Case Report

Balloon valvuloplasty in a dog with congenital bicuspid aortic valve and supravalvar aortic stenosis (atypical Shone's complex)☆

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Abstract An 8-month-old intact female pug was presented for evaluation and possible balloon valvuloplasty (BV) for severe aortic stenosis. A bicuspid, severely stenotic aortic valve of type 3 morphology with a supravalvar stenosis component was diagnosed, consistent with the diagnosis of atypical Shone's complex. There was severe concentric hypertrophy of the left ventricle, with increased echogenicity of

the myocardium nearest to the endocardial border. Mild left atrial enlargement was observed. Selective angiography and transesophageal echocardiography revealed an enlarged and relatively tortuous ascending aorta. The changes to the ascending aorta and the anatomy of the lesion made retrograde access to the left ventricle challenging. Ultimately, BV was successful using a pediatric valvuloplasty balloon catheter and rapid right ventricular pacing, and the pressure gradient across the aortic valve was decreased by more than 50% compared with preoperative measurements. Although valvar aortic stenosis is rare in veterinary medicine, this report highlights the potential challenges and feasibility of BV for this disease.

An 8-month-old, 6.2 kg, intact female pug was referred to the Auburn University Veterinary Teaching Hospital for evaluation of aortic stenosis. The dog had a systolic heart murmur auscultated by the primary care veterinarian during routine evaluation, and subsequent transthoracic echocardiography (TTE) revealed a stenotic aortic valve with severely elevated transaortic velocities. The dog was asymptomatic and was prescribed atenolol at the time of diagnosis, then referred for evaluation and possible aortic balloon valvuloplasty (AoBV).

On examination, the dog was bright with a heart rate of 120 beats/minute. A grade 6/6 left basilar systolic heart murmur was auscultated, and femoral arterial pulse strength was poor. The respiratory rate and effort were normal with normal bronchovesicular sounds auscultated bilaterally. The rectal temperature was 37.9 °C. Thoracic radiographs disclosed severe enlargement of the left ventricle (LV) with a vertebral heart size of 13.2 (normal < 10.5) [1], severe enlargement of the ascending aorta (AscAo), and mild enlargement of the left atrium. Pulmonary vasculature and parenchyma were considered normal. Electrocardiography revealed ST segment depression, notched QRS complexes in three leads, and occasional singlet ventricular premature complexes of suspected LV origin based on morphology.

Sedation with butorphanol (0.3 mg/kg IM) was administered, and TTE[c] was then performed. The LV posterior wall thickness was measured from 2D short-axis views as 1.4 cm, indicating severe concentric hypertrophy [2], with increased echogenicity of the subendocardial myocardium and normal systolic function based on a fractional shortening of 35%. A bicuspid aortic valve (BAV) was present, with no obvious raphe and cusps of

approximately equal size (Fig. 1). The BAV was most consistent with a type 3 BAV, based on a human classification scheme and a previous veterinary report [3,4]. Long-axis views of the left ventricular outflow tract demonstrated systolic doming of the BAV and an eccentric aortic orifice (Fig. 1A). Spectral Doppler analysis obtained from a subcostal view demonstrated increased transaortic velocities corresponding to a transaortic pressure gradient of ~190–210 mmHg. The aortic valve orifice area was measured as 0.2 cm^2 by planimetry. The sinus of Valsalva was dilated for each aortic valve cusp. Color flow Doppler evaluation revealed turbulent blood flow in the AscAo originating at the level of the BAV and subjectively mild aortic insufficiency (AI). Coronary artery ostia were visualized in a normal location leaving each cusp. Visualization of the AscAo was poor, but a supravalvar aortic stenosis (SVAS) was suspected. Mitral valve leaflets were subjectively normal but allowed subjectively mild regurgitation. The left atrium was enlarged with diameter of 2.8 cm measured in right parasternal long-axis views and a left atrial-to-aortic root ratio of 1.76 [5]. Mild subjective dilation of the pulmonary artery root was noted. Pulmonary valve leaflets, transpulmonic velocities, and right-sided cardiac chambers were normal.

