RESEARCH ARTICLE

Post mortem comparison of cardiac anatomy between an electrocuted sloth (Choloepus hoffmanni) and five other individuals

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Citation: Villada A., Trull S. (2025) Post mortem comparison of cardiac anatomy between an electrocuted sloth (Choloepus hoffmanni) and five other individuals. Open Science Journal 10(1)

Received: 31st October 2023

Accepted: 11th October 2024

Published: 12th February 2025

Funding: The author(s) received no specific funding for this work

Competing Interests: The authors have declared that no competing interests exists.

Abstract:

Knowledge about cardiovascular physiology in Xenarthra species is limited, despite thorough investigation in other mammals. In particular, there is not enough published literature on the detailed cardiology of either sloth genera found in Costa Rica (Bradypus or Choloepus). This discontinuity in available knowledge makes the clinical cardiac evaluation of Hoffmann's two-fingered sloth (Choloepus hoffmanni) particularly difficult. In this report, we describe the case of a wild electrocuted sloth during rehabilitation. No cardiac problems were discovered although the electrocution was severe enough to affect internal organs and ultimately cause this patient's death. We detail sloth cardiac structure in connection to our findings and highlight how electrocution during the pre- and post-mortem periods may be severe enough to alter organs inside. This information may be used to provide an improved understanding of sloth cardiology for clinical management of patients.

Keywords: Sloth, Choloepus hoffmanni, Anthropogenic disturbance, Xenarthra, Necropsy, Cardiac anatomy

Introduction

Across vertebrate taxa, cardiovascular systems remain homogenous in their primary goal to propel blood through vascular trees [1]. Evolutionarily mammals have undergone remarkable anatomic and physiologic change necessary for ecological success. The result is immense morphologic diversity in the cardiopulmonary systems of species today [2]. Mammals possess four-chambered hearts designed to continuously move blood through pulmonary and systemic circuits. There are stark variations in the shape and position of mammalian atria and ventricles, related to thoracic positioning and physiology [1]. Likewise, mammalian hearts tend to take on an elongated form. This has been suggested to facilitate faster conduction, an adaptation necessary for the lifestyle of this taxonomic class[1,3]. The correlation between structure and function is not only necessary in understanding comparative evolution, but also in the clinical management of patients. To date, there is little information available on the cardiac anatomy of any of the Xenarthra species, including both genera of sloths.

Sloths are a group of seven species within the Xenarthra clade, belonging to the order Pilosa and suborder Folivora [4]. In Costa Rica, two of the seven recognized species are present, including the Hoffmann's two-fingered (Choloepus hoffmanni) and Brownthroated three-fingered sloth (Bradypus variegatus) [5]. Despite being common patients at rescue centers due to human-wildlife conflict, their biological makeup is grossly understudied. Little information can be found on their anatomy and physiology in a clinical context. Guidance on the best ways to manage and treat these unique animals in a rehabilitation setting is therefore sparse and can present a challenge.

Sloths are extremely morphologically diverse from other mammals and possess a wide variety of adaptations to support their energy saving suspensory lifestyle. Due to their predominantly arboreal nature and diet, sloths have evolved to function with minimal consumption and use camouflage as a defense mechanism against predators. This involves adaptations such as low metabolic rates and basal temperatures, enhanced muscular attachments but minimal muscle mass, and compartmentalized stomachs [6,7]. Likewise, sloths possess specialized cardiovascular structures, including an intricate venous system that prioritizes irrigation to appendages [8]. Previous reports have described sloth hearts as primitive-appearing and small in size relative to body mass [9]. They possess large auricles as remnants of the venous sinus and irregularly shaped atrioventricular valves [3,8]. Regarding heart anomalies, few recorded cases exist in the literature. Myocardial failure was described in a Linnaeus's two-fingered sloth (Choloepus didactilus); however, the subject was captive bred [10]. To date, there is no report in the literature regarding the effect of electrocution on the body function of any sloth species.

