Demi’s Dysphagia Dilemma

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Clinicopathologic Conference – CVM 5301

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June 26, 2020

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INTRODUCTION:

During embryonic development, the great vessels of the heart and their branches develop and regress into important structures responsible for blood circulation in the adult body. These vessels can become malformed producing vascular ring anomalies which can constrict the esophagus and remain subclinical, or can present with serious complications at a young age, such as failure to thrive, malnourishment, regurgitation, respiratory distress, and aspiration pneumonia. The most common vascular ring anomaly is the persistent right aortic arch (PRAA). This congenital abnormality occurs when the right fourth aortic arch develops into the adult aortic instead of the left fourth aortic arch. Due to this development, the aortic arch is transpositioned to the right of the esophagus and the ligamentum arteriosum, a normal structure connecting the main pulmonary artery to the aorta, is responsible for the esophageal entrapment. This report describes a case of PRAA in a young canine, its surgical correction and outcome.

MATERIALS AND METHODS

An approximately 8-week-old intact female Siberian husky-Hound mixed breed dog was referred to the Mississippi State University (MSU) College of Veterinary Medicine on February 14, 2020 for evaluation of a suspected vascular ring anomaly. She weighed 2.76 kg (6.1 lb) with a thin but acceptable body condition score of 4/9 and was apparently healthy.

Medical Records Review – The patient was initially evaluated at a shelter in Texas. After being rescued by animal services, she had a regurgitation episode which was attributed to eating rapidly. After subsequent episodes, radiographs were taken which revealed a dilated esophagus beginning in the cervical spinal region and continuing into the chest until tapering at the base of the cardiac silhouette. She was presumptively diagnosed with a vascular ring anomaly causing megaesophagus. She was then adopted by a rescue group and transported from her shelter in

Texas to MSU-CVM. Her transporter noted that she ate canned puppy food well and showed no signs of regurgitation.

Upon presentation the patient was bright, alert, and responsive. She had a heart rate of 134 beats per minute with strong synchronous pulses, a respiratory rate of 44 breaths per minute with normal effort, and a body temperature of 101.2 degrees Fahrenheit. On cardiothoracic auscultation, no murmurs, arrhythmias, or harsh lung sounds were detected. Her mucous membranes were pink and moist with a capillary refill time of 1-2 seconds indicating adequate hydration. All her deciduous teeth were present, and no adult teeth were coming in. Her eyes were bright and free of discharge. She had unilateral right-sided, clear to light yellow nasal discharge. Her abdomen was soft and non-painful on palpation with no organomegaly appreciated. Her lymph nodes were small, soft, and symmetrical. The remainder of her physical exam was unremarkable. Routine complete blood count and serum biochemistry were performed. In combination with the clinical signs and physical exam findings, the thoracic radiographs and barium esophagram (Images 1-3) led to a presumptive diagnosis of persistent right aortic arch with focal megaesophagus cranial to the cardiac silhouette. Surgery was used to confirm the diagnosis of persistent right aortic arch with esophageal entrapment by the ligamentum arteriosum. Maropitant (1 mg/kg PO) was given the evening before surgery. The preanesthetic medications used were methadone (0.2 mg/kg IM) and midazolam (0.2 mg/kg IM). Alfaxalone was used to induce her (given to effect at 3.4 mg/kg IV) and she was maintained on isoflurane inhalant anesthesia. Lactated ringers' solution intravenous fluids (2 ml/kg/hr) were used for fluid maintenance and constant rate infusions of fentanyl (5-10 mcg/kg/hr IV) and lidocaine (50-100 mcg/kg/hr) for pain control. Cefazolin was given perioperatively (22 mg/kg IV

every 90 minutes). Repeat thoracic radiographs and barium esophagram were performed 7 days postoperatively.

Surgical Procedure – A left lateral 4th intercostal thoracotomy approach was made. The vagus and phrenic nerves were delicately dissected using right angle forceps and vascular loops were used to retract the vagus nerve dorsally and the phrenic nerve ventrally. A window was carefully dissected into the mediastinum using a combination of sharp and blunt dissection to expose the ligamentum arteriosum. Blunt dissection using right angle forceps was used to circumferentially dissect the ligamentum arteriosum. The ligamentum arteriosum was double ligated using 2-0 Silk braided suture. The ligamentum arteriosum was then transected and released in a controlled manner (Image 4). A Foley catheter was then passed into the esophagus and inflated to help identify any remaining fibrous tissue present. All identified fibrous bands were dissected from the esophageal wall. The cranial lung lobes were repositioned, and the thorax was lavaged with approximately 700 mls of sterile saline solution. A 3 mm hole was noted on the caudal edge of the caudal part of the left cranial lobe. A vascular clamp was placed 5 mm proximal to this portion of the lung and a line of 3-0 Monocryl was used in an overlapping continuous pattern proximal to the forceps. The lungs held pressure and the leak was resolved. A 14-gauge Mila thoracostomy tube was placed to drain air and fluid from the pleural space and monitor for a pneumothorax. A 16-gauge fenestrated catheter was placed within the muscle layers in the 4th intercostal space for administration of bupivacaine for pain control. During anesthesia, the patient experienced hypothermia and hypotension which was managed by decreasing the isoflurane concentration, giving doses of glycopyrrolate (4.8 mcg/kg IV) and a single Vetstarch bolus (2 ml/kg IV). During recovery, a dose of glycopyrrolate was inadvertently

given. The patient did not have an elevation in heart rate and was monitored for 1 hour after administration. The remainder of recovery was uneventful.

The patient was continued on lactated ringers' solution intravenous fluids (4 ml/kg/hr) and a fentanyl constant rate infusion (3-5 mcg/kg/hr) throughout the night postoperatively. She was started on acetaminophen and codeine suspension for continued pain management for 7 days (2 mg/kg PO every 8 hours). For local analgesia, bupivacaine was injected into the fenestrated catheter located at the thoracotomy site every 6 hours for 2 days (1 mg/kg). The fenestrated catheter was removed when her pain was adequately managed with oral medication. The thoracostomy tube was aseptically aspirated every 4 hours until negative pressure was achieved and removed 2 days postoperatively when her chest stopped producing fluid. The patient's thoracotomy site was cold packed for 3 days. A seroma developed ventral to the incision, a gravity dependent location, and the site was warm packed for 3 days which resolved the seroma.

Elevated feeding protocol – In the first 2 weeks following surgery, the patient was fed a blended gruel containing 1 can Purina Pro Plan Focus Puppy mixed with 1/2 cup of water to meet the daily calorie requirement (RER x 3). This gruel was divided into 4 meals and fed every 6 hours. The patient was elevated while feeding and for 10-15 minutes after feeding. Discharge instructions were given to gradually decrease the water added to the food weekly until offering canned food alone (Table 1). If regurgitation episodes occurred, instructions were given to revert to previous week's protocol. If no regurgitation occurred, the patient could be challenged by feeding in a horizontal position. Endoscopy was offered during hospitalization to evaluate the esophagus, but the client declined this procedure at this time.

