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Surgical valvulotomy for tricuspid valve stenosis in a dog

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Running title: surgical tricuspid valvulotomy

Abstract

A 2 year 4 month old female neutered Labrador retriever was presented for evaluation right sided congestive heart failure. Echocardiographic examination revealed tricuspid valve dysplasia with only two small orifices in the valve resulting in severe tricuspid stenosis. The dog underwent a right fifth lateral intercostal thoracotomy and surgical tricuspid valvulotomy, under cardiopulmonary bypass. The stenosis was relieved by dividing the valve leaflets between the two orifices with continuation to the commissures, creating a 'bi-leaflet' valve. The dog made a good recovery initially with echocardiography at 48 hours after surgery showing a reduction in tricuspid valve E and A wave velocities and pressure half time (from 230 ms to to 65 ms). She was discharged five days after surgery with spironolactone, benazepril, pimobendan and clopidogrel. The dog was re-presented two days later having collapsed, with pyrexia, facial swelling and pitting edema on the ventral neck and intermandibular region. Investigations did not reveal an underlying cause and the clinical signs resolved with supportive therapy. Two years after surgery the dog was free of clinical signs with normal exercise tolerance and only mild tricuspid regurgitation on echocardiography, with discontinuation of all medications.

Key Words

Canine; tricuspid valve dysplasia; valvulotomy

Abbreviation	**Definition**
TR	tricuspid regurgitation
TV	tricuspid valve
TVD	tricuspid valve dysplasia

A 2 year, 4 month old female neutered Labrador retriever weighing 32.6 kg presented to the Queen Mother Hospital for Animals, Royal Veterinary College, for evaluation of previously diagnosed tricuspid valve dysplasia (TVD) causing clinical signs of lethargy, exercise intolerance and cough associated with right sided congestive heart failure. On presentation she was quiet, alert and responsive with a heart rate of 128 beats per minute and a respiratory rate of 24 breaths per minute. She had a body condition score of 6/9. The dog was receiving furosemide (1.2 mg/kg q 12 hr), benazepril (0.23 mg/kg q 24 hr), spironolactone (1.8 mg/kg q 24 hr) and pimobendan (0.15 mg/kg q 12 hr). Echocardiographic evaluation[a] with a 5 MHz transducer including three dimensional echocardiographic assessment, showed a severely dilated right atrium and restricted tricuspid valve (TV) leaflet motion, with a network of fibrous structures within the right ventricle and two small valve (Fig. 1- 3, Supplemental Videos I and II, all videos available in Supplemental Material on-line). Colour flow Doppler showed turbulent diastolic inflow into the right ventricle but no tricuspid regurgitation (TR) was detected (Fig. 4, Supplemental Videos III). The TV pressure half time was 230 ms, the TV E velocity 1.35 m/s and the A velocity 2.27 m/s, indicative of severe tricuspid stenosis (Fig. 5) [1]. In addition, the mitral valve leaflets were “clubbed” but there was no left atrial enlargement.

Despite improvement with medication the dog was still lethargic and exercise intolerant and her owner remained concerned regarding the quality of her dog’s life. Given her echocardiographic findings she was considered at high risk of subsequent development of atrial fibrillation and progressive right-sided heart failure. The option of surgical management with a valvulotomy was therefore offered to the owners with

full discussion of the risks. After consideration, her owners elected to proceed with surgery.

Premedication of methadone (0.2 mg/kg intravenously) was administered to the dog and anaesthesia was induced using fentanyl (10 ug/kg), midazolam (0.3 mg/kg) and propofol (1.2 mg/kg) intravenously. A central venous catheter and peripheral arterial catheter were placed and a paravertebral nerve block with 0.2 mL/kg of ropivacaine was performed. The dog was taken to surgery and the carotid artery was exposed through a five centimetre vertical cervical incision and isolated with loose Rummel tourniquets.

