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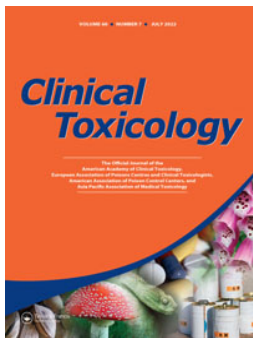
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ABSTRACT

Introduction: Snakebite is recognised as a neglected tropical disease and a cause of substantial morbidity and mortality. Whilst the most medically important snakes are typically native of Asia, Africa, Latin America and Oceania, the possibility of encountering these snakes is no longer limited by geography due to an increasing number of exotic (non-native) snakes being held in captivity.
Methods: A retrospective review of snakebite enquiries to the UK National Poisons Information Service (NPIS) between 2009 and 2020. Enquiries about the European adder (*Vipera berus*) or where the identity of the snake was unknown were excluded.
Results: There were 321 exotic snakebites in 300 patients involving 68 different species during this period. Ten patients were bitten on more than one occasion. The majority of patients (64.5%) were male. Most bites were inflicted by snakes of the family Colubridae (184/321, 57.3%); seventeen bites resulted in moderate symptoms (predominantly swelling of the bitten limb). There were 30 (9.3%) bites by Viperidae and 14 (4.3%) bites by Elapidae. All severe cases ($n = 15$) resulted from bites by either Viperidae ($n = 10$) or Elapidae ($n = 5$). Antivenom was given in 17 cases. One fatality was recorded.
Conclusions: Despite their low incidence, exotic snakebites present a substantial challenge for UK healthcare professionals. Although rare, these bites typically occur in individuals (usually male) who keep snakes as part of their occupation or hobby and are therefore at risk of multiple bites. Bites can result in venom hypersensitisation and the risk of venom-induced anaphylaxis. Rapid access to expert clinical advice is available in the UK on a 24-hour basis through the National Poisons Information Service and is strongly recommended in all cases of exotic snakebite.

Introduction

Snakebite is a global issue, recognised by the World Health Organisation (WHO) as a top-priority neglected tropical disease [1]. The true healthcare burden attributable to snakebites is uncertain, but the WHO estimates a global mortality of between 81,000 and 138,000 per year, with as many as 400,000 survivors per year being left with permanent physical and psychological morbidity [1]. However, these figures may be underestimates in view of recent data from India, indicating about 58,000 deaths per year in that country alone [2], while data are unavailable from some populous and venomous-snake-rich countries such as the Democratic Republic of Congo and Pakistan.

Most medically important snakes are indigenous to Asia, Africa, Latin America and Oceania, but the possibility of encountering these species is no longer limited by

geography. In Europe "cats and dogs have been replaced by snakes" as domestic pets [3,4], and in both the United States and the United Kingdom, reptile ownership has been increasing [5,6], among which snakes are the most common [7]. In both the USA and the UK, snake ownership is estimated to be approximately 0.8% of households [6,8].

Strict conditions regulate the keeping of dangerous animals such as venomous snakes in captivity (in the UK) [9] and clear guidelines are available for minimising the risk to those snake owners who are so entitled. However, it is recognised that many dangerous animals including venomous snakes are kept illegally.

Envenoming by exotic snakes is reported from the United States and Europe [4,10–15]. Between 1977 and 1995, fifty-four exotic snakebites were reported in the United States [13] and this increased to 258 between 2005 and 2011 [11].

In a European Poison Centre study, snakebites accounted for 39% of all bites and stings reported over an 11-year period [4]. Bites by exotic venomous snakes have also been identified as emerging medical challenges in other countries, such as Brazil [16,17], Hong Kong [18] and South Korea [19]. In all these studies, Viperidae or Elapidae were responsible for the most serious cases of envenoming.

