Study of Factors Contributing to Scorpion Envenomation in Arizona

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Abstract

Introduction Arizona has the highest incidence of scorpion envenomation reported to US poison control centers (PCCs). Most cases reported are from a residence, but specific details are limited.

Methods Specialists at Arizona's two PCCs prospectively completed the Factors of Envenomation in Arizona Residences Survey (FEARS) for residential scorpion exposures reported during 4-week periods in the summer and winter. Based on these results, a second questionnaire, FEARS-2, targeting *indoor* residential exposures was then administered.

Results Among 382 FEARS responses, no significant differences were found between summer and winter exposures, except for rainfall in the previous 24 hours. Scorpions had previously been seen in 81.8% of exposures, and 29.4% reported a previous envenomation at the residence. Most exposures occurred indoors (86.5%) and in a bedroom (42.5%), where the scorpion was in the bed in 54.7% of cases. Among all stings in a bed, 72.7% occurred while sleeping. Children were stung more often in a family room (38.6% vs. 14.5%; $p < .00001$) and by a scorpion on the floor (53.5% vs. 35.0%; $p = .0014$). Distal extremities were stung most often, particularly the foot (34.5%), with most being while barefoot (81.9%).

Conclusion A variety of characteristics and associations involving residential scorpion envenomations were identified. These details can be used to guide public education and primary prevention efforts to help decrease residential scorpion exposures.

Keywords *Centruroides sculpturatus* · Scorpions · Poison control centers · United States · Surveys and questionnaires

Introduction

Arizona has the highest incidence of scorpion envenomation in the USA, with 11,500 exposures reported to their two poison control centers annually [1]. Many scorpion species are

native to Arizona, but only envenomation by *Centruroides sculpturatus* (Arizona bark scorpion) is known to have a risk of serious medical effects [2, 3]. A unique characteristic of *C. sculpturatus* is their ability to climb, often being found under loose tree bark, leading to their common name [4].

Portions of this study were presented as a poster at the Annual Scientific Meeting of the Arizona Chapter of the American College of Physicians in Tucson on October 21, 2017. Additional portions were presented as a platform presentation at the Annual Scientific Meeting of the American College of Medical Toxicology (ACMT) in Washington, DC, on April 7, 2018.

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The venom does not produce erythema or edema but contains neurotoxins that can cause effects ranging from pain, numbness, tingling, and burning at the sting site to systemic motor nerve dysfunction, which can compromise the airway and breathing [3]. The extremes of age (< 10 and > 70 years old) tend to experience the most severe effects [1], although fortunately, fatalities are rare.

When appropriate, treatment includes administration of a F(ab')₂ antivenom, which was approved by the Food and Drug Administration in 2011 [5]. This treatment is effective but expensive [6], leading some institutions to modify dosing to decrease costs [7]. Factors to consider in treatment decisions include potential severity of the envenomation, transportation options, particularly for patients in rural areas, and the possibility of a prolonged clinical course even in mild envenomations.

Despite the high incidence of envenomation, costly treatment, and prolonged effects in some untreated cases, little data exists to help formulate primary prevention measures. Therefore, this study was designed to obtain specific information on the factors surrounding scorpion envenomation in Arizona to better guide public education and inform prevention efforts.

Methods

Banner Poison and Drug Information Center (Phoenix) and Arizona Poison and Drug Information Center (Tucson) comprise the Arizona Poison Control System and serve the entire state. For each call reporting a human scorpion envenomation at a residence, poison center staff were asked to complete an online questionnaire developed for this study, called the Factors of Envenomation in Arizona Residences Survey (FEARS). Study data were collected and managed using REDCap (Research Electronic Data Capture) electronic data capture tools hosted at the University of Arizona [8]. REDCap is a secure, web-based application designed to support data capture for research studies, providing (1) an intuitive interface for validated data entry; (2) audit trails for tracking data manipulation and export procedures; (3) automated export procedures for seamless data downloads to common statistical packages; and (4) procedures for importing data from external sources.

