Echocardiography in the bovine species with specific applications in the calf

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Introduction: Bovine Cardiac Disease

Detecting heart disease in cattle remains a clinical challenge since most cases do not display clinical signs, and many have occult disease with lesions that are only discovered at necropsy. Heart disease in cattle is associated with decreased production and therefore, generally has a poor to guarded prognosis. In most cases of heart disease, the patient will succumb to heart failure resulting in an animal that is not economically viable (Buczinski, June, 2010). In calves, the incidence of cardiac disease and heart failure attributable to congenital etiology is reportedly low compared to other causes (such as gastrointestinal disorder of infectious etiology) (Buczinski 2010, The Vet Journal). Numbers are likely an underestimation of total incidence due to lack of necropsy or lack of clinical presentation for veterinary care. Calves with cardiac disease may die prior to birth, soon after birth or may go on undetected and have normal production in the herd up to the development of cardiac failure, which carries a poor prognosis. In a retrospective review of the prevalence of congenital cardiac disease states in 469 bovine cases, over an 18-year period, a total of 835 congenital cardiac disease types were found. (Ohwada et. al, 2011). Many of these disease states are outside of the scope of this review. Approximately halve of the cases were simple cardiac defects whereas the other half were more complex in nature.

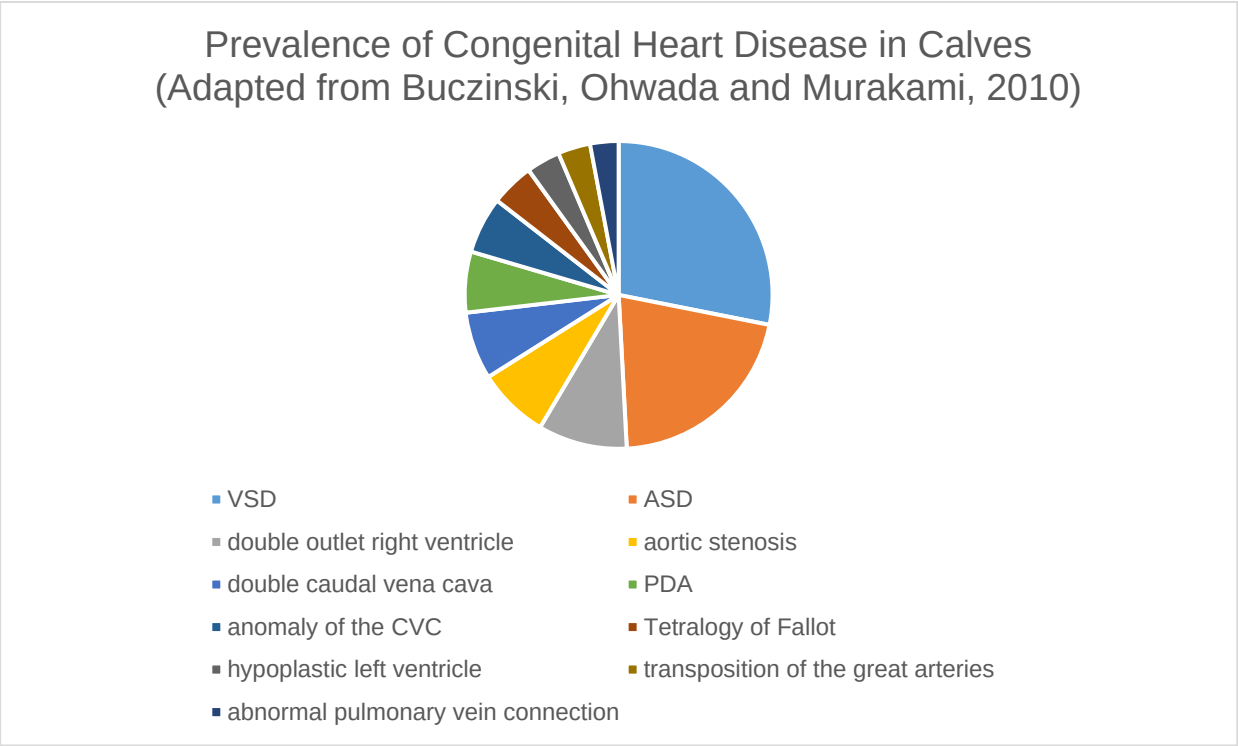
Congenital Cardiac Disease in the Calf

The prevalence of congenital cardiac disease found in calves at necropsy is reported as 0.2-0.7% (Mitchell 2016 and Smith, 2015). Congenital anomalous cardiac defects of all varieties can occur, with most resulting from defective embryologic formation of the septa and the chambers (Buczinski, June 2010). Ventricular septal defects (VSDs), as with people, dogs and cats is the most common congenital cardiac defect in calves (Mitchell 2016 and Owhada, 2011). Septal

