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Balloon Valvuloplasty of Tricuspid Stenosis: A Retrospective Study of 5 Labrador Retriever Dogs

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Background: There are limited reports of severe tricuspid valve stenosis in dogs and limited data regarding treatment and outcome.

Objective: To evaluate clinical signs, echocardiographic features, and outcome of balloon valvuloplasty (BV) in dogs with severe tricuspid valve stenosis (TVS) in which BV was attempted.

Animals: Five client-owned dogs with severe TVS.

Methods: Records were retrospectively reviewed and data collected regarding signalment, clinical signs, diagnostic findings, procedures, and outcome.

Results: All dogs were Labrador Retrievers. Presenting complaints included episodic weakness/syncope (4/5), abdominal distension (4/5), lethargy (2/5), and exercise intolerance (2/5). The median and range of measurements before BV were as follows: TV mean velocity 1.5 m/s (range 1.4–1.7 m/s); velocity-time integral (VTI) 79.8 cm (42.4–99.1 cm); and TV maximum velocity 2.9 m/s (2.3–3.2 m/s). Measurements (available for 3 of 5 dogs) after BV were as follows: TV mean velocity 1.15 m/s (0.9–1.4 m/s); VTI 44.95 cm (41.4–54.8 cm); and TV maximum velocity 1.15 m/s (1.9–2.3 m/s). The procedure was attempted in all dogs and completed in 4/5 dogs. The largest balloon diameter ranged from 15 mm to 25 mm, and length ranged from 4 cm to 5 cm. Right atrial pressure decreased in 4/5 dogs. All but 1 dog had clinical improvement after BV, but recurrence of clinical signs occurred (2/5). Tricuspid regurgitation worsened in 1 dog culminating in right heart failure and euthanasia.

Conclusions and Clinical Importance: BV can be an effective treatment; however, clinical signs can recur. Right heart failure due to worsened TR is a potential complication in dogs with pre-existing moderate-to-severe TR.

Key words: Interventional cardiology; Tricuspid dysplasia.

Congenital tricuspid valve stenosis (TVS) is rare in dogs. There are reports of individual cases in the veterinary literature, but limited information regarding treatment and outcome.[1–3] In humans, TVS commonly occurs secondary to rheumatic valve disease and rarely manifests as an isolated lesion. Concurrent tricuspid valve regurgitation that requires surgical treatment with open valvulotomy or valve replacement is common.[4] Echocardiographically, TVS is characterized by diastolic doming of the tricuspid valve leaflets, thickening of the valve leaflets, reduced excursion of the valve tips, and a reduction of the diameter of the tricuspid valve orifice. Doppler echocardiography can be used to assess severity by evaluating the diastolic blood flow velocity through the valve orifice (mean TV Vmax) to estimate the pressure gradient between the right atrium and right ventricle.[4,5,6] In humans, a normal mean pressure gradient is typically 0–2 mmHg, and severe stenosis might be associated with resting mean gradients of 5 mmHg.[7]

Abbreviations:

BV	balloon valvuloplasty
RAP	right atrial pressure
TR	tricuspid regurgitation
TVS	tricuspid Valve Stenosis
TV	tricuspid valve
Vmax	maximum velocity
VTI	velocity-time integral

There are limited reports of treatment and outcome of TVS in both the medical and veterinary literature. In 1 report, a 2-year-old Labrador Retriever with TVS and syncope experienced clinical improvement after BV,[1] and another study reported improved exercise intolerance and reduced cyanosis after BV in a Chesapeake Bay Retriever with TVS and a right-to-left atrial-level shunt.[2] There are only 5 cases of BV reported in the medical literature, and as with the veterinary literature, there are no reported data regarding selection of the appropriate balloon size for valvuloplasty and very limited information regarding complications and long-term outcome.[8]

Therefore, the aim of this retrospective analysis was to evaluate clinical signs, echocardiographic features, results of treatment, and outcome in dogs with severe TVS treated with BV.

Materials and Methods

The University of California-Davis Veterinary Medical Teaching Hospital medical record system was searched for dogs initially

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examined between January 2000 and January 2011 for which BV was performed for treatment of severe TVS.

