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1. According to the writings of Hippocrates, the function of the human body is governed by a harmonious balance of all of the following humors except which one?
   a) Saliva
   b) Phlegm
   c) Black bile
   d) Yellow bile
   e) Blood

2. During the early history of science, the spleen was perceived to be a component of which body system?
   a) Nervous system
   b) Circulatory system
   c) Digestive system
   d) Endocrine system
   e) Respiratory system

3. The first recorded splenectomy in the United States for splenic injury occurred in which year?
   a) 1788
   b) 1855
   c) 1899
   d) 1816
   e) 1904

4. The spleen first appears as a recognizable organ in which week of fetal life?
   a) 1st week
   b) 22nd week
   c) 37th week
   d) 14th week
   e) 5th week

5. Which structure is adjacent to the lateral surface of the spleen?
   a) Left kidney
   b) Stomach
   c) Chest wall
   d) Pancreas
   e) Left adrenal gland

6. The gastrosplenic ligament has a triangular shape. The apex of the triangle is in which of the following locations?
   a) Splenic hilum
   b) At the level of the short gastric vessels
   c) In contact with the tail of the pancreas
   d) Adjacent to the splenic flexure of the colon
   e) At the upper border of the left adrenal gland

7. Additional lower pole splenic and gastroepiploic arteries are found in which of the following ligaments?
   a) Splenorenal
   b) Splenophrenic
   c) Pancreaticosplenic
   d) Splenocolic
   e) Gastrosplenic
8. Which of the following statements is true regarding imaging to assist in the diagnostic process for a patient with splenomegaly?
   a) Ultrasound cannot accurately determine spleen size
   b) Positron emission tomography is the most helpful imaging test
   c) Radioscintigraphy of the spleen depends on splenic clearance of radioactive immunoglobulin M antibodies
   d) Multislice computerized tomography can evaluate the spleen as well as intrathoracic and intraabdominal lymph nodes
   e) Barium upper gastrointestinal series images can accurately diagnose splenic involvement with lymphoma

9. All of the following symptoms and signs are observed in patients with postembolization syndrome except which one?
   a) Left back and flank pain
   b) Bloody diarrhea
   c) Fever
   d) Left pleural effusion
   e) Leucocytosis

10. What percentage of splenectomies done in the United States each year is performed for iatrogenic injury?
    a) 40%
    b) 90%
    c) 10%
    d) 1%
    e) 24%

11. The mortality risk for a patient who develops overwhelming postsplenectomy sepsis is which of the following?
    a) 4%
    b) 10%
    c) Up to 50%
    d) 65%
    e) 44%

12. A patient undergoes an abdominal CT scan following a motor vehicle crash. The scan discloses a subcapsular hematoma involving 50% of the spleen surface. What is the injury grade in this patient?
    a) Grade III
    b) Grade I
    c) Grade Iva
    d) Grade V
    e) Grade II

13. The frequency of splenectomy for splenic injury in patients <15 years of age is lowest in which of the following settings?
    a) Urban general hospital nontrauma center
    b) Children's hospital designated as a trauma center
    c) Adult trauma center
    d) Children's unit in adult trauma center
    e) Level IV designated trauma center

14. Which of the following CT imaging findings has been associated with failure of nonoperative therapy for splenic injury?
    a) Gastric distention
    b) Associated hepatic laceration
    c) Renal contusion
    d) Contrast blush in the splenic parenchyma
    e) Pulmonary contusion

15. Which of the following is a risk factor for failure of nonoperative therapy for splenic injury?
    a) Age <15 years
    b) Female gender
    c) Hispanic ethnicity
    d) Fall from standing as mechanism of injury
    e) Age 55 years or more
16. Each of the following is a known risk factor for conversion of laparoscopic to open splenectomy except which one?
   a) Splenic bleeding
   b) Hilar vessel bleeding
   c) Portal hypertension
   d) Hepatomegaly
   e) Massive splenomegaly

17. In patients with hypersplenism due to sickle cell disease, anemia is produced by which of the following mechanisms?
   a) Splenic vein thrombosis
   b) Extramedullary hematopoiesis
   c) Sequestration of deformed red blood cells in the spleen
   d) Splenic infarction
   e) Splenomegaly

18. The risk of portal vein thrombosis following laparoscopic splenectomy is which of the following?
   a) 1%
   b) 88%
   c) 64%
   d) 22.5%
   e) 15%

19. A 9-year-old female with hereditary spherocytosis with easily controlled mild anemia develops symptomatic cholelithiasis. Which of the following is indicated in this patient?
   a) Cholecystostomy
   b) Extracorporeal shock wave lithotripsy
   c) Laparoscopic cholecystectomy
   d) Splenic embolization followed by laparoscopic cholecystectomy
   e) Open cholecystectomy and splenectomy

20. Which of the following is the most common malignant tumor of the spleen?
   a) Hemangiosarcoma
   b) Melanoma
   c) Gastrointestinal stromal tumor
   d) Littoral cell angioma
   e) Embryonal cell sarcoma

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In this issue of Selected Readings in General Surgery (SRGS), we will review articles dealing with surgical diseases involving the spleen. Throughout the history of medicine and science, the spleen has played an important role in scientific and philosophical efforts to define the physiologic and psychologic functions of the abdominal organs. Similarly, during the more than three centuries of progress in surgical approaches to abdominal diseases, the spleen has been a central focus. Today, the most common reason for any spleen-related medical intervention is a blunt force injury. The current gold standard for managing splenic injury consists of various nonoperative approaches for stable patients and immediate splenectomy or splenorrhaphy for patients with clinical evidence of ongoing bleeding. The initial approach is to quickly assess the patient to determine if there is ongoing bleeding that has produced or will lead to hemorrhagic shock. Patients who can be easily stabilized with small volumes of hemostatic resuscitation using whole blood, plasma, and platelets can have splenic CT imaging with arteriography and splenic embolization (based on the severity of injury and, in selected patients, evidence of high-risk lesions such as contrast blush). Areas of continuing debate include patient selection, the timing of angiographic embolization, and the decision to withhold radiographic imaging in children to reduce radiation exposure.

For the sake of a more comprehensive understanding of surgical interventions involving the spleen, we will begin with a history lesson: the first section of the review will feature classic scientific contributions on the function of the spleen and its roles in human physiology. The second section will review a classic article on the surgical anatomy of the spleen.

Laparoscopic splenectomy has become a very common focus of articles—usually retrospective clinical series—and available data will be presented that suggest the safety and effectiveness of this procedure for properly selected patients (and when expertise with minimally invasive surgical approaches is available). The use of total or partial splenectomy to treat benign hematologic disease will be discussed, along with articles that have documented the settings in which splenectomy is an effective treatment for selected benign and malignant hematologic disorders. A section of the review will also be devoted to the epidemiology, diagnosis, and management of splenic artery aneurysm.

The final section of the overview will review articles relevant to miscellaneous disorders of the spleen, including hypersplenism, splenic torsion, and splenosis.
The Spleen in Medical History

As mentioned previously, the spleen has, in many ways, been central to surgical approaches in abdominal disease management. In this first section, we will trace the history of splenic surgery. In particular, we will explore the search for an integrated definition of spleen anatomy and function. This history will be elucidated by relating the progress of surgical approaches to splenic diseases to the progressive increases in splenic physiology understanding.

The first two articles to be discussed are classic contributions by McClusky and co-authors in the *World Journal of Surgery*, 1999.1,2 Both articles are included as full-text reprints accompanying some formats of SRGS. The authors set the stage for their discussion by citing a quotation from Sir Astley Cooper: “Physiological knowledge is of the utmost importance to the profession of Surgery: this gives you knowledge of the healthy functions and thus enables you better to understand the nature of diseased action.” By including this quotation, the authors emphasized the importance of adding scientific knowledge of organ function to the existing understanding of anatomy. They went on to point out that despite this early explanation of surgical understanding, rapid progress in clarifying the physiologic function of the spleen and how this function was integrated with anatomy did not occur until the early twentieth century.

In the first of their two articles, the authors referred to the definition of “spleen” found in *Webster’s Third New International Dictionary*; this term has multiple meanings relating to the assumed role of the organ in governing personality and behavior. These meanings include: the seat of emotions; the source of laughter; violent mirth and merriment; a fit of anger; malice or bad temper; a sudden impulse; a proud, courageous, impetuous temper; latent malevolence or spite; a feeling of ill will; and extreme lowness of spirits described as melancholy or depression. These varied definitions reflected the concepts of the function of the spleen that have been presented in science since antiquity. A quote from McClusky and colleagues is apt: “Few organs, if any, can boast of having such markedly diverse effects. This confluence of malice and anger, impetuousness and malevolence, mirth and depression represented by the spleen effectively symbolizes the nuances and variances that characterize life itself.” Despite the fact that these perceptions of the affirmative nature of the spleen have been prevalent since antiquity, the organ has for much of history been deemed nonessential.

Is the spleen necessary for normal life? This question has recently been answered in the affirmative. Arriving at the answer took time, and this journey can best be understood by analyzing the scientific inquiry of the anatomy and function of the spleen, as well as assessing the evolution of surgical approaches to splenic trauma and disease. McClusky and colleagues pointed out that ancient Greek and Roman physicians understood both the need to unite anatomy and physiology in order to understand organ function and the contributions of organs to the function of the human organism; these ancient scholars stressed the relationship of structure to function. Hippocrates based his views of organ function on the basic philosophy that humans live in harmony with nature. This balance was, in his view, governed by the relative contributions of the four humors: blood, phlegm, black bile, and yellow bile. Hippocrates described veins and arteries, but did not understand circulation. His writings stressed the location and texture of the spleen as being well suited to the absorption of excess fluid. Plato expanded this view and added that the spleen functioned to cleanse the liver. The fact that the spleen does, in fact, filter and cleanse circulating blood was not understood until much later.

In subsequent writings, Aristotle expressed the view that the spleen existed mainly to provide symmetry to the array of internal organs, but was not an essential structure for the normal function of the organism. He felt that the spleen arose from the liver and was “to a certain extent, a matter of necessity in all animals, though not a stringent necessity.”

Structure and function were further emphasized by the careful dissections of Galen. His works focused on the spleen as a digestive organ. Galen believed that the spleen discharged secretions into the stomach via the short gastric vessels and that the relationship of the spleen to the liver and the stomach were crucial for the internal “balance” that led to normal function.
Renaissance scientists introduced the notion that the spleen was a storehouse for blood and complemented the liver in this function. McClusky and colleagues observed that the presence of splenomegaly in the setting of a shrunken liver (such as might occur with cirrhosis) was interpreted as an example of the spleen taking over the blood manufacturing function of the liver. Andreas Vesalius’ writings provided an example of careful anatomic dissections that refuted Galen’s findings; unfortunately, Vesalius misinterpreted the anatomy of the mesenteric circulation and perpetuated the view of the spleen as a digestive organ. A helpful quote from Vesalius’ book of medical student instruction, *Epitome*, is cited by McClusky and coauthors: “We believe the spleen draws to itself the thicker refuse of the liver and converts it into nourishment for itself and whatever it cannot assimilate, it throws up into the stomach.” Vesalius effectively took the qualitative, deductive, and vitalistic science of anatomy to its limits and his work set the stage for the dawn of the inductive approach to scientific research that characterized the work of Bacon, Galileo, Kepler, Newton, and Harvey. As a result, many misconceptions concerning the spleen, its relationship to the liver and the digestive tract, and the importance of the circulatory system were clarified. The new mantra of science, as noted by McClusky and coauthors, became “quantification and mechanization.”

The description of the circulation by Harvey incited the intravascular injection studies of the spleen by Highmore in 1651 and Glisson in 1654; these two works refuted the notion of the spleen as a digestive organ. Near in time to these discoveries were the works of microscopic anatomists who described the red and white pulp of the spleen and the adjacent splenic sinuses. The interpretation of these observations by Malpighi, the most influential of the microscopists, was that the spleen was a gland that secreted fluids into the circulation via the sinuses. The secreted substance was thought to facilitate the liver’s production of bile. Of interest is the fact that both Malpighi and Glisson performed splenectomy on dogs with full recovery and apparent normal function of the animals; these observations led to the conclusion that the spleen was disposable. In fact, a notion held since antiquity was that the absence of the spleen was beneficial. McClusky pointed out that Pliny (AD 23–79) wrote that runners cauterized the upper left abdomen with hot irons to reduce the size and function of the spleen and improve foot speed. He also cited the interesting fact that, in 1922, two American investigators reported that races between splenectomized and nonsplenectomized rats were most often won by the splenectomized animals.

According to McClusky, medical writings in the 16th century suggested that splenectomies might favorably influence or cure diseases. This concept surfaced after the first splenectomy for massive splenomegaly was performed; the patient, a 23-year-old woman, fully recovered. What was peculiar about this and subsequent reports of splenectomies performed for trauma and disease was the scanty nature of descriptive material and that all of the patients survived the procedure. This suggests that the trait of reporting only favorable results was passed to modern surgeons from the ancients.

The first American splenectomy occurred in 1816. The patient was a rapist who was stabbed by his victim in the left flank, with herniation of the spleen through the wound. The patient survived. Contrasting results were reported in 1826, when a patient had a splenectomy for splenomegaly associated with portal hypertension, ascites, and anasarca. The patient died, and at autopsy, a portion of the pancreas was found in the splenic ligature. The first splenectomy under general anesthesia was done in 1864 by Wells. The patient died, and Wells cautioned that a splenectomy should not be done for disease, but only for “trauma or obstruction” when death of the patient was virtually certain without intervention. In his lengthy discussion of the subject, Wells did opine that the spleen might be removed to treat leukemia when the spleen was the source of excess white blood cells.

McClusky and coauthors noted that the notion of the spleen as a lymphatic organ was promulgated by the observations of Von Kolliker, who confirmed that phagocytic cells within the splenic pulp contained senescent erythrocytes. The spleen was likened to a large confluence of groups of white corpuscles, such as might be found in Peyer’s patches in the intestinal tract; Billroth later produced data supporting this concept. Virchow described leukemia and hypothesized that the spleen was the site of white blood cell production in this disease. He described the lymph nodes’ involvement as well. As noted
earlier, Wells wrote that removing the spleen might stop the excess production of white cells and benefit leukemia patients; however, splenectomy for leukemia was often followed by patient death.

McClusky reported that Bryant carefully analyzed his experience with splenectomy for leukemia and concluded that leukemia was a systemic disease and that splenectomy was not likely to cure it. This evolution of scholarly thought, led by surgeons, was an important juncture in the development of surgery as an area of scientific medical practice based not on the fact that an operation was possible, but that the operation must be safe and be shown by careful scientific analysis to correct the underlying problem. This type of reasoning led to the use of splenectomy for thrombocytopenia (autoimmune thrombocytopenia or ITP), which met with much more success than splenectomy for leukemia (splenectomy’s role in managing hematologic diseases will be discussed later in the review).

The second of the two-part series of articles by McClusky and coauthors emphasized the limitations of medical knowledge about the spleen as the 20th century opened. These limitations were reflected in comments from Sir William Osler and Dr. William Mayo, both cited in the article: the renowned physician and equally famous surgeon recognized the function of the spleen in processing senescent erythrocytes and both suspected that the spleen had a role in immune function. The sentiment that the injured spleen should be removed persisted, and this perspective was bolstered by two fears: that leaving a bleeding spleen would cause patient death, and that splenic injury treated without splenectomy exposed patients to the risk of a “delayed rupture.” This debate continued, awaiting further advancements in scientific and surgical knowledge about the spleen.

McClusky and colleagues noted that in the early 20th century, as the surgical anatomy of the spleen was defined in greater detail, the technical aspects of splenectomy were refined—in 1937, Dinsmore observed that the thin nature of the splenic capsule, combined with the presence of ligamentous attachments and adhesions, facilitates the entry of the surgeon’s bluntly dissecting fingers into the splenic parenchyma. This lesson is valuable for modern splenic surgeons as well.

Additional anatomic knowledge delineated the segmental nature of the splenic body, defined by the distribution of the branches of the splenic artery. Simultaneously, research clarified the spleen’s role in the immune response to cholera and Salmonella sp. infections; Morris and Bullock subsequently demonstrated the susceptibility of splenectomized rats to the rat plague microorganism. These investigators offered the prescient opinion: “…it is not improbable that the human body deprived of its spleen shows a similar increased susceptibility to infection. Bearing this in mind, some of the fatalities following splenectomy, especially where death was attributed to infection, may find a ready explanation and tend to increase our caution in the removal of this organ.”

