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Editorial

Diagnostic Imaging of Cardiovascular Disease in Small Animals

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Received: 3 December 2020; Accepted: 11 December 2020; Published: 15 December 2020

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1. Introduction

Cardiovascular disease (CVD) has always been an important field of application for diagnostic imaging in small animal practices and, vice-versa, diagnostic imaging has greatly expanded the diagnostic capabilities of veterinary clinicians dealing with CVD.

In addition to physical examination and electrocardiography, cardiac imaging offers unique opportunities to understand and investigate cardiovascular function and dysfunction. Among the different imaging modalities, each with specific advantages and disadvantages, some focus primarily on cardiac structure and anatomy and others are mainly concerned with cardiac physiology and function.

2. From Thoracic Radiography to Echocardiography

For several decades in the last century, thoracic radiography and fluoroscopy, with or without the use of contrast medium (i.e., contrast angiography), were the imaging techniques of choice to investigate dogs and cats affected by congenital or acquired CVD [1,2]. Radiography is the most commonly available imaging technique in the veterinary clinical setting and allows the simultaneous depiction of the cardiac silhouette, pulmonary and other thoracic vessels, as well as pulmonary parenchyma and pleural space [3]. Therefore, it still plays a pivotal role in diagnosing congestive heart failure (CHF) associated with cardiac disease [3].

Starting in the 1970s, the progressively increasing number of available ultrasound technologies, from M-mode via two-dimensional sector and then three-dimensional volume scanning techniques, in combination with various Doppler methods (spectral, color-coded and tissue Doppler) and other advanced techniques (e.g., contrast echocardiography, strain and speckle-tracking imaging), has considerably increased understanding of normal and abnormal cardiovascular anatomy and function [1]. For example, prior to echocardiography, large breed dogs with cardiac arrhythmias or cardiac enlargement and CHF were diagnosed with the generic term of idiopathic or congestive cardiomyopathy [2]. With the advent of diagnostic ultrasound and the capability to more precisely quantify heart chamber size, wall thickness and contractility, as well as blood flow through the heart, specific types of myocardial disease of both dogs and cats were identified, such as dilated, hypertrophic or restrictive cardiomyopathy [2]. The widespread use of echocardiography has made it the dominant cardiac imaging modality in daily veterinary clinical practice [1,2]. Furthermore, the use of echocardiography as the reference diagnostic method has enabled the investigation of the diagnostic accuracy of thoracic radiography for the diagnosis of congenital and acquired CVD in small animals [4–7]. In addition to the valuable aid in the precise diagnosis of different cardiac diseases, echocardiography enables us to collect useful prognostic information for many of them [8–15].

3. From Computed Tomography and Magnetic Resonance Imaging to Artificial Intelligence and Beyond

In the last decade, the increasing accessibility of computed tomography (CT) and magnetic resonance imaging (MRI) units in small animal veterinary practices has offered additional powerful tools for the in-depth exploration of cardiac anatomy and the assessment of cardiac function. The high temporal and spatial resolution achievable with the modern multidetector-row CT scanners, which can acquire a three-dimensional dataset of the heart and thoracic vessels in a few seconds, allows the depiction of very small or difficult to access normal or abnormal cardiovascular structures (e.g., the coronary arteries) [16]. Furthermore, the use of contrast medium for CT pulmonary angiography represents the technique of choice for the diagnostic confirmation of subtle and challenging vascular diseases (e.g., pulmonary thromboembolism) [17].

The heart and great vessels are very well visualized with MRI because the contrast between cardiovascular tissue and blood is more pronounced than in echocardiography and cardiac CT. Therefore, cardiac MRI is the reference imaging technique for the assessment of cardiac morphology and function and is often used for the evaluation of complex cardiovascular anomalies and specific myocardial disease processes in humans. In companion animals, the early application of MRI includes the precise assessment of cardiac morphology, volume and function, as well as the identification of subtle and challenging changes in poorly accessible cardiovascular structures such as the right ventricle, the pericardium and the heart base in animals with arrhythmogenic cardiomyopathy, mesothelioma, heart base masses and vascular abnormalities, respectively [18].

