Abstract: Scorpion sting is a public health issue in several countries, particularly in America, the Middle East, India and Africa. The estimated annual global incidence of scorpion envenomings is about 1.5 million, resulting in 2600 deaths. Scorpions are Arthropoda characterized by a tail ending in a terminal bulbous (telson) containing paired venom glands and the stinger. There are 19 known families of scorpions and more than 2200 species, of which about 50 from the families of Buthidae, Hemiscorpiidae and Scorpionidae are harmful to humans. Scorpion venom is a complex structure composed of neurotoxic proteins, salts, acidic proteins and organic compounds, thereby having neurologic, cardiovascular, hematologic and renal side effects, in addition to local effects such as redness, pain, burning and swelling. When the sting is fatal, the mechanism of death is often related to cardiotoxicity with terminal pulmonary edema. However, the cholinergic excess or the neuromuscular excitation can provoke respiratory failure. Sometimes, death is due to an anaphylactic reaction to the envenoming. The purpose of this literature review is to evaluate the autopsy findings in scorpion sting-related deaths in order to better understand the pathophysiological mechanisms underlying them, thus helping pathologists in defining the correct diagnosis.

Keywords: autopsy; scorpion; toxicology; ARDS; pulmonary edema

1. Introduction

Scorpion sting is a public health issue in several countries, particularly in America, the Middle East, India and Africa [1–10]. Scorpionism epidemiology in the world is poorly known [11], even if it has been estimated that the annual global incidence is about 1.5 million envenomings, resulting in 2600 deaths [12]. The published studies suggest a higher prevalence and mortality among children [13–16]. Scorpions are classified in the phylum Arthropoda; their body is lobster-like in shape, with seven sets of paired appendages: the chelicerae, the pedipalps (claws or pincers), four sets of legs and the pectines (comb-like structures on the ventral surface). The segmented tail curves up dorsally, ending in the terminal bulbous segment called the telson, which contains paired venom glands and the aculeus (stinger) [17]. Their origin is dated to approximately 450 million years ago, since when they divided into 19 recognized families and more than 2200 species [18]. It is estimated that about 50 species from the families of Buthidae, which includes the genera Leiurus in the Near and Middle East, Androctonus and Buthus in North Africa, Tityus in South America, Centruroides in North and Central America,
Mesobuthus in Asia and Parabuthus in Southern Africa. Hemiscorpiidae and Scorpionidae are harmful to humans [18,19]. Scorpion venom is a complex structure composed of neurotoxic proteins, salts, acidic proteins and organic compounds, thereby having neurologic, cardiovascular, hematologic and renal side effects, in addition to local effects such as redness, pain, burning and swelling [1]. However, the effect of the scorpion sting is highly dependent on the species, due to the different targets of the venom [20]. Particularly, while species like Centruroides and Parabuthus cause neuromuscular issues, Buthus, Mesobuthus and Androctonus exhibit life-threatening cardiovascular effects [21]. Death may be due to the toxic action of the envenoming/poison, but also to an anaphylactic reaction to it [22,23]. Thus, if an autopsy is performed for a suspected death due to a scorpion sting, it can be challenging for the pathologist to get the correct diagnosis. The purpose of this literature review is to evaluate the autopsy findings in scorpion sting-related deaths in order to better evaluate the post-mortem evidence in those cases.

2. Materials and Method

The present review of the literature was carried out according to the PRISMA statement [24].

2.1. Literature Search

An electronic search of SCOPUS, PubMed and Web of Sciences databases was performed to recognize the relevant research available until 7 August 2020, in order to examine the autopsy findings of fatal scorpion stings. “Fatal” AND “Scorpion” AND “Sting” were used as search terms. The search was further extended by a snowball search and hand searching by using Google Scholar.

2.2. Inclusion and Exclusion Criteria

The following inclusion criterion was adopted: (1) papers reporting autopsy cases of a fatal scorpion sting with a description of the findings. The following exclusion criteria were applied: (1) animal studies; (2) scientific article not published in English or French language; and (3) full text not available. For duplicate studies, only the article with more detailed information was included.

