Acute Tubular Necrosis

Acute tubular necrosis (ATN) refers to the death of renal tubule cells in response to a variety of different insults, leading to acute kidney injury.

PLAY PICMONIC

ETIOLOGY

Ischemic Injury
Ice-ischemia Injury
Ischemic injury is a primary cause of acute tubular necrosis (ATN), occurring when renal blood flow is significantly reduced, resulting in cellular hypoxia and necrosis of tubular epithelial cells. This typically affects the proximal tubules and the thick ascending limb, which are the most metabolically active segments of the nephron. Common causes include severe hypotension, shock states such as sepsis, massive hemorrhage, and surgical procedures involving temporary clamping of the renal vasculature.

Nephrotoxic Injury
Kidney with Toxic-green-glow Injury
Nephrotoxic injury represents another major cause of ATN and occurs when tubular epithelial cells are directly damaged by toxins or medications. Substances such as aminoglycoside antibiotics, amphotericin B, cisplatin, radiographic contrast agents, and myoglobin from rhabdomyolysis are well-known culprits. The proximal tubules are most affected because they are responsible for active reabsorption and have high exposure to filtered toxins.

HISTOLOGY

Granular Muddy Brown Casts
Grains and Muddy Brown Casts
The diagnosis of ATN is supported by urine microscopy showing granular “muddy brown” casts, which consist of necrotic tubular epithelial cells and proteinaceous debris. These casts are considered pathognomonic for ATN and help distinguish it from pre-renal azotemia or post-renal causes of acute kidney injury.

Signs & Symptoms

Intrinsic Kidney Injury
N-triscuit Dead Kidney
ATN is classified as an intrinsic form of acute kidney injury, meaning the pathology lies within the renal parenchyma itself. Following the initial insult, patients progress through distinct phases of injury and recovery.

Oliguric Phase
Old-gopher
During the oliguric phase, urine output typically decreases to less than 400 mL per day (or <0.5 mL/kg/hour) due to acute tubular epithelial cell injury with necrosis and obstruction of tubules by cellular debris. This phase is characterized by rising BUN and creatinine, fluid overload (which may lead to hypertension), and electrolyte abnormalities such as hyperkalemia and metabolic acidosis, primarily due to impaired renal acid excretion.

Metabolic Acidosis

Metal-ball Acidic-lemon

The dominant mechanism is impaired acid (H? and NH??) excretion. As renal tubular function deteriorates, hydrogen ion excretion decreases, resulting in metabolic acidosis. The inability to excrete potassium results in hyperkalemia, which can manifest as ECG changes and cardiac arrhythmias in severe cases.

Hyperkalemia

Hiker-banana

In ATN, both BUN and creatinine rise as glomerular filtration rate declines. Importantly, the fractional excretion of sodium (FeNa) is typically greater than 2%, distinguishing ATN from pre-renal azotemia, where FeNa is less than 1%.

Increase in BUN and Creatinine

Up-arrow BUN and Cr-eam

As with any acute kidney injury, the kidney cannot function to filter the blood properly, and so waste products build up in the bloodstream. This includes BUN and creatinine. The fractional excretion of sodium (FeNa) will also increase since the kidney cannot function normally to reclaim excreted sodium.

Polyuria Phase

Polly-urinates

As regeneration of tubular epithelial cells begins, urine output increases markedly in the polyuric phase. Despite this rise in urine volume, the recovering tubules are unable to concentrate urine effectively, leading to large losses of water and electrolytes.

Decrease in BUN and Creatinine

Down-arrow BUN and Cr-eam

During this recovery phase, serum BUN and creatinine gradually decline toward normal levels. However, the high urine output can lead to hypokalemia and volume depletion if fluids and electrolytes are not carefully managed.

Hypokalemia

Hippo-banana

Patients in the polyuric phase are at risk for developing hypokalemia due to potassium loss in the urine.

Treatment

Supportive Care

Supportive IV bags

Treatment for ATN revolves around supportive care for the clinical manifestations of renal failure. This includes control of hypertension, fluid overload, and electrolyte abnormalities. The underlying insult should be identified and corrected. In the case of nephrotoxic medications, they should be stopped. In severe cases of ATN, dialysis could be required.