Most (>70%, and probably > 90%) upper urinary uroliths are composed with calcium oxalate. Struvite, particularly infection-induced, and other mineral types do occur.

- Struvite uroliths occur either due to a bacterial infection with a urease-producing microbial or without an infection.
- Occasionally, other minerals form uroliths in the upper urinary tract. Urate uroliths occur in the upper urinary tract in approximately 10% of cases, and occur secondary to liver disease, particularly portovascular anomalies, or in breeds predisposed to forming urate uroliths, such as Dalmatians and English bulldogs.

Upper urinary tract urolithiasis is being recognized more frequently; however, account for < 2% of uroliths that are retrieved and submitted for analysis.

- 50 fold increase in upper urinary tract stones between 1980-2000
- Nephroliths not associated with higher mortality in Feline CKD
- Ureteroliths associated with higher mortality in Feline CKD
- In 19 cats treated with renal transplantation for ureterolithiasis
  - 5/18 developed new calculi
- 23% of cats presented for peritoneal dialysis, 60% survival
- 50% of hemodialysis patients

Small, multiple uroliths are common and usually found in both kidneys and/or ureters.

- Small ureteroliths appear to migrate over time and can move retrograde in the ureter.
- Approximately 15% of cats with upper urinary tract uroliths had lower urinary tract uroliths.
- When lower tract uroliths occur in association with upper tract uroliths, it is unknown whether they formed in the lower urinary tract or whether they passed through the ureter and into the urinary bladder.
- A common scenario is to find upper tract uroliths in a cat with chronic renal failure.
- When there is unilateral nephrolithiasis, often they occur in the larger and more functional kidney.

Clinical signs

- Upper urinary tract uroliths (nephroliths and ureteroliths) can lead to obstruction to urine flow, deterioration of renal function, serve as a nidus for bacterial urinary tract infection, hematuria, or pain.
  - Clinical signs, when present, include systemic signs associated with renal failure or pyelonephritis, vague signs (abdominal pain, arched back, vomiting, or anorexia) or hematuria.
  - Sometimes animals present for an abrupt change in behavior or an acute onset of abdominal pain or vomiting when an acute ureteral obstruction occurs; this may be mistaken for intervertebral disk disease.

Clinicopathologic finding

- Most common clinicopathologic findings include azotemia, hyperphosphatemia, hyperkalemia, hypercalcemia, anemia, and hypocalcemia. Many of these may be related to the associated CKD.

Diagnosis

- Survey abdominal radiography
- Abdominal ultrasonography
  - With & without furosemide
- Excretory urography
- Antegrade contrast pyelography
- Abdominal CT
- GFR (DTPA)
  - With & without furosemide
- Combination of survey radiography and abdominal ultrasonography has 90% sensitivity
• Treatment
  o General principles
    • Not all upper tract uroliths require treatment especially by surgery.
      • In one study, presence of nephroliths without ureteral obstruction, was not
        associated with progression of chronic kidney disease
    • Treat ureteral obstruction is present
    • Treat secondary issues
    • Manage CKD – 80% of feline nephroliths occur in cats with CKD
  o Collect baseline data
    • CBC, Biochemical panel, UA, U C/S, BP, imaging
    • Up to 80% of cats with ureteroliths have CKD
  o Supportive therapy
    • Treat hyperkalemia – previously discussed
    • Fluid therapy – previously discussed
    • Increase urine output
    • Analgesia
      • Patients may experience renal “colic”
      • Caution with NSAIDs and CKD
    • Manage nausea / vomiting, if present – previously discussed
    • Anti-hypertensives – treat systemic arterial hypertension, if present – previously discussed
    • Nutritional support
    • Antimicrobials (if infected)
    • Manage obstruction
      • No therapy
      • Intervention
      • Urinary diversion
    • Long term management
      • Manage CKD
      • Manage uroliths
  o If uroliths are composed of struvite or urate, medical dissolution can be attempted (see below).
  o Indications for treatment of upper urinary tract uroliths include obstruction to urine flow, increase in
    urolith size and/or number despite appropriate therapy, if uroliths are composed of a mineral amenable
    to medical dissolution therapy, recurrent or persistent urinary tract infections, compromise of renal
    function due to uroliths, recurrent or persistent clinical signs associated with renal pain (e.g. vomiting or
    abdominal pain), or severe hematuria.
  o Many cats with upper tract uroliths already have renal compromise.
  o Removal of upper tract uroliths in cats with chronic renal failure, especially if ureteroliths, improves
    survival; however, there is an associated morbidity and mortality associated with surgery for upper tract
    uroliths.
  o Medical management
  o Review medical dissolution protocols for those minerals that are amenable to medical dissolution
  o Consider dialysis for stabilization
    • Dialysis is the process of removing solutes and/or water from one solution (plasma) to another solution
      (dialysate) by an osmotic gradient through a semi-permeable membrane. The 2 types of dialysis are
      peritoneal dialysis and hemodialysis. There is little information on utilization of dialysis in veterinary
      medicine compared with human medicine.
    • Dialysis involves the use of one type of semi-permeable membrane that allows the passage of small
      molecules while preventing the transfer and loss of large molecules. In peritoneal dialysis, the peritoneal
      membrane, interstitial tissue, and capillary endothelium act as the membrane. In hemodialysis, blood is
      circulated outside of the body through a dialyzer.
      • Peritoneal Dialysis - The foundation of peritoneal dialysis is the dynamics of fluid and solute exchange
        across a semi-permeable membrane. Large molecules such as proteins pass slowly through such a
membrane. Smaller molecules (urea and glucose) and ions (sodium and potassium) move easily across the membrane down a concentration gradient until equilibrium is reached on either side of the membrane. Water moves across the membrane from the solution of lower osmolality to that of higher osmolality until equilibrium is reached.

