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Clinical features and management of snake bites in 70 dogs in Korea

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ABSTRACT

Background: Snakebites remain a devastating and life-threatening environmental hazard. While the management of snakebites has been well described in humans, few clinical data and guidelines exist for dogs, especially in Korea.
Objectives: This retrospective study evaluated the clinical features of 70 dogs with snakebite wounds in Korea.
Methods: The medical records of 72 dogs that presented to three animal hospitals from June 2008 to July 2021 were reviewed; among these, 70 dogs that met the inclusion criteria were enrolled. Their signalment, history, clinical signs, physical examination, blood analysis, treatment, and prognosis were also evaluated.
Results: Of 70 dog owners, 35 (50%) witnessed the bite, with a mean time between bite and hospital presentation of 9.7 ± 4.1 h in 58 dogs. Blood smears were evaluated in 45 dogs, of which 28 (62%) showed echinocytosis. Anemia and acute kidney injury were found in 21 (29%) and 2 dogs (3%), respectively. A total of 37 dogs (53%) were hospitalized, 5 (7%) of which died.
Conclusions: The most significant finding was the high prevalence of echinocytosis. The data from this retrospective study could inform the management of dogs bitten by snakes in Korea.

Keywords: Snakebites; mamushi; echinocytosis; dogs; antivenin

INTRODUCTION

Snakes are carnivorous reptiles with elongated bodies and no legs. Of the approximately 3,000 snake species worldwide, 15% are considered venomous [1]. Korea has 10 types of non-venomous snakes and 4 types of venomous snakes. The venomous snakes include *Gloydius brevicaudus*, *G. saxatilis*, *G. ussuriensis*, and *Rhabdophis tigrinus* [2]. According to the World Health Organization (WHO), 5.4 million snakebites occur annually in people, of which 2.7 million are venomous, with 81,000–138,000 deaths [1]. An estimated 150,000 animals, primarily dogs and cats, are bitten by snakes in the United States annually [3]. Although mortality in humans after snakebites in the United States is low (0.06%), the reported canine mortality rates range from 1% to 30% [4,5]. In Korea, 200–600 cases of snake bites occur in humans annually, with 60% of snakes belonging to the genus *Gloydius* [6,7]. However, retrospective studies on snake bites in dogs in Korea are scarce.

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Conflict of Interest
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Mamushi is the most common venomous snake in Korea and is also found in Japan and China [8]. This pit viper is found in a variety of colors and is small (approximately 60 cm); thus, its attack range is only approximately 30 cm. The canine teeth (fangs) are approximately 5 mm long and have very thin tips. Snakes of this genus tend to live near rivers, ponds, and rice fields and are active during the day in spring and autumn and during the night in summer [9]. In Korea, mamushi are found nationwide, except on Jeju Island, and are reportedly more frequently encountered at low altitudes [10]. Owing to these characteristics, the risk of snakebite increases in dogs that frequently walk outdoors. *R. tigrinus* is also common in Korea, growing to 1–1.5 meters and sharing the same habitats as mamushi. While this species has long been considered non-venomous, recent studies have revealed that the venom has high toxicity and contains the same venom components as those in mamushi [2,9].

Snake envenomation causes a combination of local and systemic clinical signs with considerable variations, depending on the snake species. Many of these human-specific signs are similar to those observed in dogs [11]. Local manifestations such as edema at the bite site, infection, and tissue necrosis are the most common. The systemic manifestations include vomiting, nausea, dizziness, rhabdomyolysis due to muscle necrosis, renal function damage, and various other clinical conditions that lead to death. [11,12]. Mamushi venom is characterized by hemorrhagic activity and induces widespread bleeding in humans [12]. Only one case report has described the effects of mamushi envenomation in dog [13]. In this study, the bitten dog presented with extensive edema and bleeding but no other systemic disorders [13].

Few studies with small sample sizes have described the clinical features and management of snakebites in dogs in Korea. Therefore, the purpose of this study was to describe the signalment, history, clinical presentation, laboratory values, treatment, and prognosis of dogs bitten by snakes in Korea.

