INTRODUCTION

Snake bite envenomation remains a worldwide health hazard. The World Health Organization estimates that of the 5.4 million snake bites that occur annually, 2.7 million are venomous with a 5% fatality rate (137,880 deaths per year). Although mortality following envenomation is low, secondary complications are common, ranging from 10% to 44%. These include, but are not limited to local tissue pain, swelling, cellulitis, infection, skin necrosis, coagulopathy, compartment syndrome, muscle contracture, and various physical deformities. The wide range in complications are primarily attributed to a lack of antivenom availability, healthcare systems infrastructure and patients’ socioeconomic status.

Once a snake bite occurs, the first level of management is in the field. This is followed by triage and provision of acute care in a hospital setting with the goal of limiting the local and systemic effects of envenomation. Although envenomation is well studied in regards to field treatment and management of acute symptoms, there is a paucity of the literature regarding the management of secondary complications in this select patient population, making treatment guidelines unclear. Resulting wound complications can have permanent and debilitating features such as muscle and tendon contracture, gangrenous and necrotic tissue, osteomyelitis, and chronic wound infection, some of which may require reconstruction.

To adequately care for patients affected by snake bites, plastic surgeons must be well versed in the acute and long-term management of these wounds. Plastic surgeons have an important role in managing acute and chronic complications of snake bite envenomations that can lead to improved patient outcomes.
METHODS

A scoping review was conducted identifying relevant published articles using the search terms “management” AND “snake bite” AND “surgery.” Initial search of PubMed found a total of 87 review articles, and 44 additional articles via an EMBASE search of “management” AND “snake bite” AND “surgery” along with referenced articles from relevant initial database search. After removing duplicates, 110 articles were screened for inclusion (Fig. 1). Of these articles, 33 were excluded as they were not evaluating some form of snake bite management. Authors manually evaluated the articles’ suitability for the review and removed any that did not meet inclusion and exclusion criteria. Inclusion criteria included articles that were published between the years 2000 and 2020, published in English, and referenced either some form of snake bite management or factors that contribute to treatment disparities. Articles of all evidence levels were reviewed (Table 1).

RESULTS

No level I randomized control studies involving snake bite envenomation were identified. This review also found relatively few level II studies classified as nonrandomized control trials or prospective studies. The majority of articles were classified as below level II quality of evidence and included retrospective reviews, systematic reviews, and case reports. One meta-analysis was identified.

