table 1: Classification, categories and frequency of injuries, in 107 cats with high rise syndrome treated at the Hebrew University Veterinary Teaching Hospital (1999-2009)

Injury or clinical sign	n[1]	%
Head injuries		
Facial wound	28	26.2
Ocular injury	10	9.3
Epistaxis	9	8.4
Broken teeth	6	5.6
Cleft hard palate	6	5.6
Mandibular symphysis fracture	4	3.7
Temporomandibular junction subluxation	1	0.9
Respiratory signs and injuries		
Pneumothorax	23	21.5
Lung contusion	20	18.7
Dyspnea	13	12.1
Abnormal breath sounds	13	12.1
Rib fracture	9	8.4
Pleural effusion	8	7.5
Thoracic subcutaneous emphysema	6	5.6
Pneumomediastinum	2	1.9
Abdominal signs and injuries		
Abdominal pain	10	9.3
Hematuria	5	4.7
Urinary bladder rupture	2	1.9
Hemoabdomen	1	0.9

Injury or clinical sign	n[1]	%
Front limb injuries		
Humeral fracture	7	6.5
Radioulnar fracture	5	4.7
Carpal fracture	5	4.7
Scapular fracture	1	0.9
Pelvic limb injuries		
Pelvic fracture	17	15.9
Pelvic luxation	13	12.1
Tibiofibular fracture	13	12.1
Femoral fracture	8	7.5
Tarsal fracture	6	5.6
All limb injury	13	12.1
Perineal injuries		
Perineal soft tissue injury	10	9.3
Neurologic injuries		
Caudal spinal trauma	10	9.3
Head trauma	8	7.5
Cranial spinal trauma	3	2.8
Shock signs		
Pale mucous membranes	12	11.2
Hypothermia	10	9.3
Weak femoral pulse	3	2.8
Cold extremities	2	1.9

1, number of cats.

thoracic radiography was performed. Soft tissue injuries included non-orthopedic limb injuries or perineal lesions.

The injuries of cats with HRS were divided into seven categories, based on their nature, location and the body system or systems involved (Table 1). Lesions and related clinical signs within each category were subdivided based on their specific location and nature (Table 1). For the statistical analysis, particular injuries were treated as categorical variables (i.e., present or absent) while their severity was not statistically assessed. For each HRS cat, an injury category score (ICS) and a total injury score (TIS) were calculated. The ICS was the total number of different injury categories, and ranged from zero to seven (i.e., score zero for uninjured cats and score seven for cats injured in all categories). The TIS was the sum of individual injuries or abnormalities, and ranged from zero to 36 (i.e., zero for uninjured cats, and 36 for cats with abnormalities in all type of injuries). The fall height was defined by the floor number. For the purpose of further statistical analysis, floors were grouped into low (1st and 2nd), medium (3rd to 6th) and high (7th floor or higher) floors.

Statistical analysis

The distribution (normal versus non-normal) of continuous parameters was assessed using the Kolmogorov-Smirnov test. Categorical variables of two groups were compared using Chi-square or Fisher's exact tests. Continuous variables were compared between two groups using Student's *t*-test or Mann-Whitney *U*-tests, depending on data distribution. The association between continuous and categorical variables was assessed using analysis of variance (ANOVA) or Kruskal-Wallis test, depending on data distribution. The association of multiple variables with dependent variables was analyzed using multivariate ANOVA or covariance analysis. All tests were two-tailed, and $P \leq 0.05$ was considered statistically significant. Calculations were performed using statistical software package (SPSS 17.0, SPSS Inc., Chicago, IL).

RESULTS

The study included 107 cats with HRS, 482 negative controls and 59 healthy blood donor cats. The mean age of the ill control cats (healthy donors excluded) was 76.1 months (standard deviation 61.2) compared to 35.0 months (standard deviation 39.3) in the HRS cats. Cats with HRS were

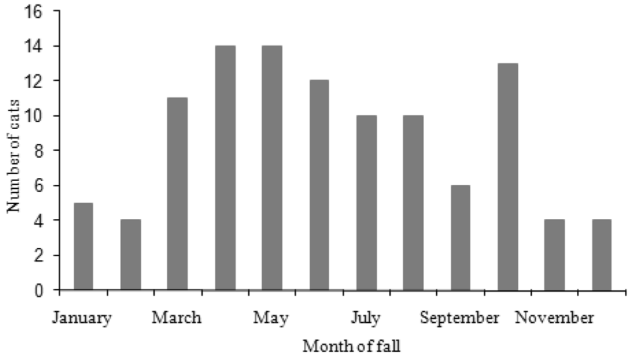

Figure 1: Monthly distribution of the fall in 107 cats with high rise syndrome at the Hebrew University Teaching Hospital (1999-2009). Most falls occurred between April and June and in October.

