Exotic Animals' Vascular System Characteristics and its Application in Clinical Practice

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Abstract:
Veterinary practice commonly involves caring for domestic and companion animal. Since the trend of owning exotic pets is rapidly increasing, veterinarians often treat exotic patients as well. As a result, veterinarians are facing increased demands for specialized skills and knowledge. This article aims to provide a concise review of the anatomy of the vascular system in exotic animals and its relevance in clinical practice. Snakes, lizards and chelonians have 3-chambered heart with 2 atria and one partially divided ventricle whereas crocodiles have 4-chambered heart. It is important to consider these characteristics during the anesthesia in reptiles since blood shunting affects changes in blood pressure, oxygen level and other anesthetic parameters. In birds, the cardiovascular system is crucial in enduring the exhausting physical activities such as swimming, flying or diving and running. Birds have renal portal system which consists of cranial and caudal renal portal vein. The recommendation of avoiding drug application in the hindlimbs of birds is present for a long time. This is valid not only for birds, but for reptiles, amphibians and most fish. The ventricle of amphibians is trabeculated, which minimizes blood shunting through various anatomical and physiological features. During biphasic systole, the left and right side of the ventricle contract separately, directing blood in different parts of aortic arches. Due to the complexity of the exotic animals, thorough education added in veterinary curricula is needed.

Keywords: amphibians, birds, cardiovascular, clinical, reptiles

Introduction

Common veterinary practice deeply relies on working with domestic and companion animals. Even though they are perceived as the most frequent patients, trend of owning exotic pets is rapidly increasing. Statistics show that the number of pet birds in Europe is around 52 million with 29 million small mammals, 10 million aquatic animals and around 9 million reptiles (Ostović et al., 2022). In the USA, the exotic animal trade market has seen significant growth in recent years. Between 2000 and 2006, United States imported around 1.5 billion wild-life animals from which 92 % was acquainted as pets (Smith et al., 2009). These numbers increase steadily every year. Thus, skills and knowledge required from veterinarians increase and become challenging (Espinosa García-San Román et al., 2023). Contrary to this, education about exotic pets and practical skills are not included in most of the veterinary schools or they are included insufficiently (Rosenthal, 2006). Institutions are often reluctant towards introducing the courses about exotic animals, not realizing that exotic pets as patients are more common than before and students should have some basic knowledge after the graduation. Recommendation of American College of Zoological Medicine regarding veterinary curricula implies that all students should be able to take history and perform physical examination of exotic patients. They also suggest that students acquire specific knowledge of physiology, methods of restrain, sample collection, and understanding of clinical data (Stoskopf et al., 2001). Many specificities characterize exotic animals in comparison with usual companion animals. However, the studies regarding cardiovascular system of exotic animals are scarce. Existing studies primarily focus on laboratory animals due to their widespread use in biomedical researche. Although American mink (*Mustela vison*) is not a typical laboratory animal, its cardiovascular system has been extensively studied. Several studies (Hadžiomerović et al., 2016; Mrvić et al., 2017; Mrvić et al., 2021) investigated mink's vascular system including kidneys, liver and lungs. They described branching of hepatic, renal and pulmonary veins and arteries comparing it to the dog as a similar carnivore model. In other studies, Ninomiya et al. (2008) and Mazensky et al. (2012) explored vascular features of rabbit eyes using vascular corrosion casting and branching of renal veins and arteries. This article aims to condense specific anatomy of exotic animal's vascular system and to refer on its use in clinical practice. It further intends to help veterinary practitioners in process of clinical examination of these animals and to highlight what to be aware of regarding their anatomy and physiology.

