

The Liver

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Certain disease processes can cause liver failure; therefore, it is crucial that technicians understand not only how the liver functions but also how various liver diseases are diagnosed and treated. Technicians can increase their value in the veterinary team by knowing how to conduct the various tests for diagnosing liver disease and by providing client education and appropriate patient care.

Anatomy

The liver—a brownish-red, friable organ—is the largest gland in the body. A gland is a group of cells that secretes a substance. The liver secretes bile. The liver is located in the cranial abdomen and is shaped to fit around neighboring structures: the caudal surface of the liver is concave (to fit around the stomach), and its cranial surface curves with the diaphragm.¹ Most of the liver is encased in peritoneum. In cats and dogs, the liver consists of six lobes² separated into tiny hepatic lobules, which help filter blood through the liver.³ The hepatic cells (i.e., hepatocytes) line the lobules and radiate toward a central vein.³ Hepatocytes are the functioning units of the liver. As an animal ages, its liver atrophies; therefore, livers of young animals weigh more than livers of adult animals.¹

The liver has a unique venous system called the *hepatic portal system*, which receives both oxygenated and deoxygenated blood.⁴ All products of digestion are filtered through the liver,⁴ and approximately 80% of the blood that flows into the liver enters via the portal vein and comes from the stomach and intestines.³ The hepatocytes are nourished by this blood, which is rich in nutrients, but not in oxygen.³ As the blood enters the lobules, plasma flows across the hepatocytes and filters into the central vein; the blood then travels from the central vein into the hepatic vein and eventually into the caudal vena cava.⁵ As the blood is filtered through the liver, it passes through Kupffer cells—specialized macrophages that help to remove bacteria. The hepatic artery supplies the remaining 20% of the blood to the liver. This blood, which is rich in oxygen and nutrients, supports the high metabolic activity of hepatocytes.

Hepatocytes secrete hormones and bile, a yellowish-green digestive liquid. Between the hepatocytes lie many bile canals, known as *bile canaliculi*, through which secreted bile moves. Canaliculi merge together to form larger channels called *bile ducts*, which merge together into the common bile duct. This duct leads to the duodenum, where bile is released. The bile pathway is important for digestion of food (FIGURE 1).

The gallbladder is attached to the diaphragm on the ventral surface of the liver and lies between the main lobes. The gallbladder stores bile between meals, concentrates bile by reabsorbing water from it, and then releases bile into the small intestine through the common bile duct.² To manage certain diseases, the gallbladder may be removed; without it, bile is discarded directly from the liver into the small intestine.

Physiology

Bile plays an important role in digestion, and bile production is one of the main functions of the liver. Bile consists primarily of bile salts, water, and bile pigments such as bilirubin (which is created when old red blood cells [RBCs] break down) and biliverdin.³ Bile salts enhance the absorption of fatty acids and fat-soluble vitamins (i.e., vitamins A, D, E, and K).³ Without bile salts, vitamin deficiencies can occur. One of the most important functions of bile is to emulsify fat so that it can be broken down by digestive enzymes in the gut.⁶

The liver also plays an important role in carbohydrate metabolism. In a process called *glycolysis*, the liver metabolizes carbohydrate by converting excess glucose into glycogen, which is then stored.⁷ Stored glycogen is converted back into glucose and released into the body to supply energy.⁷ Glucose can be produced in the liver through two processes: glycogenolysis or

Glossary

Anisocoria—Inequality in the size of the pupils

Ascites—Fluid accumulation in the abdomen

Cholestasis—Cessation of the flow of bile from the liver

Coagulation cascade—Sequence of enzymatic reactions leading to blood clot formation

Extrinsic pathway—Pathway that is initiated by tissue thromboplastin (factor III) and involves calcium ions and factor VII

Gland—Group of cells that excrete a substance

Hemolysis—Destruction of red blood cells

Hepatomegaly—Enlargement of the liver

Intrinsic pathway—Pathway in which factors VIII, IX, XI, and XII are activated by exposure to subendothelial collagen or foreign substances

Neoplasia—Formation of a tumor

Peritoneum—Abdominal lining

Bile is secreted by hepatocytes in the liver and then proceeds through the following pathway.



Figure 1. Bile Duct Pathway^{2,13}

gluconeogenesis.⁸ Both are controlled by the hormone glucagon, which is produced by α cells in the islets of Langerhans in the pancreas. When glucagon is released, the processes begin. Gluconeogenesis occurs when energy sources are low, such as during fasting, administration of low-carbohydrate diets, or intense exercise.⁸ Because liver failure can affect these processes, affected patients may have decreased glucose levels.