MATERIALS AND METHODS

We retrospectively reviewed the medical records of 72 dogs admitted with snakebites to the Kyungpook National Veterinary Medical Teaching Hospital, Haemaru Animal Referral Hospital, and Daegu Animal Medical Center from June 2008 to July 2021. This study included dogs in which two fang marks were observed at the wound site. Two dogs with bite wounds of unclear origin were excluded from the analysis.

The data collected from each record included signalment, history including witnessed snakebite and time since the snakebite, clinical signs, and physical examination records on presentation. Routine test results, including complete blood count, serum chemical profile, coagulation profile, and blood smear examination, were also recorded. The numbers of vials of antivenom as well as the types of analgesics, fluids, and additional medications were recorded. We also collected data on the length of hospitalization and outcomes for all animals. Dogs were diagnosed with anemia if the hematocrit value was < 35% [14]; acute kidney injury was defined as an increase in the serum creatinine concentration of 0.3 mg/dL from baseline within 48 h [15]. Increases in prothrombin time (PT) and activated partial thromboplastin time (aPTT) were defined as 150% of the upper limit of the reference range [16]. Dogs discharged alive or referred to another hospital were considered survivors, whereas those that died during hospitalization were defined as non-survivors.

Statistical analysis

Descriptive data are presented as mean ± SD for normally distributed data and median (range) for skewed data. The χ^2 test was performed to compare categorical data between survivors and non-survivors. Sex, bite location, and treatment were also compared between the groups. Statistical significance was set at a p value of < 0.05. Analyses were performed using IBM SPSS Statistics for Windows, version 25.0 (IBM Corp., USA).

RESULTS

The records of 72 dogs assumed to have been bitten by a snake were reviewed at the three hospitals from June 2008 to July 2021; two dogs were excluded due to the absence of fang marks. Thus, the analysis included a total of 70 animals. The dogs represented 23 breeds including mixed (11), Dachshund (7), Jindo (7), Maltese (7), Poodle (6), Yorkshire Terrier (6), French Bulldog (3), Cocker Spaniel (2), German Shepherd (2), Golden Retriever (2), Labrador Retriever (2), Pungsan dog (2), Shiba Inu (2), Border Collie (1), Beagle (1), Cane Corso (1), Chihuahua (1), Miniature Schnauzer (1), Pomeranian (1), Shih-tzu (1), Siberian Husky (1), Spitz (1), and Wolf dog (1). Overall, 20% (14) of dogs were intact males, 33% (23) were castrated males, 20% (14) were intact females, and 27% (19) were spayed females. The sex of the dogs did not differ significantly between the survivor and non-survivor groups (p = 0.149). The median age was 48 mon (range, 2–156 mon) and median weight was 12.6 kg (range, 2–50.4 kg). Bites were observed by 50% (35) of the owners, with a median time from observation of the clinical sign onset to hospital presentation of 9.7 h (range, 1–96 h).

The bite wounds were localized to the face (74%, 48/65), body (3%, 2/65), and legs (23%, 15/65). The bite location was not significantly associated with survival (p = 0.072). Four clinical signs were observed on presentation: edema, erythema, continuous bleeding, and cyanosis. Of the 65 dogs with clinical signs, 64 (98%) had edema, 54 (83%) had erythema, 6 (9%) had continuous bleeding, and 3 (5%) had cyanosis. On admission, the mean temperature was 39.1°C ± 0.6°C (64 dogs; range, 37.4°C–40.1°C) and mean heart rate was 148.5 ± 37.9 bpm (58 dogs; range, 84–240 bpm). Panting was observed in 22 dogs (40%) during physical examination, and the mean respiratory rate was 46.5 ± 23.8 breaths/min in 33 dogs. Normal skin turgor was observed in 28 dogs, whereas a loss of turgor was observed in 8 dogs. Doppler blood pressure recorded in 54 dogs showed a median arterial blood pressure of 155 mmHg (range, 70–230 mmHg).