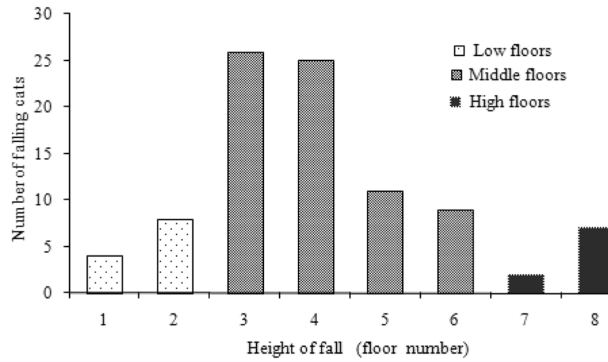

Figure 2: Distribution of cats falling from the different floors with subdivision into low, middle and high floors in 92 cats with high rise syndrome at the Hebrew University Teaching Hospital (1999-2009), showing most falls occurred from the third and fourth floors.

significantly younger compared to the ill negative controls ($P<0.001$). The proportion of cats aged less than one year old was significantly ($P<0.001$) higher in the HRS group compared to the ill, negative controls (51/107, 48% *vs*. 69/443, 16%, respectively). In the HRS group, 60 (57%) were males (32 were castrated, 53%) and 46 (43%) were females (22 were spayed, 48%), with no significant differences in gender and intact/neutered status between the HRS group and the expected 1:1 female to male ratio or between this group and the ill, negative controls. The seasonal incidence and heights of the falls (recorded in 92/107 cats), are presented in Figures 1 and 2, respectively. Twelve cats (13%) fell from low floors, while 71 (77.2%) fell from middle floors and 9 from high floors (9.8%).

The type and category of injuries sustained by the 107 cats with HRS are presented in Table 1. Orthopedic injuries occurred in 51/107 cats (48%), mostly involving the hind limbs. Other recorded injury categories included respiratory system-related injuries (49 cats, 46%), facial injuries (40, 37%), soft tissue injuries (33, 31%), neurological lesions (23, 22%), shock (16, 15%) and abdominal injuries (16, 15%).

There was a significant association ($P=0.019$) between

Table 2: Selected* types of injury, grouped by height of fall, in 92 cats** with high rise syndrome treated at the Hebrew University Veterinary Teaching Hospital (1999-2009)

Injury type or abnormality	Presence of injury	Low floors[1] n[4] (%)		Middle floors[2] n[4] (%)		High floors[3] n[4] (%)		All cats n[4] (%)		*P* value
Carpal fracture	Present	0	(0%)	0	(0%)	3	(33.3%)	3	(3.3%)	0.001
	Absent	12	(100%)	71	(100%)	6	(66.7%)	89	(96.7%)	
	Total	12	(100%)	71	(100%)	9	(100%)	92	(100%)	
Head trauma	Present	3	(25.0%)	2	(2.8%)	1	(11.1%)	6	(6.5%)	0.021
	Absent	9	(75%)	69	(97.2%)	8	(88.9%)	86	(93.5%)	
	Total	12	(100%)	71	(100%)	9	(100%)	92	(100%)	
Pneumothorax	Present	0	(0%)	22	(31.0%)	1	(11.1%)	23	(25.0%)	0.034
	Absent	12	(100%)	49	(69.0%)	8	(88.9%)	69	(75.0%)	
	Total	12	(100%)	71	(100%)	9	(100%)	92	(100%)	
Hypothermia	Present	0	(0%)	7	(9.9%)	3	(33.3%)	10	(10.9%)	0.073
	Absent	12	(100%)	64	(90.1%)	6	(66.7%)	82	(89.1%)	
	Total	12	(100%)	71	(100%)	9	(100%)	92	(100%)	
Weak femoral pulse	Present	0	(0%)	1	(1.4%)	2	(22.2%)	3	(3.3%)	0.031
	Absent	12	(100%)	70	(98.6%)	7	(77.8%)	89	(96.7%)	
	Total	12	(100%)	71	(100%)	9	(100%)	92	(100%)	

*) injuries selected if the *P* value was <0.075; **) data were missing in the medical records of 15/102 cats.
1) 1^{st} & 2^{nd} floors; 2) 3^{rd} to 6^{th} floors; 3) 7^{th} to 8^{th} floors; 4) number of cats.

