The Journal of Emergency Medicine, Vol. 57, No. 4, pp. 554–559, 2019

0736-4679/$ - see front matter

https://doi.org/10.1016/j.jemermed.2019.07.018

International Emergency Medicine

BLACK SCORPION (*TITYUS OBSCURUS*) FATALITIES IN GUYANA AND A LITERATURE REVIEW

Kenneth V. Iserson, MD, MBA*† and Sri Devi Jagit Ramcharran, MD*

*Department of Emergency Medicine, Georgetown Public Hospital, Georgetown, Guyana and †The University of Arizona, Tucson, Arizona
Corresponding Address: Kenneth V. Iserson, MD, MBA, The University of Arizona, 4930 N. Calle Faja, Tucson, AZ 85718. Reprints are not available from the authors

☐ **Abstract—Background: More than 1500 scorpion species exist worldwide, with a few scorpion species potentially lethal to humans. About 1 million stings annually result in >3000 deaths, but the incidence and mortality vary greatly by species and location. Physicians working internationally must recognize that resulting toxidromes vary significantly by region. Over the past few decades, South America has reported relatively few deaths and low case mortality rates from envenomations. In Guyana, a small tropical country on its northeast coast, they have been extremely rare. A sudden fatal case cluster suggests an extension of the black scorpion's habitat, an increase in venom toxicity, or both. Case Reports: During a 12-month period, Guyana experienced 3 deaths, including 1 adult, from black scorpion (*Tityus obscurus*) envenomation. The 30-year-old man and 2 young children experienced the same symptom complex, initially appearing well except for pain at the sting site. They soon developed persistent emesis and leukocytosis. All were flown from remote jungle areas to the only public tertiary care hospital where they received maximal available medical support. They gradually developed profound cardiopulmonary failure requiring ventilation and, eventually, dysrhythmias. None had hyperglycemia or pancreatitis, and they had no neurologic abnormalities until developing progressive obtundation immediately before intubation. Why Should an Emergency Physician be Aware of This?: Scorpion envenomation symptoms, outcomes, and treatment are geographically specific. Patients benefit when clinicians recognize the worldwide variations in grading systems and treatment options, which we discuss and compare to our patients.** © 2019 Elsevier Inc. All rights reserved.

☐ **Keywords—envenomation; Guyana; grading; symptoms; treatment**

INTRODUCTION

Three deaths from black scorpion (*Tityus obscurus*) envenomation, including 1 adult, occurred in Guyana during a 12-month period. Guyana is a small (76,000 square miles; slightly smaller than Idaho) tropical country in northeast South America, 77% of which is covered by dense forest (1). This sudden fatal case cluster appears to indicate an extension of the black scorpion's habitat, an increase in venom toxicity, or both. We compare the timing and nature of these patients' symptoms during their medical care with those reported in the literature and describe the incidence, variation, and available treatment for scorpion envenomations. The differences between these cases and many of those from other regions, even others in Central and South America, reinforce the observations that scorpion envenomation symptoms, outcomes, and treatment are highly genus-specific.

CASE REPORTS

Three deaths caused by black scorpion stings occurred in Guyana's interior within a 12-month period. When stung, the patients (1 adult and 2 children) were living in rural settlements in or adjacent to the large Guyana jungle that abuts the Amazon basin. The population in this area had not

Received: 20 April 2019; Final submission received: 4 July 2019;
Accepted: 18 July 2019

previously experienced deaths from *T. obscurus* scorpion stings. As is usually the case, all stings were to the patients' feet. None of the patients had any other comorbidities. These patients were ultimately transferred by air to Georgetown Public Hospital in Georgetown, Guyana.

In all cases, the patients' parents, local medical personnel, and the adult patient identified the sting as being from adult "black scorpions." While nonexpert scorpion species identification is difficult, they were most likely *T. obscurus* because that is the only black scorpion found in the region. As is typical for less-developed countries, many laboratory tests and medications were not available, and some records were incomplete.

