A Healed Fractured Radius in a Flying Big Brown Bat (*Eptesicus fuscus*)

by Hannah M. ter Hofstede, Jacqueline Miller, John M. Ratcliffe, and M. Brock Fenton

ABSTRACT: An adult male big brown bat (*Eptesicus fuscus*) was captured in Toronto, Canada, with a healed fractured left radius. A radiographic analysis was obtained to assess and qualify the injury. Radiographs revealed a likely spiral or oblique fracture in an advanced stage of remodeling. There was no evidence of pinning or other repair artifact. Considering that the bat was estimated an adult when the injury occurred, and bone remodeling does not occur during hibernation, the authors suggest that the bat had been treated by a local wildlife rehabilitation center for this injury.

KEYWORDS: *Eptesicus fuscus,* radial fracture, rehabilitation, Chiroptera

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Introduction

Efficient locomotion is key to an animal's survival. It is generally considered impossible for a bat to survive broken arm bones (humerus or radius) because transverse and shear stresses acting on these bones result in high torsional load during flight (Swartz et al. 1992), which would prevent healing, flight, and foraging. This paper describes finding a volant big brown bat (*Eptesicus fuscus*) with a healed broken radius.

In September 2000 the authors participated in the humane removal of a colony of *Eptesicus fuscus* from a private residence in Toronto, Canada (at the request of the owner). Bats were captured upon exiting the attic with a harp trap, held for 2 days while the house was sealed by the owner (during which time they were fed mealworms and watered), and released 15 km away close to known hibernacula. During this process, one adult male's flight appeared to be irregular. Upon closer inspection, it was observed that the bat's left radius had been broken and that the broken wing appeared shorter than the other due to this injury, but that the bat was otherwise healthy (weight at capture 20.1 g; mean weight of colony members 19.3 g). The bat was brought to York University, Toronto, for observation. The bat could fly for extended periods of time and avoid obstacles in much the same way as its uninjured conspecific roostmates. On the downstroke, however, the left wing extended farther than the right wing. The bat was kept in a flight room over the winter. Unfortunately, during transportation from one location to another, the vehicle broke down and despite efforts to protect the bat from the cold temperature, it subsequently died. To determine the possible age and nature of the injury, a postmortem radiographic assessment was obtained at the Royal Ontario Museum, Centre for Biodiversity and Conservation Biology (CBCB), Toronto.

Methods

Radiographs of the bat with wing extended were taken in dorsoventral and lateral-oblique views, using a GE Faxitron imaging unit and Kodak Industrex IR film. Multiple films were obtained at low mA kV levels and between 32–35 kV to avoid overexposing the specimen, given its small bone size and hence reduced bone density. The authors obtained positive contact prints and enlargements of the radiographs to facilitate qualification of the bony remodeling evident around the fracture (Figure 1). Some magnification distortion is inevitable in radiographic studies, particularly with imaging units such as the Faxitron, which has a maximum source-to-film distance of about 50 cm. The authors' interests, however, were in qualitative features rather than quantitative measurements. Consequently, recommendations in the literature to minimize radiographic distortion were followed wherever possible (Ballinger 1995, Hildebolte et al. 1994, Sewerin 1990, Stevens 1989, Sweeney 1983).

Both the original films and contact prints were inspected to describe the nature and degree of osseous repair and remodeling, as well as for signs of fixation by materials used in the repair of long bone fractures (see, for instance, Dallman et al. 1990, DeYoung and Probst 1985). Candidate materials that can be employed in animals of very small size include surgical steel wiring, which can be easily recognized in plain film radiography.

