At our institution, an abdominal ultrasound is typically the first imaging test performed when perforation of the lower urinary tract is suspected. However, the location of the perforation is almost impossible to determine with ultrasound. As a result, some sort of positive contrast study is usually performed when a uroabdomen or uroretroperitoneum is present. For the urinary bladder or urethra, a cystourethrogram is the best choice. An excretory urogram is necessary to evaluate for trauma to the ureters.

Cystourethrogram

In order to optimize visualization of the lower urinary tract, the descending colon should be evacuated. A lateral radiograph of the caudal abdomen can be used to ensure complete emptying of the descending colon and determine if enemas should be given before anesthetizing the patient. This can be done in conjunction with survey radiographs. Survey radiographs including right and left lateral and ventrodorsal projections are acquired and inspected prior to any contrast study. General anesthesia or sedation with adequate analgesia is required to decrease discomfort of the patient, prevent repeat catheterizations, trauma to the urethra, ease manipulation of the patient and decrease radiation exposure to personnel.

First, the external urethral opening is cleaned and a sterile urinary catheter is passed. A Foley catheter works well as the balloon can be inflated once in the urinary bladder and then moved caudally to tuck into the neck of the bladder, preventing leakage of contrast media around the catheter. The urinary bladder is emptied, the volume noted and samples collected for urinalysis and culture. Water-soluble iodine based contrast media is then slowly infused into the bladder. Typically a 50% dilution is made by mixing 240 mgI/mL – 350 mgI/mL contrast media and sterile water or saline. Barium should never be used in the urinary tract.

A normal bladder holds roughly 5 ml/kg and is the volume that should be drawn up before the procedure begins. As the contrast media is injected, palpate the urinary bladder through the abdomen. Stop injecting if the bladder becomes turgid or if there is rebound on the syringe. The volume of urine that was removed at the beginning of the study can serve as a reference for a safe volume to instill. Acquire a right and left lateral and ventrodorsal radiographic view.

Should a rupture of the urinary bladder fail to be identified, deflate the Foley and slowly retract the catheter from the bladder and into the urethra while simultaneously injecting more contrast media. Multiple right lateral radiographs should be obtained while the catheter is being retracted until the catheter exits the ureteral orifice.

Excretory urography

All animals should be adequately hydrated prior to EU. When possible, a cleansing enema should be performed approximately 2 hours prior to EU. Right lateral and VD survey radiographs are performed prior to administration of intravenous contrast material. To minimize the risk of adverse reactions, the use of non-ionic iodinated contrast media such as iopamidol or iohexol at a dose of 400mg/Iodine per pound body weight is advised. Contrast media should be delivered through a cephalic or other indwelling catheter as extravasation can be irritating to regional tissues. Right lateral and VD radiographs are obtained immediately and then at 5, 10, 20 and 40 minutes after contrast administration.

Care should be taken to closely observe the animal for evidence of an adverse reaction for at least 1 hour after administration of intravenous contrast media of any kind. Adverse reactions are rare in animals but can range in severity from mild (nausea, urticaria) to moderate (vomiting, hypotension, collapse) or severe (cardiac or respiratory failure). Readers are referred elsewhere for a discussion of contrast associated complications and how to perform EU in animals with renal compromise.

References
A standard study
At our institution, a standard thoracic series includes right and left lateral and dorsoventral projections for all patients. Both lateral projections are included in a standard thoracic series so as to optimize the likelihood of identifying all lesions. Not only does the left lateral thoracic radiograph improve the detection of pulmonary nodules but also dependent pneumonia in the right lung lobes and other right sided pulmonary pathology. The dorsoventral projection is chosen over the ventrodorsal projection so as to evaluate the heart in its normal anatomic position and to reduce the need for personnel to be present in the radiographic suite during image acquisition. A ventrodorsal projection is added to the study if pleural effusion obscures the heart or if a pulmonary lesion is suspected on the DV but needs confirmation.

