

## Anatomy and Physiological functions of Nephron in Birds

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### Introduction

Birds possess a unique kidney structure, crucial for their adaptation to diverse environments and their method of nitrogenous waste excretion. Birds possess two types of nephrons within their kidneys:

#### Reptilian-type (Cortical) Nephrons

Lack the loop of Henle. Primarily located in the renal cortex. Less capable of concentrating urine. More numerous than mammalian-type nephrons.

#### Mammalian-type (Medullary) Nephrons

Possess a loop of Henle, though typically a shorter loop than seen in mammals. Located in the medullary cones within the renal medulla. Contribute to the limited urine concentration ability of birds.

### COMPONENTS OF A NEPHRON

Regardless of type, the basic components of an avian nephron are broadly similar to those in other vertebrates and include:

**Glomerulus:** A network of capillaries within Bowman's capsule where blood filtration occurs.

**Bowman's Capsule:** Surrounds the glomerulus, collecting the filtered fluid (filtrate).

**Renal Tubules:** These include the proximal tubule, loop of Henle (in mammalian-type), distal tubule, and collecting tubule.

#### Physiological functions

Avian nephrons perform three key functions to regulate water balance and excrete metabolic waste:

**Filtration:** The glomerulus filters blood, producing an initial filtrate similar to blood plasma, excluding large molecules and cells.

**Reabsorption:** As the filtrate travels through the renal tubules, essential substances like water, salts, glucose, and amino acids are reabsorbed back into the bloodstream by specialized cells lining the tubules and their surrounding peritubular capillaries.

**Secretion:** Waste products and excess ions are actively secreted from the blood into the tubules for elimination.

Unique features in birds

**Uric Acid Excretion:** Birds primarily excrete nitrogenous waste as uric acid, a relatively insoluble compound requiring less water for elimination compared to urea in mammals.

**Limited Concentrating Ability:** While avian kidneys can produce urine hyperosmotic to plasma, their concentrating ability is generally less than that of mammals due to a higher proportion of reptilian-type nephrons with shorter or absent loops of Henle.

**Post-renal Modification:** The avian lower gastrointestinal tract, including the cloaca and colon, plays a significant role in modifying urine composition and reabsorbing water and salts through a process known as reverse peristalsis.

**Salt Glands:** Many marine and desert birds possess salt glands that secrete excess salt, further aiding in osmoregulation

#### biochemical parameters of avian renal function

In evaluating avian renal (kidney) function, veterinarians rely on a combination of

biochemical parameters, physical examination, and other diagnostic tools, as relying solely on one indicator can be misleading due to the unique avian physiology

Here are the key biochemical parameters used to assess avian renal function:

**Uric Acid:** This is the primary indicator of renal function in birds because it's the main end-product of nitrogen metabolism and is actively secreted by the renal tubules. However, interpreting uric acid levels can be complex:

Significant kidney damage (more than 70% loss of functional capacity) is required before elevations in uric acid are observed.

Dehydration can also cause elevated uric acid levels, which may normalize with rehydration.

Carnivorous birds (raptors, penguins) may show significantly increased uric acid levels after feeding; fasting for 24 hours is recommended before evaluating kidney function in these species. Normal uric acid levels do not necessarily rule out kidney disease.

**Urea/Uric Acid Ratio:** While BUN alone is not a reliable indicator of renal function in birds, the ratio of plasma urea to uric acid may be helpful in differentiating between pre-renal (dehydration) and renal (kidney tissue damage) causes of azotemia (elevated nitrogenous waste products in the blood). A high urea:uric acid ratio can indicate dehydration, as urea reabsorption is disproportionately higher during dehydration compared to uric acid.

**Blood Urea Nitrogen (BUN):** Unlike in mammals, urea is not a primary endpoint of protein metabolism in birds, so it's not a reliable indicator of renal function. Instead, BUN is primarily influenced by the bird's hydration status, with levels increasing significantly during dehydration.