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Fig. 1. PRISMA flow diagram.
| Article                        | Type of Study | Subjects | Purpose                                      | Results                                                                 |
|-------------------------------|---------------|----------|----------------------------------------------|------------------------------------------------------------------------|
| Abbey et al., 2015            | Retrospective | N/A      | Evaluate epidemiology of snake bites in west Texas along with clinical manifestations | 51 were upper extremity, 38 lower extremity, 88 patients received a median of 10 vials of antivenom. 83% of patients treated successfully.  |
| Ahmad, 2009                   | Review        | N/A      | Evaluate current level of understanding of envenomation among healthcare workers | Exclusion does not support use of empiric antibiotics. If infection is observed, antibiotic treatment includes a course of empiric antibiotics. |
| Anz et al. 2009               | Review        | N/A      | Evaluate management of envenomation injury to the upper extremity | Close observation, thorough physical examination, and measurement of intracompartmental pressure are good indicators of surgical intervention.required for a definite diagnosis. |
| Ashwin et al., 2010           | Case report   | N/A      | Evaluate rare case of ocular snake bite injury and management | Combination of surgical and laser treatment successfully treated ocular injury. |
| Aziz et al. 2015              | Review        | N/A      | Assess current management in animal bites | Evidence does not support use of empiric antibiotic. If infection is observed, (cellulitis, abscess, culture and sensitivity). Ambroton is first-line drug. |
| Balaji et al., 2015           | Case report   | 1        | Evaluate post snake bite cellulitis leading to infected open dislocation of first MCP joint | Patient was treated with debridement, irrigation, and antibiotics. |
| Bonasso et al., 2015          | Retrospective | N/A      | Evaluate use of antivenom, antibiotics, and diagnostics in pediatric populations response to CroFab | Overall, pediatric population tolerated CroFab well. 6/82 developed an allergic reaction. |
| Bozkurt et al., 2016          | Retrospective | 12       | Evaluate 12 hand envenomations from Vipera berus, how to minimize functional impairment and maximize rehabilitation | All 12 patients underwent debridement, irrigation, and antibiotics. 3 cases had groin flaps, and 2 had full thickness grafts. |
| Chattopadhyay et al., 2004     | Meta-analysis | 314,078  | Evaluate the true public health concern and economic impact of sub-Saharan Africa | Reported numbers are not a true representation of the actual epidemiological impact in sub-Saharan Africa due to many fatalities, complications, and non-complicated snake bites being underreported. Incidence was inversely correlated with population density. |
| Corneille et al., 2006         | Retrospective | N/A      | Evaluate treatment of Enb antivenen (FabKv), antivenen crotalidae polyvalent, or no antivenen | Crotalus durissus can be successfully treated with cross polyvalent antivenen. |
| Correa et al., 2011           | Case report   | 1        | Evaluate previous envenomation treatment and outcomes to positively influence surgical care | Critical to receive critical care and antivenom administration if envenomation syndromes, tissue necrosis, or compromised local function. |
| Dart and McNally, 2001        | Review        | N/A      | Evaluate efficacy and safety of antivenen in the United States | Newer antivenen are more stable, predictable, and less likely to cause a reaction with cross polyvalent antivenen used primarily in the United States. |
| Dijkman et al., 2016          | Review and case report | 1 | Evaluate case of Crotalus durissus envenomation in the United States | Evaluation of local debridement and culture of infecting organism. |
| Farrar et al., 2012           | Retrospective | N/A      | Evaluate pediatric populations response to CroFab antivenen | Overall, pediatric population tolerated CroFab well. 6/82 developed an allergic reaction. All reactions were mild and did not affect course of treatment. |
| Article                        | Type of Study | No. Subjects | Purpose                                                                 | Results                                                                                                                                                                                                 |
|-------------------------------|---------------|--------------|-------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Fry et al, 2003               | Systematic review | 0            | Evaluate global state of snake envenomation                             | The snake bite crisis is ignored and underreported. Poor disbursement of antivenom and lack of adequately trained medical personnel. Continues to be an economic burden.                                       |
| Gold et al                   | Review article | N/A          | Overview envenomation diagnosis, treatment and management               | Time to transport to hospital is imperative to be further assessed by a medical professional.                                                                                                               |
| Greene et al, 2017            | Case report    | 1            | Evaluate case of Cryptelytrops albolabris envenomation on distal thumb   | Patient successfully managed with 2 rounds of 5 vials antivenin specific for the viper. Important in identifying proper snake to treat appropriately with antivenin.                                         |