The results of complete blood count and serum chemistry tests are summarized in **Table 1**. A complete blood count was obtained for 64 dogs (91%), 21 of which (29%) had anemia (median hematocrit of the 64 dogs, 52%; range, 22.2%–78%). Hemoglobin levels and platelet counts were within the reference ranges. The median white blood cell count was 14.3 K/μL (range, 6.8–43.5 K/μL), which was close to the upper limit of the reference range (reference range, 5.1–16.8 K/μL). The plasma lactate concentration on admission was available for 51 dogs, with a median of 2.7 mmol/L (range, 0.9–6.9 mmol/L) (reference range, 0.5–2.5 mmol/L). Serum biochemistry panels were performed in 64 dogs (91%), 2 of which were diagnosed with acute kidney injury. C-reactive protein concentrations were measured in 39 dogs, with increased levels noted in 25 dogs (median, 24 mg/L; range, 10–186 mg/L; reference range, 0–20 mg/L). Blood smear evaluation was performed in 45 dogs, 28 of which (62%) had echinocytosis. The coagulation parameters PT and aPTT were tested in 62 dogs; 10 (16%) had prolonged PT and 8 (13%) had prolonged aPTT. D-dimer levels were tested in 39 dogs, with a median concentration of 0.7 mg/L (range, 0.1–5.9 mg/L); 26 (67%) had increased levels of D-dimer.

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Table 1. CBC and serum chemistry of the study dogs with snake bites

Variable	Median (range)	Reference range
CBC (n = 64)		
Hematocrit (%)	52 (22.2–78)	37.3–61.7
Hemoglobin (g/dL)	17.4 (7.9–22.6)	13.1–20.5
WBC (K/μL)	14.3 (6.8–43.5)	5.1–16.8
Platelet (K/μL)	264 (70.3–743)	148–484
Serum chemistry (n = 64)		
BUN (mg/dL)	18 (7–66.1)	7–27
Creatinine (mg/dL)	0.9 (0.3–3.3)	0.5–1.8
Total protein (g/dL)	6.3 (4.6–9)	5.2–8.2
Albumin (g/dL)	3.2 (1.6–4.9)	2.3–4
ALT (U/L)	50 (16–292)	10–100
ALP (U/L)	56 (10–1,179)	23–212
CRP (n = 39)		0–20
n = 25 (mg/L)	24 (10–186)	
n = 14 (mg/L)	< 10	
Lactate (n = 51) (mmol/L)	2.7 (0.9–6.9)	0.5–2.5
pH (n = 19)	7.3 (7.2–7.4)	7.3–7.5

CBC, complete blood count; WBC, white blood cell; BUN, blood urea nitrogen; ALT, alanine aminotransferase; ALP, alkaline phosphatase; CRP, C-reactive protein.

Table 2. Treatment variables of dogs with snake bites

Treatment (n = 70)	No. (%)
Vials of antivenom	
1–2	53 (76)
0	17 (24)
Analgesic	
Tramadol	29 (41)
Hydromorphone	10 (14)
TLK CRI	8 (11)
Fentanyl CRI	2 (3)
Butorphanol	1 (1)
None	20 (29)
Fluid	
N/S	29 (41)
Plasma-Lyte	12 (17)
H/S	6 (8)
5% DW	1 (1)
2.5% DW	2 (3)
None	20 (29)
Fluid rate (mL/kg/h)	
2.5	26 (37)
5	17 (24)
10	1 (1)
30	1 (1)
None	25 (36)
Chlorpheniramine	51 (73)
Glucocorticoids	32 (46)
Antibiotic	62 (89)

TLK, tramadol lidocaine ketamine; CRI, constant rate infusion; N/S, normal saline; H/S: Hartmann's solution; DW, dextrose water.

The types of treatment received by the dogs are summarized in **Table 2**. Out of 70 dogs, 53 (76%) received more than one vial of antivenin and 17 (24%) did not receive antivenom treatment. A total of 50 dogs received analgesics and intravenous fluid support. The most frequently used analgesics were tramadol (41%) and hydromorphone (14%). Regarding fluid therapy, normal saline was administered to 41% of dogs, followed by Plasma-Lyte (17%). The most frequent administration rate was 2.5–5 mL/kg/h. Additionally, 51 of 70 dogs (73%) received chlorpheniramine, 32 (46%) received glucocorticoids, and 62 (89%) received

antibiotics. The administration of antivenin, glucocorticoids, and antibiotics was associated with increased survival ($p = 0.008$, $p = 0.030$, and $p = 0.007$, respectively). Survival and antihistamine use were not significantly related ($p = 0.172$).