The study timeframe included 4 weeks during the summer (July–August 2017) and, for seasonal comparison, another 4 weeks in the winter (January 2018). Components of the FEARS included age range of the victim, prior sightings and stings reported at the residence, pesticide usage within the previous 3 months, rain in the previous 24 hours, location of the scorpion, and where on the body the sting occurred.

Based on results from the FEARS, a follow-up questionnaire, called the FEARS-2, was then designed and implemented for 4 weeks in May 2018. Both surveys are available for review as [supplemental material](#). This second questionnaire was completed only for calls reporting a scorpion

envenomation occurring *indoors* at a residence. The FEARS-2 again included age range of the victim, location of sting on the body, and the room where the sting occurred, but then added proximity of the furniture to the wall, type of residence, and the number of stories in the residence. To improve survey response rates, gift cards were used as incentives for staff at Banner Poison and Drug Information Center.

Results are reported using descriptive statistics. Pearson χ^2 tests of independence were also performed (IBM SPSS Statistics, IBM Corp, Version 25) simply to assess for significant associations in the setting of no clear hypothesis nor independent/dependent variables. When these post hoc analyses involved age, cases were categorized as pediatric (< 20 years of age) or adult (≥ 20 years of age). For statistically significant tests, the standardized adjusted residuals (which were available from the chi-square analysis) were examined to identify the specific comparisons within a contingency table that contributed to the significant result [9, 10]. Since the adjusted residual is a Z-score [11], it was squared to obtain a chi-square value and then converted to the associated p value. This allowed determination of the relevant significant comparison(s) without having to perform other statistical tests (minimizing issues with multiple testing). An alpha level of 0.05 was adjusted for multiple comparisons [11] using Bonferroni corrections. This study was deemed exempt by the institutional review board at the University of Arizona.

Results

FEARS

The total number of reported scorpion exposures (1163), residential exposures (1143), and surveys received (382) during the summer and winter data collection periods are listed in Table 1. When comparing between seasons, no statistically significant differences were found for any comparison except for rain in the previous 24 hours, with 62.5% of summer exposures compared to only 11.1% of winter cases ($\chi^2(1, N = 362) = 71.44, p < 0.0001$). Consequently, the summer and winter data were combined for reporting all analyses except for previous rainfall.

Most envenomations reported were in adults 20–69 years of age (61.7%), as shown in Table 1. Only 1.0% of calls involved infants less than 1 year of age and 10.5% involved individuals 70 years of age and older. Most cases were thought to be consistent with *C. sculpturatus* based on clinical effects (90.8%). Previous scorpion sightings were reported with the majority of exposures (81.8%), and nearly one third of exposures (29.4%) occurred at a home with a history of a prior envenomation. Pesticides had been applied within the preceding 3 months in one half of cases (47.3%).

Table 1 Summary of scorpion envenomations reported to Arizona's PCCs during the two 4-week study periods for the FEARS

Variable		FEARS results	
		Summer	Winter
Total reported scorpion exposures		947	216
Residential exposures (% of total)		932 (98.4%)	211 (97.7%)
Surveys received (% of eligible exposures)		287 (30.8%)	95 (45.0%)
Age (years)	< 1	4 (1.0%)	
	1–9	60 (15.7%)	
	10–19	42 (11.0%)	
	20–69	235 (61.7%)	
	70+	40 (10.5%)	
Consistent with bark scorpion		369 (90.8%)	
Previous scorpion sightings		347 (81.8%)	
Previous scorpion envenomation		343 (29.4%)	
Pesticide use in the previous 3 months		330 (47.3%)	
Rain in the previous 24 h		272 (62.5%)	90 (11.1%)
Indoors		327 (86.5%)	
Indoor room	Bedroom	139 (42.5%)	
	Family room/den	62 (19.0%)	
	Bathroom	42 (12.8%)	
	Kitchen/dining room	28 (8.6%)	
	Garage	8 (2.4%)	
	Foyer	5 (1.5%)	
	Other/unknown	43 (13.1%)	
Outdoors		51 (13.4%)	
Outdoor area	Patio	18 (35.3%)	
	Yard	17 (33.3%)	
	Other/unknown	16 (31.4%)	
Scorpion location	Floor/ground	144 (38.5%)	
	Bed/crib	77 (20.6%)	
	Clothing	31 (8.3%)	
	Chair	12 (3.2%)	
	Towel	11 (2.9%)	
	Shoes	10 (2.7%)	
	Cabinet	3 (0.8%)	
	Table	2 (0.5%)	
	Other/unknown	14 (22.5%)	
Sleeping ($N = 88$ when in a bed/crib or chair/couch)		57 (64.8%)	
Body location	Foot	142 (34.5%)	
	Hand	91 (22.1%)	
	Leg	64 (15.5%)	
	Arm	49 (11.9%)	
	Torso	41 (10.0%)	
	Head	17 (4.1%)	
	Buttock/genitalia	6 (1.5%)	
	Unknown	2 (0.5%)	