The liver also plays a vital role in deamination, in which amino acids are broken down by removal of an amino group so that they can be converted into enzymes or energy by various tissues in the body. During deamination, the liver converts ammonia (produced from the discarded amino group) into urea or uric acid, which is excreted through renal filtration.^{1,3} Patients with liver failure may have increased levels of ammonia and decreased levels of blood urea nitrogen.

The liver also synthesizes α - and β -globulins, which transport lipids and fat-soluble vitamins throughout the body.³ Prothrombin is one of the most important α -globulins produced by the liver. Factor X—an enzyme that requires vitamin K for synthesis—and calcium ions help convert prothrombin into thrombin.³ Prothrombin and thrombin are necessary for coagulation. If the liver is damaged, the body's ability to coagulate blood may be affected. Therefore, if liver disease is suspected, it is important not to perform abdominal taps, multiple venipunctures (especially involving the jugular vein), or cystocentesis until clotting times are within normal limits. Performing cystocentesis in a jaundiced patient with a coagulopathy may result in severe internal bleeding.

Albumin is produced only in the liver and is the major plasma protein that circulates in the bloodstream. Albumin is essential for maintaining oncotic pressure in the vascular system. When the liver fails to make adequate albumin, oncotic pressure decreases. A decrease in albumin allows fluid to leak from interstitial spaces, producing ascites and edema.

The liver helps to synthesize lipoproteins, phospholipids, and cholesterol and to metabolize fat by oxidizing fatty acids at a high rate.² The liver also helps to convert carbohydrate molecules into protein molecules and fats.² The fat created in the liver is transported by the blood into adipose tissue, where it is stored until it is required for energy.² Fat can be broken down to release glycerol, which can be converted by the liver into glucose.

The liver stores minerals (e.g., iron) and vitamins (e.g., vitamins A, D, and B₁₂).³ The liver also helps destroy foreign substances (e.g., drugs) and damaged RBCs,⁷ alters toxins (e.g., alcohol) by detoxification, and excretes toxins in bile. The liver is the primary organ involved in drug and toxin metabolism.

The liver plays a minor role in thermoregulation by helping to produce heat and maintain body temperature through cellular metabolism (i.e., the more active the cells, the more heat they produce).

BOX 1 summarizes the diverse functions of the liver.

Disease Processes

Certain disease processes can cause liver failure. To maintain high-quality patient care, it is important to conduct diagnostic tests to diagnose liver problems. If any of the following diseases or conditions is present, secondary liver injury could occur.

Although any **inflammatory disease** can affect the liver, the disease usually must be severe (e.g., anaphylactic shock, systemic inflammatory response syndrome, pancreatitis) to damage the liver.

Because a large amount of blood is filtered through the liver, **circulatory disorders** (e.g., hypovolemia) or any change in the circulatory system could affect the liver.

Box 1. The Diverse Functions of the Liver

Synthesis

- Protein production, secretion, and metabolism
- A large part of amino acid synthesis
- Carbohydrate metabolism
 - Gluconeogenesis (synthesis of glucose from certain amino acids, lactate, and glycerol)
 - Glycogenolysis (breakdown of glycogen into glucose)
 - Glycogenesis (formation of glycogen from glucose; muscle tissue can also do this)
- Lipid metabolism
 - Cholesterol synthesis
 - Lipogenesis (production of triglycerides [fats]).
- Production of coagulation factors I (fibrinogen), II (prothrombin), V, VII, IX, X, and XI as well as protein C, protein S, and antithrombin
- RBC production in first-trimester feline and canine fetuses (by week 32 of gestation, bone marrow has almost completely assumed this task)
- Production and excretion of bile for emulsifying fats; some bile drains directly into the duodenum, and some is stored in the gallbladder
- Production of insulin-like growth factor 1, a polypeptide protein hormone that plays an important role in growth and has anabolic effects in adult animals
- Production of thrombopoietin, a glycoprotein hormone that regulates platelet production by bone marrow

Degradation

- Protein degradation
- Breakdown of insulin and other hormones
- Conjugation of bilirubin, facilitating its excretion into bile
- Breakdown or modification of toxins (e.g., methylation) and most medicinal products (i.e., drug metabolism), possibly resulting in intoxication if the metabolite is more toxic than its precursor
- Conversion of ammonia into urea (i.e., the urea cycle)