Sloths and other arboreal mammals are electrocuted by uninsulated electric wires that run through their fragmented habitats [11]. Because sloths cannot jump between even small gaps in the forest canopy, they are very susceptible to being electrocuted. In Manuel Antonio, Costa Rica, electrocution incidents accounted for 46% of all rescue intakes for C. hoffmanni in 2021 (S. Trull unpublished data). Electrocution injuries can damage animals internally and externally in varying severity depending on the electric charge. Internally the most affected organs are liver and kidneys. [11]. The effect of the electrocution's ability to damage the cardiovascular system of a sloth has never been studied, which is further exacerbated by the lack of reported knowledge on normal Choloepus cardiac anatomy.

Material and methods

This study took place at The Sloth Institute (TSI), a nonprofit wildlife rehabilitation and research center located in the Puntarenas Province of Costa Rica. In 2018, the patient came to the center for urgent medical attention. Before passing away from renal failure, echocardiography was done to assess heart health. Additionally, the carcasses of various specimens gathered throughout the years were utilized. After passing away, the bodies were kept in a deep freezer for necropsy. Specimen age, condition, weight, and body measurements were recorded for proper evaluation of findings. Necropsy was conducted using a standard surgery kit. The post mortem exam focused on cardiovascular anatomy, including evaluation of the auricles, venous sinus, and shape of the atrioventricular valve. For comparison, five of the carcasses saved in deep freeze were evaluated simultaneously and their cardiac anatomy was compared to our case study subject. All five specimens died of causes other than electrocution and were presumed to have normal cardiac anatomy.

Results

Case study

In July of 2018 a 3.6kg adult female two-fingered sloth (Choloepus hoffmanni) presented to TSI following an electrocution injury. An odor consistent with electrical burns was noted. Appearance of the patient's wounds suggested the injury was recent and likely occurred within the prior two to three day window. A hemogram revealed an increase in leukocytes. Monocytes, neutrophils, eosinophils, and lymphocytes were elevated, suggesting chronic inflammation in the patient. Emergency treatment for ascites and third-degree burns was initiated following intake. The patient was provided analgesics, intravenous fluids, and antibiotics to prevent secondary infection. Once stabilized, the patient was transported for advanced imaging. Echocardiography was performed to ensure no additional pathology was present following the electrocution.

During the ECG study the patient's heart rate increased from 60 to 75 beats per minute. Typically, the heart rate of Choloepus species falls between 40-90 [8] beats per minute. Under anesthesia, their heart rate can slow down to only 4 beats per minute while the patient stays clinically normal [9]. During routine examinations at TSI using low stress evaluation methods (non-handling and/or distraction with favored food items), an average resting heart rate of 59 beats per minute was found. No anomaly on the functionality of the heart and blood flow was reported.

Two-fingered sloths are known for their aggressive behavior and are quickly stressed by human presence and manual restraint. However, in a rehabilitation setting, most patients eventually habituate to their caretakers to varying degrees. The patient in this case study was particularly habituated and therefore much less aggressive during manual restraint than the average wild two-fingered sloth, yet she still showed signs of increased heart rate while being restrained for the exam.

No other cardiac abnormalities were noted, therefore further cardiovascular testing or reevaluation was deemed unnecessary (Figure 1) [4,5].

Despite these unremarkable findings related to the heart, the patient died the same month a day after the ECG exam was performed. A necropsy by a third party was then conducted and revealed severe renal pathology, suggesting renal failure, a common sequela of electrocution injuries[11]. In addition, chronic pneumonia was observed, suggesting the sloth was suffering from an infection even before the electrocution incident occurred. All other findings were unremarkable. There were no signs of cardiac pathology confirmed by the pathologist during the necropsy. Heart measurements were performed after at the TSI facilities. The heart was of normal size relative to body mass and weighed 13 grams. Cardiac structures were intact and of appropriate shape and form. The tricuspid valve, papillary muscles and the chordae tendineae looked grossly normal. The mitral, aortic and pulmonary valves were not thickened or stiff. Post mortem confirmed the tricuspid valve was normal and all muscles appeared normal on gross examination.

