Abdominal radiography in small animals

Chris Warren-Smith and Chris Lamb

Chris Warren-Smith graduated from the Royal Veterinary College (RVC) in 2005 and, following two years in practice and a rotating internship, undertook a diagnostic imaging residency at the RVC. He is currently a clinical radiologist at Langford Veterinary Services. He holds the RCVS certificate in veterinary diagnostic imaging and has a Master of Veterinary Medicine degree.

Chris Lamb graduated from the University of Cambridge in 1993 and trained in radiology at Tufts University, Massachusetts, USA. After a short period in small animal referral practice in London, he joined the Royal Veterinary College, where he is currently professor of radiology. He is a diplomate of both the American College of Veterinary Radiology and the European College of Veterinary Diagnostic Imaging, and a fellow of the Higher Education Academy.

doi:10.1136/inp.e5308
Provenance: Commissioned and peer-reviewed

Increasingly widespread use of ultrasonography has led to a decline in the use of abdominal radiography in small animal practice; however, radiography remains an efficient and useful technique for examining a patient's abdomen. This article reviews the role of radiography in the diagnosis of some common conditions affecting the gastrointestinal and urinary tracts and the peritoneal cavity in small animals.

Indications

Radiography should be considered in animals that have blunt or penetrating abdominal trauma because it enables a prompt overview of the entire abdomen and spine that may reveal signs of injuries including a vertebral fracture, ruptured diaphragm and haemorrhage (Fig 1). Other frequent indications for abdominal radiography include gastrointestinal signs such as vomiting, melaena and tenesmus, and urogenital signs such as dysuria or stranguria. Radiography in such cases may reveal abnormalities that help to explain the clinical signs.

Radiography is particularly well suited to the detection of abnormal gas accumulation (Fig 2) or the presence of opaque material, such as foreign objects or calculi (Fig 3). In contrast, ultrasonography is preferred for animals with haematuria, suspected peritoneal fluid or an abdominal mass because these conditions are often associated with minimal or non-specific radiographic signs.

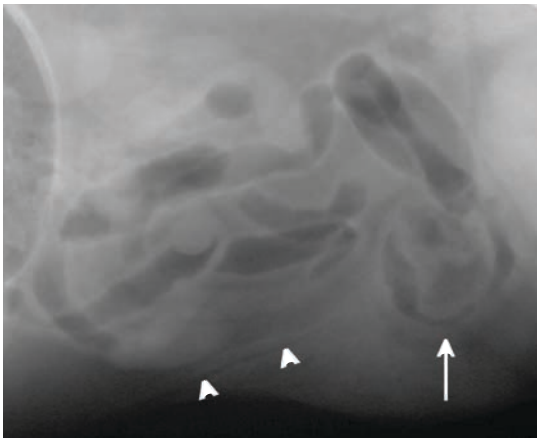


Fig 1: Lateral radiograph of a dog that had been hit by a car. A loop of small intestine (arrow) extends into a swelling, affecting tissues ventral to the abdominal wall (arrowheads). This is compatible with rupture of the abdominal wall

Principles

A basic tenet of radiography is the need to obtain a minimum of two orthogonal views of the area of interest; radiography of the abdomen is no exception to this rule. Although a lot of information is often obtained from a single lateral view, particularly in deep-chested dogs, the ventrodorsal view enables more accurate lesion localisation than is possible using the lateral view alone. Dorsoventral abdominal radiographs are not recommended for dogs or cats because in sternal

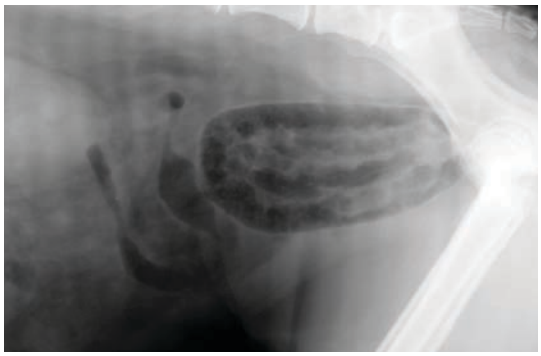


Fig 2: Gas accumulation in the urinary bladder in a dog that had not been catheterised recently. This is compatible with emphysematous cystitis

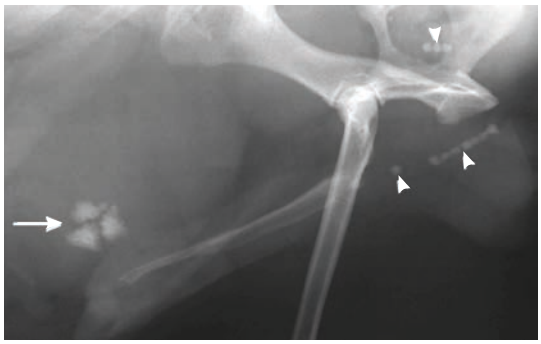


Fig 3: Multiple urinary calculi can be seen within the urinary bladder (arrow) and within the urethra (arrowheads) of a male dog, causing an obstruction

recumbency the deep shape of the abdomen leads to marked superimposition of organs, which obscures anatomical detail (and requires a higher exposure than that needed for a ventrodorsal radiograph).

Positioning

For abdominal radiographs of dogs, the x-ray beam should be centred on the last rib and collimated to include the xiphisternum, proximal femurs and the ventral and dorsal skin edges. For dogs with urogenital signs, abdominal radiographs may be centred more caudally to include the perineum. As the abdomen of many large dogs exceeds the largest cassette, two radiographs may be required.