Other Functions

- Storage of many substances, including glucose (in the form of glycogen), vitamin A (1–2 years' supply), vitamin D (1–4 months' supply), vitamin B₁₂ (1–3 years' supply), iron, and copper
- Immunologic effects—the reticuloendothelial system of the liver contains many immunologically active cells, acting as a “sieve” for antigens carried to it via the portal system
- Production of albumin, the major osmolar component of blood serum
- Synthesis of angiotensinogen, a hormone that raises blood pressure when the hormone is activated by renin, an enzyme that is released when the kidneys sense low blood pressure

Severe **anemia** can result in hypoxia, thereby affecting the liver.⁹ When the blood supplied to the liver is not appropriately oxygenated, the liver can be damaged. If the liver is damaged because of injury or disease, it may not be able to sufficiently store vitamins, including vitamin B₁₂, which is needed for hemoglobin production.

Because the liver helps to regulate glucose, liver disease should be suspected when a patient presents with **hypoglycemia**.

Shock can lead to liver damage. In dogs, the liver and gastrointestinal tract are the main body structures affected by shock.¹⁰ In cats, the main organ affected by shock is the lungs.¹⁰

In cats with **anorexia**, hepatic lipidosis is a major concern. Triglycerides accumulate in the blood, overwhelming the liver and potentially causing severe liver dysfunction.

When **petechiae** or **ecchymoses** are observed on a patient, liver involvement should be suspected. Because the liver plays a vital role in coagulation, bleeding under the skin indicates that the body's clotting ability may be jeopardized. To determine if there are signs of hemorrhage, each patient should undergo a complete physical examination, including inspection of the mucous membranes, sclera, and inguinal areas.

Liver Enzymes

The four main liver enzymes (alkaline phosphatase [ALP], aspartate aminotransferase [AST], γ -glutamyltransferase [GGT], and alanine

transaminase [ALT]) can be assessed using a blood chemistry profile. Understanding these enzymes may help determine the cause of liver failure.

Alkaline Phosphatase

ALP is an enzyme in the bile duct cells. The ALP level in plasma increases because of bile duct obstruction, intrahepatic cholestasis, or infiltrative diseases of the liver.⁹ An increase in the ALP level is not specific for liver injury or disease. While ALP is made mostly in the liver, it can also be made in bone, the intestines, and the kidneys. An increase in the ALP level alone is not specific to liver disease. Other causes of increases in the ALP level include bone disease or damage, cancer, and hyperparathyroidism (which affects the blood level of calcium).

Aspartate Aminotransferase

AST is an intracellular enzyme that helps transfer amino groups during conversion from amino acids to α -oxoacids.⁹ The AST level increases when hepatocytes degenerate or undergo necrosis, after administration of certain medications (e.g., antiseizure drugs), or after traumatic injury (e.g., being struck by an automobile). AST and ALT levels are related to the number of damaged hepatocytes; however, the damage may be reversible.⁹ Like ALT, AST is in other tissues (e.g., muscle, RBCs), so an increase in the AST level does not always indicate liver injury.

γ-Glutamyltransferase

GGT, an enzyme found in bile ducts, is usually tested in conjunction with ALP and other liver tests to rule out cholestasis. This combined testing has a higher diagnostic value than any test used alone.⁹

Alanine Transaminase

ALT is an enzyme in hepatocytes. When a hepatocyte is damaged, ALT enters the bloodstream. ALT levels increase dramatically in patients with acute liver disease. Although an elevated ALT level does not necessarily indicate liver damage, the ALT level is more specific for hepatocyte injury than ALP, GGT, or AST.¹¹ A patient can have normal fluctuations in the ALT level throughout the day.¹¹ Certain drugs (e.g., corticosteroids) and hepatic injury (e.g., resulting from being struck by an automobile) can also increase the ALT level.¹¹

Diagnosis

Albumin

Albumin, which is synthesized in the liver, is a major protein found in plasma. Albumin is responsible for maintaining colloid osmotic pressure and helping to prevent plasma loss from the capillaries. Patients with chronic liver disease can have decreased albumin levels.¹² By themselves, tests that measure the albumin level cannot determine the degree of liver damage; however, these tests can be used as additional diagnostic tools.