RESULTS

Based on the clinical signs, physical exam findings, diagnostic imaging, and surgical procedure, the patient was diagnosed with a persistent right aortic arch with focal megaesophagus cranial to the cardiac silhouette (Images 1-3) and esophageal dysmotility. The preoperative thoracic radiographs showed a leftward deviation of the trachea and the barium swallow study revealed a focally dilated esophagus with an area of constriction at the base of the cardiac silhouette. Radiographic leftward deviation of the trachea is pathognomonic for PRAA. The bloodwork findings had mild abnormalities, but none of clinical significance. Complete blood count revealed a mild normocytic, normochromic anemia with PCV of 25%, mildly decreased hemoglobin concentration of 8.6 g/dl, mild hypoproteinemia of 4.5 g/dl, and mild neutropenia of 3373/ul (normal range for puppies at 5-6 weeks of age is a PCV of about 30% and plasma protein of 5.3 g/dl, Weiss and Tvedten, 2004). Serum biochemistry revealed mild hyponatremia of 141.7 mmol/L, mild hyperglycemia of 144 mg/dl, mildly decreased ALT of 4 U/L, mild hypoproteinemia of 4.4 g/dl, mild hypoalbuminemia of 2.4 g/dl, mild hypoglobulinemia of 2 g/dl, normophosphatemia of 7.6 mg/dl (normal serum phosphorus range of young dogs <12 months of age is 4-9 mg/dl, Nelson et al., 2004), mildly decreased osmolality of 276 mOsm/kg, mild hypomagnesemia of 1.6 mg/dl, and mildly increased CK of 436 U/L.

Presence of a persistent right aortic arch with esophageal constriction by the ligamentum arteriosum was confirmed during surgery. There were also numerous fibrous bands surrounding the esophagus that had to be dissected to relieve esophageal stricture. Mild surgical and anesthetic complications occurred during surgery. Postoperative healing occurred in an expected amount of time and without complication. Repeat radiographs and dynamic esophagram were performed 7 days postoperatively (Images 5-7). Thoracic radiographs revealed an alveolar pulmonary pattern within the left cranial lung lobe, a mild pneumothorax, focal dilation of the

cranial esophagus, and leftward deviation of the trachea. Dynamic esophagram revealed esophageal dysmotility throughout the length of the esophagus with esophageal dilation cranial to the cardiac silhouette (focal megaesophagus). Barium was able to pass slowly into the stomach in small amounts. The patient gained 1.2 kg over 13 days and did not have any further regurgitation episodes. The patient was adopted and 4 months post presentation to MSU-CVM has been consistently gaining weight and has not had any further regurgitation episodes. The patient continues to eat in an elevated position.

DISCUSSION

In embryonic development, the cranial aspect of the primitive straight-tube heart gives rise to the ventral aortae where there are six pairs of aortic arches that develop or regress into the great vessels responsible for adult blood circulation. In normal fetal development, the first, second, and fifth arches regress. The third arches join the primitive dorsal aortic arch and become the common carotid arteries. The left fourth aortic arch becomes the aorta and in the adult heart is connected to the left ventricle. The sixth arches become the pulmonary trunk and pulmonary arteries and in the adult heart is connected to the right ventricle. The ductus arteriosus arises from the left sixth aortic arch and is important for fetal blood circulation to bypass the underdeveloped lungs and later becomes the ligamentum arteriosum at birth. The right fourth arch contributes to the right subclavian artery. When malformations occur of this process, it most commonly involves the fourth, fifth, and sixth aortic arches (Radlinsky, 2013; Pasquini et al., 2007). The persistent right aortic arch (PRAA) is the most common vascular anomaly, as previously described, this malformation occurs when the right fourth aortic arch becomes the adult aorta instead of the normal left fourth aortic arch. There are other vascular anomalies reported, although less common (Figure 1). The entrapment of the esophagus occurs by the

presence of the ligamentum arteriosum (or patent ductus arteriosus) dorsally, the base of the heart ventrally, the main pulmonary artery on the left, and the aortic arch on the right (Figure 2) (Radlinsky, 2013; Caliskan et al. 2018). This constriction on the esophagus prevents food from passing into the distal esophagus and stomach. Instead, it pools cranial to the heart base. This mechanical obstruction leads to clinical signs such as malnourishment, regurgitation, coughing, and respiratory distress if the trachea is involved or if aspiration pneumonia has occurred from chronic regurgitation episodes. These patients are usually identified around weaning, most being diagnosed between 8 weeks to 6 months of age (Radlinsky, 2013). There have been cases reported of patients being identified later in life due to partial obstruction. German shepherd dogs, Irish setters, and Boston terriers are the most affected breeds of dogs. Cats are less commonly affected, but Siamese and Persian breeds are reported (Caliskan et al., 2018).

Diagnosis of persistent right aortic arch is made based on clinical signs and history, physical exam findings, thoracic radiographs, fluoroscopy, contrast CT or MRI, surgical findings, and esophagoscopy. Physical exam findings may be completely normal except for a thin body condition and being small for the breed, as in our case. Abnormalities may include an enlarged esophagus at the thoracic inlet and caudal neck. On cardiothoracic auscultation, a murmur may be heard if there is a patent ductus arteriosus present, and crackles may be heard if the patient has suffered aspiration pneumonia. These abnormalities did not appear in our case.

Diagnostic imaging would reveal a dilated cranial esophagus and leftward deviation of the trachea on thoracic radiographs. Ventral deviation of the trachea may also be present and has been associated with the additional presence of an aberrant retropharyngeal left subclavian artery (Buchanan, 2004; Caliskan et al. 2018). Fluoroscopy can be used to evaluate the motility of the esophagus, the focal megaesophagus does not usually have normal peristaltic contractions and

the dysmotility can continue throughout the extent of the esophagus. In our patient's case, she had the classic radiographic findings. Repeat imaging was performed 7 days postoperatively. The radiographs revealed a focally dilated esophagus and leftward deviation of the trachea. There was also an alveolar pulmonary pattern within the left cranial lung lobe and a pneumothorax, both expected findings due to recent surgery. The fluoroscopy revealed the constriction on the esophagus had been resolved, but that area of the esophagus had not returned to normal esophageal diameter and normal peristaltic contractions had not returned. The barium pooled cranial to the base of the heart with only a minor amount passing into the stomach. Mechanical esophageal obstruction caused by the PRAA resulted in functional disease leading to esophageal dysmotility.