While this prediction was controversial, confirmatory evidence was provided in 1929 when the septic deaths of two members of a single family after splenectomy for hemolytic anemia were reported. Subsequent work defined the roles of the spleen in the facilitation of opsonization, the production of immune globulins, and the processing of liquid and particulate antigen within the pulp and sinusoids.

Overwhelming postsplenectomy infection (OPSI) is an infrequent complication associated with a high mortality rate (greater than 30%) and a rapidly progressive clinical course, thus making treatment difficult. McClusky and colleagues stated that the seminal article by King and Shumakerer describing OPSI stimulated surgeons to approach splenectomy for all indications, including trauma, with caution. Canadian surgeons led the effort to use nonoperative therapy for splenic injury in children and many successes were reported. Acceptance of these data was hindered by concern that, because of a lack of precision in diagnosing splenic injury, some of these children were misdiagnosed and did not have splenic injury. Introduction of CT scanning into initial trauma management protocols for children and adults provided data confirming that, if anything, splenic injury was being under-diagnosed rather than over-diagnosed. Excellent pediatric surgeons and general surgeons practiced nonoperative therapy for patients with splenic injury after experience taught them that many patients operated on for splenic injuries had minor injuries that were not bleeding and that, under observation, delayed bleeding was rare. This set of observations is not without precedent.
in surgical history. McClusky and colleagues noted that Billroth reported an autopsy of a patient with a history of remote trauma that demonstrated a healed laceration of the spleen. Samuel Gross, in the 1882 edition of his famous surgical text, suggested a protocol for nonoperative management of splenic injury.

According to McClusky and coauthors, recognizing the segmented nature of the spleen’s anatomy and blood supply led to the concept of partial splenectomy and splenorrhaphy as a means of preserving splenic mass. The validity of this approach was not without historic precedent; Pean reported on it in the 19th century. The potential value of partial splenectomy was also supported by the careful report of eight patients treated successfully by Christo in 1962.

The various segments of the spleen are separated by relatively avascular planes, but the segmental artery branches are not end arteries. This means that bleeding from the cut surface of the spleen will be troublesome. The development of dependable topical hemostatic agents has made open and laparoscopic partial splenectomy safer. These successes and this knowledge paved the way for the application of laparoscopic partial splenectomy, as well as angio-embolization, as a means of splenic preservation in trauma patients and in patients with hypersplenism.

McClusky and colleagues concluded with the observation that the occurrence of splenosis after splenectomy in some patients suggests that implanting splenic tissue may protect against infection. This has not been definitively established to date, but contemporary research (discussed later in the overview) has produced data that support at least a partial return of immune function in patients with regenerated splenic tissue implanted at the time of splenectomy.

Surgical Anatomy of the Spleen

This section will begin with a discussion of a classic article by Skandalakis and coauthors in Surgical Clinics of North America, 1993. This article is supplied as a full-text reprint accompanying some formats of SRGS. The authors began by reviewing the embryology of the spleen. The spleen is derived from the mesoderm and is formed from mesenchymal cells. The initial location of the spleen is between the leaflets of the dorsal mesogastrium. There is some participation in early splenic development by coelomic epithelium of the dorsal mesentery. The spleen first appears during the fifth week of fetal life; blood vessels are visible by the ninth week. Lymphocytes begin to populate the splenic parenchyma by the fourth month of gestation. The spleen assumes its left sided position when the fetus is six millimeters in length. Recognizable splenic sinusoids appear at a fetal length of eleven millimeters. Immunoglobulin is expressed on the surfaces of resident B lymphocytes and erythrocyte rosette forming T cells are present during the thirteenth week of fetal life. The cells that mediate important immune functions are located in the primitive sinusoids. Early in fetal development, the sinuses are not lined by endothelial cells, but are in communication with blood vessels.

Immunoglobulin synthetic function of the spleen is, as Skandalakis and coauthors pointed out, a subject of some controversy. They cited authors who provided evidence that IgM and IgG antibodies are produced during the third trimester of fetal development, while IgA and IgE are not synthesized. The review provided an algorithm for remembering the weight, dimensions, and location of the spleen using the odd numbers 1, 3, 5, 7, 9, and 11. The size of the spleen is 1x3x5 inches and the weight is usually 7 ounces. The chest wall adjacent to the spleen is occupied by ribs 9–11. Obviously, these relationships can change as spleen size changes. The full range of spleen weights, considering both healthy and diseased states, may be from one ounce to 20 pounds. While the long axis of the spleen runs parallel to the tenth rib, according to the authors, enlargement of the spleen causes the organ to extend below the costal margin. Under normal circumstances, spleen size may increase after meals and with an increase in blood pressure. Skandalakis and coauthors noted that the lymphoid tissue in the spleen begins to diminish at age 10, and that there is a reduction in spleen size after age 60. Splenic disease, body weight, age, and the amount of blood contained within the organ all contribute to spleen size.
Skandalakis and colleagues next discussed the various shapes the spleen may take. They cited work presenting a two-part concept of spleen shape: in the first, there are three general shapes: wedge-shaped (44% of subjects), tetrahedral (42% of subjects), and triangular (14% of subjects); in the second form, the notched spleen, has multiple small arteries that enter the hilum of the spleen, while the second form, the notched spleen, has multiple small arteries that enter the spleen via a relatively large hilum.

A recent article by Zheng and coauthors8 reported a study of the anatomy of the splenic arteries using data from imaging and direct intraoperative observation. The authors reported data from 317 patients and identified two patterns of splenic arterial anatomy. In one pattern, termed the concentrated pattern, the arteries divided into multiple branches less than two cm from the splenic hilum. In the second pattern, termed the distributed pattern, branching occurred more than two cm from the splenic hilum and there were usually two major branches that proceeded from the bifurcation; additional branches formed as the hilum was reached.

Anatomic descriptions by Skandalakis and coauthors noted that the spleen is surrounded in the left hypochondrium by the diaphragm above and posterolaterally, the stomach medially and anterolaterally, the left adrenal gland and left kidney posterolaterally, the phrenicocolic, and pancreatic-colic ligaments. These final ligaments are termed the “minor ligaments.” Variations in the length, width, and fusion status of the ligaments can occur, which may cause problems during abdominal operations. These variations may also contribute to ptosis of the spleen, splenic torsion, and wandering spleen.

The review also described the embryology and the anatomy of each of the ligaments. The gastrosplenic ligament is formed in the shape of a triangle with the apex of the triangle at the level of the short gastric vessels where the greater curvature of the stomach and the upper pole of the spleen are opposed. At the lower pole of the spleen (at the base of the triangle), the distance between the greater curvature of the stomach and the spleen is five to seven cm. Skandalakis pointed out that short gastric vessels and the gastroepiploic vessels are contained in this ligament. The splenorenal ligament is formed by the posterior dorsal mesogastrium and envelopes the splenic vessels as well as the tail of the pancreas. The outer layer of this ligament fuses with the posterior layer of the gastrosplenic ligament.

The splenophrenic ligament may be a portion of the gastroplenic ligament, according to Skandalakis. The extension of the gastroplenic ligament to the diaphragm may complicate perisplenic dissection. The splenocolic ligament is probably a remnant of the transverse mesocolon that became attached to the spleen during the fusion of the colon to the dorsal body wall. Occasionally, a lower pole splenic artery or a curved gastroepiploic artery may be contained in this ligament. Skandalakis explained that the pancreaticosplenic ligament is a cord-like structure extending from the tail of the pancreas to the spleen. It is recognizable if the tail of the pancreas does not touch the spleen. The phrenicocolic ligament is formed from the left end of the transverse mesocolon. This ligament anchors the splenic flexure and as the spleen grows and descends, the lower pole rests in a pocket formed by this portion of the transverse mesocolon. Skandalakis stressed that this ligament serves to retain fluid and blood in the perisplenic space. This structure is not duplicated on the right side of the body.

The authors stated that the splenic artery arises from the celiac trunk in 82–86% of specimens. The splenic artery is subject to many variations and is the most unpredictable of the branches of the celiac trunk. This artery is closely associated with the pancreas and may be above, behind, in front of, or contained within the pancreatic parenchyma. The termination of the splenic artery is likewise unpredictable; branches of the splenic artery supply the pancreas. This fact is important in understanding the anatomic basis of angiographic interventions for splenic trauma and disease.
The hilum of the spleen may contain a variable number of splenic artery branches and the splenic artery may give rise to branches that supply the kidneys and the adrenal glands. The venous drainage of the spleen is formed from branches that arise from the splenic parenchyma, from the left gastroepiploic vein, and, occasionally, from a branch of one or more short gastric veins. The relationship of the splenic vein and the splenic artery is variable. In more than half of specimens, the splenic artery is posterior to the vein. Lymphatic channels and lymph nodes can be found in the splenic hilum and along the course of the splenic vessels parallel to the superior border of the pancreas.

Skandalakis and coauthors said that corrosion casts of the spleen have shown that the spleen is divided into superior and inferior segments in 84% of specimens, and into superior, middle, and inferior segments in 16% of specimens. These segments are separated by relatively avascular planes. Experience with partial splenectomy has shown that the spleen, like the liver, is subject to bleeding from the cut edges of the organ and various topical hemostatic strategies may be necessary to control this bleeding. The clinical corollary to this concept is that partial splenectomy, in the setting of trauma or disease, is probably not safe in the coagulopathic or anticoagulated patient.

Skandalakis and colleagues observed that the planes of separation of adjacent splenic lobes pass entirely through the spleen in a relatively transverse direction, while the planes separating segments course obliquely through the spleen. The splenic arteries course through the spleen in the planes between segments. Injection studies cited by the authors have shown that there are anastomoses between segmental arteries in 30% of specimens. Cited research analyzed splenic arterial distribution in 66 full-term infants. This analysis disclosed multiple arterial supplies to splenic lobes in 68% of dissections. As noted earlier, splenic segmental arteries are not end arteries, and this concept has important implications for surgeons intending to perform partial splenectomy as well as for the angiographic management of trauma and splenic disease. Venous drainage is divided segmentally in parallel with the arterial supply.

Management of Diseases Involving the Spleen

The spleen may be involved in a variety of systemic diseases, usually involving benign or malignant hematologic conditions or hyperfunction of the spleen secondary to hepatic cirrhosis; primary splenic conditions such as splenic cysts and primary splenic neoplasms may also present with splenomegaly, abdominal pain, and splenic rupture. In this section, articles on these processes will be discussed, beginning with a review of diagnostic approaches that are useful when evaluating patients with splenomegaly.

Diagnostic Evaluation of Patients with Splenomegaly

Splenomegaly may present in patients with infections (mononucleosis, HIV) and with hematologic malignancies. In each instance, the basic approaches to the clinical evaluation are similar.

The article that forms the basis of our discussion on diagnosing splenomegaly was by Iannito and Tropodo in *Blood*, 2011. The authors stated that clinical history, physical examination, and basic laboratory work are useful for confirming the presence of splenomegaly, associated hepatomegaly, and enlarged lymph nodes. Splenomegaly accompanied by enlarged lymph nodes suggests, but does not confirm, hematologic malignancy. Similar findings can be discovered in patients with mononucleosis. More detailed information can be obtained by analyzing bone marrow aspirates; bone marrow examination usually follows diagnostic imaging. Iannitto and Tropodo noted that the most useful primary imaging study is abdominal ultrasonography. Ultrasonography can quantify spleen size and provide useful suggestive information based on the discovery of intrasplenic focal lesions. The authors emphasized that diffuse effacement of the spleen on ultrasound is not associated with sufficient sensitivity to accurately document a single cause for splenomegaly. Multidetector CT imaging is valuable for documenting abnormalities of the liver and spleen as well as the intraabdominal and
intrathoracic lymph nodes. The authors pointed out that positron emission tomography (PET) is rarely helpful as a diagnostic tool.

Indications for Splenectomy

Available data confirm that nontrauma splenectomy is usually performed for congenital hematologic diseases and sickle cell disease in younger patients. As the population of the United States ages, however, information on the indications and outcomes for nontrauma splenectomy in older adults becomes important. Frasier and coauthors provided perspective on this issue in the International Journal of Hematology, 2013. These authors report outcomes for 50 patients seen in a single center over a 10-year interval. The most common reasons for splenectomy were thrombocytopenic purpura (TTP) and lymphoma involving the spleen or necessitating splenectomy for staging purposes (Hodgkin disease). A variety of diagnoses were present in 46% of patients who did not have TTP or lymphoma. These included hematologic malignancies as well as primary and metastatic tumors of the spleen. Comorbid conditions in this patient group were typical of older surgical patients and included cardiovascular disease, diabetes, osteoporosis, and renal insufficiency. The authors indicated that associated conditions such as osteoporosis might preclude the medical management of hematologic disease and necessitate early splenectomy. They also pointed out that older patients with splenomegaly may experience difficulties with mobility and nutrition related to the enlarged spleen; this group may also benefit from early splenectomy. Laparoscopic splenectomy was attempted in 54% of this patient group and conversion to an open procedure was necessary in nearly half of these patients. Data on the use of hand-assisted approaches were not reported. Overall mortality during the first six months postoperatively was 10% and complications occurred in 32% of patients. All deaths occurred in patients with malignant disease. The most serious complications were infections (UTI, pneumonia) that occurred in 10 patients and wound complications (ascitic leak, dehiscence) that were observed in two patients. An association was found between overall hospital length of stay and postoperative mortality. The authors noted that this observation suggests that the shorter length of stay associated with laparoscopic splenectomy might be particularly beneficial for older patients. Data analysis led to the conclusions that successful splenectomy in older patients carries significant benefits, but that mortality and morbidity risks are significant as well.

Data has confirmed improved outcomes for procedures such as pancreaticoduodenectomy and esophagectomy that are performed in high-volume institutions; these findings have stimulated interest in regionalization for managing complex surgical problems. Perspectives on outcomes of nontrauma splenectomies in low- and high-volume institutions was presented in an article by Zemylak and coauthors in Surgical Endoscopy, 2014. The authors analyzed data from the National Inpatient Sample (NIS) for two 10-year intervals (1989–1999 and 2000–2010). When the two intervals were compared, there was a significant decrease in nontrauma splenectomy procedures in the second decade. Despite this decrease, the distribution of procedures in low-, medium-, and high-volume institutions was not significantly different in the two decades. Operative mortality was not significantly different, but postoperative complication rates decreased with increasing caseload volume. The analysis also showed that low-volume centers had an increased proportion of emergency admissions for splenic diseases and cared for patients with higher numbers of comorbid conditions compared to high-volume centers; due to this, the difference in rates of complications could not be shown to be causally related to caseload volume. The authors concluded that the evidence did not support a potential benefit of regionalization for managing nontrauma conditions that require splenectomy.

A clinical practice guideline regarding caring for patients with splenic disease has been developed by the Society for Surgery of the Alimentary Tract (SSAT). The guideline was published in the Journal of Gastrointestinal Surgery, 2005 and is available for free from the SSAT web site. This document stated that major changes have occurred in management approaches to splenic injuries and diseases in the past 15 years. These changes have been driven by advances in technology and an increasing understanding of splenic function, as well as the short- and long-term complications of splenectomy—especially splenectomies in children. The most feared complication of splenectomy is OPSI. Splenectomy complications, including OPSI, will be discussed in a later section.
The SSAT guideline confirms that mortality risk for elective splenectomy is less than 1% overall. Patients at an increased mortality risk include patients with advanced malignancy who require splenectomy for severe symptoms due to massive splenomegaly. For patients undergoing elective splenectomy for certain diseases (such as hereditary spherocytosis) and for some patients with splenomegaly, laparoscopic splenectomy using hand-assisted techniques (as needed), is usually successful. Successful laparoscopic total or partial splenectomy is facilitated by the surgical team’s complete understanding of spleen anatomy and the attachments to the spleen of such structures as the colon mesentery at the level of the splenic flexure. This knowledge will assist the surgeon in avoiding traction on the spleen from retractors or hand manipulation of the organ. The SSAT guideline emphasized the use of topical hemostatic agents in candidates for partial splenectomy or splenorrhaphy; also recommended were electrocautery, the argon beam coagulator, and suture plication to avoid bleeding necessitating total splenectomy.

**Laparoscopic Splenectomy**

Available data support the conclusions that open splenectomy is effective and safe in managing nontrauma splenic disease/splenomegaly, but that the procedure is associated with significant mortality and morbidity risks, as well as an extended period of reduced quality of life postoperatively. Mortality and morbidity risks are primarily related to the severity of the basic disease process, patient comorbidities, and spleen size. The possibility that laparoscopic splenectomy could reduce the interval of disability has led to the widespread adoption of this procedure for managing nontrauma splenic disease/splenomegaly. Papers reviewed in this section will provide information on important technical features and outcomes of laparoscopic splenectomy.

