Hybrid Balloon Mitral Valvuloplasty in an Adult Dog with Congenital Mitral Stenosis and Left Atrial Thrombus

Randolph L. Winter, DVM, PhD, DACVIM (Cardiology), Katelyn C. Hlusko, DVM, MS, DACVS-SA, D. Michael Tillson, DVM, MS, DACVS, Kara L. Maneval, DVM, Claudia Serrano Ferrel, DVM, MS, Meenakshi Rajeev, DVM, and Douglas Castro, DVM, MSc, DSc, DACVAA, *Auburn, Alabama*

INTRODUCTION

Mitral stenosis (MS) is an uncommon congenital defect in the dog.[1-3] Balloon mitral valvuloplasty (BMV) has been documented as an effective method for management of this disease in humans and in dogs.[3,4] However, when congenital MS is diagnosed later in life, medical management and BMV may be complicated by the presence of disease sequelae such as atrial fibrillation (AF) or left atrial (LA) thrombosis.[3,5,6] Here we present a case of an adult dog with congenital MS receiving hybrid BMV.

CASE PRESENTATION

A 5-year-old male intact Maltese dog (8 kg) was presented to the cardiology service of our teaching hospital for evaluation of previously diagnosed congenital MS. Before this evaluation, weakness, coughing, and tachypnea associated with light activity were observed at home. Four months before current presentation, the dog was diagnosed with congenital MS with severe LA enlargement and AF with a ventricular response rate of 200 beats/min. At that time, a mass lesion was observed within the LA lumen using transthoracic echocardiography (TTE). The dog was prescribed pimobendan (0.28 mg/kg orally, twice daily), diltiazem (1.7 mg/kg orally, three times daily), and clopidogrel (2.1 mg/kg orally, once daily). A subsequent examination 1 month later revealed an increased size of the mass within the LA lumen and an inappropriately fast ventricular response rate (180 beats/min). On the basis of this information, an increase in the diltiazem dose (2.6 mg/kg orally, three times daily) was initiated; additionally, the LA mass was assumed to be neoplastic in origin on the basis of its increase in size despite presumed appropriate antiplatelet at doses typically used in canine patients.

Two-dimensional and M-mode TTE at the cardiology service of our teaching hospital revealed severe LA enlargement, mild main pulmonary arterial dilation, mild right ventricular (RV) concentric hypertrophy, a well-defined mass lesion with heterogenous echogenicity extending from the left auricle into the LA lumen (Figure 1A, Video 1), and decreased excursion of the mitral valve (MV) leaflets with prominent diastolic doming. Mild tricuspid regurgitation was observed, with velocities that suggested the presence of mild pulmonary hypertension; however, on the basis of the remodeling of the right ventricle and main pulmonary artery, this may have been an underestimation of the severity of pulmonary hypertension.

Left ventricular (LV) systolic function was normal. Color flow Doppler imaging of the MV revealed mild mitral regurgitation (MR), turbulent blood flowing into the left ventricle for the entirety of diastole (Figure 1B, Video 2), elevated transmitral flow velocities (3.6 m/sec), and flow profiles demonstrating a decreased E-F slope with prolonged pressure halftime of 465 msec (Figure 2, Video 3). These findings were consistent with severe, congenital MS with mild MR. A one-lead electrocardiogram recorded simultaneously with TTE revealed AF.

Treatment options including current medical management, additional anticoagulant management, and BMV were discussed. The option of BMV was chosen because of the dog's poor quality of life on medical management, and a hybrid surgical approach was elected on the basis of the size of the dog and the ability to choose an entry site through the LA wall that had the potential to avoid the mass. The following day, the dog was anesthetized, and transesophageal echocardiography (TEE) was performed immediately before the surgical procedure. TEE revealed that the mass within the left atrium had increased in size compared with the previous examination, and spontaneous echocardiographic contrast was now present in the LA lumen. These new findings made the diagnosis of a LA thrombus more likely. Percutaneous access to the right jugular vein was obtained with a 6-Fr introducer, and a 4-Fr temporary pacemaker lead was positioned in the RV apex. The transvenous pacemaker was to be used subsequently during balloon inflation to aid balloon stability.