- **Hemodialysis** - Hemodialysis is a renal replacement therapy that provides a bridge of metabolic stability to patients who would otherwise die from the systemic effects of severe uremia. The principles of hemodialysis are similar to those of peritoneal dialysis except that blood is shunted outside of the body, passed through a dialyzer (“purified”), and returned to the body. The composition of uremic blood is normalized by exposure to a contrived solution, the dialysate, across a semi-permeable membrane in a device called a hemodialyzer. During hemodialysis, water and small molecular weight solutes and uremic toxins pass readily through the membrane pores (diffusion channels), along diffusive and hydrostatic gradients, but the movement of larger solutes (such as plasma proteins and cells), are limited by the size of the pores. Excessive body water and additional solute can be forced through the membrane by ultrafiltration produced by hydrostatic or osmotic forces imposed across the dialysis membrane. Net removal of uremic solutes is influence by: (a) the concentration gradient for diffusion, (b) the diffusivity of the solute, (c) permeability characteristics and surface area of the membrane, (d) blood and dialysate flow within the dialyzer, (e) duration of dialysis, (f) distribution volume of the solutes, and (g) amount of ultrafiltration (convective transfer).

- **Nephrostomy tubes**
  - A nephrostomy tube may be placed for urinary diversion in order to relieve pressure on obstructed kidney
  - One end is curled (pig-tailed) that has a locking mechanism to maintain it in the dilated renal pelvis
  - Tubing exits the body wall and is connected to external urine collection bag

- **Medical expulsion therapy (MET)**
  - Increase urine output
    - IV fluids
    - Diuretics
    - Mannitol
      - Do not use if under- or over-hydrated
    - Others?
  - Relax ureteral smooth muscle
    - Alpha blockers
      - In humans, these are a mainstay of treatment
    - Amitriptyline
      - Has been shown to relax urethral smooth muscle in cats
      - May relax ureteral smooth muscle as well
      - Calcium channel blockers
  - Contract ureteral smooth muscle
    - Glucagon
      - Used to contract ureteral smooth muscle
      - Not shown effective in cats
      - Associated with side effects
  - Decrease edema and inflammation
    - Steroids
    - NSAIDs

- **Intervention**
  - Surgical removal is not necessary for all upper urinary tract uroliths.
  - Surgery is not indicated for relatively small, non-obstructive upper urinary tract uroliths.
    - Small upper urinary uroliths may pass into the urinary bladder.
  - It is unknown what a safe time period to allow for ureteroliths passing without resulting in irreversible renal damage.
    - Renal function does not recover n dogs with unilateral ureteral ligation for 40 days.
- If a dog or cat is ill due to ureteral obstruction, it is not probably appropriate to wait for the ureteroliths to pass or to medically manage them for a prolonged period of time if renal function is to be preserved.
  - If a urinary tract infection is present, removal of the upper urinary tract urolith may be necessary to control the infection; however, it is not possible to determine prior to surgery if the uroliths are the source of infection.
  - If bilateral upper urinary tract surgery is required, the procedures should be staged with an approximate separation of 4 weeks in order to re-evaluate renal function and to allow recovery from the first procedure.
    - In general, the side with the most renal function should be operated first in order to preserve as much renal function as possible.
  - So – when to intervene?
    - BIG question
    - Non-responsive to medical management, and increasingly azotemic
    - Ureterolith
    - Evidence of pyelonephritis
    - +/- stone size/number increasing
    - Relieving obstruction may not return renal function; however, it may prevent further deterioration

- **Nephrotomy**
  - Surgical longitudinal incision through renal parenchyma
  - Do not cut arcuate arteries
  - Allows access to renal pelvis for nephrolith removal
  - Not associated with decreased renal function in healthy cats
    - But these are not healthy cats

- **Pyelolithotomy / proximal ureterotomy**
  - Pyelolithotomy is preferred because renal parenchymal tissue is not incised and so loss of renal function is less likely to occur when compared with nephrotomy; however, pyelolithotomy cannot be performed unless the renal pelvis is dilated. Often it requires microsurgical technique
  - In cats, the renal pelvis is buried within the renal medullary parenchyma; therefore, technically, a proximal ureterotomy is performed