Case 1

A 4-year-old 12-kg boy was stung at home after putting on his shoes. The child immediately experienced pain at the sting site but otherwise appeared well. Several hours later, he was brought to a remote regional hospital with persistent nonbilious, nonbloody emesis. Clinicians found him to be cold, clammy, and somnolent. He had excessive salivation, pinpoint pupils reactive to light, and mild generalized abdominal tenderness. His vital signs were: heart rate (HR) of 145 beats/min, respiration rate (RR) of 40 breaths/min, temperature 36.1°C, oxygen saturation (SpO_2) of 95% on room air, and a random blood glucose (RBG) of 78 mg/dL. He was given two 240-mL boluses of normal saline (NS), hydrocortisone 36 mg intravenously (IV), chlorpheniramine 2.4 mg IV, epinephrine 0.3 mg intramuscularly (IM), 2 doses of atropine 0.25 mg IV, and begun on D_5NS at 44 mL/h.

Eight hours after the sting, the boy was transferred to the tertiary care referral hospital. On arrival, he was alert and ill-appearing. He had and increased work of breathing with intercostal retractions, and a small wound to the fourth toe of the right foot. His vital signs were: HR 147 beats/min, RR 44 breaths/min, temperature 36.1°C, SpO_2 97% on 3 L/min O_2 by face mask, and an RBG of 150 mg/dL. Oxygen was continued, and he received ranitidine 12 mg IV, hydrocortisone 120 mg IV, ceftriaxone 600 mg IV, amikacin 90 mg IV, and two 240-mL boluses of NS. Laboratory tests showed hemoglobin 13 g/dL, a white blood cell count of 27.5 cells/μL, platelets 493,000, amylase 85 u/L, alanine transaminase 23 IU/L, aspartate aminotransferase 28 IU/L, T. bilirubin 0.4 mg/dL, blood urea nitrogen 18 mg/dL, creatinine 0.5 mg/dL, sodium 142 mmol/L, potassium 3.7 mmol/L, and chloride 110 mmol/L.

Ten hours after envenomation, while remaining afebrile and normotensive (blood pressure 128/52 mm Hg), he became markedly tachycardic (HR 181–206 beats/min), hypoxic (SpO_2 82% on high-flow O_2), and tachypneic (RR 66 breaths/min). Because of his respiratory distress, he was intubated and ventilated using positive end-expiratory pressure. He produced copious blood-tinged secretions from the endotracheal tube. A chest radiograph showed bilateral opacifications to both hilar regions with cephalization. Arterial blood gases were unavailable while he was hospitalized. Despite improvements in his saturation and vasopressor infusions, his blood pressure dropped to 65/40 mm Hg over the next several hours. He suffered cardiac arrest 17 hours after envenomation, but quickly achieved return of spontaneous circulation with Pediatric Advanced Life Support algorithm resuscitation. A half hour later he again suffered cardiac arrest and could not be resuscitated.

Case 2

A 2-year-old 12-kg boy was stung at home after he put on his shoes. The child immediately experienced pain at the sting site, but otherwise appeared well. He arrived at the remote regional hospital 6 hours after the sting. At that time, he was alert and had persistent, nonbloody, nonbilious emesis. His vital signs were: HR 130 beats/min, RR 40 breaths/min, temperature 39°C, and an RBG of 98 mg/dL. He was given ceftriaxone 600 mg IV, hydrocortisone 48 mg IV, acetaminophen 180 mg orally, a 240-mL NS bolus, and a D_5NS drip. Arrangements were made to fly him to the referral hospital.

On arrival at Georgetown Public Hospital 9 h after the sting, he was alert but ill-appearing. He had normal breath sounds but an increased work of breathing, with intercostal and subcostal retractions. His vital signs were: HR 160 beats/min, RR 44 breaths/min, temperature 38.2°C, SpO_2 99% on room air, and an RBG 88 mg/dL. He was placed on O_2 by face mask at 5 L/min. He received an initial 240-mL NS bolus, hydrocortisone 48 mg IV, chlorpheniramine 1.2 mg IV, and ondansetron 2 mg IV. Laboratory values were: hemoglobin 10.8 g/dL, a white blood cell count of 24.7 cells/μL, platelets 448,000, amylase 96 u/L, alanine transaminase 22 IU/L, aspartate aminotransferase 106 IU/L, total bilirubin 0.6 mg/dL, blood urea nitrogen 15 mg/dL, creatinine 1.5 mg/dL, sodium 142 mmol/L, potassium 2.8 mmol/L, chloride 103 mmol/L, bleeding time of 1 min, and a clotting time of 1:15 min. A chest radiograph showed large bilateral perihilar infiltrates with cephalization. Point of care ultrasound demonstrated a hyperdynamic heart, plethoric inferior vena cava collapsing with respiration, and bilateral B lines. Arterial blood gasses were not available during this patient's hospitalization.