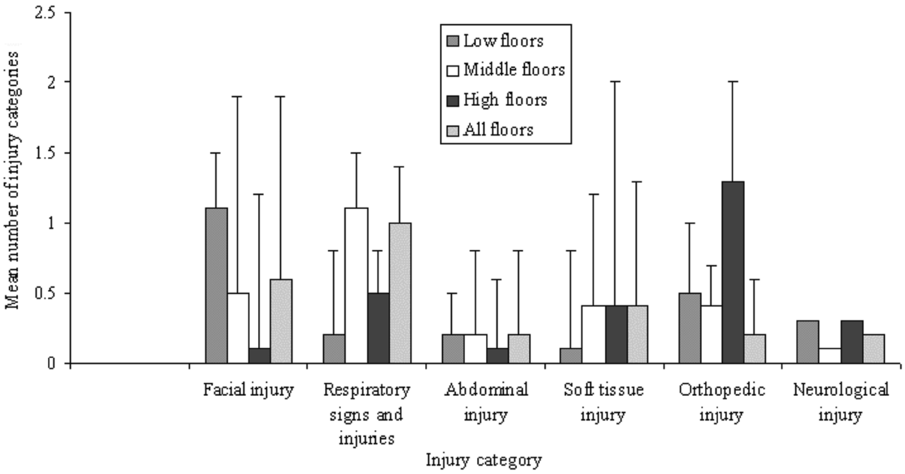

Figure 3: Mean number and positive standard deviation of selected injury categories grouped by height of fall in cats with high rise syndrome at the Hebrew University Teaching Hospital (1999-2009). Facial injuries are seen most frequently in falls from low floors while orthopedic injuries occurred mostly in falls from high floors. Respiratory signs were seen most frequently in the middle floors falls.

occurrence of facial injuries and falls from low floors (Figure 3) and a significant (P=0.036) association between presence of respiratory system-related injuries and middle-floor falls. Only 2/9 (22%) and 3/12 (25%) cats falling from either high or low floors, respectively, showed respiratory abnormalities. Pneumothorax was only observed in cats falling from middle or high floors. Three of the six cats (50%) diagnosed with neurological injury, resulting from head trauma, fell from low floors. The proportions of head injury in cats that fell from low, middle and high floors were 25%, 2.8% and 11.1%, respectively (P=0.021), and all survived. Hypothermia (rectal temperature <37°C) was only recorded in cats falling from the third floor or higher. Weak femoral pulses were only recorded in cats falling from the sixth floor or higher (Table 2).

The mean TIS increased (albeit statistically insignificantly) with the height of fall (Table 3). The relationships between the number of injury categories and the fall height, for each floor and floor group are illustrated in Figures 4 and 5, respectively. There was a significant negative association (P=0.05) between survival and the fall height (Figure 6). The survival rates of cats falling from the third, fourth and eighth floors were 88%, 76% and 71%, respectively. All cats falling from the second and fifth floors survived.

In the HRS group, 50 cats (48%) were hospitalized for up to24 hours, while only 5% of them were hospitalized for longer than five days. Cats presenting shock were hospitalized significantly (P<0.01) longer compared to those with absence of shock (median 2.5 days; range 1.0-14.0 *vs*. median 1.0 days; range 0.0-12.0 days, respectively). The duration of hospitalization was significantly (P=0.01) and positively associated with the presence of orthopedic injuries.

In the HRS group, 89 cats (83.2%) survived, 11 (10.2%) were euthanized and 7 (6.6%) died due to their sustained injuries. Excluding euthanized cases, the survival rate was 93.7%. The proportions of abdominal and spinal injuries were significantly higher among euthanized cats compared

Table 3: Number of injuries and injury categories grouped by height of fall in 92 cats* with high rise syndrome treated at the Hebrew University Veterinary Teaching Hospital (1999-2009)

Floor category	n[1]	Total number of injuries per cat		Total number of injury categories per cat	
		Mean ± SD[2]	Median (Range)	Mean ± SD[2]	Median (Range)
Low floors[3]	12	2.6 ± 1.2	2.5 (1.0-4.0)	2.0 ± 0.8	2.0 (1.0-3.0)
Middle floors[4]	71	3.1 ± 2.1	2.0 (0.0-9.0)	2.2 ± 1.3	2.0 (0.0-6.0)
High floors[5]	9	3.2 ± 2.4	2.0 (1.0-8.0)	2.0 ± 1.2	2.0 (1.0-4.0)
Total	92	3.1 ± 2.0	2.0 (0.0-9.0)	2.1 ± 1.2	2.0 (0.0-6.0)
P value		0.870		0.893	

