Emergency General Surgery

A Practical Approach

Carlos V. R. Brown
Kenji Inaba
Matthew J. Martin
Ali Salim
Editors

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Preface

The field of emergency general surgery encompasses a wide array of surgical diseases, ranging from the simple to the complex. Emergency general surgeons are tasked with caring for patients with emergent surgical diseases emanating from the emergency department or inpatient consultations. These diseases range from inflammatory, infectious, and hemorrhagic diseases spanning the entire gastrointestinal tract, complications of abdominal wall hernias, compartment syndromes, skin and soft tissue infections, and surgical diseases significantly complicated in special populations including elderly, obese, pregnant, immunocompromised, and cirrhotic patients.

The *Emergency General Surgery* textbook is a real-time and at-the-fingertip resource for surgeons and surgery residents, providing a practical and evidence-based approach to diagnosing and managing the wide array of surgical diseases encountered on emergency general surgery call. The chapters in this new and cutting-edge textbook are written by leading experts in the field and are filled with pearls of wisdom from surgeons with decades of experience taking emergency general surgery call. This compilation of thorough and cutting-edge content also serves as an excellent review for residency in-service exams, qualifying and certifying board exams, as well as up-to-date information for continuous certification in general surgery.

We wish to thank the professional editorial efforts of Springer and to acknowledge our peers, coworkers, friends, and family for their support throughout this project. Without the help of so many, this project could not have been brought to fruition.

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1 Definition of Emergency General Surgery (EGS) and Its Burden on the Society

Stephen C. Gale, Kevin M. Schuster, Marie L. Crandall, and Shahid Shafi

Defining Emergency General Surgery (EGS)

The American Association for the Surgery of Trauma (AAST) was the first to develop a formal definition of emergency general surgery (EGS) in 2013 [49]. The EGS patient was conceptually defined as "any patient (inpatient or emergency department) requiring an emergency surgical evaluation (operative or non-operative) for diseases within the realm of general surgery as defined by the American Board of Surgery" [49]. To define the actual scope of EGS practice, data were obtained from seven acute care surgeons in academic practice. Using a Delphi process, a consensus was generated over a list of International Classification of Diseases (ICD 9) diagnostic codes that encompassed EGS (Table 1.1). The list included several major disease categories including resuscitation, general abdominal conditions, upper gastrointestinal tract, hepatic-pancreatic-biliary, colorectal, hernias, soft tissue, vascular, cardiothoracic, and others. It should be noted that these surgeons practiced exclusively in relatively urban academic medical centers where the distribution of cases may be different than more rural or private practice settings. Despite this limitation, this ICD-9 code-based definition has spurred research in EGS, including early outcomes research measuring morbidity, mortality, and costs associated with EGS patients. All large-scale data analytics of EGS as a specialty must be interpreted within the context of how it is defined by ICD-9/10 codes.

At the present time, every acute care hospital with an emergency room and a general surgeon on staff cares for EGS patients. However, it is likely that the scope of EGS practice varies from center to center and from surgeon to surgeon within a center, depending upon local resources and expertise. Not all institutions will have adequate resources for addressing every EGS disease and severity. Hence, we believe that individual hospitals should define their scope of EGS practice, based upon local capabilities and ability to transfer patients to another center for a higher level of care.

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Table 1.1 Common emergency general surgery diseases

Surgical area	Clinical conditions
Resuscitation	Acute respiratory failure, shock
General abdominal conditions	Abdominal pain, abdominal mass, peritonitis, hemoperitoneum, retroperitoneal abscesses
Intestinal obstruction	Adhesions, incarcerated hernias, cancers, volvulus, intussusceptions
Upper gastrointestinal tract	Upper gastrointestinal bleed, peptic ulcer disease, fistulae, gastrostomy, small intestinal cancers, ileus, Meckel's diverticulum, bowel perforations, appendix
Hepatic-pancreatic-biliary	Gallstones and related diseases, pancreatitis, hepatic abscesses
Colorectal	Lower gastrointestinal bleed, diverticular disease, inflammatory bowel disease, colorectal cancers, colitis, colonic perforations, megacolon, regional enteritis, colostomy/ileostomy, hemorrhoids, perianal and perirectal fistulas and infections, anorectal stenosis, rectal prolapse
Hernias	Inguinal, femoral, umbilical, incisional, ventral, diaphragmatic
Soft tissue	Cellulitis, abscesses, fasciitis, wound care, pressure ulcers, compartment syndrome
Vascular	Ruptured aneurysms, acute intestinal ischemia, acute peripheral ischemia, phlebitis
Cardiothoracic	Cardiac tamponade, empyema, pneumothorax, esophageal perforation
Others	Tracheostomy, foreign bodies, bladder rupture

Source: Shafi et al. [49]

Defining the Anatomic Severity of EGS Disease

EGS patient outcomes are related to the severity of illness, based upon preexisting medical conditions, anatomic severity of disease, and physiologic derangements [39, 41]. However, until recently, there was no unified mechanism for measuring anatomic severity of EGS diseases. Hence, AAST developed a new grading system using a defined framework based upon a combination of clinical, radiographic, endoscopic, operative, and pathologic findings (Table 1.2) [11, 48, 58]. Sixteen disease grading schemas were first produced for infectious or inflammatory EGS diseases, including acute appendicitis, breast infections, acute cholecystitis, acute diverticulitis, esophageal perforation, hernias, infectious colitis, small bowel obstruction due to adhesions, bowel ischemia due to arterial insufficiency, acute pancreatitis, pelvic inflammatory disease, perforated peptic ulcer, perineal abscess, pleural space infection, and surgical site infection. These grading scales were developed empirically by consensus experts but have subsequently been validated across several conditions including diverticulitis and appendicitis [20, 50]. Once validated, this anatomic grading system will be a powerful tool for research, quality improvement, and national tracking of emergency general surgical diseases. There are multiple physiologic scoring systems that have been applied to EGS patients [36]. Examples include the Sequential Organ Failure Assessment (SOFA) score, the Acute Physiology and Chronic Health Evaluation (APACHE) score, the American Society of Anesthesiologists Physical Status (ASA-PS), and various forms of the Physiological and Operative Severity Score for the enumeration of Mortality and Morbidity (POSSUM). Disease-specific scores include the Colonic Peritonitis Severity Score, Mannheim Peritonitis Index, and the Boey score for outcome prediction in perforated peptic ulcer disease [5, 7].

Table 1.2 American Association for the Surgery of Trauma anatomic grading system for measuring severity of emergency general surgery diseases

Grade	Description
Grade I	Local disease confined to the organ with minimal abnormality
Grade II	Local disease confined to the organ with severe abnormality
Grade III	Local extension beyond the organ
Grade IV	Regional extension beyond the organ
Grade V	Widespread extension beyond the organ

Source: Shafi et al. [48]

Burden of Disease for Emergency General Surgery

Perhaps the most remarkable aspect of EGS is the sheer volume of patients and the burden on the society that these patients represent in terms of level of acuity, manpower needs, and costs of care. Much like the societal burden of trauma care which went unrecognized until the 1980s [46], EGS is now being recognized as one of the major underappreciated public health crises of the twenty-first century [15, 38].

EGS Volume

Using definitions created by the AAST [49], researchers have estimated EGS hospitalizations and described patient demographics, operative needs, and major outcomes [9, 15, 32, 45]. Recent examinations of the Nationwide Inpatient Sample (NIS), the country's largest all-payer hospital database, demonstrate that EGS diseases account for nearly three million inpatient admissions annually (7% of all hospitalizations), at more than 4700 different hospitals in the United States in 2010 [34, 15]. These studies further show that EGS volumes are steadily increasing each year [15]. Nearly 30% of EGS patients required a major surgical procedure during their initial hospital stay (Fig. 1.1). Five EGS diagnostic groups accounted for more than 90% of admissions: hepatobiliary, colorectal including appendix, upper gastrointestinal, soft tissue, and intestinal

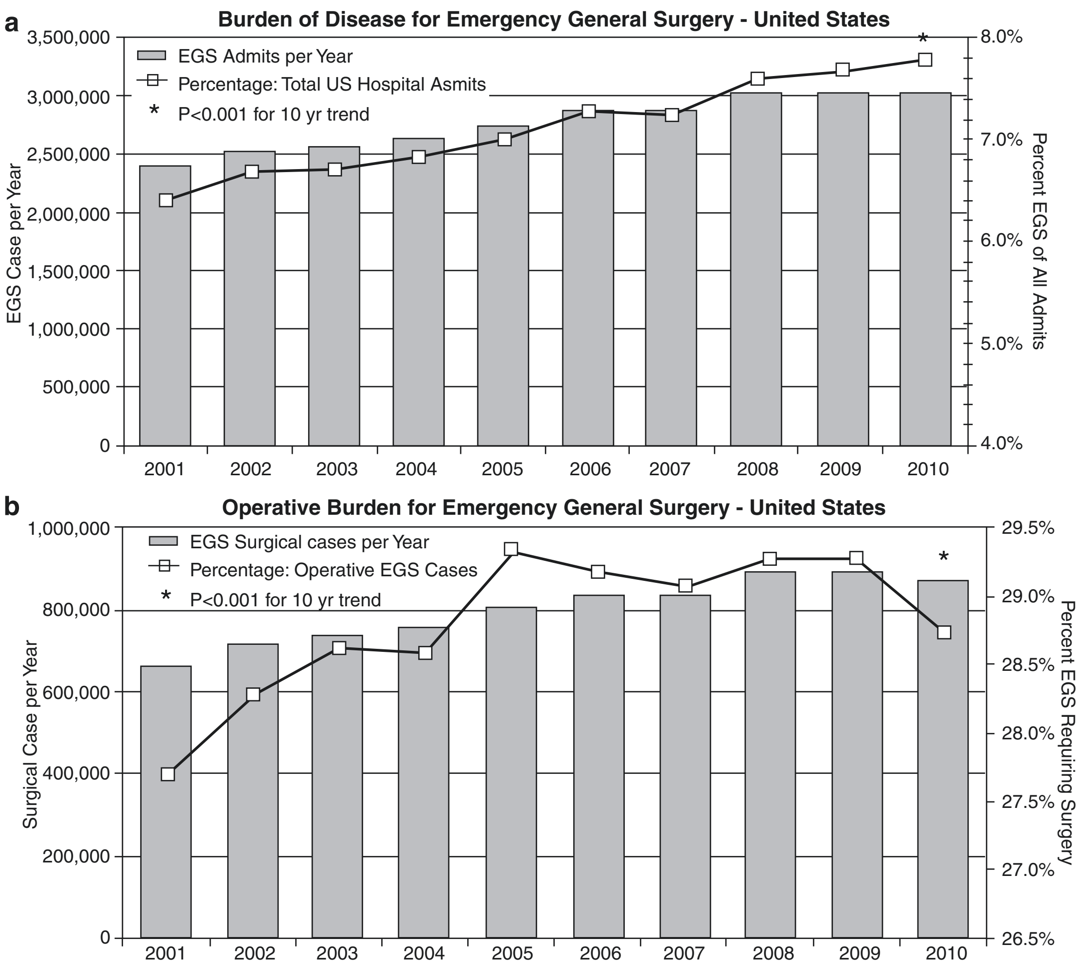

Fig. 1.1 Number of all EGS cases (**a**) and operative EGS cases (**b**) from 2001 to 2010 using National Inpatient Sample data (Source: Gale et al. [15])