Two hours after arrival (11 h after the sting), the patient's condition worsened. He became progressively more tachycardic (HR 175–190 beats/min) and tachypneic (RR 65 breaths/min), although his blood pressure was 110/53 mm Hg and he remained alert and afebrile. Soon afterward, he was found to have a troponin of 22 ng/mL with a normal electrocardiogram and blood

pressure of 88/66 mm Hg; he was sedated, intubated, and ventilated using positive end-expiratory pressure. A repeat point of care ultrasound was unchanged. He continued to receive vasopressors and other supportive medications. At 19 h postenvenomation he had minimal change in laboratory values except aspartate aminotransferase 224 IU/L, lactate dehydrogenase 1045, potassium 6.1, and phosphorus 8.5. At 24 h postenvenomation he had cardiac arrest. Standard resuscitation achieved return of spontaneous circulation in 3 min, but he soon arrested and remained in asystole despite 68 min of Pediatric Advanced Life Support algorithm resuscitation.

Case 3

A 30-year-old miner was stung after putting his boots on at work. He experienced immediate pain at the sting site but appeared well. He first sought care at a remote tertiary care hospital, but 48 h postenvenomation, his family took him to a secondary level public hospital. On arrival, he had continued pain at sting site, persistent vomiting, and lethargy. His vital signs were: HR 120 beats/min, RR 26 breaths/min, temperature 38.5°C, blood pressure 130/90 mm Hg, RBG 106 mg/dL, and an SpO_2 96% on room air. They noted an apparent sting mark on the plantar surface of his right foot where he had the pain. Believing him to have had an insignificant scorpion envenomation, they admitted him to the ward and administered ceftriaxone, diazepam, diclofenac, and began an NS drip.

At 60 h postenvenomation his condition worsened, with intercostal and subcostal retractions, profuse sweating, and his pupils reacting sluggishly to light. His vital signs were: HR 140 beats/min, temperature 37.5°C, RR 38 breaths/min, SpO_2 88% on high-flow O_2, RBG 98 mg/dL, and a Glasgow coma scale score of 7 (eye opening 2, verbal response 1, and motor response 4). His chest radiograph showed bilateral infiltrates, his hemoglobin was 10 g/dL, and his white blood cell count was 36,500 cells/μL (82% neutrophils). Other laboratory values were not available while he was hospitalized. He was intubated and arrangements were made to transfer him to the tertiary referral hospital.

On arrival at Georgetown Public Hospital, the cardiac monitor showed bradycardia, but a pulse and BP were unobtainable. The Advanced Cardiovascular Life Support protocol was initiated but was unsuccessful and was terminated 10 min after arrival.

DISCUSSION

Incidence

Scorpions are arthropods (class Arachnida, order Scorpiones), of which there are >1500 species worldwide, except for the Arctic and Antarctica. However, only a few scorpion species, mostly in the family Buthidae, are potentially lethal to humans. Scorpions sting ≥1 million people each year, resulting in >3000 deaths, with the incidence and mortality varying greatly by species and location (Table 1) (2,3).

Over the last few decades in South America, 4 deaths from *T. obscurus* envenomation have been formally reported in the medical literature. Two were from Ecuador, a 3-year-old girl (in 2014) and a 4-year-old boy (in 2016), and the other 2 were from French Guyana, a 7-year-old boy (in 1997) and a 6-year-old girl (in 2010) (4,5). In 2015, Brazil reported 77 deaths, most caused by *T. obscurus*, among >50,000 scorpion envenomations (6,7). Exceeding the norm are the Brazilian states of Pará, Amazonas, Mato Grosso, Tocantins, and Maranhão, with >200 envenomations per 100,000 population annually (5).

