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Short communication

Fang tip spread, puncture distance, and suction for snake bite

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Abstract

We measured the distance between fang tip punctures in defensive bites by western diamondback rattlesnakes (*Crotalus atrox*) and the distance between their retracted fangs. Because the fang tips at penetration average 112% further apart than their bases at rest, *The Extractor*®, a device widely marketed in the United States for snake bite first aid, will not simultaneously cover both punctures of most adult New World pitvipers.

The Extractor® (Sawyer Products, Safety Harbor, Florida; hereafter Extractor) is widely marketed in the United States for venomous snake bite first aid. This device is not recommended as definitive treatment, because it has not been shown to improve outcome in clinical studies (Hardy, 1992); nonetheless, there is a widespread public belief that aspiration of venom from the bite wound improves the outcome of pitviper envenomation (Bronstein et al., 1985, 1986; Gold, 1993;

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Hardy, 1992). Recently, a biologist was bitten by an adult terciopelo (*Bothrops asper*) in Costa Rica and the fang punctures on the foot were too far apart for simultaneous suction with the largest cup in the Extractor; two devices were necessary for simultaneous and continuous suction of both wounds (M. Maple, personal communication). Thus, this untested first aid measure may suffer from yet another limitation in that one may need to alternate a single Extractor on both wounds, reducing the overall time of suction. We explored the extent to which fang puncture distances and suction cup diameter might jointly hamper Extractor use for bites by three widespread New World pitvipers frequently involved in human snake bite (Fan and Cardoso, 1995; Hardy 1994a,b; Parrish, 1964, Parrish and Donnell, Jr., 1967): the western diamondback rattlesnake (*Crotalus atrox*), the cottonmouth (*Agkistrodon piscivorus*), and the terciopelo.

We examined all preserved specimens of the three pitviper species in the Museum of Vertebrate Zoology, University of California, Berkeley. For each specimen, we measured total body length (TL, snout-vent plus tail lengths, to the nearest mm) as the measure of size most relevant to those contemplating first aid for snake bite. The protractable fangs of pitvipers become immobilized by tissue fixation, thus, we measured inter-fang distance between retracted fangs (IF, rounded to the nearest mm) with digital calipers. IF was measured between the midlines of the bases of the fang sheaths and taken perpendicular to the long axis of the snake's head. These three species are large-bodied as adults (Table 1A) and they overlap in total length during much of their ontogeny, so our sample included neonates, juveniles, and fully mature snakes of each species.

Because the fang tips of rattlesnakes diverge during a strike (Mitchell, 1861), we

Table 1
Descriptive and comparative statistics of total length (TL) and retracted inter-fang distance (IF) among the three species included in this study*

A

Species	Mean TL	SD TL	Range TL	Mean IF	SD IF	Range IF	*N*
Crotalus atrox	780.6	344.5	279–1545	11.1	4.8	3.9–24.1	48
Agkistrodon piscivorus	710.9	194.7	261–1138	12.9	3.36	4.9–19.6	20
Bothrops asper	880.6	422.2	262–1788	10.0	5.8	3.6–26.0	16

B

Source	df	Mean square	*F*-value	*P*
species	2	118.4	37.4	< 0.001
total length	1	1558.8	492.5	< 0.001
residual	80	253.2		

* (A) Mean, standard deviation (SD) and range (min–max) of TL (mm) and IF (mm) measured from preserved specimens. (B) ANCOVA of IFs among the three species with total body length as a covariate. IFs are significantly different among species and among all pairs compared in a post-hoc Fisher's Protected LSD test.

explored the relationship between IF in live or preserved snakes and the distance between puncture wounds (PW) incurred during defensive strikes by 20 healthy *C. atrox* collected near Portal, Cochise County, Arizona. First, each wild-caught snake was induced to strike defensively five times at a flat foam surface mounted on a handle. For each strike, we measured PW with calipers and calculated mean

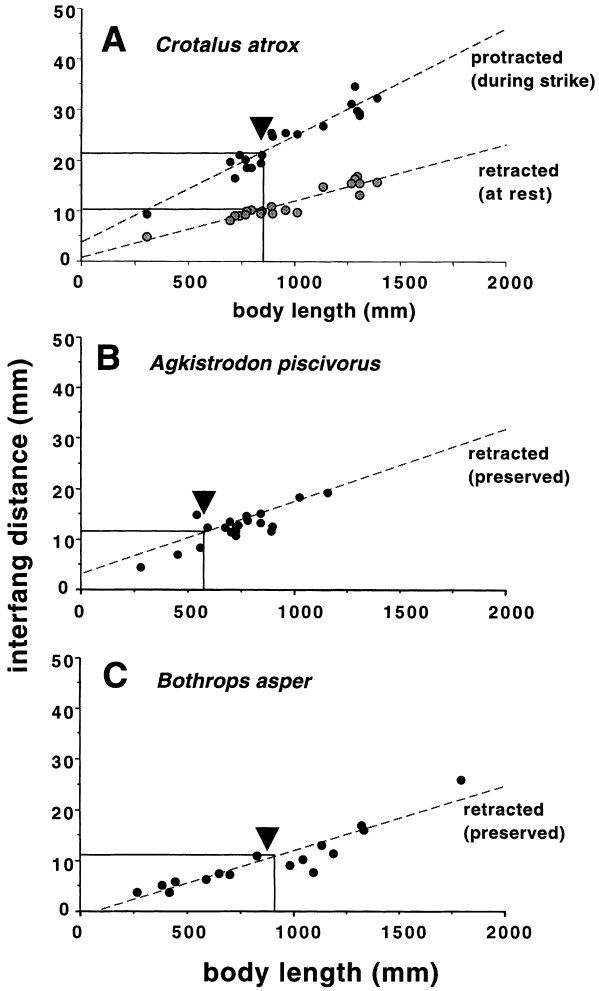

Fig. 1. Relationship between total body length (TL), distance between fang puncture wounds (PW), and retracted inter-fang distance (IF) in *Crotalus atrox* (A), and between TL and IF in *A. piscivorus* (B) and *B. asper* (C). Regression lines are plotted for retracted fangs and protracted fangs separately. On average, the distance between fang puncture wounds in a defensive bite by *C. atrox* is 112% greater than the distance between the bases of the retracted fangs in the same snake. Black triangles on the regression plots indicate the total length above which a single Extractor cup would not encompass both fang punctures, assuming 112% increase in distance between fang tips during a defensive bite.