Technique

Radiographic depiction of the abdominal organs depends largely on the difference in attenuation between soft tissues and adjacent fat; therefore, moderate kVp settings should be used. In general, appropriate exposures for the canine abdomen will use lower kVp settings than thoracic radiographs in the same dog. High kVp settings will reduce abdominal contrast and could mimic the appearance of peritoneal disease. Exposure times should be kept short to avoid blurring cased by the patient's breathing. Abdominal radiographs may be exposed at the end of expiration to take advantage of the expiratory pause.

Use of a grid is recommended when the abdomen exceeds 10 cm thick; radiographs of obese cats may be better if a grid is used. When a grid is not used, excessive scattered x-rays will affect the radiograph, making it appear dark with low contrast. Some computed radiography systems are particularly sensitive to scattered x-rays, so a grid is essential.

Contrast radiography

Contrast studies are performed less frequently when ultrasonography is available, but they are still worth considering for patients with gastrointestinal or urinary signs. The presence of an obstruction or the rupture of an organ can be proved by contrast radiography (Fig 4), whereas ultrasonography may only provide indirect evidence of these lesions.

The technique for gastrointestinal contrast radiography is summarised in Box 1. A barium sulphate suspension is the optimal contrast medium for the gastrointestinal tract (GI). A proprietary radiographic preparation of barium sulphate should always be used. Barium sulphate powder BP is unsuitable for gastrointestinal studies because it does not form a suspension in water and does not coat the mucosal surface. In theory, an organic iodide contrast medium should be used if a gastrointestinal perforation is suspected, but in practice signs of perforation (such as septic peritoneal fluid) are an indication for an immediate laparotomy, so contrast radiography is unnecessary.

Liquid contrast medium starts leaving the stomach almost immediately after administration and gastric emptying is normally complete by four hours. All of the contrast medium should be in the colon after 24 hours (Fig 5). A simple alternative method for the assessment of gastric emptying is based on feeding the patient its usual meal: a radiograph taken 24 hours

Box 1: Upper gastrointestinal contrast study ('barium series')

Patient preparation
- No food for 24 hours; administer an enema before the study
- Avoid sedation if possible. Low-dose acepromazine may aid radiography of a vicious dog but more potent sedatives adversely affect gastrointestinal motility and should not be used

Survey radiography
- Obtain good-quality survey radiographs as a necessary first step
- Lateral and ventrodorsal (not dorsoventral) views are usually required
- Examine the radiographs carefully for signs of disease that might make contrast radiography unnecessary

Contrast administration
- Administer a dilute (eg, 30 to 50 per cent w/v) barium suspension by stomach tube (approximately 6 to 12 ml/kg for dogs, 10 ml/kg for cats). It is essential to use a radiographic preparation; barium sulphate powder BP is not suitable for contrast radiography.
- Giving insufficient contrast medium can make the study useless

Contrast radiography
- Obtain repeat radiographs with a higher exposure to increase the visibility of the contrast medium
- A sequence of radiographs is needed for functional assessments (eg, 0, 30, 60, 180, 300 minutes in dogs; 0, 15, 30, 60 minutes in cats)
- Delayed radiographs (eg, at 12 or 24 hours) may be useful in animals with an obstruction
- Do not terminate the study prematurely; films taken later may show the lesion most clearly or may demonstrate that a suspected abnormality was a transient (ie, normal) phenomenon

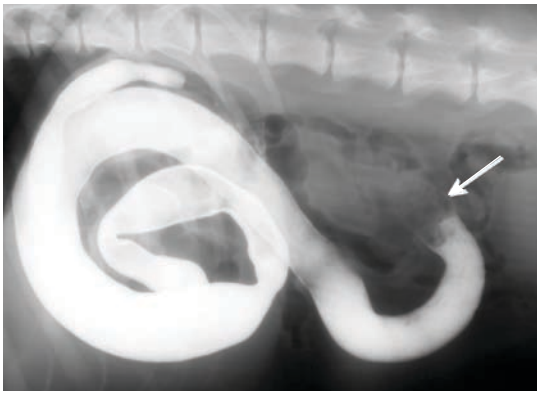


Fig 4: Upper gastrointestinal contrast study three hours after the administration of contrast medium, showing complete obstruction (arrow) of the small intestine due to a foreign object (in this case, a piece of corn cob)

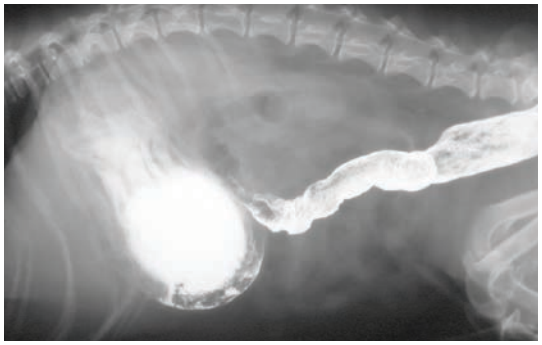


Fig 5: Upper gastrointestinal contrast study, 18 hours after the administration of contrast medium, in a dog that was vomiting repeatedly. Persistent accumulation of contrast medium in the stomach can be seen, which is compatible with delayed gastric emptying. Contrast medium that has left the stomach has collected in the colon. The final diagnosis in this case was pyloric stenosis

later will show either an empty stomach, which is normal, or retained food, which indicates delayed gastric emptying.