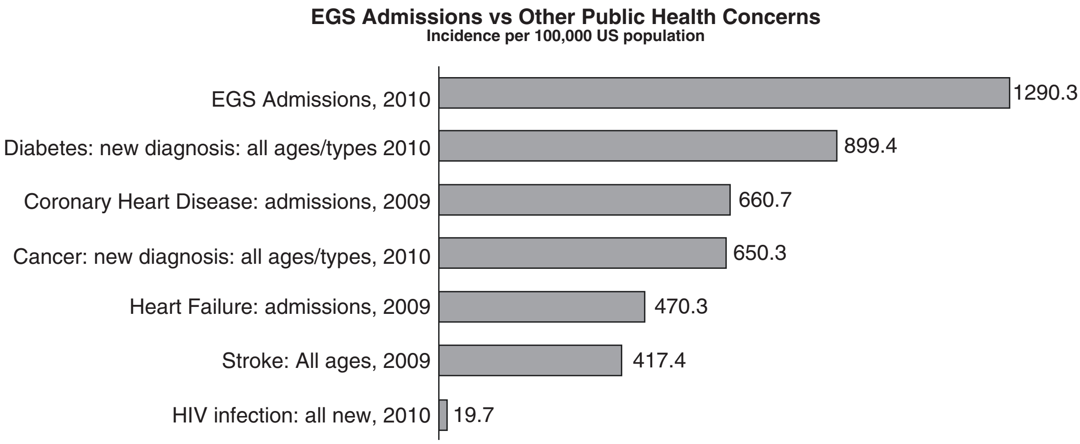

Fig. 1.2 Burden of EGS admissions compared to other common diseases (Source: Gale et al. [15])

obstruction. Cyclic seasonal variations exist in EGS hospitalizations, similar to trauma, and increase during the summer [60].

As a public health issue, the burden of EGS is very large, and population-based estimates reveal 1290 EGS admissions per 100,000 [15] – higher than many other common public health concerns including new-onset diabetes, heart disease admissions, and new cancer diagnoses, among others (Fig. 1.2).

These findings underestimate the total burden of EGS diseases, as these estimated do not include:

- Patients treated and released from the emergency room and urgent care centers (such as those with biliary colic and reducible hernias, minor soft tissue infections)
- Patients who require elective surgical procedures later in their course (such as colostomy reversal, hernia repair after reduction, delayed colectomy for diverticulitis)
- Patients who develop EGS diseases after being admitted for other conditions (such as intestinal ischemia after cardiovascular surgery, infected decubitus after prolonged mechanical ventilation, acalculous cholecystitis after prolonged parenteral nutrition)

Operative Burden

Operative rates for EGS conditions are consistent across studies at roughly one-third of admitted patients [15, 51, 52]. Further, Scott and colleagues [45] demonstrated that for patients requiring major surgery, more than 80% of procedures fall into only seven groupings: appendectomy, cholecystectomy, lysis of adhesions, colectomy, small bowel resection, hemorrhage control, and laparotomy (Fig. 1.3). These same procedures also account for more than 80% of EGS complications, deaths, and costs (Fig. 1.4) [15, 32, 35, 45].

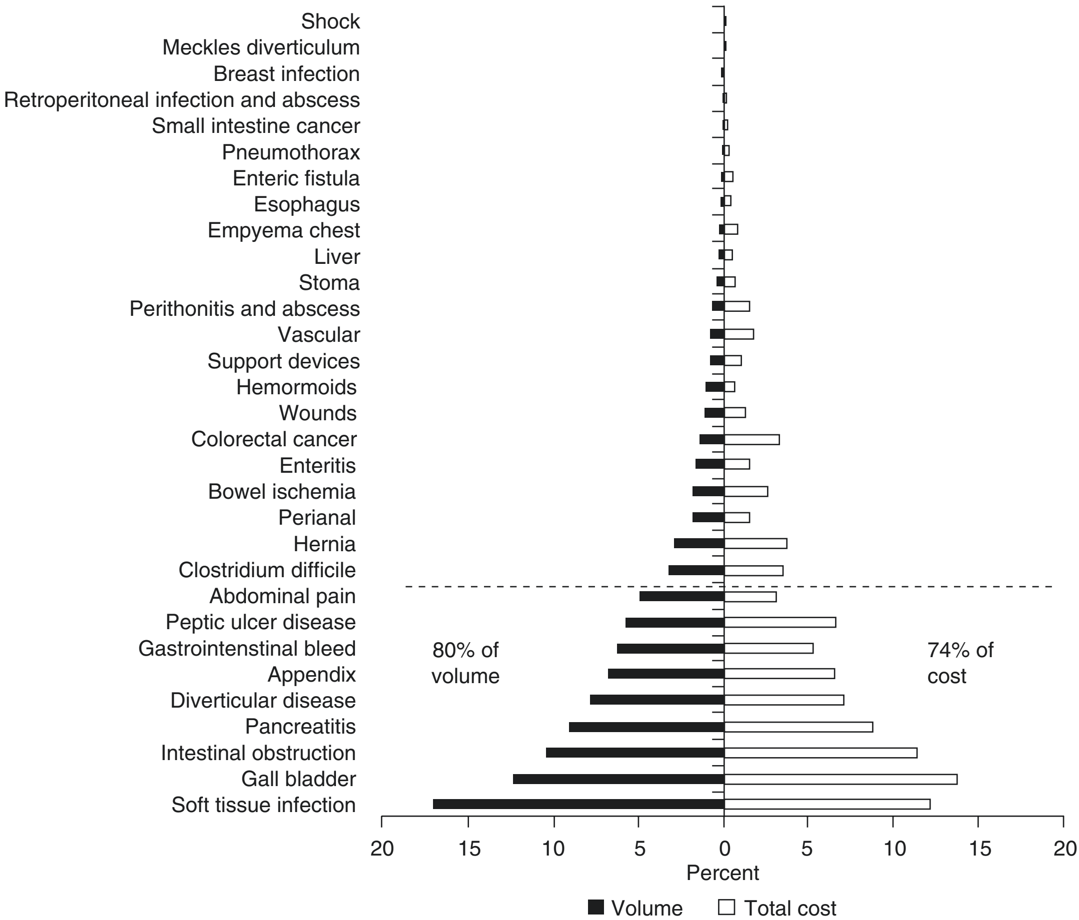

Fig. 1.3 Frequency of common EGS diseases with volume and costs (Source: Ogola and Shafi [35])

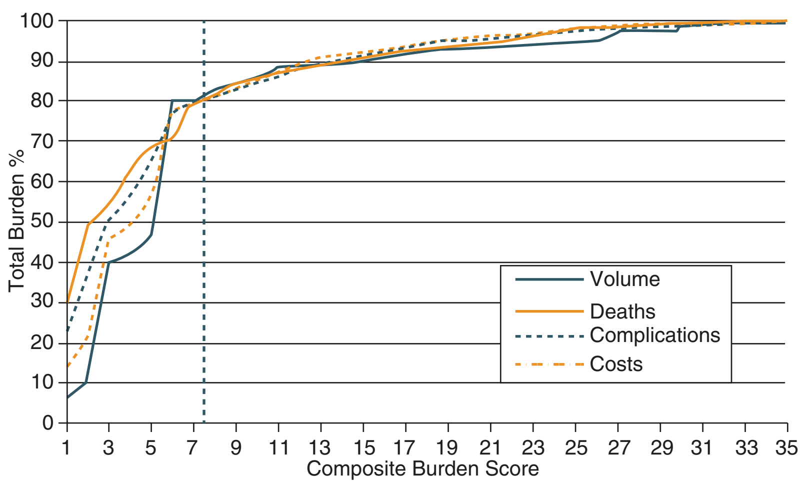

Fig. 1.4 Cumulative national burden of emergency general surgery procedures by rank. Each line represents the proportion of cumulative national burden of procedure volume, patient deaths, complications, and costs. The vertical dotted line delineates the top 7 ranked procedures, which accounted for approximately 80% of all cumulative burden. Data were obtained from the National Inpatient Sample for admissions between 2008 and 2011 (Source: Scott et al. [45])

Demographics

Most studies demonstrate a mean age near 60 years for EGS patients [15, 18, 32, 51, 52] with 10% being octogenarians or older [45, 51, 55]. There is a slight female preponderance (53%) and approximately 25% are non-White [49]. Compared to elective general surgery patients, they have higher comorbidity rates [18], and most have at least one major preexisting medical condition [15, 18, 39]. Payer mix varies between studies, but uninsured rates are reported between 8% and 12%, commercial insurers provide roughly 33% of coverage, and government insurance (Medicare or Medicaid) covers the rest – more than 50% of all EGS patients [15, 32, 35, 45, 51].

Outcomes

Patient outcomes vary between EGS conditions and are dependent on multiple factors, such as anatomic severity of diseases, physiologic derangement at presentation [20, 30, 43, 50], age [40, 51, 52, 54, 55], need for and type of surgery [45], and patient comorbidities [51, 54].

Risk Assessment

Risk assessments and outcome predictions for EGS patients are aided by validated scoring systems including Charlson age-comorbidity index (CACI) [54], frailty scores [22, 27, 37], Emergency Surgery Score (ESS) [8, 39], and the Physiological and Operative Severity Score for the enumeration of Mortality and Morbidity (POSSUM) [21, 57]. In addition, the AAST has developed a grading system for reporting anatomic severity of multiple EGS conditions [14, 20, 43, 58, 59]. Further, the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) universal Surgical Risk Calculator is available online and through smartphone apps [4]. However, NSQIP data are limited to operative cases, and some have questioned whether the same risk stratification tools should be used for both emergent and elective procedures [8, 39]. Other risk factors associated with poor outcomes of EGS patients include lack of insurance (associated with complex presentation [44] and mortality [51]) and treatment at rural [51] or low-volume hospitals [34] which carry higher mortality.

Morbidity and Mortality

Large cohort studies indicate that complication rates are approximately 15% for EGS patients requiring surgery [45]. Wound-related complications are most common, followed by pulmonary issues [26]. Postoperative stroke, major bleeding, and acute myocardial infarction present the highest risks for death [26]. Overall, mortality rates are relatively low, around 1.5% across multiple large studies [15, 45, 51], and have declined over time despite increasing volume [15]. Those requiring surgery have significantly higher mortality [26, 39].

Hospital length of stay has decreased over time [15] with median length of stay (LOS) of approximately four (4) days [15, 32, 51]. ICU admission rates are around 11% [32, 50, 54].