*) data were missing in the medical records of 15/102 cats;
1) number of cats; 2) standard deviation; 3) 1st and 2nd floors; 4) 3rd to 6th floors; 5) 7th to 8th floors

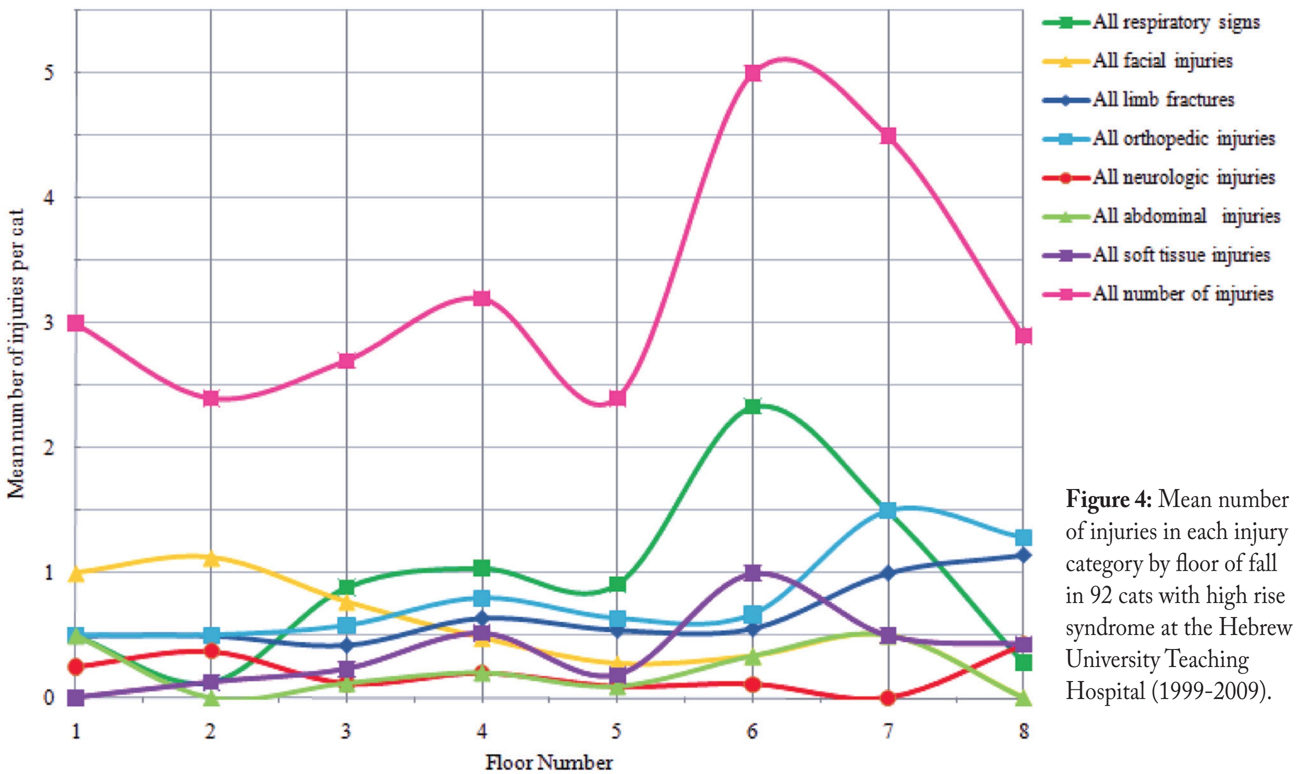

Figure 4: Mean number of injuries in each injury category by floor of fall in 92 cats with high rise syndrome at the Hebrew University Teaching Hospital (1999-2009).