Contrast medium moves down the GI by peristalsis, so it is normal to observe variations in the luminal diameter and position of the intestine over time. Abnormalities frequently result in an appearance that persists over time (eg, a lack of movement of barium, or the fixed shape of the gastric or intestinal wall).

The technique for upper urinary contrast radiography is summarised in Box 2. A normal sequence of opacification of the kidneys is shown in Fig 6.

The technique for lower urinary contrast radiography is summarised in Box 3. The combination of a large volume of air (negative contrast) and a small volume of positive contrast medium creates a 'double' contrast cystogram. Under these circumstances, the small puddle of positive contrast medium that occupies the dependent aspect of the bladder will outline mucosal lesions or any mobile material (eg, calculi) that accumulates on the dependent surface (Fig 7). It should be noted that aqueous organic iodide contrast medium does not coat the entire mucosal surface of the bladder, only the dependent surface. Therefore, left and right lateral, and left and right oblique radiographs are usually obtained to ensure a complete double contrast study of the bladder wall.

Interpretation

The ability to interpret radiographs correctly does not depend on having good eyesight; it depends on knowledge of radiographic anatomy and knowing what to look for. Radiographs should always be interpreted with knowledge of the patient's clinical history and searched for signs that could explain the animal's condition. With increasing experience comes familiarity with the appearances of most common conditions, which aids recognition of relevant lesions and reduces the likelihood of being distracted by an incidental finding. Always examine the entire radiograph and take your time.

The following are examples of radiographs of common abdominal conditions.

Gastric dilation–volvulus

Radiography is a useful method for examining the stomach in dogs with suspected gastric dilation–volvulus (GDV). In a right lateral radiograph, most affected dogs usually have marked gastric dilation and

Box 2: Upper urinary contrast study ('excretory urogram')

Patient preparation
- Explain to the owners the occasional adverse reactions to contrast media (eg, hypotension, apnoea)
- No food for 24 hours; administer an enema before the study
- Ideally, anaesthetise the patient to minimise movement blur and reduce reactions (eg, vomiting) associated with injection of the contrast medium
- Stop administration of intravenous fluids (the production of dilute urine will reduce the visibility of excreted contrast medium)
- Collect urine for bacteriology and urinalysis if this has not been done already
- Catheterise the bladder, drain the urine and insufflate until reasonably firm. This improves the visibility of the ureters by displacing the intestine away and giving a uniform lucent background

Survey radiography
- Obtain good-quality survey radiographs as a necessary first step
- Lateral and ventrodorsal (not dorsoventral) views are usually required
- Examine the radiographs carefully for signs of disease that might make contrast radiography unnecessary

Contrast administration
- Ionic organic iodide contrast media are generally used as they are cheaper than the non-ionic form; however, non-ionic agents (eg, iohexol or iopamidol) can be used in high-risk patients
- Position the patient for ventrodorsal radiographs
- Rapidly inject 800 mg Iodine/kg via a catheter placed in a jugular or peripheral vein

Contrast radiography
- Obtain two ventrodorsal radiographs in rapid sequence as soon as the injection is completed. This increases the chances of obtaining a perfect nephrogram
- Obtain ventrodorsal radiographs until the ureters are visualised, then obtain a lateral radiograph. This normally takes 10 to 15 minutes; additional radiographs may be necessary if opacification of the urinary tract develops very slowly (eg, if it is dilated)
- Restart administration of intravenous fluids (if necessary) at the end of the study

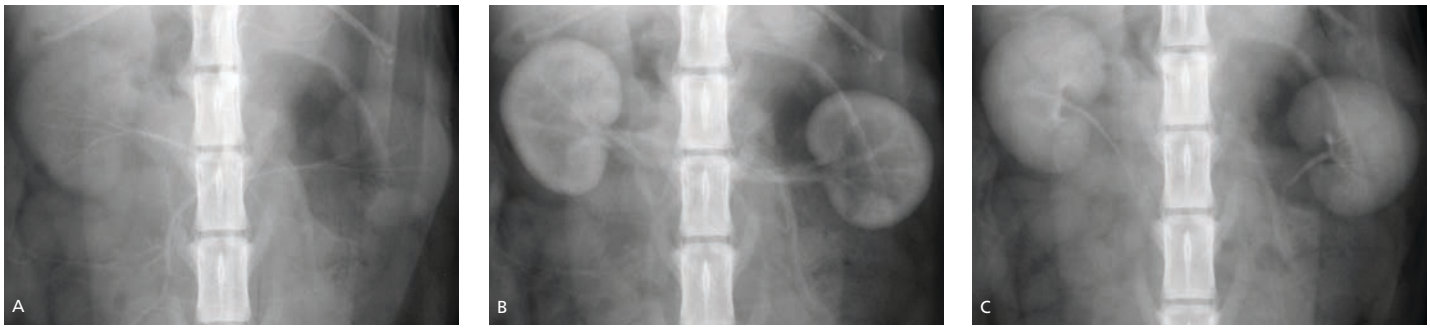


Fig 6: Excretory urogram showing the normal sequence of renal opacification following intravenous contrast administration in a cat. (a) Immediately after administration (renal angiogram), (b) 20 seconds after administration (nephrogram), (c) two to five minutes after administration (pyelogram)

Box 3: Lower urinary contrast study

Patient preparation
- No food for 24 hours; administer an enema before the study

Survey radiography
- Obtain good-quality survey radiographs as a necessary first step
- Lateral and ventrodorsal (not dorsoventral) views are usually required
- Examine the radiographs carefully for signs of disease that might make contrast radiography unnecessary