Other Outcomes: Readmissions, Reoperations, Loss of Independence, and Years of Life Lost

Havens [17] described a 5.9% readmission rate over 5 years for EGS patients – most commonly for surgical site infection – and found that Charlson Comorbidity Index score ≥ 2, patients leaving against medical advice, and public insurance were the greatest risk factors. Muthuvel [31] described a 15.2% postoperative readmission rate using ACS-NSQIP data and proposed using the surgical Apgar score (SAS) developed by Gawande [16] as a predictor. In that study, multivariable analysis demonstrated that SAS < 6 independently predicted 30-day readmission (odds ratio 3.3, 95% C.I. 1.1–10.1, $p < 0.04$). Hospital LOS > 12 days and ASA class ≥ 3 were also predictive. Shah and colleagues [53] analyzed more than 69,000 records from ACS-NSQIP and reported a 4.0% unplanned reoperation rate for EGS conditions. Appendiceal disorders were the most common underlying disease, and exploratory laparotomy was the most often required procedure. In that cohort, reoperation led to significant morbidity, increased mortality, and prolonged LOS.

EGS conditions pose a severe threat to independence, especially for older patients. In 2016 St. Louis and others [55] found that patients aged ≥80 were over four times more likely to require discharge to a facility other than home (odds ratio 4.72, 95% C.I. 1.27–17.54, $p < 0.02$). McIsaac and colleagues [27] reported on "frailty" in operative elderly EGS patients and identified 25.6% of 77,184 as frail. These patients had double the mortality rate and four times the institutional discharge rate (odds ratio 5.82, 95% C.I. 5.53–6.12; $p < 0.0001$). Berian [3] reported that of 570 elderly (aged ≥ 65) patients undergoing major EGS surgery in NSQIP database, 448 (78.6%) had some loss of independence. Many elderly and frail patients also have poor health-related quality of life (HRQOL) after EGS admission and may have indications for evaluation by palliative care clinicians [25]. The 2010 Global Burden of Disease Study [56] demonstrated a marked decline in death and disability related to EGS conditions from 1990 to 2010, and these data also indicate that 287 years of life (YLL) and 358 disability-adjusted life years (DALY) are lost per 100,000 population indicating a massive *worldwide* burden – disproportionately borne by low- and middle-income countries with poor access to emergency surgical care.

Costs

Data on the financial burden of EGS has been limited to costs associated with inpatient admission [32, 35, 52]. Factors affecting costs of care include age [52], severity of disease [32], ICU admission [32], type of hospital [32], and need for surgery [45]. Admission costs vary by study and range from $8246 [32] to $13,241 per admissions [45]. In 2010 NIS data, average adjusted cost per admission for all EGS conditions was $10,744 (95% C.I. $10,615–$10,874) [33]. For 2,640,725 inpatient admissions in 2010, total cost to care for EGS patients was $28.37 billion (95% C.I. $28.03–$28.73 billion). Recently, Ogola used US Census Bureau's population projections to conclude that by 2060, costs for EGS hospitalizations would increase by 45% to over $41 billion annually – mostly related to the aging population [33] (Fig. 1.5). As mentioned before,

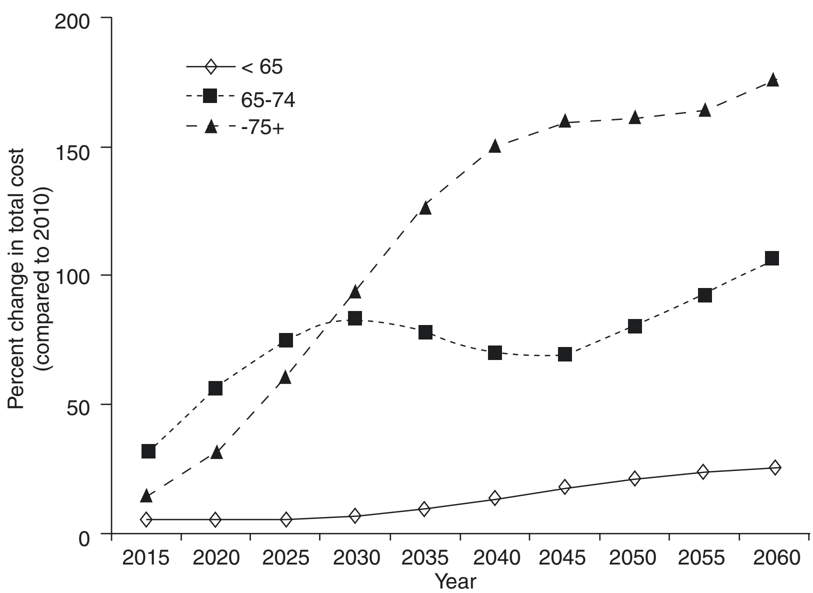

Fig. 1.5 Projected increase in cost of EGS care 2010–2060 (Source: [33])

these are underestimates due to lack of data on cost of services provided in emergency departments, urgent care centers, short-stay hospitals, post-acute care facilities (i.e., skilled nursing facilities or rehabilitation centers), physician offices, and patients' homes.

Policy and EGS Regionalization

In 2006, the Institute of Medicine described emergency care in the United States at a "breaking point" [23]; that same year the American College of Surgeons released "A Growing Crisis in Patient Access to Emergency Care" [13] outlining the issues surrounding the shortage of surgeons willing or able to provide EGS coverage. Reasons include declining reimbursement, uncompensated care, increased surgical specialization, aging of the surgeon workforce, and liability concerns. Further, as reimbursement models evolve from "fee for service" toward "value-based care," there exists a concern that the greater complexity [10] of EGS patients that results in higher complication rates, readmission rates [29], and costs [19] may place surgeons and hospitals at risk for financial penalties [61] and poor performance on published quality ratings [10]. These and other issues have led some to call for regionalization of EGS care – similar to the development of the national trauma system over the previous decades [2, 6, 12, 24, 34, 42]. Proponents argue that regionalization would capitalize on and further improve expertise, consolidate and make better use of limited resources, and ultimately lead to improved outcomes [6, 12, 24, 34]. Indeed Ogola postulated that 23.5% of EGS-related deaths in low-volume hospitals may be preventable by transfer to higher-volume hospitals [34]. Obviously costs are added with transporting patients between hospitals [28], delaying definitive care, and adding providers in tertiary centers, yet significant cost savings would occur with improved outcomes [34]. Detractors warn that, much like the evolution of trauma care, regionalization could lead to sanctioned repudiation of all EGS care – independent of severity or hospital capability – resulting in a net transfer of complex, poorly compensated care to already overburdened tertiary care centers. In the NIS database in 2010, over 80% of hospitals caring for EGS patients were "non-teaching," and 40.8% were "rural" [34]; the logistics of large-scale EGS patient transfers need to be considered, as well. Hence, given the complex financial implications [28] and large, heterogeneous EGS patient volume, much remains unknown with regard to regionalization efforts.

Data Sources and Future Work

Data sources currently available to study EGS conditions and outcomes include local institutional registries, the NSQIP database, and various administrative discharge databases including State Inpatient Databases (SID) and the NIS. Each is limited by its scope, nonstandard format, and retrospective nature. In addition, most are not designed for collecting EGS-specific clinical data including physiologic, severity of disease, and operative details further limiting their clinical and research usefulness. To improve our understanding of EGS diseases and their treatment, allow outcomes benchmarking for hospitals and surgeons, facilitate research, and serve as a quality improvement tool, a dedicated national EGS registry, modeled on the NSQIP, is a critical next step and is currently being pursued [1, 47].

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Check for updates

2 Evaluating the Acute Abdomen

Sawyer Smith and Martin A. Schreiber

Introduction

Acute abdominal pain is one of the most common complaints leading to patients seeking medical care, accounting for between 5% and 7% of all US emergency department visits [1, 2]. Due to the frequency of patients presenting with abdominal pain and the vast number of causes, a thorough and directed evaluation is necessary to rule out causes that require emergent intervention from those that may be managed conservatively. A surgeon must start making their differential diagnosis from the moment they meet the patient; keying in on pertinent positives and negatives in the patient's history of presenting illness, past medical and surgical history, and the physical exam will narrow the possible diagnoses. Determining the gravity of the patient's current physiologic state through vital signs, laboratory tests, and imaging will identify the criticalness of the patient's illness and the speed at which intervention is necessary. A thorough understanding about the potential disease processes is also necessary for a surgeon to have to make sure that all possibilities for the patient's symptoms are accounted for so that the proper diagnosis leads to the most appropriate treatment for the patient in a timely manner.

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History

Taking a thorough, concise history is essential to narrowing the differential diagnosis of the patient's abdominal pain. A surgeon must ask the pertinent questions to help guide the decision-making, imaging choice, and ultimate management of the patient, while eliminating many other causes of abdominal pain. One must take into account not only the most common causes for a patient's symptoms, but rule out less frequent life-threatening causes or other diagnoses that the patient may be predisposed to due to their previous medical history or demographics. When asking questions about a patient's pain, below is a list of categories that are essential to delineate (Table 2.1):

- *Onset:* The timing of the patient's symptoms is important as typical problems present similar time cadences. The pain can either be immediate (onset in minutes), progressive (1–4 h), or indolent (4–24 h).
- *Location*: The surgeon must differentiate between localized and generalized abdominal symptoms. If the patient's pain is located in a

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specific area, this can help narrow the differential diagnosis. Localizing the symptoms to a specific quadrant will drive the next steps in evaluation and can lead to more specific lab and imaging tests. Generalized abdominal symptoms are worrisome for a more widespread process.

- *Quality/Character*: The type of pain (dull, sharp, electric, etc.) should also be elucidated. The physician should inquire about specific things that may improve or worsen the pain. Signs that point toward peritonitis include increased pain with movement, pain when hitting bumps while driving, or pain with coughing.
- *Radiation*: Certain pathology will classically have pain symptoms that radiate from one portion of the abdomen to other locations in the body. Pancreatitis typically radiates from the epigastrium to the spine. Urogenital pathology may radiate to the inguinal area or down into the scrotum of males.
- *Associated Symptoms*: Other symptoms in concert with severe abdominal pain such as nausea, emesis, diarrhea, constipation, hematemesis, or hematochezia are important to identify.

Table 2.1 Essential components of history taking

History of present illness
Onset
Location
Quality/character
Radiation
Associated symptoms
Past medial history
Past surgical history
Family history
Medications

Care should be taken to not just focus on the history of the present illness, but also on the patient's prior medical history. A careful medical history and review of systems will help identify any risk factors that the patient may have that either could be the cause of their presenting symptoms or contribute to their overall presentation. A cardiac history including any history of coronary artery disease or arrhythmias including atrial fibrillation would put the patient at risk for mesenteric ischemia from either thrombotic or embolic causes. Uncontrolled diabetes mellitus can blunt some abdominal pain symptoms due to neuropathy from chronic hyperglycemia. Prior history of malignancy or radiation would put the patient at risk for either recurrence of the primary tumor, metastatic disease, or radiation enteritis leading to their symptoms. A history of peptic ulcer disease would put the patient at risk for stomach or duodenal perforation or intraluminal hemorrhage. A thorough gynecologic history in female patients will help identify patients at risk for pelvic inflammatory disease, endometriosis, or ectopic pregnancy.