Ammonia

The ammonia level in the blood increases when the liver cannot convert ammonia to urea. An elevated ammonia level may indicate the presence of a liver shunt, hepatitis, or liver failure.¹³

Bilirubin

Bilirubin—a product of hemoglobin breakdown—undergoes conjugation, a process in which the liver makes bilirubin water soluble. In patients with liver damage, conjugation may not occur, causing the total bilirubin level in the blood to increase (hyperbilirubinemia). Total bilirubin—the total amount of bilirubin detected in the blood—includes conjugated and unconjugated bilirubin. Some conditions, such as bile duct obstruction or hemolytic anemia, can increase the total bilirubin level.¹³

The direct bilirubin level reflects only the conjugated portion of bilirubin. If the direct bilirubin level is normal and the total bilirubin level is high, the patient is likely to have excess unconjugated bilirubin (e.g., hemolysis). However, if the direct bilirubin level is high, the patient has excess conjugated bilirubin, potentially signaling the presence of a condition such as neoplasia or gallstones.¹³

Blood Urea Nitrogen

Blood urea nitrogen may be decreased in patients with advanced liver disease because nitrogenous waste products are not being converted to urea.

Serum Protein Electrophoresis

Serum protein electrophoresis is used to measure the levels of various proteins. This test is useful for evaluating patients with

abnormal liver enzyme levels because it allows direct quantification of multiple serum proteins, such as total protein, albumin, and α-, β-, and γ-globulins. Different liver diseases can cause elevations in different globulins.⁴

Coagulation Testing

It is important not to perform abdominal taps, multiple venipunctures (especially involving the jugular vein), or cystocentesis until a patient's clotting times are within normal limits.

Prothrombin Time

Prothrombin is an α-globulin needed for blood coagulation. The prothrombin time (PT) test is performed to assess the extrinsic pathway of the coagulation cascade. Liver disease should be suspected in any patient with a prolonged PT; however, a prolonged PT does not specifically indicate the presence of liver disease, and a normal PT does not indicate the absence of liver disease.

Activated Partial Thromboplastin Time

Thromboplastin is a clotting factor that converts prothrombin into thrombin. The activated partial thromboplastin time test assesses the intrinsic pathway of the coagulation cascade to determine how long it takes a patient's blood to clot. PT and activated partial thromboplastin time tests are generally conducted at the same time.

Urinalysis

Urinalysis should be conducted to determine whether bilirubin is present in the urine (i.e., bilirubinuria). A trace amount of bilirubin is normal in a concentrated urine sample from a dog, but this finding is abnormal in a cat.¹⁰ If bilirubinuria is evident, additional diagnostic testing should be conducted to rule out liver disease, hemolysis, or other possible causes.

Imaging

Although some diseases can be ruled out by blood test results, the cause of liver damage cannot usually be determined by blood tests alone. Imaging can be used to reveal tumors, obstructions, or other abnormalities.

Radiography

Radiography is a useful tool but does not usually provide a diagnosis. For example, hepatomegaly can often be observed on a radiograph; however, a tumor originating from the liver can rarely be seen on a radiograph. If neoplasia is suspected, it is important to obtain left, right, and ventrodorsal chest views to look for metastases.

Ultrasonography

Ultrasonography can be used as a diagnostic tool for patients with liver disease. Gallbladder obstructions, tumors, bile duct obstructions, and lipidosis can often be diagnosed using ultrasonography. Ultrasonography can distinguish between solid and fluid-filled masses; however, it cannot yield a definitive diagnosis. It is important that a qualified ultrasonographer conduct the test.

For example, finding a liver (portosystemic) shunt in a small puppy can be difficult even for a highly trained individual.

Contrast Angiography

Contrast angiography uses a dye that is usually injected into the jejunal vein.¹⁴ This can be expensive and time-consuming but can definitively diagnose a portosystemic shunt. Angiographic techniques are invasive, requiring a specially trained veterinarian. Patients undergoing angiography require general anesthesia. Because of the expense and time associated with angiography, most veterinarians prefer exploratory surgery instead.