Finally, veterinary cardiologists and radiologists have very recently started the early application of deep learning, an artificial intelligence application that uses computer-aided detection methods with the aim of helping clinicians recognize cardiac or left atrial enlargement on canine thoracic radiographs [19,20].

Cardiovascular imaging has witnessed an explosive expansion of available tools providing detailed information of cardiovascular structures and physiology with noticeable improvement in the diagnosis of CVD. The future directions of cardiac imaging include the increased interconnection among the different imaging techniques and their extended use, not only for diagnostic but also for prognostic purposes in animals with CVD.

Author Contributions: Conceptualization, A.D. and C.G.; writing—original draft preparation, A.D. and C.G.; writing—review and editing, A.D. and C.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Scansen, B.A.; Drees, R. Joint virtual issue on recent advances in veterinary cardiac imaging. *J. Vet. Intern. Med.* **2020**, *34*, 546–548. [CrossRef] [PubMed]
2. Buchanan, J.W. The history of veterinary cardiology. *J. Vet. Cardiol.* **2013**, *15*, 65–85. [CrossRef] [PubMed]
3. Guglielmini, C.; Diana, A. Thoracic radiography in the cat: Identification of cardiomegaly and congestive heart failure. *J. Vet. Cardiol.* **2015**, *17*, S87–S101. [CrossRef] [PubMed]
4. Lamb, C.R.; Boswood, A.; Volkman, A.; Connolly, D.J. Assessment of survey thoracic radiography as a method for diagnosis of congenital cardiac disease in dogs. *J. Small Anim. Pract.* **2001**, *42*, 541–545. [CrossRef] [PubMed]
5. Guglielmini, C.; Diana, A.; Santarelli, G.; Torbidone, A.; Di Tommaso, M.; Baron Toaldo, M.; Cipone, M. Accuracy of the vertebral heart score and sphericity index for detection of pericardial effusion in canine thoracic radiographs. *J. Am. Vet. Med. Assoc.* **2012**, *241*, 1048–1055. [CrossRef] [PubMed]