Reptiles

Reptiles belong to the large class of *Reptilia* consisting of several orders. Snakes and lizards (order - *Squamata*), chelonians and crocodiles make the majority of this class where squamates are the most species-rich order with approximately 7000 species (Jensen et al., 2014). Their cardiovascular anatomy greatly varies. Snakes, lizards and chelonians have 3-chambered heart with 2 atria and one partially divided ventricle whereas crocodiles have 4-chambered heart. All species have 2 aortic arches, right and left with 4 systemic veins including 2 cranial caval veins and caudal caval vein (Sladky and Mans, 2012; Jensen et al., 2014). These anatomical features cause mixing of arterial and venous blood. Even though considered pathophysiological in mammals and birds, blood shunting is proven to have several roles in reptile organism unlike previous hypothesis that treats shunting as evolutive remnant without physiological significance or even detrimental. It enables stabilization of oxygen level during breaks in respiration. Furthermore, right to left shunt can partially help heating process by increasing the amount of blood in systemic circulation. Left to right shunt, where the blood level in lungs is reduced, happens during the diving apnea of aquatic reptiles (Hicks, 2002; Mosley, 2005). It is important to consider these characteristics during the anesthesia in reptiles since blood shunting affects changes in blood pressure, oxygen level and other anesthetic parameters. The shunting can also delay or hasten the excretion of the inhalation anesthetics. Another vascular system characteristic specific to reptiles is renal portal system. Cranial and caudal portal veins collect blood from the tail, pelvis, limb and caudal part of the spine and intestines forming the plexus around the kidneys. Blood flow is controlled by autonomic nervous system and valves which direct blood through or around the kidneys (Sladky and Mans, 2012). Renal portal system could possibly affect the pharmacodynamics and pharmacokinetics of drugs

administered in the caudal part of the reptile's body. Some authors suggest that drugs administered in the caudal part could be nephrotoxic or that the excretion time of the drug could be decrease, consequently affecting the effective dose and treatment of the animal. Contrary to this, some studies oppose these statements due to the lack of scientific evidence. However, current recommendations advise against the administration of nephrotoxic drugs and those excreted primarily by kidneys in the caudal part of reptiles (Mosley, 2005; O'Malley, 2017). During the clinical examination of patient, it is significant to know the sites for blood sample collection as well as drug administration sites. In lizards, ventral tail vein, ventral abdominal vein, cranial vena cava, brachial vein and jugular vein are commonly used while in chelonians, for intravenous route and blood sample collection, jugular, dorsal tail vein and brachial vein are used (**Figure 1**).

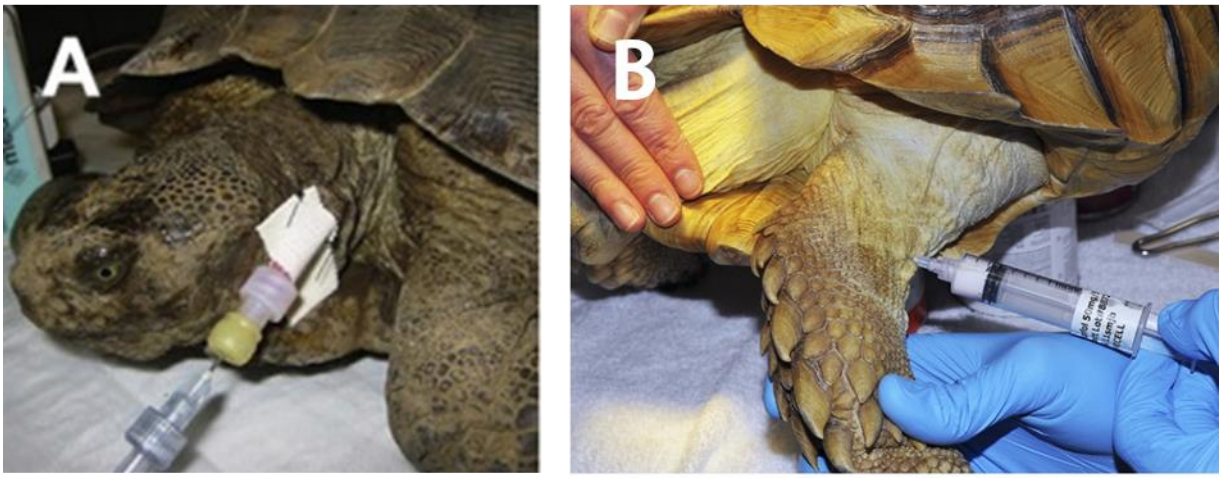

Figure 1. A: Venipuncture sites in turtle – jugular vein (Courtesy of the University of California, Davis). B: Anesthetic administration in brachial plexus of turtle (Courtesy of Kurt K. Sladky).