As previously discussed, there are numerous possibilities for vascular anomaly development. A contrast CT or MRI may be performed to identify the exact anomaly for surgical preparation. A PRAA with left ligamentum arteriosum is the most common vascular anomaly, for which the surgical approach is a left lateral thoracotomy. Most of the other vascular anomalies require a left lateral thoracotomy (Figure 1), for example a PRAA with constricting left subclavian artery, if the patient has the double aortic arch vascular anomaly and the left aortic arch is the atretic one, and a patent ductus arteriosus. The vascular anomalies that require a right approach are uncommon but include a normal left aortic arch with an aberrant right ligamentum arteriosum or aberrant right subclavian artery, or an atretic right aortic arch. We anticipated we were dealing with a PRAA and left ligamentum arteriosum, so a contrast CT was not performed, but we prepared ourselves for a scenario that we would have to change sides intraoperatively. Surgery is therefore used to confirm diagnosis is many cases. Contrast CT or angiography would be required in the case of a double aortic arch to determine which is the atretic one.

Esophagoscopy can be performed to rule out other causes of dilated esophagus such as obstruction by a foreign body, a mass, a hiatal hernia, or a stricture (Radlinsky, 2013). After surgical correction, our patient continued to have a focal narrowing of the esophagus at the base of the heart. Esophagoscopy was offered to the client to rule out any additional pathologies causing this, including esophageal stricture, but the procedure was declined by the client. Surgical treatment should be pursued if the patient is stable. It was once accepted that surgical correction should occur at a younger age for better long-term prognosis on resolution of focal megaesophagus and esophageal motility. But this has not been proven due to small sample size and lack of long-term follow-up imaging (Muldoon et al., 1997). Surgical ligation and transection of the ligamentum arteriosum and removal of the fibrous bands from the esophageal wall is the treatment of choice. If other vascular anomalies constricting the esophagus are detected, the treatment is similar. There can also be an aberrant left vena cava or a left hemiazygos vein present which could affect visualization during surgery, and these would need to be retracted from the surgical site gently (Bottorff and Sission, 2012; Radlinsky, 2013). It is no longer recommended to surgically reduce the size of the dilated esophagus as attempts to do so may lead to stricture formation and further complications such as infection and dehiscence. Thoracoscopy has been pursued as a surgical treatment option for PRAA. In a recent study, there was no difference in the number of postoperative complications, morbidity, or mortality associated with thoracotomy versus thoracoscopy (Nucci et al., 2018). Thoracoscopic procedures have the potential for decreased surgical time with experience, decreased incidence of hypothermia, decreased tissue trauma, and decreased postoperative pain (MacPhail et al., 2001). Medical management includes pain control postoperatively as thoracotomy sites are painful due to wound closure impinging on intercostal nerves. For management of the focal megaesophagus,

the patient should be fed a gruel in an elevated position whilst standing on the hind legs and then elevated for 10-15 minutes afterward to allow gravity to move the food past the esophageal dilation into the distal esophagus and stomach. The gruel should contain water mixed with canned food and the water content should be gradually reduced 2-4 weeks after surgery. If the patient continues to eat without regurgitation episodes, they may be challenged by eating normally without being elevated. In more severe cases, a gastrotomy feeding tube may be considered to avoid the risk of aspiration pneumonia (Radlinsky, 2013).

Prognosis for PRAA postsurgical correction is good for long-term survival (87% of cases) but complete resolution of clinical signs only occurs in 30% of cases (Krebs et al., 2014). The remaining long-term survivors require medical management including diet modification and/or elevated feeding and continue to have infrequent regurgitation episodes of less than one episode per week. In a study by Muldoon et al. (1997), 52% of their patients received follow-up imaging in an average of 4 months postoperatively and all patients had persistent megaesophagus and evidence of mild increases in esophageal motility. This included mostly dogs that had complete resolution of clinical signs or regurgitated infrequently.

In conclusion, PRAA is an uncommon pathology and is a good differential for regurgitation in a young dog. Surgical treatment is the best option, but medical management may be required long-term. Radiographic resolution of megaesophagus and return of esophageal motility is not necessarily related to resolution of clinical signs. This is important when communicating expectations to clients and developing a prognosis postoperatively. Our patient is a good example of this, even though she continues to have focal esophageal narrowing, focal megaesophagus, and esophageal dysmotility, she had a good to excellent outcome and the client is satisfied with the results.

