The best way to evaluate the thorax is to formulate a systematic approach and Stick With It! The information below is gleaned from notes I make available to our veterinary students as well as expect our radiology residents to know and make use of.

**Systematic Evaluation of the Thoracic Radiograph**

The first thing that must be taken into account is technical factors that were used to obtain the radiographs/digital images, such as positioning, exposure factors (should be high KvP and a grid should be used if thorax is thicker than 11 cm), motion (no more than $\frac{1}{30}$ sec), phase of respiration (want inspiration), and whether the “heel effect” has been utilized (put thickest part on the cathode side). You should be consistent in the views that you take, for example always take at least VD and right lateral, and for metastasis evaluation add the left lateral. Orient the images in a consistent fashion: head to the left on lateral views and left on viewer’s right on VD/DV views.

Once radiographs have been taken perform a quality check. The entire thorax should be on the images (thoracic inlet (manubrium) to the 13th rib), with the head and neck extended and forelegs pulled forward. In lateral recumbency be sure the costochondral junctions are superimposed and in dorsal recumbency be sure the spine and sternum are superimposed. Be sure the pulmonary vasculature is visualized to the edge of the image and that you can see the thoracic vertebrae. To determine if the image was made on inspiration as normally desired the following chart can be utilized.

<table>
<thead>
<tr>
<th>POSITION</th>
<th>ANATOMIC LANDMARK</th>
<th>INSPIRATION</th>
<th>EXPIRATION</th>
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</thead>
<tbody>
<tr>
<td>Lateral</td>
<td>Heart/Diaphragm contact</td>
<td>Minimal/None</td>
<td>Overlap</td>
</tr>
<tr>
<td>Lateral</td>
<td>Heart/Sternal contact</td>
<td>Less</td>
<td>More</td>
</tr>
<tr>
<td>Lateral</td>
<td>CVC</td>
<td>Horizontal</td>
<td>Ascends caudally</td>
</tr>
<tr>
<td>Lateral</td>
<td>Diaphragm</td>
<td>Flattened</td>
<td>Rounded</td>
</tr>
<tr>
<td>Lateral and DV</td>
<td>Pulmonary radiolucency</td>
<td>Increased</td>
<td>Decreased</td>
</tr>
<tr>
<td>DV</td>
<td>Costo-diaphragmatic angle</td>
<td>Increased</td>
<td>Decreased</td>
</tr>
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</table>
Next, evaluate the extrathoracic structures such as the soft tissues, spine, diaphragm, sternum, and ribs. Following this assessment, the intrathoracic organs should be evaluated: trachea and remaining mediastinum, pleural space, heart and pulmonary vasculature, and the lung field.

**Extrathoracic Structures**

Fully assess the extrathoracic structures by evaluating the images for body wall symmetry and opacity as well as the osseous thorax. There are 13 vertebrae with large spinous processes. T1-T10 angle caudally, T11 is anticlinal (T10-T11 is the anticlinal disc space) and T12-T13 angle cranially. There are 13 pairs of ribs that articulate at anterior end of their respective vertebrae. Ribs 1 to 9 articulate with the sternum, ribs 10 to 12 are joined together and to the sternum by long costal cartilages and rib 13 is ‘floating’ with agenesis or transitional small 13th ribs not uncommon. There are 8 sternebrae from the manubrium cranially to the broad, sword-like xiphoid process. Displacement of caudal end of the xiphoid is pectus excavatum and ventral displacement is pectus carinum. When trauma occurs to the thoracic wall resulting in rib fractures, they tend to be transverse or short oblique fractures and multiple rib fractures are common. When this occurs the animal should be examined closely for flail chest.