The dog was then moved into a tilted right lateral position for a left thoracotomy in the fourth intercostal space. The pericardium was then opened, and TEE and digital pressure on the LA wall were used to identify an entry site that would avoid the thrombus (Figure 3).

An 18-gauge intravenous catheter was used to place a 8-Fr introducer into the LA lumen through the lateral wall, using TEE to document avoidance of the thrombus (Video 4). Intravenous heparin (80 U/kg) was then administered. A 6-Fr balloon wedge catheter was inserted across the mitral orifice into the LV lumen. Fluoroscopy and TEE were used to document this catheter position. A polytetrafluoroethylene-coated guide wire was placed into the LV apex. The balloon wedge catheter was removed, and a 12 mm × 3 cm balloon catheter was positioned across the mitral orifice (Video 5). A 12-mm balloon catheter was chosen, as it was roughly half the diameter of the mitral annulus. The decision regarding balloon catheter size was based on our personal experience. The right ventricle was rapidly paced at

From the Department of Clinical Sciences, College of Veterinary Medicine, Auburn University, Auburn, Alabama.

Keywords: Cardiac, Interventional, Thromboembolism, Veterinary

Correspondence: Randolph L. Winter, DVM, PhD, DACVIM (Cardiology), Department of Clinical Sciences, College of Veterinary Medicine, Auburn University, 1220 Wire Road, Auburn, AL, 36832. (E-mail: *rlw0041@auburn.edu*).

2468-6441

https://doi.org/10.1016/j.case.2023.12.018

VIDEO HIGHLIGHTS

Video 1: Two-dimensional TTE, right parasternal long-axis view during AF, demonstrates severe MS, characterized by prominent diastolic doming of the MV leaflets, severe LA enlargement, and a large LA thrombus.

Video 2: Two-dimensional TTE, right parasternal long-axis view with color flow Doppler during AF, demonstrates turbulent blood flowing into the left ventricle for the entirety of diastole from the inflow obstruction caused by severe MS; mild MR is also noted.

Video 3: Two-dimensional TTE, left parasternal apical view with color flow Doppler during AF, demonstrates turbulent blood flowing into the left ventricle for the entirety of diastole from the inflow obstruction caused by severe MS; mild MR is also noted.

Video 4: Intraoperative two-dimensional TEE, long-axis view of the left heart, demonstrates the tip of the introducer catheter within the dilated LA lumen and the large thrombus. These images are intentionally overgained to highlight the introducer tip, and this increases the appearance of the spontaneous echocardiographic contrast.

Video 5: Intraoperative two-dimensional TEE, long-axis view of the left heart during balloon catheter inflation, demonstrates the agitated mixture of saline and contrast within the balloon as it dilates while positioned across the MV orifice (although the full extent of the balloon catheter cannot be visualized in this imaging plane). Also seen posteriorly within the left atrium (*top of the image*) is a portion of the LA thrombus.

Video 6: Cine fluoroscopic imaging with the patient in a tilted right lateral position (the patient's head is to the left) during balloon inflation and deflation demonstrates the balloon catheter positioned over the guide wire and across the mitral orifice. A distinct area of external compression is initially observed at the level of the MV that resolves with continued inflation.

Video 7: Two-dimensional TEE, four-chamber long-axis view of the left heart after completion of the BMV, demonstrates a large, highly mobile LA thrombus crossing the mitral orifice in diastole.

View the video content online at www.cvcasejournal.com.

180 beats/min before and immediately after inflation of the balloon catheter, to assist balloon stability across the stenotic valve during inflation. A distinct waist of the balloon was observed, which resolved with full inflation (Figures 3 and 4, Videos 5 and 6).

This process was repeated with a 14 mm × 3 cm balloon catheter and a 16 mm × 3 cm balloon catheter. Preplanned stepwise inflations were planned, on the basis of previous experience and in an attempt to avoid overdilation.[3] Fluoroscopy and TEE were used to observe the balloon inflations, and TEE was used after each balloon inflation to assess mitral leaflet mobility and mitral inflow profiles.

After the removal of the 16-mm balloon catheter, improved mitral leaflet mobility was observed. Additionally, pulsed-wave, color flow Doppler interrogation of the mitral inflow revealed apparently unchanged MR severity and decreases in E-F slope and pressure halftime (150 msec; Figure 2B). However, throughout the procedure, the size of the thrombus appeared to progressively increase. Additionally, a large portion of the thrombus was now mobile and in close association with the mitral orifice (Figure 5A, Video 7).