The median hospitalization time was 2.5 days in 68 dogs. Of the 70 dogs, 37 (53%) survived until discharge, 5 (7%) died, and 28 were lost to follow-up. Among 42 hospitalized dogs with follow-up data, 37 (88%) survived to discharge and 5 (12%) died. The prognosis of the dogs was assessed and the dogs were divided into two groups depending on the administration of antivenin. Of 53 dogs treated with antivenin, 31 (58%) survived to discharge, 3 (6%) died, and 19 (36%) were limited to follow-up. Of 17 dogs not treated with antivenin, 6 (35%) survived to discharge, 2 (12%) died, and 9 (53%) were limited to follow-up.

DISCUSSION

To the best of our knowledge, this is the first large-scale study conducted in Korea to assess the clinical features of dogs bitten by snakes. Our results showed that there was no predominance of sex. In humans, men are approximately 50% more likely to be bitten than women due to their occupational characteristics (farmers, gardeners, and security guards) [17]. These differences can be attributed to varying species-specific behaviors between dogs and humans. Furthermore, one study reported that young, mature dogs of medium to large breeds are most commonly bitten by snakes [18]. This finding might be explained by the fact that some of the dogs enrolled in this study were guard dogs and tended to attack and provoke snakes to bite [18]. However, contrasting results were observed in this study. We found that small breeds were more frequently bitten than large breeds, possibly because small and toy breeds are among the most prevalent breeds in South Korea [19].

In the present study, snakebites were mostly observed in the head region or on the limbs, findings consistent with those of other reports [18,20,21]. A previous study reported that, of 96 bites, 78 (81.2%) occurred in the head region and 21 (21.9%) on the limbs [20], similar to our results observed in 70 dogs (74% and 23%, respectively). These results might indicate that dogs are prone to intentional contact with vipers, as opposed to humans, who are almost exclusively bitten accidentally [1,21]. Moreover, due to these behavioral characteristics in dogs, most snakebites occur in the distal parts of the limbs or head region.

Mamushi venom contains phospholipase A2, hyaluronidases, proteases, and other enzymes. In humans, these enzymes induce erythema, local pain, and swelling at the bite site. Mamushi venom also contains hemorrhage factor I or II, which cause a significant increase in platelet aggregation, resulting in extensive ecchymosis and gastrointestinal bleeding. Hypotension can occur due to severe swelling. In these cases, increased serum levels of creatinine phosphokinase and blood levels of myoglobin due to rhabdomyolysis can cause acute renal failure [2,12,22]. In the current study, 98% of dogs had edema, 83% had erythema, and only a small number of dogs presented persistent bleeding, cyanosis, and acute kidney injury. These results may be of non-venomous snakebites or “dry” bites, which induce insufficient envenomation. While approximately 25% of bites by pit vipers in humans are dry, there are no studies on the incidence of dry bites in dogs [23]. In the present study, the number of dry bites could not be fully estimated because we did not record whether a patient was envenomated since envenomation is generally determined by witnessing snakebites, snake species, clinical signs, and typical fang marks.

The hematologic findings in the current study suggest an inflammatory reaction caused by the bites, characterized by median white blood cell counts close to the upper limit of the reference range and C-reactive protein exceeding the reference range. These results are similar to those of a previous study that suggested stress as a contributing factor [24]. Echinocytosis was another hematological abnormality observed in 28 dogs (62%). Echinocytosis is the most common hematologic abnormality in dogs envenomed by snakes from the subfamily Crotalinae [20,25]. Previous studies showed that echinocytosis is caused by phospholipase A2, a component of snake venom with a dose-dependent effect on the red blood cell membrane [26,27]. Although no relationship between echinocytosis and mamushi envenomation has been reported, echinocytosis appears to be a reasonably good marker in dogs because the venom of this snake also contains phospholipase A2. Thrombocytopenia and acute kidney injury are common conditions following hemorrhagic envenomation in both humans and dogs [2,3,5,21,23,28,29]. However, in our study, the mean platelet counts were within the reference ranges, and only two dogs had acute kidney injury. Moreover, blood analysis was performed only once at presentation, which might have contributed to these results. Further research is needed to evaluate the complications of snakebites in Korea, and serial blood sampling after hospitalization is recommended.