The first article reviewed was by Corcione and co-authors' in *Surgical Endoscopy*, 2012. This article is included as a full-text reprint accompanying some formats of SRGS. The authors reported a retrospective review of medical records from a single institution over an 18-year interval. Three hundred patients were included in the case series. Laparoscopic splenectomy was completed in all patients and the diseases for which splenectomy was performed were mainly benign hematologic conditions. In the first 92 patients, an anterior operative approach was used, with the patient in the supine position and trocars placed in the umbilicus and in the right and left upper abdomen. In the 208 patients operated upon later in the study interval, the authors converted to a lateral approach, with two 12-mm and two 5-mm trocars placed in the left, middle, and upper abdomen.

Corcione and coauthors emphasized the importance of an initial careful search for accessory spleens. The effectiveness of the laparoscopic approach in locating accessory spleens was the focus of a study reported by Koshenkov and coauthors in the *Journal of the Society of Laparoendoscopic Surgeons*, 2012. The authors reported a comparison of computerized tomography (CT) imaging with intraoperative visual identification of accessory spleens in 75 adult patients who underwent laparoscopic splenectomy for benign and malignant hematologic diseases. The analysis showed that laparoscopic exploration identified accessory spleens in 15 patients, while preoperative CT imaging identified two accessory spleens. The diseases of nine patients recurred after splenectomy, but none of these recurrences were caused by a retained accessory spleen. The authors concluded that laparoscopic exploration prior to beginning splenectomy is the most effective means of identifying accessory spleens.

In their data analysis, Corcione and coauthors compared outcomes of the anterior and lateral laparoscopic approaches. They determined that the lateral approach was associated with less blood loss and shorter durations of operation. Conversion to an open approach was necessary in 2.2% of patients undergoing the anterior approach, but in none of the lateral approach patients. While there were fewer postoperative complications observed in the lateral approach group, the fact that the anterior approach was used early in the authors’ experiences may mean that they were involved in a learning curve for laparoscopic splenectomy. Overall mortality was low (0.3%); all deaths occurred in patients operated on for malignant disease.

In describing their technique, Corcione and colleagues recommended early identification of the splenic artery above the tail of the pancreas with control and division of the artery in order to reduce spleen volume and make later dissection and division of the splenic vein less difficult. An article that compared outcomes of division...
of the splenic artery above the tail of the pancreas (primary pedicle dissection) with identification and division of arterial branches within the splenic hilum (secondary pedicle dissection) was by Yan and coauthors\(^{15}\) in the *Journal of the American College of Surgeons*, 2013. The article was a retrospective review of registries maintained in two hospitals. Massive splenomegaly was present in 34 patients. The spleens of the remaining patients were either normal or moderately enlarged; for patients in this group, data analysis showed that secondary pedicle dissection was associated with a lower risk of pancreatic fistula and postoperative fever compared with primary pedicle dissection. For patients with massive splenomegaly, primary dissection was associated with less blood loss and a lower risk of conversion to open splenectomy compared with secondary dissection. The authors emphasized that secondary splenic pedicle dissection permits identification and control of the hilar vessels at a distance from the tail of the pancreas. This may help explain the lower risk of pancreatic fistula in patients with smaller spleens; that said, this benefit is offset by the higher volume of blood loss in patients with massive splenomegaly.

Another article that reported experience with laparoscopic splenectomy was by Wang and coauthors\(^{16}\) in *Surgical Endoscopy*, 2013. The authors reported a retrospective review of medical records of patients operated on by a single surgeon over a nine-year interval. The analysis included 302 patients. Benign hematologic disease was the reason for splenectomy in 196 patients, 42 patients had malignant disease (Hodgkin disease in all patients), and 64 patients underwent splenectomy for portal hypertension-related hypersplenism. The lateral abdominal approach was used in all patients. Dissection and control of the splenic pedicle was achieved after full mobilization of the spleen and division of vessels as close to the splenic tissue as possible. Overall mortality was 0.6% and postoperative complications were observed in 23% of patients. Major complications included pancreatic leak, pleural effusion, and need for reoperation. Major complications were observed in 4% of patients with benign hematologic disease, 17% of patients with malignant disease, and 22% of patients with portal hypertension. Complication risks were related to malignant disease and portal hypertension, and were observed most often in patients who had higher ASA scores. The authors concluded that laparoscopic splenectomy is safe and effective. Larger spleens could be managed with hand-assisted techniques, and were removed via a suprapubic incision in a bag container, with morcellation used for spleens with benign disease. Spleens removed for malignant disease were sealed in a bag container and extracted through the suprapubic incision.

Another article that provided data on the use of laparoscopic splenectomy for patients with splenomegaly was by Nyilas and coauthors\(^{17}\) in the *Journal of Laparoendoscopic and Advanced Surgical Techniques*, 2015. This retrospective study compared outcomes based on spleen weight. Splenomegaly was defined as spleen weight >350 gm and massive splenomegaly was defined as spleen weight >1000 gm. Experience with 22 patients who had splenomegaly or massive splenomegaly were reported. Analysis showed no perioperative mortality. Conversion to an open procedure occurred in 5% of patients with splenomegaly and in 11.1% of patients with massive splenomegaly. In all patients with enlarged spleens, the resected organ was removed via a suprapubic incision. Recovery (as measured by hospital length of stay and return of bowel function) was equivalent for patients with normal-sized spleens and patients with enlarged spleens. The authors concluded that laparoscopic splenectomy is an acceptable approach for patients with splenomegaly.

Although available data support the conclusion that laparoscopic splenectomy is associated with lower hospital lengths of stay, lower overall morbidity, and faster recovery times, data directly comparing open and laparoscopic splenectomy are scarce. An article that attempted to compare these particular outcomes by analyzing data from a national risk adjusted database (NSQIP) and using multiple regression statistical techniques to adjust for confounding variables that might introduce selection bias was by Ahad and coauthors\(^{18}\) in *Surgical Endoscopy*, 2013. The analysis included data from nearly 2,500 patients who underwent open or laparoscopic splenectomy for nontrauma indications. After applying the statistical techniques, the data showed that mortality risks for the two approaches were equivalent. Laparoscopic splenectomy was also associated with lower morbidity risk compared with open splenectomy. The authors acknowledged that certain confounding variables could not be included in the study because of missing data; these omissions could have influenced their findings. They concluded, however,
that their data suggest an advantage, in terms of better patient outcomes, when successful laparoscopic splenectomy is possible.

Another article that reported a single-institution experience with open (68 patients) and laparoscopic (60 patients) was by Li and coauthors in *Surgical, Laparoscopic, Endoscopic, and Percutaneous Techniques, 2013*. This retrospective analysis was conducted over an interval of 19 years—this extended interval may have influenced outcomes. Nonetheless, the evaluation showed that patients who underwent successful laparoscopic splenectomy had lower morbidity risks and significantly shorter recovery times.

Laparoscopic partial splenectomy has been recommended for patients with localized benign splenic lesions as a means of reducing the risk of postsplenectomy complications. An article that described the technique of partial splenectomy and reported outcomes in 11 patients seen in a single institution over a two-year interval was by Wang and coauthors in *Surgical Endoscopy, 2014*. All patients had localized and benign splenic lesions, which were nonparasitic cysts, hemangiomas, or lymphangiomas. The lateral operative approach was used in all patients. The portion of the spleen containing the lesion was mobilized and the ligaments of the spleen to be retained were left intact. The vessels of the portion of the spleen to be removed were dissected within the splenic hilum and clipped. This produced a clearly defined demarcation line. Ultrasound was used to determine the distance between the lesion and the demarcation line; a 1-cm distance was deemed acceptable. The splenic parenchyma was divided at a point 1 cm inside the demarcation line using an ultrasonic detector. One patient required total splenectomy, but there were no conversions to open procedures; this patient developed postoperative portal vein thrombosis. Data showed no instances of postsplenectomy infection during follow-up intervals extending out to nine years, even though most patients failed to comply with immunization recommendations. De la Villeon and coauthors said this observation suggests that the remaining spleen was functioning to prevent infection. They concluded that laparoscopic partial splenectomy is safe and effective in managing isolated benign splenic lesions.

**Splenectomy Complications**

Splenectomy complications that are encountered intraoperatively and in the perioperative period include bleeding, injury to adjacent structures (colon, diaphragm), and surgical site infection. As stated earlier, the most feared long-term complication of splenectomy is OPSI. OPSI may manifest as septicemia or meningitis. Most infections are caused by *S. pneumoniae, H. influenzae*, or *N. meningitidis*. Fatal infections occur most often in the first two years after splenectomy. Available data confirm a mortality risk of 30% or more associated with OPSI. Recognition of OPSI has stimulated an increased interest in the spleen’s role in regulating immune function. A review article on this topic was by Bronte and Pittet in *Immunity, 2013*. The authors explained that the spleen is the main filter for pathogens and antigens in the bloodstream. Blood that enters the spleen is filtered through the red pulp; circulating organisms and antigens are collected in this area. Exposure of circulating organisms and antigens to various cell populations allows the spleen to initiate events that are important to the development of innate and adaptive immune response. Interactions between organisms, antigens, and immune cells (T and B lymphocytes, dendritic cells, macrophages) occur in the white pulp; these interactions lead to the sequestration of trapped bacteria and the initiation of immune responses. Lipid antigens are processed in the white pulp and in the marginal zone between the red and white pulp by interactions between B cells, T cells, and natural killer cells, resulting in the secretion of various cytokines that comprise the endogenous response to bacterial infection. According to the authors, data suggest that patients who have undergone splenectomy have an increased risk of...
developing chronic diseases such as diabetes and malignancies; similarly, when splenectomy is performed at the time of an operation for cancer, there has been an observed decrease in disease-free and overall survival. Bronte and Pittet stressed, however, that confounding factors such as blood loss and operative complexity may contribute to these increased risks.

Another review article focusing on the role of the spleen in the defense against infection was by Di Sabatino and coauthors in the *Lancet*, 2011. The authors found that experimental and clinical observations beginning early in the 20th century have documented the immune and filtration functions of the spleen. They cited the contributions of Morris and Bullock in describing an increased infection risk in asplenic rodents. King and Shumacker provided a classic publication describing OPSI due to encapsulated organisms in asplenic children. Other studies cited by the authors observed abnormal erythrocytes containing Howell-Jolly bodies in a patient with an atrophic spleen, indicating a loss of splenic filtration function.

The spleen is a large lymphoid organ, but unlike other components of the lymphatic system, the spleen is not directly connected to lymphatic ducts; instead, it is connected to the systemic circulation. This anatomic arrangement facilitates the spleen’s important roles in culling damaged and senescent blood cells and linking the innate and adaptive immune systems. Di Sabatino and associates described the internal anatomy of the spleen and provided a helpful illustration of the splenic anatomy, reproduced as Figure 1. The organ is composed of red pulp, white pulp, and the marginal zone. The white pulp surrounds the arterioles of the splenic artery and is richly populated with lymphocytes. The location of several classes of lymphocytes within the white pulp and marginal zone facilitate phagocytosis and immunoglobulin secretions in response to particulate and soluble antigens presented to the spleen.

Damaged cells are recognized by phagocytes within the spleen. Some types of microorganisms are also recognized and phagocytosed. Encapsulated organisms must be opsonized by intrasplenic Tuftsin and/or properdin in order to be phagocytosed. Deficiency of these opsonins is believed to contribute to susceptibility to OPSI caused by encapsulated organisms such as *S. pneumoniae*. Immunoglobulin M is also required for phagocytosis of encapsulated organisms such as *S. pneumoniae*.

### Figure 1
Anatomy and function of the spleen. Reproduced from Di Sabatino and coauthors with permission

<table>
<thead>
<tr>
<th>Compartments</th>
<th>Histology</th>
<th>Structure</th>
<th>Function</th>
<th>Cell</th>
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<tbody>
<tr>
<td>White pulp</td>
<td>PALS</td>
<td>PALS</td>
<td>Adaptive response (antigen specific) to interaction between antigen-presenting cells (dendritic cells or marginal zone B lymphocytes) and B lymphocytes or T lymphocytes</td>
<td>PALS (T-cell dependent) Small CD4+ T lymphocytes Dendritic cells B lymphocytes Macrophages Plasma cells Follicle (B-cell-dependent) B lymphocytes or plasma cells Dendritic cells</td>
</tr>
<tr>
<td>Marginal zone</td>
<td>Follicle</td>
<td>GC</td>
<td>Innate response (first-line defence, non-antigen specific) characterised by IgM memory B-lymphocyte production of natural antibodies</td>
<td>Resident B lymphocytes Macrophages In transit CD4+ T lymphocytes CD27+ memory B lymphocytes Dendritic cells</td>
</tr>
<tr>
<td>Red pulp</td>
<td>Sinus</td>
<td>Cords</td>
<td>Innate response characterised by activation of macrophages in cords Adaptive response characterised by plasma cell migration from the white pulp after antigen-specific differentiation in follicles Blood filter (pitting, culling)</td>
<td>Cords of Billroth CD8+ T lymphocytes Fibroblasts Macrophages Natural killer cells Sinusoids CD11b+ endothelial cells</td>
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lated organisms. This substance is produced by memory B cells that are located in the spleen. After splenectomy, there is a significant reduction in memory B cells.

Splenectomy is associated with compromised immunity. Patients who require splenectomy have a higher risk of infection compared to non-splenectomized individuals.

In children, the risk of infection is equivalent to adults, but the mortality rate is somewhat higher. Available studies probably underestimate the risk of infection and infection-related death because most of the available data come from studies of the first two to three years after splenectomy. The authors stressed that data documenting OPSI frequencies that occur more than two years after splenectomy are scarce.

Available data show that postsplenectomy infection risk is related to the reason for splenectomy. Infection risk seems to be lowest for splenectomy done for injury and highest in patients with hematologic malignancy and hepatic cirrhosis. Data from a Danish population-based study by Yong and coauthors in the European Journal of Internal Medicine, 2010, confirmed a significant risk of death from infection in splenectomized patients that extends for more than 20 years and is closely related to the reason for splenectomy.

Di Sabatino and coauthors emphasized that OPSI is a fulminant disease in both children and adults. The early symptoms resemble self-limited infections, such as viral upper respiratory infection, but systemic sepsis and shock rapidly progress. Patients frequently enter a terminal phase where rescue is impossible within 12–24 hours. A high index of suspicion and early use of systemic antibiotics and supportive care are critical in vulnerable patients. Once OPSI is suspected, microscopic examination of theuffy coat of a centrifuged peripheral blood sample often discloses microorganisms.

The key element in preventing OPSI in asplenic and hyposplenic patients is prevention through appropriate patient education, vaccination, preventive antibiotic therapy, and vigilance to assure early diagnosis of sepsis symptoms. Patient education efforts include acquainting the patient with the risk of infection and teaching them about minor wound management and the appropriate use of vaccinations and antibiotics. A summary of American guidelines for vaccination and the antibiotic management of patients after splenectomy can be found at www.surgicalcriticalcare.net/guidelines. It is important to remember that patients scheduled to undergo elective splenectomy to treat a disease should be vaccinated preoperatively.

Di Sabatino and associates found that despite the presence of strong evidence regarding the danger of postsplenectomy infection, more than 80% of patients are not aware of their infection risk, and vaccinations occur in fewer than half of the vulnerable patient population. There is, in addition, a lack of consistency in guidelines regarding the use of antibiotics to prevent OPSI in adults and children. British guidelines cited by Di Sabatino and coauthors recommend that children receive preventive antibiotic therapy with amoxicillin (or an alternative if allergic) for life. Most of the American guidelines recommend preventive antibiotic therapy for two years in low-risk patients. All of these guidelines recommend that patients be supplied with emergency doses of antibiotics to be taken at the first onset of symptoms.
Steps to improve compliance with preventive measures for OPSI are needed. Integrated care organizations have the potential to ensure the implementation and effectiveness of these measures. Efforts are also needed to ensure the optimum care of patients who are either anticoagulated or are being treated for chronic diseases such as diabetes and congestive heart failure; the electronic medical record system has the potential to assist in this. An article describing one experience in an integrated care organization was by Gandhi and coauthors in the *New England Journal of Medicine*, 2011. The authors described the case of a patient who suffered OPSI and lost several fingers from Waterhouse-Fredrickson syndrome. Records disclosed that the patient had a splenectomy for trauma 10 years prior to the OPSI infection, but was not vaccinated and did not receive postsplenectomy education. Based on their experience with this case, the authors recommended multiple avenues that are available to improve compliance with postsplenectomy infection prevention measures. These include an accurate problem list, linking operative notes with these problem lists in medical records, making an integrated effort to obtain a complete medical history through team-based care using multiple caregivers, vigorous patient education, and a system-wide integration of checklists and reminders.