Treatment options were discussed, and surgical embolectomy was elected. Following the placement stay sutures, a left atriotomy incision was made in the distal auricular appendage with the goal of thrombus extraction before potential systemic embolization. The auricular wall was grossly thickened, making it difficult to identify the lumen. Using TEE for guidance, forceps and surgical suction were used to remove thrombus material (Figure 5). A vascular clamp was used to control hemorrhage between extract attempts. There was robust adherence of the thrombus to the atrial and auricular walls. Following partial thrombectomy, the posterior wall of the left ventricle had an acute decrease in systolic motion. A few seconds later, ventricular fibrillation was observed. Resuscitation efforts were not successful, and the dog died of a suspected coronary thromboembolism. Air embolism was also considered a possibility. Although a full necropsy was not performed, histopathology of the LA mass confirmed it as an intraluminal, organizing fibrin thrombus.

DISCUSSION

MS is an uncommon cardiac disease in human patients, with congenital MS being less frequent than acquired forms such as rheumatic or degenerative mitral annular calcification.[7] When congenital MS is diagnosed in human patients, it is typically associated with additional congenital cardiac diseases.[8] In the dog, congenital MS is commonly found as an isolated cardiac defect.[1,3] Differentiating between a congenital and rheumatic etiology for MS can be a challenge in human patients, but certain echocardiographic characteristics may be of benefit in this evaluation.[9] Acute rheumatic MS in humans may have characteristic echocardiographic lesions such as chordal elongation, chordal rupture, severe regurgitation, and valve prolapse.[9] In cases of chronic rheumatic MS in human patients, echocardiographic characteristics such as leaflet thickening, chordal fusion or thickening, and leaflet calcification may be observed.[9] The dog in this report had only mild MR; no obvious chordal elongation, rupture, or fusion; and no evidence of calcification. These characteristics, in addition to the lack of evidence that dogs develop rheumatic heart disease, makes the diagnosis of congenital MS most likely in this case. Interestingly, it is not uncommon for congenital MS to be diagnosed in adult dogs, similar to the dog of this report.[1,3,10] BMV, either percutaneous or using a hybrid surgical approach, and MV replacement have all been documented as components of successful management of MS in humans.[4,5,11] In the dog, both percutaneous BMV and hybrid BMV have been documented.[3,12] Hybrid BMV was preferred over percutaneous BMV in the dog in this report for several reasons. The relatively small size of this dog was thought to increase the risk for adverse events during the atrial septal puncture for a percutaneous entry. Additionally, hybrid BMV was demonstrated in a recent publication to be a practical way to approach BMV in dogs of this size.[3,10] Hybrid BMV allows both TEE and fluoroscopy to be used during the procedure which serve as complementary imaging modalities. We prefer to use fluoroscopy in addition to TEE instead of TEE alone; fluoroscopy provides a more complete view of the entire length of the guide wire and balloon catheter within the heart during the procedure, whereas TEE is essential for certain aspects of the procedure, such as advancement of the wedge catheter across the mitral orifice.