| Hamdi et al, 2010             | Systematic review | NA          | Evaluate different options and techniques available to correct soft-tissue defects of the upper extremity | One must consider the nature of the defect and type of flap that is needed to properly restore form and function for optimal outcomes.                                                          |
| Heiner et al, 2013            | Retrospective review | 17           | Evaluate clinical significance of antivenom in the US military personnel in Afghanistan | Documented increased compartment pressure. Received fasciotomy. Patient had full recovery.                                                                                                                   |
| Hernandez et al               | Retrospective review | 72           | Evaluate the management and outcome of pediatric population in KwaZulu-Natal, South Africa | All bites to extremity, 10 cases received polyvalent antivenom for coagulopathy (no adverse effects), 6 received additional antivenin. None required surgery. All had resolution of coagulopathy, swelling, and pain at discharge. |
| Rha et al, 2015               | Retrospective review | 111          | Evaluate validity and safety of surgical management in snake bite patients | Group A received only debridement and group B received antivenom and debridement. Of the 10 patients in A, 2 developed cellulitis, 1 skin necrosis resulting in skin graft. Of 36 pts in B, 2 skin necrosis one of which received a graft. CS found in 1 patient in which fasciotomy and graft were performed. Patient subsequently developed compartment syndrome and required fasciotomy. |
| Hon et al, 2005               | Case report    | 1            | Evaluate patient who had to stop antivenom due to development of anaphylaxis | Use of antivenin, antibiotics, and timely presentation to hospital post envenomation improved outcomes. Bites by Taiwan cobra lead to more complications, tissue necrosis, infection and necrotizing fasciitis. Post envenomation patients should be observed for at least 48 hours. Increased WBC and AST levels indicate higher likelihood of compartment syndrome. Only 1 needed surgical intervention. Sufficient antivenom must be used to reduce further complications. |
| Hsieh et al, 2007             | Retrospective review | N/A          | Evaluate factors that contribute to complications post envenomation     | If rural hospital has enough experience and antivenom availability, it can be medically managed. Long-term follow-up showed persistence of integra collagen fibers in healing wound, also stated, “large volume loss wounds benefited from the ability to fill voids with multilayered applications.” |
| Hsu et al                     | Retrospective review | 136          | Evaluate factors responsible for compartment syndrome post envenomation | At the hospital, a thorough workup and use of a grading scale I–IV to guide antivenom administration. Evaluation of fasciotomy is necessary but rare. With careful planning and proper debridement, free flaps provide a great choice for wound coverage and restoration of form and function in the lower extremity. Most common symptoms were pain and swelling (93), then hematomas and ecchymosis (87) and compartment syndrome (8). Found 10.8% of all their snake bite victims needed fasciotomy. All had intracompartmental pressures measured. Mean of 89, range of 37–88, 2.7% of patients had adverse reactions, most common was rash, severe adverse events in 1.1% of patients. |
| Ince and Gundesliog, 2014     | Retrospective review | 23           | Evaluate Viperidae bites, single-center review                         |                                                                                                                |
| Iriion et al, 2016            | Retrospective review | N/A          | Evaluate management post envenomation and need to transfer to tertiary care hospital |                                                                                                                |
| Jeng et al, 2007              | Prospective    | 44           | Evaluate patients with soft-tissue loss who received integra for complex reconstruction |                                                                                                                |
| Juckett and Hancox et al, 2001| Systematic review | N/A          | Evaluate management and treatment of envenomations                     |                                                                                                                |
| Kang et al                    | Retrospective review | 49           | Evaluate the use of free flaps in lower extremity reconstruction        |                                                                                                                |
| Karlo et al, 2011             | Retrospective review | 93           | Evaluate envenomations in Croatian North Dalmatia region               |                                                                                                                |
| Kim et al                     | Retrospective review | 59           | Evaluate if fasciotomy is necessary post envenomation with elevated compartment pressure | Most common symptoms were pain and swelling (93), then hematomas and ecchymosis (87) and compartment syndrome (8). Found 10.8% of all their snake bite victims needed fasciotomy. All had intracompartmental pressures measured. Mean of 89, range of 37–88, 2.7% of patients had adverse reactions, most common was rash, severe adverse events in 1.1% of patients. |
| Kleinschmidt et al, 2011      | Review         | 373          | Evaluation of acute adverse events associated with CroFab antivenom    |                                                                                                                |
Table 1. (Continued)