**Creatine and Creatinine:** While creatinine is not a primary indicator of renal disease in most birds, because they excrete creatine before it's converted to creatinine, resulting in low or undetectable levels in the blood. Some studies suggest that

creatinine and creatine levels may be useful in monitoring kidney function, particularly in pigeons. Increases in creatinine have also been associated with dehydration, renal trauma, or nephrotoxic

**Electrolytes (e.g., Potassium, Phosphorus):** Changes in electrolyte levels can occur with renal disease, but the association is not always consistent and requires further investigation in avian species. Elevations in phosphate levels can occur with renal disease in birds, although this is not a consistent finding. It is important to note that hyperphosphatemia can also be caused by poor blood sample handling (e.g., microhemolysis).

**Urinalysis:** This involves examining a urine sample for various parameters like specific gravity, pH, protein, glucose, and sediment.

**Specific Gravity:** Normal avian urine specific gravity ranges from 1.005 to 1.020.

**pH:** The pH can vary with diet and other factors, but generally falls between 6.5 and 8.0.

**Glucose:** Only trace amounts of glucose should be present in normal avian urine. Glucosuria (glucose in the urine) along with polyuria (increased urine production) and polydipsia (increased thirst) may indicate diabetes mellitus in birds if plasma glucose is also elevated.

**Serum and Plasma Proteins:** Changes in plasma protein levels, particularly hypoalbuminemia (low albumin), have been linked to renal disease, but more research is needed in avian species. It's crucial to use accurate methods for measuring protein levels, such as serum protein electrophoresis, as standard methods using dye-binding methodologies may not be reliable.

**Ketones:** Ketonuria (ketones in the urine) can be a sign of starvation or abnormal metabolism in birds, such as during long-distance flights or with diabetes mellitus,

**Other Potential Markers:** While not yet routinely used, other markers like urinary N-Acetyl-b-D-glucosaminidase (NAG) and exogenous creatinine excretion are being

investigated as potential indicators of renal damage in birds.

Advanced Markers and Diagnostic Tests

**Urinary N-Acetyl-b-D-Glucosaminidase (NAG):** NAG is a renal tubular enzyme that may serve as an early indicator of tubular damage in birds and may be useful in monitoring disease progression.

**Renal Scintigraphy:** This non-invasive imaging technique allows for the assessment of renal function and blood flow, and can be valuable in diagnosing kidney damage, particularly in research settings and for monitoring nephrotoxicosis.

**Kidney Biopsy:** Histopathologic examination of a kidney biopsy is currently the only definitive way to diagnose the cause and severity of avian renal disease. Endoscopic guidance is often employed for safe and effective biopsy collection.

**Vanin-1 (VNN1):** VNN1 as a potentially promising early biomarker for kidney injury in chickens, showing increased levels even with mild renal damage.

**Transcriptome analysis:** This advanced technique can reveal changes in gene expression within the kidneys, offering insights into the mechanisms of renal damage and potentially identifying novel biomarkers.

**Conclusion:**

In conclusion, evaluating avian renal function requires a comprehensive approach, taking into account the unique physiology of birds and the limitations of various biochemical markers. Uric acid is the most commonly used indicator, but it needs to be interpreted carefully, considering factors like hydration status and species-specific variations.

Important Considerations

**Species-Specific Differences:** Normal ranges for biochemical parameters can vary significantly between different avian species, so it's essential to use species-specific reference intervals for accurate interpretation.

**Sample Handling:** Proper handling of blood and urine samples is crucial for accurate results. For

instance, microhemolysis can falsely elevate phosphorus levels, and immediate separation of plasma from cells can impact potassium concentrations.

**Limitations of Uric Acid:** Remember, while uric acid is a primary indicator, it's not always sensitive to early stages of kidney damage, requiring significant impairment before elevations are observed.

**Multifactorial Evaluation:** Diagnosing avian renal disease often requires a comprehensive approach, combining biochemical analysis with physical examination, clinical signs, and other diagnostic tools like imaging or biopsy.

By utilizing a combination of these markers and diagnostic techniques, veterinarians can gain a more complete understanding of avian renal health and provide appropriate care.