Horizontal beam radiography
A horizontal beam radiograph can be used to determine if fluid is present either within the pleural space or within a pulmonary mass. The x-ray tube is positioned so that beam direction is parallel to (across) the table. The detector is positioned on the other side of the table and the patient is placed between the two. The patient may be positioned in sternal or lateral recumbency.

General approach to thoracic radiographic interpretation
The thorax can be divided in to four different areas: the extra-thoracic structures, pleural space, pulmonary parenchyma and mediastinum (including heart and great vessels).1 A systematic evaluation of the thorax will often include the ‘outside in’ approach of these four areas with conclusions based upon the collective findings. While all of these areas should be evaluated as part of the thorax, the remainder of this material will focus on interpretation of pulmonary parenchymal findings.

Pulmonary parenchyma
Interpretation of thoracic radiographs requires accurate recognition of pulmonary patterns. Most practitioners encounter difficulty in confidently recognizing these patterns because of the wide variations in the normal appearance of the lung. Radiographically, the lung can be thought of as consisting of 2 compartments — one containing air and one composed of soft-tissue dense structures. The air-containing compartment consists of the lumen of airways and alveoli. Far and away, the most important factor that defines the unique radiographic appearance of lung is the presence of air within the alveolar compartment. The soft-tissue compartment contains all other structures in the lung such as the airway walls, vessels, alveolar walls, lymphatics, etc. and is generally referred to as the interstitium. In fact, the so-called “pulmonary markings” that are used to define the extent of the lung field are created by pulmonary vessels and the walls of large-diameter airways. Vessels appear as tapering, branching band shadows when viewed along their length and as dense, well-circumscribed nodules when seen end-on. Airways appear as fine branching lines (often as pairs of parallel lines) when seen from the side and as ring shadows when seen end-on. Airway shadows are most easily seen in thin, large-breed dogs. Mineralization of airway walls enhances their visualization. This process occurs in older dogs of all breeds and in chondrodystrophic dogs at an early age. On a lateral view, the relationship is artery (dorsal)->bronchus->vein (ventral), whereas on the DV or VD view it is artery (lateral)->bronchus->vein (medial). Arteries tend to follow the course of the airways; veins tend to take a straight course toward the area of the left atrium. Abnormalities in either of these structures may be manifested by characteristic changes called lung patterns. Another way to state this is that radiographic patterns of pulmonary parenchymal disease reflect alterations of alveolar air volume and/or interstitial fluid (or cellular) volume. These patterns were first described in people because many pulmonary disease entities were observed to result in characteristic radiographic changes. Accurate assessment of pulmonary patterns requires a series of steps, each involving if-then logic. The following questions should be answered when evaluating thoracic radiographs:

Is the study technically adequate?
Factors to be considered are: presence of positioning artifacts (rotation, limb position, neck position), exposure factors (overexposure or underexposure), processing artifacts, and phase of respiration.

Are abnormalities (or questionable abnormalities) present?
This constitutes the analytic phase of radiographic interpretation and is usually the most difficult question to answer. This is because breed (especially in the dog), age, and degree of obesity can cause significant alterations in the appearance of the lungs, and an appreciation for the wide variation of “normal” requires extensive experience. Another confounding problem is that the amount of interstitial density is inversely related to the degree of lung inflation and radiographic exposure. The most common mistake in film interpretation is over-reading the significance of a prominent interstitial pattern in an under-exposed or under-inflated chest. Suspect lesions can be localized to the lung by triangulation (seeing the lesion in lung field on two orthogonal views), recognizing involvement
of definite pulmonary structures (major bronchi or pulmonary vessels), use of the silhouette sign (soft tissue structures in contact with each other will lose their respective borders in the area of contact), and ruling out involvement of other non-pulmonary structures. Pulmonary lesions should be further defined to the portion of the lung field involved. There are two sets of descriptors that can be used to define location. One refers to the zone of lung field involved (central or perihilar, middle, peripheral), and the other gives geographic position (craniocentral, caudodorsal, etc.). A morphologic description of the lesion should then be attempted. One should avoid the use of terms implying etiology during this phase of evaluation and describe only structural or functional abnormalities. One of the first things to decide about a radiographic lesion is its extent of involvement. Some of the terms used to describe extent of involvement are:

- **solitary**: single, usually a reasonably well-defined lesion
- **lobar**: a lesion that involves most or all of one lobe with a clear demarcation between affected and unaffected lobes
- **multifocal**: two to several discrete lesions
- **diffuse**: fairly uniform involvement of multiple lobes of both lungs

If one is dealing with a solitary or multifocal type of lesion, one should attempt to characterize the following parameters:

1. **Density**: Relative radiodensity of an object is determined by: 1) its composition, 2) its absolute size (its thickness in the direction of the x-ray beam), 3) density of adjacent structures, and 4) superimposition with other structures. Furthermore, relative lung density is determined by:
   a. the amount of air within the terminal air spaces (acini) of the lung. The amount of air increases due to hyperinflation or air trapping, and decreases due to reduced compliance/atelectasis or replacement by fluid and/or cells (consolidation).
   b. the amount of blood circulating through the lungs. Changes in pulmonary blood flow are associated with hyperperfusion, hypoperfusion, vascular congestion, or thromboembolism.
   c. the amount of fluid and/or cells in the interstitial space (interalveolar and interlobular septae, peribronchial and perivascular sheaths). Fluid accumulation will result in a generalized haziness to the affected lung, whereas cellular accumulations will result in mass lesions or create a diffuse background of variably defined nodular and/or linear shadows. These factors are often interrelated. For example, hyperinflation will cause a reduction in blood flow to the area of involved lung; loss of air in a portion of lung will obscure visualization of concurrent interstitial or vascular changes; enlarging interstitial masses will eventually compress surrounding air spaces.

2. **Size**
3. **Shape**: linear (branching vs nonbranching), nodular, amorphous
4. **Delineation of borders**: well-defined vs poorly defined, circumscribed vs non-circumscribed
   a. For diffuse lesions, it is useful to determine if lung involvement is homogeneous, (that is all areas of affected lung show uniform involvement) or if lung involvement is better described as patchy, mottled, or heterogeneous, terms which imply varying degrees of involvement in different
   b. areas of the affected lung. Going through this process of morphologic description will usually allow one to determine involvement of specific pulmonary structures but should be tempered by considering that mixed radiographic patterns are the rule rather than the exception, and that some radiographic patterns can hide or obscure recognition of other concurrent changes.

**Specific radiographic patterns**

**Vascular pattern**

A vascular pattern is caused by a change in size and/or shape of pulmonary vessels. Pulmonary vessels create a pattern of tapering, branching, solid tubular shadows when vessels are seen from the side and very dense, small, discreet nodular shadows when vessels are seen end-on. Pathologic changes may involve arteries, veins or both. It is usually easier to assess the cranial lobar vessels on the lateral view and the caudal lobar vessels on the DV or VD view. The ability to visualize pulmonary vessels is dependent on the degree of inflation of the surrounding lung, and changes in vessel morphology are easily masked or hidden by concurrent disease affecting the alveolar or interstitial compartments. Remember that the pulmonary vessels lie within the interstitial compartment of the lung and diseases that primarily affect the pulmonary vessels often will also result in some involvement of the interstitium as well. One should pursue the vascular pattern gamut when it is obvious that the radiographic lesions exclusively or predominantly involve the vessels. Some of the specific vascular patterns that may be seen are:

1. increased size of arteries and veins. This indicates too much blood is flowing through the lungs and may be seen with left-to-right cardiac shunts.
2. decreased size of arteries and veins. This indicates too little blood is flowing through the lungs and may be seen with hypovolemia (shock, etc.) or right-to-left cardiac shunts.

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3. increased size of veins and normal or small arteries. This indicates pulmonary venous engorgement and may be seen with left heart failure.
4. enlarged, tortuous arteries. This indicates pulmonary hypertension and may be seen with heartworm disease or primary pulmonary hypertension.