**Intrathoracic but Extrapleural (Extrapulmonary) Masses**

Extrapleural masses are outside the pleural cavity between the body wall and the parietal pleura. Radiographic signs include a well-defined, sharp convex contour facing the lung tissue with cranial and caudal edges that are tapered so there is a smooth curve or margin. Normally the longitudinal and transverse diameters are approximately the same. Initially the pleural space is uninvolved. Rib involvement is frequent, but often need a VD view to confirm. These can be differentiated from intrapulmonary masses which usually are sharply demarcated or ‘angled’ around the mass. These extrapleural masses can be primary
or metastatic rib tumors such as chondrosarcoma, osteosarcoma, and chondroma, or a benign mass such as a hematoma or an abscess/granuloma.

**Radiographic Appearance of the Diaphragm**

We see the diaphragm because of the interface between the air in lung against the soft tissue of the diaphragm. In right lateral recumbency, the right crus is further forward and the vena cava enters the right crus. When the animal is in left lateral recumbency, the left crus is further forward and the fundus of the stomach is seen caudal to the left crus. When the animal is on its back and the ventrodorsal projection is obtained, there are three distinct "humps" seen representing each crus as well as the central cupula. On the dorsoventral projection only one "hump" is seen.

The diaphragm is not visualized when it is ruptured or when there is a silhouette sign associated with it such as might be seen with an alveolar pattern in a caudal lung lobe (tumor, pneumonia, heart failure etc) or with pleural effusion. There are several types of diaphragmatic hernias: acquired (trauma), congenital (hiatal, peritoneal pericardial or less commonly pleuropertitoneal or complete absence). Radiographic signs of a diaphragmatic hernia include: incomplete visualization of diaphragm, presence of abdominal structures in thorax (i.e., stomach, small intestines, liver), a mediastinal shift, silhouette sign with the heart, abdominal structures displaced cranially or not present in abdomen, pleural effusion if liver is incarcerated in the thorax, intestines/gas in pericardial sac if Peritoneal Pericardial Diaphragmatic Hernia (PPDH).

There are additional studies that are useful in diagnosing a diaphragmatic hernia such as abdominal radiographs with or without an upper GI, and ultrasound. Positive contrast peritoneography can also be performed by injecting 1 ml per lb of body weight of a sterile water soluble organic iodide into the peritoneal cavity and rolling the animal around to distribute the fluid. Observing iodine in the thoracic cavity confirms a diaphragmatic hernia.

**Trachea - Evaluate for Position, Size, and Tracheal Lumen**

The position of the trachea is important to make note of as it can be displaced by surrounding abnormal structures in the vicinity of the trachea. The trachea enters at the thoracic inlet in close proximity to the spine and then should diverge from the spine on the lateral view ventrally at an angle of 15 to 20 degrees. In smaller brachiocephalic breeds, the trachea will run almost parallel to the spine and in deep chested dogs such as collies, the angle of divergence can approach 30 degrees. On the VD view, the trachea lies along midline and is therefore relatively imperceptible, but in brachiocephalic breeds it may normally course slightly to the right of midline. The trachea can change position with a change in head position, for example there is dorsal deviation of the trachea if the animal's head is bent ventrally. The tracheal bifurcation (where the carina is located) is seen posterior to rib
#5 and dorsal to the base of the heart. At the thoracic inlet, a redundant dorsal trachealis membrane may be superimposed at the thoracic inlet and sometimes appears similar to tracheal collapse.

When the trachea is displaced dorsally, the differentials include a craniocaudal mediastinal mass (lymph node, thymic tumor, or abscess), enlargement of the heart or a heart base tumor, and the positional artifact described above. Ventral displacement of the trachea is most common with megaesophagus or can occur with a dorsal mediastinal mass. Lateral displacement can occur with a one sided cranial mediastinal mass, a pulmonary mass, mediastinal shift secondary to atelectasis, or positional artifacts. Cranial mediastinal masses can cause caudal displacement of the bifurcation of the main bronchi.

The change in opacity of the tracheal lumen can be altered in the presence of a tumor (eg, chondroma, osteosarcoma, squamous cell carcinoma), a granuloma (Fiteroides osleri), a foreign body, and scaring or adhesions. Tracheal rings commonly mineralize with age. Tracheal puncture or rupture is often accompanied by a pneumomediastinum and gas can be seen on the serosal side of the trachea giving it a “tracheal stripe sign”.