Comparative necropsies

Comparative necropsies were performed on five additional C. hoffmanni specimens: three babies and two adults, Postmortem weights ranged between 430 grams to 3.7 kg. Subjects died from natural causes unlikely to affect cardiac form following death.

All carcasses were found to be in adequate condition, they were preserved in deep freeze for further study between 1-2 years. Specimens were defrosted for necropsy. All cardiovascular systems were thoroughly evaluated for pathology and measurements of relevant structures were recorded (Table 1). Evaluation of external cardiac features revealed prominent auricles across all subjects. Auricles were measured in length and width before and after detaching them from the heart in order to have an accurate measurement, an incision was made after to make sure no pathology could be found internally; auricles were similar in size to the entire heart in terms of length and width for all subjects. Presumed left auricle hypertrophy was however noted in one specimen that had a thick red clot in it, did not present a difference in color but had adopted the shape of the auricle. The auricle muscle wall was enlarged but the muscle did not show signs of swelling, change of color or petechiae after retiring the blood coagulum the muscle remained enlarged. The subject's clinical history does not explain the presence of this clot and it was assumed to be a normal postmortem change given its color and the condition of surrounding structures. No other cardiac pathology was noted in other subjects.

Location of the hearts were similar between 3 and 4 intercostal spaces, 2 of the babies were slightly more to the left which may be a postmortem change due to freezing of the body posture. All hearts had a dark color and were still covered by the pericardium which had to be carefully removed in order to properly examine the hearts. All subjects had the vena cava accompanied by the iliac artery. The veins seemed to be of smaller caliber compared to the arteries.

The hearts were then removed from the body cavities for detailed measurement. Weights ranged from 2 grams to 13 grams. Heart mass of all individuals was an average of 0.37% of the total body weight, which is very low compared to other organs that occupy more internal space. Incisions were also made on each ventricle to identify the chordae tendineae and related musculature which looked similar in color and form between all specimens. Distinct interventricular septa were noted in all subjects, dividing the left and right ventricles. All individuals demonstrated thickening of the left ventricular wall musculature compared to the right ventricle, a normal finding. This was however more prominent in infant subjects than adults. All valves (aortic, mitral, tricuspid and pulmonary) did not look thickened and grossly looked similar in color and tissue conformation. No gross pathology was noted on the internal structure.

Findings

Comparing necropsy findings of the case study subject to the control specimens revealed distinct similarities. Most noteworthy being the prominent auricles in comparison to the overall heart size. All anatomy seemed similar in location and structure. Direction and location of the heart was mostly similar even after deep freeze of some of the specimens. In all of the subjects, the caliber of the venous system was smaller than the artery system. In addition, the ventricle muscles were consistently similar in all specimens but the left wall was thicker. The connection between the 4 chambers did not show any pathology that could suggest an abnormality of the heart rhythm or systolic and diastolic function.

Discussion

Our results show no evidence that this electrocution event altered the function or form of the heart of our case study individual. However, being that our results are based only on one individual, further studies evaluating the effect of electrocution on sloth hearts are needed to determine the true risk that electrical current poses to normal cardiac function. The post mortem examination also does not rule out any previous cardiac abnormalities experienced by the case study patient immediately after being injured, but resolved before her death from renal failure. In addition, this study confirms reports from previous authors that Choloepus spp have smaller hearts in relation to their body weight than other mammals. This difference in size is likely due to their relatively sedentary lifestyle and low metabolic needs [1,2,3,7,8]

Literature mentions that C. hoffmanni's heart is in the thoracic cavity in the mediastinum region a little to the left side [9]. Dünner and Pastor described a double vena cava, consistent with other reports [1,2,4,8] although the focus of this report was the function of the heart chambers and valves rather the vascular anatomy of Choloepus, it is important to note that some studies have found this species of sloth to have a single vena cava, instead of a double vena cava [9] as was found in our specimens. The difference in diameter between the veins and arteries is believed to be consistent with the lifestyle of an animal living in the forest canopy [6]. All the valves examined had similar anatomy and no thickening of valves was observed indicating that they were functioning normally at the time of death. All hearts examined showed very similar anatomy to what has been previously described including an intraventricular septum dividing the left and right halves and prominent auricles [9]. This report suggests a potential trend of smaller heart size relative to body mass in Choloepus as opposed to other mammals which the average is 5.1 to 6.78 grams per kilogram of body [6]. However to statistically confirm this hypothesis, further cardiological examinations and descriptions on a larger sample size are necessary. In addition, more live studies through ECG examination would help determine any anomaly on the valves of future electrocuted individuals rather than only in post mortem evaluation.