Whether or not nonoperative management of splenic injury with or without angioembolization preserves the immune function of the spleen is an important question that continues to be debated. An article that reviews data on splenic function following nonoperative management of spleen injuries was by Skattum and coauthors in the *British Journal of Surgery*, 2012. This article is supplied as a full-text reprint accompanying some formats of SRGS. The authors noted that there are abundant data supporting the fact that splenic filtration function is preserved following nonoperative therapy and that spleen size tends to return to normal after angioembolization with concomitant resumption of filtration function. Cell counts of various lymphocyte populations that are important for immune function return to normal after angioembolization as well. Data cited by the authors support the conclusion that immunoglobulin responses to pneumococcal and *H. influenzae* antigens are normal after nonoperative therapy of splenic injury. Unfortunately, there is no specific marker that would quantify the responsiveness of the spleen to an actual infectious challenge and data on the frequency of OPSI after nonoperative therapy are not available because of the rarity of these events.

Risk of OPSI in a group of splenectomized patients was the focus of an article by Forstner and coauthors in *Vaccine*, 2012. The authors reported long-term outcomes in a group of 145 patients who had undergone splenectomy. All patients had received vaccination after splenectomy. The overall risk of OPSI during the study interval of 13 years was 7%. The most important risk factor for OPSI was a diagnosis of hematologic malignancy. Of interest was the observation that pneumococcal infection was the proven cause of OPSI in four patients and all four survived. Trauma or abdominal surgery was the reason for splenectomy in 29% of patients, but the frequency of OPSI in this subgroup was not reported. The authors concluded that death following splenectomy was most commonly due to the underlying malignant disease and that OPSI risk was associated with the diagnosis of malignancy.

According to other published data, splenectomy can increase the risk of certain chronic diseases. An article that reported 27-year—follow-up data on a group of 8,149 patients who had undergone splenectomy and received their medical care in the Veterans Health Administration (VHA) system was by Kristinsson and coauthors in *Hematologica*, 2014. The authors reviewed medical records over the entire study interval. A cohort of non-splenectomized patients was matched by race and date of birth to determine the risk of developing diseases. The data showed that the splenectomized patients had an increased risk of infections, venous thrombotic events, and several types of solid and hematologic malignancies, including head and neck cancers, esophageal cancer, lung cancer, colon cancer, and pancreatic cancer. The splenectomized patients also had an increased risk of death from any cancer compared with the control cohort. Data on factors that might increase cancer risks, such as tobacco use, were not reported. The authors concluded that their data underscore the importance of vaccination, venous thromboembolism surveillance, and thromboembolism prophylaxis in selected patients who have undergone splenectomy.
An article that examined outcomes data in nearly 5,000 Taiwanese patients who had undergone splenectomy for trauma and nontrauma diagnoses was by Sun and coauthors in the *American Journal of Surgery*, 2015. The authors reviewed information from the Taiwan National Health Insurance Research Database (NHIRD) for the patients in the cohort and adjusted for age, sex, and comorbid conditions. After risk adjustment, the analysis showed that splenectomized patients had an increased risk of gastrointestinal, head and neck, and hematologic cancers. The increased risk was highest in patients who had undergone splenectomy for nontrauma reasons. Data on other malignancy risk factors, including tobacco use and alcoholism, were not reported.

Another investigation that used data from the NHIRD evaluated the effect of splenectomy for trauma on the risk for developing diabetes during a follow-up interval of three years. The article was by Wu and coauthors in the *American Journal of Surgery*, 2014. They determined outcomes in a group of 3,723 patients who had splenectomy for trauma that was matched with 3,723 patients who had abdominal injuries treated without splenectomy. Risk of diabetes was assessed in a second group: patients who had spleen injuries treated nonoperatively compared with abdominal trauma patients who did not undergo spleen injury. The analysis showed that splenectomy doubled the risk of type II diabetes in the three years following splenectomy. Diabetes risk was not elevated in patients whose splenic injuries were managed nonoperatively.

An article that reviewed the common indications for and outcomes of splenectomy for hematologic diseases was by Bickenbach and coauthors in the *British Journal of Surgery*, 2013. The authors opened their discussion by noting that splenectomy is used in patients with hematologic disease to treat thrombocytopenia, anemia, splenomegaly, and to establish a diagnosis (for example, staging of Hodgkin disease). The authors reported outcomes of splenectomy for 381 patients with hematologic diseases seen over a 13-year period in a single center. Open splenectomy was performed in 288 patients and laparoscopic splenectomy in 83 patients. Ten patients required conversion to an open procedure. Operative mortality in this group of patients was 6.3%. Risk factors for mortality were preoperative platelet count <50,000 and low Karnofsky performance score. Complications occurred in 36% of patients and risk factors for complications were age >65 years and low Karnofsky performance score. The most commonly observed complications were infections and portal vein thrombosis. Splenectomy was successful in establishing a diagnosis in 96% of patients; successful primary treatment of a hematologic disease with splenectomy was observed in 89% of patients. Thrombocytopenia and anemia were successfully treated in 66% and 63% of patients, respectively. The authors noted that the patients who underwent splenectomy in order to allow additional treatment with chemotherapy were the most severely ill; many of these patients had received prior chemotherapy. As a group, these patients also had the lowest performance scores and were most likely to have chronic thrombocytopenia; success was achieved in 78% of these patients, despite the severity of their underlying diseases. The authors concluded that splenectomy is useful for managing hematologic disease.

An article that examined data from the NSQIP database to assess outcomes of splenectomy for hematologic diseases was by Bagrodia and coauthors in *JAMA-Surgery*, 2014. The authors were able to identify 1,715 patients who underwent splenectomy over a 6-year interval. Benign hematologic disease was the indication for splenectomy in 78% of patients and malignant disease was diagnosed in the remainder of the patient group. Perioperative mortality was 1.6% and complications occurred in 17% of patients. Risk factors for complications included a diagnosis of malignant disease, low performance status, and hypo-

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**Splenectomy for Hematologic Diseases**

Surgeons may be asked to perform splenectomy in patients with benign hematologic conditions. The most common diseases requiring splenectomy are hereditary spherocytosis, idiopathic thrombocytopenic purpura, and sickle cell disease. Available data support the effectiveness of partial or total splenectomy for treating these diseases. Over the past two decades, laparoscopic splenectomy has become the approach chosen by most surgeons.
albuminemia. Risk factors for mortality included older age and hypoalbuminemia. The data analysis suggested that the mortality risk for a patient older than 65 with hypoalbuminemia was 10%.

In an invited commentary that accompanied this article, Arcelus noted that the analysis by Bagrodia and coauthors may have significantly underestimated mortality and morbidity due to the short follow-up interval (30 days). In addition, there was no separate analysis of outcomes for open and laparoscopic splenectomy. Despite these limitations, Arcelus concluded that this article supplies useful outcomes data.

A meta-analysis of the available literature comparing open and laparoscopic splenectomy for hematologic diseases was by Bai and coauthors in the *World Journal of Surgery*, 2012. The authors were able to identify 38 reports of comparisons between open and laparoscopic splenectomy. The reports described outcomes in 2,914 patients. Mortality risk was equivalent for the two approaches. Complications occurred in significantly fewer patients treated with a laparoscopic approach. Operative time was longer for laparoscopic splenectomy, but hospital lengths of stay were shorter. Similar advantages were seen when laparoscopic splenectomy was performed in patients with massive splenomegaly. The authors concluded that laparoscopic splenectomy is an acceptable alternative for patients with hematologic disease, regardless of spleen size.

**Benign Hematologic Diseases**

Englum and coauthors assessed the outcomes of total and partial splenectomy in patients with hereditary spherocytosis or sickle cell disease in the *Journal of Pediatric Surgery*, 2016. The authors queried a database maintained by a consortium of hospitals and healthcare professionals with an interest in these diseases. A total of 130 pediatric patients were identified; total splenectomy was done in 62% of patients. Patients with hereditary spherocytosis who had total splenectomy improved in all hematologic measures. Improvement also occurred after partial splenectomy, but the degree of improvement was smaller. The authors emphasized that reticulocyte counts tended to return to the subnormal range at six and twelve months postoperatively following an initial increase. The authors also stressed that the decision to perform total rather than partial splenectomy should take into account risks of postsplenectomy infection as well as the potential benefits for patients with hereditary spherocytosis. For patients with sickle cell disease, the analysis showed no improvement in hemoglobin levels after splenectomy. The authors stressed the importance of recognizing that splenectomy in children with sickle cell disease is performed primarily to improve quality of life by reducing the risk of sequestration crises.

An additional perspective on outcomes of splenectomy for patients with benign hematologic diseases was presented in an article by Rodeghiero and coauthors in the *British Journal of Haematology*, 2012. The authors documented the benefits and significant risks of splenectomy for benign hematologic disorders and acknowledged that the most feared risk following total splenectomy is OPSI. They emphasized that even though there are effective preventive treatments for this complication, these measures are used inconsistently in eligible patients.

Splenectomized patients are at an increased risk for venous thromboembolic events. One common thrombotic complication that occurs after splenectomy is portal vein thrombosis. Data cited by Rodeghiero and coauthors provided insight into the pathogenesis of the increased risk of venous thromboembolism. These data confirm that removal of the filtration function of the spleen allows particulate matter and damaged cells to persist in the circulation. Interactions of these cells with the endothelium can induce changes that produce a hypercoagulable state. The data also confirmed that there are increased levels of platelets, leucocytes, and C-reactive protein after splenectomy—these changes could contribute to the hypercoagulable state. Increased levels of circulating hemoglobin permit scavenging of nitric oxide that leads to vasoconstriction and a favorable environment to activate platelets, especially in the pulmonary circulation. Based on an understanding of the risks of splenectomy, the authors recommended that indications for splenectomy be carefully assessed in patients with benign hematologic diseases.

**Hereditary Spherocytosis**

Hereditary spherocytosis is one of the most common disorders treated with splenectomy. An article that reviewed hereditary spherocytosis was by Perrotta and coauthors.
in *Lancet*, 2008. The authors noted that hereditary spherocytosis is the most common inherited erythrocyte membrane disease in patients of Northern European ancestry. The disease is characterized by anemia that is the result of sequestration of deformed erythrocytes in the spleen. Surgical complications include gallstones and the need for splenectomy in patients with moderately severe or severe disease. The erythrocyte membrane disorder results from abnormalities of the erythrocyte membrane proteins spectrin and ankyrin. There are also abnormalities of other membrane components such as Band 3. Most patients with moderately severe or severe disease will have abnormalities of spectrin.

Symptomatic cholelithiasis will develop in many patients, even those with well compensated anemia. Although splenectomy at the time of cholecystectomy has been suggested, it is not recommended in patients with well compensated disease because of the risk of post-splenectomy infection and the potential for increased cardiovascular disease risk.

Hereditary spherocytosis may become overtly symptomatic in early childhood. Because of the infection risk, splenectomy is not recommended before age six, even in patients with severe disease. For very young patients, partial splenectomy, which can be accomplished laparoscopically, may be considered prior to age six, with repeat total splenectomy when splenic regrowth occurs and symptoms return.

**Sickle Cell Sequestration Crises**

Splenectomy is used to treat acute sequestration crises in patients with sickle cell disease. Gokarn and coauthors38 reviewed the safety and effectiveness of this approach in the *Journal of Laparoendoscopic and Advanced Surgical Techniques*, 2014. The authors pointed out that acute sequestration crises can complicate the care of children with sickle cell disease. Although an uncommon event, sequestration crises can occur as early as two years of age and can be life threatening. Data cited by the authors confirmed that mortality for the first episode is 12% and that the recurrence rate is 50%. These crises occur because of the trapping of deformed red blood cells within the spleen, leading to acute increases in spleen size, decreased hemoglobin levels, and increased risk of shock and death.

The authors reported outcomes of 30 patients treated with splenectomy. All procedures were done laparoscopically. Eighteen of the 30 patients were younger than five. There were no postoperative mortalities. Acute chest syndrome (chest pain, dyspnea) occurred in two patients. Over a follow-up interval of more than five years, no episodes of OPSI occurred. The authors concluded that splenectomy effectively prevents recurrent sequestration crises and is safe, even in children younger than five.

Additional data on outcomes of splenectomy for sickle cell sequestration crises were presented in an article by Kalpathi and coauthors39 in *Pediatric Surgery International*, 2010. The authors reported outcomes on 58 patients seen in a single center over a 15-year interval. There was no postoperative mortality, but acute chest syndrome occurred in 7% of patients and vaso-occlusive events were observed in 24% of patients, including stroke in five patients. No episodes of OPSI were observed. The authors concluded that splenectomy is an effective means of preventing sequestration crises, but that long-term complications, such as acute chest syndrome and vaso-occlusive events, are important outcomes that should be discussed with patients and families during the decision-making process prior to operation.

A systematic review of literature that evaluated the support of splenectomy for acute sequestration crises was by Owusu-Ofori and Remmington40 in *Cochrane Database of Systematic Reviews*, 2015. The authors stated that observational studies have provided weak evidence that splenectomy prevents recurrences of sequestration crises. They also argued that there are no randomized trials evaluating long-term outcomes. Available data suggest that splenectomy does not improve survival. Comparisons of splenectomy with other therapies such as transfusion have not been published. The authors concluded that evidence supporting splenectomy is weak.

There is the possibility that partial splenectomy could reduce risk of sequestration crises and potentially offer fewer long-term complications for patients with sickle cell disease and acute sequestration crises. Outcomes in a small group of six patients who were treated with partial splenectomy were reported in an article by Vick and coauthors41 in the *Journal of Pediatric Surgery*, 2009. Open partial splenectomy with preservation of the upper pole of the spleen was possible in all patients. There
were no operative mortalities. Four patients developed pneumonia postoperatively, but no other postoperative infectious episodes were observed over a follow-up interval of four years. No vaso-occlusive events were observed. The analysis showed that there were significant reductions in transfusion requirements postoperatively and no recurrence of sequestration crises was observed. The authors concluded that partial splenectomy is potentially useful for managing patients with sickle cell disease.

**Lymphoma**

Lymphoma is one of the most common malignant hematologic diseases requiring splenectomy for accurate staging or for treatment. In *Blood*, 2011, Iannitto and Tripodo provided information on the diagnosis and management of lymphoma, including the role of splenectomy in selected patients. The authors observed that while clinical presentations of lymphoma were varied, splenomegaly was a common finding. The authors recommended a thorough history and physical examination. Peripheral blood and bone marrow studies will also be necessary. Spleen and liver enlargement will be documented in a significant number of patients. Ultrasound imaging is useful in determining the size of the spleen. CT imaging is used to evaluate nodal involvement in multiple body regions. If imaging, peripheral blood, and bone marrow studies do not provide a definitive diagnosis, splenectomy is recommended. The authors provide a useful algorithm for the diagnosis and management of lymphoma; this is reproduced as Figure 2.

**Primary & Metastatic Splenic Tumors**

The spleen may be the site of primary and metastatic tumors of various types. This section of the review will examine articles on the diagnosis and management of splenic neoplasms that may be encountered in surgical practice.

Santos and coauthors presented outcomes data obtained from a retrospective medical record review, including 94 patients who had been diagnosed with myeloproliferative neoplasm (MPN), in *Leukemia and Lymphoma*, 2014. The indication for splenectomy was massive splenomegaly in all patients. The authors stated that splenomegaly is commonly observed in patients with MPN and is caused by extramedullary hematopoiesis. Splenomegaly can cause debilitating symptoms, including abdominal pain, difficulty moving and walking, early satiety with weight loss, and splenic infarction. The authors acknowledged recent data indicating that treating MPN patients with Janus kinase inhibitors had decreased spleen size. Because of the potential benefit of this drug, the authors evaluated short-term outcomes in patients undergoing splenectomy in order to provide comparative data that could be useful for evaluating the new pharmacologic agent. The data analysis associated splenectomy with improvement in anemia and thrombocytopenia in 47% and 66% of patients, respectively. Operative mortality was 5% and venous thromboembolic events occurred in 16% of patients. Splenectomy was also associated with decreased overall and progression-free survival. The authors concluded that splenectomy may be a useful therapeutic approach for carefully selected patients, but that, overall, splenectomy is associated with worse long-term outcomes.
Another article that presented outcomes data for MPN patients who underwent splenectomy was by Rialon and coauthors in the *Journal of Surgical Oncology*, 2015. This article is supplied as a full-text reprint accompanying some formats of SRGS. These authors reported results of a retrospective case series analysis involving 89 patients who underwent splenectomy over a 17-year interval. The patients were cared for in a single institution. Improvement in symptoms due to splenomegaly was observed in 50% of patients. Thirty-day mortality was 18% and the morbidity rate was 38%, with the most common complications being infection and bleeding; venous thromboembolism was diagnosed in 11% of patients during the postoperative period. Median survival after the operation was less than one year. The authors concluded that splenectomy is effective in improving symptoms, but that risks are significant. They recommended that patients be thoroughly informed of the risks as well as the benefits of splenectomy.