Two reports describing the UK experience of exotic snakebites have been published [10,20]. Between 1970 and 1977, thirty-two bites from exotic venomous species were reviewed [10]. More recently, the UK National Poisons Information Service (NPIS) reviewed all snakebite enquiries between 2004 and 2010 [20], and although the majority involved the European adder (*Vipera berus*), the only venomous snake native to the UK, a quarter of cases (equivalent to 19 cases per annum) involved exotic snakes kept in captivity. In 2007, a 22-year-old reptile shop worker (in the UK) was the subject of a case report of severe king cobra (*Ophiophagus hannah*) envenoming [21], emphasising the need for expert advice when managing these cases.

Methods

The UK NPIS provides information and evidence-based management advice to NHS healthcare professionals managing cases of poisoning. This is delivered through an online database TOXBASE® and a 24 h telephone advice service. In cases of envenoming from exotic snake species the NPIS is supported by Professors Michael Eddleston (ME), David Lalloo (DL) and David Warrell (DW) because of their specialist experience in clinical toxinology. All telephone enquiries are recorded in the UK Poisons Information Database.

The UK Poisons Information Database was interrogated for enquiries between 01/01/2009 and 31/12/2020. All calls involving snakebite were extracted but only those involving snakes where an accurate identification was provided underwent further analysis. Calls about the European adder (*Vipera berus*) were excluded. Data extracted from the enquiries included: age of patient; identity of the snake; site of bite; features and treatments administered at time of enquiry and features and treatments given during any in-patient stay obtained through routine follow up. The Poisoning Severity Score (PSS) [22] was also extracted.

This study did not require approval by a UK Research Ethics Committee as the UK Health Research Authority has declared that ethical approval is not needed for research studies that use information collected routinely in any UK administration (England, Wales, Scotland, Northern Ireland) as part of usual clinical care, provided this information is passed to the researchers in a fully anonymised format. The authors of this work (LG, RT, EAS, SMB) are also the Data Controllers for the database used in this study. Separate permission for use was not required.

Results

Three hundred and twenty-one snakebites (to 300 patients) involving identified exotic snakes were reported to the NPIS during this period. Nine patients were bitten twice and one patient three times. The majority (*n* = 207, 64.5%) of exposures occurred in males. Although most exposures occurred in adults (*n* = 249, 77.6%), 72 exposures occurred in children aged 17 years or less of whom 13 were aged 5 years or less.

Two-hundred and sixty (81.0%) bites involved pet snakes in the home, 38 (11.8%) bites occurred as a result of occupational exposure (zoologists, pet shop workers and reptile specialists), and five (1.6%) bites occurred overseas. One case (0.3%) of occupational exposure overseas was reported. The remaining 17 patients were bitten in public areas whilst participating in animal handling events (in pet shops, zoos or schools).

In total, bites from 68 snake species across seven snake families were the subject of the enquiry to the NPIS: Colubridae *n* = 184 (57.3%), Pythonidae *n* = 57 (17.8%), Boidae *n* = 34 (10.6%), Viperidae *n* = 30 (9.3%), Elapidae *n* = 14 (4.4%), Lamprophiidae *n* = 1 (0.3%) and Tropodophiidae *n* = 1 (0.3%).

The site of bite was recorded in 233 cases (72.6%). The large majority of bites (*n* = 213, 66.4%) involved the upper extremities (shoulder to finger). Seven bites involved the lower extremities (leg to foot), eleven on the head (neck, face and ears) and two on the chest.

The majority of snakebites resulted in either no or only minor symptoms (*n* = 272, 86.6%), with a maximum PSS of none (*n* = 81, 25.8%), minor (*n* = 191, 60.8%), moderate (*n* = 27, 8.6%), severe (*n* = 14, 4.5%) and fatal (*n* = 1, 0.3%) in the 314 exposures where a PSS was documented (Table 1). All severe bites involved Viperidae or Elapidae and were observed in 12 patients. Their case summaries are provided in Table 2.