Most exposures occurred indoors (86.5%), with the bedroom being the most common location (42.5%). The scorpion was most often found on the floor or ground (38.5%), but a large number were also found in a bed or crib (20.6%). In fact, a bed or crib was the most common location of the scorpion among stings occurring in a bedroom (76/139; 54.7%). Among all stings in a bed, 72.7% (56/77) of victims were sleeping. In all other rooms inside the residence, the scorpion was most frequently found on the floor or ground (51.1%). As shown in Table 2, comparing age group to the room of exposure was statistically significant ($\chi^2(4, N = 283) = 24.513$; $p < 0.0001$), with residual analysis indicating that this was due to children < 20 years of age being stung more often in the family room/den compared to adults 20+ years of age (38.6 vs. 14.5%; $p < 0.00001$). Adults were stung more often in the kitchen/dining room (13.0 vs. 2.4%; $p = .007$), but this was not significant at the Bonferroni-corrected $\alpha = 0.005$. Additionally, comparing age group to scorpion location indicated that the floor or ground was most common for children (53.5 vs. 35.0%; $p = 0.0014$). For adult stings, the scorpion was found more frequently on clothing, including towels and shoes (17.3 vs. 7.1%; $p = 0.012$), but this was not significant once corrected for multiple comparisons ($\alpha = 0.005$ for this set of comparisons).

Outdoor exposures occurred equally on a patio as often as in the yard (35.3% and 33.3%, respectively). Additionally, compared to children, adults were stung more frequently while outside (16.2 vs. 6.6%; $\chi^2(1, N = 377) = 6.04$; $p = 0.014$).

The most frequently stung body surfaces were distal extremities, with the foot envenomated (34.5%) more than the hand (22.1%). The lower extremity was more often stung (50.0%) than the upper extremity (34.0%). There were no significant differences between children and adults in the frequencies of body areas stung.

FEARS-2

The total number of scorpion exposures, residential exposures, and surveys received during this data collection are reported in Table 3. A response rate for the 375 surveys received could not be calculated because *indoor* residential exposures were specifically targeted, and the PCCs do not record data on indoor versus outdoor exposures at a residence. Houses were the most common type of residence where exposures occurred (86.4%), and most incidents were on the ground floor (85.1%). As observed in the first questionnaire, the bedroom was the most common room (39.2%). Similar to the previous results, although the scorpion was most frequently located on the floor/ground (45.1%) overall, bedroom stings most commonly occurred in a bed or crib (87/147; 59.2%). Significant differences in whether different furniture items that were touching the wall were noted ($\chi^2(2, N = 93) =$

Table 2 Comparison of age group versus envenomation factors for the FEARS. Percentages are for column (age group) totals within each section. χ^2 and significance are reported for each set of comparisons. Based on residual analysis, superscript 1 is the significant comparison for indoor room ($p < 0.00001$), and superscript 2 is the significant comparison for scorpion location ($p = 0.0014$)