Nonsurgical causes of abdominal pain can be misleading. Etiologies include cardiopulmonary, metabolic, toxic ingestions, hematologic, immunologic, and infectious (Table 2.2).

A thorough surgical history should be obtained from every patient that is being worked up for surgical pathology but especially in the case of an acute abdomen. Knowledge of prior surgeries will give an understanding of any altered anatomy, identify any complications the patient may be at risk for, or eliminate certain pathology from consideration. Prior surgeries, such as bariatric procedures, can alter the patient's intestinal anatomy which can lead to many different

Table 2.2 Medical causes for acute abdominal pain

Cardiopulmonary	Metabolic	Toxic	Hematologic	Infectious
Myocardial infarction	Addison's crisis	Withdrawal syndromes	Sickle cell crisis	Gastroenteritis
Pericarditis	Diabetic ketoacidosis	Corrosive ingestion	Lymphadenopathy	Parasitic disease
Pneumonia	Hypercalcemia	Lead poisoning	Hemorrhage due to anticoagulants	Malaria
		Drug packing		Typhoid

pathological entities. An understanding of the patient's prior operations will also alert the surgeon to potential complications or pitfalls that will help with the planning and approach if the patient requires an operation. Lastly, prior surgeries can put patients at risk for hernias leading to incarcerated or strangulated bowel that should be added to the differential diagnosis.

Physical Exam

The physical exam of the patient presenting with acute abdominal findings begins as the surgeon walks into the room. Initial visual inspection of the patient's general appearance, position on the bed, and mannerisms will tell a great deal about their condition. Patients with peritonitis will often be ill appearing and moving minimally while patients with renal or biliary colic may be writhing in pain unable to get comfortable. Along with the initial inspection of the patient, vital signs (heart rate, blood pressure, respiratory rate, oxygen saturation, and temperature) should be noted. Severe intra-abdominal processes can push the patient into shock with inadequate tissue oxygen delivery. Patients in shock will be tachycardic and hypotensive and have decreased oxygen saturation. If shock is due to sepsis, hyperthermia or hypothermia may be present. These quick determinations of the patients overall appearance along with determining if the patient is in shock will help the surgeon determine if immediate action is needed to stabilize the patient or if there is time for further evaluation prior to determining the first treatment options.

A systematic physical exam should be performed with a focus on the heart, lungs, and abdomen. Cardiac and pulmonary exams are important not just to identify abnormalities that may lead to a nonsurgical diagnosis as the cause of the abdominal pain, but also to identify any comorbidities that may preclude or need further workup prior to the patient obtaining a general anesthetic if the patient requires surgery. Cardiac examination should identify any murmurs or arrhythmias, while the pulmonary exam should focus on overall work of breathing, equal breath sounds, and auscultation of crackles consistent with pulmonary edema.

The abdominal exam should start with inspection looking for abdominal distention, previous incisions, asymmetry, or any obvious deformities consistent with a hernia. Auscultation of the abdomen, although classically taught in physical exam, is not as helpful with abdominal pathology as it is for aiding in the diagnosis in other regions of the body. There is low sensitivity and specificity along with auscultative findings being inconsistent from surgeon to surgeon [3, 4]. Percussion of the abdomen can help identify organ enlargement (hepatomegaly or splenomegaly) along with being able to help identify any free fluid such as ascites. Palpation of the abdomen will identify any signs of peritonitis with voluntary or involuntary guarding. Signs of peritonitis can be either localized to a certain area of the abdomen or diffuse throughout the abdomen. When palpating the abdomen, the surgeon should also be assessing for masses, fluid within the abdominal cavity, and any abdominal wall defects.

Examination of the inguinal canal should be completed in every patient with abdominal complaints looking for signs of incarcerated or strangulated hernias. Hernias that are extremely tender, unable to be reduced, or have overlying skin erythema are concerning for containing compromised intestine. Rectal examination and stool-occult blood testing can identify either gross or microscopic intestinal bleeding. All female patients with acute abdominal symptoms, particularly lower abdominal complaints, should have a pelvic exam including both bimanual examination and a speculum examination to identify gynecologic causes of acute abdominal pain such as ectopic pregnancy, ovarian torsion, or pelvic inflammatory disease.

Depending on a patient's presenting symptoms, further maneuvers may aid in determining the diagnosis. Rebound tenderness can be an indicator of peritonitis. This maneuver is positive when the patient has increased pain upon release of pressure on the abdomen as opposed to when the abdomen is palpated. Rovsing's sign is another maneuver that is positive when the patient has pain in the right lower quadrant of the abdomen at the time of palpation in the left lower quadrant. This sign is associated with acute appendicitis. Murphy's sign is a physical exam maneuver that classically is associated with cholecystitis. This maneuver is performed by having the patient exhale completely, palpating deeply in the right upper quadrant, and then having the patient take a deep breath in. If the patient has severe increased pain and arrests inspiration, this points toward cholecystitis.

Laboratory Studies

Although the mainstay of the diagnosis of the patient who presents with an acute abdomen is the history and physical exam, laboratory tests can aid in determining the cause of the patients' symptoms. While these tests can help, they should be used as an adjunct to the information gained from the history and physical exam, not as the mode of making the diagnosis. Along with aiding in diagnosis, laboratory tests will also show any metabolic or hematologic abnormalities that may need correction prior to the patient undergoing surgery (Table 2.3).

A complete metabolic panel will identify any electrolyte disturbances such as sodium, potassium, or chloride abnormalities. These changes in electrolytes could be associated with the primary process (emesis or diarrhea) or secondary to kidney injury due to hypovolemia or sepsis. Electrolyte disturbances can have implications with anesthetics and should be addressed prior to taking the patient to the operating room.

Table 2.3 Necessary laboratory tests for patients with acute abdominal pain

Laboratory tests
Complete metabolic panel
Complete blood count
Lipase
Amylase
PT/INR
PTT
Urinalysis
Pregnancy assessment (females of child-bearing age)
Stool studies

Creatinine and blood urea nitrogen (BUN) levels will give the clinician information about the patient's renal function. Metabolic panels will also provide liver enzymes, bilirubin, alkaline phosphatase, and albumin levels. Liver enzymes and bilirubin may be elevated from hepatobiliary processes or due to ischemia from hypotension due to other causes. Lipase and amylase are elevated with pancreatic inflammation with lipase being more specific for pancreatic inflammation. Pancreatitis is most commonly due to gallstone disease in the Western population but also may be due to alcohol abuse, hypercalcemia, hypertriglyceridemia, or autoimmune disease.

Complete blood counts and coagulation panels can also aid in the diagnosis but are essential for any patient prior to surgery. The white blood cell count can be elevated or depressed from normal values due to sepsis from an intra-abdominal infection. Hemoglobin and hematocrit levels can be depressed if hemorrhage is present but also in the setting of chronic illness. The platelet count, prothrombin time/international normalized ratio (PT/INR), and the partial thromboplastin time (PTT) are the classic indicators used to evaluate coagulopathy. Thrombelastography (TEG) is also used at some institutions giving the surgeon generalized functional coagulation information. These coagulation parameters are imperative for both the surgical and anesthesia team to evaluate prior to any operation to help minimize blood loss and correct any underlying abnormalities.

Urinalysis is another important lab to obtain for any patient with abdominal pain. Identification of a urinary tract infection that could account for the patient's symptoms should be done prior to more in-depth and expensive tests. Stool studies such as occult blood tests, fecal leukocytes, and ova and parasite examination can be helpful with patients who have symptoms of hematochezia, melena, or diarrhea and concern for gastrointestinal infection.

Imaging Studies

As medicine has evolved, there are multitudes of imaging studies that are available, many of which have various roles in evaluating patients with acute abdominal pain. Again, imaging studies should be used to assist in the diagnosis or for surgical planning. The specific imaging studies to obtain should be determined after a thorough history and physical exam have been done. After the history and physical exam, a physician should be able to narrow the differential diagnosis which can then direct the necessary imaging studies to be obtained. Reducing unnecessary tests will reduce radiation exposure, false-positive/false-negative studies, and overall cost to the patient and the healthcare system [5].

Standard X-rays, or plain films, of the abdomen provide limited anatomical information but can be very useful in the right situation. These images can readily identify obstructive or nonobstructive intestinal gas patterns. Patients with small intestinal obstruction will typically have multiple dilated loops of small bowel in the central abdomen with air/fluid levels. Plain films should be obtained with the patient in the upright or lateral decubitus position to utilize gravity to allow for visualization of air/fluid levels, which will be less apparent or not visualized on a supine radiograph. Upright and lateral decubitus images will also allow for identification of free intraperitoneal air which can be present if perforated viscous is the cause of the patient's presentation (Fig. 2.1).

Fig. 2.1 Upright plain film of the abdomen with free intraperitoneal air that can be seen under the diaphragm

Giving patients contrast, either by mouth or by rectum, can be used to identify specific problems within the gastrointestinal tract (GI tract). Upper gastrointestinal series (UGI) is used to image the esophagus, stomach, and small intestine. This can help identify perforations within these portions of the GI tract, hiatal hernias, or bowel obstructions. Barium or water-soluble contrast (i.e., gastrografin) are generally the intraluminal contrast that the patient will drink for the study. If the patient is at risk for aspiration, water-soluble contrast should not be used as it can cause intense pulmonary edema as the osmotic pressure draws fluid into the alveoli. If there is a risk for perforation, then barium should not be used as leakage into the peritoneal cavity can cause an inflammatory response and barium can persist in the peritoneal cavity making future studies more difficult to interpret.

Ultrasound is another imaging modality that can be utilized to gain more information on a patient with an acute abdomen. Ultrasound is readily available, does not use radiation, and is inexpensive. The graded-compression technique is used when evaluating the abdomen with ultrasound, where the operator gradually increases the pressure to move the underlying fat and intestine out of the way. This technique can be used to identify free fluid, abscesses, or occasionally free intraperitoneal air which is represented by gas echoes that act as an obstacle to deeper imaging. Ultrasound is also the imaging modality of choice when patients present with acute right upper quadrant abdominal pain concerning for biliary pathology (Fig. 2.2). Although ultrasound has its benefits and is without radiation, it is operator dependent, and the reliability of the imaging is reliant upon the experience of the operator. Obese patients are also more difficult to image with ultrasound as the sound waves are less likely to penetrate the deeper, more dependent areas of the abdomen that are of interest.

