TOPICAL REVIEW

Anesthesia for Patients with Renal/Hepatic Disease

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General anesthesia may be necessary for patients with significant disease processes such as renal disease or hepatic disease. A basic understanding of the effects of general anesthetics on these organs and the anticipated problems of renal and hepatic impairment on the anesthetic process is necessary to optimize conditions for patients with renal or hepatic disease. Patient preparation, drug selection, and monitoring strategies will be discussed for patients with renal and liver disease.

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The kidneys receive approximately 25% of the body’s cardiac output and are highly dependent on adequate blood flow to function properly. Nearly every anesthetic agent decreases glomerular filtration rate (GFR) and renal blood flow, so general anesthesia should not be considered an innocuous process for patients with preexisting renal disease. Nevertheless, general anesthesia may be necessary for such patients, and steps should be taken to minimize any detrimental impact to remaining nephron function. It may also become necessary to anesthetize patients with acute renal failure to relieve urinary system obstruction. Regardless, as with any critical patient, the duration of general anesthesia should be minimized whenever possible.

Patient preparation is crucial for animals with acute or chronic renal failure. Every effort should be made to reduce the level of azotemia before general anesthesia. Hypovolemia and dehydration should be avoided and corrected before general anesthesia. Patients that are anuric or oliguric must have their hydration status monitored very carefully because their volume deficits must be managed in the face of urinary obstruction to outflow. Inhalant anesthetics produce profound vasodilation and a reduction in cardiac output that can be very detrimental in the face of hypovolemia. Patients with chronic renal failure can be admitted the evening before general anesthesia and placed on intravenous fluids to ensure optimal hydration. Anemia should be identified and assessed before general anesthesia. Blood products may need to be used because anemia from chronic renal failure may potentially result in a failure to deliver adequate oxygen to tissues.

General Considerations for Patients with Compensated Chronic Renal Failure

Patient evaluation for anesthetic protocol planning is critical to optimize the condition of the patient while under general anesthesia. Renal patients can present in a wide spectrum of disease states. Well-compensated, well-hydrated chronic renal failure patients can use a wide variety of anesthetic agents, whereas decompensated, critically ill uremic patients may be very limited in appropriate drug selection and must be most carefully managed.

In general, anesthetic agents and adjuncts that optimize cardiac output are the best choices for patients with renal disease. Blood pressure monitoring is extremely valuable to manage renal blood flow, as is robust fluid therapy. Every effort must be made to ensure adequate renal blood flow.

Pharmacologic Considerations

Premedication

Premedication of renal patients with sedatives and analgesics can be very helpful to reduce stress and anxiety and provide analgesia. Stress and pain will result in sympathetic nervous system stimulation and catecholamine release, which may result in decreased blood flow to the kidney. General anesthetics do not provide antinociceptive activity, so the use of premedications will enhance the analgesic activity of the anesthetic plan (Table 1). The use of sedatives and analgesics will decrease the amount of induction and maintenance agents necessary for general anesthesia—both of which have the potential to decrease cardiac output and reduce GFR and renal blood flow. Acepromazine is a long-lasting (6 to 8 hours) phenothiazine tranquilizer and a dopamine antagonist. Premedication with a low dose of acepromazine in renal patients may be advantageous because of the vasodilatory nature (via alpha blockade) of the drug. A low dose of acepromazine (0.03 mg/kg) has been shown to reduce the effectiveness of high-dose dopamine therapy at increasing systemic vascular resistance in anesthetized dogs but did not alter the dopamine-mediated peripheral vasodilation associ-
should not be administered to cats with renal disease. Propofol has been shown to have minimal effects on GFR. Propofol induction and maintenance with a constant-rate infusion may be helpful in patients that need chemical restraint while measuring GFR. Regardless of the induction agent chosen, administration of the drug “to effect” will help maintain hemodynamic stability.

**Maintenance**

Either isoflurane or sevoflurane will maintain renal blood flow better than halothane. These agents decrease GFR, so techniques that decrease the amount of inhalant needed to maintain patients are very helpful for patient care. These include the use of opioid constant-rate infusions, regional or local anesthetic techniques, and the use of premedicants.