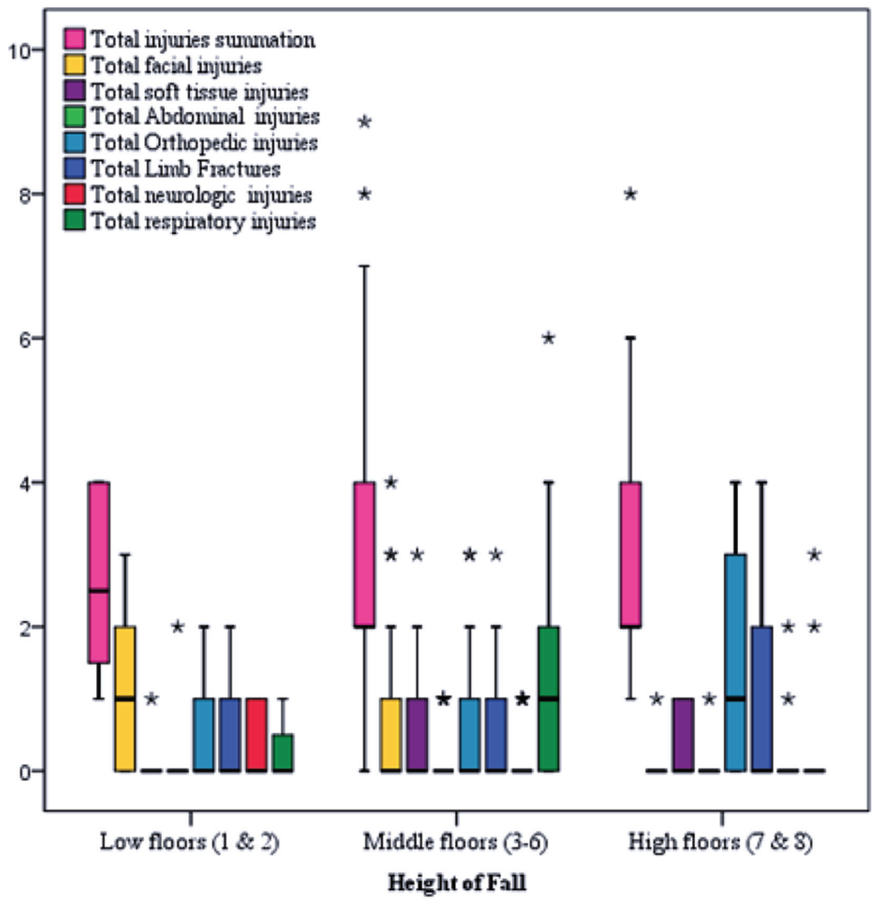

Figure 5: Box plot of injury categories (depicted as mean and standard deviation) in falls from low, middle and high floors in 92 cats with high rise syndrome at the Hebrew University Teaching Hospital (1999-2009).

to those in cats that died due to their sustained injuries or that survived (P=0.013 and P=0.038, respectively). The mortality rates in cats with abdominal and spinal injuries were 41% and 46%, respectively. There was a significant (P=0.01) positive association between mortality and presence of these injury types, and of soft tissue injury (P<0.01), subcutaneous emphysema (P<0.01) and hypothermia (P<0.05). In cats with at least two soft tissue injuries, mortality rate was 75%.

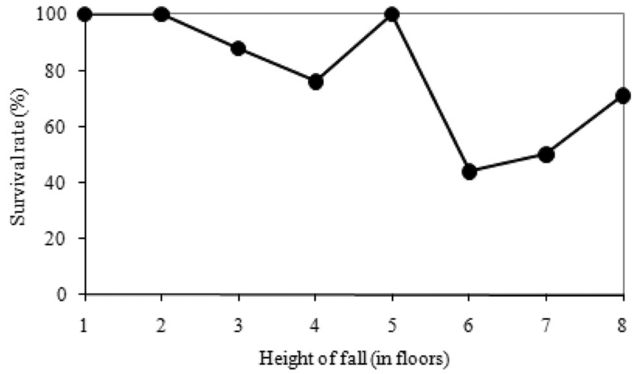

Figure 6: Survival rates of 92 cats with high rise syndrome falling from increasing heights at the Hebrew University Teaching Hospital (1999-2009). The first, second and fifth floors had a 100% survival rate whereas the lowest survival rate was recorded in cats falling from the sixth floor.

Hematology findings

There were no significant differences in the total leukocyte and monocyte counts between HRS cats and healthy donor cats (Table 4). The median neutrophil count was significantly higher in the HRS cats while the median lymphocyte, eosinophil and basophil counts were significantly lower (P<0.001) compared to the healthy donors (Table 4). The only significant hematological differences between survivors and non-survivors of HRS was in the proportion of monocytosis and monocytopenia, with a higher frequency of monocytosis in survivors (91.7% *vs*. 69.2%, respectively; P=0.02), higher frequency of monocytopenia in non-survivors (23.1% *vs*. 8.3%; P=0.02).