A standard treatment protocol for snake envenomation is lacking for dogs; however, the only accepted treatment is the administration of antivenom along with supportive care consisting of intravenous crystalloid fluid therapy and pain control [23,30]. Antivenom limits clinical signs and reverses coagulopathy [23,31,32]. In the current study, 70 dogs (76%) were administered at least one vial of antivenom; additional antivenin was administered to dogs with persistent clinical signs as there is no evidence-based protocol available for antivenom administration or dosage in dogs [23]. Regarding pain control, opioid agonists, especially fentanyl, are usually recommended because they can provide excellent short-term analgesia. And morphine should be used with caution owing to the risk of histamine release [3,23]. However, tramadol was used most frequently in the present study, possibly due to its non-narcotic properties and the fact that it is legally available and widely used in the Korean veterinary community. Nonetheless, there are some controversies regarding the efficacy of tramadol in dogs [33]. As snakebites are usually associated with pain [3,11,25], warranted analgesics should be used. Lastly, while the recommended intravenous fluids include isotonic crystalloid solutions such as lactated Ringer's solution, 0.9% sodium chloride, or Plasma-Lyte solution [23], most of our patients which administered IV fluids treated with isotonic crystalloid solutions.

Although there remain controversies regarding the use of glucocorticoids and antihistamines for snake envenomation [23,25], they were administered to 46% and 73% of dogs, respectively. Some authors favor the use of glucocorticoids in snake envenomation due to their anti-inflammatory effects, which might reduce pain and swelling, whereas others suggest that glucocorticoids might slow and reduce antivenom activity, increase the risk of infection, and interfere with the normal healing process [23,34]. Most of the literature on envenomation in humans does not recommend the routine use of antihistamines because of their potential hypotensive adverse effects; moreover, they are only indicated for the treatment of anaphylaxis [23,35]. However, two retrospective studies on dogs reported increased survival rates with diphenhydramine administration after snakebites [5,25]. All dogs that died in the present study had received both glucocorticoids and antihistamines; therefore, these drugs may worsen the clinical status due to the complications described above. However, in our study, glucocorticoid administration was positively associated with survival. Currently, there is no evidence for the effectiveness of glucocorticoids and antihistamines in snake envenomation; thus, further research is warranted.

The administration of systemic antimicrobials to patients with snake envenomation remains controversial in both human and veterinary medicine [23,36]. In human medicine, prophylactic antibiotics are not indicated as initial therapy because the incidence of infection is low following pit viper bites, likely due to the bactericidal effects of the venom itself [36,37]. Hence, antibiotics are only recommended when there is clinical and microbiological evidence of wound infection [36]. In the past veterinary studies, prophylactic antibiotics are often indicated after snake envenomation because of the variety of bacteria that can be found in dog hair and snake mouth [3,21,38]. However, according to recent veterinary study, transmission of infection through the snakebite is rare because of dilutional effects associated with the hemorrhagic lymphedema and proteolytic effects of snake venom [23]. And one prospective study performed in dogs in rattlesnake envenomation discourage antibiotic use as there was low incidences of wound infection after snake bite [39]. While use of antibiotics in treatment of snake bites is not currently promoted in veterinary medicine, our study found common usage by Korean veterinarians. These results are not supported by most recent literature and that our study could not reveal any benefit or detriment of their use. Moreover, our study revealed an association of antibiotic use with survival but could not demonstrate that antibiotic use affected survival.

The overall mortality rate in the present study was 7%. Previous studies reported mortality rates for bites of pit vipers, rattlesnakes, and tiger snakes of 4%, 1%, and 15%, respectively; however, mamushi bites have not been reported in dogs [18,20,21]. Discrepancies in mortality rates may be associated with differences in venom constituents between snake species and the amount of venom inoculated [24]. Mortality rates after antivenom administration also vary between groups [24,40,41]. In pit viper envenomation, the administration of antivenom did not increase the survival rate [21]; however, in tiger snake envenomation, the mortality rate with antivenom was 17% compared with 77% in dogs that were not treated with antivenom [42,43]. In the present study, the mortality rate of dogs that received antivenom was 6%, compared with 12% in those that did not receive this treatment. Although antivenom seemed to have a positive effect on mortality, due to the nature of a veterinary referral hospital, follow-up information on patients was limited; hence, the effectiveness of antivenom in our study cannot be estimated.