2.3. Data Extraction

Three researchers (Alessandro Feola, Marco Alfonso Perrone, Amalia Piscopo) independently examined the selected papers. The title, abstract and full text of each potentially pertinent study were reviewed. Any divergence on the eligibility of the studies was determined throughout debate or by consulting an additional reviewer (Giulio Di Mizio). The following information was extracted from all qualified papers: authors, year of publication, country, victim’s age and sex, time interval of sting–death, site of the sting and autopsy features.

3. Results

3.1. Characteristics of Eligible Studies

After a search for scientific literature by the reviewers, a total of 508 documents were screened by the analysis of the title and abstract. In conclusion, nine papers were included in the review. A flowchart depicting the choice of papers is described in Figure 1. A summary of the details of the included research papers is reported in Table 1.
3.2. Epidemiological Findings

The papers we reviewed reported cases from Brazil (6), India (5) and Turkey (1). The mean victim’s age was 13.25 years old, and in 58.33% it was <10 years old and M/F was 2:1. The site of the bite was represented in three cases by the upper extremities, in two cases by the trunk and in four cases by the lower extremities. With regard to the time interval between the sting and death, in five cases it was more than 24 h and in four cases less. In these latter cases, the time interval was >12 h.

3.3. Autopsy Findings

As known, the external examination findings were not specific and challenging to identify; usually, they are represented by a small puncture mark inside a discolored area. Internal autopsy findings are mainly represented by diffuse congestion and edema. In all the examined cases, lungs showed congestion and alveolar edema with the histological features of ARDS (hyaline membranes, atelectasis, infiltrate of PMNs common in the early stage of ARDS). In four cases, the cardiac findings were represented by PMNs or lymphocyte infiltrate around the papillary muscle and myocytolysis.
Table 1. Summary of the included papers. AG: adrenal glands; ARDS: acute respiratory distress syndrome; B: brain; H: heart; I: intestine; K: kidneys; L: lungs; LA: left atrium; Li: liver; n.a.: not available; P: pancreas; PMNs: polymorphonuclear leukocytes; RV: right ventricle; S: spleen; St: stomach; T: thymus; ↑: increase.

| Reference               | Country   | Scorpion            | Age/Sex of the Victim | Time Interval Sting–Death | Site of the Sting       | Autopsy Findings                                                                                                                                                                                                 |
|-------------------------|-----------|---------------------|-----------------------|---------------------------|-------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Amaral CSF et al., 1993 [25] | Brazil    | Tityus Serrulatus   | 3/M                   | 57 h                      | n.a.                    | H: dilatated RV. Diffuse engorgement of the myocardial vessels and mild interstitial edema. L: congested, edematous and stiffened, showing scattered areas of subpleural emphysema, septal thickening, diffuse alveolar edema with prominent hyaline membrane, mononuclear cell infiltration and areas of alveolar collapse. |
| Amaral CSF et al., 1994 [26] | Brazil    | Tityus Serrulatus   | 16/M                  | 32 h                      | Left Hand               | Sampled just the right lung congestion of the alveolar capillaries, widening of the interstitial spaces, focal areas of intra-alveolar edema with marked PMNs infiltration and prominent hyaline membranes lining small bronchioles and alveolar epithelium surface. |
| Cupo P et al., 1994 [27] | Brazil    | Tityus Serrulatus   | 5/F                   | 17 h                      | Right Supraclavicular Region | B: edema. H: dilatated, pale aspect of the pectineal muscles. Interstitial edema with a moderate inflammatory infiltrate consisting of neutrophilic and some eosinophilic cells. L: ↑ volume, diffuse alveolar edema and hemorrhage and polymorphonuclear infiltrate. P, Li, T: unremarkable. |
| Cupo P et al., 1994 [27] | Brazil    | Yellow Scorpion     | 4/M                   | 13 h                      | Sternal region          | B: edema. H: enlarged RV. L: ↑ volume, ↑ consistency, proteinaceous and amorphous material and most intermingled with confluent erythrocytes in the alveoli. P, Li, AG: unremarkable. |
| Cupo P et al., 1994 [27] | Brazil    | Tityus Serrulatus   | 4/M                   | 15 h                      | Hand                    | B: edema and congestion. H: no macroscopic changes. Focal subepicardial hemorrhage. Myocytolysis and unstructured fibrillar cytoplasmic architecture turning into an amorphous eosinophilic mass. PMNs infiltrate around the papillary muscles. L: ↑ volume, intense alveolar edema and septal congestion. P, Li, T: unremarkable. |
Table 1. Cont.