As previously mentioned, evidence suggests that sloths have smaller hearts in relation to body size than other mammals, however it has also been noted that Choloepus have larger hearts than Bradypus [6]. Wislocki (1928) determines that the average Bradypus heart to body ratio is 2 grams of heart mass per kilogram of body weight compared to Choloepus having 3.54 grams of heart weight per kilogram of body weight which is comparable to our findings. We suggest future case studies should be reported comparing the cardiac anatomy of Bradypus spp to determine the effect that electrocution has on the other genera of sloths. Interestingly, Wislocki (1928) also found an increased heart rate in Bradypus due to close proximity of human researchers which is similar to our findings with this Choloepus patient, indicating that both genera of sloths are stressed when being handled by or forced to be near humans.

Although in this particular study we did not find any injury, burn or gross damage to the heart due to the electrocution it would be important to continue monitoring other sloth electrocution patients to be able to understand how the electricity could affect the overall functionality of the heart [11]. Although we anticipated cardiac abnormalities due to the electrocution considering the patient suffered other significant organ damage which led to her death. The electrocution did not cause any heart damage, and our findings are consistent with the literature for what has been considered normal cardiac morphology in sloths. [1,2, 5 7,8,13]. We also highlight the need for more post mortem analysis of sloth electrocution victims in order to gain a better understanding of the effects these traumatic incidents have on their internal organs, particularly the heart, kidneys and liver. It is highly recommended to do a systemic and microscopic study of the cardiac anatomy to better understand the functionality and physiology of the cardiovascular system of sloths in healthy and sick individuals.

Acknowledgments

The authors thank the TSI team for their clinical and research support as well as the good Samaritans involved in the rescue of wild animals.

1. Funding information: Funding for this study was provided by The Sloth Institute, a nonprofit organization in Costa Rica: Asociación para el Estudio del Perezoso.
2. Conflict of interest: The authors state no conflict of interest.
3. Data availability statement: All data generated or analyzed during this study are included in this published article.