**Monitoring**

Monitoring of chronically ill patients while they are under general anesthesia is of paramount importance. Particular attention should be paid to blood pressure monitoring to help ensure that the kidneys are adequately perfused and have sufficient blood flow to support the remaining nephrons. Duration of the planned anesthesia and condition of the patient will help determine what type of blood pressure monitoring should be used. Critically ill patients who anticipate a lengthy duration of general anesthesia should be monitored via invasive or direct blood pressure monitoring if at all possible. Less compromised patients and patients who have very short-duration anesthesia may be managed with indirect monitors. Indirect, cuff-based monitors are easy to use in patients but are more prone to inaccuracy. Direct arterial pressure monitoring is more expensive but has the advantage of more accurate readings and permits easy access for blood gas analysis. Acid-base status is of particular importance in animals with renal disease, especially because animals with acute renal failure are prone to inaccuracy. Direct arterial pressure monitoring is more expensive but has the advantage of more accurate readings and permits easy access for blood gas analysis. Acid-base status is of particular importance in animals with renal disease, especially because animals with acute renal failure are at risk of electrolyte abnormalities such as hyperkalemia. Most point of contact blood gas analysis machines (ISTAT, IRMA®) have cartridges that analyze both blood gas values and electrolytes.

Mean arterial blood pressure can be considered an estimate of tissue perfusion pressure. Mean arterial blood pressure should be maintained above 60 mm Hg in small animal patients to provide sufficient blood flow to vital organs. Mean arterial pressures above 70 mm Hg are desirable if renal disease is present. If indirect blood pressure monitors such as Doppler or oscillometric units are used, than systolic blood pressure should be maintained above 90 mm Hg. Many patients with compensated renal disease will have secondary hypertension before anesthesia.

As in any critical patient undergoing general anesthesia, pulse oximetry and capnography will assist in respiratory monitoring of the renal disease patient. Mucous membrane color and capillary refill time should be carefully monitored and assessed. Patients should have hematocrit or packed cell volume (PCV) assessed periodically. Patients with anemia will need to have a transfusion to ensure adequate oxygen delivery to the kidney if PCV is less than 20% (dogs) or 18%

<table>
<thead>
<tr>
<th>Table 1. Sample Anesthetic Plan for Patients with Chronic Renal Disease</th>
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<tbody>
<tr>
<td><strong>Ensure optimal hydration status: preload with fluids if necessary</strong></td>
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<tr>
<td><strong>Premedication:</strong></td>
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<tr>
<td>Acepromazine (0.01-0.02 mg/kg) IV, IM, or SC, if dopamine not planned</td>
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<tr>
<td>Opioid IV, IM, or SC</td>
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<tr>
<td>Hydromorphone (0.1 mg/kg)</td>
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<tr>
<td>Butorphanol (0.2-0.4 mg/kg)</td>
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<tr>
<td>Buprenorphine (0.010-0.020 mg/kg)</td>
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<tr>
<td>Benzodiazepine</td>
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<tr>
<td>Midazolam (0.1-0.2 mg/kg) IV or IM</td>
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<tr>
<td>Diazepam (0.2 mg/kg) IV</td>
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<tr>
<td><strong>Induction:</strong> Propofol 6 mg/kg IV to effect</td>
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<tr>
<td>Isoflurane or sevoflurane maintenance</td>
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<tr>
<td><strong>Fluid therapy:</strong> Isotonic crystalloid: 10 mL/kg/h</td>
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<tr>
<td><strong>Monitoring:</strong> blood pressure, capnometry, pulse oximetry, urine output, body temperature, ECG</td>
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Abbreviations: IM, Intramuscularly; IV, intravenously; SC, subcutaneously; ECG, electrocardiogram.
Peripheral venous support is essential: 10 to 20 mL/kg/h of crystalloid isotonic fluids given intravenously should be used to maintain adequate circulating volume to the kidney. Colloid therapy can be considered if blood pressure is not adequate with crystalloids alone. Hetastarch administered intravenously at rates of 2 to 10 mL/kg/h can assist in maintaining intravascular volume, not exceeding 20 mL/kg/d. Care should be taken to make sure the patient is making urine and that volume overload does not occur from overzealous crystalloid or colloid administration. Diuretic therapy may need to be instituted if pulmonary edema occurs.

Urine output should be measured by aseptic catheterization of the bladder if a lengthy or complicated procedure is planned. Normal urine output is 0.5 to 2 mL/kg/h. Dopamine therapy may be considered in debilitated patients at the rate of 1 to 10 µg/kg/min. Low doses (1-3 µg/kg/min) of dopamine will increase renal blood flow (RBF), GFR, and urine output. Higher doses will activate beta adrenoceptors, which may dilate renal arterial beds and increase cardiac output. There is evidence to suggest that low-dose dopamine (3 µg/kg/min) therapy does not induce diuresis in cats.11

Ensure adequate analgesia because pain and sympathetic nervous system stimulation will cause catecholamine release, vasoconstriction, and decreased blood flow to the kidney.12 Perioperative use of nonsteroidal agents such as meloxicam or carprofen is generally not recommended in patients with renal disease.

