

Excretory Urography

Kerry J. Heuter, DVM, DACVIM

Excretory urography is a type of contrast study used to verify and localize upper urinary tract disease. In some instances, information regarding renal function and disease pathophysiology can also be obtained. With the recent advances in small animal ultrasonography, excretory urography has become an underutilized procedure. This article will help explain why excretory urography remains, and will remain, a ubiquitous test that gives excellent detail of the entire urinary tract, and remains an essential tool for the assessment of the renal pelves and especially the ureters. Specifically, this article will focus on technique and interpretation of a properly performed excretory urogram.

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Contrast studies of the upper urinary tract are often discussed using a number of different names such as excretory urography, intravenous pyelography, and intravenous urography. Although all are valid, excretory urography is probably the most appropriate term because the study evaluates both the kidneys' excretory function and the structure of the entire upper urinary tract (both kidneys and ureters). Excretory urography can be used to evaluate the size, shape, position, and density of the kidneys using a sterile, water-soluble ionic or nonionic iodinated contrast medium. The ureters can also be evaluated in regards to their size, shape, position, and termination.¹⁻³

Three factors—glomerular filtration, renal concentrating ability, and patient's hydration status—affect the quality of the study. Contrast medium is passively filtered by the glomerulus and any reduction in filtration will decrease the amount of radiopaque material excreted and therefore, decrease the density of the renal image. Renal concentrating ability is vital because reabsorption of water within the tubules increases the density of the contrast within the kidney and ureter. Because the renal tubules cannot reabsorb the contrast medium, the more water that can be reabsorbed yields a greater contrast medium concentration. This increased density/concentration results in better visualization of the collecting system. Finally, adequate patient hydration is essential to assure proper renal perfusion, and hence glomerular filtration and renal concentrating ability.^{1,2,4,5}

Too often, survey radiographs yield insufficient information in regards to upper urinary tract disorders. Because of these inherent limitations of plain radiographs, excretory urography has been a valuable tool for further assessing both the kidneys and ureters. The test is a relatively simple means

of verifying and localizing upper urinary tract disease. Although excretory urography is not a quantitative measurement of renal function, it can be used to assess the relative function of the kidneys. In addition, the information gained can sometimes yield information that can be used to assess the pathophysiologic mechanisms of renal failure.² For example, acute tubular necrosis will be associated with different changes in opacity than chronic glomerular disease.

Although it is true that abdominal ultrasound is noninvasive, safe, and now more commonplace, it does have some limitations. First of all, it is very dependent on the skill of the user, especially in regards to abnormalities of the renal pelvis and ureter. Secondly, whereas ultrasound may provide more detail regarding the renal parenchyma, the excretory urogram remains a ubiquitous test that gives excellent detail of the entire urinary tract, and remains an essential tool for the assessment of the renal pelves and especially the ureters.^{2,6}

Procedure

The first step in performing a good excretory urogram is to prepare the patient adequately. The gastrointestinal tract, especially the colon, should contain no ingesta. To achieve this, food should be withheld for at least 12 to 24 hours before the study, and the colon should be evacuated with either laxatives and/or cleansing enemas. The patient's renal function should be evaluated before the contrast study and the patient should be well hydrated. Plain survey radiographs should then be taken to assure that the gastrointestinal tract is empty and to obtain precontrast baseline films. The right lateral view should be used because it allows for the most longitudinal separation of the right and left kidneys.¹⁻³

The study is performed by injecting an intravenous bolus of iodinated water-soluble contrast medium with an iodine content equivalent to 400 to 800 mg of iodine per kilogram of body weight.^{1-4,7-9} The contrast agent should be injected

Bay Area Veterinary Specialists, Union City, California.
 Address reprint requests to Kerry Heuter, 34892 Herringbone Way, Union City, CA 94587. E-mail: kheuter@yahoo.com

through a previously placed intravenous catheter, which should then be maintained for at least 15 to 20 minutes after contrast medium injection. Immediately after contrast injection, ventrodorsal and right lateral radiographs should be taken. Then, a typical study requires right lateral and ventrodorsal radiographs to be taken at 5, 20, and 40 minutes after injection.^{1-3,5,9} For better visualization of the ureters, oblique films can also be obtained at the 20- and/or 40-minute films. In addition, a pneumocystogram may be performed to allow better visualization of the entrance of the ureters into the bladder.¹⁻³ It is easier to see contrast filled ureters emptying into an air filled bladder.