**Bronchial pattern**

An accentuation of bronchial shadows can occur as a result of thickening of bronchial walls or accumulation of infiltrate in the peribronchial sheath. In the former situation, the lumen of the airways is reduced; whereas in the latter instance, the lumen is preserved but the definition of the outer wall is lost. Involvement of smaller airways is often associated with air-trapping, a functional disturbance leading to hyperinflation. Chronic or severe involvement of larger airways can lead to bronchiectasis. The signs of airway disease are: 1) parallel linear shadows (so-called “train tracks” or “tram lines”) that are seen when bronchi are viewed from the side, 2) small ring shadows (so-called “donuts”) that are seen when bronchi are viewed end-on, 3) large, irregular shapes, tubular or ring shadows that occur when bronchi become grossly dilated (bronchiectasis), and 4) increased end-expiratory volume that is the functional result of diffuse small airway disease. Remember that the airways lie within the interstitial compartment of the lung and diseases that primarily affect the airways often will also result in some involvement of the interstitium as well.

**Alveolar pattern**

Alveolar patterns occur because of: 1) loss of air from the alveolar air space or 2) replacement of air by fluid and/or cellular material. The former is referred to as collapse or atelectasis and is associated with a loss in lung volume, whereas the latter constitutes consolidation and is associated with a normal or increased lung volume. The two processes may occur simultaneously. In many cases of pneumonia, exudate not only fills the alveolar space but can cause obstruction of airways leading to loss of air volume. The atelectasis that usually occurs with prolonged anesthesia often involves pulmonary edema as well as regional hypoinflation. Diseases leading to alveolar filling are typically acute conditions, with rapid onset, rapid progression, and potentially rapid clearing with therapy. Because of the unique architecture of dog and cat lungs (relatively undeveloped lobular separation, excellent collateral ventilation), alveolar infiltrates in these species tend to spread and coalesce. During the progression of the disease, the distribution tends to change from lobular to segmental to lobar.

The appearance of alveolar infiltrates will depend on the relative number of affected and normal acini. When clusters of affected acini are few in number relative to well-aerated acini, one can see an ill-defined nodular appearance. When affected and normal acini appear in near-equal proportions, one sees amorphous, patchy densities with fluffy margins that tend to coalesce. If most of the acini are involved, one sees the classical alveolar pattern of homogeneous soft tissue density and air bronchograms. It is the recognition of an obvious air bronchogram that should stimulate the classification of a radiographic lesion as alveolar. Regardless of distribution, alveolar infiltrates will hide normal parenchymal structures (vessels and airway walls) and concurrent interstitial, vascular or bronchial patterns.

**Interstitial pattern**

Abnormal interstitial densities are caused by the accumulation of fluid or cellular material along the interalveolar and interlobular septae and/or the peribronchial and perivascular sheaths. Fluid accumulation tends to create an unstructured, hazy increase in soft tissue density with blurring of vascular and bronchial markings, whereas cellular infiltrates cause fine linear shadows. Most diseases that lead to an interstitial pattern will be diffuse and uniform; however, the radiographic changes are usually most obvious in the caudodorsal lung field. The interstitial pattern is by far the most subtle and most easily misinterpreted. It is legitimate to classify a lesion as “interstitial” if you feel the lungs are radiographically abnormal (well inflated but too dense), the vessels and airways do not appear to be grossly abnormal, and there is no irrefutable evidence of alveolar involvement. Interstitial fluid accumulation often “spills over” into alveoli, causing a mixed interstitial-alveolar pattern. Occasionally, when a large number of ill-defined nodules are present, the summation of densities can appear as a homogeneous pulmonary consolidation mimicking alveolar disease; however, air bronchograms will not be present.

**References**

The Changing Role of the Upper GI Series
(Parts 1 and 2)
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Indications
At our institution, an abdominal ultrasound is typically the first imaging test performed in the vomiting animal. An UGI study is done in the face of a negative ultrasound examination if survey radiographs are suspicious for or if the clinical picture is strongly suggestive of an intestinal foreign body. An UGI or double contrast gastrogram is used for identifying gastric foreign bodies and masses. In many cases, both an abdominal ultrasound and an UGI examination may be performed. It is important to note that, if both tests are going to be done, the ultrasound should be completed first as barium blocks sound and prevents adequate assessment of the intestine.