Examining the bladder
- Drain any urine out of the bladder via a transurethral catheter. Position the tip of a catheter in the cranial part of the urethra so that it is not superimposed on the bladder
- Insufflate with air (or carbon dioxide) until the bladder feels adequately distended (ie, quite firm on palpation). Note, there is no reliable guide to bladder volume in terms of ml/kg
- Reduce exposure compared to the survey radiograph (eg, halve mAs). Obtain a lateral view
- Add a small volume (1 to 2 ml for a cat, 2 to 5 ml for a dog) of organic iodide contrast medium
- Increase the exposure factors compared to the survey radiograph (eg, add 5 kVp). Obtain left and right lateral views (and oblique ventrodorsal views if required)

Examining the urethra (and bladder in patients with a suspected bladder rupture)
- Prefill the catheter with contrast medium to prevent the introduction of air bubbles
- In a male patient, position the tip of a urinary catheter in the distal part of the urethra; in a female patient, place a Foley catheter tip in the vestibule, inflate the cuff and pull back against a clamp placed across the vulva. This will position the catheter optimally for urethrography
- Inject contrast medium (2 to 5 ml for a cat, 5 to 10 ml for a male dog, 10 to 40 ml for a female dog). Stop immediately if there is resistance and check the catheter position before continuing
- Obtain a lateral radiograph during the injection
- Repeat the injections and radiographs, if required, to determine whether suspicious appearances are consistent

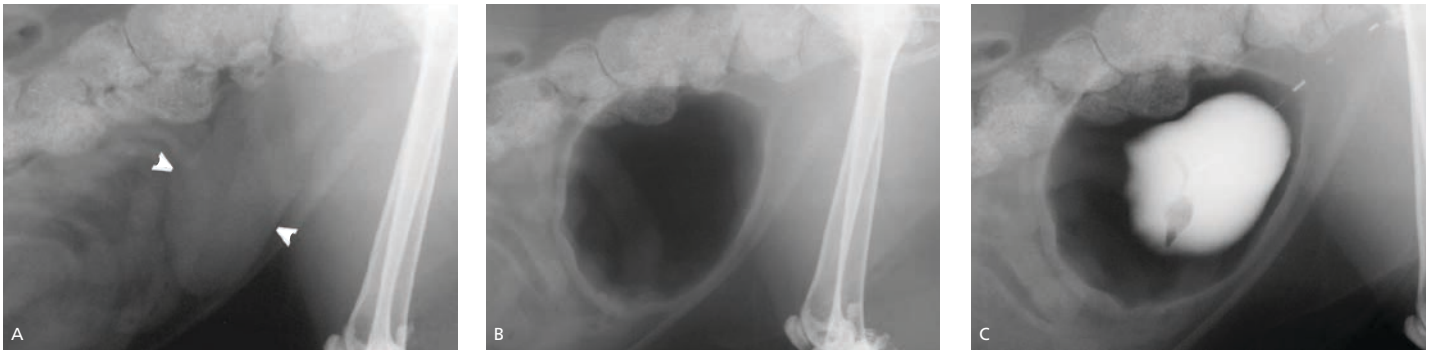


Fig 7: Cystography in a cat. (a) Survey radiograph in which a flaccid bladder is visible (between the arrowheads). Note, the colon is full and it would have been preferable if it had been emptied before the study. (b) Pneumocystogram showing a diffuse, uneven thickening of the bladder wall. Thickening is most marked on the cranial aspect, which is compatible with chronic cystitis. (c) Double contrast radiograph showing an elongated lucent structure within the contrast puddle; this proved to be a blood clot. Note, the aqueous organic iodide contrast medium has not coated the bladder mucosa

a dilated, gas-filled antrum in the craniodorsal abdomen; a fold in the gastric wall between the antrum and body produces a characteristic 'double bubble' appearance (Fig 8). The presence of gas within the wall of the stomach is a sensitive indicator of gastric necrosis.

Chronic gastric volvulus is a related condition that may be associated with vomiting, weight loss or diarrhoea, or may be clinically silent; it affects the same types of dogs as the acute GDV syndrome. Dogs with chronic gastric volvulus have a moderately or non-distended displaced stomach (Fig 9). As it is thought that this condition can lead to an acute GDV, it is often treated by prophylactic gastropexy.

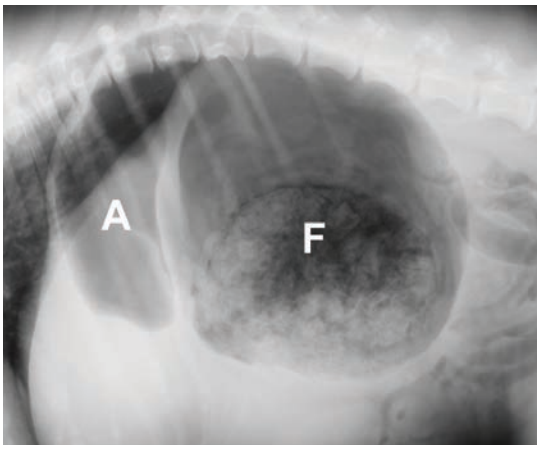


Fig 8: Right lateral abdominal radiograph of a large-breed dog with gastric dilation–volvulus. The stomach is markedly distended and displaced, with the gas-filled antrum (A) on its cranial aspect and the gas- and ingesta-filled fundus (F) on its caudal aspect