SUPPLEMENTAL MATERIAL

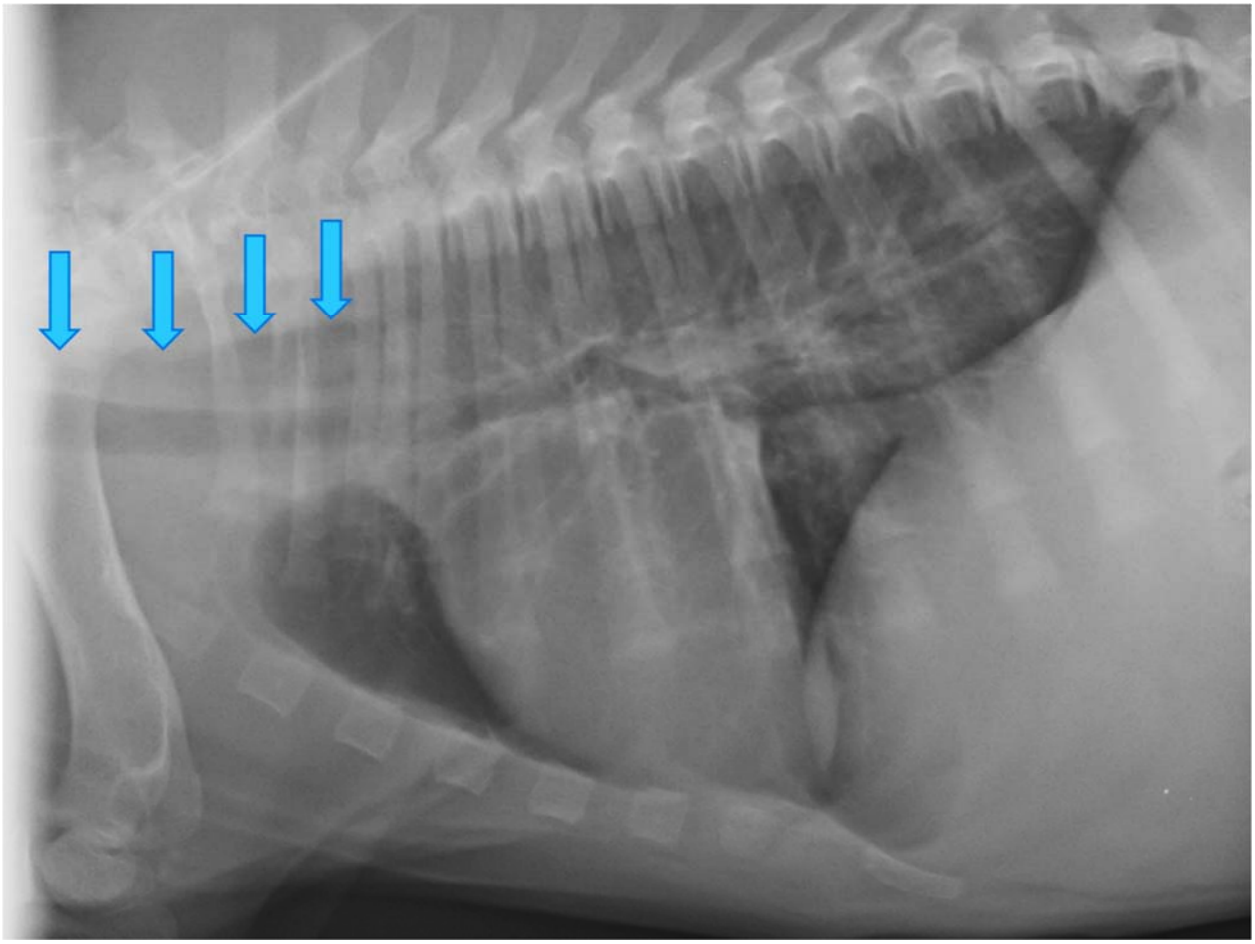


Image courtesy of the radiology department
Image 1. The right lateral projection revealed a dilated esophagus cranial to the cardiac silhouette. The blue arrows point to the dorsal border of the esophagus. This is abnormally enlarged, allowing us to diagnose focal megaesophagus.

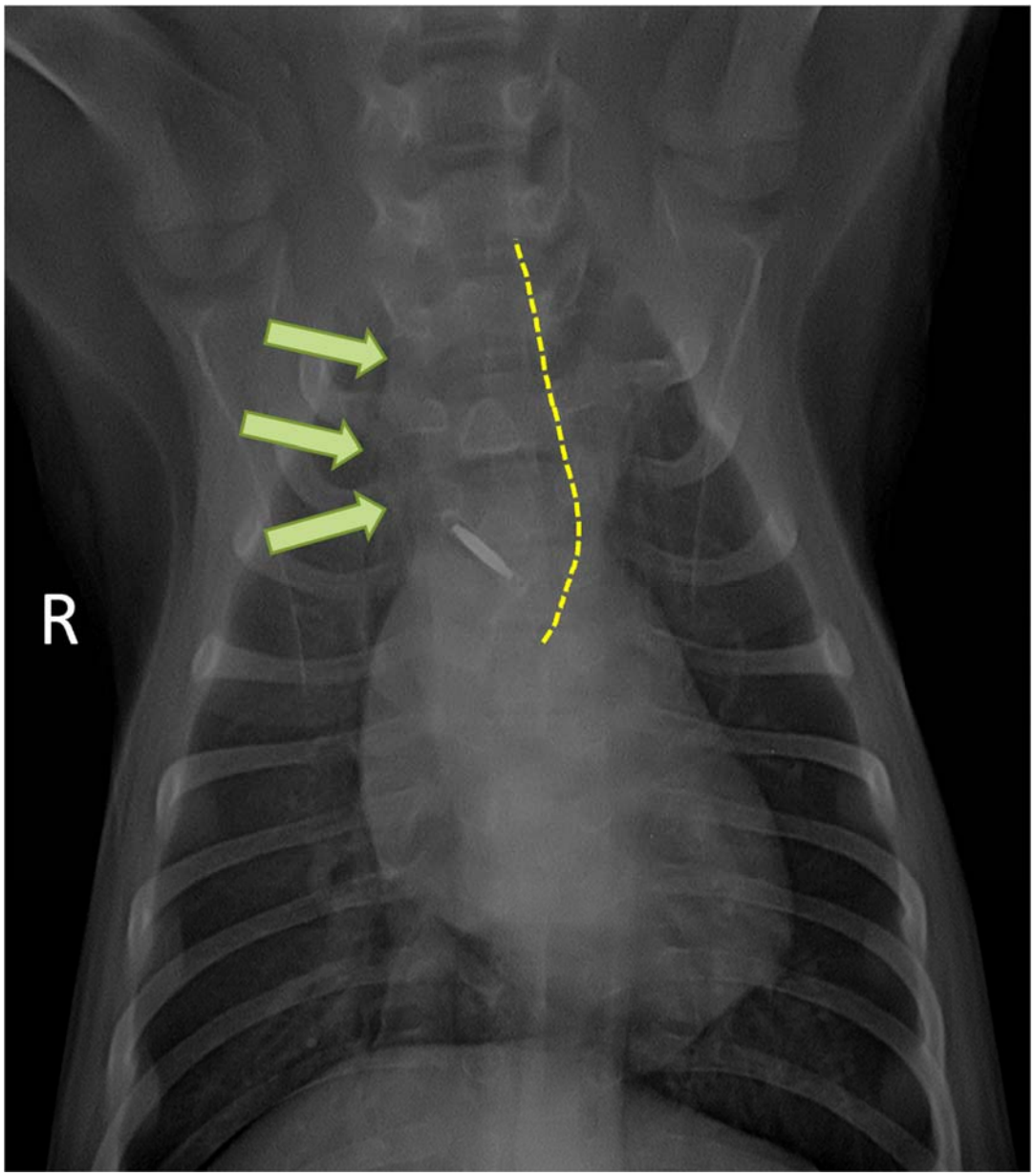


Image courtesy of the radiology department

Image 2. The dorsoventral projection reveals the focal megaesophagus, indicated by the green arrows. But there is also a leftward deviation of the trachea outlined in a yellow dashed line. This is pathognomonic for a persistent right aortic arch.