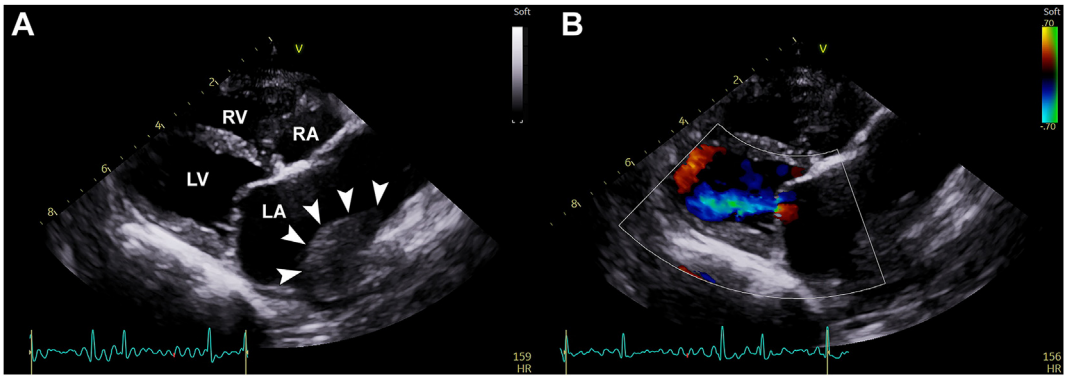

Figure 1 Two-dimensional TTE, right parasternal long-axis view, without **(A)** and with **(B)** color flow Doppler, demonstrates the prominent diastolic doming with a large LA thrombus (*arrowheads*) and turbulent blood flow across the severely stenotic MV throughout the entirety of diastole. *LA*, Left atrium; *LV*, left ventricle; *RA*, right atrium; *RV*, right ventricle.

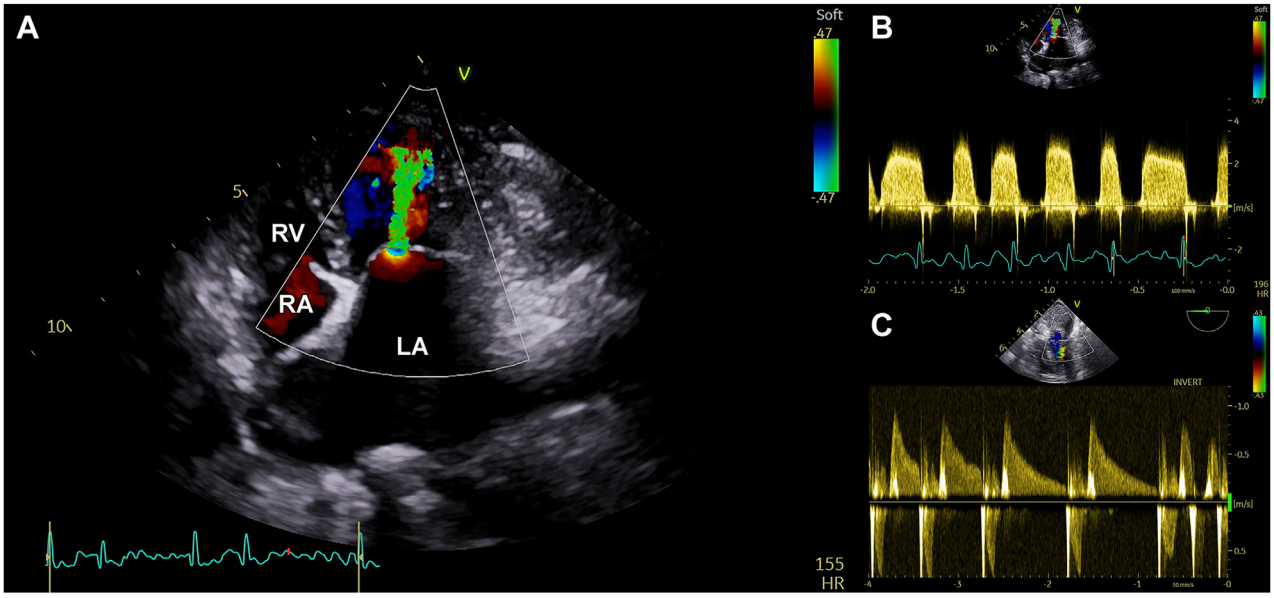

Figure 2 Preprocedural two-dimensional TTE, left parasternal apical view with color flow Doppler, demonstrates the turbulent blood flow across the MS in diastole **(A)** and a high velocity with reduced E-F slope on continuous-wave Doppler (CWD) spectrum **(B)**. **(C)** Postprocedural two-dimensional TEE, long-axis view with color flow Doppler–guided CWD spectrum of the MV, demonstrates MR, a reduction in mitral inflow velocity, and an improvement in the E-F slope.