| Article | No. | Subjects | Purpose | Type of Study | Results |
|---------|-----|----------|---------|---------------|---------|
| Lavonas et al., 2020 | 72 | Identify bacteriology of Naja atra snake bite wounds | Evaluate management of Naja atra snake bite wounds | Retrospective review | Median dose of antivenom to treat symptoms was 10 vials. Debridement in 74 patients, fasciotomy in 48, or toe amputation in 7. Most were not operated on until 3.5 d post envenomation. |
| Michael et al. | 374 | Evaluation of knowledge and management of snake bites in healthcare professionals in Nigeria | Evaluate envenomation | Cross-sectional study | 52.9% had “adequate” overall knowledge of snake bites. Clinicians need more education and training for treating snake bites. |
| Mohan et al. | 313 | Evaluate the efficacy of plasmapheresis and its use in post snake envenomation | Conduct case reports | Case report | Plasmapheresis should be used as an adjunctive treatment post envenomation. |
| Narra et al. | 100 | Evaluate AKI in snake bite victims along with early presentation and adequate antivenom and supportive care | Evaluate urotoxin envenomations | Retrospective review | Early presentation to hospital along with adequate antivenom and supportive care offers a favorable outcome for these patients. Of all patients, 86 recovered, 6 died, 8 developed chronic kidney disease. |
| Ramirez et al., 2015 | 61 | Evaluate pediatric finger envenomation resulting in chondrolysis and epiphysiolysis | Case report | Case report | One patient received PIP joint fusion and all others were managed conservatively. |
| Rha et al., 2012 | 59 | Evaluate case reports of 7 pit viper envenomations in military personnel | Evaluate pit viper envenomations | Case report | Hematologic complications were the most likely abnormality, grafts and flaps were utilized in cases where primary wound care was not sufficient. |
| Ria et al., 2015 | 111 | Evaluate urotoxin envenomations | Conduct case reports | Case report | Patients received appropriate initial treatment and had a favorable outcome. |
| Norris et al. | 313 | Evaluate use of antibiotics post envenomation. Study were randomized to receive either ampicillin alone or in combination empirically with cloxacillin prophylactically, or piperacillin or tazobactam for established infections. |
| Pulimaddi et al., 2017 | 25 | Evaluate compartment syndrome post eastern diamondback envenomation | Evaluate compartment syndrome | Case report | Treatment with multiple doses of CroFab and transfusions corrected coagulation values after patient had compartment syndrome in the right leg with “delayed recurrent coagulopathy.” |
| Rha et al., 2016 | 52 | Evaluate safety and efficacy of surgical management post envenomation | Conduct case report | Case report | 46 of 111 required debridement. Of those, who received a skin graft, 19 developed delayed closure, 2 skin necrosis, one of which needed a skin graft, and 1 had CS which required fascioplasty and skin graft. |
| Article                           | Type of Study       | No. Subjects | Purpose                                                                 | Results                                                                 |
|----------------------------------|---------------------|--------------|-------------------------------------------------------------------------|-------------------------------------------------------------------------|
| Ruha et al, 2018                 | Retrospective review| 450          | Evaluate database to explore epidemiology, clinical course, and management of snake bites in North America | 54% LE injury, 27% of which had no shoes on. Common symptoms were erythema, edema. 84% of bites received antivenom. |
| Severyns, 2018                   | Case report         | 1            | Evaluate case of Bothrops lanceolatus envenoming and its subsequent secondary complications | Surgical intervention (fasciotomy and debridement) is needed for established necrotizing fasciitis with empiric third generation cephalosporins and ICU management. |
| Sharma et al, 2008               | Review and case report| 1            | Evaluate venomous snakes in India with a focus on levantive viper case report | Identification of the snake is essential as traditional antivenom used for the “big 4” is not effective with the levantine viper. The correct antivenom is essential to successfully manage these bites. In children, adequate doses of antivenom should be administered before considering surgical treatment as 16/19 avoided surgery. Of the 3 that needed surgery, there were 2 debridements and 1 fasciotomy. |
| Shaw and Hosalkar, 2002          | Retrospective review| 19           | Evaluate if high-dose antivenom is effective in children               | Variation within venom blurs true classification of venom dichotomy. |
| Strickland et al, 2008           | Basic science       | N/A          | Evaluate the phenotypic variation within rattlesnake venom              | Necrotizing fasciitis was main reason for surgery. If patient presents with skin ecchymosis or need for high dose antivenom, they should be looked at for early surgical intervention. |
| Su et al, 2016                   | Retrospective review| 28           | Evaluate ways to predict patient who will need surgery in Naja atra envenomation | Statistically significant improvement in knowledge along with correction of common treatment myths. |
| Taieb et al, 2016                | Randomized controlled trial | 98          | Evaluate current healthcare worker knowledge of treating bee and wasp stings before and after information course | If high clinical suspicion for CS, early intervention is needed to improve outcome in these patients. Rattlesnake venom can cause prothrombotic state, leading to a DVT and CS. |
| Tincu et al, 2017                | Case report         | 1            | Evaluate case of rattlesnake bite in which DVT and compartment syndrome developed | Poor disease surveillance, lack of patients who seek medical attention, lack of widely distributed antivenom and high cost. Need to revise policy, price of antivenom, and education and medical centers. |
| Toshi et al, 2001                | Review              | N/A          | Evaluate disease burden and management of snake bites in Cameroon       | Determined incision and suction, tourniquets, and cryotherapy increase risk of needing surgery. Recommend the use of an objective envenomation scale to guide treatment and antivenom use. |
| Tokish et al, 2001               | Retrospective review| 164          | Evaluate the management of snake bite envenomations in southern Arizona | With the use of antivenom, urgent surgical intervention in crotalinae envenomation is rare. |
| Toschlog et al, 2013             | Review              | N/A          | Evaluate the best form of surgical management in North American crotalinae envenomations | Compartment pressure was 48 in thenar eminence and 59 in thumb. |
| Tucker & Josty                   | Case report         | 1            | Evaluate the case of adder bite to the hand                           | Warranted fasciectomy due to compartment syndrome. 5 mo later have full recovery and movement of all digits. |
| Türkmen and Temel, 2016          | Retrospective review| 37           | Evaluate criteria for fasciomy post envenomation                      | Fasciomy should not be performed unless intracompartamental pressure measurement is greater than 55 mmHg. |
| Wagener et al, 2017              | Prospective audit   | 164          | Determine offending bacteria of infection secondary to snake bite      | Common bacteria found in wounds were Enterobacteriaceae and enterococci. Stringently advocate for good antibiotic policy at the hospital. |
| Wu et al, 2001                   | Case report         | 1            | Evaluate the case of snake bite with Vibrio vulnificus infection       | 79yo-old man had snake bite on palm of the hand. Presented with rapidly enlarging bullae, compartment syndrome necrotizing fasciitis, and septic shock. Had debridement and several reconstructions. |
| Yildirim et al, 2006             | Retrospective review| 20           | Evaluate if plasmapheresis in snake bite patients is beneficial       | Plasma exchange is considered for treatment of snake bite management as it is safe and effective. Rapidly resolved hematologic parameters that were off. |
| Yuenyongwiwat et al, 2014        | Review and case report| 1            | Evaluate Cakile myxerosis in post snake bite patient                   | 66yo-old patient who was bit by Malayan pit viper at 14 y old has had 10 y history of progressively enlarged mass in the left leg. Broke through the skin when became infected. Excision followed by antibiotics was treatment. Plasma exchange should be considered in ED for rapid resolution of patient symptoms, especially in hematologic abnormalities, limb salvage. |
| Zengin et al, 2013               | Retrospective review| 37           | Evaluate if plasma exchange is beneficial in acute treatment of envenomation | |

