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Acute Appendicitis Diagnosis and Treatment in 2009: Part I

The emergency department assessment of appendicitis has sure changed a lot in the past 30 years. I remember when the presence of less than one day of right lower quadrant pain, nausea, vomiting, localized tenderness and guarding, and a white count of 13,000 was enough to get the surgeon out of bed and the patient into the operating room. Conversely, patients with less than "classic findings" were either admitted for serial examinations or told to go home and come back in 12 hours for re-examination. In both circumstances, there was an understood and acceptable "miss rate"; a number of patients taken to the operating room with the clinical diagnosis of acute appendicitis would have a normal appendix on pathologic examination, and some patients would have appendicitis diagnosed on their second emergency department visit. We all understood and accepted these facts as we exercised our clinical judgment to balance the risks of operating too leniently and removing more normal appendices or operating too strictly and increasing the rate of perforation and abscess formation.

Not anymore. Now, it seems as if a surgeon will not come in until the distended and inflamed appendix is visualized on advanced imaging modalities. Likewise, patient expectations and retrospective professional judgment often criticize the emergency physician for missing even one case of the most obscure presentation of acute appendicitis. Like much of our popular culture, we want the diagnosis of appendicitis to be right, and right now. We don't easily tolerate uncertainty or delays.

Like a good book, the story of acute appendicitis deserves periodic re-reading. In the first of a two-part series, this issue will discuss the presentation and diagnosis of acute appendicitis, with an emphasis on the use of current imaging modalities.

—J. Stephan Stapczynski, MD, FACEP, Editor

Epidemiology and Overview

Acute appendicitis is the most common surgical emergency in the United States, with an occurrence rate of about 80-90 per 100,000 persons each year.[1] Because almost all patients with strong clinical evidence of appendicitis undergo appendectomy, the occurrence rate of acute appendicitis is based on the pathologic examination of the removed appendix. However, not all removed specimens demonstrate disease. A study of appendectomies performed between 1997 to 2003 in the United Kingdom is typical of this observation.[2] Overall, only 65% of cases showed pathologic evidence of acute appendicitis. The peak incidence of pathologically confirmed acute appendicitis was in the second decade of life. There was evidence of perforation in 14% of all patients, with a significantly higher rate in those older than 70 years of age. The negative ("no pathologic evidence of acute appendicitis") appendectomy rate was 29% in all patients, with a significantly higher rate in female patients and in the 11- to 30-year-old group.

Making the diagnosis of appendicitis in a timely manner is important to prevent unnecessary morbidity and mortality and limit potential medico-legal exposure from a risk management standpoint. Missed appendicitis is one of the most common reasons for malpractice litigation in emergency medicine.[3] In a recent review of a large insurance company database of malpractice claims, appendicitis was

Executive Summary

- The most sensitive findings in acute appendicitis are right lower quadrant abdominal tenderness, nausea, and anorexia.
- Clinical scoring systems are useful for risk stratification but not for excluding the diagnosis.
- US, CT, or MRI is most useful in equivocal cases or patient groups with multiple possible alternative diagnoses.
- With rapid helical and multidetector CT scanning, oral contrast is not necessary for the detection of acute appendicitis.
- Intravenous contrast is of some additional utility in the CT detection of acute appendicitis, especially in thin patients with little intra-abdominal fat.
- The CT scan is useful for making the diagnosis of acute appendicitis ("ruling-in"), but a normal or negative CT scan is less useful for excluding ("ruling-out") the diagnosis.
- Ultrasound is a useful imaging study in pregnant women and children with suspected acute appendicitis.

second only to meningitis as the most common diagnosis involved in pediatric malpractice claims.[3]

Anatomy

The appendix is an outpouching of the cecum, usually located in the right lower quadrant. Unlike the adjacent bowel, the appendix contains lymphoid follicles, but no immunologic function has ever been demonstrated. The exact position is variable; it may be retrocecal, pelvic, subcecal, preilial, postilial, or paracolic. In a classic study of 10,000 post-mortem cases, retrocecal was the most common location (65%).[4] The length is 2-20 cm, with an average length of 9 cm. The lumen is small relative to its length.

Sixty-nine percent of cases of perforated appendicitis involved a retrocolic location of the appendix in one study.[5] It commonly has been thought that the presence of overlying bowel delays the development of pain and detection of tenderness when the appendix is in this retrocecal location and leads to potential diagnostic delays. Like other aspects of conventional wisdom, this belief is not supported by the published data; a retrocecal location for acute appendicitis does not differ in the duration of symptoms, presenting signs and symptoms, initial white blood cell count, or rate of perforation compared with an anterior location.[6,7] As discussed later, a non-anterior location of acute appendicitis may present with additional symptoms or signs, but usually not different ones.