Forty-three cases (13.4%) were discussed with an NPIS clinical toxinologist for specialist advice. Administration of antivenom was documented in 17 (5.3%) cases of which

Table 1. Exotic snake exposures and associated maximum Poisoning Severity Score.

| Family | N | Maximum Poisoning Severity Score | | | | | |
		0	1	2	3	4	Unknown
Colubridae	184	47	118	17	–	–	2
Pythonidae	57	20	36	–	–	–	1
Boidae	34	14	20	–	–	–	–
Viperidae	30	–	9	9	9	–	3
Elapidae	14	–	7	–	5	1	1
Tropidophiidae	1	–	–	1	–	–	–
Lamprophiidae	1	–	1	–	–	–	–
Total	321	81	191	27	14	1	7

Table 2. Case histories involving severe snakebites.

Patient one

An amateur snake keeper was bitten on the hand by a monocled cobra (*Naja kaouthia*). They developed local swelling and anaphylaxis including difficulty swallowing, and lip, tongue and upper airway oedema. The patient was admitted to intensive care, intubated and ventilated and received 15 vials of expired (by 4 years) Thai Red Cross King Cobra Monospecific Ophiophagus hannah F(ab)'$_2$ antivenom (claimed to have cross-reactivity with *Naja kaouthia*), within 24 h of the bite, and subsequently made a complete recovery. Venom-induced anaphylaxis was the most likely explanation for their symptoms, caused by previous hypersensitisation to cobra venom, rather than neurotoxic envenoming. They re-presented 14 months later following a bite to the hand by a dusky pygmy rattlesnake (*Sisturus miliarius barbouri*). The patient developed severe pain and paraesthesiae with swelling up to the elbow. Specialist advice included a recommendation to administer antivenom only if swelling extended beyond the elbow. Antivenom was not administered, and the patient made a full recovery

Patient two

An amateur snake keeper was bitten on the left index finger by a Mozambique spitting cobra (*Naja mossambica*). They presented to hospital 30 min after the bite and developed pain and bleeding with local swelling progressing just beyond the wrist. The patient was treated with SAIMR Polyvalent Equine, F(ab')$_2$ antivenom (4 vials) within 12 h of the bite. They subsequently required partial amputation of the finger due to necrosis at the bite site. Approximately 14 months later they sustained a bite to the wrist from an Indian cobra (*Naja naja*) and presented to hospital after one hour with swelling, bruising and discolouration of the bite site. The patient reported pain in the wrist radiating to the shoulder. Over the next hour they developed drowsiness and blurred vision. At the time of the next contact with the NPIS (8 h post-bite) the patient had been admitted to intensive care, intubated and ventilated, and had received 5 vials of Haffkine Polyvalent Snake Antivenin I.P. Haemofiltration and large volumes of IV fluid were given to help combat the risks of rhabdomyolysis evidenced by elevated creatine kinase activity (23,000 IU/L). However, the patient developed acute kidney injury with persistent anuria (no peak creatinine documented) lasting for several days post-bite. Renal injury was attributed to rhabdomyolysis with a peak creatine kinase activity of 25,500 IU/L. By 31 h post-bite, when a second dose (5 vials) of antivenom was administered, the creatine kinase had decreased to 20,000 IU/L. The patient was extubated at approximately 48 h post-bite, but was still experiencing significant peripheral weakness and anuria. At ten days post-bite, the patient developed skin necrosis which subsequently required debridement. They were discharged with stable renal impairment (creatinine 500 mmol/L) but no longer requiring renal replacement therapy following a three week admission.

Patient three

An amateur snake keeper was bitten three times during the review period. The first bite was to the index finger from a copperhead (*Agkistrodon contortrix*). The patient developed paraesthesiae and swelling limited to the fingers. Although advice from a clinical toxinologist was sought, no antivenom was administered as the patient remained systemically well. They presented again three months later following a bite to the hand from a brown spotted pit viper (*Trimeresurus venustus*). The hand was described as very swollen, but case documentation was incomplete, and the precise clinical course was not available for review. The patient presented a third time approximately 18 months after the first bite following a bite to the thumb from a dusky pygmy rattlesnake (*Sistrurus miliarius barbouri*). CroFab® Fab antivenom was administered because of substantial swelling to the forearm. Specific details regarding antivenom dose and time of administration were not documented. Following antivenom the swelling subsided and the patient was discharged following a two day admission.