Sileri and coauthors reviewed information relevant to managing patients with metastases to the spleen in the *Southern Medical Journal*, 2009. The authors presented a case of a male patient with a solitary lesion of the spleen five years after colon resection for colon cancer. Splenectomy disclosed the presence of a metastatic focus of colon cancer in the spleen. The authors reviewed data that support the hypothesis that hematogenous spread is the most likely route for development of splenic metastases. This view is supported by the observation that most metastatic lesions are not associated with regional lymphatic metastases. The data cited by the authors showed that most patients with splenic metastases were asymptomatic or had mild abdominal discomfort. Confirmation of the location of lesion was most often accomplished with ultrasound or CT imaging. These images were helpful in excluding additional sites of metastatic disease. The authors noted that positron emission tomography can detect lesions that are too small to be seen on CT or ultrasound and this modality could be helpful in determining the presence of small metastatic lesions. Most data sources suggested that splenectomy was an effective treatment for isolated spleen metastases. Median survival after splenectomy, in the absence of known metastases in other sites, was three years.

Another rare lesion of the spleen is littoral cell angioma; littoral cell angioma may be a precursor of splenic angiosarcoma, a highly lethal disease that few patients survive for more than six to eight months after diagnosis, even with chemotherapy. This lesion may present with symptoms of abdominal pain with splenomegaly or with symptoms and signs of hypersplenism with anemia and thrombocytopenia. The lesion arises from the littoral cells that line the splenic sinuses. Kranzfelder and coauthors described the clinical presentations and offered evidence relevant to the biologic behavior of this neoplasm in the *Journal of Gastrointestinal Surgery*, 2012. The authors presented a case of two siblings: one died of splenic angiosarcoma and the other had a littoral cell angioma. Histologic examination of tissue from both lesions showed deposits of littoral cell angioma in the splenic tissue of the patient who died of splenic angiosarcoma. In their survey of available literature, the authors noted studies supporting a genetic disposition of family clustering of these lesions. They also found that littoral cell adenomas and splenic angiosarcomas present in middle-aged adults with equal frequencies in both genders. Prior studies cited by the authors recommended observation for patients with small littoral cell angiomas; however, based on the evidence from their own study, Kranzfelder and coauthors recommend laparoscopic splenectomy and thorough histologic evaluation of the excised spleen.

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**Hypersplenism Associated with Portal Hypertension**

Portal hypertension may be associated with thrombocytopenia alone or in combination with other cytopenias. Splenectomy has been used alone or in combination with a portal decompression procedure for treating this condition. Open and laparoscopic splenectomy has been used to treat thrombocytopenia, but both of these procedures have been associated with significant risks of intraoperative bleeding, perioperative mortality, and morbidity. Recently, splenic embolization and radiofrequency ablation of the spleen have been used to manage these patients.
Gonsalves and coauthors presented data from a retrospective clinical series of splenic embolization in patients with hypersplenism in Vascular and Interventional Radiology, 2010. They noted a significant limitation to using splenic embolization to manage hypersplenism: the development of postembolization syndrome, which is characterized by abdominal pain, nausea, vomiting, ileus, and anorexia. In this small clinical series, the authors used ethylene vinyl alcohol copolymer as the embolic agent. Platelet counts improved in all patients and this improvement was sufficient to permit chemotherapy for the patients’ underlying disease. Progress was maintained over long-term—follow-up and postembolization syndrome did not occur in this patient group. Data cited by the authors confirmed a reduced risk of postembolization syndrome associated with the use of ethylene vinyl alcohol copolymer.

A randomized trial of splenectomy vs. laparoscopic or percutaneous radiofrequency ablation of the spleen in patients with hypersplenism from hepatic cirrhosis was reported by Feng and coauthors in the British Journal of Surgery, 2011. The results of the trial indicated satisfactory early results of treatment with both splenectomy and radiofrequency ablation of the spleen. Recurrence of hypersplenism was observed at six months after the ablation procedure if less than 50% of splenic mass had been ablated. Recurrence of hypersplenism was common at one year after ablation, but patients usually had sustained blood counts over long-term—follow-up that were higher than the baseline. Durable reversal of hypersplenism was seen in patients who underwent splenectomy, but this was realized at the cost of a 6% mortality risk.

Diagnosis & Management of Spleen Injuries

The nonoperative management of spleen injuries in adults and children is successful and associated with low rates of mortality and morbidity in the vast majority of hemodynamically stable patients. Comparisons of outcomes of care has been greatly facilitated by the development and widespread use of the American Association for the Surgery of Trauma (AAST) spleen injury severity scale. The scale is reproduced as Figure 3. Currently, the main areas of concern are the development of selective approaches for using CT imaging to reduce radiation exposure in injured children, the refinement of indications for angiography and embolization, and the standardization of practices relating to intensive care unit (ICU) admission and stay, intervals of bedrest, and the length of time that activity should be restricted. This section of the review will provide information on current approaches to managing spleen injuries in adults and children. We will also review articles on managing penetrating spleen injuries, splenic injuries in combat casualties, iatrogenic spleen injuries, and spontaneous splenic rupture.

Spleen Injuries in Children

Nonoperative management of isolated spleen injuries in children is the preferred approach, unless the risk of ongoing bleeding (hemodynamic instability) or major associated abdominal organ injury (hollow viscus, pancreas) is
Data have become available that associate care based on multidisciplinary teams and established protocols with improved outcomes. Clinical practice guidelines were proposed by the Trauma Committee of the American Pediatric Surgery Association (APSA) for managing patients with isolated liver and spleen injuries. These guidelines were discussed in an article by Stylianos in the Journal of Pediatric Surgery, 2000. The article documented the variability in practices at different trauma centers. Outcomes in more than 850 patients were reviewed and recommendations based on the rates of successful management were proposed. The final guidelines are reproduced as Figure 4.

The APSA guidelines were applied prospectively in a cohort of more than 300 patients cared for in 16 pediatric trauma centers over a two-year interval. Stylianos presented the outcomes in the Journal of Pediatric Surgery, 2002. The data analysis showed that compliance with guideline recommendations exceeded 80% overall and the compliance rates improved over the interval of the study. No adverse effects on outcomes of care were observed. The authors concluded that compliance with the guidelines is feasible and safe.

Outcomes of care for spleen injuries in children were presented in an article by Wisner and coauthors in the Journal of Trauma and Acute Care Surgery, 2015. The authors reported a secondary analysis of data from a multicenter prospective study. This article is supplied as a full-text reprint accompanying some formats of SRGS. The cohort included 12,044 patients under the age of 18 years who sustained blunt torso trauma. Abdominal solid organ injuries (liver, spleen, kidney) were diagnosed in 5% of patients. Motorized vehicle crashes and vehicle pedestrian collisions were the causes of blunt force trauma in 56% of patients. Falls were the cause of injury in 18% of patients. Spleen injuries were present in 49% of patients. Isolated single-organ injury was present in 69% of patients. Splenectomy was performed in 7.4% of patients and nonoperative therapy was successful in the remaining patients. Patients selected for nonoperative therapy had injury grade quantified and the presence of peritoneal fluid was documented using CT imaging. Angiography was used in 4.6% of patients. All splenectomies and angiographic interventions occurred in patients with grade III or higher injuries. The authors found that current clinical practice guidelines recommend ward observation for patients with grade I or II spleen injuries. Of interest was the observation that 40% of the patients in their cohort who had grade I injuries and 36% of patients with grade II injuries were observed in the ICU. The authors recommended that these findings be used to develop performance improvement interventions. Comparison of splenectomy rates at freestanding children’s hospitals and nonfreestanding children’s hospitals showed lower rates of splenectomy at freestanding children’s hospitals, but this difference was not statistically significant. The authors concluded that the nonoperative management of spleen injuries in children is safe and effective and is the single approach used in the overwhelming majority of injured children.

Lee and coauthors assessed trends in managing pediatric spleen injury based on national registry data in Archives of Surgery, 2012. The authors used data from the NIS and the Kids’ Inpatient Database. Nearly 90,000 patients were admitted for care of spleen injury over an eight-year interval. During the study interval, annual splenectomy rates declined from 18% to 11%. Rates of angiography increased from 2.4% to 7%. The data analysis showed that patients injured in rural areas were more likely to undergo splenectomy. In an invited critique of this article by Aidlen and Luks, data were cited from verified children’s trauma center reports that indicated lower rates of both splenectomy and angiography. The authors suggested that the rates of splenectomy and angiography reported in national databases may reflect a large proportion of management by adult trauma surgeons. Lee and coauthors also encouraged an active exchange...
of information on management protocols and outcomes among adult and pediatric trauma centers so that best practices could be recognized and implemented as widely as possible.

Additional data on outcomes of care for pediatric patients with spleen injuries cared for in a verified pediatric trauma center were presented in an article by Duron and coauthors in the American Surgeon, 2014. The authors presented a retrospective medical record review of 180 patients cared for over a 10-year interval in a single pediatric trauma center. The cohort had equal numbers of isolated and nonisolated spleen injuries. The study interval was divided into three periods to identify trends. The mean injury severity score was 14.7. The data analysis showed that splenectomy rates (1.7%) and angiography rates (0.6%) were significantly below national rates reported in the literature. Rates of transfusion were similar to national data. The authors concluded that the care processes in place at their pediatric trauma center resulted in low splenectomy and transfusion rates.

Data on the variability in compliance with available guidelines for care of children with spleen injuries by general surgeons were presented in an article by Bowman and coauthors in Archives of Surgery, 2010. The authors reported results of a survey that was completed by 375 general surgeons who were Fellows of the American College of Surgeons. In response to questions about the value of practice guidelines, more than 97% of surgeons indicated that practice guidelines were useful. Of interest was that only 18.7% of surgeons were familiar with the recommendations of the APSA and of the Eastern Association for the Surgery of Trauma (EAST) for managing children with spleen injuries; 90% of surgeons who were familiar with the guidelines said they believed the guidelines were valuable. When respondents reviewed these recommendations, they expressed reluctance to consider transfusion before operative intervention and to consider angiography for patients with a contrast blush on CT imaging. The data analysis also showed that rural surgeons were less likely to be familiar with and to use the guidelines. The authors concluded the variability might be explained by a lack of specialized pediatric support services (intensive care capability, interventional radiology) in the various practice locations. They also concluded that focused educational interventions might improve familiarity and compliance with the guidelines.

In an editorial critique that accompanied the article, Colombani agreed that the resources available to general surgeons were the most likely drivers of the variability in guideline compliance. He emphasized that the surgeon caring for the patient will be familiar with the clinical capabilities available in the location where care is being delivered and will have developed care approaches that will be the most likely to succeed.

An article that focused on the variations in managing adolescent patients with abdominal solid organ injuries in managed in pediatric and adult trauma centers was by Matsushima and coauthors in the Journal of Surgical Research, 2013. The authors used data from a statewide trauma system registry. Abdominal solid organ injuries occurred in 1,532 patients over the study interval; spleen injuries were present in 946 patients. The authors found that patients cared for at adult centers were older and had higher injury severity scores. Logistic regression techniques were used to adjust for these factors. After adjustment, the analysis showed that splenic procedures and angiography were more likely to be used in patients admitted to adult trauma centers. The authors were unable to document a negative impact on outcomes based on the use of splenic procedures and angiography. They recommended further studies to determine the impact of admission to adult or pediatric trauma centers on short- and long-term outcomes. Additional studies would also be able to identify best practices that might lead to improved outcomes regardless of the type of trauma center where care is delivered.

The effectiveness of a clinical care pathway for children with spleen injuries based on hemodynamic status, as well as recommendations contained within available guidelines, was assessed and reported on in an article by Dervan and coauthors in the Journal of Trauma and Acute Care Surgery, 2015. The authors reviewed outcomes data on 712 patients with abdominal solid organ injuries (332 spleen injuries) cared for in a single institution over a 12-year interval. The care pathway was implemented in year seven of the interval; outcomes were compared in the cohorts cared for before and after implementation of the pathway. The study cohort was comprised of patients with severe injury (average ISS=21)—solid organ injury grades showed that nearly 29% of patients had grade IV
or V injuries. Both injury severity and the proportion of patients with high-grade injuries increased over the study interval. The data analysis showed that rates of splenectomy remained low (4%) and were within the range suggested by national guidelines both before and after implementation of the pathway. Mortality decreased significantly for patients with nonisolated spleen injuries and hospital length of stay decreased for patients with isolated spleen injuries. The authors concluded that implementing a dedicated spleen injury pathway reduces mortality and results in earlier identification of patients with low-grade injuries, facilitating earlier discharge.

Gutierrez and coauthors⁶⁰ presented data on the impact of clinical practice guidelines on costs of care when managing isolated spleen injuries in children in Langenbecks Archives of Surgery, 2013. The authors queried a national database and obtained outcomes data for 1,154 patients cared for in 26 pediatric trauma centers over a five-year interval. A defined care pathway based on national clinical practice guidelines was in place in 20 of the trauma centers. Data on the use of imaging and laboratory services, lengths of stay, readmission rates, and costs of care were obtained. The data analysis showed that, after risk adjustment with linear regression techniques, lengths of stay and overall costs were significantly lower in centers that used a care pathway based on clinical practice guidelines.

Outcomes of managing pediatric spleen injuries in a rural adult trauma center were reported in an article by Bird and coauthors⁶¹ in the Journal of Trauma and Acute Care Surgery, 2012. The authors reported a retrospective review of medical records involving 38 patients seen at a single rural trauma center over a 13-year interval. All patients were managed using a care pathway based on injury grade and hemodynamic status. Admission to intensive care, bedrest intervals, and use of follow-up imaging were based on benchmarks recommended by the APSA. The mean injury grade in this cohort of patients was III. No patients died and nonoperative management was successful in 97% of patients. Three patients had a contrast blush in CT imaging and all three were managed nonoperatively without angioembolization. Follow-up imaging was performed in 74% of patients, but reviews of images indicated that, in the absence of symptoms suggesting intraabdominal pathology, these should not be routinely obtained. The authors concluded that pediatric patients with spleen injury can be successfully cared for in a rural adult trauma center if a care pathway is in place.

The role of angioembolization as a means of avoiding splenectomy in children with spleen injuries continues to be debated. Gross and coauthors⁶² published a retrospective review of trauma registry data in the Journal of Trauma and Acute Care Surgery, 2013. Outcomes were evaluated in 259 children with spleen injuries seen at a single institution over a 10-year interval. Average injury severity was high (21) and the average grade of spleen injuries was III. The proportion of patients with grade IV and V injuries was not reported. Observation was the initial approach in 227 patients. Nine patients showed clinical signs of continued bleeding and underwent embolization. One patient failed embolization and received a splenectomy. Transfusion was administered in 17% of observation patients and 40% of embolization patients. Immediate splenectomies were performed in 15 patients because of ongoing hemodynamic instability; transfusion rate in this group was 88%. Seven patients died, six due to brain injury and one from uncontrollable bleeding from multiple injury sites. The authors concluded that angioembolization is a useful adjunct in patients who fail early observation for spleen injury.

Bansal and coauthors⁶³ investigated the need for angioembolization in pediatric patients with spleen injuries in whom a contrast blush was detected on CT imaging; this article was published in the American Journal of Surgery, 2015. The authors reported a retrospective case series including 270 patients with spleen injuries seen in a single children’s hospital. The authors focused their analysis on 160 of the patients who had injury grades of III-V. In this group, 47 patients had a contrast blush observed on CT imaging. None of these patients had angioembolization and none required splenectomy. The authors concluded that angioembolization is not required in hemodynamically stable patients with contrast blush identified on CT imaging.

Because of their smaller arteries, children with spleen injuries who undergo angioembolization may be at an increased risk of developing embolization complications; splenic infarction, splenic abscess, and postembolization syndrome are complications that may arise in adults and children treated with angioembolization for spleen inju-
ries. Postembolization syndrome (abdominal pain, nausea, vomiting, ileus, fever) has been observed in patients who receive angioembolization for conditions such as hepatocellular carcinoma and uterine fibroids. Ben-Ishay and coauthors\(^6^4\) reported data on the frequency and severity of this syndrome in children with spleen injuries in the *Journal of Trauma and Acute Care Surgery*, 2012. The report described data from a retrospective case series that included 448 patients seen at a single institution over a 12-year interval. Eleven patients were treated with angioembolization for splenic injury; not surprisingly, the angioembolization patient group had lower hemoglobin levels, larger hemoperitoneum, and a higher transfusion risk than patients who did not have angioembolization. Signs of postembolization syndrome were confirmed in 90% of the eleven patients. The time it took to resume an oral diet, as well as ICU/total hospital lengths of stay, were longer for these patients. The authors concluded that postembolization syndrome is common in patients undergoing angioembolization for splenic injury. Given that available data confirm the safety of continued observation in patients with contrast blush on CT imaging, a conservative approach to angioembolization in children with spleen injury could reduce postembolization syndrome risks.