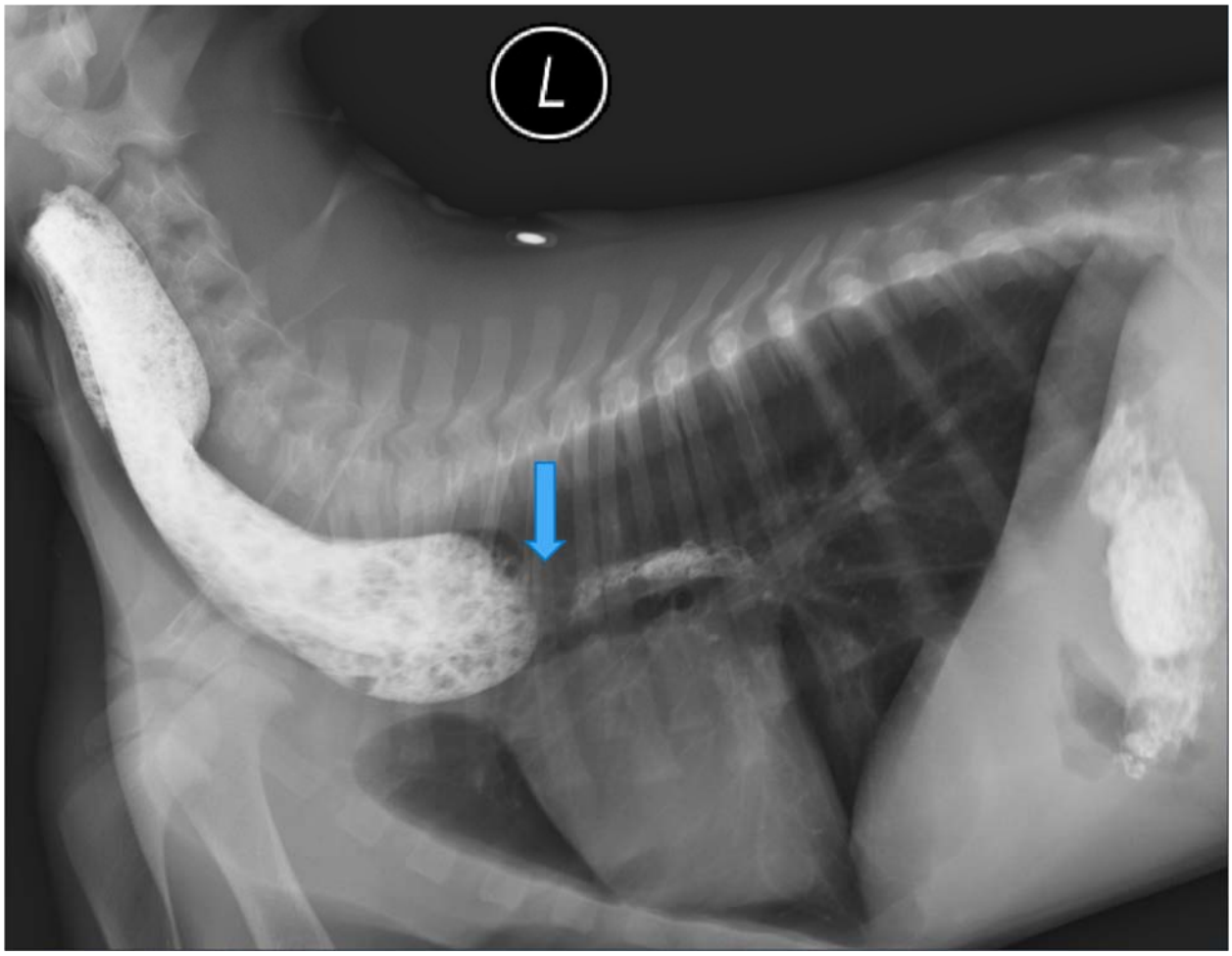
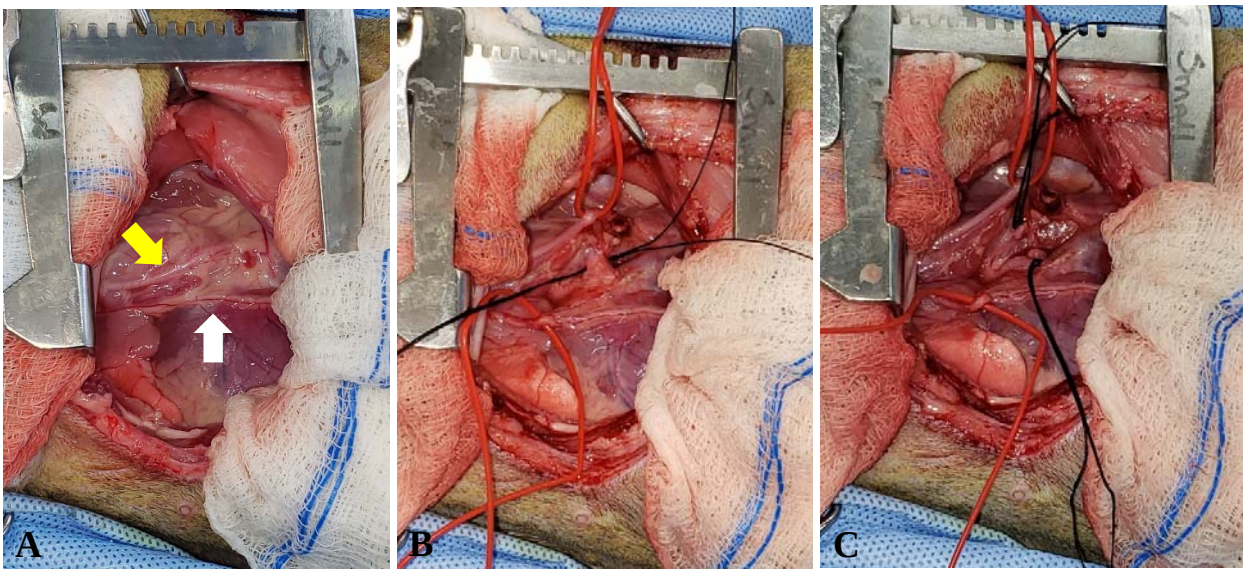


Image courtesy of the radiology department

Image 3. This static esophagram uses barium to provide contrast and highlight the esophagus. We can appreciate the dilated esophagus that tapers at the base of the cardiac silhouette, indicated by the blue arrow.



Images courtesy of Dr. Sarah Shane, Dr. Haley Gallaher, and Dr. Melody Whitney

Image 4. Intraoperative photographs of the left lateral thoracostomy site exposing the heart. (A) The yellow arrow points to the vagus nerve. The white arrow points to the phrenic nerve. (B) The vagus nerve is gently retracted dorsally and the phrenic nerve is gently retracted ventrally by vascular loops. The ligamentum arteriosum has been delicately dissected out and 2-0 Silk braided suture has been passed underneath. (C) The ligamentum arteriosum has been ligated twice and transected between.

Elevated Feeding Protocol		
	Gruel Ratio	
	# cans	Water volume
Week 1	1	1/2 cup
Week 2	1	1/2 cup
Week 3	1	1/4 cup
Week 4	1	1/8 cup
Week 5	1	-

Table 1. Ratios for a blended gruel of Purina Pro Plan Focus Puppy canned food combined with water volumes designed to decreased water content weekly to challenge the megaesophagus to find the ratio the patient tolerates without regurgitation episodes.