| Reference                  | Country  | Scorpion | Age/Sex of the Victim | Time Interval Sting–Death | Site of the Sting                                                                 | Autopsy Findings                                                                                                                                 |
|----------------------------|----------|----------|-----------------------|---------------------------|-----------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| Das S et al., 2013 [28]    | India    | n.a.     | 16/F                  | n.a. but >24 h            | Left Foot. An area (2 × 1 cm) of the skin thickened, indurated and pigmented. Normal subcutaneous. Evidence of hyperkeratosis | Blood stained secretions in the lumen of the larynx and trachea. L: heavy, congestion. K: congestion. Li: H: unremarkable. |
| Das S et al., 2013 [28]    | India    | n.a.     | 38/F                  | n.a.                      | Right Foot Area of thickening and pigmentation (4 × 3 cm) with hemorrhagic marks. Hemorrhagic aspect of the subcutaneous. | L: congestion with multiple petechial hemorrhages and edema. H: edema between the myocytes. K: congestion. P: unremarkable. |
| Kaya K et al., 2018 [29]   | Turkey   | n.a.     | 5/M                   | n.a. but >14 h            | n.a.                                                                              | L: edema, atelectasis, hyaline membranes and hemosiderin-loaded macrophages (ARDS). Li, K, S, H, B, T: congestion. |
| Kumar L et al., 2012 [30]  | India    | n.a.     | 8/M                   | 48 h                      | Right Foot. Small abrasions over the foot, and no edema or redness.               | H: dilated chambers. Pale in aspect. Lymphocyte infiltrate around the papillary muscles. Myocytolysis (vacuolar degeneration). Wavy fibers and focal hylainization. L: liver-like consistency and congestion. Alveoli filled with homogeneous eosinophilic proteinaceous material. P: parenchymal necrosis accompanied by interstitial hemorrhage. K: congestion. |
| Mahamuni NM et al., 2016 [31]| India | n.a.     | 4/M                   | <24 h                     | Left Foot. Thickening and pigmentation of the skin (1 × 1 cm) at the base of the left little toe. | B, L: petechial hemorrhages, edema and congestion. HLA mononuclear cell infiltration in cardiomyocytes with myocytolysis. K: necrosis of tubular epithelium. Congestion of all other organs. |
| Melo IMLA et al., 2019 [32]| Brazil   | Jaguajir Rochae | 44/M                | n.a.                      | n.a.                                                                              | Glottal and lung edema.                                                                                                                                 |
| Patil A et al., 2017 [33]  | India    | n.a.     | 12/F                  | 40 h                      | Left Hand. A dark-brown discoloration and swelling area (1.5 × 1 cm) with a punctured wound mark (0.2 × 0.2 cm) inside thick laminated keratin with unremarkable epidermis and upper dermal congestion. | Diffuse congestion. L: edema, hemosiderin-laden macrophages with focal destruction of alveoli. St, K: congestion and hemorrhagic spots. H: edema and pericardial infiltration of lymphocytes. Li: unremarkable. |
4. Discussion