defects can occur as isolated anomalies or as part of more complex malformations, including tetralogy or pentalogy of Fallot. Most commonly, VSDs in the calf occur in the perimembranous region, a location defined as proximate to the right cusps of the aortic valve and the septal leaflet of the tricuspid valve (Mitchell, 2016). Additional sites include subpulmonic, supracristal, which is located directly beneath the aortic and pulmonic valves, and rarely, in the muscular portion of the interventricular septum (Mitchell, 2016). Atrial septal defects (ASDs) occur with less frequency (Mitchell, 2016). Small ASDs can be easily confused with a patent foramen ovale (PFO), a normal fetal structure which closes at birth, on echocardiography (Mitchell, 2016 and Tou, 2015). The use of agitated saline (gas bubble) studies, imaged with echocardiography, can assist in differentiation of such defects (Mitchell, 2016). With a true ASD, there is a defect present within the septum primum or septum secundum, with defects of the septum secundum occurring more commonly (Tou, 2015). In contrast, a patent foramen ovale would be seen as a defect occurring between the two normally formed septa (Tou, 2015). Outflow tract obstructions (pulmonic or aortic stenoses) can occur, and when they do, these tend to occur in conjunction with complex anomalies such as tetralogy of fallot, double outlet right ventricle, or transposition of great vessels (Mitchell, 2016 and Smith, 2015). Some congenital anomalies are rare and extremely difficult to diagnose with physical examination and imaging. Rare anomalies may include congenital malformations such as coronary artery-ventricular fistulas, anomalous pulmonary venous return, persistent left cranial vena cava, aberrant caudal venous return, aortic tubular hypoplasia, duplication of the cranial vena cava, hypoplastic left ventricle, cor atriatrium, hamartoma, chamber hypoplasia, valvular dysplasia, vascular ring anomalies, great vessel transposition, pulmonary vein abberations or an ectopic heart (ectopia cordis) (Mitchell, 2016, Smith, 2015 and Buczinski, June 2010). We present below a review of advanced imaging in the

calf and a two-case series exemplifying the application of advanced imaging modalities in the clinical setting.

Figure 1.



Acquired cardiac disease

The reported incidence of acquired cardiac disease in cattle in the form of endocarditis is 4% (Smith, 2015). Vegetative valvular endocarditis is common in cattle and is a result of bacterial infiltration secondary to septicemia (Reef, 1996 and Yoshinori, 1987). The true incidence in calves is not reported. Inflammation of the endothelial lining of the heart can result in valvular insufficiency or stenosis leading to congestive heart failure (Andrews, 2004). Valvular endocarditis leads to valvular dysfunction and insufficiency and is one of the main cardiac disorders of adult cattle with the prevalence being as high as 1% (Reef 1996 and Yoshinori 1987). The disease is commonly misdiagnosed and discovered only at necropsy (Reef, 1996). In cattle,

leaflet vegetations affect the tricuspid valve most often. The aortic, pulmonary and mitral valves may also be afflicted (Buczinski June, 2010, Mohamed et al. 2013). In addition, multiple valves may be affected at a given time (Buczinski June, 2010). Endocarditis that affects the mural endocardium occurs less commonly, and animals with abnormal cardiac architecture may be predisposed in these cases (Divers, 2008, Buczinski June, 2010). Bacteremia is the most common cause of endocarditis with Group D streptococci, *Trueperella pyogenes*, *Enterobacteriaceae*, *Manheimia* or *Pasteurella species* being the most common microbial agents involved (Andrews, 2004). *Trueperella pyogenes* is the organism most commonly cultured from the blood of cattle with endocardial disease (Divers, 2008). Insufficient jet lesions can damage the endocardium and predispose the endocardium to infectious lesions (Buczinski, June 2010). Persistent bacteremia is required for the development of endocardial lesions and a primary focus of infection is identified at post–mortem evaluation in most cases, or in the author's experience with echocardiography (Andrews, 2004, Gambino, pers. comm.). Agents likely arrive at damaged endocardial (or endothelial) lesions by way of hematogenous spread (Andrews, 2004). Often, damaged endothelium predisposes to infective endocarditis, but the disease can also occur in calves with normal valves (Kittleson, 2015). The bacteria adhere to the damaged endothelium, most often along the free edges of the valves or on appositional surfaces (Andrews, 2004). Bovine cardiac valves have their own blood supply which may preclude bacterial emboli formation within the capillaries (Andrews, 2004). Bovine valves and cardiac tissue, specifically the pericardium, are also unique in that they are commonly used in human cardiac valve replacements (Yap, 2013). Unlike the case presented herein, early endocardial lesions are seldom noted. Initially, the valve leaflets are swollen with an irregular ulcerative surface, which gives rise to the characteristic vegetative structures (Andrews, 2004). Platelets adhere to the damaged endothelium which

produces microthrombi (Kittleson, 2015). Bacteria can become entrapped within the thrombi lattices producing localized infection and progressive valve destruction (Kittleson, 2015). With regard to prognosis for endocarditis (as with the case presented herein), younger animals (mean, 14-months of age) had better survival rates than older animals (mean, 38-months of age), with early recognition and lack of clinical signs also having a more favorable outcome (Buczinski, June, 2010).