Variable		Age		χ^2 (df)	Significance (p)
		< 20 years old	≥ 20 years old		
Indoors		99 (93.4%)	227 (83.8%)	6.044 (1)	0.014
Outdoors		7 (6.6%)	44 (16.2%)		
Indoor room	Bedroom	33 (39.8%)	106 (53.0%)	24.513 (4)	< 0.0001
	Family room/den ¹	32 (38.6%)	29 (14.5%)		
	Bathroom	12 (14.5%)	30 (15.0%)		
	Kitchen/dining room	2 (2.4%)	26 (13.0%)		
	Foyer/garage	4 (4.8%)	9 (4.5%)		
Outdoor area	Patio	4 (66.7%)	14 (48.3%)	0.673 (1)	0.412
	Yard	2 (33.3%)	15 (51.7%)		
Scorpion location	Floor/ground ²	53 (53.5%)	91 (35.0%)	15.915 (4)	0.003
	Bed/crib	17 (17.2%)	60 (23.1%)		
	Clothing/shoes/towel	7 (7.1%)	45 (17.3%)		
	Cabinet/chair/table	7 (7.1%)	9 (3.5%)		
	Other	15 (15.2%)	55 (21.2%)		
Body location	Foot	48 (42.9%)	93 (31.4%)	6.471 (5)	0.263
	Hand	20 (17.9%)	71 (24.0%)		
	Leg	19 (17.0%)	45 (15.2%)		
	Arm	12 (10.7%)	36 (12.2%)		
	Torso/buttock/genitalia	10 (8.9%)	37 (12.5%)		
	Head	3 (2.7%)	14 (4.7%)		

14.36; $p = 0.001$), with residual analysis indicating two significant contributors: the furniture was touching the wall in 90.5% of cases occurring in a bed or crib but only 50.0% of stings occurring on a chair or couch. Bedsheets/clothing was simultaneously touching the furniture item and the ground in 44.9% of cases in a bed/crib but only 23.5% of those on a chair/couch ($\chi^2(1, N = 72) = 7.74$; $p = 0.005$).

The most commonly stung body location was again the foot (38.4%), with the majority of these individuals being barefoot (81.9%).

Discussion

This study identified several characteristics of residential scorpion envenomations reported to PCCs in Arizona. Scorpions had been seen previously at the residence in the majority of cases and almost a third of exposures already had a prior envenomation at that residence. In light of previous data indicating hotspots of scorpion activity [12], it appears that these are important risk factors to consider. Interestingly, half of the callers had pesticides applied in the previous 3 months, suggesting an inappropriate selection, application, too long of an interval between treatments, or ineffectiveness of pesticides. On the other hand, with so many callers having previously seen scorpions at the residence, it is surprising that only half of the callers even had pesticides applied. Further study is

needed to determine factors of effective pesticide use. The only seasonal difference identified was rainfall in the previous 24 hours, and this was likely due to the summer data collection having been during the monsoon season. It does not appear that rain within 24 hours makes it any more likely for an envenomation to occur since close to half of the summer reports were not after a rainfall.

Most envenomations occurred inside a residence and on the ground floor. One tenth of exposures occurred on a higher level of the residence, primarily in bedrooms, presumably due to the ability of *C. sculpturatus* to climb, although they could also have been taken to a higher floor inadvertently. When envenomations occurred in a bedroom, the scorpion was most commonly found in the bed or crib, with more than two thirds occurring while the victim was asleep. These findings suggest that preventing scorpions from reaching the bed may be a helpful preventive measure. Since the furniture was touching a wall so frequently, it may be worthwhile to leave some space between the wall and furniture. However, leaving a space did not appear to contribute as much for couch or chair envenomations, so its importance is unclear. Nearly half of the bed cases and one quarter of the chair/couch cases occurred with a cloth item simultaneously touching both the floor and the furniture. It may be useful to minimize this route of access, particularly since in all other rooms outside of a bedroom, stings were

Table 3 Summary of scorpion envenomations reported to Arizona's PCCs during the 4-week study period for the FEARS-2. *This number represents only *indoor* residential exposures since these were the exposures that were eligible