Most scorpion stings cause localized pain, whereas only an estimated 10% of stings, even from the most dangerous scorpions, result in severe systemic envenomation. Edema, erythema, paresthesia, muscle fasciculations and numbness may occur at the site of the sting [34]. In 2011, Khattabi et al. proposed a three-classes classification of the clinical consequences of scorpion stings [35]. The I class includes local manifestations such as bullous eruption, burning sensation, ecchymosis, erythema, hyperesthesia, itching, necrosis, paresthesia, pain, purpura/petechia, swelling and tingling [35]. The II class includes minor manifestations (non-life-threatening) such as abdominal distension, agitation, anisocoria, arthralgia, ataxia, confusion, convulsion, diarrhea, dry mouth, dystonia, encephalopathy, fasciculation, gastrointestinal hemorrhage, hematuria, headache, hypertension, hyperthermia, hypothermia, lacrimation, local muscular cramps, miosis, mydriasis, myoclonia, nausea, nystagmus, odinophagia, pallor, pancreatitis, general paresthesia, priapism, prostration, ptosis, rhinorrhea, salivation, somnolence, stridor, sweating, tachycardia, thirst, urinary retention, vomiting and wheezing [35]. Finally, the III class includes the most severe and life-threatening scenarios, limited to those patients presenting at least one of the following criteria: (1) cardiogenic failure (hypotension, ventricular arrhythmia, bradycardia and cardiovascular collapse); (2) respiratory failure (cyanosis, dyspnea and pulmonary edema) or/and (3) neurological failure (GCS ≤ 6 in absence of sedation, paralysis) [35]. As reported in most of the cases analyzed in our review, pulmonary edema is one of the key elements in the case of a fatal scorpion sting [25–33]. The origin of this finding is challenging [36], but it would be helpful to understand the pathophysiology of fatal scorpion stings. Acute cardiogenic pulmonary edema is one of the manifestations of acute heart failure. It is characterized by ventricular dysfunction, reduced cardiac output and hypoperfusion, increased pulmonary capillary pressure and therefore congestion. The venom can cause myocardial damage by several pathogenetic mechanisms. Myocardial infarction by coronary spasm may occur after the scorpion sting. Indeed, the release of vasoactive, inflammatory and thrombogenic peptides and amine constituents (histamine, bradykinin, serotonin, thromboxane, leukotrienes) can induce coronary artery vasospasm and facilitate platelet aggregation as well as thrombosis [37]. Agrawal et al. showed a case of a 14-year-old boy with myocardial infarction due to vasospasm after a scorpion sting [37]. The venom can also have a direct cardiotoxic effect causing toxic myocarditis and adrenergic myocarditis by releasing adrenaline and noradrenaline, thus increasing the myocardial oxygen demand, resulting in cardiac dysfunction [38]. Bahoul et al. examined the histopathology of two fatal myocarditis cases caused by a scorpion sting, revealing a mixed picture of toxic myocarditis and coagulative myocytolysis, similar to catecholamine-induced cardiomyopathy [39]. Valdivia et al. reported a series of 32 children with scorpion bites who developed cardiac complications. Among these, 50% exhibited myocarditis, 12.5% had subclinical disease and 63% had observed electrocardiographic changes [40]. Another cause of death is due to the release of allergenic proteins that provoke anaphylactic shock leading to hypotension with vasodilation and decrease in the intravascular volume with reduced myocardial perfusion and consequent ischemia and heart failure [41]. Scorpion venom inhibits angiotensin converting enzyme (ACE), resulting in accumulation of bradykinin, which is implicated in the development of pulmonary edema [41]. Noncardiogenic pulmonary edema is a disease process that results in acute hypoxia secondary to a rapid deterioration in respiratory status [42]. The disease process has multiple etiologies, all of which require prompt recognition and intervention. Increased capillary permeability and changes in pressure gradients within the pulmonary capillaries and vasculature are mechanisms for which noncardiogenic pulmonary edema occurs [42]. Acute pulmonary edema corresponds to the brutal flooding of the pulmonary alveoli and therefore to a histological picture characterized by alveolar wall thickening, dilated capillaries and interstitial edema and transudation in the alveolar lumen (granular and pale eosinophilic) [43] as reported in the cases included in our review [25–33]. With regard to the physiopathology, it is known that among the many constituents of scorpion venom, alpha toxins produce a significant portion of human toxicity by binding to sodium channels in cell membranes and inhibiting inactivation of
the action potential [34]. This action, along with synergistic effects by other venom components, causes prolonged depolarization and excessive release of acetylcholine from parasympathetic ganglia and epinephrine and norepinephrine from sympathetic ganglia and adrenal glands. This excessive release of neurotransmitters provokes an autonomic storm consisting of cardiovascular (tachycardia, peripheral vasoconstriction, hypertension, diaphoresis), metabolic (hyperthermia, hyperglycemia), urogenital (bladder dilatation, urinary retention, ejaculation in males), respiratory (bronchial dilation, tachypnea) and neuromuscular (mydriasis, tremor, agitation, convulsions) complications. More rarely, delayed or masked by the adrenergic storm, a cholinergic (or muscarinic) syndrome can occur involving the parasympathetic nervous system and resulting in a hypersecretion syndrome (salivation, sweating, vomiting, urinary incontinence, bronchial hypersecretion and diarrhea), abdominal pain, miosis, bronchospasm, bradycardia with hypotension and, in the male, priapism [44]. Some of the symptoms could be reinforced and exacerbated by the release of inflammatory substances or vasodilators (kinins, prostaglandins) (Figure 2) [44].