Presentation, Clinical Findings and Pathophysiology

Presentation

Cardiac disease in calves is clinically challenging to diagnose. Congenital cardiac disease occurs sporadically (Divers, 2008). The more common congenital anomalies may be inherited (Divers, 2008). Calves with congenital cardiac disease may appear normal at birth but may develop respiratory signs including dyspnea, coughing or pneumonia (Divers, 2008). Other clinical signs may include tachycardia, abnormal heart sounds or peripheral edema (Buczinski, 2010, The Vet Journal). Calves may also have vague signs such as ill-thrift, poor growth and venous (jugular) pulsation or distention (Divers, 2008). Calves with more extensive anomalies such as abnormalities that result in shunting of blood from the right to left can show signs of severe exercise intolerance and may develop cyanosis or hypoxia (Divers, 2008). Congenital defects that may present with cyanosis include VSD, patent ductus arteriosus (PDA), tricuspid atresia, truncus arteriosus, single ventricle, double outlet right ventricle, Eisenmenger complex or tetralogy or pentalogy of Fallot (Smith, 2015). Calves with more extensive anomalies will have pronounced stunting of growth that becomes more readily apparent as they age (Divers, 2008). Some cardiac abnormalities are associated with other forms of congenital defects (Divers, 2008). In certain

breeds, microphthalmos, ocular defects and various tail malformations have been linked to the presence of a VSD (Divers, 2008).

Clinical findings and auscultation of common congenital defects

Investigation of cardiac disease begins with cardiac auscultation, assessment of pulse quality and appearance of mucous membranes (Divers, 2008) and a general examination. In neonatal calves, it is common for them to have a heart rate as high as 110 – 120 beats per minute, due to stress or excitement. However, the average heart rate of a healthy calf is expected to be 70 – 100 beats per minute (Divers, 2008 and Fleming, 2015). Likewise, a healthy calf at rest is expected to have a respiratory rate of 15 – 45 breaths per minute (Fleming, 2015). Calves with congenital heart defects generally present with non-specific clinical signs; however, if the anomaly is severe enough there may be signs of heart failure present (Buczinski, June, 2010). One study reviewed the prevalence of clinical signs in 59 cattle with congestive heart failure, with the more common signs on presentation including tachycardia (89%), abnormal heart sounds (74%), jugular distension (69%), peripheral edema (54%) and jugular pulses (44%) (Buczinski, 2010, The Vet Journal). The less common clinical signs of heart failure were ascites (8%), cough (5%) and syncope (3%) (Buczinski, June, 2010, The Vet Journal).

Calves with congenital disease usually have a soft murmur (< grade 3) but it should be noted that it is common for young calves to have a physiologic murmur, often associated with excitement or nervousness, near the left heart base. Physiologic murmurs have a point of maximal intensity (PMI) near the pulmonic or aortic valves. Other causes of murmurs in ruminants may include infective or degenerative valvular disease, fever, or anemia (Smith, 2015). The detection of cardiac murmurs, and their intensity depends on the anomaly present, the stage of disease and whether or

not comorbidities are present. The PMI of a cardiac murmur, as well as where they occur in the cardiac cycle (systolic or diastolic) can clue the clinician in as to the location and character of the cardiac anomaly. Systolic murmurs are commonly auscultated with a VSD, ASD, tetralogy of Fallot and aortic or pulmonic stenosis (Smith, 2015). A VSD has a PMI located near the tricuspid valve (3^{rd} to 5^{th} intercostal space on the right thorax near the point of the elbow) with the possibility of detecting a palpable thrill and on occasion, a split second heart sound (Smith, 2015 and Fleming, 2015). Additional clinical findings that may be associated with VSD include exercise intolerance, dyspnea, poor growth or signs of congestive heart failure if the defect is large (Smith, 2015). Left to right shunting VSDs are most common. However, increased pressures in the right ventricle at birth resulting in left to right shunting, can also occur. This is called Eisenmenger complex (Smith, 2015). This should not be confused with acquired Eisenmenger's syndrome which is an acquired condition, resulting from long standing left to right shunting, increased right-sided cardiac pressures and the reversal of shunt flow (Buczinski, 2009). Eisenmenger's physiology is associated with a pansystolic murmur with a PMI over the pulmonic valve. Clinical signs associated with this anomaly include polycythemia, exercise intolerance and the presence of a fourth heart sound (Smith, 2015). In calves, failure of the septum primum to close at birth results in a patent foramen ovale (PFO) which is a common finding in calves with a PDA. Calves with ASD may be asymptomatic with the only clinical sign being a holosystolic murmur heard best over the left heart base (Smith, 2015). An ASD usually presents as a left to right shunt with the presence of right atrial, right ventricular and left atrial enlargement if the defect is large (Smith, 2015). Patent ductus arteriosus (PDA) can result in either a continuous murmur or a systolic murmur and can be identified as left to right shunting of blood in the pulmonary artery (Divers, 2008 and Mitchell

2016). A PDA has a PMI that can be heard best over the left heart base within the 3rd intercostal space and the animal may have bounding pulses (Smith, 2015).

Cardiac tumors overview

The most commonly reported cardiac tumor of cattle is lymphoma, with the right atrium being a site of predilection (Buczinski, 2010, The Vet Journal). Lymphoma has a higher incidence in areas where bovine leukosis virus has increased prevalence and it is generally associated with a poor prognosis (Buczinski 2009 and 2010, The Vet Journal). Clinical findings associated with cardiac lymphoma include pericardial effusion and muffled heart sounds, dilation of the right atrium, and a thickened endocardium (Buczinski, 2009). Cardiac neurofibroma is an uncommon tumor seen in cattle which causes fluctuating heart sound intensity and may cause paresis or paralysis if metastasis of the spinal cord occurs (Divers, 2008). To date, only 3 cardiac vascular hamartomas have been reported in cattle (Brisville, 2012). Hamartoma is a rare, benign, tumor-like nodule, usually an incidental finding, with a hyperechoic, cystic-like, homogenous appearance on echocardiography (Brisville, 2012). As with the other cardiac tumors, all reported cases of hamartoma occurred in the right atrium (Brisville, 2012).