Based on the severity of changes to the left heart and the age of the patient, it was assumed that future progression to congestive heart failure or other clinical signs such as syncope or arrhythmias were likely. Therefore, AoBV was elected. Further diagnostics included a complete blood count and a serum biochemistry panel. Other than mild anemia (hematocrit 37%) which was considered normal for the patient's age, there were no significant laboratory abnormalities.

Anesthesia was induced on the following day. Transesophageal echocardiography (TEE) confirmed a SVAS at the sinotubular junction and an eccentric opening of the BAV (Fig. 2). The aortic diameter at the valve hinge points was 8.3 mm.

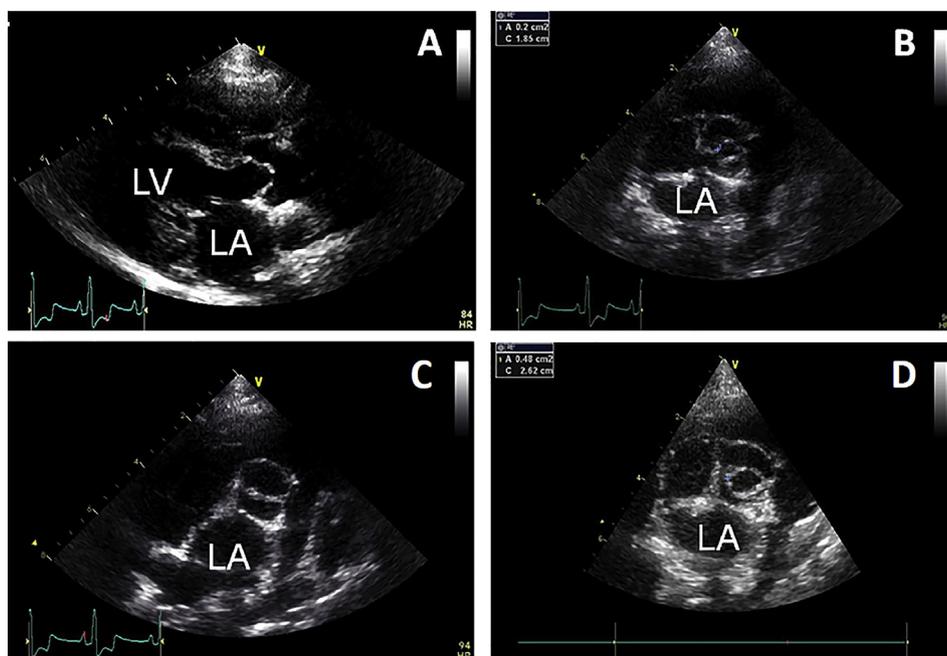[c] Vivid E9 with XDclear; GE Medical Systems, Waukesha, WI, USA.

Fig. 1 A: Preprocedural right parasternal long-axis image showing systolic doming of the fused BAV. B: Preprocedural right parasternal short-axis image showing the aortic orifice size during systole. C: Preprocedural right parasternal short-axis image showing the closed BAV during diastole demonstrating the lack of a raphe and the type 3 morphology. D. Postprocedural right parasternal short-axis image showing an enlarged aortic orifice during systole compared with the preprocedural image. BAV, bicuspid aortic valve; LA, left atrium; LV, left ventricle.