Variable		FEARS-2 results
Total reported scorpion exposures		832
Residential exposures (% of Total)		805 (96.8%)
Surveys received		375*
Age (years)	< 1	4 (1.1%)
	1–9	49 (13.1%)
	10–19	45 (12.0%)
	20–69	238 (63.5%)
	70+	39 (10.4%)
Type of residence	House	324 (86.4%)
	Apartment/townhouse	27 (7.2%)
	Mobile home	4 (1.1%)
	Other/unknown	20 (5.3%)
Story	Basement	2 (0.5%)
	Ground floor	319 (85.1%)
	Second+ floor	39 (10.4%)
	Unknown	15 (4.0%)
Indoor room	Bedroom	147 (39.2%)
	Family room/den	60 (16.0%)
	Bathroom	39 (10.4%)
	Kitchen/dining room	40 (10.7%)
	Garage	22 (5.9%)
	Foyer	12 (3.2%)
	Other/unknown	55 (14.7%)
Scorpion location	Floor/ground	169 (45.1%)
	Bed/crib	89 (23.7%)
	Clothing	20 (5.3%)
	Chair	17 (4.5%)
	Towel	12 (3.2%)
	Shoes	10 (2.7%)
	Cabinet	4 (1.1%)
	Table	2 (0.5%)
	Other/unknown	52 (13.9%)
Furniture touching wall (N = 93 when applicable and known)		78 (83.9%)
Cloth item touching both furniture and floor (N = 72 when applicable and known)		44 (61.1%)
Body location	Foot	144 (38.4%)
	Hand	102 (27.2%)
	Leg	56 (14.9%)
	Arm	41 (10.9%)
	Torso	21 (5.6%)
	Head	8 (2.1%)
	Buttock/genitalia	2 (0.5%)
	Unknown	1 (0.3%)
Footwear (for foot stings)	Barefoot	118 (81.9%)
	Socks only	2 (1.4%)
	Open-toe shoes	10 (6.9%)
	Closed-toe shoes	6 (4.2%)
	Other/unknown	8 (5.6%)

from scorpions on the floor. Interestingly, scorpions were more commonly on the floor when children were stung, compared to adults. It would be interesting to investigate whether the children were playing on the floor at the time of the sting, as this may be one potential explanation. The foot was the most common body part that was stung. This has not been a consistent finding in other studies of varying *Centruroides spp.* [13], many of which have reported

an upper extremity preponderance. Of note, victims who were stung on the foot were barefoot in most cases, so wearing socks or closed footwear may be another helpful preventive measure.

Adults were stung more frequently outdoors than children. This suggests that outdoor activities of adults increase the risk of scorpion exposure, relative to children. These may include working on the exterior of the residence or performing yardwork. Indoors, children were stung more often in the family room/den, perhaps related to the amount of time spent in this area of the residence. Although not statistically significant, adults were stung more often in the kitchen. Again, this may be related to time spent in a particular room, but further study is needed to investigate these associations.

Limitations

There are important limitations to studies that rely on PCC calls, including the voluntary nature of scorpion exposure reports and geographic differences in PCC usage. Additionally, although surveys targeted only actual scorpion stings, the accuracy of the reports cannot be completely verified by PCC staff. It is likely that only a fraction of the total number of exposures that occur annually are captured, and there may be a greater tendency to report more severe envenomations. Finally, even when reported to the PCC, many envenomations likely were not included in this study as suggested by the survey response rate. Since narrative accounts of the events surrounding each envenomation were not collected, other important contributing factors may have been missed.

Conclusion

In conclusion, this study identified several characteristics and associations involving residential scorpion envenomation in Arizona, which would likely apply to other states where *C. sculpturatus* appears to be present [13]. Residential stings in Arizona primarily occurred indoors and in a bedroom while victims were asleep. Stings were most frequently reported to the foot, and victims commonly were not wearing socks or footwear. Children were stung more often in the family room/den and from scorpions on the floor, while adults were stung more often outdoors. Knowledge of the details surrounding exposures may help improve public education and primary prevention measures, hopefully decreasing residential scorpion exposures. Further study is needed to understand the reasons behind the identified associations.

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Compliance with Ethical Standards

Conflict of Interest None.

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