According to the WHO, snakebites remain a devastating and life-threatening environmental hazard for humans not only in tropical developing countries but also in developed nations with high population densities [1,44]. Envenoming resulting from snakebites is an important public health problem because it can lead to death and requires antivenom, the only specific treatment [1]. Despite increasing knowledge of the management of snake bites in humans, satisfactory data and guidelines remain lacking in veterinary medicine, especially in Korea. Our study is of great importance for veterinary public health as it provides baseline information for veterinary clinics to better control patients bitten by snakes.

The present study has several limitations owing to its retrospective design. First, the medical records were occasionally incomplete because data from three different animal hospitals were collected for analysis due to the low incidence of snakebites in dogs in Korea. Second, several species of snakes are implicated in snakebites and our study was not confined to mamushi only. Thus, it was impossible to evaluate whether envenomation occurred in the dogs included in this study. Third, many of the dogs in our study presented to the hospital only for antivenom treatment; thus, the possibility of follow-up and assessment of prognosis was limited, and complications could not be evaluated properly because serial laboratory examinations were performed only in a small number of dogs.

While snakebite in dogs in Korea is an uncommon medical problem, it should be considered as it can eventually lead to death. To the best of our knowledge, this is the first study to retrospectively analyze the clinical features of snakebites in dogs in Korea. The most significant finding of our study is that the most prevalent clinical signs were edema, erythema, and echinocytosis in blood smears. The mortality rate in this study was 7%, and antivenom seemed to have a positive effect on mortality; however, further research is essential to determine the effectiveness of antivenom. In our opinion, the presented data could help in the management of dogs with snakebites in Korean veterinary medicine.

REFERENCES

1. World Health Organization. Snakebite envenoming [Internet]. Geneva: World Health Organization; https://www.who.int/news-room/fact-sheets/detail/snakebite-envenoming. Updated 2021. Accessed 2022 Mar 1.
2. Lim H, Kang HG, Kim KH. Antivenom for snake bite in Korea. J Korean Med Assoc. 2013;56(12):1091-1103. CROSSREF
3. Peterson ME. Snake bite: pit vipers. Clin Tech Small Anim Pract. 2006;21(4):174-182. PUBMED | CROSSREF
4. Seifert SA, Boyer LV, Benson BE, Rogers JJ. AAPCC database characterization of native U.S. venomous snake exposures, 2001-2005. Clin Toxicol (Phila). 2009;47(4):327-335. PUBMED | CROSSREF
5. McCown JL, Cooke KL, Hanel RM, Jones GL, Hill RC. Effect of antivenin dose on outcome from crotalid envenomation: 218 dogs (1988-2006). J Vet Emerg Crit Care. 2009;19(6):603-610. PUBMED | CROSSREF
6. Kasturiratne A, Wickremasinghe AR, de Silva N, Gunawardena NK, Pathmeswaran A, Premaratna R, et al. The global burden of snakebite: a literature analysis and modelling based on regional estimates of envenoming and deaths. PLoS Med. 2008;5(11):e218. PUBMED | CROSSREF
7. Shim JH, Son YJ, Lee SS, Park KS, Oh HB, Park YD. Ecological study on poisonous snake and investigation of the venom characteristics, snakebiting frequency in Korea. Korean J Environ Ecol. 1998;12:58-77.
8. Fukuda T, Iwaki M, Hong SH, Oh HJ, Wei Z, Morokuma K, et al. Standardization of regional reference for mamushi (*Gloydius blomhoffii*) antivenom in Japan, Korea, and China. Jpn J Infect Dis 2006;59(1):20-24. PUBMED
9. Hifumi T, Sakai A, Kondo Y, Yamamoto A, Morine N, Ato M, et al. Venomous snake bites: clinical diagnosis and treatment. J Intensive Care. 2015;3(1):16. PUBMED | CROSSREF
10. Kim JB, Min MS, Park DS, Song JY. *Red Data Book of Endangered Amphibians and Reptiles in Korea*. Incheon: National Institute of Biological Resources; 2011, p 85.
11. Bolon I, Finat M, Herrera M, Nickerson A, Grace D, Schütte S, et al. Snakebite in domestic animals: first global scoping review. Prev Vet Med. 2019;170:104729. PUBMED | CROSSREF
12. Debono J, Bos MH, Do MS, Fry BG. Clinical implications of coagulotoxic variations in Mamushi (Viperidae: *Gloydius*) snake venoms. Comp Biochem Physiol C Toxicol Pharmacol. 2019;225:108567. PUBMED | CROSSREF
13. Park J, Lee J, Jee H, Park S, Kim M, Jeong S. Treatment of snakebite wound in a dog. J Vet Clin. 2007;24(3):449-452.
14. Lynch A. Non-regenerative anemia. In: Drobatz KJ, Hopper K, Rozanski E, Silverstein D. *Textbook of Small Animal Emergency Medicine*. Hoboken: Wiley; 2019, 413-418.
15. Palm C. Acute azotemia. In: Drobatz KJ, Hopper K, Rozanski E, Silverstein D. *Textbook of Small Animal Emergency Medicine*. Hoboken: Wiley; 2019, 593-600.
16. Holowaychuk MK, Hanel RM, Darren Wood R, Rogers L, O'Keefe K, Monteith G. Prospective multicenter evaluation of coagulation abnormalities in dogs following severe acute trauma. J Vet Emerg Crit Care. 2014;24(1):93-104. PUBMED | CROSSREF