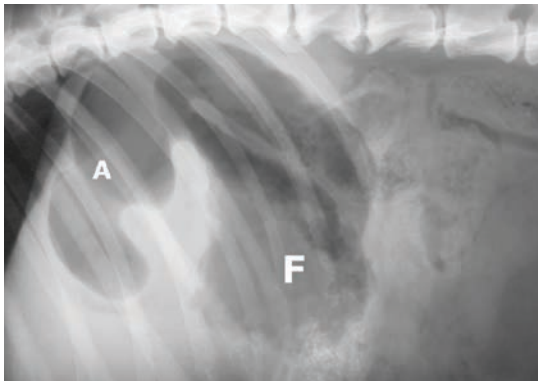


Fig 9: Right lateral abdominal radiograph of a German shepherd dog that had been referred for investigation of a nasal discharge (the final diagnosis was a nasal adenocarcinoma). The stomach is displaced with the gas-filled antrum (A), dorsal and cranial to the fundus (F). This appearance is compatible with chronic gastric volvulus

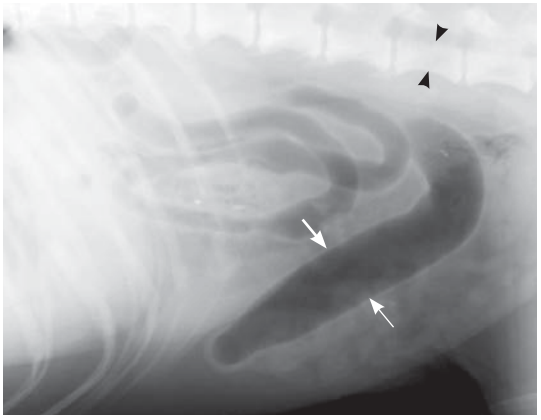


Fig 10: Lateral abdominal radiograph of a dog with an intestinal obstruction caused by a piece of a stuffed toy. A loop of small intestine is distended with gas; its maximum diameter (arrows) is approximately 2·3 times the depth of L5 vertebral body (arrowheads)

Intestinal obstruction

Vomiting is one of the major indications for abdominal radiography because of the possibility of intestinal obstruction (eg, by foreign bodies, an intestinal mass or intussusception). In the acute phases of intestinal obstruction, hyperperistalsis promotes fluid and gas accumulation proximal to the obstruction and emptying of the intestine distal to the obstruction. Continued swallowing of saliva and air, and continued secretion into the GI, also promote fluid and gas accumulation, which may be observed radiographically.

Recognition of localised intestinal dilation is key to the radiographic diagnosis of an obstruction. Various quantitative guidelines have been used to assess the diameter of the small intestinal lumen; for example, a small intestinal diameter greater than 1·6 times the depth of the mid-centrum of the fifth lumbar vertebra is associated with an intestinal obstruction (Fig 10). However, it should be remembered that the severity of intestine dilation varies according to the completeness of the obstruction and the degree to which fluid accumulates. Even a complete obstruction of the duodenum usually causes minimal fluid accumulation because most of the fluid refluxes into the stomach and is vomited. Similarly, the completeness of obstruction may vary over time as a foreign object passes through the stomach and intestine. Repeat radiographs can give a clearer indication of the completeness of an obstruction depending on how intestinal dilatation varies over time (Fig 11).

Recognition of foreign material in the small intestine of an animal with clinical signs of obstruction is a good indication for exploratory surgery even in the absence of marked intestinal dilatation. Types of foreign material that may be identified on survey radiographs include:

- Metals (eg, jewellery or coins);
- Minerals (eg, bones or stones);
- Other opaque materials (eg, certain rubber or plastic items);
- Non-opaque foreign materials (eg, various fruit seeds and corn cobs [Fig 12]).

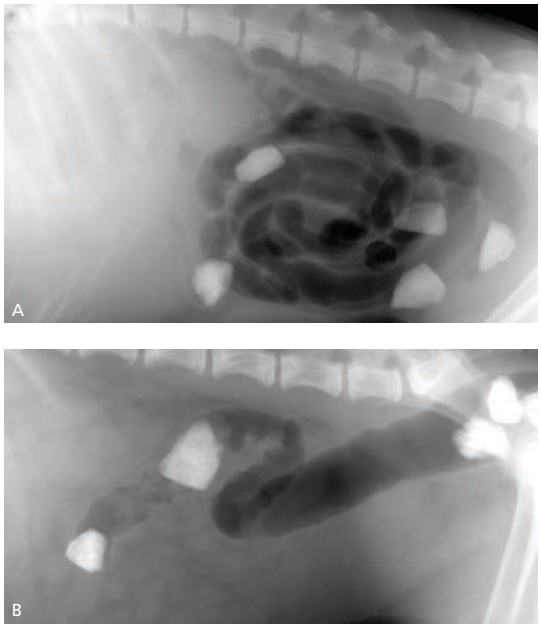


Fig 11: (a) Initial abdominal radiograph of a vomiting dog, showing several large stones within distended loops of the small intestine. The maximum diameter of the small intestine is approximately twice the depth of the L5 vertebral body, which suggests an obstruction. (b) Radiograph of the same dog taken 12 hours later, showing that the stones have moved into the colon and the small intestinal dilation has resolved

Pneumoperitoneum

Gas may be present in the peritoneum following rupture of the GI tract (eg, as a result of a perforated ulcer or erosion due to a sharp foreign body), penetrating trauma or recent abdominal surgery (large volumes of peritoneal gas may persist for up to 28 days after a laparotomy). The presence of peritoneal gas without a history of recent laparotomy is an indication for an immediate exploratory laparotomy (Fig 13).