Scorpion envenomation has long been studied in French Guyana. With a similar size and geography, Guyana's close neighbor seems to have had more scorpion envenomations. Between 1998 and 2001, their emergency medical services received 56 calls for scorpion envenomation (8). Between 2003 and 2010, their main hospital ED admitted 253 patients for scorpion stings (∼30/year) (9).

In Guyana. nearly all its 740,000 residents live along the coast, with the jungle being sparsely populated (1). Deaths from scorpion stings are extremely rare and usually occur in children. According to the physician Chief Medical Officers in the regions (1,7) covering Guyana's jungle areas, the cases reported here were the only patients with scorpion stings that sought medical attention during that year. In addition, our review of medical records showed that no nonfatal cases were seen at the country's only tertiary care public hospital during that year.

T. obscurus

Tityus (family Buthidae) is a genus of about 220 described species of thick-tailed scorpions first named by C. L. Koch in 1836 (10). "*Tityus*" meaning "dark" describes the genus's most conspicuous adult characteristic (11). *T. obscurus* (Figure 1) was discovered by Paul Gervais in the year 1843. Alternative names (junior synonyms) for *T. obscurus* include *Tityus amazonicus* (Giltay, 1928), *Tityus cambridgei* (Pocock, 1897), *Tityus paraensis* (Kraepelin, 1896), *Tityus werneri* (Mello-Leitão, 1931), *Tityus sampaiocrulsi* (Mello-Leitão, 1931), and *Tityus piceus* (Caporiacco, 1947) (12).

The range for *T. obscurus,* commonly known as the "Guyana black devil scorpion" or "Amazonian scorpion," extends from Costa Rica to Argentina (13). As of 2011, a regional survey of *Tityus* species did not report any in Guyana (14). The species has expanded its

Table 1. Approximate Incidence and Mortality of Scorpion Envenomations*

	Incidence/100,000 Population/Year	Mortality/100,000 Population/Year
Saudi Arabia (some rural areas)	>1000	N/A
Mexico	600–2000	5
Brazil (some states)	>200	N/A
Iran	140	N/A
Africa	50–400	0.4–>5
South America (especially east of the Andes)	5–40	6
United States (Southwest)	22	Rare

N/A = not available.
* The exact incidence and mortality of scorpion envenomation in Guyana and French Guyana is unclear, but available information is described in the text.

geographic region significantly over the past few decades, possibly in response to changes in human habitation in its environment. *T. obscurus* lives 25 years in captivity and can survive almost a year without food. They hide during the day and come out at night to feed by waiting for prey to approach (11). *T. obscurus* scorpions are 80 to 100 mm long, about the size of an adult's palm (12).

Scorpion Venom and Mechanism of Envenomation

Scorpions' venom glands and stingers are in their curved tails. To inject venom, they swing their tail over their body to penetrate their victim. Despite substantial local pain, the paucity of enzymes in Buthid venom usually makes visualizing the sting site difficult (15). Severe systemic envenomation, usually occurring in children, is rare, even from the most dangerous scorpions (16).

Figure 1. Adult *Tityus obscurus* scorpion. Photograph courtesy of Dick Culbert, shared through Creative Commons. Available at: https://nv.wikipedia.org/wiki/E%CA%BCelyaa%C3%ADg%C3%AD%C3%AD:Tityus_obscurus_-_Flickr_-_Dick_Culbert.jpg Accessed April 1, 2019.

Scorpion venom's complex composition makes formulating effective antivenoms difficult (4). It causes a mixed cholinergic/adrenergic toxidrome with a massive endogenous release of epinephrine, norepinephrine, and other vasoactive peptides (17). Along with a direct toxin effect on the heart and lungs, these cause many of the severe systemic effects, including myocardial injury, pulmonary injury, and cardiogenic shock. The result is often myocarditis, myocardial ischemia (coronary vasoconstriction), pulmonary injury and, in many parts of the world, central nervous system dysfunction. After envenomation, the venom quickly diffuses throughout the body before being slowly eliminated (4).