AKI, acute kidney injury; AST, aspartate aminotransferase; CS, compartment syndrome; DVT, deep vein thrombosis; ICU, intensive care unit; INR, international normalized ratio; IP, interphalangeal; MCP, metacarpophalangeal; OR, operating room; PIP, proximal interphalangeal joint; UE, upper extremity; WBC, white blood cell.
Venom

Common symptomatology can be identified across snake species. Presenting symptoms of any envenomation can include generalized weakness, numbness, paresthesia, and pain. A snake’s venom is composed of a variety of enzymes and proteins that are responsible for both local tissue damage and systemic manifestations. Each species has altering levels of gene expression that control which proteins and enzymes are expressed. For example, certain species’ venom primarily expresses metalloproteinases, which can lyse membranes and cellular adhesions, causing rubor, calor, tumor, and tissue necrosis. This can present clinically as tachycardia, petechia, confusion, vomiting, disseminated intravascular coagulation, acute renal failure, shock, and compartment syndrome. Commonly, laboratory values show depleted fibrin levels, anemia (intravascular hemolysis), thrombocytopenia, and elevated BUN, creatinine, and prothrombin time/partial thromboplastin time.

Alternatively, gene expression of either alpha protein or phospholipase A2 can give the venom a neurotoxic effect in which presynaptic or postsynaptic blockade prevents signal transmission. This can lead to visual disturbance (ptosis and diplopia), dysphagia, diaphoresis, peripheral nerve palsy, diminished reflexes, and in severe cases, respiratory depression, and paralysis.

Field Management

When in the field, accurate assessment of the wound is difficult, as there are no immediate differentiating symptoms between a snake bite with or without envenomation. The focus of first aid has shifted from field treatment to timely transport to the nearest medical facility. Once at the hospital, further assessment, additional resources, and treatment options can be offered.