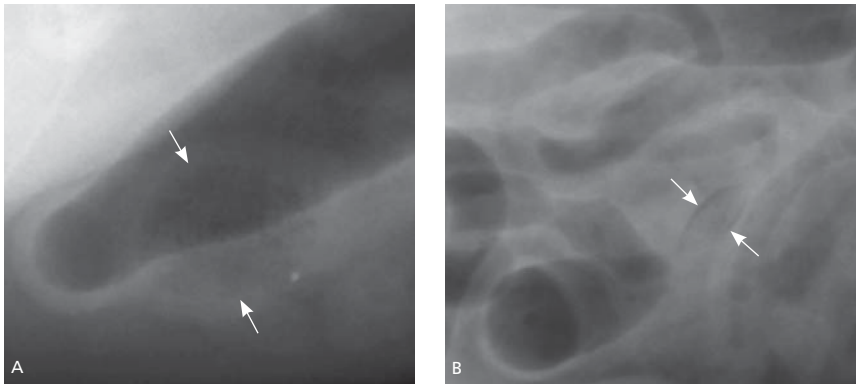


Fig 12: Examples of non-opaque foreign bodies. (a) Close-up view of Fig 10, showing a rounded, speckled opacity (between the arrows), which was found to be a piece of a stuffed toy. (b) Radiograph of a dog that was vomiting as a result of small intestinal obstruction caused by a peach stone (arrows)

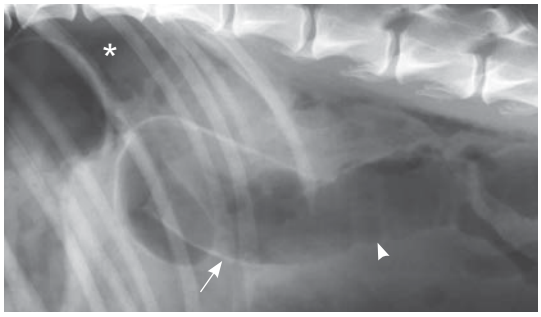


Fig 13: Lateral abdominal radiograph of a pneumoperitoneum in a dog with a perforated duodenal ulcer, showing gas (*) adjacent to the gastric fundus. Parts of the colonic wall are outlined by peritoneal gas (arrow), whereas in other areas the wall is not visible (arrowhead), probably because it is obscured by peritoneal fluid

Peritoneal gas increases the visibility of the outlines of the abdominal organs, and enables structures that are not normally visible to be seen (eg, the fissures between liver lobes and the diaphragm).

Calculi

Calculi (nephroliths/cystoliths/urethral stones) may be seen in any part of the urinary tract, with the most common site being the bladder. Struvite, calcium oxalate, calcium phosphate and silica calculi are opaque and therefore visible in survey radiographs, whereas cysteine and urate stones have a similar opacity to fluid, so are not usually visible without contrast radiography. Compared to contrast medium with a high iodine content, virtually all bladder inclusions appear lucent regardless of their composition; therefore, in a positive contrast study, calculi appear as radiolucent filling defects (Fig 14). Ultrasonography is a more convenient method for detecting urinary calculi than contrast radiography as it requires no patient preparation or injection of contrast medium, and is unaffected by variations in the opacity of the calculi.

Although ureteral calculi may be detected by both survey radiography and ultrasonography, diagnosis of a ureteral obstruction can be difficult because the degree of dilation of the proximal ureter and renal pelvis does not correlate well with the degree of obstruction. Furthermore, examination of the ureter by excretory urography may be compromised by poor renal excretion of contrast medium. Under these circumstances, direct pyelography (ie, injection of contrast medium into the renal pelvis) should be considered (Fig 15).

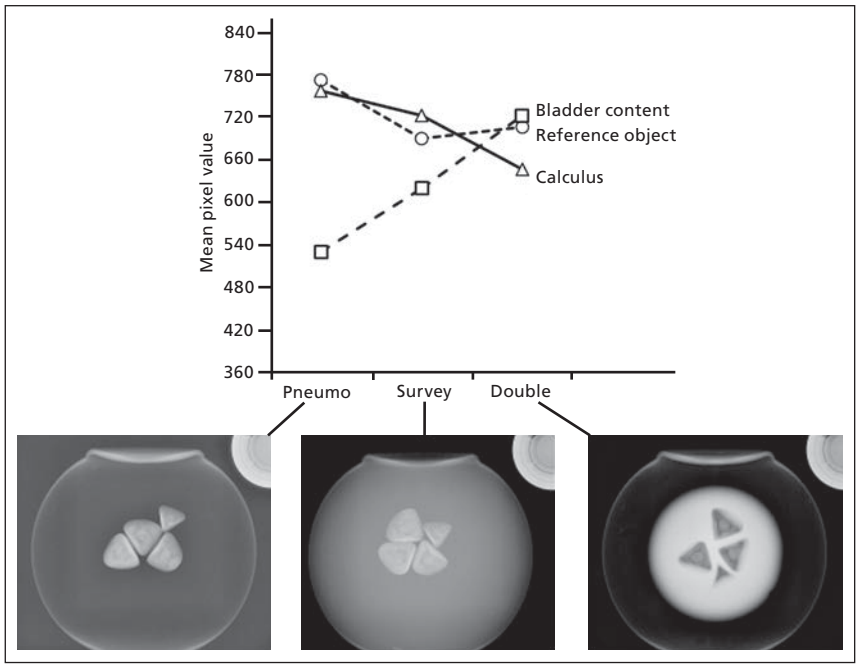


Fig 14: Relative radiographic opacity of structures. Struvite calculi in a bladder phantom appear opaque when surrounded by gas (pneumo) or water (survey), but appear lucent when surrounded by positive contrast medium (double). In the study shown here, opacity is measured by mean pixel value. The effect of varying the exposure factors is accounted for by using a reference object (in this case, a phantom in the top right corner)