The study is complete when the question concerning the upper urinary tract has been answered. For some cases, only one radiograph is needed to determine renal position. However, because the complete study does have further diagnostic utility and may even signal the onset of contrast medium-induced hypotension, the normal sequence described above is suggested as a general operating procedure. Also, by completing the study, future questions may be answered.^{1,2}

Adverse Effects

Some tests may be affected by excretory urography. The contrast material will affect the urinalysis by increasing specific gravity, yielding false positive results for urine protein, altering cellular morphology, and creating unusual appearing crystals. In addition, the contrast may inhibit the growth of certain bacteria. Therefore, urinalysis and urine culture should be obtained before the study is performed. Also, ultrasound should be performed before the study, or delayed until the following day.^{1,2,10} The diuresis that results from contrast administration may cause ureteral dilation, which could be mistaken for mild hydronephrosis during ultrasound examination. Also, while not documented in animals, contrast material may increase the echo density of the kidneys.^{1,2}

Excretory urography may be used in both azotemic and nonazotemic patients, provided that hydration is adequate. As the degree of renal failure progresses, however, it may be necessary to increase the dose of contrast medium to provide adequate visualization of the kidneys. If opacification is inadequate with the initial dose, the dose can then be repeated until visualization is sufficient, although it is recommended to not exceed 1760 mg of iodine per kilogram of body weight.¹⁻⁴ Dehydration and oliguria are strong relative contraindications. Iodinated contrast medium can cause acute renal failure in circumstances of low urine flow.^{1,2,11} Recommendations to avoid contrast radiographic procedures in people with other specific disease processes (such as diabetes mellitus, renal failure, liver failure, or heart disease), have been made, but the major underlying factor contributing to the contrast medium-induced renal failure in these patients appeared to be poor urinary flow secondary to inadequate hydration.¹ In animals with multiple myeloma, excretory urography should be performed cautiously, because Bence Jones proteins may react with the contrast medium and precipitate in the renal tubules. If the study is needed, it can still be performed, as long as the patient is well hydrated and diuresis continues beyond the procedure.^{1,4,6}

The most common contrast-induced reaction is retching and/or vomiting, which usually occurs during or immedi-

ately after the hyperosmolar contrast injection. It is transient, and results in no long-term problems for the patient.^{1-3,6} Other reactions, such as cutaneous reactions (hives), involuntary urination, and hypotension can occur after contrast administration. Anaphylactic shock is extremely unlikely in animals. In humans using ionic contrast media, fatalities occur in about 1 of every 100,000 contrast procedures.⁶ If any of these reactions have occurred in the past, the study should be avoided.^{1,2,4,6}

Contrast induced acute renal failure and osmotic diuresis have been documented in both the dog and cat after systemic administration of iodinated contrast media.^{1,2,4,6,11} In people, the degree of renal impairment is usually mild and transient. However, even a minor elevation in serum creatinine level leads to an increase in length of hospitalization and mortality, and some people suffer a permanent decline in renal function.^{12,13} The clinical significance of this temporary decreased function in animals is considered minimal in the presence of adequate urinary output and patient hydration.^{1-3,10,11}

Although there are no studies comparing ionic to nonionic media in animals, some recommend the use of isotonic (non-ionic) iodinated contrast medium in older or seriously ill patients and in patients with significant renal dysfunction. These agents have a proven reduction in toxicity for people. However, they are more expensive than the ionic agents and are not completely without risk of contrast-induced renal failure.^{1,2,4,6}

With self-limiting vomiting, assessment of the cardiovascular system (heart rate, pulse quality, blood pressure, etc.) to ensure that the patient is stable, and perhaps short-term fluid therapy, are the only interventions required.^{2,11} With most contrast reactions, intravenous fluids should be administered to the patient to induce diuresis, and the patient should be carefully monitored. If the patient develops shock, it should be managed as necessary, including the use of epinephrine or rapidly acting glucocorticoids. Atropine may also be necessary to treat bradycardia from systemic hypotension induced by a contrast-medium reaction.^{1,4}

Interpretation

The phases of the excretory urogram are the nephrographic and pyelographic phases. The nephrogram is seen as the opacification of the functional renal parenchyma, whereas the pyelogram is the opacification of the renal pelvis, pelvic recesses, and ureters (Fig. 1).^{2,3} Each phase should be evaluated separately, and then the sequence of these phases should be compared in view of the normal findings.