The dog was placed in left lateral recumbency, and the right carotid artery and right external jugular vein were exposed via surgical cutdown. A 4Fr introducer[d] was placed in the external right jugular vein, and a 6Fr introducer[d] was placed in the right carotid artery using the modified Seldinger approach. Using fluoroscopic guidance,[e] a 4Fr temporary pacing lead[f] was advanced to the right ventricular (RV) apex. A 4Fr non-taper angled catheter[g] over a 0.018″ x 180 cm hydrophilic guidewire[h] was advanced to the AscAo. Angiography revealed severe dilation of the relatively tortuous AscAo and aortic arch, severe dilation of the brachiocephalic trunk, SVAS at the ventral sinotubular junction of approximately 6 mm, and mild AI (Video 1). Separate coronary ostia were confirmed, with dilation of the left coronary artery, primarily the paraconal interventricular branch. The orientation of the C-arm was manipulated with additional injections to best visualize the course of the aorta to the level of the BAV. With guidance from fluoroscopy and TEE, a straight-tipped 0.014″ x 300 cm guidewire[i] was advanced into the LV. The 4Fr non-taper angled catheter, a 4.1Fr Judkins right catheter,[j] 4Fr snare catheter,[k] and the dilator of a 4Fr guiding sheath[l] were unable to pass into the LV over the guidewire.

Pediatric valvuloplasty balloon (PVB) catheters were then used in an attempt to create a larger aortic orifice. A 4 mm × 2 cm PVB catheter[m] was advanced over the guidewire across the aortic valve orifice. The RV was paced at 180 beats/minute, and the PVB was inflated by hand. Balloon position was maintained across the BAV, and full inflation was achieved. This 4 mm × 2 cm PVB catheter[m] was then replaced with a 5 mm × 2 cm
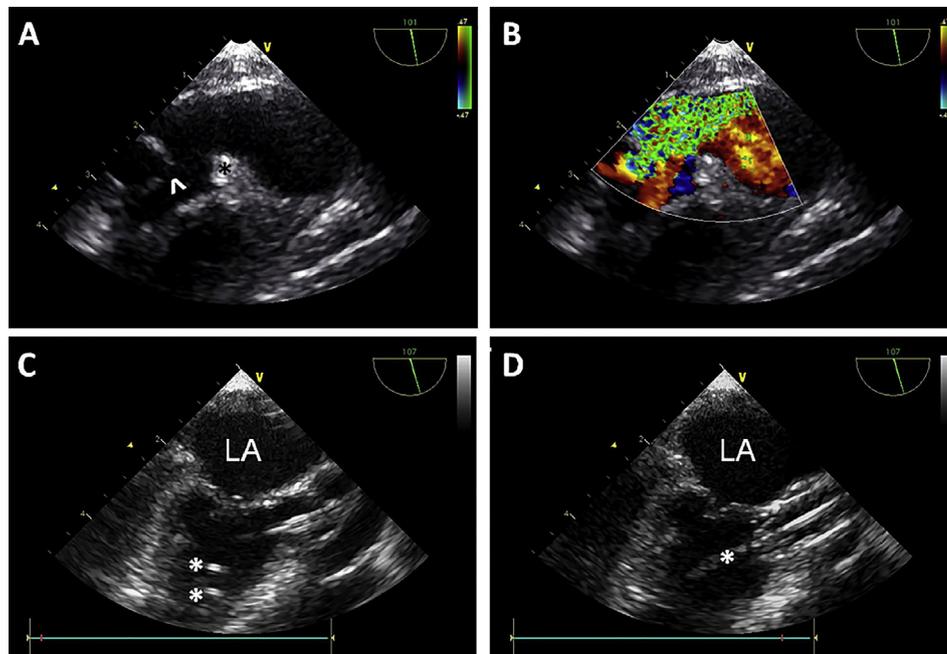
Fig. 2 A: Long-axis view of the BAV and AscAo obtained by TEE. The aortic orifice (white arrowhead) and SVAS (black asterisk) is noted. B: Color Doppler imaging of image A demonstrating turbulent blood flow originating at the BAV. C: Midprocedure TEE image of the LA, LV, and the deflated 8 mm × 2 cm PVB across the BAV. The guidewire (white asterisk) is coiled within the LV. D: Midprocedure TEE image of the fully inflated 8 mm × 2 cm PVB maintaining position across the BAV with complete loss of waist. The guidewire (white asterisk) is within the LV. AscAo, ascending aorta; BAV, bicuspid aortic valve; LA, left atrium; LV, left ventricle; PVB, pediatric valvuloplasty balloon; SVAS, supravalvar aortic stenosis; TEE, transesophageal echocardiography.