Bacterial Endocarditis

Similar to some occult congenital cardiac anomalies, acquired endocarditis can also present a diagnostic challenge, especially when not accompanied by clinical signs of congestive cardiac failure. (Buczinski, 2010, The Vet Journal). The presence of (primary) tachycardia not caused by underlying disease states that cause (secondary) tachycardia, fever, anomalous heart sounds and other signs of heart failure such as venous distension, pulmonary edema, or evidence of a primary focus of infection can be indicators of endocarditis, with 50 – 80% of cases having a murmur

detected on physical examination (Buczinski, 2010, The Vet Journal). Common clinical signs associated with bacterial endocarditis included tachycardia, murmurs, recurrent fever, jugular vein distension with palpable pulses and ventral and submandibular edema (Mohamed, 2011). There are other clinical criteria that can help with the diagnosis of endocarditis which include positive blood culture, fever, signs of congestive heart failure and a murmur, however, it is not determined if these findings increase the sensitivity for diagnosing bovine endocarditis (Buczinski, 2012). Common echocardiographic changes associated with endocarditis include thickened hyperechoic valve leaflets, chordal rupture or diastolic valve fluttering or oscillation (Pennick, 2008). Other echocardiographic findings of endocarditis can include ventricular hyperkinesis and eccentric hypertrophy of the ventricle on the affected side (Yoshinori, 1987). Doppler echocardiography can confirm the presence of valve regurgitation and helps determine the severity (Nyland, 2002).

Diagnostic approach for investigating cardiac disease in the calf

The following provides the in - depth diagnostic approach for cardiac disease as would be offered to any client at the level of a tertiary referral institution. Each case should be suited to the individual clients needs or wishes as some may view their cattle as member of the family. Every individual case is valuable since each one will provide a unique learning opportunity.

Laboratory findings

Abnormalities found on bloodwork are usually non–specific. as certain myocardial isoenzymes are also increased with muscle damage (Buczinski, June 2010). In calves with bacterial endocarditis, complete blood count (CBC) and serum biochemistry abnormalities included neutrophilic leukocytosis, hyperproteinemia, hypoalbuminemia, hypergammaglobulinemia and azotemia (Buczinski, 2010, The Vet Journal). Mohamed et al. 2011). The cardiac serum

biomarker cardiac troponin I (cTnI) has been documented to be highly sensitive and have a specificity of 100% for the detection of cardiac injury and disease (Suzuki, 2012 and Tunca, 2008). In cattle, cardiac biomarkers were seldom used, but the use of this blood test is gaining popularity as cardiac troponin proteins have been shown to be valuable indicators of myocardial cell necrosis and ischemia. Cardiac troponin I (cTnI) is recognized as the most sensitive and specific biomarker (Buczinski Feb. 2010, June 2010). Cardiac troponin T (cTnT) may be also helpful but is less specific for cardiac disease since it can also increase with skeletal muscle damage (Karapinar, 2010). Increased cardiac troponin I (cTnI) correlates with the severity of myocardial injury (Buczinski, Feb. 2010 and Suzuki, 2012). In healthy calves, the normal reference range for serum cardiac troponin I (cTnI) is reported as 0.01 to 0.05 ng/ml with any value above 0.05 ng/ml being associated with myocardial injury (Buczinski, Feb. 2010). Calves with various forms of congenital heart disease can have cardiac troponin levels between 0.035 - 0.17 ng/ml (Suzuki 2012).

Advanced Imaging Modalities

Radiography can be useful in calves to evaluate heart size, pulmonary lobar vein size, and to screen for the presence of cardiogenic pulmonary edema (Smith, 2015). Cardiomegaly, specifically left atrial enlargement with pulmonary lobar vein enlargement, can be seen with VSD (Smith 2015). With a large PDA, cardiomegaly may be present in the form of left heart dilation and right ventricular hypertrophy (Dehkordi, 2016). Other radiographic changes may include pulmonary congestion and pulmonary artery dilation (Dehkordi, 2016). Cardiac failure may be seen as increased soft tissue opacity over the caudal dorsal lung fields and peri-hilar region with border effacement of the cardiac margin, air bronchograms or a lobar sign. Complex anomalies may not be accompanied by specific radiographic hallmarks or may be accompanied by a combination of

cardiac chamber enlargement, great vessel dilation and pulmonary lobar vascular changes (Gambino, pers comm.)