A right fifth intercostal thoracotomy was performed. The pericardium was opened and “pericardial basket” sutures placed to expose the heart. The right external carotid artery was cannulated with a 14 F arterial cannula. Venous drainage was achieved with two 26 F right angle cannulas placed in the cranial and caudal vena cavae through purse-string sutures in the adjacent right atrial myocardium. Cardiopulmonary bypass was initiated and the dog cooled to an oesophageal temperature of 28ºC. Rummel tourniquets of umbilical tape were used to form a seal around the intracaval part of the venous cannulas and the azygous Rummel was tightened to stop flow through the azygous vein. Umbilical tape was passed around the root of the aorta and an 18 G cardioplegia cannula was inserted into the aortic root through a horizontal mattress suture of 5-0 polypropylene. The aorta was cross-clamped distal to the cardioplegia cannula and cold (4ºC) cardioplegia solution[b], combined with blood from the bypass circuit, was infused into the aortic root. Cardioplegia was delivered at 20 minute intervals or whenever cardiac muscular activity was observed. A right atrial incision was made along a line parallel with the

atrioventricular groove and equidistant from it and the dorsal pericardial reflection of the right atrium, as previously described [2]. Stay sutures of 3-0 polyglactin 910 were placed around the atrial incision to maintain exposure of the tricuspid valve orifice. The TV was inspected and had two almost equally sized orifices that were approximately three mm's in diameter and 1.5 cm apart (Fig. 3). Stay sutures of 5-0 polypropylene were placed at the edges of the rostral valve orifice and the valve leaflets were divided between the two orifices in a cranial to caudal direction, using right angle Potts scissors, taking care not to damage the underlying chordal attachments. The valve was made into a "bicuspid" valve by continuing the incision to the cranial and caudal tricuspid annulus, preserving chordal attachments to each valve edge. During this process, an iatrogenic "cleft" was created in the septal leaflet of the valve and this was repaired using simple interrupted sutures of 6-0 polypropylene. Valve leaflet motion was subjectively good following this procedure. There was a small amount of regurgitation when the valve was tested by filling the right ventricle with saline but this was considered to be acceptable. The atrium was closed using 4-0 polypropylene with expanded polytetrafluoroethylene pledgets in a continuous mattress suture oversewn by a simple continuous suture, with de-airing performed as the suture was tied. The aortic cross clamp was removed just after atriotomy closure when the dogs oesophageal temperature reached 30ºC ventricular fibrillation occurred and normal sinus rhythm was established with one internal defibrillation of 20 joules. Transesophageal echocardiographic evaluation showed mild tricuspid regurgitation and a subjective reduction in diastolic inflow turbulence compared to the pre-operative transesophageal echocardiogram.

Total cross clamp time was 50 minutes, bypass time was 120 minutes and surgical time was 265 minutes. The dog was moved to the intensive care unit where two units

of fresh frozen plasma and one unit of packed red blood cells were administered over the next 8 hours. The chest drain was removed 20 hours post-operatively after reduction of fluid to < 1 mL/kg/hour. Clopidogrel therapy (2 mg/kg per os) every 24 hours was initiated following chest drain removal. Benazepril (0.23 mg/kg q 24 hr), spironolactone (1.8 mg/kg q 24 hr) and pimobendan (0.15 mg/kg q 12 hr) were continued the morning following surgery. The dog recovered from surgery uneventfully initially, with echocardiography at 48 hours post-operatively showing a reduction in TV E and A wave velocities (1 m/s and 0.97 m/s, respectively) and a reduction in TV pressure half time to 65 ms. The right atrium had decreased in size and moderate TR was present.