PVB catheter.[m] The aforementioned procedures were repeated and resulted again in successful balloon inflation. This PVB catheter was removed while maintaining the guidewire position. A 4Fr guiding sheath,[l] 4Fr dilator,[m] 4Fr non-taper angled catheter,[g] 4Fr snare catheter,[k] and a 2.8Fr x 150 cm microcatheter[n] were used to attempt entry into the LV over the guidewire, but all were unsuccessful. Both PVB catheters[m] had a deflated profile of 2.5Fr, and it was assumed that nothing larger than 2.5Fr could advance through the aortic orifice. No additional inventory was available that could advance through the aortic orifice, so the guidewire and temporary pacemaker were removed. Both introducers were removed, and the right carotid artery and right external jugular vein were ligated. The following morning, TTE revealed an unchanged pressure gradient across the BAV.

A second procedure was planned for the following day, and additional PVB catheters[m] were obtained. Anesthesia was induced with the patient in right lateral recumbency, and a 4Fr introducer[d] was placed percutaneously in the left jugular vein

using the modified Seldinger technique. A 4Fr temporary pacing lead[f] was placed into the RV using fluoroscopic guidance. The patient was then moved to left lateral recumbency. The previous incision was explored, but the right carotid artery was thrombosed. The patient was then positioned in dorsal recumbency. A ventral midline incision was made to allow for access to both carotid arteries. The right carotid artery was thrombosed even at this more proximal location. A 6Fr introducer[d] was placed in the left carotid artery, and a 4Fr guiding sheath[l] was advanced into the AscAo. A straight-tipped 0.014" x 300 cm guidewire[i] was placed into the LV using fluoroscopic guidance and TEE. A 8 mm × 2 cm PVB catheter,[m] with a deflated profile of 2.5Fr, was advanced through the 4Fr guiding sheath[l] over the guidewire to enter the left ventricular outflow tract. The RV was paced at 180 beats/minute, and the balloon catheter was inflated by hand and advanced into the AscAo before full inflation (Video 2). The balloon was deflated, and the 4Fr guiding sheath[l] was positioned closer to the balloon to provide support and prevent balloon dislodgement into the aorta. The PVB[m] was again positioned across the aortic orifice (Fig. 2C), and the RV paced at 180 beats/minute. After 10 s of rapid RV pacing, the balloon was again

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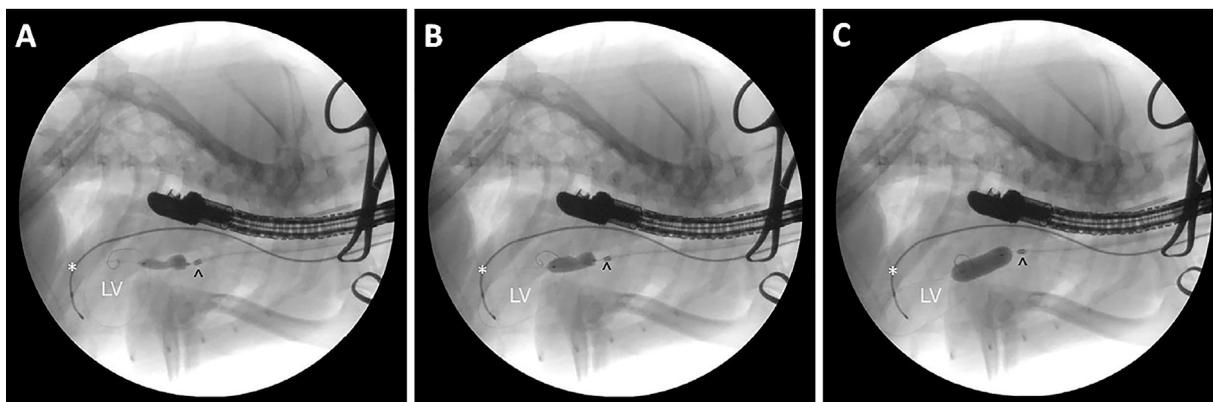[n] PROGREAT® 2.8Fr Microcatheter; Terumo Medical, Sumerset, NJ, USA.