Rupture of the ureter, bladder or urethra

Abdominal or pelvic blunt trauma (eg, due to a road traffic accident) is a relatively frequent cause of urinary tract rupture. Depending on the site of rupture, extravasated urine may accumulate in the retroperitoneum, peritoneal cavity or in subcutaneous tissues around the pelvis. Demonstration of contrast leakage from the urinary tract proves that the tract has ruptured and usually indicates the site of the rupture as well (Fig 16). In contrast, ultrasonography might enable the detection of fluid accumulation, but the nature and origin of the fluid would be uncertain without further tests. An inability to visualise the bladder on survey radiographs should lead to the suspicion of a ruptured bladder, but absolute proof requires the use of positive contrast radiography (Fig 17).

Other urethral conditions

Although it is possible to examine the penile urethra ultrasonographically, the intrapelvic portion of the urethra is not accessible to ultrasound. Furthermore, when clinical signs suggest lesions affecting the urethra, it is the lumen of the urethra that is the target of the examination. For the urethra to be visualised, the lumen must be dilated, and this is most readily accomplished by obtaining a radiograph during the injection of contrast medium (Fig 18). Urethrography is an essential method for examining the urethra in

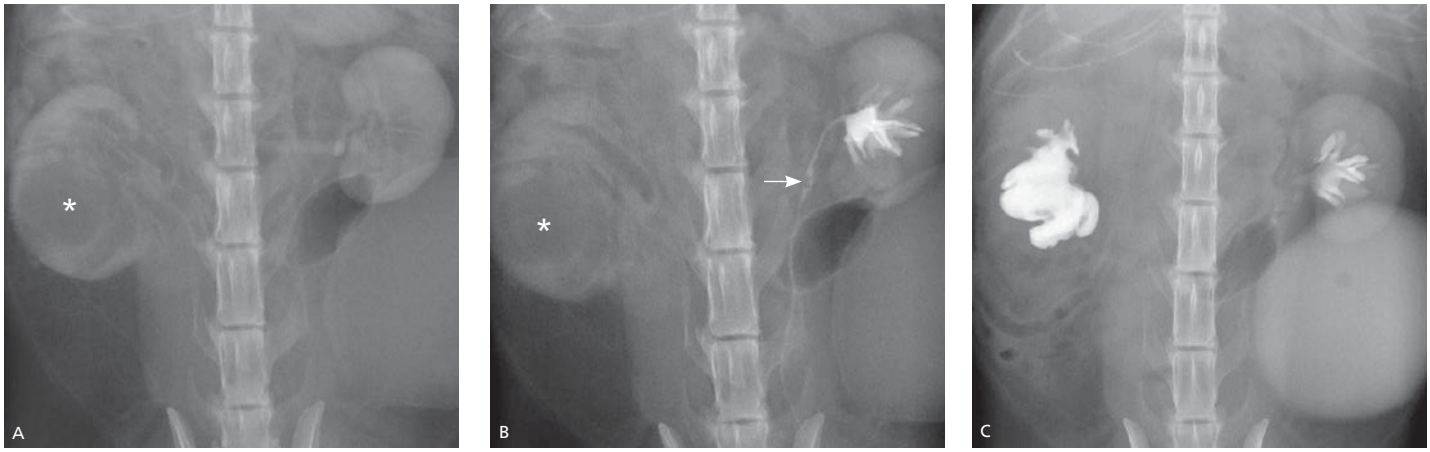
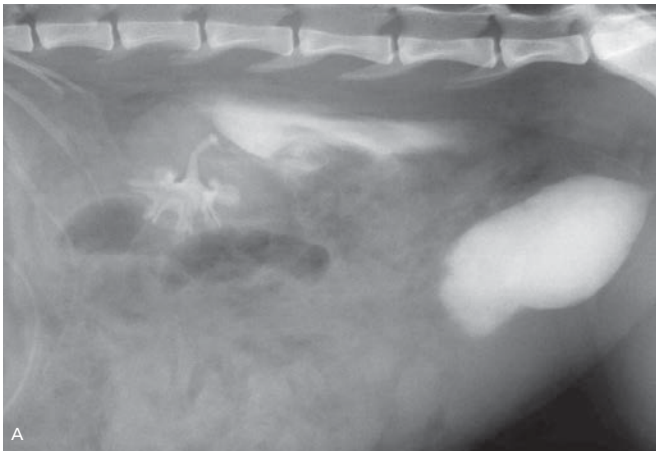


Fig 15: Direct pyelography in cat with a ureteral obstruction. (a) Radiograph taken immediately after the intravenous administration of contrast medium, showing a lucent zone (*) in the middle of the right kidney. (b) This appearance persists (*) three to five minutes later, and there is a lack of opacification of the right ureter despite optimal opacification of the left kidney and ureter. A non-obstructing calculus (arrow) is present in the left ureter. (c) Injection of contrast medium into the right renal pelvis demonstrates marked hydronephrosis and complete obstruction of the proximal ureter