Intravenous route for drug administration in snake is jugular, palatine, and ventral tail vein. Important note for the examination of exotic animals is to restrain animal properly but in most cases, sedation or general anesthesia is necessary (Coutant et al., 2018).

Birds

Avian heart is located in the median plane of cranioventral part of coelomic cavity surrounded by the lobes of liver. It consists of two atria and two ventricles. Mass of the avian heart in regard to body mass surpasses the mammal heart (Strunk and Wilson, 2003). The avian heart is well-adapted due to the high demands for oxygen. The cardiovascular system is crucial in enduring the exhausting physical activities in different birds such as swimming, flying or diving and running (Dzialowski and Crossley, 2022). Even though heart of mammals and birds share substantial amount of similarities, during the evolution, birds developed many physiological characteristics which reflect on the gross anatomy. For example, heart size of goose increases before the period of migration (Bishop et al., 1995). Peripheral resistance is lower in pulmonary blood vessels, therefore the right ventricle wall is thinner compared to left ventricle (Dzialowski and Crossley, 2022). Generally lower peripheral resistance in birds compared to mammals demands higher arterial pressure for the high cardiac output. Heart rate in birds is variable and depends on the size of the bird, physical activity and different physiological needs (King and Lelland, 1984). With powerful heart muscle birds achieve bigger heart stroke volume, large cardiac output and are able to increase the heart rate over 1000 beats per minute (Dzialowski and Crossley, 2022). Birds major systemic blood vessels consist of aorta which originates from right aortic arch and three caval veins including right and left cranial vena cava and caudal vena cava. Aorta gives branches to the two brachiocephalic trunks for the vascularization of cranial part of the body and continues as descending aorta. Right cranial vena cava and caudal vena cava terminate in right atrium separately from left cranial vena cava which enters to sinus venosus (Strunk and Wilson, 2003). Amongst other

characteristics in birds, vascular system of kidney is to be highlighted. Birds have renal portal system which consists of cranial and caudal renal portal vein. These veins drain blood from common iliac, external iliac, internal iliac, caudal mesenteric and ischiatic veins along with the internal vertebral venous sinus (**Figure 2**).

Arterial supply is done by renal arteries which enter each lobe separately (Burgos-Rodriguez, 2010). Kidneys of the bird itself have specific structure, embedded in renal fossa of the sacrum and divided into three parts, cranial, middle and caudal lobe. Birds have two types of nephrons, mammalian-like and reptile-like. Mammalian type is of more complex structure with longer proximal and distal tubules while reptilian type of nephron is missing Henley loop and the tubules are numerous but shorter (Burgos-Rodriguez, 2010; Hadžiomerović et al., 2021). Detailed description of kidneys and renal portal system encompasses the objectives of the study but it is assessed briefly to emphasize a complexity of these features in birds. This has clinical significance, since the recommendation of avoiding drug application in the hindlimbs of birds is present for a long time. Due to the lack of extensive studies that would distinguish which drugs are safe for application, most of the practitioners still avoid it. Many existing studies have opposite results and claims, therefore it is most appropriate to administer drugs in the cranial part of animal. This is valid not only for birds, but for reptiles, amphibians and most fish (Coutant et al., 2018). For the intravenous route in birds and blood sample collection in birds, mostly there are three blood vessels available including ulnar superficial vein, also known as basilic or wing vein, medial metatarsal vein and jugular vein. Important to note is that right jugular vein is often bigger then the left, hence it is more accessible (Coutant et al., 2018).