T. obscurus venom's toxicity may be significantly increasing in Guyana. In the past, deaths from scorpion envenomations have been rare, with previous studies indicating that *T. obscurus* venom toxicity was relatively low. In mice, the venom has an medial lethal dose of 3.13 mg/kg compared with 0.43 mg/kg for *Tityus serrulatus* (yellow scorpion), a common toxic species in Brazil, and to 0.69 mg/kg for *Centuroides limpidus* (bark scorpion), the most significant scorpion in Mexico and similar to that in the United States (7,18). The lower the median lethal dose the more potent the venom.

Clinical Findings

Because of the depolarizing action of the low molecular mass toxin, scorpion sting victims generally have symptoms related to early cholinergic (e.g., excessive salivation, lacrimation, bradycardia, and hypotension) and persistent stimulation of the adrenergic (e.g., tachycardia, hypertension, dysrhythmias, and mydriasis) autonomic nervous system (5). However, geographic isolation of scorpion populations, including *T. obscurus*, results in inter- and intraspecific variations in signs and symptoms after envenomation (14,19,20). In Iran, many patients have muscle weakness and generalized rigidity, acute pancreatitis, rhabdomyolysis, ophthalmoplegia, and consumption coagulopathies (3). In India, 7–8% of those admitted to referral centers develop a stroke from either diffuse coagulopathy or spasm of intracranial arteries (3). In Pará, Brazil, envenomation by *T. obscurus* usually causes neurologic manifestations in addition to severe local pain and paresthesias (18).

Death from scorpion envenomation is usually caused by cardiopulmonary dysfunction. Experimentally in rats, *T. obscurus* venom resulted in hemorrhagic patches in the lung parenchyma but not pulmonary edema (7,18). This has been postulated to result from both catecholamine and direct venom-induced ischemic heart disease and the involvement of proinflammatory cytokines (4,21,22).

Consistent with previous reports, the 3 Guyanese patients experienced immediate local pain and persistent emesis and had leukocytosis and liver function abnormalities. They all gradually developed profound tachycardia, cardiopulmonary failure requiring ventilation and, eventually, dysrhythmias. None had hyperglycemia or pancreatitis, and they had no neurologic abnormalities (i.e., progressive obtundation) until immediately premortem.

Clinical Grading of Envenomation

Clinical grading systems for scorpion envenomation differ across the world depending upon the local effects of scorpion venom. The Scorpion Consensus Expert Group, with input from worldwide experts, developed a useable system that recognizes these variations. It groups multiple possible findings into 3 classes. A subsequent attempt to simplify it and link grades to specific treatments is too simplistic and general to be useful (5).

Class I, which constitutes most stings, includes mild envenomation with only local symptoms, such as pain, paresthesia, swelling, and skin discoloration at and around the sting site. Pain intensity does not signal envenomation severity. Most improve within a few hours, but symptom progression may occur unpredictably, often within 12 h (4,15). Class II stings are moderate envenomations with an extensive list of systemic, non–life-threatening symptoms that are often species-specific or geographically specific, and include diverse findings related to nicotinic and muscarinic stimulation. In our cases, the obvious class II symptoms included early nausea and continuous emesis and tachycardia and late diaphoresis. There were no significant neurologic findings and the patients remained alert until late in their course. Class III manifestations are life-threatening and include failing cardiac, respiratory, and neurologic systems (23). Our patients developed all the scorpionism-related elements of cardiac failure (e.g., hypotension, ventricular dysrhythmias, bradycardia, and cardiovascular collapse) and respiratory failure (e.g., cyanosis, dyspnea, and pulmonary edema).

Evaluation and Treatment

As with differences in clinical grading of scorpion envenomations, laboratory testing, imaging, and treatment (often limited in resource-poor settings) should be used to assess the complications seen in species-specific toxidromes (16). In our cases, tests for renal, cardiac, and pancreatic involvement were conducted. When available at the tertiary center, electrocardiographic monitoring was used sporadically.

