Hulk's Cardiac Calf-tastrophe

Pentalogy of Fallot

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Introduction

Pentalogy of Fallot (POF) is defined as a congenital heart abnormality that includes the 4 components of tetralogy of Fallot (TOF), pulmonic stenosis, overriding aortic arch, ventricular septal defect, and right sided hypertrophy, with either a patent ductus arteriosus (PDA) or atrial septal defect[3,7,14]. POF has been described in cattle, goats, dogs, Siberian tigers, and humans[7]. Clinical signs consistent in patients with POF or TOF include cyanosis, heat and exercise intolerance, lethargy, poor-doing, tachycardia, and tachypnea[3,7,14]. In cattle, congenital heart defects represent less than 3% of all congenital defects[11]. In addition, it has been reported that congenital heart defects have a prevalence of 0.17% in cattle[5]. Though statistically cardiac defects are uncommon, they may occasionally be seen in practice given the large population of cattle.

History and Presentation

Hulk (calf #701), a 2 week old Holstein-Friesian bull calf, presented to Mississippi State University College of Veterinary Medicine (MSU-CVM) Food Animal Service on June 23, 2020 as part of the MSU-CVM Calf Rearing Project. He had a limited history of lethargy, unthriftiness, and dehydration. On Hulk's initial presentation to MSU-CVM, he was quiet, alert, and responsive. He had a body condition score of 2/5, with 3/5 being ideal. He had a temperature of 102.9 Fahrenheit, a heart rate of 180 beats per minute, and a respiratory rate of 60 breaths per minute. Hulk had tacky mucous membranes and was noted to be 5% dehydrated. His capillary refill time was less than 2 seconds. On auscultation of his chest, no crackles or wheezes were appreciated. However, it was noted that he had a mild cough. In addition, it was appreciated that he had abdominal effort on inspiration. Furthermore, the beating of his heart was noticeable on visual inspection of his thorax. A left sided, grade 3/6 holosystolic murmur with the point of

maximum intensity over the mitral valve was appreciated and was characterized as a gallop rhythm. The remainder of his physical exam was within normal limits.

Diagnostics

Due to the specific circumstances of limited finances for diagnostic workup for hutch calves in the Calf Rearing Project, limited pre-mortem diagnostics were performed to diagnose his heart murmur. Modalities such as electrocardiography and radiography can be used to narrow down and eliminate potential diseases[15]. Electrocardiogram of TOF is usually consistent with right ventricular enlargement. These include a deep S wave, right axis deviation, and terminal orientation of the QRS complex toward the right ventricle[15]. However, radiographic signs are variable. Abnormal radiographic signs may include enlarged pericardial silhouette and abnormal lung patterns[15]. On the other hand, electrocardiography of PDA patients usually consist of atrial and left ventricular enlargement. These signs include widened or plateaued P waves and spiked QRS complexes[15]. Radiographic signs that are suggestive of a PDA are enlargement of the main pulmonary artery, right auricle, and descending aorta. Nonetheless, these modalities cannot definitively diagnose heart diseases. Echocardiography is the modality of choice in both small animal and large animal medicine to confirm heart diseases in patients[15].

Echocardiography is occasionally performed in food animal medicine. The technique is usually done while the animal is standing with both the left and right third, fourth, and fifth intercostal spaces shaved for complete examination of the heart[1]. A 3-0 MHz phased array transducer in 2-D mode or M-mode echocardiography is used to ultrasound the heart[12,13]. The interventricular septum and the left ventricular outflow tract can be appreciated by placing the probe in the caudal long cardiac axis position on the right side[1,6]. Evaluation of these structures are of great importance to identify abnormalities, such as interventricular septal defects and

overriding aortic arches. Comparisons of the right and left ventricular free walls and lumens can be done using the caudal short axis view or the caudal long axis view of the heart[1,6]. Measurements of the right and left ventricular free walls are used to identify normal or abnormal patterns of blood flow through the heart. The cranial long axis view of the heart can be used to image the right ventricular outflow tract[1,6]. This is used to assess the pulmonary artery and valve for abnormalities, such as narrowing of the lumen or insufficiencies of the valve. A brief echocardiogram was performed on Hulk on 7/17/2020. It revealed thickened and irregular tricuspid and mitral valves, which were suggestive of endocarditis. He was presumptively diagnosed with valvular endocarditis secondary to bacteremia.