Echocardiography is the most sensitive tool for the detection cardiac disease or anomalies in calves. When evaluating calves, sequential segmental analysis (SSA) is the recommended systematic approach (Mitchell, 2016). Sequential segmental analysis is defined as segmental evaluation of sonographic windows that are well established in the literature. These windows allow the ultrasonographer to evaluate cardiac morphology, connections between the various cardiac chambers and great vessels and transvalvular and transdefect pressure gradients (Anderson, 2009, Gambino pers. comm) Depending on age, small calves are best evaluated using a medium-frequency, small footprint, phased array probe (Mitchell 2016). Other probes will suffice, such as a large sectorial probe or a curvilinear probe, but for larger calves (i.e. those approximately 4-6 months of age) medium-frequency, medium to large footprint phased array probes will provide optimal imaging (Mitchell, 2016 and Buczinski, 2009). The typical frame rate is 30 to 60 frames per second and an imaging depth of 10 to 15 cm is optimal for younger calves (Mitchell 2016). With color flow Doppler mode, using a high frame rate, a minor reduction in the tissue priority settings, variance coding color maps and maximum velocity, enables recognition of blood flow patterns (Mitchell 2016). Color flow Doppler mapping calculates blood velocity, direction and location. Blood in the region interrogated is assigned a color based on direction and velocity of blood flow (Boon, 2011). With conventional color Doppler maps, blood moving away from the transducer is mapped in shades of blue while blood moving towards the transducer is mapped in shades of red (blue-away, red-towards or BART) (Boon, 2011). Blood that has increased velocity or turbulence will be mapped with an assortment of other colors (white, green, etc.) and if there is no blood flow, no color will be assigned and the area will appear black (Boon, 2011). Pulsed –

wave Doppler is used to record frequencies that have had their depth and site gate previously set by the examiner (Boon, 2011). The higher the depth, the more time is required to record frequency shifts (Boon, 2011). Contrast that to continuous wave Doppler, in which depths and gates are not previously set and therefore there is no range resolution and all velocities are recorded (Boon, 2011). Since the mitral valve has blood flow that moves toward the transducer the result is positive frequency shift, or a profile that is above baseline (Boon, 2011). Likewise, the aortic valve has flow that moves away from the transducer resulting in a negative frequency shift, or a profile that is below baseline (Boon, 2011).

Similar to people and small animals, electrocardiography (ECG) is a non-invasive tool that can assess cardiac arrhythmias. Atrial fibrillation is the most common arrhythmia in cattle (Buczinski, June 2010) Additional electrophysiologic abnormalities seen would depend on the primary disease process present. Most primary abnormal arrhythmias noted in cattle are tachyarrhythmias and are usually caused by myocarditis, valvular disease, conduction abnormalities or pericarditis. Sinus bradycardia and sinus arrhythmia have been found in normal cattle that are fasted for 1 – 2 days (Smith, 2015). Atrial premature complexes and atrial fibrillation have been noted in cattle with gastrointestinal disease (Smith, 2015). ECG is commonly used simultaneously with echocardiography for recording of the cardiac cycle throughout the examination (Mitchell 2016).

Cardiac catheterization is used for angiocardiography, which can determine the direction of cardiac shunts, size of cardiac chambers and establish valvular and cardiac morphology when echocardiography fails to elucidate the specific defect present (Smith, 2015). Angiocardiography is historically used in animals to confirm septal defects, persistence of

the ligamentous ductus, or other complex anomalies such as tetralogy of Fallot and truncus arteriosus and can be used prior to more invasive procedures such as cardiac interventions.

Omphalophlebitis may predispose the calf to endocarditis since one of most common organisms involved in endocarditis is *Trueperella pyogenes* (Smith, 2015). Ultrasonography can be a useful tool to aid in diagnosis of inflammation of the umbilical structures, or more specifically either omphaloarteritis (arteries) or omphalophlebitis (vein) (Smith, 2015*).* Septicemia can be a consequence if there is an ascending infection present in the umbilicus. *Trueperella pyogenes, E. Coli, Proteus* and *Enterococcus* are pathogens most commonly cultured from the calf umbilicus and it may result in liver abscessation if the infection travels the length of the umbilical vein (Smith, 2015). Thoracic ultrasound can aid in detection of pleural or pericardial effusion, left atrial or other chamber enlargement all of which could be signs of heart failure. The main advantage of focused thoracic assessment is that this diagnostic modality can be used by non–radiology clinicians. Finally, computed tomography (CT) is a valuable imaging tool as it is superior to standard radiography in defining structures, visualization of lesions and eliminating superimposition of structures.

Case demonstration of the value of echocardiography in the calf

Case 1

A 2–week–old Holstein – Friesian heifer presented for anorexia, ataxia and profound weakness. On presentation, she was laterally recumbent with a 104°F temperature (101.5 – 103.5°F), with a mildy elevated pulse ([120], 70 – 100 bpm) and a normal respiratory rate ([40], 15 – 45 brpm). A complete blood count (CBC) and serum biochemistry panel were performed and revealed profound hyponatremia (114mmol/L, 132 – 152mmol/L), hypochloremia (84 mmol/L, 97 – 111 mmol/L),