![Scorpion Envenomation Diagram]

**Figure 2.** Physiopathological mechanisms leading to scorpion envenomation-related death [34,44].

The cardiotoxicity mechanism with acute pulmonary edema of a scorpion sting is still under debate. Likely, it reflects a complex interplay of multiple venom effects, such as catecholamine-mediated coronary, cardiac microcirculatory and systemic vasoconstriction, catecholamine-induced tachycardia, arrhythmias and myocarditis and depression of myocardial contractility caused by direct effects of the scorpion venom and the pro-inflammatory response to envenomation [34,43,45–47]. In four of the
cases reviewed, a PMNs or lymphocyte infiltrate around the papillary muscle and myocytolysis is described [27,30,31,33]. The diagnosis of scorpion envenomation is based on the evidence of a scorpion sting (by history or recovery of the scorpion) and clinical findings of scorpion envenomation or on suggestive findings in a patient presenting in a region where scorpions are indigenous [48]. Several conditions should be considered in the differential diagnosis, such as: snake bites, spider envenomation, poisoning caused by cholinesterase inhibitors, neuroleptic drug overdose, Guillain–Barré syndrome, tetanus, poliomyelitis, botulism, myasthenia gravis, encephalitis, meningitis, subdural hematoma and diphtheria [49]. The management of scorpion sting is based on the severity of the symptoms [44]. As first aid measures, the National Institute for Occupational Safety and Health (NIOSH) of the U.S.A. suggest to contact a qualified health care provider or poison control center for advice and medical instructions; to apply ice directly to the sting site without submerging the affected area in ice water; to remain relaxed and calm without taking sedatives; and, when possible, to capture the scorpion for identification [50]. In patients with localized and remote pain or paresthesia, treatment consists of pain and wound management [34,44], while in patients with signs of systemic toxicity, the antivenom, Prazosin and supportive care are necessary [34,44].

5. Conclusions

Autopsy findings in the case of a fatal scorpion sting are not well-described in the literature and only few case reports or case series are available. Although there is a limited number of published papers, the frequent finding of pulmonary edema and ARDS suggests an impairment of the respiratory function that can be secondary, or not, to the cardiac one. It is also important, in the context of forensic pathology, to report and investigate—with histological and immunohistochemical examinations—this type of death in order to better understand the pathophysiological mechanisms underlying them.

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References

1. Abd El-Aziz, F.E.A.; El Shehaby, D.M.; Elghazally, S.A.; Hetta, H.F. Toxicological and epidemiological studies of scorpion sting cases and morphological characterization of scorpions (Leiurusquinquestriatus and Androctonus crassicauda) in Luxor, Egypt. Toxicol. Rep. 2019, 6, 329–335. [CrossRef] [PubMed]
2. Silva-Domínguez, R.; Paredes-Solís, S.; Cortés-Guzmán, A.J.; Flores-Moreno, M.; Baldazo-Monsiváiz, J.G.; Anderson, N.; Cockcroft, A. Factors associated with scorpion stings in schoolchildren: Cross-sectional study from two rural communities of Guerrero, Mexico. Bol. Med. Hosp. Infant. Mex. 2019, 76, 79–86. [CrossRef] [PubMed]
3. Furtado, A.A.; Daniele-Silva, A.; Silva-Júnior, A.A.D.; Fernandes-Pedrosa, M.F. Biology, venom composition, and scorpionism induced by brazilian scorpion Tityus stigmurus (Thorell, 1876) (Scorpiones: Buthidae): A mini-review. Toxicon. 2020, 185, 36–45. [CrossRef] [PubMed]
4. Firoozfar, F.; Saghafighpour, A.; Jesri, N. Scorpions and Their Human Mortality Report in Iran: A Review Article. Iran J. Public Health. 2019, 48, 2140–2153. [PubMed]
5. de Araújo, K.A.M.; Tavares, A.V.; Marques, M.R.V.; Vieira, A.A.; Leite, R.S. Epidemiological study of scorpion stings in the Rio Grande do Norte State, Northeastern Brazil. Rev. Inst. Med. Trop. Sao Paulo. 2017, 59, e58. [CrossRef]
6. Rafizadeh, S.; Rafinejad, J.; Rassi, Y. Epidemiology of Scorpionism in Iran during 2009. J. Arthropod Borne Dis. 2013, 7, 66–70.
7. Borges, A.; Morales, M.; Loo, W.; Delgado, M. Scorpionism in Ecuador: First report of severe and fatal envenoming cases from northern Manabi by Tityus asthenes Pocock. *Toxicon* 2015, 105, 56–61. [CrossRef]