The innervation is from the autonomic nervous system. No somatic pain fibers are found in the appendix itself. The pain is poorly localized initially; when the adjacent parietal peritoneum becomes inflamed, the somatic pain fibers are activated and the pain becomes more localized.

Pathophysiology

The classic hypothesis describes obstruction of the lumen by a fecalith or lymphoid hyperplasia that causes an increase in intraluminal pressure. This leads to venous hypertension and ischemia of the appediceal wall, with resultant bacterial invasion of the appendix with necrosis and perforation. However, luminal obstruction is found only in a minority of cases. Additionally, direct measurement of the intraluminal pressure at appendectomy reveals an elevated pressure in only a few cases.[8]

The reality is that any one of several inciting events such as luminal obstruction, bacterial or viral enteric infection, or trauma may initiate the breakdown of the appendiceal mucosa, resulting in bacterial invasion from normal flora and appendicitis. Fecaliths are found only in 8-44% of cases of acute appendicitis.[9-11] Lymphoid hyperplasia is more common in noninflamed appendixes than in acute appendicitis.[12]

In 75% of appendicitis cases, well defined superficial mucosal ulceration is seen. Mucosal ulceration is a more consistent finding than dilatation of the appendix or fecaliths and is found earlier in the course of acute appendicitis.[13]

No specific infectious agent has been linked to appendicitis, although lymphoid hyperplasia can occur due to any number of infectious agents, including viral, salmonella, or shigella. Flora in the normal appendix are similar to that in the colon, including a variety of facultative aerobic and anaerobic bacteria such as *E. coli*, *Strep. viridans*, *Bacteroides* species and *Pseudomonas* species.[14]

Clinical Presentation

The cornerstone of the diagnosis of acute appendicitis traditionally has been the combination of history and physical examination. Timely diagnosis of appendicitis is important, as the delay in diagnosis and treatment can transform a simple case of appendicitis into a complex case of perforation and abscess. Unfortunately, the overall accuracy of the clinical examination in diagnosing acute appendicitis has been reported to be 70-87%. This falls to 54-70% in children and 50-70% in women of child-bearing age.[15-17] Clinical diagnosis alone in women is particularly problematic due to the possibility of multiple alternate diagnoses that may have a similar presentation. Elderly patients and children may present diagnostic challenges as well.

Classically, the pain begins in the umbilical or epigastric region of the abdomen. It usually is vague and nagging in character, sometimes described by patients as similar to intestinal gas or the need to defecate. The pain later becomes more intense and, usually between 12-24 hours,

Table 1: Alvarado/MANTRELS

Variables	Score
Migration of pain to RLQ	1
Anorexia	1
Nausea/vomiting	1
Tenderness in RLQ	2
Rebound pain	1
Elevation of temp (> 37.3°C)	1
Leukocytosis (WBC> 10,000)	2
Shift of WBC to left (> 75% polys)	1
	10

Table 2: Pediatric Appendicitis Score

Variable	Score
Migration of pain to RLQ	1
Anorexia	1
Nausea/vomiting	1
Temperature > 38°C	1
Cough/percussion tenderness	2
RLQ tenderness	2
WBC > 10,000	1
Polys > 7500 cells/mm^3	1
	10

localizes to the right lower quadrant. Migration of the pain from the epigastric or mid-abdomen to the right lower quadrant is common in appendicitis.[16] This pain is of visceral origin, and it radiates to the part of the abdomen supplied by somatic sensory fibers associated with the same segment of the spinal cord that receives visceral sensory fibers from the associated visceral organ.[19] Afferent sensory nerve fibers from the appendix accompany the sympathetic nerve fibers to the T10 segment of the spinal cord. This explains why the onset pain often is in the epigastric region.[19]

Nausea and/or anorexia in a previously healthy person are so common that appendicitis may be considered unlikely if both of these are absent. Vomiting also occurs frequently with appendicitis, but characteristically only several hours after the onset of pain.

Physical examination of a patient with suspected appendicitis begins with an examination of the vital signs. Fever is variably present in uncomplicated cases of appendicitis.[20] One prospective case series found that temperatures greater than 99°F had only a 47% sensitivity and 64% specificity for appendicitis. This implies that the presence of a fever makes the diagnosis of uncomplicated appendicitis less likely.[20] The presence of a fever may indicate perforation and abscess formation. Other vital signs should be normal unless more severe disease is present and the patient is becoming septic. In that case, variable degrees of tachycardia, hypotension, and tachypnea may be present.