Following initial presentation, Hulk was monitored and placed outside in a calf hutch. On 7/7/2020, it was noted that he had a grade 4/4 diarrhea with blood in his stool. Differentials included Salmonellosis, Cryptosporidiosis, and Coccidiosis. He was moved to isolation and was treated accordingly. In isolation, no signs of respiratory distress were appreciated. Isolation is a separate, air-condition building. The cool temperature of isolation removed many stressors, such as heat and hyperthermia, that would cause peripheral vasodilation and exacerbate shunting of de-oxygenated blood to his systemic circulation. This would explain the reduction of respiratory effort appreciated in isolation.

Hulk remained in isolation until all signs of diarrhea were resolved. On 7/28/2020, he was moved back outside and monitored. Once outside, it was noted that he had an increased respiratory rate with abdominal effort. Over the following days, he became lethargic and partially anorexic. On 8/11/2020, he began to bloat and was brought into the hospital for evaluation. A tube was passed down his esophagus and approximately 2 liters of foul smelling milk was removed. He remained in hospital overnight, however he remained lethargic and

depressed. On 8/12/2021, Hulk was humanely euthanized due to poor systemic condition and ill thrift, along with guarded prognosis due to presumed bacterial endocarditis.

A necropsy was performed on 8/12/2020 for further evaluation and determination of Hulk's poor-doing. External findings on necropsy were consistent with pre-mortem examinations. He was moderately thin with decreased subcutaneous and intrabdominal fat. Examination of the thoracic cavity revealed an enlarged and globoid heart. The right ventricle below the pulmonic valve was moderately constricted and the pulmonary artery was mildly dilated just distal to the semi-lunar valves. The right ventricular free wall was thickened and approximately the same size as the left ventricular free wall. There was a high ventricular septal defect that communicated the right and left ventricles. The aorta was displaced toward the right of the body and laid immediately above the septal defect. A PDA was noted and described as not being dilated. The lungs were severely edematous. The signs are suggestive of congestion and pulmonary hypertension that lead to pulmonary edema. The liver had a mildly increased reticular pattern. There was a moderate amount of sand in his rumen, reticulum, omasum, and abomasum. In addition, there was a large ulcer located in the rumen. Lastly, there was retroperitoneal hemorrhage at the pelvic inlet that was associated with the left testicular artery. This was most likely caused by the castration performed a week prior. Findings on necropsy diagnoses pentalogy of Fallot.

Treatment and Management

Treatment and management of tetralogy of Fallot and PDA is not recommended nor practical in cattle. Life expectancy of patients with tetralogy of Fallot averages around a few months of life[15]. However, it was reported that an exercise intolerant and cardiovascular compromised Holstein heifer lasted 2 years with tetralogy of Fallot[10]. Nevertheless, the study

suggested that life expectancy after 2 years was unexpected. Similarly, life expectancy of calves with PDA is not expected to be longer than a few months[15].

In small animal medicine, phlebotomy is the medical management of choice for patients with TOF[9]. These patients commonly have polycythemia and the primary goal of phlebotomy is to reduce the clinical signs that accompany polycythemia. Palliative surgery and interventional therapy is an option, but requires experienced surgeons. Case studies in dogs report variable success after interventional balloon valvuloplasty of the pulmonic valve and palliative surgeries, such as the Blalock-Taussig technique[2,9].

On the other hand, stabilization and reduction of pulmonary hypertension prior to surgical or interventional treatment is the primary goal in managing PDA patients[9]. The main sequela in patients with a PDA is pulmonary hypertension caused by increase pre-load of blood into pulmonary circulation. Diuretics and vasodilators, such as furosemide, ACE-inhibitors and sildenafil, can be used to reduce pulmonary hypertension[9]. Once pulmonary pressures have decreased, intrathoracic ligation or intravenous occluder devices are used to close the PDA[4,9].