6. Guglielmini, C.; BaronToaldo, M.; Poser, H.; Menciotti, G.; Cipone, M.; Cordella, A.; Contiero, B.; Diana, A. Diagnostic accuracy of the vertebral heart score and other radiographic indices in the detection of cardiac enlargement in cats with different cardiac disorders. *J. Feline Med. Surg.* **2014**, *16*, 812–825. [CrossRef] [PubMed]
7. Guglielmini, C.; Baron Toaldo, M.; Quinci, M.; Romito, G.; Luciani, A.; Cipone, M.; Drigo, M.; Diana, A. Sensitivity, specificity, and interobserver variability of thoracic radiography in the detection of heart base masses in dogs. *J. Am. Vet. Med. Assoc.* **2016**, *248*, 1391–1398. [CrossRef] [PubMed]
8. Borgarelli, M.; Santilli, R.A.; Chiavegato, D.; D'Agnolo, G.; Zanatta, R.; Mannelli, A.; Tarducci, A. Prognostic indicators for dogs with dilated cardiomyopathy. *J. Vet. Intern. Med.* **2006**, *20*, 104–110. [CrossRef] [PubMed]
9. Borgarelli, M.; Savarino, P.; Crosara, S.; Santilli, R.A.; Chiavegato, D.; Poggi, M.; Bellino, C.; La Rosa, G.; Zanatta, R.; Haggstrom, J.; et al. Survival characteristics and prognostic variables of dogs with mitral regurgitation attributable to myxomatous valve disease. *J. Vet. Intern. Med.* **2008**, *22*, 120–128. [CrossRef] [PubMed]
10. Hezzell, M.J.; Boswood, A.; Moonarmart, W.; Elliott, J. Selected echocardiographic variables change more rapidly in dogs that die from myxomatous mitral valve disease. *J. Vet. Cardiol.* **2012**, *14*, 269–279. [CrossRef] [PubMed]
11. Payne, J.R.; Borgeat, K.; Connolly, D.J.; Boswood, A.; Dennis, S.; Wagner, T.; Menaut, P.; Maerz, I.; Evans, D.; Simons, V.E.; et al. Prognostic indicators in cats with hypertrophic cardiomyopathy. *J. Vet. Intern. Med.* **2013**, *27*, 1427–1436. [CrossRef] [PubMed]
12. Sargent, J.; Muzzi, R.; Mukherjee, R.; Somarathne, S.; Schranz, K.; Stephenson, H.; Connolly, D.; Brodbelt, D.; Luis Fuentes, V. Echocardiographic predictors of survival in dogs with myxomatous mitral valve disease. *J. Vet. Cardiol.* **2015**, *17*, 1–12. [CrossRef] [PubMed]
13. Baron Toaldo, M.; Romito, G.; Guglielmini, C.; Diana, A.; Pelle, N.G.; Contiero, B.; Cipone, M. Prognostic value of echocardiographic indices of left atrial morphology and function in dogs with myxomatous mitral valve disease. *J. Vet. Intern. Med.* **2018**, *32*, 914–921. [CrossRef] [PubMed]
14. Spalla, I.; Payne, J.R.; Borgeat, K.; Luis Fuentes, V.; Connolly, D.J. Prognostic value of mitral annular systolic plane excursion and tricuspid annular plane systolic excursion in cats with hypertrophic cardiomyopathy. *J. Vet. Cardiol.* **2018**, *20*, 154–164. [CrossRef] [PubMed]
15. Chan, I.P.; Weng, M.C.; Hsueh, T.; Lin, Y.C.; Lin, S.L. Prognostic value of right pulmonary artery distensibility in dogs with pulmonary hypertension. *J. Vet. Sci.* **2019**, *20*, e34. [CrossRef] [PubMed]
16. Auriemma, E.; Armienti, F.; Morabito, S.; Specchi, S.; Rondelli, V.; Domenech, O.; Guglielmini, C.; Lacava, G.; Zini, E.; Khouri, T. Electrocardiogram-gated 16-multidetector computed tomographic angiography of the coronary arteries in dogs. *Vet. Rec.* **2018**, *183*, 473. [CrossRef] [PubMed]
17. Marschner, C.B.; Kristensen, A.T.; Rozanski, E.A.; McEvoy, F.J.; Kühnel, L.; Taeymans, O.; de Laforcade, A.; Sato, A.F.; Wiinberg, B. Diagnosis of canine pulmonary thromboembolism by computed tomography and mathematical modelling using haemostatic and inflammatory variables. *Vet. J.* **2017**, *229*, 6–12. [CrossRef] [PubMed]
18. Dennler, M.; Baron Toaldo, M.; Makara, M.; Lautenschläger, I.E.; Ribbers, G.; Wang-Leandro, A.; Waschk, M.; Richter, H.; Glaus, T.M. Recommendations for standardized plane definition in canine cardiac MRI. *Vet. Radiol. Ultrasound* **2020**, *61*, 696–704. [CrossRef] [PubMed]
19. Burti, S.; Longhin Osti, V.; Zotti, A.; Banzato, T. Use of deep learning to detect cardiomegaly on thoracic radiographs in dogs. *Vet. J.* **2020**, *262*, 105505. [CrossRef] [PubMed]
20. Li, S.; Wang, Z.; Visser, L.C.; Wisner, E.R.; Cheng, H. Pilot study: Application of artificial intelligence for detecting left atrial enlargement on canine thoracic radiographs. *Vet. Radiol. Ultrasound* **2020**, *61*, 611–618. [CrossRef] [PubMed]