17. Kumar KS, Narayanan S, Udayabhaskaran V, Thulaseedharan NK. Clinical and epidemiologic profile and predictors of outcome of poisonous snake bites - an analysis of 1,500 cases from a tertiary care center in Malabar, North Kerala, India. Int J Gen Med. 2018;11:209-216.
PUBMED | CROSSREF

18. Aroch I, Harrus S. Retrospective study of the epidemiological, clinical, haematological and biochemical findings in 109 dogs poisoned by *Vipera xanthina palestinae*. Vet Rec. 1999;144(19):532-535.
PUBMED | CROSSREF

19. Kim E, Choe C, Yoo JG, Oh SI, Jung Y, Cho A, et al. Major medical causes by breed and life stage for dogs presented at veterinary clinics in the Republic of Korea: a survey of electronic medical records. PeerJ. 2018;6:e5161.
PUBMED | CROSSREF

20. Hackett TB, Wingfield WE, Mazzaferro EM, Benedetti JS. Clinical findings associated with prairie rattlesnake bites in dogs: 100 cases (1989-1998). J Am Vet Med Assoc. 2002;220(11):1675-1680.
PUBMED | CROSSREF

21. Segev G, Shipov A, Klement E, Harrus S, Kass P, Aroch I. *Vipera palaestinae* envenomation in 327 dogs: a retrospective cohort study and analysis of risk factors for mortality. Toxicon. 2004;43(6):691-699.
PUBMED | CROSSREF

22. Chiba T, Koga H, Kimura N, Murata M, Jinnai S, Suenaga A, et al. Clinical condition and management of 114 mamushi (*Gloydius blomhoffii*) bites in a general hospital in Japan. Intern Med. 2018;57(8):1075-1080.
PUBMED | CROSSREF

23. Armentano RA, Schaer M. Overview and controversies in the medical management of pit viper envenomation in the dog. J Vet Emerg Crit Care. 2011;21(5):461-470.
PUBMED | CROSSREF

24. Lobetti RG, Joubert K. Retrospective study of snake envenomation in 155 dogs from the Onderstepoort area of South Africa. J S Afr Vet Assoc. 2004;75(4):169-172.
PUBMED | CROSSREF

25. Julius TM, Kaelble MK, Leech EB, Boyle KL, Strandberg EJ, Clare MC. Retrospective evaluation of neurotoxic rattlesnake envenomation in dogs and cats: 34 cases (2005-2010). J Vet Emerg Crit Care. 2012;22(4):460-469.
PUBMED | CROSSREF

26. Walton RM, Brown DE, Hamar DW, Meador VP, Horn JW, Thrall MA. Mechanisms of echinocytosis induced by *Crotalus atrox* venom. Vet Pathol. 1997;34(5):442-449.
PUBMED | CROSSREF