Patient four

A reptile conservationist was bitten by an eastern green mamba (*Dendroaspis angusticeps*). Case details were limited and precise treatments administered were unclear. The patient was bitten again 27 months later by a king cobra (*Ophiophagus hannah*) but developed only local swelling. Two weeks later, they were bitten on the arm by a king cobra while working alone. The patient was seen staggering "as if drunk", hosing water onto their arm but soon became cyanosed and collapsed. The patient received CPR and adrenaline but was pulseless when paramedics arrived. Despite administration of 10 vials of privately held Thai Red Cross King Cobra F(ab)'$_2$ antivenom, the patient was pronounced dead from asystolic cardiac arrest after 1 h. Venom-induced anaphylaxis is the most likely explanation.

Patient five

An amateur snake keeper was bitten on the left middle finger by a juvenile Mexican jumping pit viper (*Atropoides nummifer*). They developed a 0.5 cm haematoma and pain at the bite site but otherwise remained well. Eight months later the patient was bitten on the ring finger by a hybrid eastern and western diamondback rattlesnake (*Crotalus adamanteus x Crotalus atrox*) that they had specifically bred. They presented to hospital 2 h after the bite with localised blackening of the finger, but by the time the NPIS was consulted (15 h post-bite) the patient had developed substantial swelling as far as the elbow and increasing pain. In the absence of Antivipmyn®, the patient was administered Antivipmyn® Tri F(ab')$_2$ antivenom (7 vials) at 21 h post-bite and required morphine throughout their in-patient stay for pain management. No further antivenom was required and the patient was discharged following an eight day hospital stay.

Patient six

A zoologist was bitten on the right index finger by a common lancehead (*Bothrops atrox*) while working in Trinidad. They were discharged from hospital in Trinidad and presented to hospital in the UK 42 h after the bite with swelling up to the elbow. Details of any initial clinical management whilst overseas was not documented, but no antivenom was administered in the UK and the patient was discharged with a course of antibiotics for suspected secondary infection.

Patient seven

An amateur snake keeper was bitten on the right thumb by a Namibian puff adder (*Bitis arietans*) in the early hours of the morning. Initially they appeared well on presentation to the emergency department at 2 h post-bite, but subsequently developed significant swelling (reaching the shoulder) and thrombocytopenia (nadir platelet count 36×10^9 /L) without coagulopathy. The patient received two doses of SAIMR Polyvalent Equine, F(ab')$_2$, the first dose (5 vials) on the afternoon of the first day and a further 5 vials (due to increased swelling) approximately 24 h later. The patient developed some antivenom associated adverse effects including fever, rigors, tachycardia and hypertension but these resolved with supportive measures. After four days, the wound was debrided revealing soft tissue oedema but no signs of local infection. The patient made a complete recovery and was discharged after seven days.

Patient eight

A zoologist was bitten at home by a cantil (*Agkistrodon bilineatus*) on the right index finger and developed a blood blister at the site but no other symptoms until 15 h later. They subsequently developed increasing oedema and swelling as far as the armpit which prompted presentation to hospital at 19 h post-bite. On examination there was patchy erythema on the upper arm and the axilla. Although there was no evidence of compartment syndrome, orthopaedic support was requested to decompress a haemorrhagic blister and the wound was dressed. The patient was administered Instituto Clodomiro Picado (ICP) Polyvalent Crotalinae Equine IgG antivenom (8 vials) at 26 h post-bite and was deemed medically fit for discharge at four days post-bite. However, five days later they represented with features of serum sickness (macular rash to the trunk, legs and face, lip swelling, hoarseness and fever), which was treated with adrenaline, hydrocortisone and chlorphenamine. The patient was admitted for observation overnight and discharged the following day.