Other indications for performing an UGI include diagnosing and localizing a perforation of the intestinal tract or assessment of gastric emptying or small intestinal transit times. Identification of a diaphragmatic hernia with bowel in the thorax is a final potential application.

Performing the study
The most common contrast agent used for an UGI is liquid barium sulfate. A suspension of 30% weight/volume barium is typically used. Although sedation is not ideal, should it be necessary, acepromazine is the sedation of choice in the dog and ketamine in the cat. The animal is fasted for 12-24 hours prior to the study (unless it is an acute abdomen) and a survey radiographic study is performed including a right and left lateral and ventrodorsal projections. Should the colon be full, an enema should be performed. Barium dosage is typically 5-7 ml/kg in dogs weighing more than 20 kg, and 10-12 ml/kg in cats and dogs weighing less than 20 kg.1 If the animal is willing to drink the barium, it can be administered from a bowl. Alternatively, barium may need to be fed to the animal with a syringe or by passing an orogastric tube. It is important to note that GI foreign bodies may still be visible if an inadequate dose of barium is given, but gastric emptying and transit times (Table 1) will be wrong.

Table 1. Barium transit times1

<table>
<thead>
<tr>
<th></th>
<th>Contrast in Duodenum</th>
<th>Stomach is empty</th>
<th>Contrast reaches the colon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dog</td>
<td>15 minutes</td>
<td>30-120 minutes</td>
<td>30-120 minutes</td>
</tr>
<tr>
<td>Cat</td>
<td>10 minutes</td>
<td>15-60 minutes</td>
<td>30-60 minutes</td>
</tr>
</tbody>
</table>

Immediately after barium administration, right and left lateral, ventrodorsal and dorsoventral radiographs should be obtained. Right lateral and ventrodorsal radiographs are obtained at 15, 30 and 60 minutes and then every 30 minutes until the contrast has reached the colon or until an obstruction has been confirmed. Left lateral and dorsoventral projections may be useful if a suspicious lesion is seen and needs confirmation with additional projections. If gastric emptying time is being assessed, radiographs are obtained until the stomach is empty.

Non-ionic, iodinated contrast agents can also be used to perform an UGI when GI perforation is suspected.2 Barium leakage into the peritoneal cavity can cause granulomatous peritonitis whereas non-ionic iodinated agents that leak into the abdomen will simply be absorbed into circulation and eliminated by the kidneys. If the animal is dehydrated, this should be corrected prior to the study as the osmotic effect of the contrast agent will pull fluid into the GI system. Patient preparation is similar to that for a barium study. The dosage of iodinated contrast agent is 700-800 mgI/kg diluted with water to a total volume of 10 ml/kg for both dogs and cats.1 Iodinated contrast agents typically do not taste good so syringe feeding or administration by orogastric tube may be necessary. Right and left lateral, ventrodorsal and dorsoventral projections are obtained immediately following contrast administration. Right lateral and ventrodorsal projections are obtained at 15, 30, and 60 minutes and then every 30 minutes until contrast agent reaches the colon. Iodinated contrast agents can be used for a UGI in cases of obstruction but are not recommended for assessment of the mucosal margin.

References
Top ER Imaging Diagnoses
(Parts 1 and 2)
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One of your main goals is to perform a repeatable and complete abdominal ultrasound every time you scan. To do this, you’ll need to be able to acquire diagnostic quality images of each major abdominal organ including liver, spleen, kidneys, urinary bladder, and small intestine. For smaller organs that are difficult to see or not normally seen, (adrenals, pancreas, sublumbar lymph nodes), you should be able to identify landmarks that guide you to scanning the correct region. As long as you scan the correct region, you’ll be able to find most abnormalities. If you are just starting, searching for normal small organs is not the best use of your ultrasound time and might be skipped until skill and confidence is increased by experience.

Focus on evaluating each organ in its entirety so as not to miss a lesion. Large organs such as the liver can be difficult to scan completely. In addition, evaluate each organ for size, shape, and echogenicity relative to other organs. Describe any lesions that you find and relate them to the clinical history of the patient. Ultrasound is a challenging discipline, but can be very rewarding!