The diameter of the tracheal lumen should be approximately three times the width of the third rib, or 1/5 (20%) the height of thoracic inlet. In brachiocephalic dogs this can be as low as 16%. Bulldogs have been reported to have a ratio of as low as 13% without being clinically affected by having a small trachea.

Differentials for a small tracheal lumen are: hypoplasia (which is congenital - especially Brachycephalic breeds), stenosis (either congenital of from trauma) and collapse. A normal intra-thoracic trachea increases in size during inspiration and decreases in size during expiration. Collapse should not be confused with overlying soft tissue, most commonly the dense dorsal trachealis membrane; or the longus colli muscle or esophagus at the thoracic inlet. In addition, compression by an extraluminal mass can cause the tracheal lumen to be decreased. A large trachea is most often caused by an upper airway obstruction.

**Mediastinum**

The mediastinum is the space between the pleural cavities that is formed by the mediastinal pleura that should be no wider than 2 times the width of the thoracic vertebrae on a VD view. The mediastinum opens cranially and caudally and can be divided into 3 regions: Cranial (precardiac), middle (perciardiac), and caudal (postcardiac). The
mediastinum does not communicate directly with the pleural space but does communicate with perivascular and peribronchial structures. Mediastinal structures that are normally visualized are the trachea, heart, aorta, caudal vena cava, and in a young animal the thymus. Also visible in the thorax are the caudoventral mediastinal reflection (two sheets of mediastinal pleura between the accessory lung lobe and the caudal left lung lobe that gets thicker in fat animals) and the cranioventral mediastinal reflection (two sheets of mediastinal pleura between the tip of the left cranial lung lobe and right cranial lung lobe). Structures within the mediastinum that are not normally visible are the cranial vena cava, brachiocephalic trunk, left subclavian artery, esophagus, azygous vein, and lymph nodes. The lymph nodes in the thorax that can be seen when abnormal in size or opacity are the hilar (tracheobronchial), sternal (retrosternal, 1 or 2, above 2nd sternebrae), and cranial mediastinal.

Clinical signs of mediastinal abnormalities are dyspnea, dysphagia and regurgitation, and cardiovascular disturbances such as forelimb edema, ascites and hepatomegaly. Radiographic signs of mediastinal abnormalities are a mediastinal shift, a pneumomediastinum, a mediastinal mass, and other things that cause mediastinal widening that are not solid masses.

A mediastinal shift can be due to loss of lung volume (atelectasis of lung lobes), a diaphragmatic hernia, adhesions, or a unilateral pneumothorax or pyothorax which are both rare. A pneumomediastinum is caused by the presence of air within the mediastinum that causes increased radiolucency so that mediastinal structures not normally seen become visible, especially on the lateral view. In addition, the serosal border of the trachea becomes visible causing a “tracheal stripe sign”. Causes of a pneumomediastinum are soft tissue wounds especially in the neck or axilla; tracheal, bronchial, or alveolar rupture; esophageal perforation; a difficult jugular venipuncture; and rarely gas producing organisms. Complications of a pneumomediastinum include a pneumothorax, a pneumoretroperitoneum, or mediastinitis. Pneumomediastinum is usually self-limiting with resorption of the air within 7-10 days. If a secondary pneumothorax occurs and the animal is dyspneic the pneumothorax should be treated. If the animal develops signs of an infection antibiotics are indicated.
Mediastinal masses can occur in the following quadrants of the mediastinum demonstrated in the outline below, and identifying their location aids in formulating appropriate differentials.

**Cranioventral mediastinal mass**
(1) Causes: fat; thymus (thymoma, thyroid adenocarcinoma); mediastinal and retrosternal lymph node enlargement (lymphosarcoma or inflammatory changes); or an abscess.

(2) Radiographic signs: dorsal displacement of trachea on the lateral view +/- lateral deviation on VD view; increased opacity in the mediastinum cranial to the heart; silhouette sign with the heart; carina displaced caudally; and possibly esophageal air.