Fig. 3 Obliqued right lateral fluoroscopic images showing the 8 mm × 2 cm PVB across the BAV at the beginning (A), middle (B), and end (C) of inflation. The temporary pacemaker lead (white asterisk) is in the RV, the coiled guidewire is observed in the LV, and the tip of the 4Fr guiding sheath (black arrowhead) is observed near the partially inflated balloon. The TEE probe is also visualized within the esophagus. Note that the guiding sheath and PVB catheters do not move during this inflation. BAV, bicuspid aortic valve; LV, left ventricle; RV, right ventricle; TEE, transesophageal echocardiography.

inflated by hand (Fig. 2D). No cranial displacement of the balloon occurred (Video 3), and the balloon was fully inflated showing a loss of waist of the balloon (Fig. 3). Invasive peripheral pressure measurements immediately revealed an increase in systolic pressures (~60 mmHg pre-balloon; ~90 mmHg post-balloon). The balloon was deflated and, after a few minutes, inflated again. The balloon again achieved full inflation, but this time, it revealed no obvious waist.

The PVB catheter[m] was removed, and the 4Fr guiding sheath[l] readily passed over the guidewire into the LV. Selective left ventriculography revealed mild mitral regurgitation, thickened BAV leaflets with reduced systolic excursion, and SVAS (Fig. 4A). Based on angiography, the aortic annulus was measured as 7.5 mm. Selective angiography of the AscAo was performed, revealing mild AI (Fig. 4B). The 6Fr introducer[d] was removed, and the left carotid artery was ligated. The skin
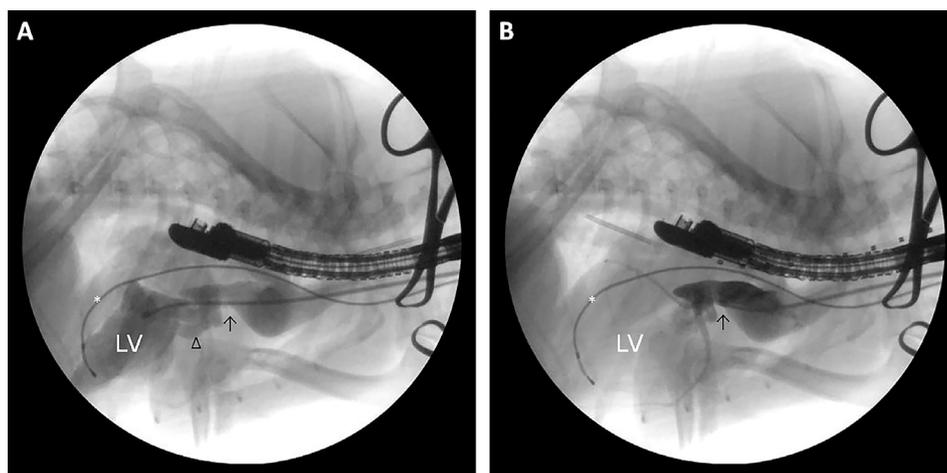
Fig. 4 A: Obliqued right lateral fluoroscopic image of selective left ventriculography. The stenotic BAV leaflets, dilated sinus of Valsalva (black arrowhead), SVAS (black arrow) at the sinotubular junction, and dilated AscAo and BCT are observed. The temporary pacemaker lead (white asterisk) in the RV is also seen. B: Obliqued right lateral fluoroscopic image of an AscAo selective angiogram. The TEE probe is also visualized within the esophagus. Mild AI can be observed in the LV, and prominent left coronary arterial branches are observed. The dilated AscAo and BCT are observed, and the temporary pacemaker lead (white asterisk) is observed in the RV. AI, aortic insufficiency; AscAo, ascending aorta; BAV, bicuspid aortic valve; BCT, brachiocephalic trunk; LV, left ventricle; RV, right ventricle; SVAS, supravalvar aortic stenosis; TEE, transesophageal.

