Dextrocardia in Short-Nosed Fruit Bats (*Cynopterus sphinx*) and Their Relative Heart Masses

Author(s): Qian Yao , Guangjian Zhu , Jon R. Flanders and Libiao Zhang
Source: Acta Chiropterologica, 14(2):497-499. 2012.
Published By: Museum and Institute of Zoology, Polish Academy of Sciences
DOI: http://dx.doi.org/10.3161/150811012X661800
URL: http://www.bioone.org/doi/full/10.3161/150811012X661800

Acta Chiropterologica, 14(2): 497–499, 2012
PL ISSN 1508-1109 © Museum and Institute of Zoology PAS
doi: 10.3161/150811012X661800

Dextrocardia in short-nosed fruit bats (*Cynopterus sphinx*) and their relative heart masses

QIAN YAO[1], GUANGJIAN ZHU[2], JON R. FLANDERS[3], and LIBIAO ZHANG[2, 4]

[1]*Institute of Zoology, Chinese Academy of Sciences, 1-5 Beichen Xilu, Chaoyang District, Beijing, 100101 China*
[2]*Guangdong Entomological Institute, 105 Xingang Xilu, Haizhu District, Guangzhou, 510260 China*
[3]*School of Biological Sciences, University of Bristol, Woodland Road, Bristol BS8 1UG, Great Britain*
[4]*Corresponding author: E-mail: zhanglb@gdei.gd.cn*

Autopsies carried out on 26 short-nosed fruit bats (*Cynopterus sphinx*, Pteropodidae, Chiroptera) from Guangdong Province, South China, revealed that the hearts of three individuals were found lying in the right hemithoracic cavity with their base-to-apex axes directed to the right. This is the reverse of what is normally seen in mammals and is similar to the rare congential heart defect known as dextrocardia which has been described in humans. A comparison of the two orientated hearts found that there was no significant difference in heart mass (MH) or relative heart mass (RHM). We observed that the short-nosed fruit bat has higher RHM compared to non-flying mammals but lower RHM when compared to insectivorous bats, and similar RHM when compared to those of other fruit bats.

Key words: *Cynopterus sphinx*, dextrocardia, short-nosed fruit bat, heart mass, relative heart mass

INTRODUCTION

The mammalian heart is an asymmetric structure, which receives its polarit y from the three body axes; the anterior-posterior axis (A-P), the dorsal-ventral axis (D-V), and the left-right axis (L-R) (Brand, 2003). The vast majority of mammalian hearts, including those of bats, are located in the left hemithorax along the A-P axis (Rowlatt, 1967; Tagoe *et al.*, 1995; Pauziene *et al.*, 2000; Mauricio *et al.*, 2005). However, in rare cases, the position of the human heart has been found lying in the right hemithorax with its base-to-apex axis directed to the right. This cardiac positional anomaly is known as dextrocardia (Mahendrakar and Seth, 2004) which is a congenital heart disease with a low incidence rate of around one in 12,000 pregnant women (Bohun *et al.*, 2007). To the best of our knowledge, although dextrocardia has been described in domestic animals such as dog (Carrig *et al.*, 1974) and cat (Abduch *et al.*, 2003), it has not been found in any wild mammal population. In this paper, we report the first case of dextrocardia in bats (order Chiroptera).

MATERIALS AND METHODS

Twenty-six adult female short-nosed fruit bats (*Cynopterus sphinx*) were captured from the same colony in Guangdong Province, South China (113.14°E, 23.10°N) as part of the investigation into the SARS outbreak in China. *Cynopterus sphinx* is not a protected species in China and is widely distributed in Guangdong Province. The handling of all bats conformed to guidelines for animal care and approved by the Ethical Committee, State Key Laboratory of Reproductive Biology, Institute of Zoology, Chinese Academy of Sciences. Before any bats were euthanized their body mass (M_b) was measured. The hearts were extracted through a standard thoracotomy procedure after which the venous and connective tissues were removed. Each heart was squeezed empty of blood, weighed on electronic scales (SB-S702, Shanghai; accurate to 0.01 g) and then measured immediately. The transverse and vertical diameters of the hearts (D_T, D_V) were measured using vernier calipers. Comparisons between right and left orientated bat hearts were carried out using Mann-Whitney (M-W) *U*-tests. A comparison of heart mass (M_H) and relative heart mass (RHM, M_H/M_b, in %) was also carried out between the two different types of heart (Mann-Whitney *U*-test).

RESULTS

Out of the 26 short-nosed fruit bats studied, three individuals were found to have their hearts situated in the right hemithoracic cavity when their thorax was opened (Fig. 1A). In comparison with the normal orientated hearts (vertical diameter, D_V: 10.61 ± 1.13 mm), these three hearts (D_V: 11.77 ± 0.52 mm) were longer along their A-P axis (M-W *U*-test: $U = 9.00$, $P < 0.05$), with the apex of their hearts lying in the right hemithorax. The right morphologic atrium was situated to the right and slightly posteriorly with the left morphologic atrium situated to the left and slightly anteriorly. The right morphologic ventricle was situated to the right and posteriorly, with the left morphologic ventricle to the left and anteriorly (Fig. 1A). All of the other 23 bats' hearts were located in the left hemithorax with the apex lying in the left hemithorax as would normally be expected (Fig. 1B).