Records were reviewed and data collected regarding signalment (age, breed, weight, and sex), historical clinical signs, physical examination findings, diagnostic testing before and after BV, details of the BV procedure including catheter approach, balloon size, before- and after-BV catheterization data, and outcome. Severe tricuspid stenosis was defined by the presence of diastolic doming of the tricuspid valve leaflets, severe right atrial enlargement, reduced excursion of the valve tips, and a severe reduction of the diameter of the tricuspid valve orifice on 2D evaluation. On Doppler echocardiography, the diastolic blood flow velocity through the valve orifice (mean TV Vmax) was used to estimate the pressure gradient between the right atrium and right ventricle, and severe was characterized as >5 mmHg.[4,5]

An echocardiographic machine[a] equipped with S5-1 and S8-3 MHz blended (multifrequency) transducers was used for all echocardiographic examinations. All echocardiographic evaluations were performed in unsedated dogs. Echocardiographic images were retrospectively reviewed by 1 individual (GLB) and VTI calculations confirmed or performed. Spectral Doppler information for maximal and mean diastolic tricuspid flow velocities was obtained using standard technique and recorded. Pressure gradients were obtained utilizing the Bernoulli equation. Mean pressure gradient was calculated by tracing the VTI.[5] If the last medical record entry indicated that the dog was alive, an attempt was made to contact the owner, referring veterinarian, or both, via email or telephone.

Each dog was anesthetized and a surgical cutdown performed on either a jugular or a femoral vein. Cardiac catheterization, including a mean right atrial pressure measurement obtained from right atrial catheterization and angiography of the right atrium and structures distal to it, was performed using appropriate catheters (wedge pressure catheter, and Berman catheter[b] when indicated for angiography). A cardiac catheter was advanced into a pulmonary artery branch and a guide wire advanced into a distal pulmonary artery branch. The catheter was removed, leaving the guidewire in place. Balloon size was selected based on estimation of tricuspid valve orifice based on angiography and clinician's judgment. A balloon valvuloplasty catheter (Numed Tyshak II balloon catheter[b]) was then introduced over the guidewire and manipulated through the stenotic tricuspid valve orifice so that at least 1/3 of the balloon was in the right ventricle. Balloon inflations were then performed. A successful valvuloplasty was defined as occurring when there was an indentation identified in the balloon that subsequently popped open when the balloon was inflated. This procedure was repeated 1–3 times. An unsuccessful valvuloplasty was defined as occurring when a guidewire could not be passed through the tricuspid valve orifice. After an apparently successful procedure, right atrial pressure was measured again. Each dog was recovered from anesthesia. Echocardiography was repeated the next day.

Results

Five dogs within the 11-year search period were identified. All were Labrador Retrievers (3 males; 2 females). Age range was 1 year to 5 years, and body weight range was 26.7–37.7 kg.

Presenting complaints included episodic weakness/syncope (4/5), abdominal distension (4/5), weakness/lethargy (2/5), and exercise intolerance (2/5). Examination findings included ascites (4/5), weak femoral pulse (3/5), muffled heart sounds (3/5), and atrial fibrillation (1/5). A diastolic murmur was not detected in any dog. Electrocardiographic abnormalities included right atrial enlargement pattern (2/5) and splintered QRS complex (2/5). Thoracic radiographic abnormalities included severe right atrial enlargement (5/5) and a distended caudal vena cava (3/5). One dog had echocardiographic evidence of pleural effusion that was not detected radiographically.

On echocardiography, the right atrium was severely enlarged in all dogs. The tricuspid valve leaflets were thickened with restricted motion at the leaflet tips, with varying degrees of diastolic doming of the TV leaflets appreciated in all dogs (Video S1). The valve morphology was similar in all dogs. Pleural effusion was detected in 1 dog. No dogs had evidence of hypoplastic right ventricle. An eccentric diastolic color-flow Doppler jet was also appreciated in all dogs and tricuspid insufficiency identified in 3 dogs (mild in 2 dogs, and moderate in 1 dog). A persistent left cranial vena cava was visualized in 3 dogs. The ranges before BV (first procedure) of continuous-wave velocity measurements/calculations were as follows: TV mean velocity 1.4–1.7 m/s; velocity-time integral (VTI) 42.4–99.1 cm; and TV maximum velocity 2.3–3.2 m/s. Measurements for the first procedure after BV (available for dogs 3, 4, and 5) were as follows: TV mean velocity 0.9–1.4 m/s; VTI 41.4–54.8 cm; and TV maximum velocity 1.4–2.3 m/s. Contrast echocardiography was performed in 2 dogs, 1 of which had a right-to-left shunt through a patent foramen ovale.

Angiography was performed in all dogs. All dogs had severe right atrial and right auricular enlargement and retrograde filling of the caudal vena cava (Video S2).

Balloon valvuloplasty was attempted in all 5 dogs. All procedures were performed with a Numed Tyshak II balloon catheter.[c] The largest balloon size used in each dog ranged from 15 mm to 25 mm, and length ranged from 4 cm to 5 cm.

