Anatomy/Physiology Review:
The spleen is a hemolymphatic organ that contributes to immune function, platelet synthesis, erythrocyte storage, and removal of senescent erythrocytes. A tough, muscular splenic capsule surrounds the “red pulp” (venous sinuses and mixed cellular tissue) and white pulp (nodular and diffuse lymphoid tissue). The splenic capsule is capable of significant contraction after alpha adrenergic stimulation, causing release of additional erythrocyte mass into the circulation during times of stress. The spleen lies immediately caudal to the stomach, in the superficial leaf of the greater omentum. The head of the spleen lies cranially and is closely associated with the fundus of the stomach on the left side of the abdomen, being attached by a short gastroplenic ligament. The tail of the spleen extends caudally and to the right, although the location of this portion of the spleen can vary significantly in due its greater mobility. Arterial supply to the spleen is from the splenic artery, a branch from the celiac artery (Figure 1). Before reaching the spleen, the splenic artery sends off several arterial branches to the left lobe of the pancreas, which constitute the majority of the blood supply to that area. The splenic vein drains into the gastro-splenic vein, then into the portal vein where blood is processed before returning to the heart.

Although the spleen serves a variety of functions described above, the spleen is not an essential organ in the dog and can be removed without significant consequence to long-term health. A number of benign conditions of the spleen are noticed routinely during abdominal surgery and should not raise concern. These include siderotic plaques (small irregular, off-white deposits on the surface of the spleen that represent iron or calcium deposits), fibrin (areas of previous trauma), and splenosis (small “satellite” spleens in the omentum that arise from previous trauma or as congenital malformation).

Clinical signs/diagnosis:
The most common clinical sign associated with splenic disease is weakness and collapse after rupture of a splenic mass and development of hemoabdomen. Alternatively, splenic pathology may be discovered incidentally on routine physical examination (abdominal palpation of splenomegaly) or during abdominal imaging for other, unrelated signs (e.g. vomiting). Interestingly, clinical signs at presentation are the most effective predictor of splenic malignancy. Up to 70% of dogs that present with hemoabdomen and a splenic mass will have hemangiosarcoma (HSA), an aggressive tumor characterized by rapid metastasis. On the contrary, dogs with splenic masses that are discovered incidentally, without concurrent hemoabdomen, are more likely to have benign lesions (hematoma, hemangioma, leiomyoma). Other predictors of malignancy include concurrent thrombocytopenia, coagulopathy, ventricular arrhythmias, and anemia.

Due to the high metastatic potential of splenic neoplasia, standard diagnostic evaluation in a dog or cat with a splenic mass would include complete blood count, serum biochemistry panel, thoracic radiographs, and abdominal ultrasound. Fine needle aspiration of splenic masses can be helpful in evaluating splenic pathology, but has a relatively low sensitivity (if it does not show cancer, it does not mean that it is not cancer). In dogs with hemoabdomen, a coagulation panel should be performed to rule out a primary coagulopathy causing the hemoabdomen (rodenticide/warfarin) and other causes of hemoabdomen should be considered (trauma,
ruptured hepatic mass, ruptured adrenal mass, etc). Even in dogs with an identified splenic mass, baseline coagulation status should be checked prior to surgery due to the association of splenic neoplasia with DIC. *Electrocardiography* should be considered since ventricular premature complexes are common in dogs with splenic pathology. Some clinicians also advocate *echocardiographic screening* of dogs with splenic masses due to a relatively high incidence of concurrent tumors on the right atrial appendage in dogs with HSA.

**Preoperative care:**

The key to successful preoperative therapy in animals with hemoabdomen is proper fluid resuscitation. The first aspect to fluid therapy is selection of fluid type. Stable dogs with no clinical evidence of hemorrhagic shock and with preoperative PCV > 30% may be resuscitated with standard crystalloid replacement fluids (e.g. Lactated ringer’s, 0.9% NaCl, etc). However, blood loss, hemodilution from fluid therapy and anesthesia will commonly cause PCV to decrease 20% during surgery, so animals with preoperative anemia (PCV< 25%) should ideally be transfused with whole blood or packed RBC’s prior to surgery. The amount of fluid therapy administered is initially determined using formulas for shock therapy (90-100 mLs/kg in dogs and 50-60mLs/kg in cats), but the most important determination of efficacy in fluid therapy is LOOKING AT THE PATIENT. Essentially, fluid therapy is delivered until mucous membranes return to a pink coloration, CRT is <2 seconds, heart rate decreases to <120 in dogs and <180 in cats. If one “dose” of shock fluid therapy does not lead to stabilization, then significant ongoing bleeding is likely to be occurring and emergency surgical intervention may be required despite having an unstable anesthetic candidate.

**Splenectomy:**

Although techniques for partial splenectomy are described in textbooks, there is little justification for performing this procedure in veterinary patients. We have already considered that the spleen is a non-essential organ in veterinary patients and that the primary indication for splenic surgery is neoplasia. Since complete complete splenectomy is no more time consuming or dangerous than partial splenectomy, this procedure should be the standard of care for removal of splenic masses in order to maximize surgical margins during resection.