Figure 2. Venous vascularization of fowl's kidney and blood vessels of renal portal system (corrosion technique). 1. *V. cava caudalis*; 2. *V. iliaca communis*; 3. *V. iliaca externa*; 4. *V. portalis renalis cranialis*; 5. *V. portalis renalis caudalis*; 6. *V. renalis cranialis*; 7. *V. renalis caudalis*; 8. *V. ischiadica*; 9. *V. mesenterica caudalis*; 10. *V. iliaca interna*

Amphibians

Among three types of animals reviewed in this article, species from the group of amphibians represent the rarest patients for veterinarians. Earlier studied mostly by

biologists, in the last few decades veterinarians are more involved in working with amphibians. Amphibians are divided into three groups: *Anura*, *Caudata* and *Caecilians*. Frogs and salamanders are the representatives of first two groups as the commonly studied species (Forzán et al., 2017). The three-chambered heart of amphibians is generally similar among species, but some differences can be noted. In anurans and salamanders, the right atrium is usually larger than the left, except in a few species of anurans, such as African Clawed frog (*Xenopus laevis*). The interatrial septum is fenestrated in salamanders, allowing for the mixing of blood, while it is complete in anurans. Blood from both atria enters the undivided ventricle (Sharma, 1961; Heinz-Taheny, 2009). Trabeculated ventricle in amphibians and different anatomical and physiological features minimize the blood shunting. During biphasic systole, the left and right side of ventricle contract separately forcing the blood in different parts of aortic arches. Separation of the blood is enabled by spiral valve in the conus arteriosus. Three separate trunks exit the ventricle, systemic arch, carotid and pulmocutaneous arch (**Figure 3**).

In the first phase of heart contraction, deoxygenated blood from the right side of the ventricle enters the pulmocutaneous arch which gives pulmonary and cutaneous arterial vessels carrying the blood for gas exchange in the lungs and skin of amphibians. In the second phase, blood is sent to the systemic and carotid arches for oxygenation of the cranial and caudal parts of the animal. Therefore, very small portion of blood from the right side of ventricle goes to the left side. The blood from the left side is directed mainly to the systemic circulation avoiding right side (Heinz-Taheny, 2009). Along with systemic and pulmocutaneous circulation, amphibians also have renal portal system. According to O'Malley (2005), since the blood from the hindlimbs does not bypass the kidneys, drug administration in the caudal part of the body may cause changes in drug distribution. Additionally, ventral abdominal vein, often used in clinics passes through the liver as a part of the hepatic portal system. This could affect pharmacokinetics of drug administered in this vein and its branches. Hence, it is suggested to avoid the application of drugs primarily metabolized in the liver in the caudal part of the body (Heinz-Taheny, 2009). Furthermore, taking in considerations amphibians are poikilothermic animals, clinicians should keep the patients in their optimal temperature zones due to the fact physiology, behavior and therapy are influenced by temperature (Whitaker et al., 1999; Wright, 2001). Venipuncture sites differ between the species. In the frogs, cardiac puncture, ventral abdominal vein, femoral vein and lingual vein are used. Ventral tail vein is most commonly used in salamanders. Amount of blood sample should not exceed 1% of body weight in healthy animal nor 0.5 % in diseased animal (Heinz-Taheny, 2009).