The normal radiographic findings for both the dog and the cat are listed in Table 1. Nephrographic measurements should be taken on the ventrodorsal view and compared with the length of the second lumbar vertebra. In general, the dog kidney should be approximately 3 times the length of the L2 vertebral body as visualized on the ventrodorsal view. The range of kidney size is 2.5 to 3.5 times the length of L2. In the cat, the most accepted renal length is 2.4 to 3 times the length of the L2 vertebral body.²

Pyelographic variables (width of pelvic recesses, renal pelvis, and proximal ureter) may be measured on excretory urograms. In general, the renal pelvis, and pelvic recesses (pelvic diverticula) in the dog does not exceed 2 or 3 mm in diame-

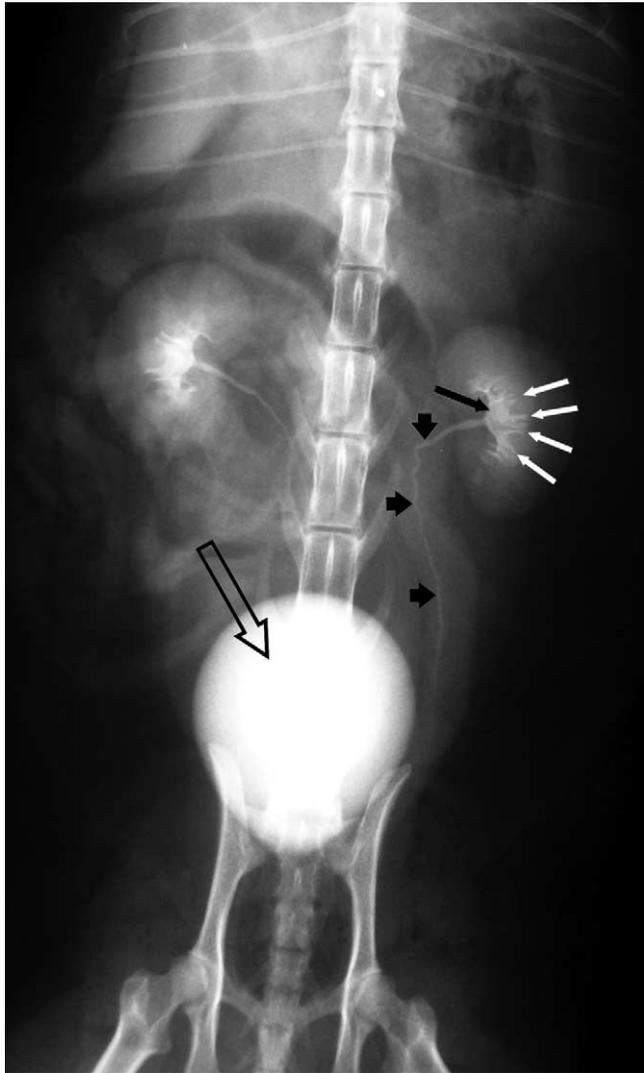


Figure 1 Normal excretory urogram in a cat. Pelvic diverticula (white arrows), renal pelvis (black arrow), ureter (arrowheads), bladder (open arrow).

ter. More exact comparisons are given in Table 1, which are related to the length of the L2 vertebral body.²

The kidneys in both the dog and cat are located in the retroperitoneal space in association with the last thoracic and first three or four lumbar vertebrae. The right kidney is located more cranial than the left. The shape of both the dog and cat kidney is somewhat elongated, resembling a bean, whereas that of the cat is more rounded.^{2,5}

During excretory urography, the nephrogram is homogeneous, with the exception of the early combined vascular and tubular nephrograms, when the cortex can be more radiopaque than the medulla. The pyelogram is more radiopaque than the nephrogram in the normally functioning kidney.^{2,5}

The normal ureters are not visible on survey radiographs. With contrast, the size of each ureter is usually less than 2 to 3 mm in diameter as they exit the kidney. The shape of the ureters is tubular, with segmentation occurring secondary to ureteral peristalsis. The ureters are primarily retroperitoneal, but become intraperitoneal as they approach their termination at the bladder trigone (Fig. 2).²