hypoproteinemia (5.0g/dL, 7.0 – 8.4 g/dL), hypoglycemia (42mg/dL, 61 – 102 mg/dL), and a mature neutrophilia (7,636 cells/uL, 600 – 4,000 cells/uL). A cerebrospinal fluid (CSF) centesis and analysis was performed and was within normal limits (clear, colorless, RBC 15/ul, nucleated cells 9/ul, protein 9.4 mg/dL, no evidence of infectious agents, inflammation or neoplasia). The patient was hospitalized for supportive care and diagnostics. Intravenous fluids (Lactated Ringers Solution + 2.5% Dextrose, initially 120 ml/hr then decreasing to 60ml/hr for a total of 5000ml given over 3 days), a plasma transfusion (frozen, 350 ml given IV once), florfenicol (20mg/kg, 900mg, SQ, once) and ceftiofur (2.2mg/kg, 100mg, SQ Q12H for 6 days) as well as a vitamin E and selenium (0.5ml, 2.5mg selenium, 25mg vitamin E was given SQ once) cardioprotective supplementation were administered. On day 3 of hospitalization, repeat serum biochemistry was performed due to persistent weakness and diarrhea. Hypomagnesmia (1.2mg/dL, 2.0 - 2.8 mg/dL) was noted and an oral electrolyte solution with added magnesium sulfate (MgSO4) (0.5g/kg (30cc) diluted in 2 quarts of electrolyte solution) was given PO Q24H. Worsened tachycardia (150 – 170 bpm, N= 70 - 100) was noted on the third day and flunixin meglumine (1.1 mg/kg, 38.5mg, IV Q24H for 4 days) was started for possible cardiac inflammation. Differential diagnoses at this time included cardiac inflammation secondary to possible sepsis, electrolyte imbalance, and congenital cardiac defects. On day 7 of hospitalization, the patient was markedly improved but was persistently tachycardic (130 – 170 bpm) at rest. A grade 2 holosystolic murmur was auscultated with the PMI on the left side adjacent to the pulmonic valve. ECG was performed, and confirmed sinus tachycardia. Due to the persistent tachycardia and evolution of a murmur, serum was submitted for evaluation of cardiac troponin I. Results demonstrated elevated value at 0.273 ng/ml (0.00 – 0.05 ng/ml). For further investigation, echocardiography was performed. Findings on the

initial echocardiogram included mild tricuspid insufficiency and an irregular vegetative lesion associated with an aortic valve leaflet and the fossa ovale.

Echocardiographic findings were highly suspicious for a vegetative valvular lesion associated with bacterial endocarditis. Given patient stability, the patient was discharged with instructions to return for a 2-week follow–up echocardiogram. Findings on the second echocardiogram included a hyperechoic, thickened aortic valve and persistence of the aortic valve lesion (Figure 2 and 3). A small, 3mm, irregularly marginated, hyperechoic, out-pouching in the region of the foramen ovale was also noted (Figure 4). Sonographic screening of the umbilicus for omphalophlebitis was performed and the umbilicus was normal (*not shown*). Figure 1.

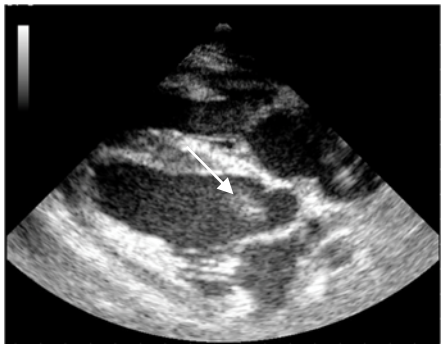


Figure 1.a - Echogenic vegetative lesion on the aortic valve upon initial evaluation

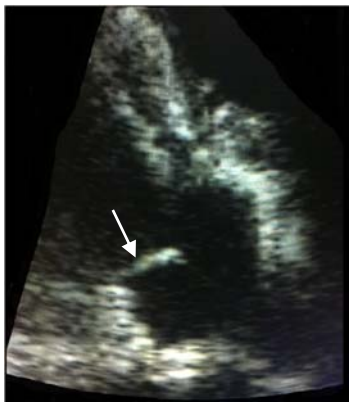


Figure 1B: Echocardiograph. Thickened, hyperechoic aortic valve.

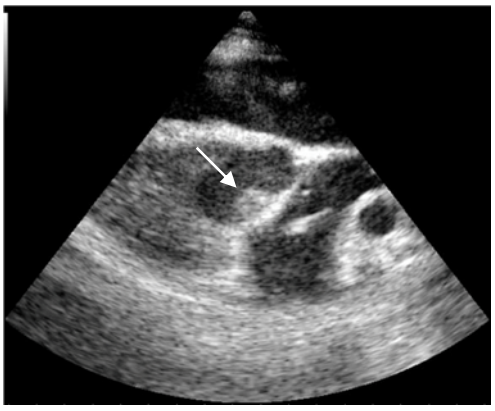


Figure 1C: Echocardiograph. Vegetative aortic valve lesion on follow up examination.

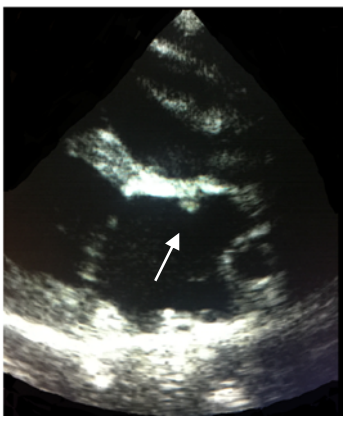


Figure 1D: Echocardiograph. Vegetative fossa ovale lesion.