Results

Radiographs reveal a mid-shaft radial fracture in advanced stages of healing and remodeling. Viewed more obliquely, the fracture shows a larger area of bony

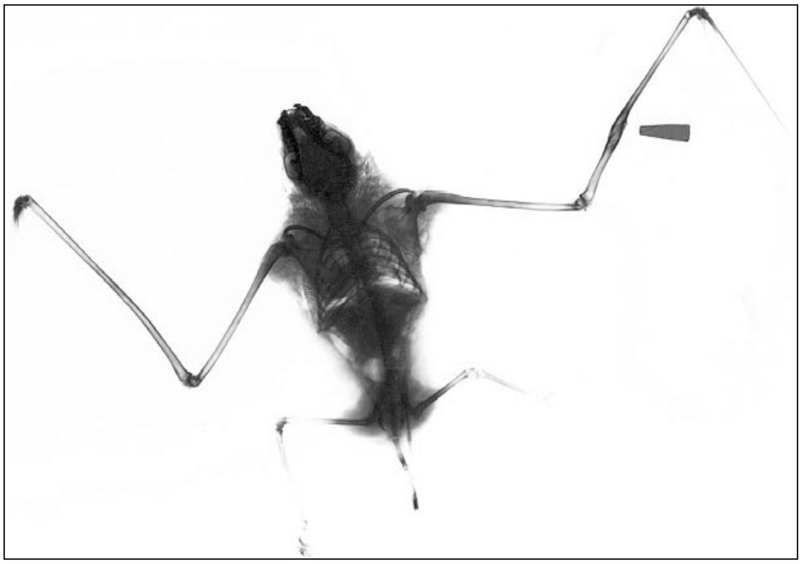

Figure 1 (left): A positive contact print of the bat radiographed in the dorsoventral view with the affected wing extended, showing the slight shortening and rotation of the fractured radius compared to the uninjured wing (scale factor x 0.7).

Figure 2 (below left): An enlarged positive contact print of the fracture (dorsoventral view) demonstrating the continuity of cortical bone, cortical/medullary differentiation, and the appearance of progressive remodeling (scale factor x 7.25).

Figure 3 (below right): An enlarged positive contact print of the fracture radiographed in the lateral-oblique (complementary) view, in which significant mal-alignment is most evident. Stress lines indicating bony reinforcement are marked (scale factor x 7).

deposition than when viewed dorsoventrally, suggesting healing while offset (Figures 2 and 3). The proximal end of the original fracture zone appears to override the distal end, and this thickened region of overlap is consolidated with woven bone. The shaft is completely bridged in the region of the fracture with no mal-union, such as false joint formation. In dorsoventral view, the shaft is fully remodeled with differentiation evident between cortical periosteum and medullary bone. The remodeled shaft appears only slightly wider here than elsewhere along the length of the radius. Given its location and the nature of wing architecture, the fracture was likely spiral or oblique. Viewed dorsoventrally, the bone appears more uniform and shaft-like in contour and some shortening is evident. While the healed fracture site appears slightly less dense than either end of the humerus, the difference is not pronounced. Longitudinal ridges bridge the zone of fracture and give the impression of exaggerated lines for muscular attachment. There is no evidence of prior fixation by pinning for stabilizing the bone.

Discussion

The forearm in bats consists of the cubitus (the fused radius and ulna) of which the radius is the largest component, compared to the ulna in typical terrestrial mammals (Adams 1992). The radius and humerus have the highest mineral content of the wing bones, giving them strength and stiffness to withstand considerable shearing stress (Papadimitriou et al. 1996). The radius in bats is generally long and gently bowed anteriorly. Its topographic features include the proximal flexor fossa on the medial surface, which receives the tendons of the biceps brachii and the insertion of the brachialis muscle. The supinator muscle inserts along the proximal midshaft. Distally there are the attachments of the abductor pollicus longus and extensor indicus posteriorly, and the extensor carpi ulnaris posterolaterally (Vaughan 1970a, 1970b). Maintenance of proper insertion would have been necessary for wing function. The fact that the bat could fly when it was caught suggests that such insertions had been maintained. The exaggerations of lines in the area of the healed fracture suggest that some compensation had occurred before the bat regained flight.