The dynamic aspects of excretory urography lie in the

Table 1 Quantitative Appearance of Normal Canine and Feline Excretory Urograms

Structure	Measurement*	Value†
Kidney	Length	Dog 3.00 ± 0.25 × L2 2.50 to 3.50 × L2
		Cat 2.4 to 3.0 × L2 4.0–4.5 cm
	Width	Dog 2.00 ± 0.20 × L2
		Cat 3.0 to 3.5 cm
Renal pelvis	Width	Dog 0.03 ± 0.017 × L2 (generally < 2.0 mm)
		Cat Not reported
Pelvic recesses	Width	Dog 0.02 ± 0.005 × L2 (generally < 1.0 mm)
		Cat Not reported
Proximal ureter	Width	Dog 0.07 ± 0.018 × L2 (generally < 2.5 mm)
		Cat Not reported
Distal ureter	Width	Not reported in dogs or cats

Modified from Feeney DA, Johnston GR: The kidneys and ureters, in Thrall DE (ed): Textbook of Veterinary Diagnostic Radiology (ed 3). Philadelphia, PA, Saunders, 1997, pp 466-478

*Measurements apply only to ventrodorsal view.

†L2, the length of the body of the second lumbar vertebral body as visualized on the ventrodorsal view.

assessment of nephrographic opacification of the nephrogram and the subsequent fading sequences. The normal nephrogram should be most radiopaque within 7 to 30 seconds after bolus injection of contrast medium. The nephrographic opacity should decrease progressively with time after injection.^{2,3}

The pyelogram should be consistently opaque, and the



Figure 2 Oblique view of normal excretory urogram. Ureters can be individually identified in this view.

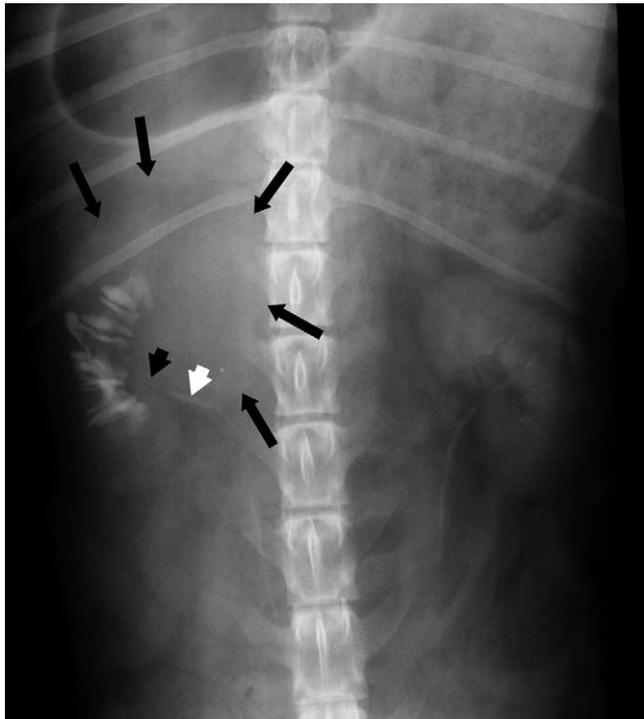


Figure 3 Excretory urogram of a renal mass on the cranial pole of the right kidney. A well-demarcated radiolucent mass (black arrows) can be seen impinging on adjacent renal parenchyma, collecting system, and ureter (white arrowhead), causing partial ureteral obstruction (black arrowhead).

diameter of the ureter should vary with time because of peristalsis.^{2,3} Renal function can be qualitatively estimated by evaluating not only the degree of opacification in the nephrogram and pyelogram, but also by evaluating the opacification and fading patterns of the nephrogram. In general, the poorer the renal function, the poorer the opacification of the nephrographic and pyelographic phases of the excretory urogram.²

Abnormal Findings

Abnormal findings can usually be classified in regards to number, size, shape, location, and radiopacity. Obviously, the normal number of kidneys is 2. If only 1 kidney is seen, it could be a result of renal agenesis, extreme hypoplasia, or chronic disease.^{2,5} More than 2 kidneys can be explained by renal duplication or transplantation.²

As previously stated, excretory urography causes increases in the radiographic opacity of the renal parenchyma by the accumulation of contrast medium within the renal tubules and vasculature. This “blush” or nephrogram phase can be evaluated for irregularities in the opacification.^{2,3} If the opacification is uniform, either the tissue is normal, hypertrophied, or a disease is present that does not disrupt the renal tubules or vasculature. Some examples of this include acute glomerular or tubulointerstitial disease, perirenal pseudocyst, and renal hypoplasia.^{2,3,14}