PW for each individual. Only snakes that readily completed five measurable strikes within a two-hour period were included in the study. Following the strike measurements, we anesthetized the same individuals with isoflurane (Enflurane) vapor and measured IF. Because solenoglyphous snakes have two sockets in each maxilla, we measured IF using the groove formed in the tissues between these sockets, as was done with the preserved specimens. For each anesthetized animal we also measured TL. The regressions of PW, IF, and TL of live *C. atrox* were used to estimate fang spread that occurs with maxillary rotation during a defensive strike. A correction factor (representing this fang spread) was estimated from the *C. atrox* data and used to test the limits of Extractor suction for punctures by all three species.

The variables measured from preserved specimens are summarized in Table 1A. IF was highly correlated with TL in all species (Fig. 1; *C. atrox*: IF = 0.825 + 0.013 TL, $r^2 = 0.895$, $P < 0.001$; *A. piscivorus*: IF = 2.693 + 0.014 TL, $r^2 = 0.695$, $P < 0.001$; *B. asper*: IF = −1.283 + 0.013 TL, $r^2 = 0.859$, $P < 0.001$) both for the raw values and log-transformed variables (not shown). The three species differ significantly in IF in an ANCOVA with TL as the covariate (Table 1B). At any body size, IF is largest in *A. piscivorus*, intermediate in *C. atrox*, and smallest in *B. asper*. However, the latter achieve much larger absolute IF due to their larger maximum TL (Table 1A). We also compared IF between anesthetized and preserved rattlesnakes, to validate our use of the latter. The two samples are similar and the slopes of regression lines for IF and TL are statistically indistinguishable between live or preserved snakes (test for homogeneity of slopes: interaction between the covariate (TL) and group (anesthetized or preserved) not significant. ANOVA F-value = 0.545, df = 1, P-value = 0.4630).

Comparing mean PW from live *C. atrox* with their IF underscores the extreme mobility of cranial elements during a pitviper strike (Fig. 1A). Both PW and IF of anesthetized snakes are significantly correlated with TL (PW = 3.603 + 0.021TL, $r^2 = 0.913$, $P < 0.001$; IF = 0.754 + 0.011 TL, $r^2 = 0.893$, $P < 0.001$). The distance between fang tips at the time of a bite (PW) increased an average of 112% (range 75–160%) over IF measured in the same anesthetized snakes. Thus, during a strike, the protraction mechanism, which moves the maxillae and attached fangs upward and outward, more than doubles the distance between the tips of the fangs at rest.

We used the correction factor of 112% from the strike measurements with *C. atrox* to explore the limits of the Extractor for three species of pitvipers. The Extractor comes with four suction cups of different shapes and sizes to accommodate different fang wounds; its largest suction cup is round and has an inside diameter of 21.7 mm. Thus, a single Extractor will not encompass both punctures from bites of *C. atrox* larger than 86 cm (Fig. 1A). Assuming that flaring of the fangs of other striking pitvipers is comparable to that of *C. atrox* (112%), we estimate that their IF must not exceed 10.2 mm to produce puncture wounds that average no further apart than 21.7 mm. Thus, a single Extractor will not be sufficient for bites of cottonmouths larger than 54 cm (Fig. 1B) and terciopelos larger than 88 cm (Fig. 1C). These values approximate body sizes of

subadults or small adults, and are well below maximum reported TL for the three species we studied: *A. piscivorus*: 1.88 m (Gloyd and Conant, 1990), *C. atrox*: 2.34 m (Klauber, 1997), and *B. asper*: 2.50 m (Campbell and Lamar, 1989).

Claims about the efficiency of the Extractor as a first aid device rely on the assumption that maximum removal of venom from fang puncture wounds occurs during the first few minutes immediately following a bite. Although Bronstein et al. (1985, 1986) inferred effectiveness of this device, their methodology and data were published only as abstracts and not as peer-reviewed contributions (Hardy, 1992), resulting in controversy about the use of this device for first-aid (Forgey, 1993; Gellert, 1992, 1993; Gold, 1993). If a single Extractor cannot span adjacent punctures, suction must then be alternated between puncture wounds, perhaps resulting in at least a 50% reduction in efficiency. Our analyses thus support a robust conclusion: for continuous suction, two Extractors will be required for bites by most adult pitvipers. We note in closing that both species of *Agkistrodon* and at least seven species of rattlesnakes within the United States reach maximum body lengths greater then one meter (Conant and Collins, 1991; Stebbins, 1985), and almost all Central and South American lanceheads (*Bothrops*) exceed one meter as adults (Campbell and Lamar, 1989; M. Martins, unpublished data). We emphasize that the effectiveness of the Extractor in snake bite first aid has not been rigorously demonstrated; nonetheless, our general recommendation is that anyone contemplating use of the Extractor for snake bite should consider the likelihood that two kits will be necessary for maximizing any benefits from this device.

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