A comparison of the transverse diameters of the different orientated hearts (D_H) revealed no significant difference (right: 14.20 ± 3.03 mm; left 15.81 ± 1.66 mm — M-W *U*-test: $U = 16.00$, $P > 0.05$). Similarly, comparisons between body mass, heart mass (M_H), and relative heart mass (RHM) between right (49.25 ± 10.15, 0.42 ± 0.03 g and 0.87 ± 0.17%, respectively) and left (normal) hearts (53.84 ± 9.88, 0.46 ± 0.09 g, 0.89 ± 0.17%, respectively) were not statistically different (M-W *U*-test: $U = 30.00$, $U = 20.50$, and $U = 31.00$, respectively; in all cases $P > 0.05$).

Discussion

The mammalian heart is thought to be located in the left hemithorax because the left ventricle has to pump bloody with more force than any of the other chambers (Grossman *et al.*, 1975). However, the hearts of three short-nosed fruit bats studied as part of this investigation were not found in the left hemithorax.

The location of the heart in the right hemithorax is similar to the heart disease described in humans known as dextrocardia. Dextrocardia is one type of cardiac malformation, which is intrinsic to the heart but not caused by extracardiac abnormalities (Maldjian and Saric, 2007). It is thought that this condition can be traced back to the primitive heart tube, which loops to the right (dextro- or D-) or to the left (levo- or L-), forming either a D-loop or an L-loop, respectively (Maldjian and Saric, 2007). The L-loop is the normal (situs-solitus) cardiac loop while the D-loop is its mirror-image (situs-inversus) (Vanpraagh *et al.*, 1964).

Identifying three out of 26 bats with dextrocardia is surprising because it has never been recorded in bats before and is a relatively rare condition in humans. However, as this study only sampled one population there is a possibility that there may be some genetic, viral or environmental factor affecting these individuals. Due to the limited number of bats used in this study it is impossible to identify a possible mechanism for this event without further research.

A search of the literature indicates that RHM of short-nosed fruit bats is greater than the majority of non-flying mammals (Jurgens *et al.*, 1981; Bishop, 1997). This is unsurprising because the high RHM of bats corresponds to the greater cardiac outputs needed to cope with the large energetic

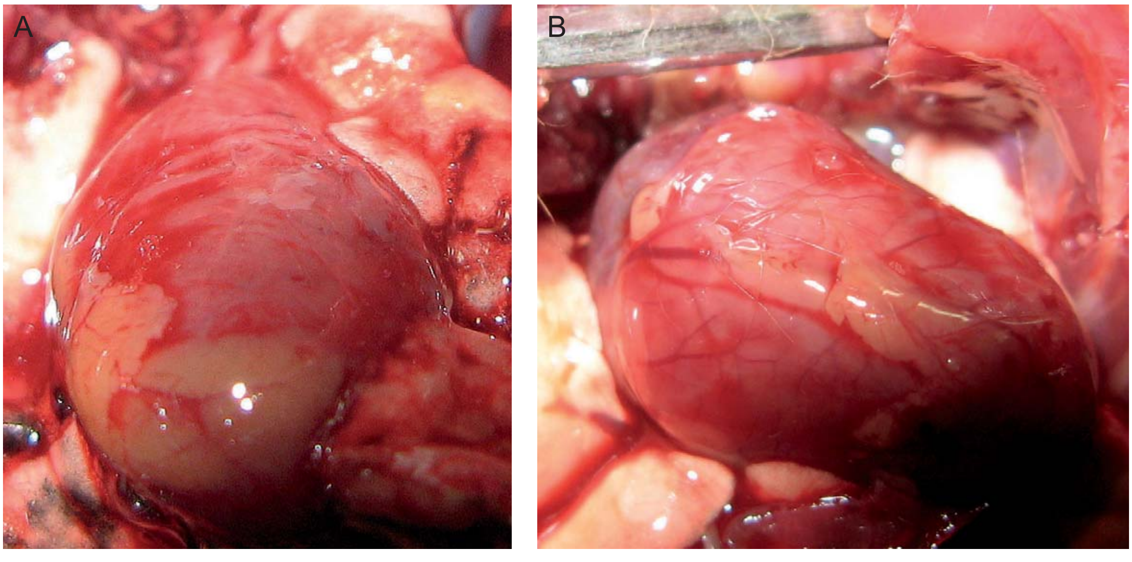

Fig. 1. Comparison of the right heart and normal left heart of the short-nosed fruit bats: A — dextrocardia, the apex lies in the right hemithorax, B — normal heart, the apex lies in the left hemithorax