Focal, nonuniform opacification may be caused by a neoplasm, hematoma, cyst, infarct, hydronephrosis, and abscess (Figs. 3 and 4). Multifocal, nonuniform opacification can be seen with polycystic disease, multiple infarcts, acute pyelonephritis, chronic generalized glomerular or tubulointersti-

tial disease, feline infectious peritonitis, and neoplasia. Non-opacification may occur with renal aplasia, renal artery obstruction, nephrectomy or nonfunctional renal tissue, and insufficient or extravascular contrast medium injection.^{2,3}

The pyelogram phase can be associated with abnormalities that point to specific disease processes. Pyelonephritis can either be acute or chronic. In the acute disease, there can be pelvic dilation, proximal ureteral dilation, and absent or incomplete filling of the pelvic diverticula. It is important to remember that acute infections may also have no radiographic abnormalities. In the chronic form, there will still be proximal ureter dilation and the pelvic diverticula will be shortened and blunted. The pelvic dilation is variable with irregular borders.^{2,3}

Hydronephrosis will present with dilation of the renal pelvis, diverticula, and ureter. If the pelvic dilation is severe enough, the renal pelvis and diverticula will be indistinguishable (Figs. 5 and 6).^{2,3} With neoplasia, abnormalities can be present in either the renal parenchyma and/or the renal pelvis. If present in the renal parenchyma, it may distort or deviate the renal pelvis and diverticula. If in the renal pelvis, it may distort or deviate the renal pelvis and there may be filling defects in the pelvis.^{2,3}

Uroliths and blood clots present as filling defects in the renal pelvis. Uroliths may be radiopaque or radiolucent when compared with the contrast while blood clots are always radiolucent. There may also be changes similar to those described with pyelonephritis.^{2,3}

The same criteria can be used when evaluating the ureters. Again, the normal number of ureters is 2. If only 1, it could be a result of renal agenesis or poor renal function.^{2,5} More than 2 ureters can be explained by renal duplication.² If a diffusely enlarged ureter with a regular shape is seen, the most likely causes are an obstruction or atony induced by infection (Fig. 7). Ectopic ureters also present this way. Although the specific cause is unknown it is probably because of a combination of obstruction, inflammation, and developmental anomaly.^{2,3}

A focally enlarged ureter with regular shape is most likely either an ureterocele or diverticulum.¹⁵ Enlarged ureters with a diffusely irregular shape are most likely associated with fibrosis secondary to chronic inflammation. If the irregularity appears to be a focal process, the most likely possibility is

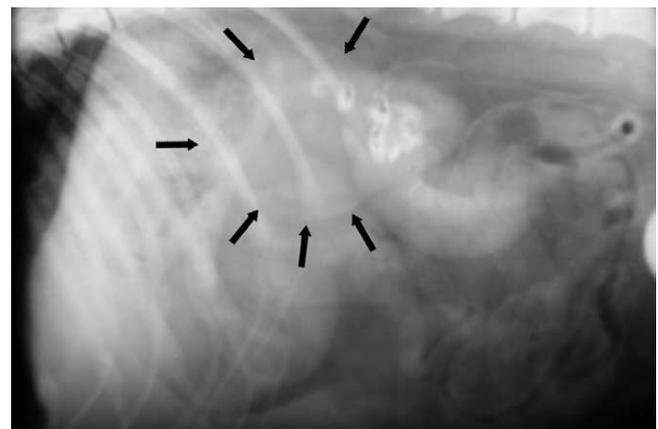


Figure 4 Lateral view of excretory urogram of a renal mass on the cranial pole of the right kidney. A well-demarcated radiolucent mass is indicated by the black arrows.