The procedure was aborted in dog 1 (jugular vein approach) due to inability to pass a catheter through the TV orifice. BV was successfully performed in the remaining 4 dogs. Mean right atrial pressure (RAP) measurements were obtained before and after BV via right heart catheterization in all 4 dogs (Table S1).

Balloon TV inflow, RAP, and VTI measurements were as follows before and after BV: TV Vmax before BV 2.9 m/s (range 2.3–3.2 m/s) and after BV 2.05 m/s (range 1.8–2.3 m/s); TV mean velocity before BV 1.5 m/s (range 1.4–1.7 m/s) and after BV 1.15 m/s (range 0.9–1.4 m/s); right atrial pressure before BV 17.5 mmHg (range 14–30 mmHg) and after BV 13 mmHg (range 9–22 mmHg); and VTI before BV 79.8 cm (range 42.4–92.9 cm) and after BV 44.95 cm (range 41.4–54.8 cm) (Table S2). Right heart failure evident as ascites resolved after BV in 2 dogs (dogs 3 and 4), but recurred within 2 years in both dogs (406 days and 484 days, respectively). In the first procedure on dog 3, the balloon appeared to never fully cross the valve (although numerous balloon inflations were performed), and before and after BV, right atrial pressure measurements were unchanged (20 mmHg), but ascites resolved after surgery. Dog 4 (18 mm balloon diameter; jugular vein approach) had pleural effusion and ascites that resolved after BV, with a reduced right atrial pressure. Pleural

effusion redeveloped 485 days after surgery. Repeat BV (20 mm balloon diameter; right femoral vein approach) resulted in resolution of the pleural effusion, with minimal reduction in right atrial pressure. Exercise intolerance and episodic weakness resolved or improved in both dog 2 and dog 3 that had these signs before surgery. In dog 5, on initial attempt via the right jugular vein, the procedure was aborted due to inability to cross the tricuspid valve orifice with the catheter. During this same procedure, an attempt via the right femoral vein was made; however, it was aborted and femoral vein ligated when the vein tore. The procedure was repeated 7 days later (25 mm balloon diameter; left femoral vein approach). Prior to the procedure, the dog had moderate tricuspid regurgitation (TR) based on color jet relative to color area and right atrial enlargement but no right heart failure. Severe TR (based on the color jet relative to atrial area and progressive right atrial enlargement) was appreciated after BV and ascites developed 14 days after BV. The dog was euthanized 160 days after BV because of refractory right heart failure.

Discussion

In this study, all dogs had improvement or resolution of clinical signs after BV; however, heart failure recurred in the dogs which had heart failure prior to the procedure, suggesting that recurrence of heart failure is common. The largest balloon size used in any given procedure ranged from 15 mm to 25 mm.

Tricuspid valve dysplasia is inherited as an autosomal dominant (incomplete penetrance) trait in Labrador Retrievers and has been mapped to chromosome 9.[9,10] Dogs with TVD typically have variable degrees of tricuspid regurgitation. It has been suggested that TVS might represent a variant of TVD,[3] an observation that is supported by the predominance of the Labrador Retriever breed in this study.

In humans, 90% of TVS is due to rheumatic fever. Most of the remaining 10% is congenital or due to carcinoid syndrome. Congenital TVS is commonly seen in infants. Congenitally abnormal valves can have incompletely developed tricuspid leaflets, a small annulus, shortened and malformed chordae tendineae, an abnormal number and size of papillary muscles, or any combination of these abnormalities.[11] In this study, the TVS was presumed to be congenital and was also most likely heritable. Given that extensive maternal medical histories were not available, *in utero* infection or exposure to teratogenic factors could not be completely ruled out but is considered unlikely.

In this study, common presenting complaints were abdominal distension (ascites due to right heart failure) and episodic weakness or syncope that occurred with excitement or exertion. These findings are consistent with previous reports.[1,2,12] All dogs in this study with these clinical signs experienced resolution or clinical improvement after BV.

Echocardiographic findings were similar in all dogs in this study. All dogs had mean TV gradients around 8 mmHg or higher. After BV and associated resolution of presenting complaints, mean gradients ranged between 3.2 and 6.8 mmHg. In humans, severe tricuspid stenosis is associated with resting mean TV gradients of 5 mmHg or greater.[7]

Interestingly, a persistent left cranial vena cava was a relatively common finding (3/5 dogs). In the general population, persistent left cranial vena cava is a relatively uncommon finding,[13,d] and can complicate access to the right heart via the left jugular vein approach. This was not a complication in this study, given that the authors routinely use a right jugular vein approach for catheter procedures; however, this potential complication should be considered when selecting a site for venous access.