General Considerations for Patients in Acute Renal Failure

Patients in acute renal failure may present in a wide spectrum of clinical states—anywhere from occult disease to profoundly ill. Every effort should be made to stabilize the patient and avoid unnecessary general anesthesia. Careful attention must be made to intravascular volume in the face of anuria. Central venous pressure can be very helpful to assess volume status and guide fluid therapy in these animals. Acid-base status and electrolyte levels should be frequently assessed in these patients, so point of contact monitors such as I-stat® or IRMA® can be very helpful.

Patients with postrenal azotemia from complete urinary obstruction are the most likely to require general anesthesia on an emergent basis. These patients present in a clinical spectrum of nearly normal to extremely obtunded and in shock. Near normal patients with acute obstruction can be treated in a similar manner as a well-compensated chronic renal failure patient. Obtunded patients will need to be managed with extreme care. Intense fluid therapy will be necessary before general anesthesia, and general anesthesia should be instituted with extreme caution. The most common causes of postrenal azotemia include urethral obstruction, ureteral obstruction, and traumatic urinary tract rupture, including ruptured bladder.13

Electrolyte abnormalities like hyperkalemia, hyponatremia, and hypochloremia may occur with a ruptured bladder, as well as acidaemia. An electrocardiogram should be run on patients with a ruptured bladder before general anesthesia to look for evidence of cardiac abnormalities due to hyperkalemia. Serum potassium levels greater than 5.5 to 6.0 mEq/L should be treated before general anesthesia and the serum potassium level corrected as much as possible. Intravenous fluids like 0.9% NaCl should be used, as well as dextrose, insulin, or bicarbonate if necessary to reduce potassium levels. Calcium gluconate or calcium chloride may be administered to antagonize the cardiac effects of hyperkalemia if treatment is not successful.9

Hepatic Disease

Like the kidney, the liver is a major user of the body’s blood supply. About 20% of cardiac output is delivered to the liver. Seventy percent of its blood supply comes from the portal vein and 30% of the blood supply from the hepatic artery, which supplies most of its oxygen needs.14 Maintenance of adequate blood flow and oxygen delivery during general anesthesia is crucial to reduce further damage to hepatocytes. The liver is responsible for the metabolism and biotransformation of most substances in the body, both endogenous and exogenous. Anesthetics and adjuncts should be chosen to support vital organ blood flow. They should be expected to have a longer duration of effect in patients with liver disease. The liver has a central function in the formation, storage, and release of glucose. It also produces coagulation factors such as plasminogen and antithrombin and is responsible for metabolism of many activators of the coagulation and plasmin cascades. Liver failure may result in disseminated intravascular coagulation. Hemostasis [prothrombin time (PT), partial thromboplastin time (PTT), bleeding time] should be evaluated before general anesthesia in patients with liver disease, especially if surgery is planned. Patients with significant liver disease may ooze and bleed more than anticipated.

The liver is the primary site of plasma protein synthesis except for gamma globulins and factor VIII. Plasma albumin values are one of the best indicators of liver function. Albumin is very important with respect to anesthesia. Many anesthetic agents bind with plasma proteins so that the drug is divided into active versus bound (inactive) fractions. If the plasma albumin is low, this will allow a higher concentration of the active component and therefore a more profound patient response. In addition, albumin is important for producing plasma oncotic pressure, which retains fluid in the intravascular space. If albumin is low (< 1.5-2.0 g/dL), fluid may redistribute to the extracellular spaces with resulting edema.

General Considerations for Patients with Liver Disease

As in renal disease, patients with liver disease can present with a diverse clinical spectrum. Patients with mild liver dis-
ease can be expected to have fewer problems with general anesthesia than patients with severe, fulminant disease. Patients with signs of liver dysfunction like hypoglycemia, hypoalbuminemia, high ammonia levels, and elevated serum bile acids should be considered at greater risk for complications associated with general anesthesia. Every effort should be made to reduce ammonia levels before general anesthesia to minimize the potential for hepatic encephalopathy post anesthesia. Lactulose administration and enemas can be performed to help reduce blood ammonia levels.

To minimize further hepatic damage, techniques and drugs that support liver function, including vital organ blood flow and oxygen delivery, should be used. Anesthetic drugs that have a short half-life, depend on some mechanism other than liver metabolism for their termination, or are reversible should be considered when formulating the anesthetic plan (Table 2). Normal arterial carbon dioxide levels should be maintained, because both hypoventilation and hyperventilation can result in a decrease in hepatic blood flow.