Liver
Place your transducer as far cranially as possible in the xiphoid region, then angle it cranially. To do this, the transducer will be nearly parallel to the ventral body wall and aligned along midline. You should be able to see the diaphragm meet the body wall at the top left of the image.

Next, point your transducer to the animal’s right (don’t slide caudally along the ribs). You should be able to see the gallbladder, portal vein, and hepatic veins. Continue pointing to the right until the liver disappears from the image. That tells you that you have seen the entire right side of the liver.

Repeat this scan procedure for the left side. The stomach may get in the way so make sure your transducer is as far cranially as possible against the xiphoid.

Finally, rotate your transducer into the transverse plane. Start with it in a slightly cranially angled position so that you can see liver cranial to the stomach. Then angle more cranially so that you see the entire liver to where it meets the diaphragm.

Evaluate the liver for size, shape, and echogenicity. The portal veins have thick hyperechoic walls. Look at the liver margin for sharpness, and how far it extends ventral to the stomach (left). During your examination, make sure to see the entire diaphragm until it connects to the body wall (right, arrow). That way you are sure not to miss lesions in the cranial part of the liver.

Spleen
The spleen is located caudal to the liver on the left side. The gastrospenic ligament fixes this area of the spleen in position, but the distal extremity is mobile. To image the spleen, you must be perpendicular to the long axis of the spleen, which is not likely to be the same as the long axis of the animal.

Once you find it, rotate your transducer to obtain a cross section. The spleen should look triangular with the apex pointing toward the bottom of the image. Look for vessels exiting the spleen at the apex to make sure you are in a true cross section.

Look at the proximal extremity of the spleen. To do this, slide your hand cranially maintaining the cross section until you reach the ribs. Watch the screen as you do this, not the dog! Next, keep the transducer in the same position and angle it dorsally and cranially. You should see spleen filling most of the image. Increase the depth if needed so that the far edge of the spleen is visible.
Finally, trace the distal extremity of the spleen. Concentrate on keeping the triangle of the spleen in the middle of the image. You may need to pause and move from one side to the other to see a large spleen. Continue until the spleen disappears from view in the center of the screen.

The head, or proximal extremity of the spleen, curves dorsally along the left body wall. Since you are examining it almost parallel to its long axis, it fills the near and far fields of the screen.

**Kidneys**

The left kidney is caudal to the spleen in the lateral portion of the abdomen. Once you locate it, move the transducer from side to side until you find the center. Then, rotate the transducer to make the kidney look as long as possible. This is a sagittal image from where you can evaluate size, shape and echogenicity. Fan through the kidney from side to side. Then, rotate the transducer 90 degrees to get a transverse view. The renal pelvis is hyperechoic because of fat, and the papilla forms a “V” shape. The potential space surrounding the papilla is the renal pelvis where urine passes into the ureter. Check here for any pelvic dilation, which appears as a black line or wedge shape.

To find the right kidney, place your left thumb caudal to the last rib and press inward. Start in sagittal and optimize the image as for the left kidney. Examine the kidney in two planes.

The left kidney is examined in sagittal (top) and transverse (bottom left) planes. Use the sagittal view to compare the echogenicity of the cortex and medulla to each other, and to the spleen. In transverse, look for the v-shaped papilla (arrows). In this example, it marks the potential space of the pelvis (arrows) which is not visible if it is not dilated. The renal pelvis on the bottom right is dilated.

**Urinary bladder**

The urinary bladder is in the caudal abdomen, with the trigone and urethra positioned in the pelvic inlet. It is usually large enough that you need to image it in cranial and caudal sections. First, examine the cranial pole in sagittal position. Move the transducer from lateral to medial to see the entire bladder. Next, move the transducer caudally and identify the trigone. Use small rotating movements to align the urethra with the trigone of the bladder. You can also rotate the transducer 90 degrees and follow the bladder from the cranial pole to the urethra in transverse section.

Sagittal images of the cranial pole (top) and the trigone (bottom) of the bladder. The urethra (arrows) leads out of the trigone.