Computed Tomography

While computed tomography (CT) is not as readily available as other imaging diagnostics, it does allow for quick scans of the liver before and after contrast is administered. CT can identify hepatic nodules that cannot be detected by ultrasonography. CT can also help diagnose portosystemic shunts. The disadvantages of CT are high cost, poor availability, and the need for general anesthesia.¹⁵

Magnetic Resonance Imaging

As with CT, magnetic resonance imaging (MRI) can identify hepatic nodules that cannot be detected by ultrasonography. MRI also offers excellent anatomic detail of the liver. As with CT, the disadvantages of MRI are high cost, poor availability, and the need for general anesthesia.¹⁵

Biopsy

Fine-Needle Aspiration

Ultrasound-guided fine-needle aspiration biopsy can be very useful for diagnosing liver disease; however, this test has an increased risk of complications because patients with liver disease may have clotting abnormalities and may hemorrhage. Fine-needle aspiration biopsy can also be performed “blindly,” without ultrasonography, but samples obtained in this manner are often of poor diagnostic quality.

Because the liver plays a role in the coagulation cascade, it is important to rule out clotting problems before a biopsy. Little or no sedation is generally needed to perform a needle biopsy; however, patient movement may result in liver laceration and/or retrieval of an inadequate sample. Certain diseases or types of neoplasia can be diagnosed using this method; however, the sample obtained does not always yield a diagnosis.

Percutaneous-Needle Aspiration

Ultrasound-guided percutaneous-needle aspiration can also be used to obtain a biopsy sample. Although the needle used can obtain a larger sample than a fine needle, the sample can also be nondiagnostic.

Laparoscopic Biopsy

Compared with needle biopsy, laparoscopic biopsy can be used to obtain a larger sample of the affected area of the liver, and the

laparoscope provides a better view of the liver than does ultrasound imaging. Laparoscopic biopsy is more invasive than ultrasound-guided fine-needle aspiration; therefore, patients undergoing the former require general anesthesia. As with needle biopsy, it is important to ensure that a patient does not have a clotting problem before laparoscopic biopsy.

Treatment

Once a diagnosis has been made, a treatment plan should be formulated. Because many treatment options are available for patients with liver disease, it is important that clients be informed of, and understand, these options. Even if the patient's prognosis is good, some clients may decide to forgo treatment because it can be expensive and time-consuming; other clients may choose to euthanize their pet if it requires long-term care or extended hospitalization.

The overall treatment goal for a patient with liver disease is to use a specific treatment, when possible, and provide supportive care. During treatment, it is important to manage complications associated with liver failure, such as gastrointestinal ulceration, anemia, infection, ascites, edema, and coagulopathy.¹⁰ Treatment varies according to the identified cause of the disease.

When caring for a patient with liver disease, the technician should frequently monitor all vital systems (e.g., cardiovascular, respiratory, neurologic). Because the technician likely spends the most time with the patient, he or she can alert the veterinarian to early signs of complications. It is important for the technician to thoroughly evaluate the patient during monitoring. For example, if the color of a patient's mucous membranes is not checked regularly, the technician may not recognize that anemia has developed. In addition, the color of a jaundiced patient can change hourly, so it is important to notify the veterinarian if a change occurs.

Aggressive fluid therapy is one of the most important treatment options when managing a patient with liver disease. By returning perfusion parameters to normal, fluid therapy can help to improve hepatic circulation and prevent complications such as disseminated intravascular coagulation, shock, or renal failure.¹⁰ Often, 0.45% sodium chloride is used to help prevent sodium retention and portal hypertension.¹⁰ Colloids such as hetastarch may be used to help restore oncotic pressure. Electrolyte levels should be monitored, and fluid adjustments should be made accordingly. Ascites may need to be drained to increase comfort and ease breathing.

Proper nutrition is essential for patients being treated for liver disease. During the initial treatment stages, patients that appear nauseous or are vomiting should not be fed by mouth. However, nutritional needs must be considered in patients that require long-term care. A feeding tube may be placed if a patient is unwilling to eat.¹³ A feeding tube allows controlled, effective feeding compared with force-feeding using a syringe. Technicians can encourage the patient to eat by offering a variety of foods or by hand-feeding. Because patients with certain liver diseases require special diets, the veterinarian should be consulted before feedings are initiated. In patients with diseases such as feline hepatic lipidosis, nutrition plays a crucial role in recovery.¹⁰