Patient nine

Patient nine worked in an exotic pet shop and was bitten on the right index finger whilst feeding an African rhinoceros viper (*Bitis nasicornis*). They presented to the emergency department after 30 min with local erythema and swelling. By seven hours the patient developed more severe swelling to the upper arm which prompted transfer to the intensive care unit and administration of 3 vials of EchiTAb-plus-ICP IgG antivenom (expired <12 months). They received a total of 6 vials of antivenom within 24 h of the bite. Following administration of antivenom the patient developed transient tachycardia and hypertension. Four days post-bite the right arm remained swollen with a yellow healing bruise extending from the upper arm over the back to just

Table 2. Continued

beyond the right flank. Routine blood coagulation tests and renal function remained normal throughout admission and they were discharged six days after the bite. The patient presented again eight days later with features of serum sickness including widespread urticaria, bruising and swelling to the right hand (which had previously settled) with new petechial dots to the right arm. The symptoms were managed supportively with antihistamines and corticosteroids. Ten months later the patient presented to hospital 3 h after sustaining a bite to the dorsum of the right hand from an Indian cobra (*Naja naja*). Despite localised swelling they were initially clinically well but subsequently developed ptosis. The patient was administered 5 vials of Haffkine Polyvalent Snake Antivenin I.P. within 6 h of the bite. The clinical course involved minimal ptosis and marked swelling to the hand. There was relatively limited spread of oedema which required limited debridement (2 cm × 2 cm necrosis over the metacarpophalangeal joint).

Patient ten

A herpetologist was bitten on the thumb by an eastern sand viper (*Vipera ammodytes meridionalis*) and developed marked swelling to the arm. The patient was assumed to have made a complete recovery. They were bitten again 4 years later by a Baja California rattlesnake (*Crotalus enyo*) on the right index finger and developed immediate symptoms of anaphylaxis, despite self-administering adrenaline. On admission to an emergency department 30 min after the bite, the patient was hypotensive, tachycardic and tachypnoeic with bronchospasm. They were treated for anaphylaxis, but they deteriorated, and 30 min later had an unrecordable blood pressure. The patient was intubated, ventilated and given inotropes with marked improvement. Antivenom was not administered as it was not thought the patient had suffered systemic envenoming but acquired venom hypersensitivity. The precise clinical course was not documented but the patient was known to have survived.

Patient eleven

A reptile centre worker was bitten on the dorsum of the left hand by a western diamondback rattlesnake (*Crotalus atrox*) whilst cleaning its enclosure. On admission (approximately 1 h post-bite) they had developed localised swelling with diarrhoea, vomiting and light headedness. At 4 h post-bite due to progressive swelling along the forearm Antivipmyn® Tri F(ab)'₂ antivenom was administered. At 24 h post-bite the swelling continued to progress reaching the shoulder, they developed thrombocytopenia (platelets 74 × 10⁹ /L) and a further dose of antivenom was administered. No outcome was reported but two years later the patient presented to hospital with visual disturbances including decreased visual accommodation, ptosis and peri-oral tingling following a bite to the right hand from a forest cobra (*Naja melanoleuca* – now considered to be a complex of at least 5 different species). There was swelling to the right hand with erythema tracking up the arm and bleeding at the bite site. Within two hours of the bite the patient had complete ptosis and diarrhoea and was complaining of breathing difficulties and a swollen tongue. They were admitted to intensive care and administered 10 vials of SAIMR Polyvalent Equine, F(ab')₂ antivenom. The patient continued to deteriorate with cardiovascular instability and lactic acidosis. They received a further 10 vials of antivenom within 24 h of the bite and was extubated after 4 days. Despite complications including suspected acute respiratory distress syndrome, acute kidney injury and thrombocytopenia, the patient was discharged after a 15 day admission. Despite undoubted systemic envenoming on both occasions, some of the symptoms (diarrhoea, swollen tongue) suggest venom-induced anaphylaxis in someone whose occupation exposed them to the risk of becoming hypersensitised.