Blood glucose concentrations should be carefully monitored. If persistently low, the addition of dextrose to a balanced, crystalloid isotonic fluid should be used. A final concentration of 2.5% dextrose is helpful for many patients. If hypoalbuminemia and hypoproteinemia are present, avoid drugs with high protein binding or be aware that a higher concentration of active drug may result. Colloids such as hetastarch can be added to the fluid therapy plan to avoid further dilution of blood proteins. Patients with severe hypoalbuminemia or clotting disorders may need a plasma transfusion.

Pharmacologic Considerations

Premedication

Tranquilizer and sedative selection in the patient with liver disease presents a significant challenge to the anesthetist. Avoid acepromazine and alpha-2 adrenergic agonists in patients with moderate to severe liver disease. Acepromazine has a long duration of effect in a normal patient and is heavily dependent on the liver for elimination from the body, so one can expect its actions to be prolonged in a patient with liver disease. Alpha-2 agents like xylazine or dexmedetomidine compromise vital organ blood flow and oxygen delivery, so their use should be limited to animals with mild disease and an overwhelming need for profound sedation. Some clinicians consider benzodiazepines to exacerbate problems with hepatic encephalopathy in patients with liver disease and avoid their use. Others consider them a helpful and appropriate choice for patients with mild to moderate disease. Nonetheless, their sedative qualities may be exaggerated and present for a prolonged duration in a patient with significant liver disease.

Opioids, although dependent on the liver for metabolism, tend to be a good choice for patients with liver disease. Animals with significant liver dysfunction can be expected to have an exaggerated sedative response to opioid administration. Opioids provide analgesia, a fundamental necessity for patients with liver disease. Alpha-2 agents like xylazine or dexmedetomidine have an exaggerated hypotensive response to opioid administration. Etomidate, an imidazole anesthetic, can be used in patients with liver disease if at all possible. Propofol, a nonbarbiturate, ultra short–acting anesthetic agent should be considered a drug of choice for animals with liver disease. Its rapid redistribution after injection is helpful in terminating its anesthetic effects. Propofol is also eliminated from the body by extrahepatic mechanisms, because clearance of the drug from the body is faster than hepatic blood flow.

Etomidate, an imidazole anesthetic, can be used in patients with liver disease, because it has excellent cardiovascular support and rapid redistribution. It is metabolized by the hepatic microenzyme system and plasma esterases, but it clears the body faster than thiopental. It can produce twitching and muscle activity that can be minimized with prior

### Table 2. Sample Anesthetic Plan for Patient with Liver Disease

<table>
<thead>
<tr>
<th>Premedication: opioid alone</th>
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<tbody>
<tr>
<td>Induction</td>
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<tr>
<td>Propofol 6 mg/kg IV</td>
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<tr>
<td>Etomidate 1-2 mg/kg IV—consider diazepam immediately prior</td>
</tr>
<tr>
<td>Maintenance</td>
</tr>
<tr>
<td>Crystalloid 5 mL/kg/h with 2.5% dextrose if hypoglycemic</td>
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<tr>
<td>Hetastarch 5 mL/kg/h if hypoalbuminemic</td>
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<tr>
<td>Monitoring: see above</td>
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Abbreviation: IV, Intravenously.

administration of a benzodiazepine. Ketamine, a dissociative anesthetic, is heavily metabolized by the liver in dogs, and prolonged recovery may occur in patients with significant liver disease. A single, small bolus dose is appropriate for patients with mild or moderate liver disease, unless they have a seizure history.

**Maintenance**

Inhalation anesthetics tend to be the most convenient choice to maintain general anesthesia, and they are also used to induce anesthesia if necessary. Halothane should be avoided, but either isoflurane or sevoflurane is an appropriate choice for patients with liver disease.

**Monitoring**

Like any other critical patient undergoing general anesthesia, patient monitoring is a vital component to excellent patient care in patients with liver disease. Particular attention should be made to maintenance of vital organ blood flow and oxygenation. Blood pressure monitoring and pulse oximetry can be very helpful in this regard. Mean arterial pressure should be maintained above 70 mm Hg and oxygen saturation above 95%. As with any anesthetized patient, body temperature should be monitored and maintained as near to normothermic as possible.

Patients with severe liver disease may have ascites. If the volume of transudate in the abdominal cavity is large, removal of some of this fluid should be done before general anesthesia to reduce the pressure on the diaphragm and resulting impairment of ventilation. However, ascitic fluid removal must be done with extreme care and with concomitant fluid therapy to support cardiovascular function.9

**References**