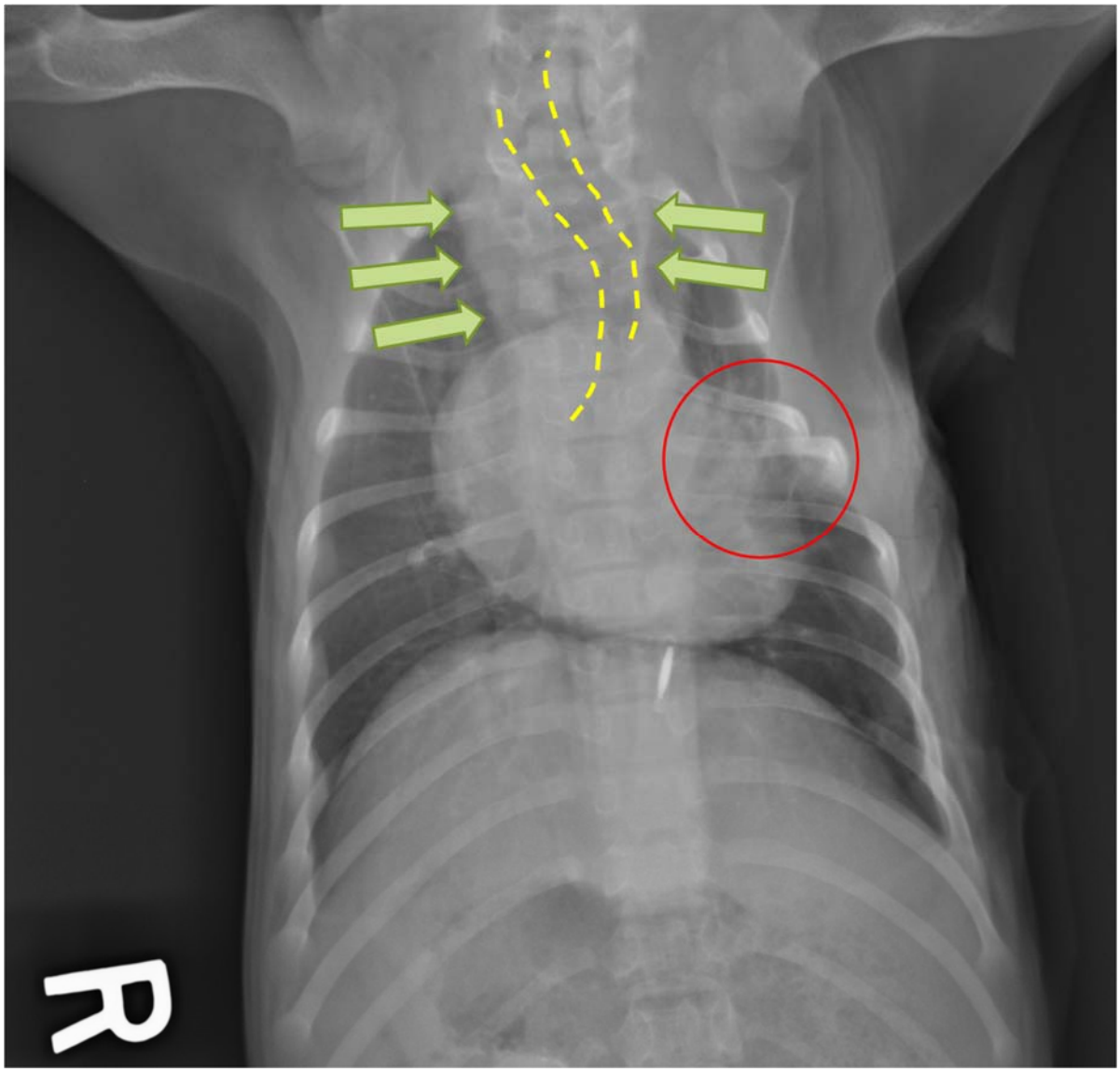


Image courtesy of the radiology department

Image 5. The postoperative dorsoventral projection reveals widening of the mediastinum due to the focal megaesophagus, indicated by the green arrows. The leftward deviation of the trachea is still present, indicated by the yellow dashed lines. There is also a mild alveolar pulmonary pattern at the surgical site, indicated by the red circle, which is an expected finding.