Hemodynamically stable children who have sustained blunt torso trauma are frequently seen in trauma centers. The decision process in determining the need for CT imaging and hospital admission is complex and often challenging. Efforts to reduce hospitalization risks and radiation exposure have stimulated interest in quantifying severe injury and bleeding risks without imaging or inpatient observation. Adelgais and coauthors\(^6^5\) assessed the accuracy of abdominal examinations in identifying significant abdominal injuries in the *Journal of Pediatrics*, 2014. The authors reported a multiinstitutional observational study that included 12,044 patients. The sensitivity of abdominal physical exams in identifying patients at high risk of significant intraabdominal injuries decreased with decreasing GCS. Sensitivity of patients with a GCS of 15 was 79% and decreased to 34% in patients with a GCS of 13. According to the authors, these findings suggest that serial physical examinations may be the best approach for patients with localized pain and tenderness and a GCS of 15. For patients with a lower GCS, ultrasound or CT imaging should be considered.

An article that attempted to determine circumstances in which CT imaging of children who had suffered blunt trauma to the torso could be omitted was by Acker and coauthors\(^6^6\) in *Surgery*, 2015. The authors reported a retrospective case series from two pediatric trauma centers. The cohort consisted of 206 patients with documented blunt trauma who had sustained liver or spleen injuries. The authors defined a “low risk” group as patients with a GCS of 15, blunt abdominal trauma caused by a nonmotorized force, and persistently normal pediatric hemodynamic status score (ratio of systolic blood pressure to heart rate). There were no deaths in the low-risk group. No patient required operation or angioembolization, and all patients were discharged to home. The authors concluded that serial assessments of hemodynamic status and hemoglobin would be safe in the low-risk patients and that CT imaging could potentially be avoided in these patients. They recommended that additional studies be conducted to validate this approach.

### Spleen Injuries in Adults

The nonoperative management of blunt spleen injuries, especially isolated spleen injuries or injuries associated with stable liver and/or kidney injuries, has been shown to be a safe and effective approach. Continued refinement of nonoperative management has occurred along with increased use of angioembolization. In this section, we will review articles that provide guidance for managing spleen injuries in adults, identify predictors of success and failure of nonoperative management techniques, and present information on the complications of nonoperative management. Penetrating spleen injuries and spleen injuries sustained in combat will also be discussed.

Clinical practice guidelines for selective nonoperative management of spleen injuries have been developed by EAST and published in an article by Stassen and coau-
thors\textsuperscript{67} in the Journal of Trauma and Acute Care Surgery, 2012. The article is included as a full-text reprint accompanying some formats of SRGS. The authors conducted a systematic review of literature to provide a scientific foundation for the practice guidelines. Although 126 articles were identified, there were no randomized, prospective trials available, so the guidelines were based on data from high-quality observational studies. The recommendations in the guidelines were divided into three levels: level 1 recommendations were defined as “convincingly justifiable” based on strong observational evidence; level 2 recommendations were deemed “reasonably justifiable” based on available evidence; level 3 recommendations were defined as being supported by available evidence that lacked the strength to form a strong foundation for the recommendation.

The guidelines had one level 1 recommendation—that patients presenting with hemodynamic instability and/or clinical signs of peritonitis should be managed with immediate operation. The level 2 recommendations included a statement that patients who were hemodynamically stable without signs of peritonitis do not require immediate surgical exploration. The guidelines recommended that CT imaging be used to document and grade the splenic injury using the AAST spleen injury grading scale\textsuperscript{49}; the guidelines also recommended documenting the amount of hemoperitoneum. The spleen injury grade, amount of hemoperitoneum, neurologic status, age >55 years, and associated injuries are not categorical contraindications to nonoperative management. The guidelines supported the consideration of angiography and embolization in patients with grade III-V injuries, presence of a contrast blush, moderate hemoperitoneum, and/or evidence of ongoing bleeding. The final level 2 recommendation was that nonoperative management should only be conducted in an environment with adequate resources (intensive care, interventional radiology, availability of resources for continuous monitoring, and an available operating room for urgent surgical intervention).

Level 3 recommendations included repeat imaging based on the patient’s clinical status (abdominal pain, systemic inflammatory response syndrome, unexplained drop in hemoglobin); also included was that contrast blush on CT imaging in stable patients does not mandate angiembolization. The guidelines supported angiography as an adjunct to nonoperative management protocols and to detect other vascular lesions such as splenic artery pseudoaneurysms. The final recommendation was that venous thromboembolism prophylaxis (VTEp) could be used without fear of increasing risk of nonoperative management failure.

Persistent unanswered questions include the optimum frequency of monitoring and examinations, documentation of the optimal transfusion trigger, the best time to resume oral intake, duration of restricted activity, optimal ICU and hospital lengths of stay, and indications for repeat imaging. Additional questions included timing of VTEp and whether embolized patients should receive vaccination against postsplenectomy infections. Finally, the guidelines emphasized the need for strong data that document or refute immunologic deficiency after splenic embolization.

The guidelines document reviewed data on predictors of nonoperative management failure. Available data supported the conclusion that failure is more common with high-grade injuries and that 93% of failures occur within one week of injury. Available data showed that splenectomy risk in the year following injury was 1.4%.

An article that described a Delphi approach for determining expert opinions on the unanswered questions identified in the EAST guidelines was by Olthof and co-authors\textsuperscript{68} in the Journal of Trauma and Acute Care Surgery, 2013. The authors enlisted the participation of 30 expert surgeons and interventional radiologists and sent them a questionnaire; the response rate was greater than 80%. A statement was deemed to have satisfactory value for practice guidance if 80% or more of the experts agreed.

The expert participants agreed that:

- The AAST spleen injury grading scale should be used (90% agreed).
- There is no CT or angiographic finding other than the angiographically documented contrast extravasation that mandates angioembolization.
- Hemodynamic instability and/or presence of severe associated intraabdominal injuries are indications for immediate surgical exploration.
- Operative management is recommended if there is a need for five or more units of transfusion (82% agreed).

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Patients should have inpatient monitoring for up to three days; a routine period of bedrest is not needed. Time to mobilization is not related to the risk of delayed splenic bleeding.

There is no indication for routine postinjury imaging.

An article that presented data documenting an increased short-term risk of infection after splenectomy for trauma was by Demetriades and coauthors in the *Journal of Trauma*, 2012. The authors reported a multiinstitutional prospective study that included 269 patients enrolled over a 22-month interval. Splenectomy was performed in 36% of patients and the remainder had splenic preservation (successful nonoperative management, angioembolization, or splenorrhaphy). After adjusting for associated risk factors, splenectomy, hypotension on admission, and high injury severity scores were associated with a significant increase in infectious complications. Additional regression analysis showed that splenectomy was independently associated with an increased infection risk. The authors concluded that splenic preservation is indicated whenever possible to reduce the risk of postinjury infection complications.

Outcomes of managing spleen injuries were presented in an article by Zarzaur and coauthors in the *Journal of Trauma and Acute Care Surgery*, 2015. This article is supplied as a full-text reprint accompanying some formats of SRGS. The authors presented data from a prospective multiinstitutional study of outcomes of nonoperative management of spleen injuries. The study enrolled 383 patients and six-month—follow-up data was available for all surviving patients. The data analysis showed that splenectomy was required during the index hospitalization in 3.1% of patients. There was one delayed splenectomy that was performed on postinjury day 12. Splenectomy was not performed in any patient with a grade I injury. Out of the patients who had a contrast blush on CT imaging who did not undergo angioembolization, 11% required splenectomy compared with 6.3% of patients who had a contrast blush followed by angioembolization. This difference was not statistically significant. The authors recommended that, based on their data, monitoring be discontinued after 24 hours of stability in patients with grade I injuries. They recommended 10–14 days of monitoring for patients with grade II-V injuries; monitoring can occur on an inpatient or outpatient basis depending on the clinical circumstances. They also recommended that hemodynamically unstable patients undergo immediate splenectomy or angioembolization based on the clinical picture.

Rosati and coauthors presented data on outcomes of spleen injury management in a single-institution in the *American Journal of Surgery*, 2015. The authors reported outcomes data for 926 patients seen over an eight-year interval. The data showed that nonoperative management was used in an increasing proportion of patients over the study interval, despite the fact that the injury grade distribution did not change. The mortality rate for immediate splenectomy was 25%; this was explained by the high rates of hemorrhagic shock, traumatic brain injury, and injury severity score greater than 36 in this group. Mortality following nonoperative management ranged from 4% to 6.5% and was predominantly driven by the presence of traumatic brain injury. Nonoperative management was successful, with splenectomy being required in less than 4% of patients. The authors concluded that nonoperative management is being used increasingly and is safe and effective in blunt splenic injury management.

One clinical condition that may affect outcomes of spleen injury is coexistent liver cirrhosis. This topic is addressed in two articles. The first was by Bugaev and coauthors in the *Journal of Trauma and Acute Care Surgery*, 2014. The authors used data from the National Trauma Databank for the interval 2002 to 2010. Liver cirrhosis was present in 289 patients who sustained spleen injury. Nonoperative management was successful in 83% of patients with cirrhosis compared with 90% of patients without cirrhosis. The lower success rate in cirrhosis patients was present even though the use of splenic artery angioembolization increased over time. Mortality for splenectomy in cirrhosis patients was 35% if done immediately and 46% if done after failure of nonoperative management. Failure of nonoperative management was predicted by high injury grade and preexisting coagulopathy. The authors concluded that cirrhosis patients are at an increased risk for mortality, morbidity, and nonoperative management failure.
Cook and coauthors\textsuperscript{3} reported similar outcomes in a multinstitutional case control study involving 77 patients from three trauma centers; this study was presented in the American Journal of Surgery, 2015. The authors found that cirrhosis was associated with an increased risk of nonoperative management failure. Cirrhotic severity and coagulopathy, as reflected in the admission model for end-stage liver disease score, was an independent predictor of mortality in cirrhotic patients with spleen injury.

Risk factors for nonoperative management failure was the focus of an article by Olthof and coauthors\textsuperscript{4} in the Journal of Trauma and Acute Care Surgery, 2013. A systematic literature review was described in the article. The authors identified 31 articles of sufficient quality for inclusion. There were no randomized controlled trials; included articles were deemed to be high-quality observational studies. The authors identified 25 prognostic factors that were associated with failure of nonoperative management. The authors concluded that strong evidence existed for age >40 years, injury severity score >25, and splenic injury grade of III or higher as prognostic factors for nonoperative management failure. Moderate evidence also supported two additional failure predictors: contrast blush on CT imaging and transfusion of one or more units of blood. The authors pointed out other analyses that looked only at English-language publications. These publications identified moderate-to-large hemoperitoneum as a risk factor for failure; however, the authors’ analysis did not support this observation.

In the Journal of the American College of Surgeons, 2012, Bhullar and coauthors\textsuperscript{5} provided contrasting evidence of how age impacts nonoperative spleen injury management. The article contained data from a retrospective, single-institution cohort of patients that had been entered into a national trauma registry. The cohort contained 539 patients and the authors stratified the patients according to age and spleen injury grade. The data analysis showed that advancing age did not significantly increase the risk of nonoperative management failure. The authors found, as others have reported, an increased rate of failure for patients older than 55 years with grade IV and V injuries, but this did not reach statistical significance because of the small sample size. In patients older than 55 years with grade IV and V injuries, angioembolization was associated with a failure rate of zero, but, again, the sample size was small. The authors suggested that the low rates of failure in all age groups that they observed could be due to the application of strict criteria for operation and angioembolization. They performed early surgical exploration in 36% of patients; this proportion is not significantly higher than those reported in other articles. The authors concluded that age is not a significant risk factor for nonoperative management failure.

An article that presented data on the frequency of delayed bleeding in patients managed nonoperatively for spleen injury was by Leeper and coauthors\textsuperscript{6} in the Journal of Trauma and Acute Care Surgery, 2014. The authors noted that factors associated with nonoperative management failure, such as splenic artery pseudoaneurysm formation, may be detected on initial CT imaging or may appear later. They hypothesized that repeat CT imaging would detect these abnormalities and that managing these with splenectomy or angioembolization would reduce nonoperative failure risks. The authors compared outcomes between two cohorts: 616 patients seen in a single center (from 2000 to 2012) that were managed with a protocol that mandated repeat CT imaging at 48 hours after injury, (with angioembolization used if indicated); and a cohort of 157 patients seen in the same institution from 1995 to 1999. During the early interval, the protocol mandating repeat CT imaging was not in place. The data showed a significant reduction in the nonoperative management failure rate in the later cohort (0.6% vs. 12% in the earlier cohort). Splenic artery pseudoaneurysm or other indications for angioembolization were discovered in 6% of repeat CT imaging studies. The authors cited data from other reports acknowledging the increased nonoperative management failure risk in patients older than 55 years with grade III-V injuries. These reports suggested angioembolization’s effectiveness in reducing failure rates in this subgroup of patients; however, Leeper and coauthors emphasized that their protocol had discovered splenic artery pseudoaneurysms in patients with grade I and II injuries, and they concluded that their findings support their continued use of this protocol.

Patients who sustain blunt torso injuries are at an increased risk of venous thromboembolism; in this situation, low molecular weight heparin has been recommended.
How and when to use VTEp therapies has been a topic of vigorous debate because of the fear of increasing bleeding risks in patients with brain injuries, spine injuries, and abdominal solid organ injuries. As low molecular weight heparin agents have become available and their improved safety profile has been well recognized, interest in the early institution of prophylaxis has increased. Rostas and coauthors27 focused on the safety of low molecular weight heparin in patients with blunt liver and spleen injuries in the American Journal of Surgery, 2015. This article is supplied as a full-text reprint accompanying some formats of SRGS. The article reported on a retrospective review of outcomes in a cohort of 328 patients seen over a five-year interval. Patients were grouped according to the time of their first dose of low molecular weight heparin. Patients were classified as “early” if the first dose was given 48 hours or less after injury. Patients receiving the first dose at 48–72 hours after injury and greater than 72 hours after injury were termed intermediate and late, respectively. The authors found that transfusion needs were less than two units in all groups and that there was no instance of bleeding requiring surgical intervention. Venous thromboembolic complications were seen more often in the intermediate and late groups. According to other reports cited by the authors, no failure risk increases were associated with the early implementation of low molecular weight heparin to help manage solid organ injuries nonoperatively. In the reported patient cohort, there was a lower proportion of grade III-IV injuries in patients receiving early VTEp, but this difference was not statistically significant. Rostas and coauthors concluded that prospective studies of early use of low molecular weight heparin are needed to document the safety of this approach.

Angioembolization in Adults with Spleen Injuries

In response to evidence of nonoperative management failure in “high-risk” patient groups, protocols have been developed that apply angioembolization to all high-risk patients; high-risk factors include older age, high-grade injuries, and findings such as contrast blush on CT imaging. Available data, however, emphasize that angioembolization, when applied liberally, is not associated with significant improvement in outcomes and exposes patients to complications. In this section, we will review perspectives relevant to angioembolization.

The first article reviewed presented a prospective study on angioembolization use for all grade III-V spleen injuries at a single center over a three-year interval.78 The study cohort consisted of 168 patients. Nonoperative management was initiated in 113 patients and the angioembolization protocol was followed in 97 patients, with a failure rate of 5%. In the 16 patients who did not follow the protocol, there were four failures (25%). Outcomes in the study cohort were compared to a group of historical control patients—this comparison showed a significant decrease in the failure rate of nonoperative management in the later cohort. Of interest was the fact that the injury severity scores of patients in the earlier cohort were significantly higher compared to the later cohort. In the discussion section of the article and in an exchange of letters to the editor following the article’s publication,79,80 the authors stressed that “failure” was defined as the need for surgical exploration and that no repeat episodes of angioembolization occurred.