Patient twelve

Patient twelve was bitten on the right index finger by their pet juvenile prairie rattlesnake (*Crotalus viridis*) and presented to hospital within 30 min with localised redness and swelling. The case was discussed with a clinical toxinologist, but as there was no evidence of systemic envenoming and localised swelling only, antivenom was obtained but not administered. The patient was observed overnight and remained well until discharge. Eighteen months later they were bitten on the right index finger by a western diamondback rattlesnake (*Crotalus atrox*). The patient presented with pain and numbness in the right hand and swelling which rapidly progressed beyond the elbow. Diffuse subcutaneous oedema was noted to the dorsum of the hand. The patient was administered 5 vials of CroFab® Fab antivenom approximately 6 h post-bite and subsequently a further 5 vials, both without adverse effects. No derangements in blood investigations were recorded and the patient was discharged on antibiotics after a three day stay.

eleven involved Viperids (three receiving antivenom in an overseas medical facility) and six involved Elapids.

The time of antivenom administration from time of bite was known in 13 of the 17 cases, with a median (IQR) time of 12 h (6–24 h) to administration (eleven within 24 h of which eight were within 12 h). Of the remaining four cases receiving antivenom, three were treated overseas and detailed documentation was not available.

Outcome data were available for 44 episodes of snakebite. Thirty-eight episodes resulted in patients making a complete recovery. Four patients were recorded as having ongoing features at the time of discharge but were expected to make a complete recovery. One patient was documented as having permanent sequelae and there was one documented fatality.

Bites by Colubridae spp

There were 184 cases of Colubridae snakebite in 183 patients. One patient was bitten on two separate occasions. Ninety percent of bites (*n* = 165) involved either hognose snakes (*n* = 74) [71 of which were the western hognose (*Heterodon nasicus*)], corn snakes (*Pantherophis guttatus*) (*n* = 56), king snakes (*Lampropeltis spp*) (*n* = 18) or false water cobras (*Hydrodynastes gigas*) (*n* = 17). Fifty-three bites occurred in children aged 17 years or less (nine aged 5 years or less). Seventeen bites resulted in moderate symptoms (predominantly local limb swelling; four in children aged between 13 to 17 years), 16 of which involved pet snakes.

Bites by Pythonidae spp

There were 57 cases of Pythonidae snakebite in 56 patients (49 cases involved pet snakes). One patient was bitten on two separate occasions. Thirty-six bites involved royal pythons (*Pythion regius*), eight Burmese pythons (*Python bivittatus*) and five carpet pythons (*Morelia spilota*). Ten bites were in children aged 17 years or less. The majority of bites (*n* = 56) resulted in either no or minor symptoms. The severity of the remaining case was unknown.

Bites by Boidae spp

There were 34 cases of Boidae snakebite in 34 patients (30 cases involving pet snakes). Twenty-nine were by common boas (*Boa constrictor*), 4 by rainbow boas (*Epicrates cenchria*) and one case by a green anaconda (*Eunectes murinus*). Nine bites were in children aged 17 years or less. All bites resulted in either no or minor symptoms.

Bites by Viperidae spp

There were 30 cases of Viperidae snakebite involving 20 different species in 25 patients (Table 3). Bites by Western

Table 3. Non-native Elapidae or Viperidae exposures reported to the UK National Poisons Information Service, 2009–2020.

Family	Common name	Latin name	n
Elapidae	Indian cobra	*Naja naja*	3
	King cobra	*Ophiophagus hannah*	2
	Monocled cobra	*Naja kaouthia*	2
	Black mamba	*Dendroaspis polylepis*	1
	Egyptian cobra	*Naja haje*	1
	Forest cobra	*Naja melanoleuca*	1
	Mozambique spitting cobra	*Naja mossambica*	1
	Eastern green mamba	*Dendroaspis angusticeps*	1
	Coastal taipan	*Oxyuranus scutellatus*	1
	Equatorial spitting cobra	*Naja sumatrana*	1
	Total (*n*)		14
Viperidae	Western diamondback rattlesnake	*Crotalus atrox*	5
	Copperhead	*Agkistrodon contortrix*	3
	Dusky pygmy rattlesnake	*Sistrurus miliarius barbouri*	2
	White lipped green pit viper	*Trimeresurus albolabris*	2
	Asp viper	*Vipera aspis*	2
	Blunt nosed viper	*Macrovipera lebetinus*	2
	Bornean keeled green pit viper	*Tropidolaemus subannulatus*	1
	Brown-spotted pit viper	*Trimeresurus venustus*	1
	Cantil	*Agkistrodon bilineatus*	1
	Common lancehead	*Bothrops atrox*	1
	Eastern/western diamondback rattlesnake	*Crotalus adamanteus x Crotalus atrox*	1
	Eastern sand viper	*Vipera ammodytes meridionalis*	1
	Eyelash viper	*Bothriechis schlegelii*	1
	Green bush viper	*Atheris squamigera*	1
	Mexican jumping pit viper	*Atropoides nummifer*	1
	Namibian puff adder	*Bitis arietans*	1
	Northern Pacific rattlesnake	*Crotalus oreganus*	1
	Prairie rattlesnake	*Crotalus viridis*	1
	African rhinoceros viper	*Bitis nasicornis*	1
	Baja California rattlesnake	*Crotalus enyo*	1
	Total (*n*)		30