Figure 5 Excretory urogram of ureteral obstruction 5 days after right ureterotomy for ureterolith removal. Right renal pelvis is dilated, indicating continued obstruction. Left renal hypertrophy with renal pelvic dilation, suggestive of pyelonephritis.

primary or metastatic neoplasia, even though it is uncommon.^{2,3}

A diffusely small ureter with a regular shape is most likely because of inadequate contrast medium dose or primary renal oliguria. If there is only a focal decrease in size, extramural compression should be considered, while if the area is irregular, a stricture or neoplasm is should be considered most likely.^{2,3}

A reproducible filling defect in the contrast medium in the ureter may be caused by a calculus, neoplasm, or stricture. A nonreproducible filling defect is usually because of normal peristalsis. Ureteral atony can be induced by infection, inflammation, trauma, or obstruction.^{2,3}

Abnormalities in location include ectopic ureter and trauma

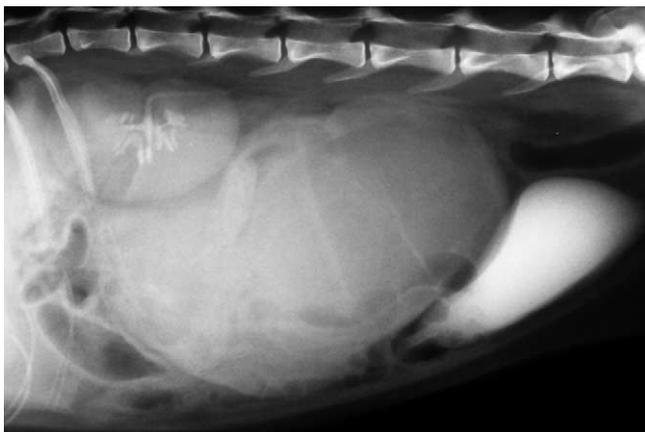


Figure 6 Excretory urogram of severely hydronephrotic kidney in a cat. Essentially no renal parenchyma is present.



Figure 7 Excretory urogram of a young Newfoundland dog with urinary incontinence and recurrent urinary tract infections. Both ureters are ectopic with marked hydroureter.

associated avulsions. In ectopic ureters, the termination of the ureter is more distal than the bladder trigone (Fig. 8). The most common site is the vagina, followed by the urethra, bladder neck, and uterus.^{2,5}

Renal Function

The function of the renal tissue may be assessed by evaluating alterations in the nephrogenic opacification and subsequent fading sequences. In general, these changes are classified ac-

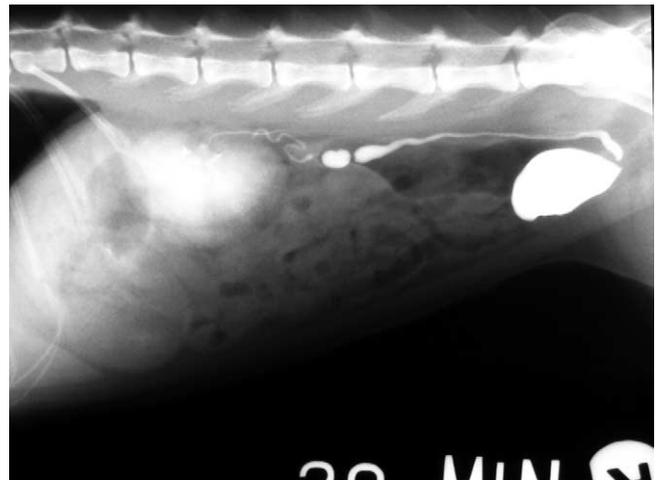


Figure 8 Excretory urogram of a young female cat with urinary incontinence from ectopic ureter. Note the ureter bypasses the bladder and appears to enter the proximal urethra.

ording to the degree of initial opacification (first radiograph) as well as comparing that to the following opacification (subsequent radiographs). For example, a good initial opacification followed by decreasing opacity is seen in a normally functioning kidney.²

Fair to good initial opacification followed by increasing opacity is seen with systemic hypotension (natural or contrast induced), acute renal obstruction, and contrast induced renal failure. Fair to good initial opacification followed by persistent opacity can be seen with acute renal tubular necrosis, contrast medium-induced renal failure, and contrast induced systemic hypotension. Poor initial opacification followed by progressively decreasing opacity may be because of primary polyuric renal failure and inadequate contrast dose. Poor initial opacification followed by progressively increasing opacity is seen with acute extrarenal obstruction, pre-existing systemic hypotension, and renal ischemia. Poor initial opacification followed by persistent opacity is caused by chronic primary glomerular dysfunction and severe generalized renal disease.²

Pyelographic alterations associated with change in renal function generally manifest as poor or undetectable opacification of this phase of the excretory urogram. Because the opacity of the pyelogram depends on both glomerular filtration and renal concentrating ability, the loss of either of these capabilities may result in a less than optimal pyelogram.^{1,2,4,5}