The dog in this report also had an LA thrombus, and TEE was used to guide the entry of the introducer into the left atrium in a way that avoided the thrombus.[13]

The dog in this report had AF, spontaneous echocardiographic contrast in the left atrium, and a thrombus extending from the left auricle into the LA lumen, all of which were suspected to be sequelae of severe congenital MS. The dog in this report was considered symptomatic from congenital MS, and similar clinical signs such as collapse or congestive heart failure have been reported in dogs and human patients with congenital MS.[1,3,5,6,10,14] It is common for human patients with MS and LA thrombi to have AF and be older, similar to the dog in this report.[15] Human patients with MS have also been documented with spontaneous echocardiographic contrast and LA thrombi,[5,6,13,14] but the presence of an LA thrombus in a dog with MS has not previously been identified. In human patients with MS, LA thrombi are treated with oral anticoagulants such as warfarin or rivaroxaban, or with surgical thrombectomy.[5,14] Some patients with MS and secondary LA thrombi are relatively resistant to thrombolysis with standard dosing, regardless of the type of oral anticoagulant.[4,13] Clopidogrel is a commonly used oral antiplatelet in the dog. This dog was considered to be a young adult (the average life span for the breed is approximately 13.5 years), but it is unclear how this compares with the age of people with MS and secondary complications. In this dog, an increase in LA thrombus size was observed despite long-term therapy with the antiplatelet clopidogrel, and spontaneous echocardiographic contrast developed over a short time frame, as it was not apparent 24 hours before surgery.

Immediately after partial thrombectomy, this patient had an acute decrease in LV systolic motion of the posterior wall, followed

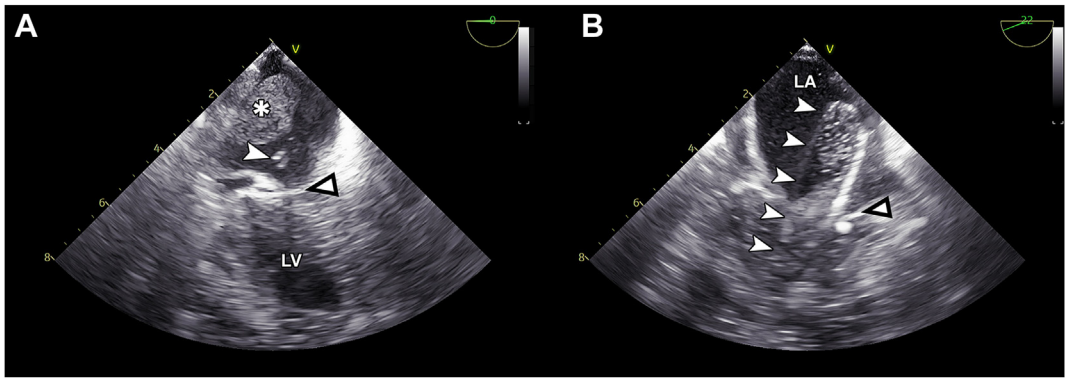

Figure 3 **(A)** Intraoperative two-dimensional TEE, long-axis view of the left heart, demonstrates the tip of the introducer catheter in the dilated left atrium (LA; *white arrowhead*) near the MV (*white arrowhead outlined in black*), distinct from the LA thrombus (*asterisk*). **(B)** The balloon catheter (*white arrowheads*) can be seen positioned across the MV during inflation (*white arrowhead outlined in black*).