While antivenom would seem to be useful, there are several reasons that it would have been of little help in these cases. First, there is currently no antivenom for *T. obscurus*. Antivenom is species and, possibly, biogeographically specific and exists for few scorpions (24). [One study successfully used *T. serrulatus* antivenom against *T. obscurus* in Pará State, Brazil (20).] Those that exist are expensive (>$10,000 in 2013 in the United States) and can cause complications, such as serum sickness and anaphylaxis (25,26). Second, to be effective, antivenom needs to be administered before severe envenomation develops, because it primarily binds toxins and prevents them from reaching their target sites. While it seems not to reverse existing injury, such as excess catecholamine levels and cardiopulmonary injury, it may increase the rate of toxin elimination (16,27). However, as the 3 cases presented here and other published data show, patients do not seek medical care until the symptoms are well established, so the already underresourced remote medical facilities would need to have a supply of the antivenom available.

Other Treatments

Management of scorpion stings is primarily symptomatic, and many medications have been used, depending upon the presenting symptoms. As in these cases, cholinergic symptoms have been treated with anticholinergics, such as atropine, without demonstrable effect. In critical cases, myocardial depression of accompanies significant adrenergic symptoms, so clinicians rarely use beta blockers.

Tetanus immunization is given for the puncture and, when the necessary resources are available, patients should be monitored for cardiac dysrhythmias and blood pressure abnormalities. Pain at the puncture site should be treated with local anesthetics by infiltration or nerve blocks, and with non–central nervous system–depressing medications. The α_1-blocker prazosin is now considered standard treatment, particularly in children when combined with antivenom, and may prevent some cardiopulmonary complications and enhance recovery time. To be effective, it must be administered soon after symptom onset (28). A recent review of prazosin use found evidence for this effect only in envenomations outside the Americas (Old World scorpions) (29). It was not available for our patients. In children with systemic symptoms, administering antihistamines and steroids may lead to a worse outcome (26).

WHY SHOULD AN EMERGENCY PHYSICIAN BE AWARE OF THIS?

The signs, symptoms, and lethality of scorpion envenomation vary significantly around the world, often being genus-specific and geographically specific. Even lethal

envenomations may present solely with localized pain and paresthesias. The increased frequency of lethal scorpionism in Guyana highlights the ability of scorpion species to expand their geographic range and venom toxicity. Patients benefit when clinicians recognize the worldwide variations in grading systems and treatment options.