The dog was discharged on day five, however, she collapsed on day seven and was taken to her primary care veterinarian where intravenous antibiotics with potentiated amoxicillin were started. She was readmitted to our hospital the same day and on presentation she was pyrexic (40ºC), had a heart rate of 120 beats per minute and was lethargic with facial swelling and pitting edema on the ventral neck and intermandibular region. Hematology revealed a mild lymphopenia (0.79 x10e9/L, reference range 1-4.8 x10e9/L) and a hematocrit of 23.5% (reference range 37-55%) with strong evidence of red cell regeneration (1+ anisocytosis, macrocytosis and codocytosis as well as rubriocytosis). Biochemistry revealed mild increase in serum bilirubin concentration (3.1 umol/L, reference range 0-2.4 umol/L) but was otherwise within normal limits. Blood cultures were negative and prothrombin time and activated partial thromboplastin time were within normal limits. Echocardiographic examination was unchanged from the previous scan (four days prior) and ultrasound of the neck revealed subjectively reduced flow through the left jugular vein (where the jugular catheter had been placed). The differentials for the dog's cranial caval

146 syndrome included compression from a mediastinal bleed from the repaired carotid
147 surgical site or a thrombus in the cranial cava. Intravenous clavulanate potentiated
148 amoxicillin (20 mg/kg q 8 hr) was continued while waiting for blood culture results,
149 along with intravenous fluid therapy consisting of balanced electrolytes (compound
150 sodium lactate) at 2 mL/kg/hr. The facial swelling progressed and thoracic limb
151 swelling developed, along with intermittent lingual cyanosis over the next two days
152 but the dog remained bright and normothermic. Low molecular weight heparin was
153 started at 200 iu/kg SQ q 8 hr for 24 hours, then reduced to 150 IU/kg q 8 hr for a
154 further 72 hours due to the concern for a thrombus in the vena cava at the site of the
155 jugular catheter or one of the bypass cannulas. The dog made a steady recovery
156 with resolution of all edema, and was discharged on the seventh day following re-
157 admission (14 days following surgery) with the same dose of pimobendan,
158 benazepril, spironolactone and clopidogrel.

159 The dog was re-examined two months after surgery, and was bright, alert and
160 responsive with a grade II/VI right apical systolic heart murmur, a heart rate of 114
161 beats per minute and a body condition score of 7/9. The owner reported that the dog
162 was normal at home. Echocardiography showed a further reduction in right atrial
163 size, and only mild TR. The TV E and A velocities had decreased further to 0.85 m/s
164 and 0.71 m/s, respectively. Mitral valve stenosis was present (mitral valve pressure
165 half time 74 ms, normal <50 ms [3]), but there was no enlargement of the left heart
166 chamber dimensions (Supplemental Videos IV and V). Clopidogrel was continued for
167 three months post-operatively and the dog remained on benazepril, spironolactone
168 and pimobendan.

169 At seven months after surgery, she had no reported abnormalities at home and
170 physical examination revealed no change in heart murmur. The right heart chamber
171 dimensions had decreased further with only mild TR present at this time. There was
172 a mild increase in left atrial size (left atrial:aortic annulus 1.8, compared to 1.3 and
173 left atrial diameter in the right parasternal long axis view now 40 mm compared to 37
174 mm; Supplemental Video VI). Two and a half years after surgery, the owner reports
175 no clinical signs with normal exercise tolerance. Physical exam reveals no audible
176 murmur on the right and a grade II/VI left apical systolic murmur. The left atrial size
177 and TR is unchanged from the previous visit (considered subjectively mild). The
178 spironolactone, benazepril and pimobendan have been discontinued.

179

180 **Discussion**

181 To the authors' knowledge, this is the first report of a dog undergoing surgical repair
182 of a dysplastic stenotic TV in the veterinary literature. This dog reported here
183 demonstrates that valve surgery may be a feasible treatment option in selected
184 patients with TVD. Both palliative balloon dilation [4,5] and valve replacement [2,6],
185 have been described for the treatment of TV stenosis. The decision to perform a
186 surgical repair in the form of a valvulotomy, rather than to perform balloon dilation or
187 valve replacement was made for a number of reasons. The main concern with
188 balloon dilation of the stenotic valve was the potential for alleviation of stenosis at the
189 expense of severe valvular regurgitation [5]. In addition, we have previously reported
190 poor medium to long term results with TV replacement in dogs with TVD; largely
191 because of acute and chronic thrombus formation, causing valve failure [2].
192 Furthermore, our growing experience with successful repair of the mitral valve led us

193 to believe that repair of this stenotic TV would give the dog reported here the best
194 chance of a long term solution even in the face of residual valve regurgitation.