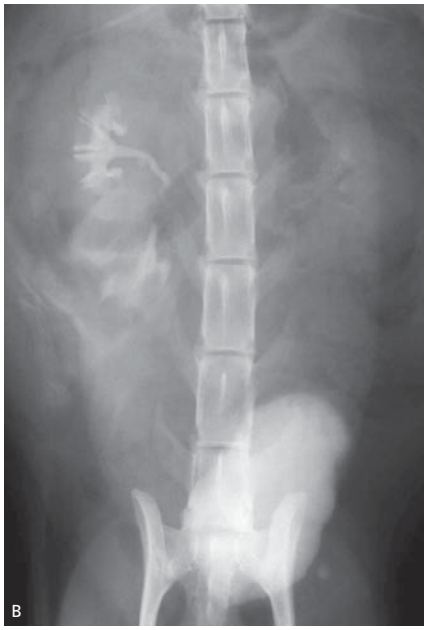


Fig 16: Excretory urogram in a cat that had been hit by a car. (a) Lateral view, (b) ventrodorsal view. There is slight dilation of the right renal pelvis, extravasation of contrast medium into the retroperitoneum to the right of the midline and lack of opacification of the right distal ureter. A ruptured right ureter was confirmed surgically. The trauma has also caused the bladder to become misshapen

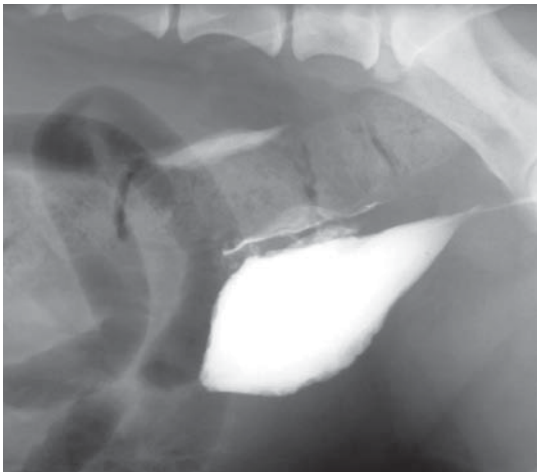


Fig 17: Positive contrast cystography in a dog with a ruptured bladder following blunt abdominal trauma. Contrast medium has leaked from the dorsal aspect of the bladder and collected around the colon

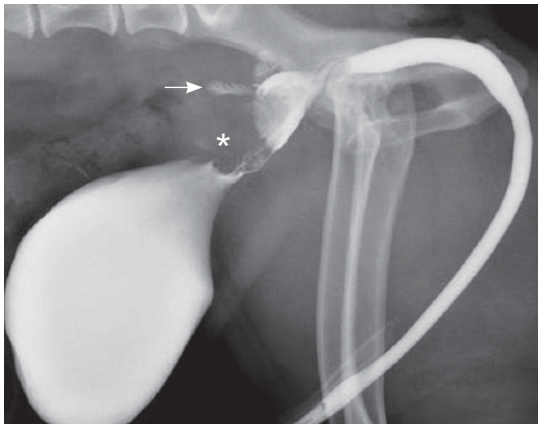


Fig 18: Positive contrast retrograde urethrogram in a male dog with dysuria and haematuria. A lobular mass (*) can be seen invading the urethra just cranial to the prostate, and contrast medium has refluxed into the prostatic ducts (arrow). The final diagnosis was prostatic carcinoma

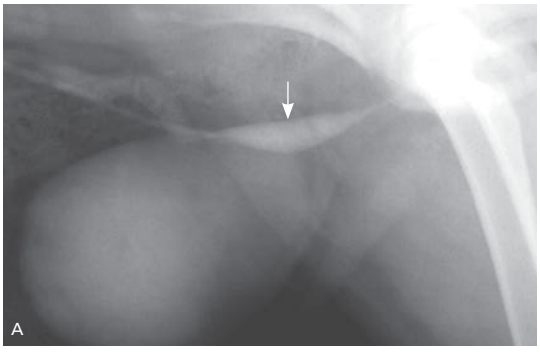


Fig 19: Retrograde vaginourethrography in a case of a suspected ectopic ureter. (a) Close-up view of the caudal abdomen of an incontinent female dog during excretory urography. A faintly opacified, elongated structure (arrow), compatible with a dilated ectopic ureter, can be seen superimposed on the dorsal aspect of the bladder. (b) Marked opacification of the ureter during retrograde urethrography enables a confident diagnosis to be made and the site of communication with the urethra to be determined

patients with signs such as dysuria, stranguria, lower urinary tract haemorrhage and incontinence. It is frequently useful in animals with a suspected ectopic ureter, because a ureter that communicates with the urethra may be opacified by the retrograde injection of contrast medium and therefore visualised more clearly than during excretory urography (Fig 19).

Summary

The ability to make and correctly interpret abdominal radiographs remains a cornerstone of small animal practice. Contrast radiography is worth considering for selected patients, even when ultrasonography is available.

Further reading

LAMB, C. R. (2007) How to look at radiographs. *European Journal of Companion Animal Practice* **17**, 79-84

O'BRIEN, T. R. (1978) Radiographic Diagnosis of Abdominal Disorders in the Dog and Cat: Radiographic Interpretations, Clinical Signs, Pathophysiology. W. B. Saunders

THRALL, D. E. (Ed) (2007) Textbook of Veterinary Diagnostic Radiology, 5th edn. Saunders Elsevier

InPractice

Abdominal radiography in small animals

Chris Warren-Smith and Chris Lamb

In Practice 2012 34: 454-461
doi: 10.1136/inp.e5308

Notes