8. Queiroz, A.M.; Sampaio, V.S.; Mendonça, I.; Fé, N.F.; Sachett, J.; Ferreira, L.C.; Feitosa, E.; Wen, F.H.; Lacerda, M.; Monteiro, W. Severity of Scorpion Stings in the Western Brazilian Amazon: A Case-Control Study. *PLoS ONE* 2015, 10, e0128819. [CrossRef]

9. Chakroun-Walha, O.; Karray, R.; Jerbi, M.; Nasri, A.; Issaoui, F.; Amine, B.R.; Bahloul, M.; Buaziz, M.; Ksibi, H.; Rekik, N. Update on the Epidemiology of Scorpion Envenomation in the South of Tunisia. *Wilderness Environ. Med.* 2018, 29, 29–35. [CrossRef]

10. LoVecchio, F.; McBride, C. Scorpion envenomations in young children in central Arizona. *J. Toxicol. Clin. Toxicol.* 2003, 41, 937–940. [CrossRef]

11. Santos, M.S.V.; Silva, C.G.L.; Neto, B.S.; Grangeiro Júnior, C.R.P.; Lopes, V.H.; Teixeira Júnior, A.G.; Bezerra, D.A.; Luna, J.V.; Cordeiro, J.B.; Júnior, J.G.; et al. Clinical and epidemiological aspects of scorpionism in the world: A systematic review. *Wilderness Environ. Med.* 2016, 27, 504–518. [CrossRef] [PubMed]

12. Chippaux, J.P.; Goyffon, M. Epidemiology of scorpionism: A global appraisal. *Acta Trop.* 2008, 107, 71–79. [CrossRef] [PubMed]

13. BahLou, M.; Chabchoub, I.; Chaari, A.; Chtara, K.; Kallel, H.; Dammak, H.; Ksibi, H.; Chelly, H.; Rekik, N.; Ben Hamida, C.; et al. Scorpion envenomation among children: Clinical manifestations and outcome (analysis of 685 cases). *Am. J. Trop. Med. Hyg.* 2010, 83, 1084–1092. [CrossRef]

14. Dudin, A.A.; Rambaud-Cousson, A.; Thalji, A.; Juabehe, L.I.; Abu-Libdeh, B. Scorpion sting in children in the Jerusalem area: A review of 54 cases. *Ann. Trop. Paediatr.* 1991, 11, 217–223. [CrossRef] [PubMed]

15. Vazirianzadeh, B.; Farhadpour, F.; Hosseinzadeh, M.; Zarean, M.; Moravvej, S. An epidemiological and clinical study on scorpionism in hospitalized children in khouzestan, iran. *J. Arthropod. Borne Dis.* 2012, 6, 62–69.

16. Baseer, K.A.; Naser, M.A.A. Predictors for Mortality in Children with Scorpion Envenomation Admitted to Pediatric Intensive Care Unit, Qena Governorate, Egypt. *Am. J. Trop. Med. Hyg.* 2019, 101, 941–945. [CrossRef]

17. LoVecchio, F. Scorpion Envenomation Causing Neuromuscular Toxicity (United States, Mexico, Central America, and Southern Africa). Available online: https://www.uptodate.com/contents/scorpion-envenomation-causing-neuromuscular-toxicity-united-states-mexico-central-america-and-southern-africa?search=scorpion&source=search_result&selectedTitle=1~18&usage_type=default&display_rank=1 (accessed on 2 September 2020).