Differentials for the persistent echogenic lesions of the aortic valve included infectious nodular proliferation (abscess or granuloma), and vegetation, or to a lesser degree valvular dysplasia. The presence of the fossa ovale lesion was also concerning, as it was possible that this lesion served as the infective focus. Review of the images remotely by a board-certified cardiologist confirmed these suspicions, and other diagnoses were considered highly unlikely. A series of 3 consecutive negative blood cultures was recommended at the time of diagnosis. This was not performed due to the likelihood of negative culture as the patient had been on antibiotics. Three negative sequential blood cultures could have been performed following the discontinuation of all antibiotic therapy to screen for recrudescence or low-grade persistent infection and complete resolution of septicemia.

Treatment for bacterial endocarditis is antibiotic therapy with penicillin. Blood culture may help with antibiotic selection, but it should be noted that false negatives can occur if the sample is not taken after peak fever or if the patient is on antibiotics at the time of culture. Penicillin is the first choice for clinicians since *Trueperella pyogenes* and *Streptococcus sp*. are the most common organisms involved with endocarditis (Divers, 2008). Penicillin is given at 22,000 to 33,000 IU/kg twice daily for a minimum of 3 weeks. Ampicillin is an alternative choice at 10 to 20mg/kg twice daily. Calves with jugular venous distention or edema require furosemide 0.5 mg/kg once or twice daily but only on an as – needed basis because it may result in electrolyte depletion or dehydration (Divers, 2008). Signs of clinical improvement include absence of fever, increased appetite, resolution of the heart murmur and tachycardia, as well as echocardiographic evidence of resolution of the endocarditis lesions (Divers, 2008). It is recommended to perform serial cultures

with having 3 serially negative cultures correlating with a true negative result. Calves (and cattle in general), with endocarditis and congenital cardiac disease have a guarded to grave prognosis. The prognosis may be improved for patients that are diagnosed before the clinical signs of heart failure and the patients that respond to antibiotic therapy (Divers, 2008). Repeat echocardiography allows for serial monitoring and re-assessment of lesions for evaluation of progression, which can provide valuable long – term prognostic information and, in the author's opinion, can aid in decision making when humane euthanasia should be considered (Divers, 2008). Other antibiotic choices include ampicillin or ceftiofur. The patient was sent home for monitoring and her owners were advised that increased activity, once she was turned out to open pasture, may result in sudden death. At the time of publication of the current report, almost one year following presentation, the owner states that she is doing well and has had no medical issues.

Case 2

A 2 month old Holstein-cross bull calf presented for failure to thrive and coughing. Physical examination revealed a normal 102.3F temperature (101.5 – 103.5), a normal pulse rate at 80 beats per minute (80 – 100) and a slightly elevated respiratory rate at 48 breaths per minute (15 – 45). The calf was a smaller stature compared to age matched herdmates. A grade 4/6 right-sided cardiac murmur was auscultated and an umbilical swelling was noted on routine evaluation. Differential diagnosis for the murmur included a VSD, ASD, PDA and tricuspid endocarditis. Echocardiography was performed, which revealed turbulence in the right atrium, a cyst like lesion proximal to the tricuspid valve annulus, and turbulent flow at the lesion along the right atrial surface. A tricuspid valve mass and tricuspid valve dysplasia were considered but further diagnostic imaging was necessary to facilitate diagnosis. Echocardiography also showed blood flow from the aorta to the pulmonary artery. The primary consideration for differentials at that

time, prior to evaluation by a boarded cardiologistwas the presence of a PDA. The umbilicus was also examined sonographically at this time and findings were believed to be consistent with an extra-abdominal abscess. About 10 days later, he was diagnosed with an umbilical hernia. The hernia was medically treated with a belly band. At 4 months of age, a follow-up echocardiogram was performed by a boarded cardiologist and an agitated saline gas bubble study was performed. The test was negative for the presence of an ASD, VSD or PDA.

Angiocardiography was performed one day later. A cardiac catheter was placed into the right atrium at which time atrial premature complexes were noted. The catheter was advanced into the pulmonary artery without incident and a pressure pull-back study was completed. Atrial fibrillation was noted as the catheter was returned to the right atrium. Lidocaine was administered, the catheter was drawn back into the cranial vena cava and the patient returned to normal sinus rhythm approximately 5 – 8 minutes later. The catheter was advanced into the right atrium and 25 ml of an iodinated contrast was administered. The test was positive for a large filling defect within the mass like lesion within the right atrium. A mass or windsock anomaly (an anomaly not previously described in the bovine species) was considered most likely. The catheter was advanced into the right ventricular outflow tract (RVOT) and 10ml of contrast was injected which identified apparently normal anatomy. The catheter was withdrawn into the right ventricle (RV) and 25ml of contrast was used for angiography showing normal RV size and shape. Then 20ml was injected into the caudal vena cava identifying normal blood flow into the right atrium. The catheter was withdrawn into the cranial vena cava and 20ml of contrast was injected showing normal return into the right atrium with the previously described filling defect present. The catheter was removed, direct pressure was applied digitally for approximately 10 minutes and the patient recovered uneventfully.

The calf was scheduled to undergo cardiac gated computed tomography (CT), and cardiac angiography. The calf had a jugular catheter placed and was prepped to receive contrast agent administered at 5 mls/s for a total of 150ml followed by a saline chaser. The contrast was diluted 60/40 with saline to provide a lighter enhancement. Gated CT was not performed due to the inability to lower the calf's heart rate in the absence of propranolol and esmolol which were unavailable at the time the study was performed. Regardless, a round, 3 – 4 cm, distinct filling defect (mass) located cranioventrally in the lumen of the right atrium, just proximal to the tricuspid valve annulus was noted. Differentials for this filling defect included granuloma, neoplasia, windsock deformity or some other aneurysmal mass. Anomalous vessel and or blood flow within the mass was highly suspected given the turbulence seen on CFD evaluation.