Several hepatosupportive agents may be used to help control chronic liver problems in some pets, and the use of these agents to control acute liver failure has become more common. Most of these agents are nutraceuticals that are antioxidants.¹⁶ Antioxidants that are considered hepatosupportive are vitamin E, S-adenosylmethionine, silymarin, phosphatidylcholine, vitamin C, and N-acetylcysteine.¹⁶ Ursodeoxycholic acid is also considered hepatosupportive.¹⁶ Because hepatosupportive agents do not cure severe disease but may improve the health of the liver, they should be used in conjunction with other treatments.¹⁶ S-Adenosylmethionine—one of the most commonly used agents—has been shown to help improve liver function and appears to have no adverse effects.¹⁶ It is commonly used in people to help protect against alcoholic hepatitis.¹⁶ Denamarin (Nutramax Laboratories)—a newer supplement for dogs and cats—contains S-adenosylmethionine and silybin. Silybin is the most active fraction derived from milk thistle, which has been used to help support liver function.¹⁶

Additional treatments may be necessary to address complications associated with liver disease. For example, mannitol and furosemide may be used to help reduce cerebral edema, which may develop in patients with severe liver disease. Technicians should immediately notify the veterinarian of anisocoria or changes in neurologic status. If a patient develops a coagulopathy, fresh frozen plasma may be given. A technician may be the first to notice petechiae on a patient.

Follow-Up

Often, patients are discharged from the hospital even though they remain slightly jaundiced or have elevated levels of liver enzymes. In some cases, it may take months for a patient's liver to fully recover; therefore, rechecking blood work and/or performing ultrasonography can help monitor response to treatment. Occasionally, a patient may be readmitted to the hospital if its condition worsens. Technicians should educate owners about signs that a pet's condition has worsened; for example, owners can be taught to look for signs of jaundice by checking the color of the patient's mucous membranes and sclera. If the pet becomes lethargic, develops anorexia, begins vomiting, develops diarrhea, or exhibits worsening jaundice, the owner should ensure that the pet receives immediate medical attention.

Prognosis

Depending on the underlying cause of liver disease, some patients may recover quickly. Within 24 hours, a patient's condition can

change drastically—a patient that is very jaundiced and lethargic can become alert and exhibit no jaundice. However, some patients experience severe complications from liver disease, potentially resulting in a wide variety of sequelae.

Patients with acute liver failure generally have a good prognosis if the disease is diagnosed early and treatment is started immediately.¹⁰ However, patients with chronic liver disease have a variable prognosis. Patients with neoplasia may have a favorable outcome if complete resection is possible and chemotherapy is started early. However, the prognosis is guarded in most patients with hepatic neoplasia.¹⁰

Conclusion

Technicians should know how various liver diseases are diagnosed and treated and should be able to recognize complications in affected patients. If a technician understands the effects of liver disease, he or she can notify the veterinarian about important changes in a patient's condition.

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1. Which of the following is not a main liver enzyme typically measured in patients with liver disease?
 - a. AST
 - b. ALP
 - c. bilirubin
 - d. GGT
2. The direct bilirubin level reflects only the portion of bilirubin that has undergone
 - a. hemolysis.
 - b. deamination.
 - c. conjugation.
 - d. none of the above
3. Albumin is synthesized in the liver and is responsible for maintaining
 - a. coagulation.
 - b. colloid osmotic pressure.
 - c. production of RBCs.
 - d. production of bile.
4. A trace amount of _____ is not typically found in a cat's urine.
 - a. bilirubin
 - b. glucose
 - c. granular casts
 - d. protein
5. _____ can be used to diagnose the presence of a liver shunt.
 - a. Radiography
 - b. Ultrasonography
 - c. Serum protein electrophoresis
 - d. Fine-needle aspiration biopsy
6. _____ is a potential complication in cats that are not eating.
 - a. Hepatic lipidosis
 - b. Shock
 - c. Inflammatory disease
 - d. none of the above
7. An important part of managing a patient with liver failure is
 - a. frequently walking the patient.
 - b. providing soft bedding.
 - c. thoroughly evaluating the patient during monitoring.
 - d. none of the above
8. Which fluid can be used to help prevent sodium retention and portal hypertension?
 - a. lactated Ringer solution
 - b. 0.45% sodium chloride
 - c. Normosol-R (Baxter Healthcare)
 - d. hetastarch
9. Which of the following statements is true regarding patients with acute liver failure?
 - a. Patients can have a good recovery if treatment is started immediately.
 - b. Liver values are always elevated on blood work.
 - c. Patients have a guarded prognosis despite early intervention.
 - d. If the patient is jaundiced, the prognosis is poor.
10. _____ may be administered if a patient develops a coagulopathy.
 - a. Fresh frozen plasma
 - b. Heparin
 - c. Hetastarch
 - d. none of the above