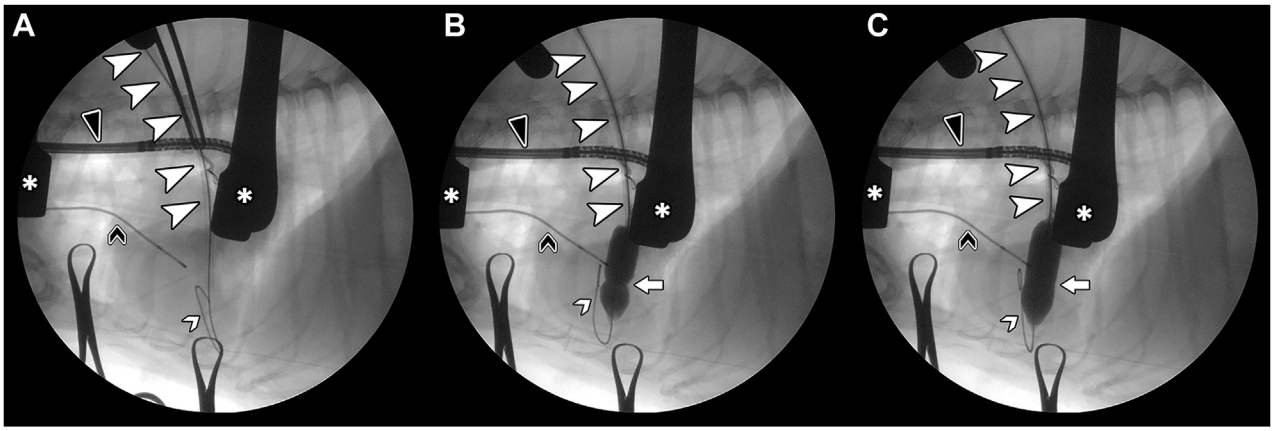

Figure 4 Serial fluoroscopic images during BMV with the patient in a tilted right lateral position (the patient's head is to the left) at baseline **(A)** demonstrate the rib-spreader retractors (*left asterisk*), the temporary pacemaker lead within the RV (*black caret*), the TEE probe (*central asterisk*), and the introducer catheter (*white arrowheads*) in the left atrium through a peratrial hybrid approach with a guide wire seen exiting the introducer, crossing the MV, and entering the left ventricle (*white caret*). **(B)** The balloon catheter is passed over the guide wire, and a distinct area of external compression is observed at the level of the MS (*white arrow*) that resolves upon maximal inflation **(C)**.

immediately by ventricular fibrillation. These findings are consistent with a coronary arterial embolism. In human patients with MS and LA thrombi, systemic and coronary arterial thromboembolism have been reported both before surgery (with medical anticoagulation alone) and during BMV.[15-17] In human patients with MS, reported causes of myocardial infarction during or following BMV include an occlusion of a stenotic coronary artery through a low-flow state during balloon inflation, thromboembolism of a preformed LA thrombus due to a dislodgement, and embolism of actual valve material.[15] The exact cause of the sudden decline in the dog in this report is unknown, but thromboembolism due to partial thrombus dislodgment is strongly suspected.

CONCLUSION

Congenital MS is an uncommon diagnosis in the dog, and disease sequelae such as the development of AF, heart failure, and LA thrombus may become more common with advanced age. BMV is an established method for the management of congenital MS, with both percutaneous and hybrid surgical approaches documented options in the dog. Thrombus formation in the left atrium secondary to MS may complicate disease management and BMV, and thromboembolism is a risk in this patient population.

ETHICS STATEMENT

The authors declare that the work described has been carried out in accordance with the ARRIVE guidelines and with the U.K. Animals (Scientific Procedures) Act, 1986 and associated guidelines, EU Directive 2010/63/EU for animal experiments, or the National Research Council's Guide for the Care and Use of Laboratory Animals.

CONSENT STATEMENT

The authors declare that since this was a non-interventional, retrospective, observational study utilizing de-identified data, informed consent was not required from the patient under an IRB exemption status.

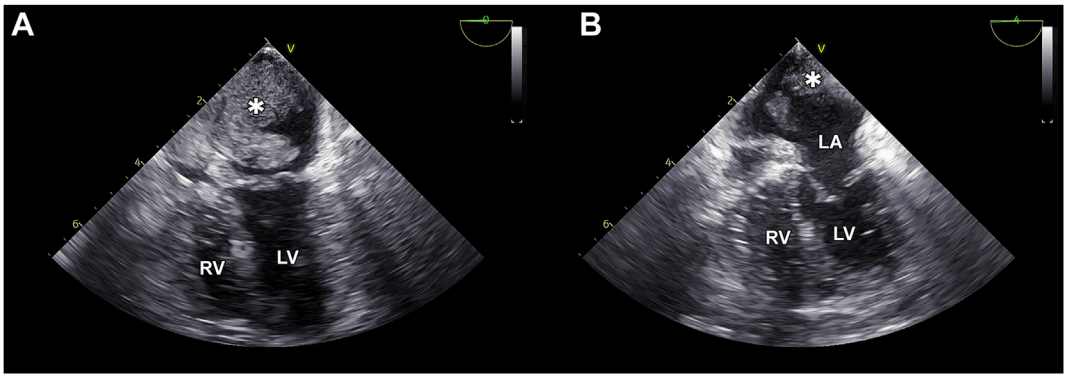

Figure 5 Intraoperative two-dimensional TEE, four-chamber long-axis view of the left heart, demonstrates a very large LA thrombus (*asterisk*) positioned near the MV in systole **(A)**, but after thrombectomy, there is significant reduction in the size of the thrombus and its proximity to the MV in diastole **(B)**.