incision was closed, and the temporary pacemaker and 4Fr introducer[d] were removed. The patient recovered uneventfully from anesthesia. The following morning, TTE revealed only subjectively mild AI. Aortic valve motion was improved (Fig. 1), with an orifice area measured as 4.8 cm^2 by planimetry, and transaortic velocities had decreased roughly 50% compared with the previous study and now estimated a gradient of ∼95 mmHg.

The dog was discharged with atenolol (1 mg/kg PO q12h), tramadol (2.5 mg/kg PO q8h), and a 10-day supply of cephalexin (25 mg/kg PO q12h). The day after discharge, the owner reported regurgitation. This was attributed to the extended use of the TEE probe. The owner was instructed to skip one meal and then begin to give small amounts of food every 4 h. No additional regurgitation occurred. The owner reports a drastically increased activity level at the time of writing as compared with preballooning.

Discussion

Congenital BAV is the most common congenital cardiac abnormality in humans, with 1—2% of the population affected [6—8]. Most have type 1 or type 2 BAV, which results from fusion of the right and left cusps or of the right and non-coronary cusps, respectively [9]. There are few reports of congenital BAV in the dog [4,10,11]. One described congenital BAV in an English Bulldog, which also had mild pulmonic stenosis and a persistent left cranial vena cava [4]. In that report, the authors described a type 3 BAV without an obvious raphe, noting fusion of the left and non-coronary cusps, causing moderate stenosis and mild AI [4]. This is similar to the dog described in this report, with a type 3 BAV without a raphe diagnosed which created aortic stenosis and insufficiency. Another report describes BAV in a 6-month old pug dog that had concurrent subaortic stenosis [11]. To the authors' knowledge, this is the first report describing procedural detailing AoBV for a stenotic BAV in a dog.

The dog of this report had a stenotic BAV and a SVAS at the sinotubular junction, a combination termed atypical Shone's complex [12—15]. Shone's complex is a combination of congenital obstructive lesions at multiple levels within the left heart or systemic circulation, simultaneously having a parachute mitral valve, a supravalvular stenosis in the left atrium, subaortic stenosis, and coarctation of the aorta [16]. However, in the original report, few had all 4 lesions. The definition of Shone's complex has been expanded to include congenital obstructive lesions at multiple levels of the left heart or systemic circulation, commonly called partial, incomplete, or atypical Shone's complex [12,13,15]. Interestingly, BAV may be considered as a component of both typical and atypical Shone's complex, as 4/8 patients in the initial description of Shone's complex had BAV [14,16]. In a report of atypical Shone's complex, BAV was common and sometimes reported in combination with SVAS [12]. It is important to know that BAV in the dog is associated with concurrent congenital defects. The SVAS was only clearly visualized with TEE and angiography, and this lesion likely influenced access to the LV as well as the transaortic pressure gradient decrease after AoBV.