18. Ward, M.J.; Ellsworth, S.A.; Nystrom, G.S. A global accounting of medically significant scorpions: Epidemiology, major toxins, and comparative resources in harmless counterparts. *Toxicon* 2018, 151, 137–155. [CrossRef]

19. Marks, C.J.; Muller, G.J.; Sachno, D.; Reuter, H.; Wium, C.A.; Du Plessis, C.E.; Van Hoving, D.J. The epidemiology and severity of scorpion envenoming in South Africa as managed by the Tygerberg Poisons Information Centre over a 10 year period. *Afr. J. Emerg. Med.* 2019, 9, 21–24. [CrossRef]

20. Mullen, G.R.; Durden, L.A. *Medical and Veterinary Entomology*, 3rd ed.; Elsevier: Amsterdam, The Netherlands, 2019.

21. Shamoon, Z.; Peterfy, R.J.; Hammoud, S.; Khazaeni, B. *Scorpion Toxicity*; StatPearls Publishing: Treasure Island, FL, USA, 2020.

22. Naseem, S.; Altamemi, S.; Ullah, I. Scorpion sting envenomostion or anaphylaxis? Report of a child with overlapping clinicle picture following scorpion sting. *Arch. Dis. Child.* 2016, 101, A44. [CrossRef]

23. Castillo, A.; Attaluri, P. Acute respiratory failure following scorpion stings: Anaphylaxis or severe systemic envenomation? *Southwest Respir. Crit. Care Chronicles*. 2018, 6, 47–50. [CrossRef]

24. Moher, D.; Liberati, A.; Tetzla, J.; Altman, D.G.; PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Med.* 2009, 6, 264–269. [CrossRef] [PubMed]

25. Amaral, C.F.; de Rezende, N.A.; Freire-Maia, L. Acute pulmonary edema after Tityus serrulatus scorpion sting in children. *Am. J. Cardiol.* 1993, 71, 242–245. [CrossRef]