REFERENCES

1. Central Intelligence Agency. Guyana. The World Fact Book. 2019. Available at: https://www.cia.gov/library/publications/the-world-factbook/geos/gy.html. Accessed February 28, 2019.
2. Chippaux JP, Goyffon M. Epidemiology of scorpionism: a global appraisal. Acta Trop 2008;107:71–9.
3. Del Brutto OH. Neurological effects of venomous bites and stings: snakes, spiders, and scorpions. Handb Clin Neurol 2013;114:349–68.
4. Ganteaume F, Imbert C. 2013 update about arthropod envenomations in French Guyana. Bull Soc Pathol Exot 2014;107:31–8.
5. Román JP, García F, Medina D, et al. Scorpion envenoming in Morona Santiago, Amazonian Ecuador: molecular phylogenetics confirms involvement of the Tityus obscurus group. Acta Trop 2018; 178:1–9.
6. de Oliveira Pardal PP, dos Santos PR, da Silva Cardoso B, et al. Spatial distribution of envenomation by scorpions in Pará state, Brazil. Rev Patol Trop 2017;46:94–104.
7. Mullen GR, Stockwell SA. Scorpions (scorpiones). In: Mullen GR, Stockwell SA, eds. Medical and Veterinary Entomology. New York: Elsevier; 2002:411–23.
8. Mimeau E, Chesneau P. Fauna attacks in French Guiana: retrospective 4-year analysis [in French]. Med Trop 2006;66:69–73.
9. Benmesbah MS. Aspects épidémiologiques, cliniques et biologiques de l'envenimation scorpionique au centre hospitalier de Cayenne [thesis]. Nuremberg, Germany: Cayenne: Université des Antilles et de la Guyane; 2011.
10. Koch CL. Die Arachniden. Nürnberg: C. H. Zeh'sche Buchhandlung 1836;5:17–104.
11. Lourenço WR. What do we know about some of the most conspicuous scorpion species of the genus Tityus? A historical approach. J Venom Anim Toxins Incl Trop Dis 2015;1:20.
12. Cozijn M. *Tityus obscurus* (Gervais, 1843). Available at: www.ntnu.no/ub/scorpion-files/t_obscurus_biography.pdf. Accessed January 5, 2019.
13. Guerrero-Vargas JA, Mourão CB, Quintero-Hernández V, Possani LD, Schwartz EF. Identification and phylogenetic analysis of *Tityus pachyurus* and *Tityus obscurus* novel putative Na+-channel scorpion toxins. PLoS One 2012;7:e30478.
14. Lourenço WR. The distribution of noxious species of scorpions in Brazilian Amazonia: the genus Tityus CL Koch, 1836, subgenus Atreus Gervais, 1843 (Scorpiones, Buthidae). Entomol Mitt Zool Mus Hamburg 2011;15:287–301.
15. Goyffon M, Billiald P. Envenimation. IV. Le scorpionisme en Afrique. Med Trop 2007;67:439–46.
16. Isbister GK, Bawaskar HS. Scorpion envenomation. N Engl J Med 2014;371:457–63.
17. Ismail M. The treatment of the scorpion envenoming syndrome: the Saudi experience with serotherapy. Toxicon 1994;32:1019–26.
18. de Paula Santos-da-Silva A, Candido DM, Nencioni AL, Kimura LF, Prezotto-Neto JP, Barbaro KC, et al. Some pharmacological effects of *Tityus obscurus* venom in rats and mice. Toxicon 2017;126:51–8.
19. Nencioni AL, Neto EB, de Freitas LA, Dorce VA. Effects of Brazilian scorpion venoms on the central nervous system. J Venom Anim Toxins Incl Trop Dis 2018;24:3.
20. Pardal PP, Ishikawa EA, Vieira JL, et al. Clinical aspects of envenomation caused by *Tityus obscurus* (Gervais, 1843) in two distinct regions of Pará state, Brazilian Amazon basin: a prospective case series. J Venom Anim Toxins Incl Trop Dis 2014;20:3.
21. Peytel E, Goyffon M, Tortosa JC, Lenoir B. Œdème pulmonaire et scorpionisme: mécanisme cardiogénique ou lésionnel? In: Mion G, Goyffon M, eds. Les envenimations graves. Arnette, France: Rueil-Malmaison; 2000:149–54.
22. Cologna CT, Marcussi S, Giglio JR, Soares AM, Arantes EC. *Tityus serrulatus* scorpion venom and toxins: an overview. Protein Pept Lett 2009;16:920–32.
23. Khattabi A, Soulaymani-Bencheikh R, Achour S, Salmi LR. Classification of clinical consequences of scorpion stings: consensus development. Trans R Soc Trop Med Hyg 2011;105:364–9.
24. Borges A, Rojas-Runjaic FJ, Diez N, Faks JG, den Camp HJ, De Sousa L. Envenomation by the scorpion *Tityus breweri* in the Guayana Shield, Venezuela: report of a case, efficacy and reactivity of antivenom, and proposal for a toxinological partitioning of the Venezuelan scorpion fauna. Wilderness Environ Med 2010;21: 282–90.
25. Armstrong EP, Bakall M, Skrepnek GH, Boyer LV. Is scorpion antivenom cost-effective as marketed in the United States? Toxicon 2013;76:394–8.
26. Postma TL. Neurotoxic animal poisons and venoms. In: Dobbs MR, ed. Clinical neurotoxicology syndromes, substances, environments. Philadelphia, PA: Elsevier; 2009:463–89.
27. Abroug F, Nouira S, El Atrous S, et al. A canine study of immunotherapy in scorpion envenomation. Intensive Care Med 2003;29: 2266–76.
28. Bawaskar HS, Bawaskar PH. Efficacy and safety of scorpion antivenom plus prazosin compared with prazosin alone for venomous scorpion (*Mesobuthus tamulus*) sting: randomised open label clinical trial. BMJ 2011;342:c7136.
29. Rodrigo C, Gnanathasan A. Management of scorpion envenoming: a systematic review and meta-analysis of controlled clinical trials. Syst Rev 2017;6:74.