Table 4: Complete blood counts and differential white blood cell counts of high rise syndrome cats and healthy blood donor cats treated at the Hebrew University Teaching Hospital (1999-2009)

Parameter (units)		HRS [1]	Healthy blood donors	RI [2]	P value
White blood cells ($x10^9$/L)	n	95	60		0.727
	Median (Range)	10.3 (1.0-37.2)	10.4 (4.4-23.8)	5.0-14.0	
Red blood cells † ($x10^{12}$/L)	n	95			NA [3]
	Median (Range)	8.5 (4.4-17.3)	NA [3]	5.0-9.0	
Hemoglobin † (g/L)	n	95			NA [3]
	Median (Range)	107 (53-475)	NA [3]	8.0-15.0	
Hematocrit † (L/L)	n	95			NA [3]
	Median (Range)	0.337 (0.169-0.760)	NA [3]	0.240-0.450	
MCV [4] † (fL)	n	95			NA [3]
	Median (Range)	41.0 (14.0-53.0)	NA [3]	39.0-55.0	
MCHC [5] † (g/L)	n	95			NA [3]
	Median (Range)	31.8 (20.3-42.9)	NA [3]	30.0-38.0	
Neutrophils †† ($x10^9$/L)	n	85	60		0.039
	Median (Range)	8.8 (0.0-29.2)	6.1 (2.6-19.0)	2.5-11.3	
Neutrophil bands †† ($x10^9$/L)	n	85	60		0.930
	Median (Range)	0.1 (0.0-7.0)	0.0 (0.0-0.0)	0-0.5	
Lymphocytes †† ($x10^9$/L)	n	85	60		<0.000001
	Median (Range)	1.1 (0.0-1.4)	3.4 (0.5-5.2)	1.4-6.1	
Monocytes †† ($x10^9$/L)	n	85	60		0.802
	Median (Range)	0.2 (0.0-5.0)	0.3 (0.1-0.4)	0.1-0.6	
Eosinophils †† ($x10^9$/L)	n	85	60		<0.000001
	Median (Range)	0.1 (0.0-5.0)	0.6 (0.0-6.1)	0.0-1.5	
Basophils †† ($x10^9$/L)	n	85	60		<0.000001
	Median (Range)	0.0 (0.0-0.45)	0.01 (0.00-0.1)	0.0-0.1	

1) high rise syndrome; 2) reference interval; 3) not assessed; 4) mean corpuscular volume; 5) mean corpuscular hemoglobin concentration;
†) normal distribution; ††) non-normal distribution.

DISCUSSION

This study is, to the best of our knowledge, the first to characterize HRS in Israel, and in contrast to all the previous reports of feline HRS (3-7), it is case-controlled and includes the hematological findings of such cats for the first time.

Our results confirm previous observations, that cats under the age of one year are predisposed to HRS, and are significantly younger compared to a general population of ill cats in a hospital setting, most likely due to behavioral differences (3, 4, 6, 7). Because there were no sex or neutering status differences between the HRS cats and the negative controls, as previously reported, sex hormone influence is not an important predisposing factor to HRS (2-6). The incidence of HRS showed seasonal variation. Similar to previous studies, more cats fell when weather conditions were comfortable, probably because windows and balconies were left open (1, 3, 4, 6). The lower incidence of HRS in Israel during the warmest, most humid months of the year likely occurred because windows and balconies are mostly kept closed when air conditioning is used.

The most common falls in this study were from the 3rd and 4th floors, similar to previous European reports (3, 4, 6). Surprisingly, we recorded no falls from above the 8th floor. Based on the Israeli Central Bureau of Statistics (11), 13% of the residential buildings built in Israel over the last decade are higher than 9 stories. Possibly, cats falling from very high floors did not survive to presentation and were thus underrepresented in the present study. This interpretation should be made cautiously, however, as previous US studies of HRS have reported that some cats falling from heights greater than eight floors did survive (1, 2).

The proportion of shock cases reported in feline HRS ranges between 8% and 58% (2-7). This wide variation likely results from differences in the definition of shock, which has been fully described only in a single previous study of HRS (3), and due to presentation after resolution of clinical signs of shock (2). In this study, 10% of the HRS cases presented with hypothermia, possibly due to exposure to low environmental temperatures for prolonged time periods prior to presentation, presence of shock or both. Since most falls in our study have occurred during the warmer months, when environmental temperatures are often above 25°C, the presence of shock seems to be the most likely mechanism for hypothermia. Tachypnea, commonly present in the HRS group was likely due to respiratory system-related injuries, pain, anxiety or shock.