Despite the availability of data supporting the use of angioembolization to improve nonoperative management outcomes of spleen injuries, the adoption of this approach has not been uniform. Banerjee and coauthors81 described the variability of this treatment modality in the Journal of Trauma and Acute Care Surgery, 2013. The authors reported a retrospective analysis of outcomes in four level 1 trauma centers over a two-year interval. Spleen injuries were diagnosed in 1,275 patients. Angioembolization use was documented in 19% and 11% of patients in two “high-use” centers, and in 4% and 1% of patients in two “low-use” centers. Successful nonoperative management of spleen injuries occurred more often in “high-use” centers. After the data was risk-adjusted, angioembolization was still an independent predictor of successful nonoperative management. In the discussion section of the article, the authors emphasized that differences in the patient populations seen at “high-use” and “low-use” centers would need to be considered. It is possible, for example, that patients in “low-use” centers had an increased proportion of significant traumatic brain injuries that would have led to earlier cessation of nonoperative management and/or lower use of angioembolization. Despite these caveats,
the data suggest that angioembolization is safe, effective, and associated with a decreased risk of nonoperative management failure.

Bhullar and coauthors also provided data supporting the value of selective use of angioembolization in the *Journal of Trauma*, 2012. The authors presented data from a retrospective case series of patients with spleen injuries seen in a single trauma center over an interval of 10 years. A total of 539 patients were eligible for inclusion in the analysis. The data associated angioembolization with a significant reduction in failure risk for patients with grade IV and V spleen injuries, but not for other injury grades. The authors stressed the importance of using a standard definition of hemodynamic instability. They also suggested using the NIH/Western Trauma Association score to document hemodynamic instability. When this was done for their patients, the authors found that more than half of the patients were hemodynamically unstable and should not have been entered into a nonoperative management protocol. Bhullar and coauthors concluded that selective use of angioembolization in stable, high-risk patients improves nonoperative management success rates.

Additional data on angioembolization for high-grade spleen injuries in the absence of contrast blush in CT imaging was presented in an article by Bhullar and coauthors in the *Journal of Trauma and Acute Care Surgery*, 2013. The authors provided a retrospective analysis of outcomes in 556 patients with spleen injuries that were entered into a nonoperative management protocol. The analysis showed that 95 patients had contrast blush on CT imaging; subsequent angiography in 88 of these patients showed contrast extravasation in 86 patients. Three patients in this group failed nonoperative management. Of the seven patients who had a contrast blush and did not have angiography, failure of nonoperative therapy occurred in 71% of patients. Of patients with high-grade injuries without a contrast blush (n=51), 20 underwent angiography and 17 of these showed extravasation. After embolization, there were no nonoperative management failures in this group. In the 31 remaining high-grade injuries without contrast blush, nonoperative management failure occurred in 26% of patients. The authors concluded that, according to the data, high-grade spleen injuries should be considered for angioembolization, even when high-risk features on CT imaging are absent.

Brault-Noble and coauthors investigated the role of patient age in the decision process for prophylactic angioembolization in the *Journal of Trauma and Acute Care Surgery*, 2012. A retrospective case series of patients seen in a single center was presented. The authors defined CT imaging criteria associated with a high risk of nonoperative management failure; these included contrast blush, pseudoaneurysm, grade III injury with large hemoperitoneum, and grade IV-V injury. The case series included 208 patients, and high-risk CT imaging criteria were present in 49 patients. Data analysis showed that the highest positive and negative predictive values for failure were observed in patients aged 50 and older (positive=67%, negative=90%). In younger patients, the negative predictive values were high, but the positive values were low. The authors concluded that prophylactic angioembolization should be considered in patients older than 50 years with high-risk CT imaging findings.

In *The American Surgeon*, 2013, Post and coauthors questioned the importance of contrast blush as an indication for angioembolization in patients with spleen injuries. The report was a retrospective case review that focused mainly on patients with spleen injuries of grade III or less. The authors compared outcomes in patients with a contrast blush with those in patients without a contrast blush. The data showed that for patients with low-grade injuries, outcomes of nonoperative management were not worse in patients with a contrast blush. The limitations of this study, including the small sample size (18 patients with CT blush and 22 patients without), suggest that these findings be interpreted cautiously.

Ekeh and coauthors presented data relevant to angioembolization complications in the *American Journal of Surgery*, 2013. The authors performed a retrospective case series analysis, including 1,383 patients with spleen injuries seen over an 11-year interval in a single center. Nonoperative management was used in 1,085 patients and angioembolization was performed in 8.1% of this group. Major complications (spleenic infarction, spleen cyst, splenic abscess, and contrast-induced renal insufficiency) were documented in 14% of patients. Most of the major complications occurred in patients who underwent distal splenic artery embolization. The authors cited data from other studies that confirmed their finding that distal embolization was associated with a higher risk of major
complications. Data on risk factors for complications (e.g., history of diabetes as a risk factor for kidney injury) were not reported. The authors concluded that complications of angioembolization occur in a significant proportion of patients and that distal embolization is associated with the highest risk of major complications.

Penetrating Splenic Injuries
The single article reviewed in this section of the review was by Berg and coauthors in Injury, 2014. The authors presented a retrospective case series obtained from a trauma registry review in an urban, inner-city trauma center; the study identified 225 patients seen over a 10-year interval. Immediate operative management was used in 83% of patients. A trial of nonoperative management was instituted in 38 clinically stable patients (hemodynamically stable, no clinical evidence of peritonitis), and was successful in 63% of this patient group. Of the 14 patients who failed nonoperative management, three underwent splenectomy and the remainder had splenorrhaphy. The authors stated that signs of hollow viscus injuries were the main reason for nonoperative management failure and occurred within 24 hours in all affected patients; delaying operative intervention until 24 hours after injury in this group was not associated with an increased risk of complications. According to the authors, 40% of patients managed nonoperatively had diaphragmatic injuries and they recommended diagnostic laparoscopy at 24 hours after admission in patients who remained stable to exclude diaphragmatic injury.

Spleen Injuries in Combat Casualties
Zonies and Eastridge reviewed a clinical practice guideline for managing splenic injuries in combat casualties in the Journal of Trauma and Acute Care Surgery, 2012. The authors stated that the Joint Trauma System that is active in the combat areas of Iraq and Afghanistan mandates that splenectomy be done for all patients with grade III injuries or higher since there will be an unavoidable eight- to nine-hour air evacuation interval, during which time a patient cannot undergo an operation, even if signs of bleeding emerge. The authors said that the guidelines permit nonoperative therapy for stable patients who will have air evacuation delayed so that they can be monitored. Zonies and Eastridge reviewed the trauma registry maintained by the Joint Trauma System and found 393 patients who had sustained a spleen injury. The most common injury was from blunt or concussive force from explosions or vehicle crashes. Grade III-V injuries were diagnosed in 53.2% of patients. Nonoperative management was used in 27% of high-grade injuries with no failures reported in the article. The authors concluded that nonoperative management of combat-related spleen injuries is possible if resources are available to monitor the patient and provide immediate operative care.

Iatrogenic Spleen Injuries
Unintentional spleen injuries can complicate intraabdominal operations on adjacent organs. Spleen lacerations can also occur during colonoscopy. Two articles that presented data on this topic will be reviewed in this section. Singla and coauthors conducted a review of available literature and included a small experience from their institution in the Journal of Gastrointestinal Surgery, 2012. The authors identified 75 articles and outcomes data were available for 102 patients. Nearly 85% of the reported patients had a colonoscopy after 2005. More than three-fourths of the reported patients were female and the median age was 65. None of the splenic lacerations were associated with a “difficult” colonoscopy. Almost all patients reported symptoms (usually left-sided abdominal pain and/or dizziness) within 24 hours of the colonoscopy. Operations were performed in 73 patients and splenectomy was done in 96% of these patients. The overall mortality rate was 5%. The authors noted that while previous authors recommended placing patients in the lateral decubitus position to lessen the risk of spleen injury, they could find no strong data to support this. They hypothesized that the increased emphasis on reaching the cecum in screening and surveillance colonoscopy may have increased performance of sigmoid straightening and “hooking” maneuvers, potentially resulting in traction on the splenic ligaments. Singla and coauthors recommended that patients be cautioned to report any abdominal pain or other symptoms after colonoscopy and that any injuries be managed with approaches deemed effective in trauma literature.
A second systematic review of the literature focusing on splenic injury associated with colonoscopy was by Piccolo and coauthors in Surgical Laparoscopy, Endoscopy and Percutaneous Techniques, 2014; data on 103 patients was identified. The authors stated that the risk of splenic injury associated with colonoscopy is approximately 1 per 100,000. This review confirmed that most colonoscopy-related spleen injuries occur in women. It is unclear whether this increased risk is due to prior hysterectomy or pelvic adhesions. The authors also pointed out that more female patients undergo colonoscopy for screening or surveillance than males—this may partially explain the female predominance of colonoscopy-related splenic injuries. The data reviewed in the article confirmed a higher risk of splenic injury in patients who are taking anticoagulant drugs at the time of colonoscopy. The authors recommended that patients be informed of this small risk of injury and be instructed on splenic injury symptoms. These suspected spleen injuries should be managed similarly to patients who sustain blunt splenic injury.

**Spontaneous Rupture of the Spleen**

Atraumatic spleen rupture is most often a complication of splenic pathology. Infection and neoplastic disease of the spleen are the most common abnormalities discovered. A small minority of patients have no identified cause. A systematic literature review of this topic was performed by Renzulli and coauthors and reported in the British Journal of Surgery, 2009. In 78% of patients, infections (HIV, malaria), neoplasms (primary splenic tumor or hematologic malignancy), and noninfectious inflammations (pancreatitis) were the causes of spontaneous spleen ruptures. The overall mortality was 12%; older age, neoplastic disease, and known splenomegaly were mortality risk factors. Splenectomy was used in 84% of patients. According to the authors, splenectomy is preferred in acceptable risk patients. Removing the spleen will facilitate diagnosis. In patients with diffuse hematologic malignancy or primary/metastatic spleen tumors, functional hyposplenism is probably already present. Based on their analysis, the authors recommended total splenectomy for patients with spontaneous spleen rupture whenever possible.

A case of recurrent spontaneous splenic rupture in an adolescent patient with congenital factor XIII deficiency was reported by Shariff and coauthors in the Journal of Pediatric Hematology and Oncology, 2014. The patient had been diagnosed with congenital factor XIII deficiency at age 18 months and had received intermittent doses of cryoprecipitate and fresh frozen plasma transfusions to maintain his coagulation status. For economic reasons, the patient had not been receiving these treatments. He presented with signs of ongoing bleeding and had an emergency splenectomy performed. The authors noted that half of the reported patients with this condition were Pakistani citizens. The authors recommended that patients with known congenital coagulopathic conditions be alerted to the risk of spontaneous splenic rupture.

**Splenic Artery Aneurysms**

The first article reviewed in this section was by Lakin and coauthors in the Journal of Vascular Surgery, 2011. This article is supplied as a full-text reprint accompanying some formats of SRGS. The authors reported a retrospective medical record review of a single institution experience with 128 patients encountered during a 13-year interval. The authors noted that the majority of the patients were women and the mean age at diagnosis was 61 years. In nearly half of the patients, the aneurysm was discovered during an imaging evaluation for abdominal pain. The authors acknowledged that it was unusual for the pain symptoms to be from the aneurysm. The remaining patients had the aneurysm discovered incidentally. Clinical features of patients with splenic artery aneurysm included hypertension and dyslipidemia. The mean aneurysm size at diagnosis was 2.4 cm.

The authors considered aneurysms >2 cm in diameter to be candidates for therapy. Sixty-two patients were deemed candidates for elective aneurysm repair. Thirteen patients underwent open repair, but the majority had endovascular ablation of the aneurysm. Seven patients presented with aneurysm rupture and required emergency operation. The mortality rate in this group was 29%; there...
was no perioperative mortality in patients treated electively. In the 66 patients treated with observation because of small aneurysm size, the annual rate of growth of the aneurysm was 0.2 cm per year. Fewer than 10 patients in this series were women in the childbearing age range and none were pregnant at the time of diagnosis. There were no late aneurysm ruptures, and no late deaths were noted in patients managed with observation and imaging surveillance. In the discussion section of the article, the authors emphasized that specific etiologic factors leading to splenic artery aneurysm formation have not been confirmed. The fact that the lesion is common in women has raised concern over hormonal influences. Histologic studies of arterial walls of true aneurysms have disclosed changes in the arterial wall suggestive of atherosclerosis, fibrodyplasia, and vasculitis. Portal hypertension is present in many patients with splenic artery aneurysm. Although atherosclerotic changes are found on microscopic examination of the aneurysm wall, atherosclerosis is not thought to be the cause of splenic artery aneurysm. False aneurysms are encountered in patients with aneurysms that develop after trauma or acute pancreatitis.

Splenic artery aneurysm rupture is a potentially lethal event that is seen most often in women during pregnancy. In the Journal of Obstetrics and Gynaecology-Canada, 2015, Parrish and coauthors96 presented a representative case and provided information from a literature review. The authors stated that most splenic artery aneurysms are asymptomatic and are discovered incidentally during evaluations for other abdominal problems. Aneurysm rupture during pregnancy occurs most often in the third trimester. The authors found that most reports of repair of splenic artery aneurysms during pregnancy dealt with instances of aneurysm rupture. The pathogenesis of aneurysm rupture is not known, but the increased levels of estrogen, progesterone, and relaxin that occur during pregnancy could increase blood flow and pressure within the splanchnic arteries. The authors presented a case of a 36-year-old patient who had a splenic artery aneurysm discovered when imaging was done for abdominal pain. The patient became pregnant and a multidisciplinary team performed a splenic artery embolization, including coil occlusion of the splenic artery branch where the aneurysm was located. Coil occlusion of the aneurysm alone was not possible because of the wide mouth of the aneurysm. Three weeks after embolization, the patient presented with a splenic abscess, which was successfully treated with percutaneous drainage. Ultimately, the patient delivered a healthy infant. In their literature review, the authors noted that mortality for ruptured splenic artery aneurysm is 75% for the mother and 95% for the fetus. They recommended that any patient known to have a splenic artery aneurysm who becomes pregnant have the aneurysm treated, since rupture risk is not related to aneurysm size. They also recommended that splenic artery aneurysm be suspected in any pregnant women complaining of left-sided abdominal pain.

An article that presented outcomes data for patients treated for splenic artery aneurysms was by Hogendoorn and coauthors97 in the Journal of Vascular Surgery, 2014. The authors conducted a systematic review of available literature and identified 47 acceptable articles that reported outcomes on 1,321 patients. Open repair of the aneurysm was performed in 511 patients, endovascular repair in 385 patients, and conservative management was used in 425 patients. The analysis showed that patients treated conservatively were older and had smaller aneurysms; of interest was the observation that this group of patients had a higher long-term mortality risk compared to the other treatment groups, but no data were available to confirm whether the late mortalities were related to complications of the aneurysms. Patients treated with open techniques had higher short-term mortality risks than patients treated with endovascular approaches, but the authors pointed out that the open group had a much higher proportion of patients with ruptured aneurysms. The authors stated that the rarity of splenic artery aneurysms makes it difficult to analyze the benefits and risks of each treatment modality.

Hogendoorn and coauthors98 developed a decision analysis model to attempt to determine the most cost-effective treatment for a hypothetical cohort of 10,000 55-year-old patients with splenic artery aneurysms. These investigators reported their results in the Journal of Vascular Surgery, 2015. The benefit threshold was set at $60,000 per quality-adjusted life-years gained. The analysis showed that endovascular repair was the most cost-effective approach for most patients. The data also showed that conservative management was cost-effective for patients >78 years of age. The authors concluded that selecting management approaches should be individualized, but that
their data could provide guidance for surgeons seeking to counsel patients and select approaches for managing splenic artery aneurysms.

Miscellaneous Splenic Conditions

In this section, we will discuss the management of uncommon splenic diseases. Many of these conditions are asymptomatic and are discovered when CT imaging is used to evaluate patients who have been injured or who have abdominal symptoms that require imaging evaluation.

Splenic Cysts

Splenic cysts may develop in patients with hydatid disease; nonhydatid cysts of the spleen include epithelial cysts and cysts that develop following splenic injury. Chen and co-authors focused on the management of epithelial cysts of the spleen in the *Journal of Gastrointestinal Surgery*, 2013. The authors reported a retrospective, single-center medical record review. They reported clinical characteristics and outcomes for 115 patients. The majority of cysts were diagnosed in the spleen, but nearly one-third of patients had cysts that arose in intrapancreatic accessory spleens. Epithelial cysts arising in the spleen were most often discovered because of clinical symptoms (mainly a left upper-quadrant mass or left-sided abdominal discomfort). The majority of patients with splenic cysts were women. Cysts arising in the intrapancreatic accessory spleen were most often discovered in imaging studies. The female predominance noted in splenic cysts was not observed in these cysts. The main indications for total or partial splenectomy in patients with splenic cysts were splenomegaly with or without concomitant clinical symptoms of pain or palpable mass. For cysts arising in intrapancreatic accessory spleens, the main indication for operation was suspicion of a malignant lesion. Based on their experience, the authors recommended total or partial splenectomy for splenic cysts; for patients with intrapancreatic splenic cysts, the authors recommended a complete excision of the cyst, the accessory spleen, and the distal pancreas. Chen and co-authors noted that the procedures could be accomplished using both open and laparoscopic techniques, depending on spleen size and surgeon experience. They recommended against cyst aspiration, marsupialization, or injection of sclerosing agents because of excessive recurrence risks with these approaches.