requirements during flight (Lev *et al.*, 1968). However, compared to other bats, the RHM of *C. sphinx* was lower than some insectivorous species, including *Tadarida brasiliensis*, *Mormopterus kalinowski*, *Myotis chiloensis*, *Histiotus macrotus*, *H. montanus*, *Lasiurus borealis*, *L. cinereus*, and *Pipistrellus pipistrellus*, but similar to those of other fruit bats such as *Rousettus aegyptiacus* and *Phyllostomus discolor* (Jurgens *et al.*, 1981; Mauricio *et al.*, 2005). This suggests that heart size is determined by physiological demands and is not linearly related to body mass in bats (Jurgens *et al.*, 1981; Mauricio *et al.*, 2005) and may relate to behavioral, ecological and physiological traits relating to the flight performance (Bishop, 1997). This is supported by Bullen *et al.* (2009) who indicate that heart mass is a measure of a bat's ability to hover while gleaning food from foliage and to consistently fly within clutter environments. We conclude, that for insectivorous species, higher RHM may satisfy the oxygen demands of energetic flight to catch highly mobile prey, while for the fruit bats, lower RHM may fill the requirement of their lower oxygen demands of feeding on fruit.

Acknowledgements

We thank Dr. J. P. Chen, D. W. Li, W. Zhang, J. P. Ye, and M. Tan for assistance in collecting bats. This work was supported by the National Natural Science Foundation of China (No. 30800102), Special Foundation for Young Scientists (GDEI-yxqn201101) of Guangdong Entomological Institute, and Science and Technology Planning Project of Guangdong Province, China (No. 2010B060200034).

Literature Cited

Abduch, M. C., P. L. Tonini, L. D. Barbusci, S. M. de Oliveira, and R. R. de Freitas. 2003. Double-outlet right ventricle associated with discordant atrioventricular conection and dextrocardia in a cat. The Journal of Small Animal Practice, 44: 374–377.

Bishop, C. M. 1997. Heart mass and the maximum cardiac output of birds and mammals: implications for estimating the maximum aerobic power input of flying animals. Philosophical Transactions of the Royal Society of London, 352B: 447–456.

Bohun, C. M., J. E. Potts, B. M. Casey, and G. G. Sandor. 2007. A population-based study of cardiac malformations and outcomes associated with dextrocardia. American Journal of Cardiology, 100: 305–309.

Brand, T. 2003. Heart development: molecular insights into cardiac specification and early morphogenesis. Developmental Biology, 258: 1–19.

Bullen, R. D., N. L. McKenzie, K. E. Bullen, and M. R. Williams. 2009. Bat heart mass: correlation with foraging niche and roost preference. Australian Journal of Zoology, 57: 399–408.

Carrig, C. B., P. F. Suter, G. O. Ewing, and D. L. Dungworth. 1974. Primary dextrocardia with situs inversus, associated with sinusitis and bronchitis in a dog. Journal of the American Veterinary Medical Association, 164: 1127–1134.

Grossman, W., D. Jones, and L. P. McLaurin. 1975. Wall stress and patterns of hypertrophy in the human left ventricle. Journal of Clinical Investigation, 56: 56–64.

Jurgens, K. D., H. Bartels, and R. Bartels. 1981. Blood oxygen transport and organ weights of small bats and small non-flying mammals. Respiration Physiology, 45: 243–260.

Lev, M., R. R. Liberthson, F. A. Eckner, and R. A. Arcilla. 1968. Pathologic anatomy of dextrocardia and its clinical implications. Circulation, 37: 979–999.

Mahendrakar, M., and G. S. Seth. 2004. Cardiac anatomy — viewed through the eyes of clinicians. Journal of Anatomical Society of India, 53: 44–48.

Maldjian, P. D., and M. Saric. 2007. Approach to dextrocardia in adults: review. American Journal of Roentgenology, 188: S39–49.

Mauricio, C., A. Cristlan, G. Bruno, and I. Jose. 2005. Relative size of hearts and lungs of small bats. Acta Chiropterologica, 7: 65–72.

Pauziene, N., D. H. Pauza, and R. Stropus. 2000. Morphological study of the heart innervation of bats *Myotis daubentoni* and *Eptesicus serotinus* (Microchiroptera: Vespertilionidae) during hibernation. European Journal of Morphology, 38: 195–205.

Rowlatt, U. 1967. Functional anatomy of the heart of the fruit-eating bat, *Eidolon helvum*, Kerr. Journal of Morphology, 123: 213–230.

Tagoe, C. N., A. S. Ayettey, E. Dennis, and R. D. Yates. 1995. Ultrastructural and morphometric features of nodal and impulse-conducting cardiac myocytes of the bat *Pipistrellus pipistrellus*. Italian Journal of Anatomy and Embryology, 100 (Supplement 1): 273–286.

Tonkin, I. L., and A. K. Tonkin. 1982. Visceroatrial situs abnormalities: sonographic and computed tomographic appearance. American Journal of Roentgenology, 138: 509–515.

Vanpraagh, R., S. Vanpraagh, P. Vlad, and J. D. Keith. 1964. Anatomic types of congenital dextrocardia: diagnostic and embryologic implications. American Journal of Cardiology, 13: 510–531.

Received 23 February 2012, accepted 23 May 2012