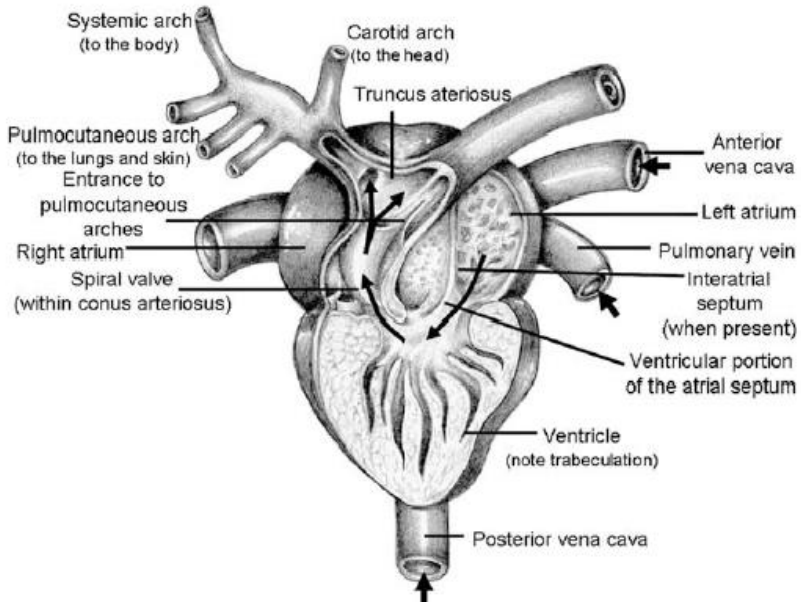

Figure 3. Anatomy of the anuran heart. Large block arrows indicate blood flow into the heart. Thin black arrows indicate flow of oxygenated blood (Courtesy of Frank Taheny).

Conclusion

The number of exotic pets is increasing over the past few years. Aside from usual work with companion animals, veterinarians often treat exotic patients as well. This demands certain level of knowledge about specific anatomy and physiology of these animals. The article provides a brief insight in vascular system of reptiles, birds and amphibians with an emphasis on important clinical considerations regarding these characteristics. However, due to the complexity of the exotic animals, thorough education is needed.

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References

1. Bishop CM, Butler PJ, Egginton S, el Haj AJ, Gabrielsen GW. Development of metabolic enzyme activity in locomotor and cardiac muscles of the migratory barnacle goose. Am J Physiol. 1995; 269(1 Pt 2):R64-72. DOI: 10.1152/ajpregu.1995.269.1.R64
2. Burgos-Rodriguez A. Avian Renal System: Clinical Implications. Vet Clin North Am Exot Anim Pract. 2010; 13:393-411. DOI:10.1016/j.cvex.2010.05.001
3. Coutant T, Vergneau-Grosset C, Langlois I. Overview of Drug Delivery Methods in Exotics, Including Their Anatomic and Physiologic Considerations. Vet Clin North Am Exot Anim Pract. 2018; 21:215-259. DOI: 10.1016/j.cvex.2018.01.006
4. Mosley CAE. Anesthesia and Analgesia in Reptiles. Seminars in Avian and Exotic Pet Medicine. 2005; 14:243-262. DOI: https://doi.org/10.1053/j.saep.2005.09.005
5. Dzialowski EM, Crossley DA. The cardiovascular system, In: Scanes CG, Dridi S, editors. Sturkie's Avian Physiology. Amsterdam, The Netherlands. Elsevier Science. 2022; pp. 329-296.
6. Espinosa García-San Román J, Quesada-Canales Ó, Arbelo Hernández M, et al. Veterinary Education and Training on Non-Traditional Companion Animals, Exotic, Zoo, and Wild Animals: Concepts Review and Challenging Perspective on Zoological Medicine. Vet Sci. 2023; 10:357. DOI: https://doi.org/10.3390/vetsci10050357
7. Forzán MJ, Heatley J, Russell KE, Horney B. Clinical pathology of amphibians: a review. Vet Clin Pathol. 2017; 46:11-33. DOI: 10.1111/vcp.12452
8. Hadžiomerović N, Avdić R, Minnich B, et al. 3D morphometric study of domestic fowl glomerulus-A scanning electron microscope study of vascular corrosion casts. Anat Histol Embryol. 2021; 50:678-682. DOI: 10.1111/ahe.12676
9. Hadžiomerović N, Avdić R, Tandir F, et al. Intrahepatic Distribution of The Hepatic Veins and Biliary Ducts in American Mink Liver (*Mustela vison).* Journal of Veterinary Anatomy. 2016; 9:15-23. DOI:10.21608/jva.2016.37294
10. Heinz-Taheny KM. Cardiovascular physiology and diseases of amphibians. Vet Clin North Am Exot Anim Pract. 2009; 12:39-50. DOI: 10.1016/j.cvex.2008.08.005.
11. Hicks JW. The physiological and evolutionary significance of cardiovascular shunting patterns in reptiles. News Physiol Sci. 2002; 17:241-245. DOI:https://doi.org/10.1152/nips.01397.2002
12. Jensen B, Moorman AF, Wang T. Structure and function of the hearts of lizards and snakes. Biol Rev Camb Philos Soc. 2014; 89:302-336. DOI: https://doi.org/10.1111/brv.12056
13. King AS, McLelland J. Cardiovascular system. In: Birds—their structure and function. London, UK, Baillière Tindall. 1984; pp. 214–228.
14. Mazensky D, Purzyc H, Danko J. Variations in the vascular anatomy of the rabbit kidney and its experimental significance. Acta Scientiarum Polonorum. Medicina Veterinaria. 2012; 11:25-33
15. Mrvić V, Avdić R, Hadžiomerović N, et al. Arterial and venous vascularization of the lung in American mink *(Neovison vison*). Veterinaria. 2021. 70:49-58. DOI:10.51607/22331360.2021.70.1.49
16. Mrvić V, Avdić R, Hadžiomerović N, et al. Renal vasography in mink (Mustela vison). Acta Veterinaria-Beograd. 2017; 67:71-81. DOI: https://doi.org/10.1515/acve-2017-0007
17. Ninomiya H, Inomata T, Kanemaki N. Microvascular Architecture of the Rabbit Eye: A Scanning Electron Microscopic Study of Vascular Corrosion Casts. Journal of Veterinary Medical Science. 2008; 70:887–892. DOI: 10.1292/jvms.70.887
18. O'Malley B. Clinical Anatomy and Physiology of Exotic Species. London, UK, WB Saunders. 2005; pp.7-9.
19. O'Malley, B, Anatomy and Physiology of Reptiles. In: Doneley B, Deborah M, Johnson R, Carmel B, editors. Reptile Medicine and Surgery in Clinical Practice. Oxford, UK, Wiley. 2017; pp. 15–32.