Pathophysiology

Tetralogy of Fallot is a complex disease state that is formed by the combination of four congenital heart defects: pulmonic stenosis, right sided hypertrophy, ventricular septal defect, and overriding of the interventricular septum by the aorta[9,15]. This congenital defect arises from an abnormal development of the conotruncal septum in the embryonic heart, which, narrows the right ventricular infundibulum[8,9]. The narrowing of the right ventricular infundibulum leads to pulmonic and right outflow tract stenosis. The conotruncal septum is responsible for forming the upper portion of the interventricular septum. Due to the abnormal cranial position and the

narrowing of the right ventricular infundibulum, the conotruncal septum is unable to partake in the closure of the interventricular septum[8,9].

As a result of the developmental abnormalities, TOF is primarily a shunting defect. The flow of blood through the heart is largely determined by the severity of the pulmonic stenosis[8,9]. As a general rule, blood will flow to areas of least resistance. In most cases of TOF, resistance through the pulmonic valve is greater than the pressure created by the systemic circulation. Subsequently, unoxygenated blood will flow from the right ventricle through the ventricular septal defect and out the aorta. The decrease of blood flow through the pulmonary circulation and into the left atrium results in a decrease of oxygenated blood that reaches the systemic circulation. This classical presentation of TOF is referred to as a cyanotic TOF. However, if pressures being exerted by the pulmonic stenosis is less than pressures of the systemic circulation, then blood flow will continue its normal trajectory and will adequately oxygenate[8,9]. This less common version of TOF is referred to as acyanotic TOF. Clinical signs of acyanotic TOF patients usually include exercise and heat intolerance, tachycardia, tachypnea, and ill to thrive[9].

The physiologic consequences of TOF depend solely on the severity of pulmonic stenosis and changes in systemic vascular resistance[8,9]. Pulmonary resistance creates a fixed amount of right-to-left shunting. However, the amount of right-to-left shunting changes as systemic vascular resistance changes[8]. For example, in circumstances of peripheral vasodilation, such as exercise, systemic vascular resistance decreases causing an increase in right-to-left shunting. Furthermore, in circumstances of peripheral vasoconstriction, systemic vascular resistance increases causing a decrease in right-to-left shunting. In addition, pulmonic stenosis causes

increased right ventricular pressures and turbulent flow that produces compensatory right sided hypertrophy[9,15].

Similarly, PDA is also a ductal defect. It is the failure of the ducuts arteriosus to close post-partum[9,15]. The ducuts arteriosus is a fetal structure that allows communication between the main pulmonary artery and the aorta. This allows maternal, oxygenated blood to by-pass the lungs and enter the systemic circulation. In most cases, it causes a left-to-right shunt due to differences in pressure gradients[9]. Pressure leaving the aorta is much greater than pressure entering the pulmonic circulation. Therefore, blood prioritizes traveling through the PDA and back into the pulmonary circulation[9]. Consequently, an increase in left sided pre-load causes compensatory left sided hypertrophy and pulmonary hypertension[9].

Conclusion

During his stay at MSU-CVM, Hulk developed severe diarrhea and fever. As a result, it was believed that he was bacteremic. With the combination of fever, grade 4/4 diarrhea, and a heart murmur, Hulk was presumptively diagnosed with valvular endocarditis. Unfortunately due to the limited circumstances of the Calf Rearing Project, diagnostics were not performed to accurately assess Hulk's condition. Diagnostics such as a complete blood count profile could have potentially revealed polycythemia and a complete cardiac workup would have diagnosed POF.

Currently, only 7 cases of POF have been reported in cattle[7]. This case was unique in that Hulk was diagnosed with the acyanotic version of POF. The most likely explanation for his adequate oxygenation is that the resistance created by the pulmonic stenosis mildly exceeded or was equal to the systemic circulatory pressure, creating mild amounts of right-to-left shunting. However, it is undetermined if his PDA played a role in oxygenating blood and creating his

acyanotic presentation. In circumstances of right-to-left shunting, de-oxygenated blood would flow from the right ventricle to the left ventricle and out the aorta. A PDA would permit de-oxygenated blood to circulate back through the lungs and become oxygenated.

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