Computed tomography (CT) is the mainstay for imaging of the acute abdomen as it shows the greatest anatomic and pathologic detail while being relatively quick to obtain. CT obtains axial slices of variable thickness, most commonly 5–7 mm, of the entire abdomen and pelvis. These images can be reconstructed to give the clinician multiplanar views of the abdomen, traditionally

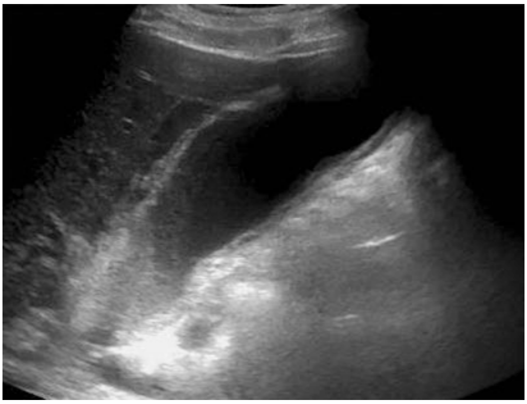

Fig. 2.2 Ultrasound of the gallbladder with a thickened perihepatic gallbladder wall, pericholecystic fluid, and sludge in the neck of the gallbladder in a patient with cholecystitis

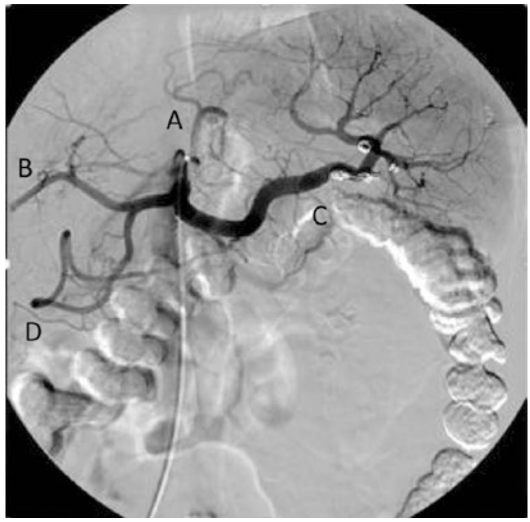

Fig. 2.3 Visceral angiogram showing the celiac truck with the left gastric (A), common hepatic (B), splenic (C), and gastroduodenal arteries (D)

coronal and sagittal images in addition to the originally obtained axial views. This allows for viewing of the abdomen from multiple viewpoints. These images can be enhanced with the use of intestinal (oral, rectal, or both) contrast with a water-soluble contrast agent or barium along with the use of iodinated contrast given intravenously (IV). Iodinated IV contrast should be used cautiously in patients with chronic or acute renal impairment; therefore laboratory examination of renal function with a current creatinine level should be obtained prior to administering the IV contrast. CT images can help identify perforations with either free intraperitoneal air or leakage of contrast material. Intestinal wall thickening indicates an inflammatory response which can be due to many different causes. Decreased IV contrast uptake of the intestine indicates ischemia in that area. Other pathology such as appendicitis, diverticulitis, neoplasm, obstruction, trauma, or foreign bodies can also be diagnosed using CT imaging.

Another method for evaluating the blood flow to the abdominal organs is visceral angiography (Fig. 2.3). This is generally performed through accessing either femoral artery and passing a catheter up through the abdominal aorta to visualize its branches. Contrast is deployed with subsequent visualization of the abdominal vascular supply. This method can be both diagnostic and therapeutic for ischemia. Stenosis, thrombosis, or emboli can be identified. When the lesion is located, intra-arterial thrombolysis and percutaneous transluminal angioplasty with or without stent placement are possible therapeutic interventions. Lesions that are not amenable to percutaneous interventions will give the surgeon specific information for operative planning. Visceral angiography can also be used for acute gastrointestinal hemorrhage, again for both therapeutic and diagnostic purposes. For visceral angiography to be able to locate the site of bleeding, the hemorrhage must be at a rate > 0.5 ml/min. If located, embolization can stop the ongoing bleeding. Patient factors must be taken into account prior to using angiography. Patients with iodinated contrast allergy or acute/chronic kidney disease may require either premedication prior to angiography or, depending on the severity, have absolute contraindications for angiography.

Nuclear medicine imaging tests also can be helpful in certain patients with acute abdominal pain. In patients with suspected cholecystitis and equivocal imaging, cholescintigraphy (HIDA scan) is a reasonable option. HIDA scan uses technetium-99 m iminodiacetic acid (Tc99m IDA) analogue to image the biliary system. This tracer is taken up by hepatocytes and then excreted into the biliary system. When the gallbladder does not fill with this tracer, obstruction of the cystic duct confirms the diagnosis of cholecystitis. False-positive studies may occur in patients who have been NPO for prolonged periods or who have extremely slow radiotracer uptake and biliary excretion by the liver.

Technetium-99 m-labeled erythrocytes can be used for scintigraphy, also known as a tagged red blood cell scan. This imaging modality is another option for localization of an acute gastrointestinal hemorrhage. This imaging study can be performed relatively quickly and only requires a bleeding rate > 0.1 ml/min for reliable detection of hemorrhage. Knowledge of the location of hemorrhage can help with planning for either endoscopic, angiographic, or surgical intervention. The tagged red blood cell scan is diagnostic and does not allow for therapeutic intervention. False-positive rates may be as high as 25% [6]. The most common reason for false-positive tests is rapid transit of intraluminal blood causing the imaging to indicate that the hemorrhage is more distal in the gastrointestinal tract than it actually is. Localization of GI hemorrhage is less accurate utilizing the tagged red blood cell scan compared to arteriography.

Differential Diagnosis

When approaching any patient, the surgeon should start formulating their differential diagnosis as they walk into the room. This holds true when evaluating the patient with acute abdominal pain. Formulating the differential diagnosis while taking the patient's history, observing the patient, and performing the physical exam will drive the surgeon's decisions on laboratory tests, imaging examinations, and ultimately the management decisions that will need to be made. The differential for acute abdominal pain can be broad, but applying physiology, the patient's history, exam findings, and diagnostic tests will help the surgeon narrow it greatly.

Differential diagnosis can be approached in many ways, but the most common methods are either by location of pain or by anatomical systems. A common method is to break the abdomen up into quadrants and narrow the diagnosis based on the location of the abdominal pain. The abdomen can be divided into the right upper, left upper, right lower, and left lower quadrants. While there are a number of pathologic findings that are not limited to one particular location in the abdomen, this approach can make certain diagnoses much less likely if the patient's symptoms are not in a typical location. If a patient's symptoms span multiple quadrants or are diffuse across the entire abdomen, this also narrows the options for a diagnosis as there are limited disease processes that will cause this type of diffuse pain.

Right upper quadrant abdominal pain is classically hepatobiliary in origin. Gallbladder pathology is the most common cause of right upper quadrant abdominal pain. Gallbladder causes generally are sequela of cholelithiasis, or gallstones, and can present along a spectrum of diseases. The most benign is symptomatic cholelithiasis, or biliary colic. This generally presents as pain after eating in the right upper quadrant but lacks any laboratory or imaging signs of inflammation of the gallbladder. If there is inflammation of the gallbladder, ultrasound imaging can show thickening of the gallbladder wall adjacent to the liver and pericholecystic fluid collections along with an elevated white blood count. Choledocholithiasis, or gallstones that are lodged in the common bile duct, can present with or without cholecystitis. Choledocholithiasis will also have ultrasound findings of a dilated common bile duct along with elevated bilirubin, aspartate aminotransferase (AST), alanine aminotransferase (ALT), and alkaline phosphatase from the obstruction of bile excretion from the liver. Gallstones can also lodge further down the biliary tree causing obstruction of the pancreatic duct leading to pancreatitis. Pancreatitis from gallstones can lead to intense pain and an inflammatory response and can present with or without signs of cholecystitis.

There are also non-biliary causes for right upper quadrant abdominal pain. Hepatic causes for right upper quadrant pain included acute alcohol intoxication, viral hepatitis, hepatic abscess (Fig. 2.4), and ruptured hepatic adenoma.

Processes involving the stomach or duodenum such as gastritis, gastroesophageal reflux disease, or peptic ulcer disease (Fig. 2.5) can also present with right upper quadrant pain. Pneumonia causing pleuritic pain may also cause pain in the right upper quadrant. Less commonly, but depending on the location of the appendix, appendicitis can rarely present with right upper quadrant pain instead of the more classic right lower quadrant pain. Right-sided colonic diverticulitis, although less common, can be a cause of right upper quadrant abdominal pain.

Fig. 2.4 CT axial image with a large hepatic abscess in the posterior aspect of the right lobe

Left upper quadrant abdominal pain is less common and has fewer causes than other regions of the abdomen. Pancreatitis can present with isolated left upper quadrant pain or in conjunction with epigastric or right upper quadrant pain. Peptic ulcers are much rarer in the fundus and cardia, which are located in the left upper quadrant, but still can occur. Pathology involving the spleen such as abscess, infarct, or rupture can lead to severe left upper quadrant pain. Rupture of the spleen is most frequently due to trauma but can occur spontaneously from splenic enlargement seen with portal hypertension or lymphoma. Infarcts of the spleen can occur in patients with sickle-cell anemia, generally in their youth, or in patients with hypercoagulable disorders. Splenic aneurysms can rupture and lead to intraperitoneal hemorrhage, a disease entity more commonly problematic in pregnant patients. Splenic flexure colorectal adenocarcinoma can lead to acute abdominal pain, generally once the mass has grown to a critical size causing obstruction.