The calf continued to appear bright, alert and responsive. However, when compared to age matched herdmates, the calf's growth was obviously stunted from his condition. Pulmonary pressures and the gradient across the tricuspid valve was suspicious for early pulmonary hypertension. All imaging studies were reviewed by a boarded cardiologist and the calf was considered at high risk for sudden death, tacharrythmias, pulmonary hypertension and right sided cardiac failure. True outcome for the case of the current report is unknown, given that soon after the advanced imaging took place, the patient was culled and processed for human consumption. Limited necropsy evaluation of the pluck was performed which confirmed the presence of a mass within the right atrium (Figure 2a and 2b).

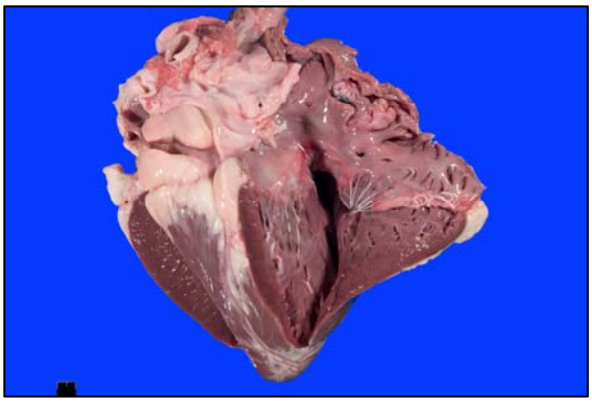


Figure 2a: Necropsy image showing filling defect (mass) associated with right atrium.

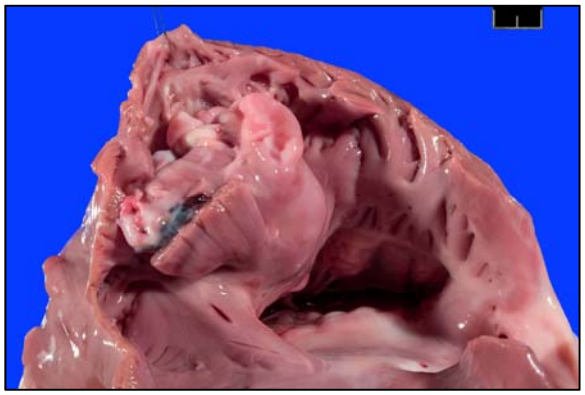


Figure 2b: Necropsy image showing close-up view of mass

The necropsy was performed and reviewed by a board-certified pathologist. In the pathologist's opinion, the lesion was an aberrant overgrowth of tissue and vessels that are normally present in that area which is consistent with a diagnosis of hamartoma.

Cardiac vascular hamartoma is a very rare anomaly, therefore very limited literature regarding treatment and prognosis for this condition in cattle exists. Histopathology is gold standard to diagnose most tumors; therefore, without a biopsy other more common cardiac diseases or right atrial neoplasms should be considered. Since right atrial tumors such as lymphoma or severe endocarditis cannot be ruled out, the long – term prognosis for such suspected diseases is poor.

Conclusion

Diagnosing cardiac disease in calves remains a challenge due to lack of clinical signs and occasionally, undectable cardiac changes early in life. Blood work findings can be non-specific and in our clinical experience, blood culture may be falsely negative despite the presence of an infective focus or septicemia. Multiple imaging modalities can be instituted including radiographs, positive contrast studies cardiac angiography, echocardiography, agitated saline bubble study

assisted echocardiography and CT cardiac angiography can be considered in cases of highly valuable cattle or bovine pets. Echocardiography remains the most clinically accurate test and provides the best antemortem assessment of cardiac disease in calves. Congenital cardiac defects or acquired disease can be easily diagnosed with this imaging modality. Potential limitations for each of the described modalities exist. Radiographs may be a low – cost method to diagnose certain heart conditions but a big limitation is the superimposition of structures on the images. CT scans can overcome structure superimpostition; however, limitations for this modality include expense, size of patient (mature cattle), the use of radiocontrast agents and delivery of higher doses of radiation. Cardiac angiography is an excellent tool to detect cardiac blood flow but limitations for angiography include a possible reaction to the contrast agent, and inadvertent introduction of bacteria. Additionally, the process requires a highly skilled board certified practitioners. ECG is an excellent tool to diagnose arrhythmias; however, it has limited value in determining cardiac pathology or chamber size (Divers, 2008). Serum levels of cardiac troponin I has been shown to be a highly sensitive and highly specific indicator of myocardial damage; however, this marker is of best value when determined immediately after peak cardiac injury (Tunca, 2008). Echocardiography may not be readily available in general practice or in the field, or if financial restraints exist; therefore, cardiac troponin I levels can be a very valuable clinical assessment of cardiac injury. Serum protein troponin levels are directly correlated with the degree of myocardial damage. If advanced imaging modalities are not a viable option, the measurement of cardiac troponin I levels can be a suitable alternative to diagnose and prognosticate cardiac disease.

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