**Technique:**

Reflecting the hemolymphatic function of this organ, the vessels to the spleen are relatively large (artery 2-4mm, vein 4-6mm diameter) and removal of the spleen is a major exercise in hemostatic technique. A ventral midline laparotomy is performed and hemorrhagic fluid is suctioned from the abdomen to improve visualization. Auto transfusion is contraindicated in animals with suspected neoplasia. In dogs with ruptured splenic masses, it is common to discover a large omental adhesion that prevents access to the splenic pedicle for ligation. In these cases, the omentum is ligated near the adhesion with the spleen and partial omentectomy is performed. Once the splenic pedicle is exposed, vessel ligation is begun at the tail of the spleen. Vessels are smaller, but more numerous at the splenic hylus. Surgeons will typically use an automatic method of hemostasis along the splenic hylus to perform rapid splenectomy (**Figure 2**). The most commonly used device is the LDS™ (Ligate and Divide Stapler), a stapling unit that places a hemostatic clip on either side of the vessel, then cuts between the clips. Other options include the coagulating devices (Harmonic scalpel™ or the Ligasure™), both of which are capable of coagulating splenic vessels in the dog and cat, allowing rapid splenectomy without implantation of any foreign material. Private practitioners that do not have access to this equipment can easily perform splenectomy using simple 3 clamp technique for vascular ligation with suture. When performing hand ligations, it is simpler to place ligatures more proximal on the splenic pedicle (not at the hylus). In this way, fewer ligations are performed, but larger vessels are encountered. The splenic pedicle is divided into 3 large pedicles (short gastric aa, left gastroepiploic a. and splenic a distal to the pancreatic branches) that are each double ligated with monofilament absorbable suture (PDS, Chromic gut, etc) and transected as depicted in **Figure 3**. During this process, the surgeon should identify and preserve the branches to the left lobe of the pancreas, to
avoid devascularizing this organ. After completion of splenectomy, the organ is sectioned and placed in formalin (1:10 ratio) for histopathologic analysis. The abdomen is lavaged with warmed sterile saline and suctioned to remove all remaining fluid. Due to the highly metastatic potential of HSA, glove and instrument change is recommended prior to closure.

Postoperative care:
Monitoring:
Postoperative complications after splenectomy reflect a continuation of preoperative concerns: hemorrhage, DIC, and ventricular arrhythmias. When returning from the operating room, baseline data should include postop PCV, total solids and arterial blood pressure (direct or indirect). A urinary catheter may be placed to monitor urine output as an indirect measure of renal perfusion. Central venous catheters may also be helpful in using central venous pressure to gauge volume status during fluid therapy. A continuous ECG is maintained for at least 24 hours in animals that experienced ventricular arrhythmias before or during anesthesia.

Fluid therapy:
In stable patients undergoing splenectomy, crystalloid fluid therapy is administered at a maintenance rate after surgery until the animal is eating and drinking spontaneously. Animals that have experienced major blood loss and preoperative fluid resuscitation will often be affected by varying degrees of hypoproteinemia and can develop peripheral edema or body cavity effusions with continued crystalloid therapy. In these instances, synthetic colloids (e.g. Hetastarch™) are often used to help meet hydration needs and increase colloid oncotic pressure. Postoperative antibiotics are not required unless specifically indicated by other conditions in the affected patient.

Prognosis:
Prognosis for dogs with benign masses of the spleen (hematomas or leiomyomas) is good to excellent, with no requirement for other specific therapies after splenectomy. On the contrary, animals with hemangiosarcoma have a mean survival of only 2-4 months without ancillary chemotherapy and this time is increased only slightly by using chemotherapeutic drugs. Unfortunately, veterinarians cannot typically distinguish the etiology until biopsies return 3-5 days after surgery is performed. Thus, clients are forced to choose whether or not to pursue surgery using only the “predictors of malignancy” that were previously mentioned (hemoabdomen, thrombocytopenia, anemia). Our role as veterinarians is to provide them with the data so that they may make an informed decision.

Liver Biopsy:
Liver biopsy is indicated in the diagnosis of focal or diffuse conditions of the liver. While ultrasound guided liver biopsy may be performed using a spring operated needle, surgical biopsy is preferred in most cases as it 1) provides a larger volume of tissue to allow culture, histopath and determination of copper levels 2) can allow direct application of hemostatic agents/techniques if
bleeding occurs and 3) can be performed even in cases where the liver is small, under the diaphragm and cannot be safely accessed with percutaneous needle biopsy. Methods of surgical liver biopsy are selected based on the type of disease that is suspected. In animals with diffuse liver disease, suture (a.k.a. guillotine biopsy) is obtained by encircling the tip of a liver lobe with a loop of suture and crushing the liver parenchyma until vessels are compressed. Tissue distal to the suture ligation is cut and divided for histopath and other testing as indicated. Focal liver nodules or masses that are not located at the periphery can be biopsied using a 6-8mm skin biopsy punch. The defect is then filled with a piece of hemostatic gelfoam- a iotable gelatin sponge that provides tamponade and a surface for platelet adherence. A mattress suture can be placed over the gelfoam in cases where continued bleeding occurs.

Liver neoplasia:

Hepatic masses can exist without causing direct clinical signs and are often discovered incidentally on abdominal palpation during physical exam, during abdominal imaging to investigate unrelated signs (e.g. vomiting, etc) or due to detection of elevated liver enzymes on a screening biochemistry panel). In dogs, the most common type of hepatic neoplasia is hepatocellular carcinoma, constituting approximately 50-70% of primary liver masses. While this is a malignant form of neoplasia, masses are most commonly solitary and 70% are located in the left medial or lateral lobes, making them more easily resectable than right-sided masses that can contact the vena cava. Median survival time is up to 4 years (1460 days) if masses are resected surgically. Cholangiocellular carcinomas (22% of primary neoplasias) are more biologically aggressive and 88% of dogs have metastases at the time of diagnosis. In older cats, biliary cystadenomas are a common benign tumor, although they can cause biliary obstruction as they expand. Prognosis is good if surgical resection is performed.

Diagnosis is most typically confirmed by ultrasound examination which also allows evaluation of local lymph nodes. Thoracic radiographs are indicated as part of the staging of hepatic masses, since lung metastasis is possible. Prior to surgery, we typically use advanced imaging (CT) to assess resectability of hepatic masses, with contact or invasion of the vena cava being a negative indicator.