A successful procedure was defined by ability to pass a catheter across the tricuspid valve orifice and inflate the balloon across the valve (Video S3). Abortion of the procedure due to failure to cross the tricuspid valve orifice occurred in 2 dogs attempted via the right jugular vein approach. In 1 dog, the procedure was repeated successfully using the femoral vein. The procedure was not repeated in the second dog. Alterative venous access should therefore be considered in such cases, particularly those in which the procedure has failed from the jugular approach. One dog was considered to have an unsuccessful BV (due to failure to pass the balloon across the TV orifice) although multiple balloon inflations were performed, but still experienced a resolution in presenting complaint. Although RAP did not decrease in this dog, the measured Doppler parameters did decrease. This suggests that clinical improvement might be appreciated in cases where the balloon cannot pass completely across the valve due to widening of the stenotic orifice or creation of an additional small orifice during the process of attempting to pass a catheter across the valve resulting in decreased resistance and consequent increase in flow such that RAP remained relatively unchanged under anesthesia.

Four of 5 dogs had right heart failure (3 with ascites, 1 with pleural effusion and ascites) prior to BV. Of the dogs in which the procedure resulted in reduction of RAP gradient (3 dogs), heart failure resolved in 2 dogs, despite a small reduction in right atrial pressure. As previously discussed, this finding might reflect inaccuracies in RAP measurement. Alternatively, it might suggest relatively small/imperceptible reductions in RAP might result in clinical improvements.

Heart failure recurred within 2 years in both dogs in which BV was performed, suspected secondary to restenosis of the tricuspid valve, although right heart failure secondary to worsened disease cannot be completely ruled out. If due to the former, this might suggest that restenosis after BV is a common occurrence. Although a reduction in RAP was appreciated, none of the dogs in which heart failure resolved had a normalized RAP, with procedural pressures after BV ranging from 9 to 20 mmHg, which suggests that achievement of a normal right atrial pressure is not necessary for resolution of clinical signs.

The largest balloon size used in any given procedure ranged from 15 mm to 25 mm. Complications after BV such as worsening tricuspid regurgitation were not appreciated in any of the dogs in which a 15- to 20-mm

balloon was used. Severe right heart failure 14 days after BV occurred in the 1 dog with pre-existing moderate TR. A 25-mm balloon was used in this dog. The development of right heart failure could have represented a natural progression in disease; however, given the echocardiographic evidence of worsened tricuspid regurgitation and right atrial enlargement after surgery, there is concern that the right heart failure was procedurally induced. However, further conclusions based on this single dog should be made with caution. Successful use of a 25-mm balloon in a Labrador Retriever has been reported;[1] however, this dog did not have tricuspid insufficiency before the procedure, nor did it develop as a consequence of the procedure.[1] This might suggest that right heart failure secondary to worsened tricuspid regurgitation in dogs with pre-existing moderate-to-severe tricuspid regurgitation is a potential complication of the procedure.

The limitations of this study are inherent to a retrospective study and include lack of standardized examination, diagnostic, and treatment protocols. Given that there is limited literature regarding the appropriate assessment of TV stenosis, a "gold standard" assessment does not exist. In humans, several echocardiographic assessment criteria have been recommended for the diagnosis of hemodynamically severe tricuspid stenosis including mean pressure gradient, VTI, pressure half-time, and calculation of valve surface area.[14] However, many of these methods such as pressure half-time have questionable repeatability and reliability or have not been validated in animals (e.g, calculation of valve surface area).[5,6,14] Consequently, future studies are necessary to validate such methods in dogs with TVS and to determine whether other echocardiographic diagnostic criteria eventually prove to be more reliable measures of disease severity than those reported in the present study. Additionally, there was inconsistency of follow-up, with only 1 dog available for follow-up at the time of data analysis.

In conclusion, given that Labrador Retrievers are predisposed to TVD and that all dogs in this study were Labradors Retrievers, it is likely that TVS represents a variant of TVD. Common presenting complaints include episodic weakness/syncope, and ascites due to right heart failure. Balloon valvuloplasty using a 15- to 20-mm balloon (in a Labrador Retriever) can be an effective treatment; however, recurrence of right heart failure might occur. Severe right heart failure due to worsened tricuspid regurgitation is a potential complication of BV in dogs with pre-existing moderate-to-severe TR.