(3) Differential diagnoses are pleural fluid or pleural, pulmonary, or thoracic wall masses.

**Craniodorsal mediastinal mass**
(1) Causes: abnormalities associated with the esophagus, trachea, cranial vena cava, aortic arch, or nerves.

(2) Radiographic signs: ventral displacement of the trachea +/- a distended esophagus.

**Perihilar mediastinal mass**
(1) Causes: abnormalities associated with the tracheobronchial lymph nodes, pulmonary vessels, left and/or right atria, or the esophagus.

(2) Radiographic signs: increased perihilar opacity, displacement of the tracheal bifurcation, and/or construction of the trachea.

**Dorsocaudal mediastinal mass**
(1) Causes: abnormalities with the caudal esophagus such as a granuloma, hiatal hernia, an epiphrenic diverticulum, or Spirocerca lupi; a diaphragmatic hernia; or a problem with the descending aorta or nerves.
(2) Radiographic signs: increased opacity in the dorsocaudal thorax on lateral views and increased opacity on midline on VD or DV view.

Caudoventral mediastinal mass
(1) Causes: a pericardial cyst, peritoneopericardial or other diaphragmatic hernia, or an abscess/granuloma.
(2) Radiographic signs: silhouette sign with the heart or increased opacity caudal to the heart along midline on VD or DV views.

Mediastinal widening can also occur that is not caused by a mass such as mediastinitis from an esophageal rupture, bite wound, or descending infection; hemorrhage from trauma or coagulopathy, an abscess from esophageal perforation, etc; fat, or fluid from FIP, etc. With fluid there will not be tracheal compression. An erect horizontal VD view can be helpful in displacing fluid to allow better evaluation of the mediastinum. Alternatively, computed tomography and/or ultrasound are often utilized to further evaluate the mediastinum.

Pleural Space
The pleural space is a 0.8 mm thick space between the parietal and visceral pleura that is filled with a small amount of fluid which is nothing more than a capillary film for lubrication of the lungs movement. This space is not seen in normal animals radiographically, but becomes visible if it is filled with fluid (100 ml in small dogs, 200 ml in large dogs), cellular, or fibrinous material (hydrothorax). The pleural space also is visible if it is filled with gas (pneumothorax). The pleura become visible if they are thickened or if calcium is deposited, there is infiltration of lung tissue underlying the visceral pleura, or occasionally if the pleura is seen end on.

Pleural effusion (aka - hydrothorax) is created by the accumulation of any type of fluid in the pleural space. Normally, fluid is formed at the parietal pleura and absorbed at visceral pleura due to the hydrostatic pressure gradient. However, if there is increased
systemic venous pressure and lymphatics (i.e., right and left heart failure), low colloidal osmotic pressure, or increased capillary permeability due to neoplasia, infection or trauma these mechanisms fail. A diaphragmatic hernia with incarceration of the liver can also lead to pleural effusion. Pleural effusion is classified as free if it moves freely across the mediastinum and the location is dependent on gravity. Trapped pleural fluid has an atypical distribution, but it is still capable of moving under the influence of gravity. Fluid in the pleural space can also be encapsulated due to its nature of being loculated by fibrinous deposits or adhesions and is unable to be moved by gravity such as with chronic pleuritis or pyothorax. It is important to perform a thoracocentesis as these generalizations are not sufficient to differentiate the type of fluid present.

Radiographic signs of pleural effusion on a lateral view are: a scalloped appearance of the lung borders in the ventral portions of the thorax, loss of visualization to varying degrees of the cardiac silhouette and the image often appears underexposed, and the visibility of interlobar fissures (> 100 mls fluid in medium sized dogs necessary). On a VD or DV view retraction of the lobar borders from the thoracic body wall can be seen along with rounding of the costophrenic angle in DV projection, widening of the cranial and caudal mediastinum (especially in DV projection), and silhouetting with the heart and diaphragm if severe. On a VD view, fluid accumulates in the dorsocaudal thorax in the spinal ‘trough’ allowing better visualization of the heart, cranial lung lobes, and ventral diaphragm which can be obscured on a DV view. Small amounts of fluid are easiest to see on radiographs taken during expiration, in DV positioning, or using a horizontal beam. A true fluid line is only seen with a pneumohydrothorax or on a standing lateral horizontal beam view. Radiographs are often repeated after the pleural effusion is removed via thoracocentesis to better evaluate the heart, mediastinum, and diaphragm.