There was an interesting variation in the injury distribution in the HRS cats, with an increase in the fall height. While facial injuries were present more frequently in cats falling from lower floors, the proportion of thoracic and abdominal injuries increased with increasing height of fall, up to the 6th floor, after which, they decreased. In contrast, bone fractures and orthopedic injuries linearly increased with an increase in fall height, but only above the 6th floor. Thus, the relationship between type and number of injuries and the fall height in feline HRS is complex. Our findings were neither curvilinear nor linear, as has been reported. In the curvilinear pattern, the number of orthopedic injuries and the total number of injuries increase with increasing fall height, up to the 7th floor, while above the 7th floor their proportion decreases, with a concurrent increase in the number of thoracic, head and abdominal injuries (2). Our results for thoracic and abdominal injuries do support the curvilinear pattern of injury, however, in contrast, in the present study, the number of thoracic and abdominal injuries decreased with high floor falls.

It has been hypothesized that falling cats are able to adjust their mid-fall posture using gyroscopic turns (1). Cats falling from heights exceeding the 5th floor achieve maximum velocity. At this velocity, the vestibular system is no longer stimulated and the cat's body takes on a more horizontal position (2, 12, 13). Once maximum velocity is reached, cats relax their skeletal muscles and spread their body, thereby slowing fall speed and minimizing injury (2, 12, 13). With this posture, the impact force is spread over a larger surface area. The force is transferred to the rest of the body via the relaxed muscles, thereby decreasing occurrence of fractures, but increasing the frequency of secondary thoracic, abdominal and head injuries (2). Landing with the limbs extended, results in the force being transferred through the skeleton, resulting in long bone fractures, but less severe injury to the chest and abdomen. The latter is supported, in this study, by the presently observed decrease in thoracic and abdominal injuries, with an increase in orthopedic injuries, in high-floor falls. In the present study orthopedic injuries were associated with a positive prognosis, thus supporting this theory. Additionally, facial and neurological injuries were more common in low-floor falls in this study, supporting the hypothesis that cats falling from lower heights have insufficient time to adjust their posture, resulting in injuries to these body parts.

Our HRS cats were hospitalized for a significantly shorter time compared to previous reports (2.2 days *vs*. 2.9-5.0) (2, 4).Our results suggest that longer periods of hospitalization in HRS cats are expected when orthopedic injuries and shock are present, likely due to the need for intensive care and corrective surgery.

Mortality in feline HRS was associated with lung contusion, pneumothorax and shock (2, 4). In the present study hypothermia at presentation was positively associated with death, and likely with shock. Interestingly, all cats that fell from the 2nd and 5th floors survived. Possibly, the injuries sustained from 2nd floor falls are less extensive than those sustained with higher floor falls. We hypothesize that when cats fall from the 3rd and 4th floors, they sustain more severe injuries compared to those sustained in 2nd floor falls because they have insufficient time to reposition their body in order to attain maximal impact protection. When the height of the fall exceeds this height, they may possibly adequately reposition, however, despite their repositioning, the sustained impact is severe enough to induce potentially lethal outcomes. In other words, the 5th floor height is the 'optimal compromise' height between the increasing impact severity with height on one hand, and cats' ability to attain the ideal protective position from this impact. This is supported by the fact that the survival rate was lowest in falls from the 6th floor. However, this is in contrast with a previous study, in which all cats which fell from above the 4th floor survived (4). The number of cats falling from higher floors in our study was small, thereby precluding analysis and conclusions.

Soft tissue injuries occurred in 5% to 8% of the HRS cats, and were not associated with death (2-6). However, surprisingly, the mortality rate in HRS cats presenting with abdominal injury was 3-fold that of the rest of the cats, and 2.5-fold that of the overall HRS population. The presence of abdominal tissue injury is likely indicative of severe trauma, and should be regarded as a negative prognostic sign in feline HRS.

Multiple injuries, particularly multiple fractures and spinal injuries, as well as financial constraints were the main reasons for euthanasia in feline HRS (2, 4). When excluding euthanized cases, the present survival rate of our HRS population was 93%, well within previous study results (88% - 97.3%) (2-7). However, when euthanized cases were included, the present survival rate is lower (83.2%) compared to previous findings.