The authors noted that the causes of cysts are not known. Traumatic fluid collections may develop epithelial linings and convert to cysts. Residual deposits of epithelium within splenic sinususes may also contribute to cyst formation. Intrapancreatic cysts may develop as a consequence of persistent connections between the accessory spleen and the pancreatic ductal system.

Additional perspective on splenic cyst disease was presented in an article by Ingle and co-authors in the *World Journal of Gastroenterology*, 2014. The authors conducted a review of available literature, and stressed the importance of obtaining a history of exposure to hydatid disease, infection (especially due to *Salmonella sp.*), and documentation of any prior abdominal trauma. In the absence of any of these factors, excision of the cysts is indicated to achieve an accurate histologic diagnosis. Data cited in this review supported a recommendation of total or partial splenectomy based on the degree of splenic involvement. The authors noted that nonoperative approaches such as cyst aspiration and marsupialization have also been used in an attempt to preserve splenic function. No data regarding recurrence rates associated with the use of these approaches were presented.

Kalogeropoulos and co-authors described a spleen-preserving laparoscopic approach for managing splenic cysts in the *Australia and New Zealand Journal of Surgery*, 2015. The authors reported experience with 11 patients. Their technique, used in six of these eleven patients, involved aspiration of all cyst fluid, followed by laparoscopic excision of at least 85% of the cyst wall using a laparoscopic vascular stapler. The cyst wall was excised and stapled down to the border with the splenic tissue. This approach was successful in all six patients. One recurrence was observed over 28 months of follow-up and the recurrent cyst was small and asymptomatic. Observation with twice-yearly ultrasound examinations was chosen for this patient. The authors noted that partial splenectomy is useful for cysts located in the poles of the spleen. They
emphasized that their approach can be used for cysts located in the hilar area or in the central portions of the splenic substance.

Two articles that reported experience managing hydatid cysts of the spleen will be reviewed in this section. The first article was by Arikanoglu and coauthors in the Journal of Gastrointestinal Surgery, 2012. The authors reported a retrospective review of 230 patients operated on for abdominal hydatid cyst disease in a single center over an eleven-year interval. Eleven patients had splenic hydatid cysts. Diagnosis was confirmed by positive hydatid serology in all patients. Isolated involvement of the spleen was present in five patients. The remaining patients had additional foci of hydatid cysts, usually in the liver or in the lungs. Total splenectomy was performed in eight patients using an open approach in order to minimize the risk of cyst fluid spillage. Three patients had partial splenectomy. All of these patients were young and/or had isolated peripheral splenic cysts. Data on long-term outcomes were not reported.

The second article reviewed was by Akbulut and co-authors in the Journal of Gastrointestinal Surgery, 2013. The article reported outcomes with up to 60 months of follow-up in nine patients, along with a review of available literature that included outcomes analysis of 333 patients reported in 27 articles. The authors reviewed their protocol, which included albendazole therapy preoperatively and postoperatively in seven patients and vaccination in all patients. Of all the patients operated on by the authors, eight underwent total splenectomy and three underwent spleen preserving procedures, usually cystectomy and omentoplasty. The literature review reported by the authors disclosed that most reported series relied on total splenectomy, usually using an open or laparoscopic approach. Spleen preserving approaches were used in 25% of patients and 17 of the reported patients were treated using various nonoperative approaches (cyst aspiration). Recurrence rates were low following both total and spleen preserving approaches. The authors stressed that their data and their literature review could not establish a superior approach for any of the available treatment options. They recommended spleen preserving approaches for patients with small, peripheral cysts and for young patients.

**Sclerosing Angiomatoid Nodular Transformation**

The single article reviewed in this section was by Pradhan and Mohanty in Archives of Pathology and Laboratory Medicine, 2012. The authors conducted a review of available literature, and pointed out that sclerosing angiomatoid nodular transformation (SANT) is seen predominantly in women in the 30- to 60-year age range. Most of the lesions are asymptomatic and discovered on abdominal imaging; a minority of patients will present with abdominal pain. The authors emphasized that differentiating SANT from other conditions, some of them associated with malignancy, is difficult—for this reason, most patients are treated with splenectomy in order to make an accurate histologic diagnosis. Diagnosis of SANT is confirmed by documenting the unique immunohistochemical profile in the sinusoid tissue, the capillaries, the small veins, and in macrophages. The authors stated that SANT recurrence is extremely rare following splenectomy.

**Sarcoidosis Involving the Spleen**

Souto and coauthors reported on a case of splenic sarcoidosis in the Journal of the Society of Laparoendoscopic Surgeons, 2014. The authors stated that sarcoidosis is most commonly a disease that involves the pulmonary interstitium; however, clinically significant extrapulmonary disease is observed in 25%–38% of patients according to data cited in the article. The case they reported was of a 29-year-old woman who presented with a history of nausea, vomiting, and upper abdominal pain. Abdominal imaging showed multiple splenic lesions and an extensive evaluation did not disclose evidence of benign or malignant neoplasia or infection. Because a diagnosis could not be made with assurance, laparoscopic splenectomy was recommended. The patient did well, and when a definitive diagnosis of sarcoidosis of the spleen was made, the patient was treated with chemotherapy. The authors stressed that splenectomy for diagnosis is needed in the rare instances of diseases that can’t be diagnosed, but that may mimic splenic neoplasia. The use of laparoscopy in these cases permits rapid recovery and, if needed, an early course of pharmacologic therapy.
Splenic Torsion

Splenic torsion occurs in spleens that lack the normal supporting ligaments that hold the organ in the left upper quadrant. Migration of the spleen from its normal location occurs when the splenic ligaments are undeveloped and may lead to discovery of the spleen in an abnormal location (wandering spleen). If the spleen is anchored only by an elongated vascular pedicle, twisting of the pedicle (torsion) can lead to splenic infarction; infarction may be acute or chronic. A case of wandering spleen with a useful image of the abnormally located organ was presented in an article by Misawa and coauthors in the American Journal of Surgery, 2008. The image is reproduced as Figure 5.

Additional perspective on the problem of splenic torsion was presented in an article by Le and coauthors in the Journal of the Society of Laparoendoscopic Surgeons, 2012. According to the authors, splenic torsion is a rare entity that may result from relaxation of the splenic ligaments. Congenital laxity of the ligaments occasionally occurs in patients with Ehlers-Danlos syndrome. Symptomatic wandering spleen or splenic torsion can occur in males and females under the age of 10, but is observed mostly in women above this age range. Splenectomy is required for torsion that leads to severe symptoms or acute splenic infarction. According to data cited by the authors, splenopexy has been reported to be successful in patients with normal sized spleens and no splenic damage due to ischemia.

Splenic Abscess

To and coauthors reported on splenic abscess treated by splenectomy in Surgical Infections-Larchmont, 2013. The authors presented a case of a 63-year-old male who developed splenic abscess as a complication of mitral valve endocarditis. The splenic fluid collection was initially treated with percutaneous drainage and antibiotics with the intent to replace the mitral valve. The abscess resolved on imaging, but recurred after removal of the percutaneous drainage catheter. Laparoscopic hand-assisted splenectomy was performed. The authors noted that splenic abscess is an unusual disease, with fewer than 600 cases reported in literature. The condition is usually observed in patients with endocarditis or patients who are immunosuppressed. There is evidence of systemic embolization in nonspleen sites in up to 50% of cases that are due to endocarditis. Data cited by the authors supported the conclusion that percutaneous drainage is useful for patients with single abscess cavities and/or patients with excess operative risk. Splenectomy is more suitable for multiloculated abscesses, abscesses with ill-defined margins, and/or necrotic debris. Additional data cited by the authors support laparoscopic splenectomy and staged cardiac valve replacement for most patients, although cases of simultaneous splenectomy and valve replacement have also been reported.
I hope that you have found the information in this issue helpful. As always, we welcome your input and encourage you to contact us with comments and suggestions. The next issue of *SRGS* will begin our three-issue series focusing on surgical conditions of the liver.

Thanks for reading *SRGS*!

Lewis Flint, MD, FACS
Editor in Chief


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1. Plato hypothesized that the function of the spleen was to accomplish which of the following?
   a) Digestion of solid food
   b) Absorption of bile
   c) Cleansing of the liver
   d) Formation of urine
   e) Management of anger

2. Malpighi described the microscopic appearance of the red and white pulp of the spleen and believed that these structures secreted fluids into the circulation to facilitate which of the following functions?
   a) Maintenance of blood pressure
   b) Production of bile by the liver
   c) Absorption of food
   d) Formation of urine
   e) Secretion of digestive juices

3. Fatal sepsis in asplenic patients was first described in 1929 by which of the following physicians?
   a) O’Donnell
   b) Mayo
   c) Osler
   d) Virchow
   e) Halsted

4. During embryonic development, the first location of the spleen is which of the following?
   a) Transverse colon mesentery
   b) Greater omentum
   c) Parenchyma of the pancreas
   d) Dorsal mesogastrium
   e) Within the renal capsule

5. According to data cited by Skandalakis and coauthors, the spleen is divided into three segments (superior, middle, inferior) in what percentage of specimens?
   a) 84%
   b) 33%
   c) 55%
   d) 4%
   e) 16%

6. Data cited in the clinical practice guidelines promulgated by the Society for Surgery of the Alimentary Tract show that the overall mortality risk for elective splenectomy is which of the following?
   a) Less than 1%
   b) 2.5%
   c) 4%
   d) 8%
   e) 3.2%

7. According to data reported by Yan and coauthors, identification and control of the splenic artery within the splenic hilum in patients undergoing laparoscopic splenectomy with normal or slightly enlarged spleens was associated with which of the following outcomes?
   a) Increased risk of bleeding
   b) Decreased risk of pancreatic fistula
   c) Increased risk of intestinal injury
   d) Lower risk of conversion to open splenectomy
   e) Increased risk of surgical site infection
8. In the case series reported by Nyilas and coauthors, conversion from laparoscopic to open splenectomy occurred in which percentage of patients with massive splenomegaly?
   a) 5%
   b) 28%
   c) 11.1%
   d) 17%
   e) 1.2%

9. Interaction of filtered red blood cells and organisms and antigens with cells that mediate responses of the innate and adaptive immune systems occurs in which of the following locations?
   a) Red pulp
   b) White pulp
   c) Splenic vein
   d) Splenic hilar lymph nodes
   e) Beneath the first layer of the splenic capsule

10. Opsonization of encapsulated organisms requires which of the following?
    a) Properdin
    b) Immunoglobulin G
    c) Insulin-like growth factor
    d) Tumor necrosis factor
    e) Cortisol

11. Which of the following is an important risk factor for death from postsplenectomy infection?
    a) Female gender
    b) Age >65 years at the time of splenectomy
    c) Splenectomy for hereditary spherocytosis
    d) Splenectomy for splenic injury
    e) Splenectomy for hematologic malignancy

12. A nine-year-old girl undergoes splenectomy for a splenic injury. American guidelines suggest that this patient be treated with preventive antibiotics for which of the following intervals?
    a) Lifetime
    b) 20 years
    c) 6 months
    d) 2 years
    e) 5 years

13. Available data suggest that splenectomy increases the risk for all of the following diseases except which one?
    a) Esophageal cancer
    b) Lung cancer
    c) Alzheimer disease
    d) Venous thromboembolism
    e) Pancreatic cancer

14. According to the study by Bickenbach and coauthors, patients undergoing splenectomy for diagnosis of hematologic disease had the correct diagnosis made in which percentage of patients?
    a) 66%
    b) 96%
    c) 63%
    d) 50%
    e) 28%

15. According to the report by Bagrodia and coauthors, the estimated mortality risk of a patient older than 65 years with hypoalbuminemia undergoing splenectomy for hematologic disease is which of the following?
    a) 0.3%
    b) 1.6%
    c) 17%
    d) 2.1%
    e) 10%
16. One explanation for the increased risk of venous thromboembolism after splenectomy is which of the following?
   a) Heparin resistance
   b) Chronic increased platelet counts
   c) Interaction of retained damaged cells and the endothelium
   d) Persistent anemia
   e) Elevated levels of tumor necrosis factor

17. According to data presented in the large case series reported by Wisner and coauthors, the rate of splenectomy for pediatric patients who sustained blunt force trauma to the torso was which of the following?
   a) 1.4%
   b) 0.6%
   c) 28%
   d) 7.4%
   e) 50%

18. According to survey data reported by Bowman and coauthors, what percentage of surveyed general surgeons thought that practice guidelines were useful?
   a) 18.7%
   b) 97%
   c) 50%
   d) 29%
   e) 72%

19. Data reported by Gutierrez and coauthors indicate that implementation of a clinical practice guideline for management of spleen injury is associated with which of the following outcomes?
   a) Reduced costs
   b) Lower rates of splenectomy
   c) Increased lengths of hospital stay
   d) Reduced risk of surgical site infection
   e) Increased use of angiography and embolization

20. The highest risk for rupture of a splenic artery aneurysm during pregnancy is observed in which of the following settings?
   a) First pregnancy after age 34
   b) Pregnancy in women with type 1 diabetes
   c) During the third trimester of pregnancy
   d) Women with more than three pregnancies
   e) Pregnancy in a patient who is obese

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21. This issue met the stated learning objectives.
   a) Strongly agree
   b) Agree
   c) Neutral
   d) Disagree
   e) Strongly disagree

22. The content was relevant to my educational needs and practice environment.
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   d) Disagree
   e) Strongly disagree

23. There are potential barriers to incorporating what I have learned from this issue into my practice.
   a) Strongly agree
   b) Agree
   c) Neutral
   d) Disagree
   e) Strongly disagree

24. The content was fair, objective, and unbiased.
   a) Strongly agree
   b) Agree
   c) Neutral
   d) Disagree
   e) Strongly disagree

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McClusky DA, 3rd, Skandalakis LJ, Colborn GL, Skandalakis JE
McClusky and coauthors present classic articles that review the medical history of the spleen and splenic surgery.

2. Tribute to a triad: history of splenic anatomy, physiology, and surgery-part 2...63-75
McClusky DA, 3rd, Skandalakis LJ, Colborn GL, Skandalakis JE
McClusky and coauthors present classic articles that review the medical history of the spleen and splenic surgery.

3. The surgical anatomy of the spleen...76-88
Skandalakis PN, Colborn GL, Skandalakis LJ, Richardson DD, Mitchell WE, Jr., Skandalakis JE.
This is a classic article describing the surgical anatomy of the spleen.

4. Laparoscopic splenectomy: experience of a single center in a series of 300 cases...89-95
Corcione F, Pirozzi F, Aragiusto G, Galante F, Sciuto A
Corcione and coauthors provide useful guidance relevant to approaches and technical details of laparoscopic splenectomy.

5. Non-operative management and immune function after splenic injury...96-102
Skattum J, Naess PA, Gaarder C.
This article reviews available evidence on immune function in patients who have undergone successful nonoperative management of splenic injury.

6. Outcomes following splenectomy in patients with myeloid neoplasms...103-109
This article provides useful information on outcomes of patients undergoing splenectomy for myeloid neoplasms.

7. Management of children with solid organ injuries after blunt torso trauma...110-118
Wisner DH, Kuppermann N, Cooper A, et al.
Wisner and coauthors review outcomes of management of children with abdominal solid organ injuries following blunt trauma. The success of nonoperative approaches is reviewed and guidance is provided for choosing immediate operative management strategies.

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Stassen NA, Bhullar I, Cheng JD, et al.
This clinical practice guideline presents useful approaches for management of splenic injury.

9. The splenic injury outcomes trial: An American Association for the Surgery of Trauma multi-institutional study...126-133
This article presents results of a multi-center study of the management of splenic injury.

10. The safety of low molecular-weight heparin after blunt liver and spleen injuries...134-137
Rostas and coauthors present data confirming the safety of low molecular-weight heparin for thromboembolism prophylaxis in patients who have undergone splenectomy or splenorrhaphy for trauma.

11. The contemporary management of splenic artery aneurysms...138-145
Lakin RO, Bena JF, Sarac TP, et al.
This article is a useful review of the diagnosis and management of splenic artery aneurysms.
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