Differential diagnoses for pleural effusion are based on the type of fluid present with examples in the outline below:
Modified transudates

a. Hydrothorax
   (1) Heart failure
   (2) Hypoproteinemia
   (3) Diaphragmatic hernia

b. Hemothorax – differentiate differentials below by thoracocentesis
   (1) Trauma – blood clots
   (2) Coagulopathy – blood often does not clot
   (3) Neoplasia – blood does not clot, eg. hemangiosarcoma or malignant melanoma

c. Chylothorax – often fibrosis and permanent rounding of lung lobes when chronic

d. Neoplasia – hemothorax or ‘neoplastic effusion’

e. Lung lobe torsion
   (1) Most commonly affected lobes are the right middle and left cranial lung lobes
   (2) Non-inflated lung lobe, +/- air bronchograms
   (3) Large breed, deep chested dogs most common

Exudates

a. Pyothorax
   (1) Systemic infection
   (2) Penetrating wounds
   (3) Foreign body
   (4) Often involves the hemithorax in the cat and can be restrictive

b. Pleuritis – similar findings as hydrothorax with added feature or a white line around the lung due to thickened pleura. The parietal pleural thickening is best seen on the V/D between the ribs. The pleural thickening may restrict expansion of lung with resulting ‘clover-leaf’.

Pneumothorax is the presence of air/gas within the pleural space.
Pneumothorax can be classified as open and closed, and there are 2 types of a closed pneumothorax: simple and tension. An open pneumothorax happens when there is a body wall wound allows free communication between atmosphere and pleural space. Pleural pressure is less than atmospheric pressure. A closed pneumothorax is due to wound on the lung parenchyma. If the closed pneumothorax is simple, air enters space on inspiration and exits on expiration. Pleural pressure is less than atmospheric pressure. If a tension pneumothorax is present, the wound acts as one-
way flap and air enters space on inspiration and is trapped. Pleural pressure is
greater than atmospheric pressure and this type of pneumothorax is a much more
serious emergency. Pneumothorax is often caused by trauma (look for rib
fractures), iatrogenic causes such as thoracocentesis, a spontaneous cause like
rupture of a pulmonary bulla, or as a sequelae from a pneumomediastinum.

The radiographic findings of a pneumothorax are the apparent elevation of
the cardiac silhouette dorsally from the sternum on lateral views, retraction of lobar
borders of the lung, increased pulmonary opacity due to atelectasis +/- pulmonary
contusions, lack of visible vessels in the periphery of the lung field, and a variable
mediastinal shift away from the most affected side with flattening of the diaphragm
which are more often seen with tension pneumothoraxes. A mild pneumothorax is
more easily seen on DV view, an expiratory radiograph or with the animal in lateral
decubitus using a horizontal beam.

Differential diagnoses for a pneumothorax are skin folds (these are normally
at different angles than lung margins), pulmonary hyperinflation (check to see if the
ribs are no longer parallel and if the diaphragm is ‘tented’ on a VD or flattened on a
lateral view), or a hypovascular lung field (eg. Secondary to a cardiac anomaly or
severe dehydration).

Treatment of a pneumothorax varies with its severity. A mild simple
pneumothorax is usually self-limiting. A tension pneumothorax leads to progressive
dyspnea and impaired cardiovascular function, because the trapped air leads to a
severe increase in intrathoracic pressure. Tension pneumothorax and severe simple
pneumothorax require intervention such as removal of excess air and repair of the
tear.

References
   York, NY, 1986.