The fracture appears to have been in advanced stages of bony remodeling, as defined by conventional assignment of stages of fracture repair (see for instance Adams 1983, Stevens and Lowe 2000). While a fracture begins to heal as soon as the break occurs, in early stages there would be evidence of a large proliferation forming a callus that would be radiographically less opaque. The fact that the remodeled shaft appears to be only slightly wider at the original site of the fracture than elsewhere along the length of the radius, coupled with the appearance of stress ridges suggest that bony remodeling occurred under some functional strain. It is likely that the original fracture was partly stabilized by impaction of the adjacent ends, which would account for the slight shortening of the forelimb noted. There is, however, an absence of massive deposition at the site, although such deposition is common in fractures of long bones that repair independently while under functional strain or weight-bearing stress (see, for instance, accounts in Hoar 1945).

An adult bat with a broken radius would likely not survive due to the limitations on flight and foraging. How this bat could have survived its injury is puzzling. Combined, the authors have captured thousands of bats and never observed this injury before, although broken phalanges have occasionally been observed. Likewise, Mark Engstrom of the Royal Ontario Museum has captured tens of thousands of bats and has also never observed a healed fractured radius (pers. comm.). Three possible explanations were considered: the bat was a juvenile when the fracture occurred and was cared for by its mother during healing; the bat fractured its radius in the autumn and the bone healed during hibernation; or the bat was treated by a wildlife rehabilitation center.

The bat was believed to be an adult at the time of injury because there is no overall evidence of limb stunting, less the effect of bony compaction implied by the original injury. One would expect foreshortening that represents developmental delay in a limb as severely damaged as by a complete long bone fracture. Secondly, long bone fractures are physiologically demanding in terms of the resources necessary for repair. An example of such a stress would be the appearance of Harris lines, a feature common in long bones if there is a period of physiological/energy challenge during the period of skeletal development (Steele and Bramblett 1988). No such indicators are present. Also, the above-mentioned developmental perturbations would also delay the rate of epiphyseal fusion if the injury occurred prior to this event.

It is unlikely that the bat broke its arm immediately before hibernation, healing gradually over the winter, because bone remodeling does not occur during hibernation (Kwiecinski et al. 1987). A wildlife rehabilitation center might have cared for the bat during its convalescence. Bats with broken limb bones have been successfully rehabilitated using external skeletal fixtures (Wellehan et al. 2001) and splints (Northway 1975). The healing process can take up to 100 days (Wellehan et al. 2001), making the possibility that the bone healed on its own negligible. Since *E. fuscus* usually do not move long distances from year to year (Beer 1955), it was likely a local rehabilitation center. Toronto had three wildlife rehabilitation centers at the time the bat was captured: Wildcare, the Toronto Humane Society, and the Toronto Wildlife Centre. The Toronto Wildlife Centre stated they rehabilitate bats and generally use external splints for injuries of this nature. However, none of these institutions has easily accessible records for animals treated and released prior to 2001.

Once the bone healed, the bat would have had to learn how to fly with differently shaped wings before becoming a successful forager. The injured radius measures only 89% the length of the intact radius, based on measurements from a contact print (Figure 1). Fluctuating asymmetry is very low in bat forearms (Gummer and Brigham 1995), and weights of left and right bones are very similar in individuals (Dawson 1975), suggesting that symmetry may be important for efficient flight in bats. Perhaps the extended downstroke of the left wing was necessary to provide the equivalent lift as the right wing, since the shortening of the arm reduced the surface area of the left wing. This chance encounter not only provides evidence that bats can be rehabilitated after breaking major bones in the wing, but also that they can function after release into the wild.

Acknowledgements

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References

Adams, J. C. 1983. *Outline of fractures,* 8th ed. New York: Churchill Livingstone.

Adams, R. A. 1992. Comparative skeletogenesis of the forearm of the little brown bat (*Myotis lucifugus*) and the Norway rat (*Rattus norvegicus*). *J. Morphology* 214: 251–60.