After sustaining a snake bite, victims and bystanders should move out of the snake’s striking distance and take a picture of the snake, if possible. The victim’s airway, breathing, and circulation should be assessed as envenomation can affect these vital functions within minutes. Current recommendations for field treatment include limiting the victim’s activity while lying them flat and keeping the bitten extremity immobilized at heart level. Keeping the bitten extremity immobilized at heart level helps prevent signal transmission. This can lead to visual disturbance (ptosis and diplopia), dysphagia, diaphoresis, peripheral nerve palsy, diminished reflexes, and in severe cases, respiratory depression, and paralysis.

Acute Hospital Treatment

Upon arrival to the hospital, intravenous access should be obtained and fluids administered, this is provider and patient dependent, as 500–1000 ml bolus of lactated ringers or normal saline is typically infused in adult patients. Current literature does not recommend prophylactic antibiotics, but if signs of infection are present, cultures and sensitivities of the wound and blood should be obtained to target the offending bacteria. A full patient workup should be performed, along with irrigation and careful inspection of the wound. The border of swelling and erythema should be marked and observed every 30 minutes to monitor progression. Consistent monitoring of clinical symptoms along with serial laboratory draws to proximal at an optimal pressure of 55 mm Hg, has been shown to be error prone and is not recommended. Initial treatment of wound incision and suction or suction alone was thought to withdraw a portion of the venom load, thus limiting the quantity of absorbed venom; however, studies have shown it can actually worsen patient outcomes and is therefore no longer recommended. Application of medicinal herbs, chemicals, and intense scrubbing/cleaning of the wound is also not recommended.

Antivenom

The mainstay of medical management is antivenom administration. Antivenom is made up of purified IgG antibodies from venom injected into animal hosts. Adverse reactions range from mild (rash, diarrhea, diaphoresis, and pain) to severe (anaphylactic shock, bronchospasm, angioedema, and hypotension). A hospital should be aware of the most common envenomations to obtain the most needed antivenoms. Antivenom can be stored in lipophilic or liquid form and has to be refrigerated. If an adverse reaction is detected upon administration, immediate antivenom discontinuation is followed by antihistamines, corticosteroids, or a combination of both should follow. Epinephrine can be used in severe cases with bronchospasm, angioedema, and hypotension.

Antivenom is indicated when there is a progression of local symptoms. This includes swelling that is either rapidly expanding, encompassing more than half an extremity, or present at the digits or toes. Antivenom is also given at any sign of systemic illness including any laboratory derangements (Table 3). Studies have found early intervention (within 4 hours of envenomation) along with higher doses of antivenom offer more favorable patient outcomes and a decreased risk of requiring surgical intervention. However, antivenom can be given within 24 hours of envenomation and still provide beneficial effects. As there is no maximum dose of antivenom—the medication should be given until clinical and laboratory derangements are corrected. Some studies report the use of an envenomation scale to aid in this decision. Initial infusion of antivenom should occur at a rate of 2 ml/min or diluted bolus with 5–10 ml/kg of isotonic saline administered at a fixed rate over 1–2 hours. With a slower rate of antivenom infusion, adverse effects are less likely to occur.
Table 2. Location Dependent Reconstructive Options

| Upper Extremity | Reconstructive Options | Comment |
|-----------------|------------------------|---------|
| Digit           | • Cross finger flap (transposition) |
|                 | • V-Y advancement flap  |
|                 | • Homodigital island flap |
| Hand—dorsal     | • Full-thickness skin graft |
|                 | • Posterior interosseous artery perforator propeller flap |
|                 | • Radial forearm flap (free or pedicled) |
| Hand—volar      | • Groin flap            |
|                 | • Cross finger flap     |
|                 | • Thenar flap           |
| Forearm/arm     | • Posterior interosseous artery perforator propeller flap |
|                 | • Radial forearm flap (free or pedicled) |
|                 | • Lateral arm flap      |
|                 | • ALT flap              |
|                 | • Latissimus dorsi flap |

| Lower Extremity | Reconstructive Options | Comment |
|-----------------|------------------------|---------|
| Toes            | • Lateral toe pulp flap |
| Foot—plantar    | • Latissimus dorsi muscular flap (larger defect) |
|                 | • Medial planter myocutaneous flap (smaller defect) |
|                 | • Lateral calcaneal    |
|                 | • Reverse sural flap   |
| Foot—dorsal     | • Scapular flap (fascial or fasciocutaneous or osteocutaneous) |
|                 | • Latissimus dorsi muscular flap (if larger defect) |
| Leg             | • Scapular osteocutaneous flap |
|                 | • Fibular osteocutaneous flap |
|                 | • Iliac osteocutaneous flap, |
|                 | • Gastrocnemius or soleus muscle flap |
|                 | • Perforator flap (propeller or keystone) |
| Thigh           | • ALT flap |
|                 | • Latissimus dorsi muscle, fascial or fasciocutaneous flap |