27. Brown DE, Meyer DJ, Wingfield WE, Walton RM. Echinocytosis associated with rattlesnake envenomation in dogs. Vet Pathol. 1994;31(6):654-657.
PUBMED | CROSSREF

28. Kim OH, Lee JW, Kim HI, Cha K, Kim H, Lee KH, et al. Adverse cardiovascular events after a venomous snakebite in Korea. Yonsei Med J. 2016;57(2):512-517.
PUBMED | CROSSREF

29. Moon JM, Koo YJ, Chun BJ, Park KH, Cho YS, Kim JC, et al. The effect of myocardial injury on the clinical course of snake envenomation in South Korea. Clin Toxicol (Phila). 2021;59(4):286-295.
PUBMED | CROSSREF

30. Wingert WA, Chan L. Rattlesnake bites in southern California and rationale for recommended treatment. West J Med 1988;148(1):37-44.
PUBMED

31. Riffer E, Curry SC, Gerkin R. Successful treatment with antivenin of marked thrombocytopenia without significant coagulopathy following rattlesnake bite. Ann Emerg Med. 1987;16(11):1297-1299.
PUBMED | CROSSREF

32. Russell FE, Ruzić N, Gonzalez H. Effectiveness of antivenin (Crotalidae) polyvalent following injection of *Crotalus* venom. Toxicon. 1973;11(6):461-464.
PUBMED | CROSSREF

33. Donati PA, Tarragona L, Franco JV, Kreil V, Fravega R, Diaz A, et al. Efficacy of tramadol for postoperative pain management in dogs: systematic review and meta-analysis. Vet Anaesth Analg. 2021;48(3):283-296.
PUBMED | CROSSREF

34. Lenchner I, Aroch I, Segev G, Kelmer E, Bruchim Y. A retrospective evaluation of *Vipera palaestinae* envenomation in 18 cats: (2006-2011). J Vet Emerg Crit Care. 2014;24(4):437-443.
PUBMED | CROSSREF

35. Willey JR, Schaer M. Eastern Diamondback Rattlesnake (*Crotalus adamanteus*) envenomation of dogs: 31 cases (1982-2002). J Am Anim Hosp Assoc. 2005;41(1):22-33.
PUBMED | CROSSREF

36. Gold BS, Barish RA, Dart RC. North American snake envenomation: diagnosis, treatment, and management. Emerg Med Clin North Am. 2004;22(2):423-443, ix.
PUBMED | CROSSREF

37. August JA, Boesen KJ, Hurst NB, Shirazi FM, Klotz SA. Prophylactic antibiotics are not needed following rattlesnake bites. Am J Med. 2018;131(11):1367-1371.
PUBMED | CROSSREF

38. Gilliam LL, Brunker J. North American snake envenomation in the dog and cat. Vet Clin North Am Small Anim Pract. 2011;41(6):1239-1259.
PUBMED | CROSSREF

39. Carr A, Schultz J. Prospective evaluation of the incidence of wound infection in rattlesnake envenomation in dogs. J Vet Emerg Crit Care. 2015;25(4):546-551.
PUBMED | CROSSREF

40. Gold BS, Dart RC, Barish RA. Bites of venomous snakes. N Engl J Med. 2002;347(5):347-356.
PUBMED | CROSSREF

41. Dart RC, McNally J. Efficacy, safety, and use of snake antivenoms in the United States. Ann Emerg Med. 2001;37(2):181-188.
PUBMED | CROSSREF

42. Barr SC. Clinical features therapy and epidemiology of tiger snake bite in dogs and cats. Aust Vet J. 1984;61(7):208-212.
PUBMED | CROSSREF

43. Katzenbach JE, Foy DS. Retrospective evaluation of the effect of antivenom administration on hospitalization duration and treatment cost for dogs envenomated by *Crotalus viridis*: 113 dogs (2004-2012). J Vet Emerg Crit Care. 2015;25(5):655-659.
PUBMED | CROSSREF

44. Alirol E, Sharma SK, Bawaskar HS, Kuch U, Chappuis F. Snake bite in South Asia: a review. PLoS Negl Trop Dis. 2010;4(1):e603.
PUBMED | CROSSREF