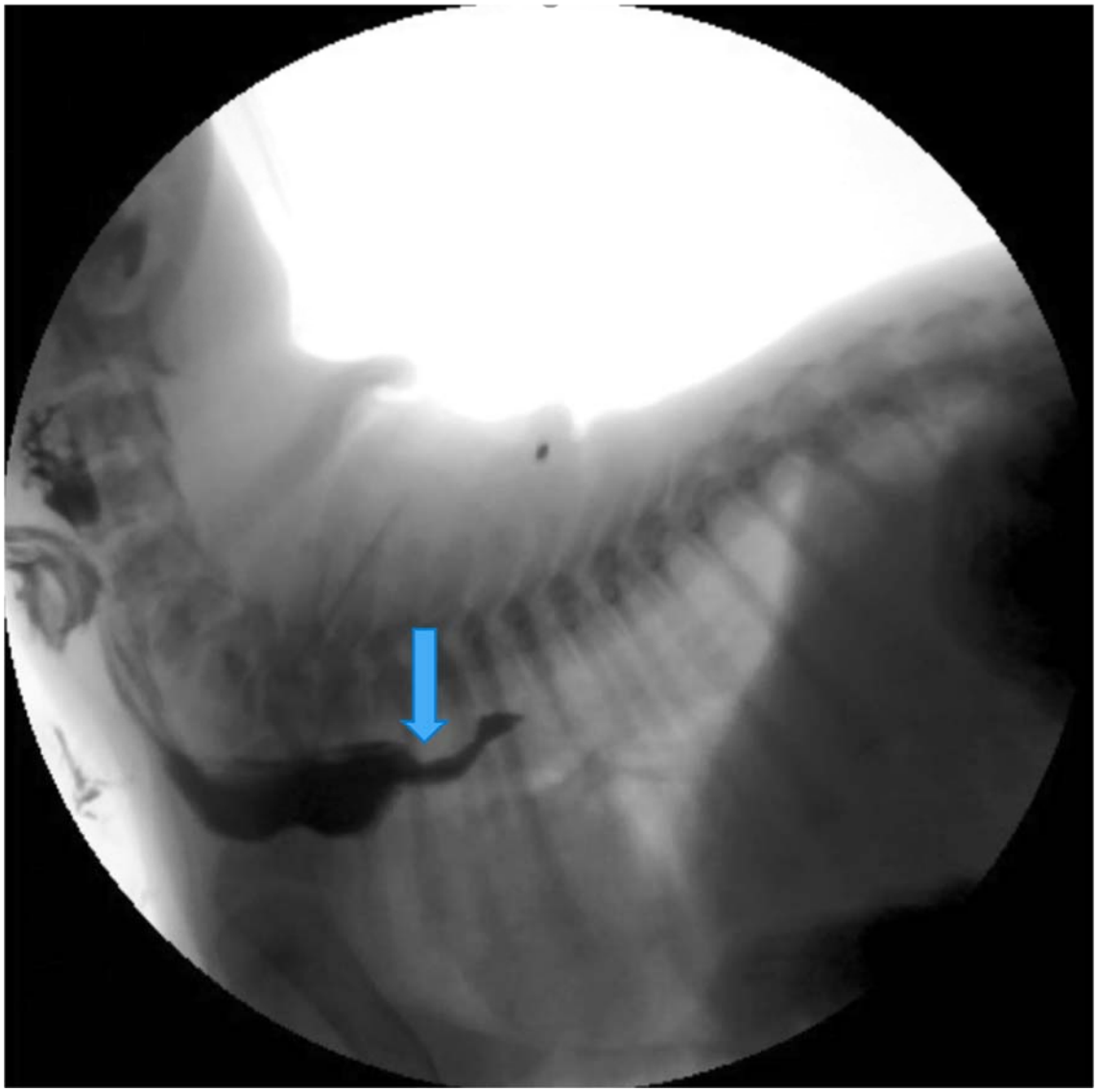


Image courtesy of the radiology department

Image 6. A postoperative dynamic esophagram was performed to evaluate the esophageal motility. This technique is achieved with fluoroscopy. The barium is providing negative contrast to highlight the esophagus. The patient had primary swallowing present which is initiated by a bolus of barium. But the bolus stopped cranial to the base of the cardiac silhouette and pooled there. The constriction on the esophagus had been resolved, but that area of the esophagus had not returned to normal esophageal diameter, indicated by the blue arrow, and normal peristaltic contractions have not returned.

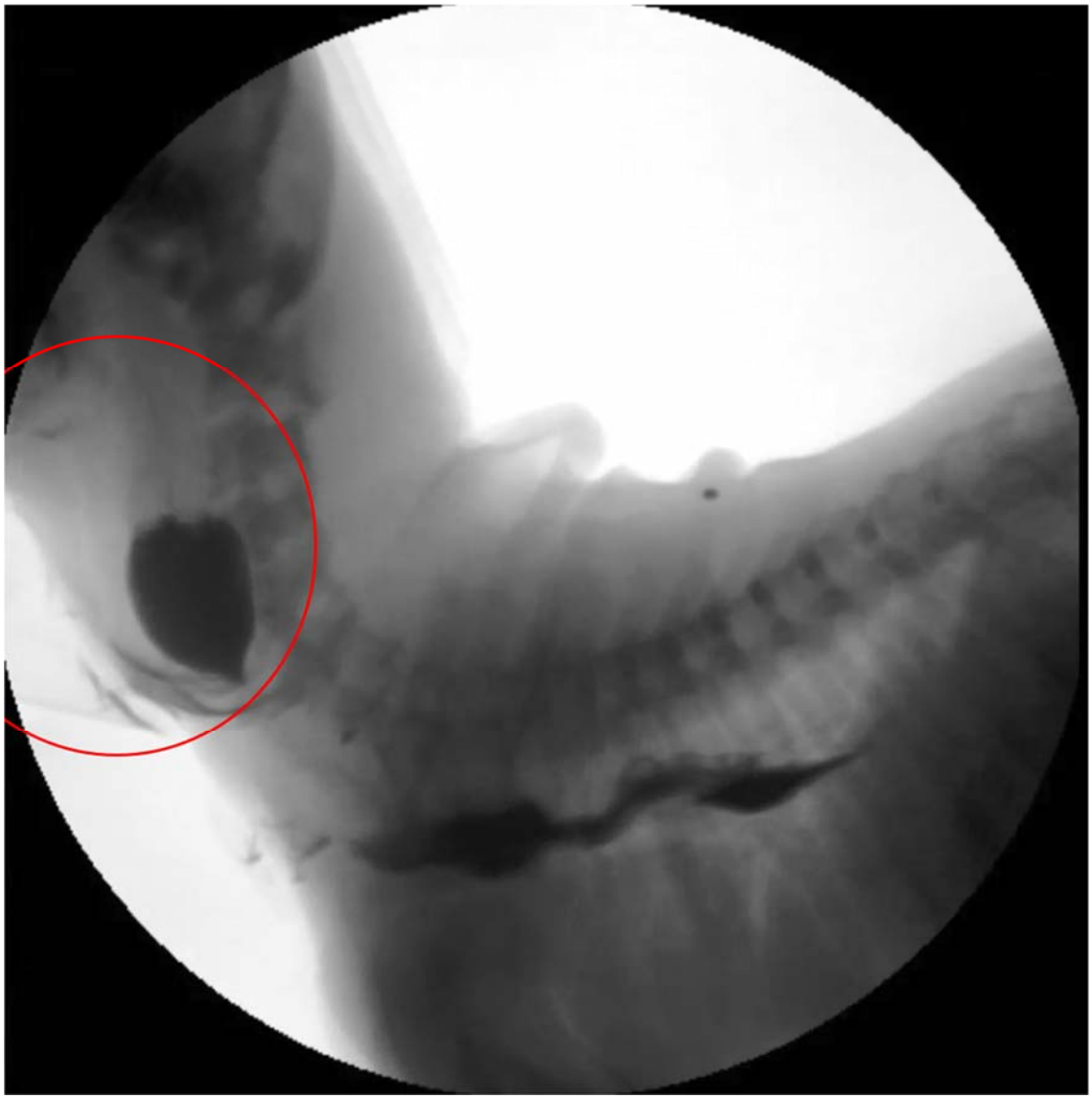
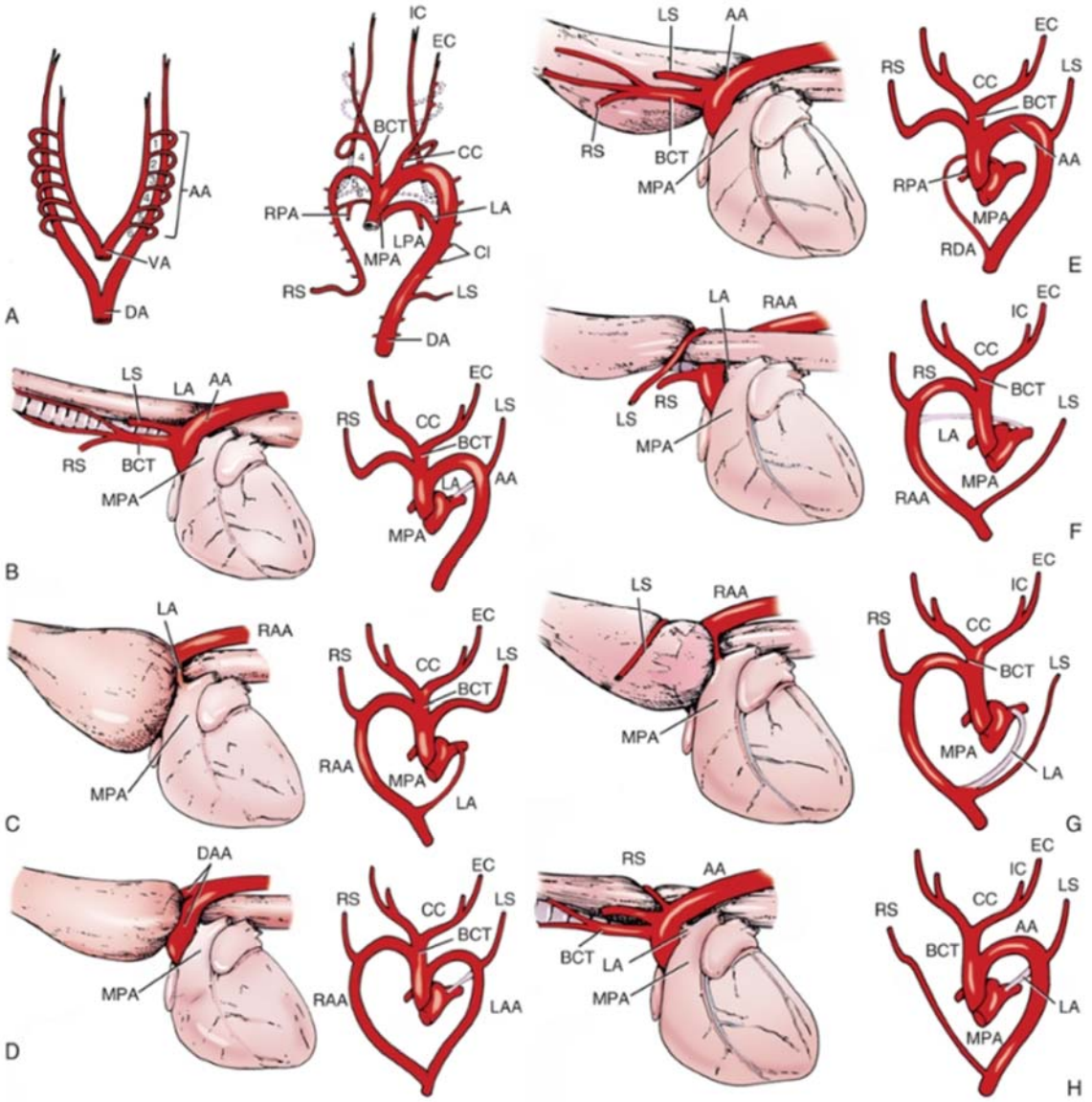