Right lower quadrant abdominal pain is a common presenting complaint for patients, most often due to appendicitis (Fig. 2.6). Appendicitis can initially present with periumbilical pain that

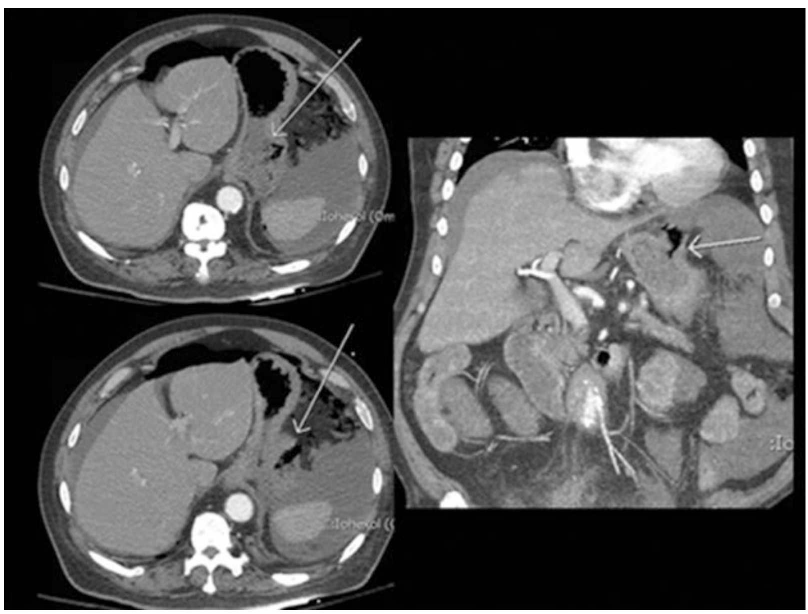

Fig. 2.5 Axial and sagittal CT images showing a perforated gastric ulcer (arrows) with extravasation of intraluminal fluid and air

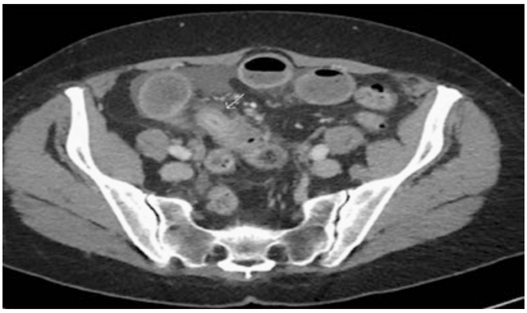

Fig. 2.6 Axial CT image showing acute appendicitis with thickened appendiceal wall (arrow) and surrounding fat stranding

migrates to the right lower quadrant, classically with pain over McBurney's point, or two-thirds of the way between the umbilicus and the anterior superior iliac spine. The pain can be associated with fevers along with nausea, vomiting, and anorexia that classically occur after the pain starts. Although appendicitis is a very common entity seen as the cause of acute abdominal pain in the right lower quadrant, there are a myriad of other causes that the surgeon must take into account and rule out prior to proceeding with operative management for appendicitis. Crohn's disease flares commonly occur in the distal ileum and can present with very similar symptoms and imaging showing inflammation similar to appendicitis. Meckel's diverticulum is a remnant of the omphalomesenteric duct and it occurs in about 2% of the population. This diverticulum is located in the distal ileum and can become inflamed leading to acute right lower quadrant pain. Sigmoid diverticulitis can also present with right lower quadrant pain in the patient with a redundant sigmoid. Urogenital disease processes such as pyelonephritis, perinephric abscess, urolithiasis, or urinary tract infections can all cause right lower quadrant pain. In female patients, gynecologic causes of right lower quadrant pain must also be excluded. For all female patients of childbearing age, pregnancy testing should always be part of the workup for any abdominal pain to rule out ectopic pregnancy, which can be a surgical emergency. This information is also critical as it could significantly alter the medical and/or surgical approach to the pathology responsible for the abdominal pain. Other gynecologic causes include ruptured follicular or corpus luteum cyst, ovarian torsion, pelvic inflammatory disease, or salpingitis. Infectious causes such as viral gastroenteritis, Yersinia infections, and mesenteric adenitis can all mimic appendicitis with acute right lower quadrant abdominal pain. Abdominal wall defects, such as ventral and inguinal hernias, can also cause acute onset of abdominal pain in this region if intestinal contents become incarcerated or strangulated within the hernia.

Causes of left lower quadrant abdominal pain include many of the disease processes that cause pain in the right lower quadrant with some variability in the likelihood of certain diagnoses. Diverticulitis of the sigmoid colon more frequently causes left lower quadrant pain (Fig. 2.7). Out-pouches of the colon, or diverticulum, are common in the Western population and increase in frequency with age. These diverticula can become inflamed and lead to localized pain, perforation, abscess, and more rarely gross contamination of the abdominal cavity. Similar to right lower quadrant symptoms, urogenital and gynecologic causes of pain along with abdominal wall defects can also present with left lower quadrant pain if the process occurs on the left side.

Many of the disease entities that can present with localized pain can also lead to more diffuse abdominal pain depending on the timeline of symptoms. Any cause of perforated viscus, whether it is due to a peptic ulcer, small bowel obstruction, appendicitis, or colonic diverticulitis, can lead to diffuse abdominal pain throughout

Fig. 2.7 Axial CT images of a patient with sigmoid diverticulitis and associated colovesicle fistula (arrow)

Fig. 2.8 Intussusception of the small intestine in the left upper quadrant (arrow) and proximally dilated bowel

any or all quadrants. The peritonitis that ensues when intestinal contents are spilled into the abdomen leads to a swift inflammatory response and the sensitive nature of the lining of the peritoneum can lead to excruciating pain. Inflammatory bowel disease, such as Crohn's disease or ulcerative colitis, can lead to diffuse abdominal pain. Intussusception is another entity, where a proximal piece of intestine telescopes into a more distal piece of intestine, which can cause obstruction and vascular compromise to the piece telescoping inside (Fig. 2.8). This can happen anywhere throughout the abdomen and therefore can cause pain in any location. Intestinal ischemia can also occur throughout the abdomen and lead to either localized or diffuse symptoms.

Management Considerations

After taking a history and performing a physical exam, reviewing the laboratory and radiographic results and narrowing the differential diagnosis, then the decision must be made on what to do for the patient. The ultimate decision will depend on many factors involving the patient's hemodynamic status, goals of care, and disease processes. While many causes of acute abdominal pain may require urgent surgical intervention, others may require a period of observation or be able to be managed nonoperatively. The patient and the surgeon should have a discussion to consider the options for management, outline what those options entail, the risks involved with each option, and answer any questions that the patient has about the proposed procedure or disease process. It is important to not just consider the immediate short-term expectations and risks, but what the long-term sequela and recovery period will be like for the patient and tailor it to consider the patients' other comorbidities. If the patient is unable to participate either due to prior medical conditions or altered mental status, then these discussions should take place with the patient's legal representative. Each state has laws that govern the hierarchy for which of the patient's family members or representatives would be in charge of making decisions for them if they are unable to and do not have a medical power of attorney or physician's order for life-sustaining therapy (POLST) already established.

Endoscopic interventions can be used to address a multitude of issues leading to acute abdominal pain. Esophagogastroduodenoscopy can evaluate any lesions in the esophagus, stomach, and duodenum (Fig. 2.9). Peptic ulcers, although less common now with the widespread use of proton-pump inhibitors, can be intervened on with endoscopy if they have not led to a perforation. For complicated gallstone disease, endoscopic retrograde cholangiopancreatography (ERCP) can also be used. This is especially useful in the patient who presents with acute abdominal pain and is found to have gallstone pancreatitis as relieving the obstructing gallstone from the ampulla of Vater in a timely manner is essential to reducing the morbidity. Foreign body ingestion can also lead to acute abdominal pain, and upper endoscopy can be used to remove many objects as long as they have not traveled past the duodenum into the jejunum. Colonoscopy also has a role in patients with acute lower gastrointestinal hemorrhage and can be diagnostic and therapeutic by either clipping a bleeding vessel or using other methods to stop hemorrhage.

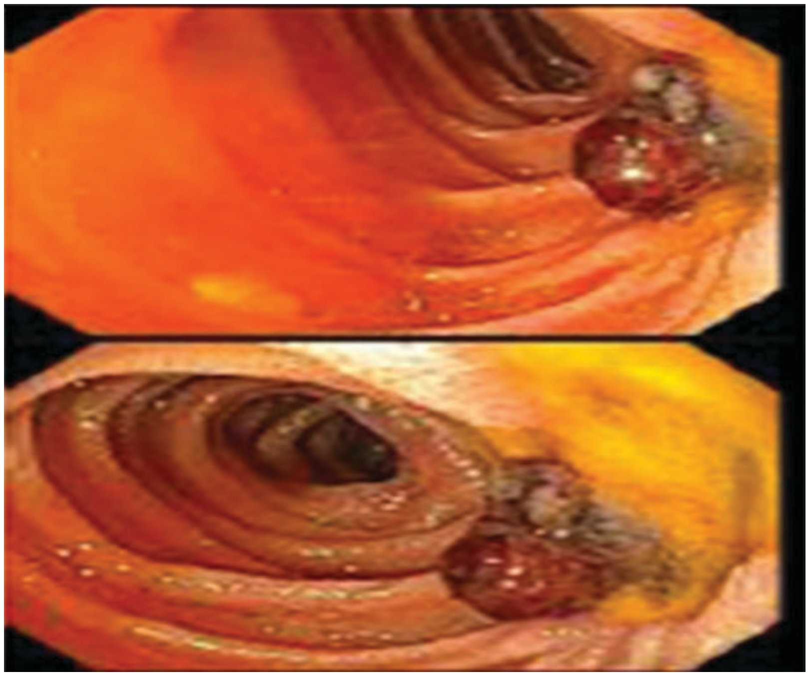

Fig. 2.9 Endoscopic images showing a duodenal ulcer with adherent clot

There are many disease processes that require surgical intervention to relieve the patient's symptoms. Appendicitis is one of the most common causes for acute abdominal pain and traditionally has been a disease process that has been managed surgically. There have been many studies and conflicting data, but some advocate for nonoperative treatment with antibiotics. Nonoperative treatment has higher failure rates but may avoid the risks of surgery in some patients [7, 8]. Acute cholecystitis is another very common cause of acute abdominal pain. For patients that do not have associated pancreatitis and are surgical candidates, operative cholecystectomy is the treatment of choice. In patients that are not good surgical candidates, due to other comorbidities or instability due to sepsis, cholecystostomy tube placement for decompression and source control is another option with the possibility of future cholecystectomy when the patient is more stable and optimized for the operating room.

Over the last few decades, a push toward more minimally invasive surgery with laparoscopy and now robotic-assisted laparoscopy has led to shorter hospitalizations and improved outcomes for many general surgery procedures. Although some patients presenting with acute abdominal pain are either not candidates or have contraindications for laparoscopy, minimally invasive techniques still have a large role in acute care surgery and patients with acute abdominal symptoms. Not only is laparoscopy generally used for common operations, such as appendectomy and cholecystectomy, it can also be used to explore the abdomen in a patient who still does not have a definitive diagnosis after their initial workup. Laparoscopy may be performed when certain pathology such as bowel obstruction, intussusception, or ischemic bowel is suspected but not confirmed with imaging. By starting with this technique, the surgeon can explore most parts of the abdomen quickly and, if no pathology is identified, only leave the patient with a few small incisions greatly reducing postoperative pain and morbidity. If concerning findings are identified on laparoscopic exploration, depending on the disease process, the patient's status, and the surgeons minimally invasive skills, the issue can often be addressed laparoscopically. If conversion to a laparotomy is necessary, this can be done easily and quickly. Patients who have had extensive prior abdominal operations are hemodynamically unstable, or if preoperative workup indicates the need for operative intervention that the surgeon does not feel can be completed laparoscopically, laparotomy is indicated.