diamondback rattlesnakes (*Crotalus atrox*) (*n* = 5) and copperheads (*Agkistrodon contortrix*) (*n* = 3) were the most common. Sixteen patients were bitten at home, eight during the course of their work and six overseas (one of six during the course of their occupation). Twenty-six patients were bitten on the finger, thumb or hand (86.7%). Antivenom was administered to 11 patients. Complete recovery was documented in 18 cases, ongoing symptoms in one, and the outcome was unknown in the remaining 11.

Bites by Elapidae spp

There were 14 cases of Elapidae snakebite involving 10 different species in 12 different patients (Table 3). Bites by Indian cobras (*Naja naja*) (*n* = 3), monocled cobras (*Naja kaouthia*) (*n* = 2) and king cobras (*Ophiophagus hannah*) (*n* = 2) were the most common. Seven snakebites occurred in the home and seven during the course of the individuals' occupations. Eight bites involved the upper extremities (seven on the hand; three to the hand itself, two to the fingers, and one on both the thumb and wrist), two to the leg or foot, and the site of bite was not documented in four cases. Antivenom was administered in six cases. Complete recovery was documented in five cases, ongoing symptoms in two, permanent sequelae in one and one death. An outcome was not available in five cases.

Bites by other spp

A further two bites were recorded in this series. One involved a Schokari sand racer (*Psammophis schokari* family

Lamprophiidae) and the other a dwarf boa (*Tropidophis melanurus* family Tropidophiidae).

Discussion

Our results show an overall increase in the number of exotic snakebites reported to the NPIS compared to what has been described previously [20]. Consistent with other reports [3,4,11–14,23,24], the diversity of species remains broad, and males were more likely to be the victims of snakebites.

The majority of bites in this series, and others where snakes are kept in captivity, occur on the upper extremities, to fingers, hands and wrists, following deliberate handling interaction especially by males [12], as is the case with bites by native adders (*Vipera berus*) in the UK [25]. This is in contrast to tropical snakebite-endemic countries, where the majority of bites occur on the lower extremity, suggesting that the bite is the result of an unintentional encounter [26].

Bites from colubrid snakes were most common. Most of these often brightly coloured and attractive snakes, do not require a special license under the Dangerous Wild Animals Act 1976 (Modification) (No.2) Order 2007 [9]. However, while most bites from non-front-fanged colubrid snakes are harmless, some (17 in our series) can cause mild local envenoming particularly in instances where the snake retains its hold after a bite [27]. Colubrids were responsible for the majority (74%) of paediatric snakebites, this is in contrast to experience in the United States where boa constrictors accounted for 49% of paediatric exotic snakebites [28].

All severe snakebites in our series were caused by front-fanged Elapidae or Viperidae. Despite very small case numbers, consistent with previous experience in the UK [10,20], western diamondback rattlesnakes (Crotalus atrox) and Indian cobras (Naja naja) remain a common cause of venomous snakebite, often requiring antivenom administration.