Anthony, E. L. P. 1988. Age determination in bats. In *Ecological and behavioral methods for the study of bats,* edited by T. H. Kunz. Washington, D.C.: Smithsonian Institution Press.

Ballinger, P. 1995. *Merrill's atlas of radiographic positions and radiologic procedures,* vol. 1, 8th ed. Toronto: C. V. Mosby Company.

Beer, J. R. 1955. Survival and movements of banded big brown bats. *J. Mammalogy* 36: 242–48.

Gummer, D. L., and R. M. Brigham. 1995. Does fluctuating asymmetry reflect the importance of traits in little brown bats (*Myotis lucifugus*)? *Can. J. Zool.* 73: 990–92.

Dallman, M. J., R. A. Martin, B. P. Self, and J. W. Grant. 1990. Rotational strength of double-pinning techniques in repair of transverse fractures in femurs of dogs. *Am. J. Vet. Research* 51: 123–27.

Dawson, D. L. 1975. "Ambidexterity" in bat wings as evidenced by bone weight. *J. Anatomy* 120: 289–93.

DeYoung, D. J., and P. C. W. Probst. 1985. Methods of fracture fixation. In *Textbook of small animal surgery,* edited by D. H. Slatter. Philadelphia: W. B. Saunders Co.

Hildebolte, C., M. Bartlett, M. Shrout, N Yokoyama-Crothers, and R. Rupich. 1994. Image-based quantification of alveolar bone. *Yearbook of Physical Anthro.* 37: 155–76.

Hoar, W. S. 1945. Repair of fractured deer bones. *Acadian Naturalist* 2: 44–46.

Kwiecinski, G. G., L. Krook, and W. A. Wimsatt. 1987. Annual skeletal changes in the little brown bat *Myotis lucifugus* with particular reference to pregnancy and lactation. *Am. J. Anatomy* 178: 410–20.

Northway, R. B. 1975. Repair of fractured radius and ulna in a brown bat. *Vet. Med./Sm. Animal Clinician* 70: 952.

Papadimitriou, H. M., S. M. Swartz, and T. H. Kunz. 1996. Ontogenetic and anatomic variation in mineralization of the wing skeleton of the Mexican free-tailed bat, *Tadarida brasiliensis. J. Zoo.* 240: 411–26.

Sewerin, I. 1990. Errors in radiographic assessment of marginal bone height around osseointegrated implants. *Scandinavian J. Dental Research* 98: 428–33.

Steele, D. G., and C. A. Bramblett. 1988. *The anatomy and biology of the human skeleton.* College Station: Texas A+M University Press.

Stevens, P. 1989. Radiographic distortion of bones: A marker study. *Orthopedics* 2: 1457–64.

Stevens, A., and J. Lowe. 2000. *Pathology,* 2nd ed. Toronto: C. V. Mosby Company.

Swartz, S. M., M. B. Bennett, and D. R. Carrier. 1992. Wing bone stresses in free flying bats and the evolution of skeletal design for flight. *Nature* 359: 726–29.

Sweeney, R. 1983. *Radiographic artifacts: Their cause and control.* Philadelphia: J. B. Lippencott.

Vaughan, T. A. 1970a. The skeletal system. In *Biology of bats,* edited by W. A. Wimsatt. New York: Academic Press

——. 1970b. The muscular system. In *Biology of bats,* edited by W. A. Wimsatt. New York: Academic Press

Wellehan, J. F. X., M. S. Zens, A. A. Bright, and S. J. Voss. 2001. Type I external skeletal fixation of radial fractures in microchiropterans. *J. Zoo and Wildl. Med.* 32: 487–93.

Recommended Reading

French, B., and A. Lollar. 1998. *Captive care and medical reference for the rehabilitation of insectivorous bats,* 2nd ed. Austin, Tex.: Bat Conservation International.

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