Hematological findings and their association with morbidity and mortality in feline HRS have never been reported, to the best of the authors' knowledge, and hematological data of feline trauma cases, in general, are limited. It would seem logical that cats with HRS would present changes resulting from both catecholamine and glucocorticoid effects. Indeed, HRS cats presented with a significantly higher neutrophil count compared to healthy cats, although their WCC did not differ. The latter is somewhat surprising, since stress, anxiety, and inflammation, were expected to result in neutrophilia, and leukocytosis (14). The clinical significance of this finding is unclear. Increased tissue demand for neutrophils and redistribution of lymphocytes could both negatively affect the WCC. In human trauma patients, the hematological findings over time were described and the prognostic value of the hemogram was analyzed (9). Leukocytosis, mainly due to neutrophilia with left shift, was noted at presentation, and persisted for at least two hours. The lymphocyte count was increased during the first hour post trauma, and then decreased linearly with time. The monocyte count transiently increased above reference interval during the fourth hour post trauma, and later on varied, depending on individual patient condition. Both lymphocytosis and lymphopenia following trauma have prognostic value in human trauma patients when the time of blood collection in relation to the trauma is known (8). We did not find an association between the lymphocyte, neutrophil and leukocyte counts and mortality in HRS. However, monocytosis was significantly more common in survivor HRS cats. Possibly, non-survivors had an inappropriate stress response resulting in a lower monocyte count; however, the value of this finding deserves further study. It would appear that leukocyte differential count differences have no prognostic value in feline HRS, although the time-period between the fall and presentation and blood collection time varied tremendously between cases, limiting the value of the analysis. Cats with HRS had a significantly lower eosinophil and lymphocyte counts compared to healthy cats as would be expected under stress (14, 15). However, stress cannot explain the significant band neutrophil count which probably reflects inflammation, as seen in human trauma patients (8, 9).

This study has several limitations. First, cats that were dead on arrival or died shortly after presentation, and had incomplete or no medical records, were excluded from this study, thereby introducing bias. Second, likely additional bias in case selection probably existed, because most cats presented for treatment included those judged by their owners to have a reasonable chance of survival, thereby resulting in a bias towards inclusion of cats with better chance of survival. Third, no long-term survival data were available. Fourth, this was a retrospective study, and some data were missing, thereby decreasing the strength of our statistical analyses. In addition, the clinical definition of shock is variable. Although it involves concurrent presence of certain clinical signs, it also depends on the clinicians' assessment, which was sometimes missing. Fifth, the high number of injury types and categories and floor number of the falls weakened the strength of the statistical analyses, as the number of cats in each group was limited, and probably led to Type-I errors. It is for this reason that in certain analyses (e.g., floor category) cases were united under categories to provide statistical analytical strength. Sixth, the scoring system (i.e., ICS and TIS) used in this study has not been validated in feline HRS, or in other types of trauma in cats. Ideally, such scoring systems should be validated. However, to the best of our knowledge, there is no uniformly accepted or validated scoring system for trauma in cats. A comparison of HRS cats with cats suffering from other types of blunt trauma, especially with regards to prognosis, is warranted, in order to understand whether HRS is a unique type of trauma, characterized by better prognosis. Lastly, it would have been interesting to assess the trends in the hematological findings, especially in the leucogram, over time, in order to examine if these are of prognostic value in feline HRS. Such studies are warranted in order to understand if the trends in the leucogram in cats suffering from blunt trauma in general, and particularly in feline HRS, are similar to those described in human trauma patients. However, due to the relatively short hospitalization of the HRS cases and due to financial constraints, additional blood counts were very limited.

In conclusion, feline HRS generally has a good to excellent prognosis, although it varies depending on the height of the fall. Orthopedic injuries were the most common ones, and their presence influenced the hospitalization period. Thoracic injuries, especially pneumothorax, as well as subcutaneous emphysema, shock, abdominal soft tissue and neurologic injuries were negative prognostic signs. Cats suffering from multiple soft tissue injuries should be monitored closely. Thoracic injuries were also common. Thus, careful evaluation and physical examination should be performed and when possible thoracic radiography should be performed even if the cat does not present with marked respiratory abnormalities at presentation, as suggested previously (2, 3). The hematological findings in HRS cats were unremarkable; however, the WCC was surprisingly in the low reference interval. Several differences between these cats and healthy cats were recorded.

Statement of ethical and animal welfare conduct

None of the cats included in this study was subjected to any experimental procedure.

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