Footnotes

[a] Phillips IE33, Philips Healthcare, Andover, MA
[b] Angiographic balloon catheter, Balloon wedge pressure catheter, Arrow International Inc.
[c] B. Braun Interventional Systems Inc., Bethlehem, PA
[d] ECVIM Abstract. Anomalies and anatomical variations of the thoracic great vessels in dogs. Sebastian P, Warren-Smith C, Fontara S et al. 2016

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Conflict of Interest Declaration: The authors declare no conflict of interest.

Off-label Antimicrobial Declaration: The authors declare no off-label use of antimicrobials.

References

1. Brown WA, Thomas WP. Balloon valvuloplasty of tricuspid stenosis in a Labrador retriever. J Vet Intern Med 1995;9:419–424.
2. Kunze SP, Abbott JA, Hamilton SM, Pyle RL. Balloon valvuloplasty for palliative treatment of tricuspid stenosis with right-to-left atrial-level shunting in a dog. J Am Vet Med Assoc 2002;220:491–496, 464.
3. Liu S, Fox PR. Cardiovascular pathology. In: Moïse NS, Fox P, Sisson D, eds. Textbook of Canine and Feline Cardiology. Philadelphia: WB Saunders; 2012:823–824.
4. Otto CM, Bonow RO. Valvular heart disease. In: Libby P, Bonow RO, Mann DL, Zipes DP, eds. Braunwald's Heart Disease: A Textbook of Cardiovascular Medicine, 8th ed. Philadelphia: Saunders Elsevier; 2008:1674–1675.
5. Boon JA. Stenotic lesions. In: Boon, JA, ed. Veterinary Echocardiography, 2nd ed. Oxford: Wiley-Blackwell; 2011:507–515.
6. Oyama M, Weidman J. Calculation of pressure half-time. J Vet Cardiol 2008;10:57–60.
7. Shah PM, Raney AA. Tricuspid valve disease. Curr Prob Cardiol 2008;32:47–84.
8. Krishnamoorthy KM. Balloon dilatation of isolated congenital tricuspid stenosis. Int J Cardiol 2003;89:119–121.
9. Andelfinger G, Wright KN, Lee HS, et al. Canine tricuspid valve malformation, a model of human Ebstein anomaly, maps to dog chromosome 9. J Med Genet 2003;40:320–324.
10. Famula TR, Siemens LM, Davidson AP, Packard M. Evaluation of the genetic basis of tricuspid valve dysplasia in Labrador Retrievers. Am J Vet Res 2002;63:816–820.
11. Waller BF, Howard J, Fess S. Pathology of tricuspid valve stenosis and pure tricuspid regurgitation–Part III. Clin Cardiol 1995;18:225–230.
12. Sousa M, Gerardi D, Alves R. Tricuspid valve dysplasia and Ebstein's anomaly in dogs: Case report. Arq Bras Med Vet Zootec 2006;58:762–767.
13. Buchanon JW. Persistent left cranial vena cava in dog: Angiography, significance and coexisting anomalies. Vet Rad 1963;4:1–8.
14. Baumgartner H, Hung J, Bermejo J, et al. Echocardiographic assessment of valve stenosis: EAE/ASE recommendations for clinical practice. J Am Soc Echocardiogr 2009;22:1–23.

Supporting Information

Additional Supporting Information may be found online in the supporting information tab for this article:

Fig S1. Necropsy specimen from dog 3, performed 2 months after second BV. Tricuspid valve viewed from the atrial aspect (the top portion of the right atrium has been removed). The stenotic tricuspid valve is viewed in the center of the image. There is diffuse thickening with

fusion of the valve leaflets resulting in a small tricuspid orifice. A probe is placed through a second office, presumed to have been created by the balloon valvuloplasty.

Table S1. Summary of patient signalment, clinical findings, and balloon procedure, and outcome.

Table S2. Summary of pre- and post-balloon valvuloplasty tricuspid inflow echocardiographic measurements (performed in awake patients) and right atrial pressure measurements (performed under general anesthesia).

Video S1. Apical four-chamber view of the heart obtained from the left parasternal caudal transducer location. The right atrium is markedly enlarged. The tricuspid valve leaflets are mildly thickened with restricted motion at the tips and severe diastolic doming of the tricuspid valve leaflets.

Video S2. Angiographic video obtained following injection of iodinated contrast. The catheter tip is in the right atrium via the right jugular vein. The right atrium and right auricular appendage are severely dilated. Retrograde filling of a severely distended caudal vena cava is appreciated. The tricuspid valve is severely stenotic.

Video S3. Angiographic video of a successful balloon valvuloplasty procedure. The catheter tip is in the right atrium via the right jugular vein. Note the indentation identified in the balloon across the stenotic tricuspid valve that subsequently pops open when the balloon is inflated.