20. Ostović M, Sabolek I, Piplica A, et al. Opinions and knowledge of veterinary students relating to exotic non-mammal pet animals and their welfare. Veterinarski arhiv. 2022; 92:349-358. DOI: https://doi.org/10.24099/vet.arhiv.1018
21. Rosenthal, K. Future Directions in Training of Veterinarians for Small Exotic Mammal Medicine: Expectations, Potential, Opportunities, and Mandates. Journal of Veterinary Medical Education. 2006; 33:382–385. DOI: https://doi.org/10.3138/jvme.33.3.382
22. Sharma HL. The circulatory mechanism and anatomy of the heart of the frog Rana pipiens. Journal of Morphology. 1961; 109:323–349. DOI:10.1002/jmor.1051090307
23. Sladky KK, Mans C. Clinical Anesthesia in Reptiles. Journal of Exotic Pet Medicine. 2012; 21:17-31. DOI: https://doi.org/10.1053/j.jepm.2011.11.013
24. Smith KF, Behrens M, Schloegel LM, et al. Ecology. Reducing the risks of the wildlife trade. Science. 2009; 324:594-595. DOI: 10.1126/science.1174460
25. Stoskopf MK, Paul-Murphy D, Kennedy-Stoskopf S, Kaufman G. American College of Zoological Medicine recommendations on veterinary curricula. J Am Vet Med Assoc. 2001; 219:1532-1535. DOI: https://doi.org/10.2460/javma.2001.219.1532
26. Strunk A, Wilson GH. Avian cardiology. Vet Clin North Am Exot Anim Pract. 2003; 1:1-28. DOI: https://doi.org/10.1016/S1094-9194(02)00031-2
27. Whitaker BR, Wright KM, Barnett SL. Basic husbandry and clinical assessment of the amphibian patient. Vet Clin North Am Exot Anim Pract. 1999; 2:265-290. DOI: 10.1016/s1094-9194(17)30125-1.
28. Wright KM, Applied Physiology. In Wright KM, Whitaker BR, editors. Amphibian medicine and captive husbandry. Florida, USA, Krieger Publishing. 2001; pp. 31–34.