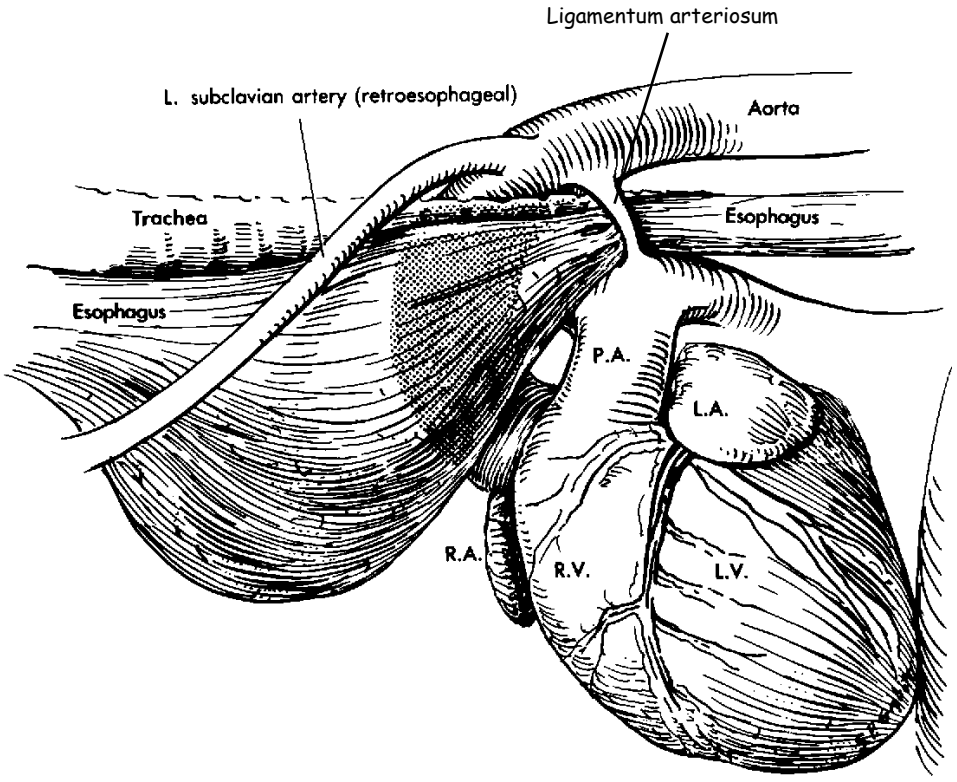
Image courtesy of the radiology department

Image 7. The primary phase of swallowing was initiated, but there were no peristaltic waves once the bolus reached the megaesophagus. The red circle depicts the bolus attempting to advance by the patient’s secondary swallow attempts. The dysmotility continued throughout the caudal esophagus with only a minor amount of barium passing into the stomach. Mechanical esophageal obstruction caused by the PRAA resulted in functional disease leading to esophageal dysmotility.



Kyles and Huck, 2018

Figure 1. (A) The normal embryonic vasculature with 6 pairs of aortic arches and the fetal vasculature to the right of it. (B) The normal adult feline and canine heart and the normal vasculature to the right of it. (C) The persistent right aortic arch (PRAA), the most common vascular anomaly, occurring with a persistent left ligamentum arteriosum. Another vascular anomaly reported is the double aortic arch (D). (E) A normal left aortic arch but with an aberrant right ductus arteriosus (or ligamentum arteriosum). (F) A PRAA with an aberrant, or deviated, left subclavian artery. (G) A PRAA with persistent left ligamentum arteriosum and aberrant left subclavian artery. (H) A normal left aortic arch with aberrant right subclavian artery. In addition to these reported vascular anomalies, a patent ductus arteriosus rather than ligamentum arteriosum can be present, which means there is still blood flow bypassing the lungs. AA, Aortic arches; BCT, Brachiocephalic trunk; CC, Common carotid; CI, Cervical intersegmental arteries; DA, Dorsal aorta; EC, External carotid; IC, Internal carotid; LAA, Left aortic arch; LPA, Left pulmonary artery; LS, Left subclavian; MPA, Main pulmonary artery; RPA, Right pulmonary artery; RS, Right subclavian; VA, Ventral aorta.



Buchanan, 2004

Figure 2. The entrapment of the esophagus occurs by the presence of the ligamentum arteriosum (or patent ductus arteriosus) dorsally, the base of the heart ventrally, the main pulmonary artery on the left, and the aortic arch on the right. In this image the trachea is also involved.
P.A. Pulmonary artery; L.A. Left atrium; R.A. Right atrium; R.V. Right ventricle; L.V. Left ventricle.

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