Midline laparotomy is the approach for many patients who require surgical intervention after presenting with acute onset abdominal pain. Many disease processes will require an open approach, as opposed to the minimally invasive approach described earlier. But, it is not always the disease process that mandates a more invasive approach but rather the patient's condition. Patients with hemodynamic instability should not undergo laparoscopy. The insufflation of the abdomen with carbon dioxide reduces the venous return from the inferior vena cava and therefore decreases preload. This may worsen a patient's hemodynamics to a critical point and can lead to cardiovascular collapse. This increased intra-abdominal pressure with laparoscopy also may preclude laparoscopy in patients with underlying pulmonary disease causing hypercapnia as the increased pressure can make ventilation difficult. Patients who have had multiple prior abdominal surgeries also present an increased risk when performing laparoscopy and should be approached with an open operation due to likely dense scar tissue and risk of injuring the underlying bowel. Uncorrectable coagulopathy is also a contraindication to laparoscopic intervention due to the concern for not being able to control bleeding adequately that may occur. Although not an absolute contraindication, laparoscopy should be used with caution in patients with bowel obstruction and severely dilated small intestine due to the increased risk for iatrogenic injury.

The postoperative care of patients is a crucial part of their management. The care after the operation is as essential as any other step in the diagnosis or treatment. After undergoing abdominal operations, patients are at risk for many different complications, some inherent to the specific operation, but there are many that are ubiquitous to all operations.

Infection, mainly wound infections, is a common complication after abdominal surgery and is increased if there is leakage or resection of the intestine involved in the operation. Wounds should be examined daily for signs of infection such as erythema, increased pain, or drainage. Patients are also at risk for other infections such as pneumonia or urinary tract infections. Respiratory care with incentive spirometry, early mobilization, and adequate pain control to facilitate deep breathing and coughing are key to reducing the risk of pneumonia. Proper Foley catheter insertion and care help reduce the risk of urinary tract infections, and early removal of the Foley postoperatively is critical. Intra-abdominal infections can also be seen after abdominal operations, and again the risk is increased if there is gross contamination or resection of bowel is necessary. If a resection and anastomosis is performed, there is a risk that the new anastomosis may leak postoperatively.

Surgery and immobilization also puts patients at risk for deep vein thrombosis (DVT) and pulmonary embolism (PE). Hospitalized patients who have decreased mobility after surgery should be placed on prophylactic anticoagulation with either unfractionated heparin, low-molecular-weight heparin, or fondaparinux [9]. DVT can cause morbidity with leg swelling and pain due to venous congestion, but the concerning sequela of DVT is dislodgement of the thrombosis leading to pulmonary embolism. Other postoperative complications include myocardial infarction, intra-abdominal adhesions leading to bowel obstruction, hernia at the site of the incision, or injury to other intra-abdominal organs that were not involved in the original operation.

Special Populations

Certain populations of patients are at increased risk of developing particular disease processes or have distinct considerations that a surgeon must take into account when caring for them. These populations can also require variations in postoperative management that may influence their ultimate outcome.

Elderly patients are becoming an increasing demographic and require more medical care than their younger counterparts. Elderly patients are more likely to be frail and malnourished and have more comorbidities than younger patients which puts them at higher risk for postoperative complications. Frailty in elderly patients requiring an emergency surgical procedure is associated with increased mortality, ICU and total length of stay, institutional discharge, and cost of care [10]. One particular postoperative complication that occurs commonly in the elderly is delirium after general anesthesia which affects around 20% of patients >65 years in the general emergency surgery population [11]. Using minimally invasive techniques, nonnarcotic pain control, radiologic interventions, and early recognition of symptoms can lead to improved outcomes in the elderly experiencing delirium.

The pregnant patient also brings unique challenges to dealing with an acute abdomen. Pregnancy causes many different physiologic changes in the mother and adds the extra element of the care for the unborn fetus while approaching these patients. While there can be diagnostic challenges when working up a pregnant patient with acute abdominal pain, it is important to decrease any fetal risk when possible but never at the expense of the safety of the mother. When working up a pregnant patient with acute abdominal pain, the imaging test of choice is ultrasound whenever possible as this does not expose the fetus to radiation. While it is important to minimize the radiation to the fetus, critical imaging such as CT can be done with reasonable risks of future malignancies [12]. While there are risks of general anesthesia to the fetus, current recommendations support proceeding with an indicated operation regardless of term of pregnancy. Postponing necessary surgery until after the baby is delivered can lead to increased complication rates for both the mother and fetus.

When a pregnant patient requires an operation, there are a few very important things to consider. Patient positioning is very important, and pregnant patients in the supine position should have a bump placed under their right flank to reduce the pressure on the IVC from the gravid uterus when laying supine and facilitating venous return. Laparoscopy can safely be performed in the pregnant patient regardless of term of gestation. Entrance into the abdomen should be done using an open (Hasson) technique, and adjustment of port placement should take the fundal height into account. Insufflation pressures during laparoscopy should be maintained between 12 and 15 mmHg. Prior to taking a patient to the operating room, consultation with the obstetrics team and discussion of intraoperative fetal monitoring should also be considered. Current recommendations recommend against prophylactic tocolytic therapy, but these should be initiated if there are any signs of preterm labor preoperatively, during the operation, or postoperatively [13].

Another population that can present a unique set of challenges for a surgeon evaluating acute abdominal pain is the immunocompromised patient. Whether the immunodeficiency is congenital or acquired from malignancy, acquired immunodeficiency syndrome (AIDS), post-organ transplantation, or chronic steroid use, these patients can present with severe pathology but only minimal symptoms and therefore require a thorough workup. These minimal or atypical presentations are due to the depressed immune response that these patients will mount. Due to this, immunocompromised patients can decompensate quickly. Patients with intestinal lymphoma leading to perforation are not uncommon and this may be the presenting event. Other types of therapies the patient may need in the near future, such as chemotherapy for lymphoma, should be taken into consideration if resection of bowel is necessary as this may affect the decision to make an anastomosis or opt for an ostomy.

Conclusion

When evaluating a patient who presents with acute abdominal pain, the surgeon must be thorough and systematic in their approach. Outcomes for many patients presenting with acute abdominal pain rely on prompt and accurate diagnosis and proper management. Some of the most difficult decisions a surgeon will make are when to and when not to operate. The ability to take a focused history, perform a proper physical exam, and know what confirmatory laboratory and imaging studies is the key to elucidating the correct management. Early diagnosis and management is critical to reducing morbidity in patients presenting with acute abdominal pain.

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Imaging in Emergency General Surgery

3

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The modalities of imaging patients with abdominal pain vary greatly. From plain film X-rays to nuclear imaging, all tests must be pertinent, sensitive, and specific in that they will change management depending on their results. The quickest exams such as a chest or abdominal X-ray may show signs of an emergent pathology which preclude further, more time-consuming, and expensive imaging. However, if initial tests are negative, more powerful tools such as ultrasound, multidetector computed tomography (CT), or magnetic resonance imaging (MRI) may be needed. Nuclear imaging has a role in further delineating the pathology if these subsequent studies require further characterization. Invasive radiologic procedures can be ordered as well, such as endoscopic ultrasound (EUS) and endoscopic retrograde cholangiography (ERCP) and angiography (Table 3.1).

Generalized Abdominal Pain

Abdominal pain in the acute setting can be a diagnostic challenge for which radiologic tests become increasingly useful. The most common causes of the acute abdomen are appendicitis, bowel obstruction, urinary tract disorders, and diverticulitis [1]; however when a physical exam fails to localize pain and laboratory tests cannot predict the most likely pathology, the recommended imaging is a CT scan with IV contrast. In a prospective study of 584 patients, CT improved diagnostic certainty to 92% from 70.5% and altered management in 42% of cases. In that study, 24.1% of patients who were planned to be admitted but subsequently underwent a CT scan were able to be discharged due to the findings on imaging [2]. Given the clinical suspicion, postsurgical/trauma state, chronicity, or underlying comorbidity, this can be altered to forgo or include oral contrast. A CT scan with IV and oral contrast may aid in visualizing mucosal pathology which can be common in the immunocompromised or HIV-/CMV-infected patients. Multiple studies have shown CT scans for acute abdominal pain do not require oral contrast, however, as most radiologists determine that no further information would have been provided by enteric contrast [3, 4]. Additionally, omitting oral contrast speeds throughput in the emergency room, and rarely do patients require additional imaging

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Table 3.1 Types of radiologic imaging

Modality	Common indications	Possible limitations
Chest X-ray	Perforated viscus Hiatal/paraesophageal hernia	Limited view of the abdomen, nonspecific
Abdominal X-ray	Small bowel obstruction, ileus, large bowel obstruction	Nonspecific
CT/CTA scan	All the above + inflammatory disease, mesenteric ischemia	Ionizing radiation, contrast allergy/reaction, expensive
MRI/MRA	Assessing the pregnant patient, chronic mesenteric ischemia, bile duct continuity	Slower, more time consumptive, expensive
Ultrasound	Cholecystitis, appendicitis	Operator dependent, body habitus dependent, does not view the entire abdominal field

CT computed tomography, *CTA* computed tomography angiography, *MRI* magnetic resonance imaging, *MRA* magnetic resonance angiography

due to a lack of oral contrast [5]. The advantages of a CT scan are that it can visualize most structures well and can detect many acute surgical pathologies. Smaller droplets of air, particularly located at the mesentery root, are best imaged through a CT scan compared to abdominal X-ray. Bowel wall edema, bowel distention, and ischemia as well as transition point locations are all best imaged on CT scan [6].

Fluid radiodensity is of particular interest to emergency general surgeons as it allows the differentiation between simple fluid and blood. The radiodensity is measured by Hounsfield units (HU) where water is 0 HU and air is −1000 HU. Fluid can measure anywhere between 0 and 50 HU, whereas a hematoma may measure approximately 45–65 HU. Bile, blood, and other fluids have ranges where the radiologist or surgeon can make a reasonable differential regarding the fluid, in some reports finding that <43 HU is sensitive for bowel perforation in blunt trauma [7]. Infections cannot be reliably predicted in this manner, but the presence of gas, loculation, or rim enhancement around a collection can all be signs of an infection or abscess. The postoperative period may make free intraperitoneal fluid more or less concerning depending on the operation and scenario and characterization of this fluid.

Other imaging modalities can be sought if presented different clinical situations. As will be discussed in their respective sections, suspected appendicitis and cholecystitis warrant an ultrasound of the right lower or right upper quadrant as their initial imaging. Due to the poor specificity of abdominal plain films, KUB X-rays are not the recommended primary imaging modality. Kellow et al. reviewed a series of more than 800 patients and found that abdominal X-rays obviated follow-up imaging in as little as 4% of patients and aided in diagnosis in only 2–8% [8]. The pregnant patient should undergo ultrasound or MRI rather than a CT as to avoid radiation. However, recent literature as shown that CT scans in the pregnant patient are safe with limited use and after nonionizing studies are deemed inconclusive. If a patient exhibits ongoing sepsis with an unclear source on CT scan, nuclear imaging with a tagged WBC abdominal scan to locate infection and/or abscesses may be used. Neutropenic patients may benefit from immediate CT scan due to their unreliability to develop leukocytosis or peritonitis on physical exam. However, a CT in this patient population rarely alters nonoperative intentions as most patients will likely have a medically treated disease such as enterocolitis or typhlitis [9].