- **Ureterotomy**
  - A ureterotomy can be performed in dogs
  - Ureteral stricture often occurs
  - A 5cm defect will heal over days if a ureteral stent is placed and the abdomen is kept evacuated of urine

- **Neoureterocystostomy**
  - If enough ureter is present proximal to the ureterolith, the ureter is transected and distal part removed.
    - The kidney and ureteral remnant is moved to the urinary bladder
    - The dilated ureter is sutured to the urinary bladder

- **Nephrectomy**
  - With or without ureterectomy
  - Removal of the obstructed kidney
  - Indicated with cancer, pus-filled kidney, or no functional tissue
  - Try to avoid as many cats with nephroureteroliths have CKD

- **Lithotripsy**
  - Extracorporeal shock wave lithotripsy (ESWL) is a standard of care for many human patients with upper urinary tract uroliths, and has been performed successfully in dogs and cats.
  - Acceptable canine candidates are those with nephroliths smaller than 2-3 cm in their greatest dimension or ureteroliths.
    - With bilateral nephroliths, both kidneys are treated at the same time, unless there is concern about compromising renal function further.
More than 100 dogs with nephroliths or ureteroliths have been treated at 3 institutions. Most of the uroliths were composed of calcium oxalate. Most canine upper urinary tract uroliths fragment with 1 or 2 treatments.

- Feline upper urinary tract uroliths appear to be more difficult to fragment with ESWL than in dogs, and renal function is more likely to be compromised. Successful fragmentation has been reported to occur in < 20-25% of feline cases.
- Although renal function was normal in 4 healthy cats undergoing lithotripsy of clinical cases of upper urinary tract urolithiasis in cats suggests that many cats, particularly those with pre-existing renal disease, experience renal function compromise or worsening of their renal failure.
- While lithotripsy is considered safer and less invasive than surgical removal of upper urinary tract uroliths, there are risks. Abdominal pain, hemorrhage, and bruising of the kidneys occurs, and hematuria may be observed immediately after the procedure. More significant hemorrhage within or around the kidney may occur in some cases. Residual stone fragments often take several weeks to move from the kidney into the urinary bladder. Transient or permanent ureteral obstruction can occur. If permanent and progressive ureteral obstruction occurs, it requires re-treatment by lithotripsy or surgical intervention. Uncommon complications include pancreatitis, bowel irritation, hemolysis, and systemic hypertension.

- Percutaneous nephrolithotomy
  - A rigid scope can be inserted through the renal parenchyma into the dilated renal pelvis. The nephrolith is visualized and either retrieved or fragmented using laser lithotripsy and fragments retrieved.

- Ureteral stent
  - In patients where nephroureteroliths cannot be managed surgically, urinary diversion may be accomplished by placing a ureteral stent. Usually a double pig-tailed stent is placed surgically, fluoroscopically, or via cystoscopy. One of the pig-tails is placed so that it is within the dilated renal pelvis and the other pig-tail is placed so that it is within the urinary bladder. The body of the stent connects the 2 pigtails and provides diversion of urine flow around the obstructive ureteroliths. Stents are often used with neoplastic ureteral obstruction.

- Subcutaneous urinary bypass device (SUB)
  - Used to divert urine from renal pelvis to urinary bladder bypassing the ureter. Similar to a nephrostomy tube; however, used long term and implanted subcutaneously. A locking pig-tail catheter is inserted into the renal pelvis and the kidney is pexied to the body wall (nephropexy). Tube is tunneled subcutaneously to a metallic port that is implanted subcutaneously just off of ventral midline. The metallic port is used for collecting a urine sample using a special needle (Huber needle). A tube exits the other side of the port and re-enters the abdomen and is inserted near the apex of the urinary bladder, which is pexied to the ventral abdominal wall (cystopexy). These are often used with neoplastic ureteral obstruction.

- Comparison of medical vs surgical management
  - In a retrospective analysis of medically versus surgically managed patients with ureteroliths, surgically managed patients tended to do better over a longer time. Surgery, though, was associated with more complications primarily in the perioperative period. There was a recurrence rate of 40%.

- Renal transplantation
A retrospective study of 19 cats with renal failure associated with calcium oxalate urolithiasis has been published

- There were 13 females and 7 males
- All cats were azotemic and 17 were anemic
- Hypercalcemia was present in 7 cats
- Mean duration of survival in all cats was 605 days
  - 8 cats were alive 282-1,005 days (median = 1,305 days)
  - 11 cats died 2-1,197 days (median = 300 days)
  - 5 cats formed uroliths in their allograft kidney
    - 2 were hypercalcemic
    - 4 died following complications associated with urolith formation

- **Post-obstruction relief**
  - Fluid therapy – VITAL
    - Post-obstructive diuresis
  - Electrolytes
    - Hypokalemia
  - Acid-base
    - Metabolic acidosis
  - Clinical signs of uremia
  - Anemia
  - Analgesia
  - Nutrition
  - Manage CKD – see previous lectures