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ORIGINAL RESEARCH

Interfang Distances of Rattlesnakes: Sexual, Interspecific, and Body Size-related Variation, and Implications for Snakebite Research and Management

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Objectives.—Snakebite severity corresponds to size of snake because the amount of venom a snake injects is positively associated with snake size. Because fang marks are often present on snakebite patients, we tested whether the relationship between snake length and distance between fang puncture wounds can be generalized for rattlesnakes of genus *Crotalus*.

Methods.—We measured 2 interfang distances from 79 rattlesnakes of both sexes, 5 species, and varying body length: 1) distance between fang bases in anesthetized snakes, and 2) distance between fang punctures in a membrane-covered beaker bitten defensively.

Results.—Statistical analyses supported our 2 hypotheses, that 1) body size-related fang divergence during fang protraction (ie, anterolateral movement during fang erection), and 2) the relationship between snake length and interfang distance are similar between the sexes and among different rattlesnake species. We therefore derived a general equation to estimate snake length based on distance between fang marks, and recommended 5 snake size categories: very small (<10 mm), small (10–15 mm), medium (15–20 mm), large (20–25 mm), and very large (>25 mm).

Conclusions.—The distance between fang marks on a snakebite patient may be used to estimate the size or size category of the offending snake, which in some cases may have predictive value for overall clinical severity of a given envenomation. Assessing interfang distance from puncture wounds can improve snakebite research and anticipation of snakebite severity.

Keywords: animals, body size, *Crotalus*, envenomation, snakebite treatment, venom

Introduction

Several factors potentially contribute to the clinical severity of a venomous snake bite. These have been categorized as factors related to the human victim and those related to the snake.[1] Factors related to the patient include body mass, anatomical location of the bite, presence of clothing, delay to treatment, and the treatment itself, whereas those related to the snake include species (eg, venom composition and toxicity) and body size (eg, fang length and amount of venom injected). Of these factors, size of the snake (along with size of the patient) may have the greatest effect on envenomation severity. Hospital-based studies have consistently shown that larger snakes cause more severe bites[2–6] because they inject larger quantities of venom.[7–10] Knowing the size of the envenoming snake has significant predictive value for overall clinical severity, symptom progression, and the amount of antivenom needed to treat a bite.[4–6]

Since knowledge of the size of the envenoming snake may be of use to clinicians, and because the perceived size of the snake reported by patients or other witnesses may be unreliable (or unavailable if the patient is unconscious), a more objective means of determining snake size in a clinical setting would be desirable. One potential method is to use the distance between the

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wounds caused by the fangs (ie, fang spread or interfang distance) to estimate snake size.[11] Zamudio et al[12] demonstrated experimentally that the interfang distance, measured by strikes to a flat foam surface, predicted total body length in the Western Diamondback Rattlesnake (*Crotalus atrox*). Janes et al[4] found that in patients bitten by southern California rattlesnakes (genus *Crotalus*), snakes in the larger size classes had larger measurable interfang distances. Thus, in cases wherein 2 fang marks are present, the treating physician should be able to infer the relative size and danger of the offending snake.

The main purpose of this study was to evaluate whether the relationship between snake length and distance between fang puncture wounds is similar between the sexes and among different species of medically significant venomous snakes in southern California. Because head size relative to body size varies somewhat among different species of rattlesnakes, and even to some extent between the sexes,[13,14] differences in the relationship might exist. When rattlesnakes protract their fangs to deliver a bite (ie, extend them from a resting, or retracted, position against the roof of the mouth), the fang tips diverge, which increases the distance between them.[12,15] This kinematic feature of anterolateral fang movement may also differ between the sexes and among species. Collectively, these considerations prompted us to experimentally test 2 hypotheses using 5 species of southern California rattlesnakes: 1) that body size-related fang divergence during fang protraction associated with a defensive bite is similar between the sexes and among different rattlesnake species; and 2) that the relationship between snake length and distance between fang punctures during a defensive bite is similar between the sexes and among different rattlesnake species. Support for the latter hypothesis in particular would suggest that a single equation or set of measurements could be used by researchers and treating physicians to estimate or categorize a rattlesnake's body length—and relative danger from a bite—by measuring the distance between 2 fang punctures when visible on a snake-bitten patient.

Methods

SUBJECTS

We obtained measurements from 5 southern California rattlesnake species of varying snout-vent length (SVL). The 79 specimens included 16 *Crotalus cerastes* (8 male, 4 female, 4 undetermined sex; 31–52 cm SVL), 20 *C (oreganus) helleri* (14 male, 6 female; 41–105 cm), 12 *C* (*mitchellii*) *pyrrhus* (5 male, 7 female; 32–91 cm), 10 *C ruber* (8 male, 2 female; 53–123 cm), and 21 *C scutulatus* (8 male, 13 female; 30–83 cm). We chose these species because they represent diverse clades within the genus[16] and vary substantially in adult size,[13] both of which might affect body proportions. These species also inflict a substantial number of bites in southern California, where clinicians often treat bites from multiple species.[2–6] Our sample included both long-term captives and recently captured specimens, all from southern California locations with the exception of 2 *C cerastes* from Arizona. We assumed that husbandry exerted a negligible effect on the kinematics of fang use, and therefore included all snakes in our analyses. All subjects appeared to be in excellent health.

MEASUREMENTS

To minimize handling and disturbance of snakes, we obtained data from each specimen in a single session. First, we determined interfang distance during a defensive bite (ie, fangs protracted) by subjecting each snake to a routine venom extraction, which involved grasping the snake by the head and inducing it to voluntarily bite a Ziploc plastic sandwich bag secured by a rubber band over the top of a glass beaker (50 or 150 mL, depending on size of snake). We then used a caliper to measure the distance (nearest 0.5 mm) between the pair of fang punctures in the membrane. Next, we anesthetized the snake in a transparent plastic tube using sevoflurane[17] and used a caliper to measure interfang distance (nearest 0.5 mm) between the midlines of the bases of the fang sheaths.[12] Finally, we measured the snout-vent length (nearest 1 cm) of the anesthetized snake with a metal ruler and determined its sex via sexing probes. Research was conducted with permits issued by the California Department of Fish and Wildlife and approval by the Institutional Animal Care and Use Committee of Loma Linda University.

ANALYSES

We conducted 3 sets of analyses using SPSS 13.0 (SPSS Inc, Chicago, IL), with standard defaults and α set at 0.05. Prior to analyses, we $\log_{10}$-transformed the 2 measures of interfang distance (retracted fang bases and protracted fang punctures) to meet multivariate assumptions of normality, homoscedasticity, and linearity. Because of missing data for sex (n = 4 *C cerastes*) and distance between fang bases (n = 1 *C scutulatus*), our sample size varied from n = 74–79, depending on which variables were included in a given model.

First, we compared the sexes and 5 species using a multivariate analysis of covariance (MANCOVA[18]) model that included both measures of interfang distance (retracted fang bases and protracted fang punctures) as dependent