195 As expected, TR was present after surgery. This regurgitation was subjectively
196 “moderate” at 48 hours post-operatively and changed over time to “mild” at the three
197 and seven month post-operative echocardiogram. This is most likely a result of a
198 reduction in right atrial size secondary to a reduction in the TV stenosis and
199 consequent reduction in the valve annulus dimensions, enabling improved
200 coaptation of the valve leaflets.

201 The reason this dog developed cranial caval syndrome seven days after surgery,
202 remains unclear. The two main possibilities we considered were: extracaval
203 compression secondary to bleeding into the mediastinum from the surgically repaired
204 carotid cannulation site, or a thrombus in the cranial cava. We were not able to
205 document either using ultrasound examination. Computed tomographic angiography
206 might have helped to identify the cause, but in the light of ongoing clinical
207 improvement, the additional risk and cost associated with this could not be justified.
208 This complication did present a significant therapeutic dilemma however, with the
209 treatment for our two most likely causes being diametrically opposed. If hemorrhage
210 had been the cause, discontinuation of the dog’s anticoagulant medications would
211 have been necessary. A thrombus however would require reinstitution of more
212 aggressive anticoagulant therapy. Additional testing such as thromboelastography,
213 fibrinogen concentration and d-dimers may have helped to clarify the likelihood of
214 clot formation compared with ongoing bleeding, however, interpretation of such tests
215 would have been difficult given the lack of information regarding the effects of
216 cardiopulmonary bypass on these parameters [7,8]. Whilst these tests can help

clarify the coagulation status in some cases, they do not confirm the presence of a clot and are no more sensitive to overt bleeding than conventional coagulation analytes such as partial thromboplastin time and activated partial thromboplastin time which were both within normal limits at this time [7,8,9].

In conclusion, this case report confirms that TV stenosis can be successfully managed surgically and a degree of TV incompetence may be tolerated well by some dogs for an extended period of time. This report confirms that repair of some forms of TVD is possible and suggests that the repair may not have to be perfect in order to achieve a good clinical outcome.

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Footnotes

a: Vivid E9, General Electric Medical Systems Ultrasound, Hatfield, UK

b: Cardioplegia infusion, Martindale Pharmaceuticals, Romford, UK

Figure Captions

Figures 1a and b: Right parasternal long axis view pre- (Fig. 1a) and post-surgery (Fig. 1b). Pre-surgery the right atrium is severely dilated with the region of valve leaflet coaptation apically (arrow) displaced. Two months post-surgery there is a reduction in right atrial size with more normal chamber geometry.

Figures 2a, 2b, 2c, 2d: Left apical views of the tricuspid valve in systole (Figs. 2a and c) and diastole (Figs. 2b and d) demonstrating reduced opening of the tricuspid leaflets (arrow) in 2b. Pre-operative images (Figs. 2a and b), post-operative images (Figs. 2c and d).

Figure 3: Pre-operative three-dimensional echocardiogram showing the two small orifices in the valve leaflet (green arrows).

Figures 4a and b: Pulsed wave spectral Doppler interrogation of the tricuspid valve before and after surgery, showing a decrease in pressure half time.

Figure 5: Intraoperative photo showing the two equally sized orifices in the tricuspid valve, approximately 3 mm in diameter and 1.5 cm apart.

Supplemental Videos	Title	Description
I	Right parasternal long axis 4-chamber view	There is apical displacement of the area of coaptation of the tricuspid valve leaflets demonstrated
II	Left apical view	Optimized for the right ventricular inflow, demonstrating abnormal opening of the tricuspid valve leaflets
III	Left apical view	Zoomed to show the tricuspid valve apparatus pre-operatively
IV	Left apical view	Zoomed view, two months post-operatively, demonstrating improvement in valve motion
V	Left apical view with color flow Doppler	Two month post-operative view demonstrating resolution of tricuspid

		stenosis
VI	Right parasternal four chamber view	Seven month post-operative view demonstrating maintained reduction in right atrial size

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