Due to the emergent nature of these surgical pathologies and patients, imaging can help stratify risk using the American Association for the Surgery of Trauma (AAST) grading system, allowing the emergency patient to be distinguished from the elective case [10].

Stomach and Duodenum

Radiological exams should focus on ruling in or out inflammation, perforation, volvulus, hernia, ischemia, and obstruction; however there are many pathologies which may cause pain from a gastric or duodenal source.

Gastroduodenal Perforation

The stomach may perforate from ulceration, cancer, ischemia, or post-chemotherapy treatment and other pathologies which present as pneumoperitoneum on imaging. The first step in evaluation of the upper GI tract is usually through upright chest X-ray (CXR) or a KUB (kidney, ureter, and bladder X-ray), most likely in the AP (anterior-posterior) view. Although this imaging modality tends to be of lower sensitivity and falsely enlarges structures closest to the X-ray source (such as the heart), it is ideal for critically ill patients who cannot stand upright for long periods of time required for the PA (posterior-anterior) view. The pathognomonic sign for a perforated viscus is pneumoperitoneum, commonly referred to as "free air," which is gas presumably from the intestinal tract within the peritoneal cavity. The presence of free air and peritonitis on abdominal exam is a surgical emergency, and one may proceed to the operating room with the suspicion of a perforated viscus; however, further imaging can aid with operative planning in the stable patient. Demonstration of a perforation can be achieved via CT scan with IV contrast if ischemia/ulceration is suspected, with the ability to enhance the bowel walls. In this setting, oral contrast can be omitted as it does not increase the sensitivity of demonstrating a leak (19–42%) and can mask nonopacification of the bowel wall. In a study of 85 patients with pathologically confirmed perforations, radiologists could accurately locate the perforation in 86% of the patients on preoperative CT scan without oral contrast [11].

Nonvariceal Upper Gastrointestinal Bleeding

Treatment for gastrointestinal hemorrhage centers around stabilizing the patient and locating the site of the active bleed. History, presentation, and gastric lavage can aid in locating the bleed. Esophagogastroduodenoscopy (EGD) within 24 h is recommended for both definitive diagnosis and simultaneous treatment [12]. Multiple randomized controlled and retrospective studies have shown no benefit to early (within 6 h) endoscopy compared to endoscopy before 24 h from diagnosis [13, 14]. These studies enroll different patients with discrepancies between their Rockall and Glasgow Blatchford scores but overall confirm this finding. Early endoscopy does however have a higher likelihood to finding an actively bleeding vessel and a high incidence of hemostatic intervention by the endoscopist [15]. If EGD is performed and upper GI blood is found but the exact location is not delineated, CT angiography (CTA) of the abdomen is useful. The advantage over conventional angiography is that CTA can detect multiple sites of bleeding simultaneously, even if they are anatomically distant from each other [16]. CTA can detect acutely bleeding sources at rates from 0.3 mL/min, whereas conventional angiography may be slightly less sensitive at 0.5 mL to 1 mL/min [17]. In the setting of a bleed which is definitively found by endoscopy, but cannot be controlled, angiography and transcatheter arterial embolization (TAE) is the preferred treatment.[9]

Gastric Volvulus

The stomach may rotate upon two different axes to cause a mechanical obstruction and ischemia. Urgent decompression and detorsion is needed and as such, recognition must occur rapidly. Given the constellation of symptoms such as retching, epigastric pain, and inability to pass a nasogastric tube (Borchardt's triad),

Fig. 3.1 CT scan showing organoaxial gastric volvulus with massive gastric distension

Fig. 3.2 CT scan showing gastric outlet obstruction with a distended stomach and decompressed small bowel

plain films can be ordered first. Gastric volvulus can be seen on chest X-ray and/or abdominal X-ray as a distended portion of the stomach with an air-fluid level and decompressed duodenum and small bowel. If necrosis or perforation is suspected, a CT scan with IV contrast may help visualize an under-perfused or frankly ischemic stomach wall as well as an abscess (Fig. 3.1). An upper GI fluoroscopic series can delineate the type and severity of volvulus: the twisting occurring upon the organoaxial or mesoenteroaxial axis as well as if contrast passes through the twisted portion. A volvulus may also be associated with paraesophageal hernia with herniated intrathoracic stomach, colon, or spleen.

Gastric Outlet Obstruction

This pathology had been a more prevalent etiology of upper abdominal pain and bloating; however since gastric acid suppression therapy, chronic strictures due to ulceration have declined. Along with an upright CXR, the absence of passage of oral contrast on either upper GI series or CT scan with PO contrast is indicative of gastric outlet obstruction (Fig. 3.2).

Small Bowel

Small Bowel Obstruction

Suspected SBO is a frequent emergency surgical consultation. Most commonly caused by postoperative adhesions or hernias, a thorough physical exam is mandatory. Should a hernia be found, it can be rapidly dealt with; however in the absence of an overt hernia, radiologic exam is warranted. There is controversy with diagnosing an SBO on plain film X-rays vs immediately obtaining a CT scan. A CT with IV contrast can yield the most pertinent information as radiologists are able to adequately predict a need for surgery based on image characteristics [18]. If a high-grade SBO or an SBO with ischemia is suspected, oral contrast should *not* be given. Dilation of the small bowel >3 cm is concerning as well as the presence of a transition point, free fluid, and mesenteric edema. Small bowel fecalization (“small bowel feces sign”) may represent functioning bowel, a reassuring sign; however this also portends slow transit through the small bowel [19].

Pathways requiring imaging to calculate the probability of an SBO requiring operative management have been proposed. Zielinski et al. found statistically significant features on CT scan were mesenteric edema, the lack of a small bowel feces sign, as well as a history of obstipation [20]. It is important to note most studies that use radiologic criteria to stratify risk for SBO exclude patients with peritonitis and/or findings of ischemia on CT. Also, a CT scan is not adequately sensitive for detecting early ischemia; however when the aforementioned signs are present, it is very specific for ischemia; one must rely on clinical judgment if findings are equivocal [21]. Only in the setting of a stable patient with an intermittent or low-grade SBO should oral contrast evaluate the bowel and/or be given as per a small bowel follow-through protocol or pathway [22]. In this setting, undiluted oral contrast can be followed with serial KUBs until it reaches the colon, usually within 8 h; however any time before 24 h is considered successful. This can be ~92% sensitive and specific for nonoperative resolution of the SBO [23]. The usage of oral contrast does have controversy within the literature, as most emergency surgical pathologies do not require opacification of the bowel lumen. However, there are still possible benefits of oral contrast as outlined by Kammerer et al., suggesting careful patient selection is required to obtain meaningful use. They argue that bowel edema, inflammation, and bowel delineation from surrounding structures, especially in thinner patients without much mesenteric fat, may benefit from oral contrast [24]. Oral contrast used as a cathartic is also a therapeutic option in those without the suspicion of ischemic bowel or strangulation. A closed-loop bowel obstruction is an entity which should be recognized early and treated quickly. A segment of the bowel with two transition points, a lumen narrowing or "beak sign," a radial pattern of mesenteric vasculature, and a "U/C" shape of the bowel are characteristic of a closed-loop obstruction [25] (Fig. 3.3). In patients with diffusely dilated small bowel, a CT can differentiate between an ileus reliably, with a sensitivity and specificity approaching of 90%. An Ileus is radiologically defined as distention of both the small and large bowel without a clear transition point. Non-passage or oral contrast through the intestinal tract can also detect adynamic ileus. MRI for intestinal obstruction is reserved for the pediatric or pregnant population but should be pursued if all other tests are inconclusive.

Fig. 3.3 Closed-loop SBO with free fluid

CT enterography has questionable value in SBO, as some patients cannot tolerate large volumes of liquid [26].

Mesenteric Ischemia

One of the most worrisome pathologies which causes diffuse abdominal pain is acute mesenteric ischemia, commonly caused by embolism or thrombosis of the superior mesenteric artery. Nonocclusive mesenteric ischemia is caused by a generalized low-flow state to the intestines. In the clinical setting in which mesenteric ischemia is suspected, the recommended first-line imaging is a CTA of the abdomen and pelvis [27]. The CTA will reveal the site of embolism or thrombosis, stenosis, or dissection (Fig. 3.4). A venous phase CT will reveal mesenteric venous thrombosis as well. Bowel characteristics of ischemia can

Fig. 3.4 Superior mesenteric artery embolism (arrow) causing acute mesenteric ischemia

include wall thickening, hypoattenuation, portal-venous gas, pneumatosis, and mesenteric stranding. With the findings of vessel abnormalities and the latter findings of bowel ischemia, the sensitivity and specificity of a CTA reach 94% and 96%, respectively [27]. Conventional angiography is considered if preoperative planning is needed; however given the acuity of the ischemia, this is usually forgone to allow for rapid operative treatment. Magnetic resonance angiography is generally not recommended as it has a poor sensitivity to detect distal thrombus or emboli [28].

Large Bowel

Appendicitis

Along with a compelling history and physical, imaging can diagnose appendicitis in the vast majority of cases with an acceptable negative exploration rate. In the setting of an unclear exam, imaging becomes the underpinning of diagnosis – in some reports cutting the negative appendectomy rate from 16% to 8% [29]. The current guidelines for imaging a patient with suspected appendicitis begins with a right lower quadrant ultrasound. Ultrasound is a very useful technique but is highly operator dependent and relies on favorable anatomy and anatomic windows. In combination with a high Alvarado score, findings such as a dilated and noncompressible appendix, hyperemia, and free fluid on ultrasound can approach sensitivity and specificity of CT scan [30]. It is reserved as the sole modality for those who wish to avoid radiation such as the pediatric and pregnant population before an MRI. If the ultrasound is inconclusive, a CT with IV contrast is recommended as the sensitivity is near 90% and specificity is about 95% [31]. Evaluation by a surgeon should be carried out before ordering a CT scan in children or young adults due to the relatively benign nature of diagnostic laparoscopy and availability of MRI. PO contrast should only be given if IV contrast cannot be used. CT is also beneficial in that perforation, phlegmon, typhlitis, or a fecalith can be visualized and alter the treatment plan from surgery to medical management or vice versa. The anatomic position of the appendix can also be seen, facilitating surgical planning (retrocecal, malrotation). MRI is reserved for pregnant patients; however it should be noted that appendicitis in the pregnant patient is an emergency, mandating a STAT MRI. If an MRI cannot be obtained, a CT scan while pregnant is thought to be safe, as previously stated in the Generalized Abdominal Pain section.

Diverticulitis

Diagnosing and staging the severity of diverticulitis depends on radiographic evidence of inflammation of the colon and any associated abscesses, free fluid, or air. Thus, a CT scan with IV contrast should be ordered in this scenario. The IV contrast is used to delineate the bowel wall and any abscess cavities. If used, PO contrast can differentiate diverticular pockets from adjacent abscesses – in some cases aiding in percutaneous