Percutaneous Antegrade Pyelography

Percutaneous antegrade pyelography is another form of pyelography that is performed with either fluoroscopy or ultrasound guidance.¹⁶⁻¹⁸ Because ultrasound is more readily available, that is the technique that will be described. The patient should be heavily sedated or anesthetized and placed in dorsal recumbancy. A midtransverse, ultrasonographic image of the affected kidney is then acquired, including both the renal hilus and dilated renal pelvis and ureter. After a surgical scrub of the skin is performed, a sterile 3.5-in, 22-gauge spinal needle is advanced into the renal cortex, perpendicular to the capsule, and advanced into the renal pelvis with ultrasound guidance using aseptic technique. The needle stylet is then removed. Nephropylcentesis is performed until the transverse diameter of the renal pelvis is reduced to about one-half its original diameter. A urinalysis and culture should be performed on the sample removed.

Fifty to 100% of the volume of urine removed should be replaced with an aqueous, iodinated contrast media under direct ultrasonographic visualization. Bolus injections of contrast can be repeated until adequate opacification of the ureter is achieved. Immediately after contrast injection, right lateral and ventrodorsal radiographs should be taken. The same radiographs should then be repeated in 15 minutes.^{16,17}

The indications for this procedure are any patients who produce inadequate excretory urograms, despite proper technique. Some would advocate the use of this procedure in any patients with severe renal dysfunction. However, that point remains debatable. Although it would reduce the risk of contrast-induced hypotension and renal failure, the risks of antegrade pyelography are not well established. The possible

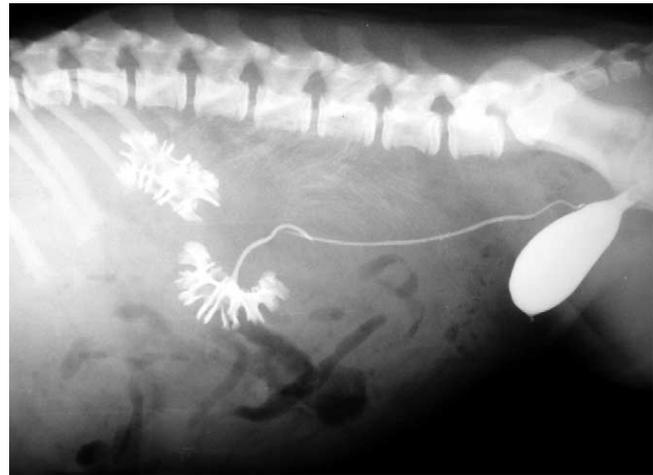


Figure 9 Cystogram with retrograde pyelogram of puppy with acute renal failure. Pelvic diverticula, although normal, are more distended than with an excretory urogram.

risks include direct renal damage from the needle, renal bleeding, clot formation (with or without subsequent obstruction), and laceration/rupture of the renal pelvis.¹⁶⁻¹⁸ Also, it should be noted that a diagnostic study was achieved in only 13 of 18 studies. Leakage of dye was from the renal pelvis was seen in 8 of the 18 studies. Five of those cases were considered nondiagnostic because of the contrast leakage. However, in the diagnostic studies the sensitivity and specificity for diagnosing an obstruction was 100%. The location of the obstruction was also accurate in those studies.¹⁸

Retrograde Pyelography

In human medicine retrograde pyelography is an accepted technique. First, an endoscope is used to visualize the ureteral opening at the trigone. A catheter is then inserted into the ureter and contrast is injected. This particular technique has not been performed in veterinary medicine, most likely because of the equipment needed. In veterinary medicine, another type of retrograde pyelography is sometimes obtained during cystography. Although this can sometimes be useful, this is not a recommended technique for evaluating the renal pelvis and ureters because of the risk of inducing pyelonephritis (Fig. 9). This vesiculoureteral reflux with cystography is more common in immature dogs.¹

Conclusion

When performed properly, an excretory urogram can yield information that cannot be obtained any other way. While ultrasound is certainly useful in the diagnosis of urinary tract disease, it is important to not forget about excretory urography. Diseases of the ureters and even the renal pelvis can often be visualized easier with a contrast study than with ultrasound. In addition, information regarding renal function and disease pathophysiology may be obtained.

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