| Face            | Reconstructive Options | Comment |
|-----------------|------------------------|---------|
| Face            | • Local V-Y advancement flaps |
|                 | • Rotational flaps (single/bilobed flap) |
|                 | • transposition flaps (Limberg flap) |
|                 | • Median forehead flap |
|                 | • Parascapular flap |
|                 | • Rectus abdominis flap |
|                 | • Radial forearm flap |

ALT, anterolateral thigh.

(CBC, CMP, coagulation studies, and liver function tests) should be performed every 2–3 hours to evaluate possible progression of systemic complications.\(^6\,^9\)

An identified envenomation with primarily hematological sequelae and no signs of secondary complications should be monitored for a minimum of 12 hours to ensure no development or progression of symptoms.\(^9\) If bitten by a snake and neurological symptoms are present, a minimum observation period of 24 hours is required with specific neurological monitoring to ensure no further progression of symptoms (Table 4).\(^3\,\(^9\)\)

If compartment syndrome is clinically suspected, action needs to be taken in a timely manner as ignoring the need for a fasciotomy can lead to further tissue necrosis, ischemic complications and even loss of limb.\(^9\,\(^3\,\(^9\)\)

The patient will present with pain that is disproportional to examination, diminished peripheral pulses and paresthesia, increased firmness upon palpation, or have a sustained intracompartmental pressure greater than the normal values of 0–8 mm Hg.\(^9\,\(^3\,\(^9\,\(^3\,\(^9\)\)

In children, more accurate signs and symptoms that identify acute compartment syndrome are agitation, anxiety, and analgesia.\(^9\) The literature has reported independent risk factors associated with a patient needing a fasciotomy such as a hemoglobin <11 mg/dL, leukocytosis and an INR >1.2.\(^9\)

Physician disagreement regarding fasciotomy post envenomation centers around local tissue complications (pain, tense, and numb) that can potentially mimic compartment syndrome.\(^3\,\(^9\,\(^3\,\(^9\)\)

In the past, this has led to unnecessary fasciotomies.\(^9\) To further ensure a true compartment syndrome, several studies have used various cutoffs (30, 40, 45, and 55 mm Hg) indicating a need for fasciotomy.\(^9\,\(^3\,\(^9\,\(^3\,\(^9\)\)

Current literature, however, supports serial clinical evaluation with an accompanying clinical picture of compartment syndrome.\(^3\) The definitive role of measurements of elevated intracompartmental pressure to confirm
Surgical Interventions

Overall, the true incidence of envenomation injuries requiring some form of formal reconstruction is unknown. Post envenomation, plastic surgeons are frequently consulted regarding wounds where restoration of form and function are desired. Surgical interventions are more common for certain envenomations such as the cobra, as its venom is known for causing higher rates of tissue necrosis. These surgical interventions include but are not limited to fasciotoysis, wound debridement, tissue grafts, local and free tissue flaps, and rarely amputations. Resulting sequelae of snake bite envenomation that prompt surgical intervention includes infection, tissue necrosis, compartment syndrome, necrotizing fascitis, chronic wounds, and ischemic contracture. In the past, delayed wound debridement has been recommended to prevent the unnecessary removal of viable tissue. However, more recent techniques utilizing autolytic and enzymatic debridement, as well as topical wound staining that specifically targets dead tissue, may help prevent the removal of healthy tissue. Locoregional tissue grafts and flaps can be utilized to restore previous form and function of smaller defects. Occasionally, free flaps are required when there is insufficient soft tissue available for locoregional flaps. When selecting a flap, it is important to consider matching skin, bulk, composition, and size of vessels, to the recipient defect.