26. Amaral, C.F.; Barbosa, A.J.; Leite, V.H.; Tafuri, W.L.; de Rezende, N.A. Scorpion sting-induced pulmonary oedema: Evidence of increased alveolocapillary membrane permeability. *Toxicon* 1994, 32, 999–1003. [CrossRef]
27. Cupo, P.; Jurca, M.; Azevedo-Marques, M.M.; Oliveira, J.S.M.; Hering, S.E. Severe scorpion envenomation in Brazil: Clinical, laboratory and anatomopathological aspects. Rev. Inst. Med. Trop. S. Paulo. 1994, 36, 67–76. [CrossRef] [PubMed]
28. Das, S.; Badhe, B.; Kumar Shaha, K.; Manickam, N.; Mani Gandan, G. Fatal Scorpion Envenomation: Report of Two Cases. J. Indian Acad. Forensic Med. 2013, 35, 404–407. [CrossRef] [PubMed]
29. Kaya, K.; Topataş, F.; Çekin, N.; Gülmen, M.K.; Akgündüz, E. A death after scorpion envenomation: ARDS. Int. Clin. Pathol. J. 2018, 6, 3–4. [CrossRef]
30. Kumar, L.; Naik, S.K.; Agarwal, S.S.; Bastia, B.K. Autopsy diagnosis of a death due to scorpion stinging—a case report. J. Forensic Leg. Med. 2012, 19, 494–496. [CrossRef] [PubMed]
31. Mahamuni, N.M.; Patne, S.S.; Gadgil, P.A.; Pandit, G.A. Autopsy Case Findings in Fatal Scorpion Bite. Int. J. Eng. Sci. 2017, 6, 1145–1147.
32. Melo, I.M.L.A.; Ramalho, R.D.; Bezerra, M.M.V.; de Oliveira Filho, I.E.; Medeiros, C.R.; da Costa Gadelha, M.A.; Pereira de Oliveira Pardal, P. Fatal anaphylaxis to Jaguajir rochae (borelli, 1910) (Scorpiones, Buthidae) in Brazil: A case report. J. Trop. Path. 2019, 48, 1–8.
33. Patil, A.; Jatti, V.; Shashikala, P.; Dileep Kumar, R.; Pravinkumar, N.K. Fatal Anaphylactic Shock Following Scorpion Sting Envenomation. J. Karnataka Med. Leg. Soc. 2017, 26, 32–34.
34. Isbister, G.K.; Bawaskar, H.S. Scorpion envenomation. N. Engl. J. Med. 2014, 371, 457–463. [CrossRef] [PubMed]
35. Khattabi, A.; Soulaymani-Bencheikh, R.; Achour, S.; Salmi, L.R. Scorpion Consensus Expert Group. Classification of clinical consequences of scorpion stings: Consensus development. Trans. R. Soc. Trop. Med. Hgy. 2011, 105, 364–369. [CrossRef] [PubMed]
36. Amaral, C.F.; Rezende, N.A. Both cardiogenic and non-cardiogenic factors are involved in the pathogenesis of pulmonary oedema after scorpion envenoming. Toxicon 1997, 35, 997–998. [CrossRef]
37. Agrawal, A.; Kumar, A.; Consul, S.; Yadav, A. Scorpion bite, a sting to the heart! Indian J. Crit. Care Med. 2015, 19, 233–236.
38. Rahav, G.; Weiss, A.T. Scorpion sting-induced pulmonary edema. Scintigraphic evidence of cardiac dysfunction. Chest 1990, 97, 1478–1480. [CrossRef]
39. Bahloul, M.; Chaari, A.; Dammak, H.; Samet, M.; Chtara, K.; Chelly, H.; Ben Hamida, C.; Chellali, M. Cardiovascular dysfunction following severe scorpion envenomation. Mechanisms and physiopathology. Presse Med. 2005, 34, 115–120. [CrossRef]
40. Valdivia, H.H.; Kirby, M.S.; Lederer, W.J.; Coronado, R. Scorpion toxins targeted against the sarcoplasmic reticulum Ca (2+)–release channel of skeletal and cardiac muscle. Proc. Natl. Acad. Sci. USA 1992, 89, 12185–12189. [CrossRef]
41. Bawaskar, H.S.; Bawaskar, P.H. Management of scorpion sting. Heart 1999, 82, 253–254. [CrossRef]
42. Clark, S.B.; Soos, M.P. Noncardiogenic Pulmonary Edema: StatPearls: Treasure Island, FL, USA, 2020. Available online: https://www.ncbi.nlm.nih.gov/books/NBK542230/ (accessed on 5 September 2020).
43. Dobbe, L.; Rahman, R.; Elmassry, M.; Paz, P.; Nugent, K. Cardiogenic Pulmonary Edema. Am. J. Med. Sci. 2019, 358, 389–397. [CrossRef]
44. Chippaux, J.P. Emerging options for the management of scorpion stings. Drug. Des. Devel. Ther. 2012, 6, 165–173. [CrossRef]
45. Maheshwari, M.; Tanwar, C.P. Scorpion bite induced myocardial damage and pulmonary edema. Heart Views. 2012, 13, 16–18. [CrossRef] [PubMed]
46. Bahloul, M.; Chaari, A.; Dammak, H.; Samet, M.; Chellali, K.; Chelly, H.; Ben Hamida, C.; Kallel, H.; Bouaziz, M. Pulmonary edema following scorpion envenomation: Mechanisms, clinical manifestations, diagnosis and treatment. Int. J. Cardiol. 2013, 162, 86–91. [CrossRef] [PubMed]
47. Dokur, M.; Dogan, M.; Yagmur, E.A. Scorpion-related cardiomyopathy and acute pulmonary edema in a child who is stung by Leiurus abdullahbayrami. Turk. J. Emerg. Med. 2017, 17, 104–108. [CrossRef] [PubMed]
48. LoVecchio, F. Scorpion Envenomation Causing Autonomic Dysfunction (North Africa, Middle East, Asia, South America, and the Republic of Trinidad and Tobago). Available online: https://www.uptodate.com/contents/scorpion-envenomation-causing-autonomic-dysfunction-north-africa-middle-east-asia-south-america-and-the-republic-of-trinidad-and-tobago?source=history_widget#H1242305292 (accessed on 14 August 2020).
49. Muller, G.J.; Modler, H.; Wium, C.A.; Veale, D.J.H. Scorpion sting in southern Africa: Diagnosis and management. *Contin. Med. Educ.* **2012**, *30*, 356–361.

50. Insects and Scorpions. Available online: [https://www.cdc.gov/niosh/topics/insects/scorpions.html](https://www.cdc.gov/niosh/topics/insects/scorpions.html) (accessed on 2 September 2020).

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