In a European Poison Centre study, 28 of 29 severe exotic snakebites were caused by those from the Elapidae (n = 3) or Viperidae (n = 25) families and antivenom was administered in 11 cases [4]. In the United States, 54 exotic venomous snakes bites were reported over a 17-year period [13]. Bites by Elapidae and Viperidae were the most common, accounting for 89% of cases.

In the present study, ten patients were bitten on more than one occasion (nine patients bitten twice and one patient bitten three times). Individuals who have a particular interest in keeping venomous snakes must accept the risk of being bitten, potentially on more than one occasion, as one of the hazards of ownership. They should be aware of the risk of becoming hypersensitised to venom [29]. In patient four, venom-induced anaphylaxis was the most likely explanation for the fatal outcome. It was also suspected in patients 1, 10, and 11 of this series. Fatalities (in snake handlers) due to venom-induced anaphylaxis have been described previously [24]. The potentially fatal risk of venom-induced anaphylaxis is that its symptoms are misinterpreted as envenoming resulting in an emphasis during resuscitation on antivenom administration rather than adrenaline.

As in other reports [12,23], the specific time from bite to administration of antivenom was not always recorded but was available in approximately 70–80% of cases (76% in our series). In our review the median time to antivenom administration for exotic species was 12 h (range 1–48 h) but included one case of administration of privately held antivenom. After exclusion of this case, the range changed to 4–48 h but the median remained at 12 h. This compares to a median time of 4 h for antivenom administration for native Vipera berus envenomings in the UK [25].

We report one case in which two species of venomous rattlesnake had been intentionally crossbred. On this occasion, the antivenom administered covered both parent species. However, this might not be possible for all instances of hybridisation [30]. A similar situation was encountered in France involving a spitting cobra hybrid (African x Asian species) [31]. Although that patient suffered venom opthalmia only, had he been bitten and systemically envenomed, the clinical course would have been difficult to predict and more challenging in determining the most suitable antivenom.

Rapid access to expert toxinological advice and availability and acquisition of appropriate antivenom are important considerations when these very rare accidents occur. In two cases (patients one and nine), the only antivenom available had expired. There is published evidence of retention of potency in expired antivenoms, although there is uncertainty about whether they pose a greater risk of adverse reactions. In such scenarios a careful risk benefit assessment is necessary [32]. The NPIS makes this assessment in consultation with the physician in charge, recommending that the patient be told about this assessment and suggesting that a simple form acknowledging the decision should be signed by the prescribing clinician.

There are some limitations to the data presented here resulting from its retrospective analysis, as is the case for most poison centre studies [33]. Data collection was not consistent across the study period and precise circumstances surrounding the bite were not always recorded. Data on alcohol consumption or intoxication around the time of the bite was not routinely collected, though this has been reported elsewhere [14,31]. Similar to experience in the United States and Europe, information on patient outcome was not always available [3,11,34]. This is common to poison centre epidemiology studies since there is no actual contact with the patient, only with the enquiring clinicians.

A prospective study with a pre-agreed structured data collection sheet with daily follow up of these cases would ensure a standardised dataset for future exotic snakebite presentations in the UK. This is currently underway. It will support educational needs for poison centre staff and potentially inform the UK antivenom supply chain.

Ownership of exotic and venomous species of snakes (particularly some Colubridae, and all Viperidae and Elapidae) requires compliance with The Dangerous Wild Animals Act 1976 (Modification) (No.2) Order 2007 [9]. It is recognised that some individuals may keep these snakes illegally [30] and therefore the true incidence of envenomation by these species may be underreported.

Conclusion

Despite their low incidence, envenoming from exotic (non-native) snake species presents a substantial challenge for UK healthcare professionals. Although the most severe envenomings result from bites by Viperidae or Elapidae, these are rare and typically occur in those people (usually male) who keep snakes as part of their occupation or hobby and are therefore at risk of multiple bites. These exposures can result in venom hypersensitisation and the risk of venom-induced anaphylaxis. Rapid access to expert clinical advice and guidance on antivenom administration is available in the UK on a 24-hour basis through the National Poisons Information Service.

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