FUNDING STATEMENT

The authors declare that this report did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

DISCLOSURE STATEMENT

The authors report no conflict of interest.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found at https://doi.org/10.1016/j.case.2023.12.018.

REFERENCES

1. Lehmkuhl LB, Ware WA, Bonagura JD. Mitral stenosis in 15 dogs. J Vet Intern Med 1994;8:2-17.
2. Schrope DP. Prevalence of congenital heart disease in 76,301 mixed-breed dogs and 57,025 mixed-breed cats. J Vet Cardiol 2015;17:192-202.
3. Winter RL, Saunders AB, Gordon SG, Nelson DA, Cusack K, Hubert S, et al. Hybrid balloon valvuloplasty for management of severe mitral stenosis in four symptomatic, adult dogs. J Vet Cardiol 2022;42:83-91.
4. McElhinney DB, Sherwood MC, Keane JF, del Nido PJ, Almond CSD, Lock JE. Current management of severe congenital mitral stenosis. Circulation 2005;112:707-14.
5. Manjunath CN, Srinivasa KH, Ravinddranath KS, Manohar JS, Prabhavathi B, Dattatreya PV, et al. Balloon mitral valvotomy in patients with mitral stenosis and left atrial thrombus. Catheter Cardiovasc Interv 2009;74:653-61.
6. Turek Ł, Sadowski M, Janion-Sadowska A, Kurzawski J, Andrychowski J. Giant left atrial thrombus despite anticoagulation with apixaban in a patient with mitral stenosis and atrial fibrillation. Am J Case Rep 2021;22:e933162.
7. Vahanian A, Beyersdorf F, Praz F, Milojevic M, Baldus S, Bauersachs J, et al. ESC/EACTS Scientific Document Group. 2021 ESC/EACTS Guidelines for the management of valvular heart disease. Eur Heart J 2021;00:1-72.
8. Walter EMD, Hetzer R. Repair for congenital mitral valve stenosis. Semin Thorac Cardiovasc Surg Pediatr Card Surg Annu 2018;21:46-57.
9. Gewitz MH, Baltimore RS, Tani LY, Sable CA, Shulman ST, Carapetis J, et al. Revision of the Jones Criteria for the diagnosis of acute rheumatic fever in the era of Doppler echocardiography: a scientific statement from the American Heart Association. Circulation 2015;131:1806-18.
10. Trehiou-Sechi E, Behr L, Chetboul V, Pouchelon JL, Castaignet M, Gouni V, et al. Echoguided closed commissurotomy for mitral valve stenosis in a dog. J Vet Cardiol 2011;13:219-25.
11. Baykan A, Ceyran H, Kaya MG, Narin N. Mitral balloon valvuloplasty in a child by hybrid approach. Pediatr Cardiol 2009;30:377-9.
12. Arndt JW, Oyama MA. Balloon valvuloplasty of congenital mitral stenosis. J Vet Cardiol 2013;15:147-51.
13. Kamalesh M, Burger AJ, Shubrooks SJ Jr. The use of transesophageal echocardiography to avoid left atrial appendage thrombi. Am J Cardiol 1995;75:302-4.
14. Sadeghipour P, Pouraliakbar H, Parsaee M, Shojaeifard M, Farrashi M, JamalKhani S, et al. Rivaroxaban in mitral stenosis (RISE MS): a pilot randomized clinical trial. Int J Cardiol 2022;356:83-6.
15. Hou S, Pan W, Zhou D, Ge J. Percutaneous balloon mitral valvuloplasty using veno-arterial loop and neuro-embolic protection for mitral stenosis with thrombus. Catheter Cardiovasc Interv 2022;99:2113-6.
16. Eftekhari A, Damgaard D, Grove EL. Fatal stroke following treatment with apixaban in a patient with atrial fibrillation and left atrial appendage thrombus. Int J Cardiol 2016;214:131-2.
17. Ohyagi M, Nakamura K, Watanabe M, Fujigasaki H. Embolic stroke during apixaban therapy for left atrial appendage thrombus. J Stroke Cerebrovasc Dis 2015;24:e101-2.