Upper Extremity Envenomation

Envenomation of the upper extremity and hand often requires a graft or flap in a complex reconstruction to allow for the return of form and function. Soft-tissue dysfunction within the hand can be debilitating, as many people rely on their function to perform activities of daily living, as well as occupations. Grafts and flaps must be utilized to reduce contracture of the affected area while maintaining mobility and function. The volar and dorsal hand require different flap characteristics (Table 2) as the dorsal hand has little subcutaneous and adipose tissue that easily exposes tendon and bone upon envenomation induced tissue necrosis. A variety of flaps can also be used in reconstruction of the upper extremity that closely matches the missing tissue defect (Table 2). In any hand or upper extremity injury, early rehabilitation is key to making a full recovery.

Face Envenomation

Snake bite envenomation of the face often occurs in children or agricultural workers working close to the ground. Envenomation to the face can cause tissue necrosis, contracture, and deformity making reconstruction essential. Depending on the extent of damage, local or free flaps can be used in a range of defects (Table 2).
Lower Extremity Envenomation

Envenomation of the lower extremity is most common.\(^6\),\(^13\) The foot and toes are most often involved, especially if the victim is not wearing shoes.\(^5\) Envenomation of the lower extremity can be difficult for reconstruction as neither the foot nor the toes have abundant tissue or a robust blood supply to utilize for local grafts and flaps.\(^1\) Flaps are selected based on where the defect is located, along with the defect characteristics, making each reconstruction unique and individualized.\(^4\) Defects to the plantar surface and heel of the foot need special consideration as this region contains thick tissue with glabrous skin to sustain ambulation and weight bearing.\(^4\) A variety of flaps can be used to reconstruct defects of the anterior leg and thigh as well (Table 2).\(^4\)

DISCUSSION

Snake bite envenomation is an underreported global health crisis.\(^6\) True incidence is likely underreported due to lack of contact with healthcare system for less severe snake bites.\(^5\)\(^,\)\(^13\) Multiple studies support the use of early and sufficient doses of antivenom administration to reduce the need for surgical intervention. However, there is a sparse availability of antivenom in rural and resource poor areas, especially in LMICs as the price of antivenom is cost prohibitive. Socioeconomic factors and a lack of access to resources also preclude timely treatment of snake bites in LMICs.\(^5\)\(^,\)\(^6\)\(^,\)\(^8\) This results in higher rates of secondary complications than seen in HICs, indicating even more of a need for plastic surgeons to treat the resulting sequelae in this patient population. Efforts in LMICs should be focused on envenomation education as treatment myths can potentiate local effects of the venom’s cytotoxic enzymes, worsening local tissue injury, and patient outcomes. Although antivenom availability can be limited in LMICs, receiving treatment at a healthcare facility should be encouraged.

Plastic surgeons are well suited to care for the acute and chronic management of snake bite victims through reconstructive procedures.\(^1\)\(^,\)\(^5\)\(^,\)\(^11\) These procedures are essential for allowing patients to regain their normal life.\(^10\) Post envenomation, wound debridement was among the most cited procedures which is essential to any successful reconstructive outcome. Although fasciotomies are a controversial intervention post envenomation, they cannot be ignored as there are severe consequences if true compartment syndrome is not acted upon in a timely manner. Studies also showed that overall amputations are most common in envenomation to the digits or toes, especially if antivenom is not administered. After the effects of envenomation have been controlled, reconstructive options post envenomation should be evaluated as any other soft-tissue defect, paying special attention to proper debridement.

Patient education is important to provide the general population with knowledge about treatment post envenomation. Further global effort is needed among private companies and governments to provide effective and affordable antivenom that is widely distributed and readily available to those who need it most.

This study is limited by the level of evidence of available studies; many case reports and single-center retrospective reviews composed the literature search.

CONCLUSIONS

Plastic surgery has an important role in snake bite management and the resulting complications. Published reports have demonstrated multiple ways to manage envenomation with a variety of techniques in an effort to reduce these secondary complications and improve patient outcomes.\(^3\) Timing of plastic surgery intervention can range from immediate (fasciotomy) to days, weeks, or years (debridement, scar contracture release, and flap) which is unique to each patient’s situation, geographic location, and timing of presentation. Victims of snake bite envenomation need a multidisciplinary team that understands the underlying pathophysiology and potential complications to avoid a delay in treatment. It is essential for plastic surgeons to take responsibility for these patients to help restore both form and function.

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