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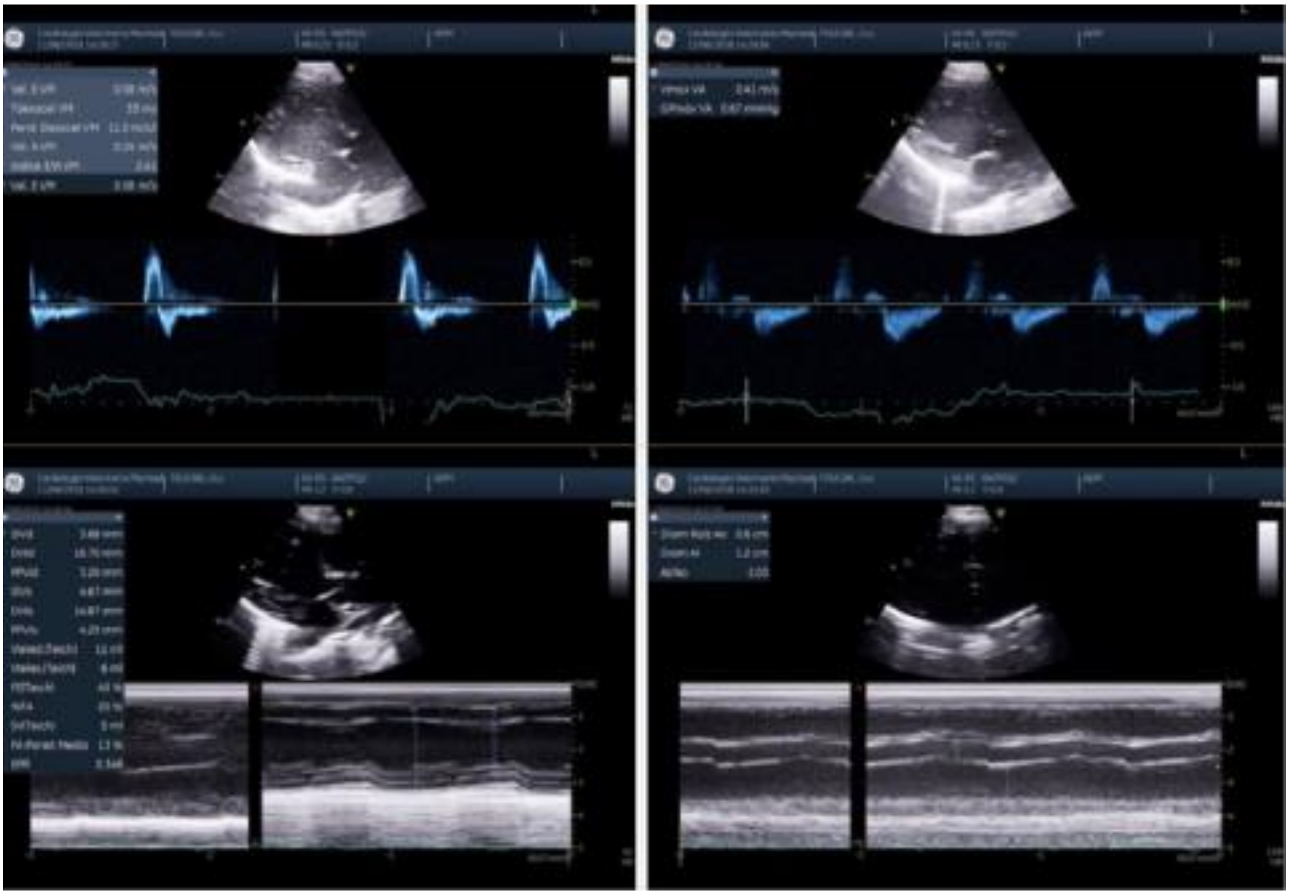

Figure 1. C. Hoffmanni Electrocardiography Images. **A and B) Electrocardiography**. Had a heart frequency of 75 with regular sinus and normal atrio ventricular conduction there is no hypoxia and not alterations of the sinus rhythm**. C and D) Echocardiography**. Pericardium normal, normal mitral, tricuspid and aortic appearance. Normal systolic function and normal atrial pressure.

Table 1. C. hoffmanni postmortem cardiac measurements. Specimen weight, body length (measured along dorsal midline from nares to distal coccygeus), and cardiac measures taken on case study subject and comparative specimens. Heart mass was measured following removal from body cavity and compared to total body weight for relative size determination. Heart size was measured length and width to be able to compare with the auricle although the focus was to be able to calculate heart mass vs body mass.

The weight of normal hearts in relation to body weight are described for each subject.

Specimen	Weight (kg)	Body length (cm)	Heart				Left auricle (cm)		Right auricle (cm)	
			Mass (g)	Average of Total Body Weight	Size (cm)					
					Length	Width	Length	Width	Length	Width
Case	3.600	61.0	13.0	0.36%	6.0	3.0				
Necropsy 1	0.555	30.0	2.0	0.36%	2.5	1.0	0.5	1.0	0.5	1.0
Necropsy 2	0.665	31.0	2.0	0.3%	2.5	2.0	2.0	1.5	1.0	1.0
Necropsy 3	0.430	25.5	2.0	0.46%	2.0	1.5	1.0	0.5	1.0	1.0
Necropsy 4	1.710	43.0	6.0	0.35%	3.5	3.0	1.0	1.0	1.0	1.0
Necropsy 5	3.715	63.0	14.0	0.37%	5.7	3.0	2.0	1.0	2.0	1.0