Balloon valvuloplasty is commonly performed in children and adolescent humans for BAV [17—21]. Criteria for pursuing AoBV involves assessing transaortic pressure gradients and whether patients have critical aortic stenosis, defined as ductal-dependent systemic blood flow, depressed LV systolic function, or elevated transaortic pressure gradients >100 mmHg with evidence of hypoperfusion [17,18]. Severity of AI and dilation of the aorta also influence whether AoBV or aortic valve replacement is chosen [6,8,19]. In the dog of this report, severe changes to the LV and mild enlargement of the left atrium had already occurred. The severity of changes and likelihood of progression to left heart failure in the future influenced the decision to pursue AoBV. The transaortic pressure gradient was 190—210 mmHg preoperatively, and this decreased to 95 mmHg postoperatively. In humans, acute success for AoBV of BAV is considered a decrease in transaortic pressure gradient to <35 mmHg with mild aortic regurgitation [20]. Although no procedural details were provided, one article describes a 65% decrease in pressure gradient in a dog that underwent AoBV [10]. The dog of this report had a decrease in pressure gradient of roughly 50%. Even though severe stenosis remained, this was considered successful based on the lack of worsened AI and the reduction in pressure gradient and reports of BV for pulmonary valve stenosis in veterinary medicine [10,22,23]. Solely using the modified Bernoulli equation with serial obstructive lesions is not advised, but the increased geometric aortic valve orifice area and improvement in energy level also suggested a good outcome. The SVAS lesion likely prevented further pressure gradient decrease. Although successful balloon dilation has been documented in a dog with SVAS [24], the preferred treatment in humans is surgical removal which may highlight the ineffectiveness of balloon dilation in a majority of cases [25].

This case presented several challenges. Gaining guidewire access across the aortic orifice was achieved with TEE guidance, which allowed visualization of the catheter tip for direction towards the aortic valve orifice. By using TEE to direct the catheter tip towards the aortic valve orifice, the guidewire had a more direct path towards the valve orifice as it exited the catheter. Even with TEE, access took between 30 and 60 min, similar to reports in humans, where the time required for this can take over an hour [17]. Rapid RV pacing provided a method of decreasing ventricular stroke volume, decreasing movement of the inflated balloon. This decision was made from the authors' experience and recommendations in humans [7,19,21]. Minimizing balloon movement across the valve decreases valve damage and postprocedure regurgitation [19]. A thicker and/or stiffer guidewire may have helped maintain balloon position, but a catheter large enough to deliver such a guidewire could not enter the LV until after successful AoBV. Using the guiding sheath to stabilize the balloon catheter during inflation may be useful in similar cases where the use of thick/stiff guidewires is not feasible. Recommendations in humans for AoBV include choosing a balloon-to-aortic ratio of ≤1.0, and in some reports, higher numbers of balloon inflations are associated with a worse outcome [7,18], although reports exist that contradict these recommendations [19,21]. Given

In conclusion, we describe AoBV in a dog with atypical Shone's complex consisting of a severely stenotic BAV and concurrent SVAS. Successful AoBV was achieved with the combination of rapid RV pacing and a PVB catheter. Both fluoroscopy and TEE were performed and essential for a successful procedure. To the authors' knowledge, this is the first report detailing AoBV in a dog.

Conflict of interest statement

The authors do not have any conflicts of interest to disclose.

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Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jvc.2019.02.002.

Video table		
Video	Title	Description
I	Selective aortic root angiogram	Selective angiography of the aortic root using a 4Fr guiding sheath. This view is an obliqued right lateral view.
II	Unsuccessful inflation of 8 mm x 2 cm pediatric valvuloplasty balloon	Inflation of an 8 mm x 2 cm pediatric valvuloplasty balloon is observed, with cranial displacement of the partially inflated balloon into the ascending aorta. The view is an obliqued right lateral view.
III	Successful inflation of 8 mm x 2 cm pediatric valvuloplasty balloon	Inflation of an 8 mm x 2 cm pediatric valvuloplasty balloon is observed. Note that the 4Fr guiding sheath tip is closer to the pediatric valvuloplasty balloon than in Video I, and no cranial displacement of the balloon into the ascending aorta is observed. The balloon is fully inflated while across the aortic valve, and a loss of waist is observed. The view is an obliqued right lateral view.

this uncertainty, the lack of information on this procedure in veterinary medicine and the inability to routinely offer aortic valve replacement in the face of severe AI, it may be wise to follow these guidelines in dogs undergoing AoBV. Based on the TEE images, a balloon-to-aortic ratio of 0.96 was used in the dog of this report.

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