Abdominal tenderness is the most common finding on examination and occurs in more than 95% of patients with appendicitis.[21] The point of maximal tenderness usually lies directly above the inflamed appendix, most commonly at McBurney's point. The appendix may rotate and lie at any point around the base of the cecum. This may change the location of maximal tenderness. Once perforation occurs, the pain usually becomes more intense and more diffuse.[22]

Signs classically associated with appendicitis include the psoas, obturator, and Rovsing's signs. However, the psoas and obturator signs occur in fewer than 10% of patients with appendicitis, and their absence does not exclude the diagnosis.[21] The presence or absence of any of these signs should not be used to rule out the diagnosis of appendicitis.

Peritoneal signs may become apparent on examination as the peritoneum becomes inflamed. Early in the disease course, peritonitis will be localized to the area overlying the appendix. When the appendix ruptures, tenderness and peritoneal findings become more generalized. Lin et al conducted a retrospective chart review of 202 patients with surgically proven appendicitis and found that peritoneal signs were 63.5% sensitive and 57.3% specific for appendiceal rupture.[23] Another study of adults presenting with right lower quadrant pain found that rebound and percussion tenderness, respectively, were the most sensitive (82%) and specific (86%) ways to detect peritoneal irritation on examination.[24] Physical examination may be least useful in certain populations such as young children, the elderly, immunocompromised patients, and pregnant patients as their physical examination may be misleading. These patients will be discussed in a subsequent section.

If the appendix lies in an atypical location, the clinical presentation may change. For appendices that are retrocolic or retrocecal, right groin pain may be present. Guarding may be absent due to protection from the overlying cecum.[25] If the appendix is subcecal or pelvic in location, suprapubic or urinary frequency may be prominent. Diarrhea may be present due to rectal irritation, and abdominal tenderness may be minimal. If the appendix is pre-ileal or post-ileal, signs and symptoms may be minimal. Vomiting and diarrhea may present due to irritation of the distal ileum.[25]

A digital rectal examination (DRE) may be a useful screening tool for suspected anorectal or urologic pathology or gynecologic disorders, but its usefulness in supporting or refuting the diagnosis of appendicitis is questionable.[26] The DRE often is uncomfortable or even painful for the patient and, in most cases, the DRE offers no

Table 3: CT Findings in Acute Appendicitis[77,78]

- Distended with fluid with or without inflammation
- 8 mm diameter or > 6 mm diameter with periappendiceal inflammation
- Thickened wall with increased enhancement with IV contrast
- Appendicolith (secondary sign)
- Periappendiceal inflammation (secondary sign)

Table 4: CT Signs of Perforation

- Phlegmon
- Abscess
- Extraluminal gas
- Extraluminal appendicolith
- Focal defect in enhancement in appendiceal wall

additional diagnostic information.[21,27] In a study by Dixon et al., 39-50% of patients with rectal tenderness or mass had appendicitis. However, 36-38% of patients with a normal rectal examination also had the disease.[28] A pelvic examination should be performed for all women of child-bearing age.

Diagnostic Strategy

No major medical association or professional organization currently endorses a standardized pathway for the evaluation of patients with suspected appendicitis.[29] The path to diagnosis for patients with possible appendicitis varies, depending in the sex and age of the patient, experience of the physician, desires of the surgical consultant, and local practice patterns. The major decision point involves which patients need imaging and, of those, what is the best study.

Are clinical scoring systems useful?

Several scoring systems exist with the goal of identifying patients in whom the diagnosis of appendicitis is likely. These systems are intended as guides to help determine when to obtain an immediate surgical consultation, when imaging is warranted, or when it is advisable to continue to search for another, more likely, diagnosis. The most widely know scoring system, the Alvarado system, assigns value to symptoms (migration, anorexia-acetone, n/v), clinical signs (right lower quadrant tenderness, rebound pain, temperature > 37.3°C) and laboratory findings (leukocytosis, left shift) for a possible combined score of 10. Patients with Alvarado scores > 7 or < 3 have a likelihood of acute appendicitis of 77-93% and 4-6%, respectively.[30] (*See Table 1.*)

Most scoring systems have been developed for use in the adult population. However, retrospective design, lack of clinical evaluation, addition of other diagnostic modalities, and small sample size made the creation of a diagnostic clinical score for use in children challenging.[31] In 2002, Samuel introduced a pediatric appendicitis score (PAS) on the basis of a cohort of children 4-15 years old.[32] The sensitivity was 100%, specificity was 92%, PPV 96%, and the NPV 99%. A score $\geq$ 6 was highly associated with appendicitis. Goldman et al validated this rule in a study of 849 children. They found that a cutoff score of $\leq$ 2 (found in 73% of children without appendicitis) had high validity for ruling out appendicitis, and a score of $\geq$ 7 (found in 61% of children with appendicitis) had a high validity for predicting the presence of appendicitis. Children with PAS of 3-6 (37% with appendicitis and 23% without appendicitis in this study) should undergo further investigation such as observation, ultrasonography, or CT.[31] (*See Table 2.*)

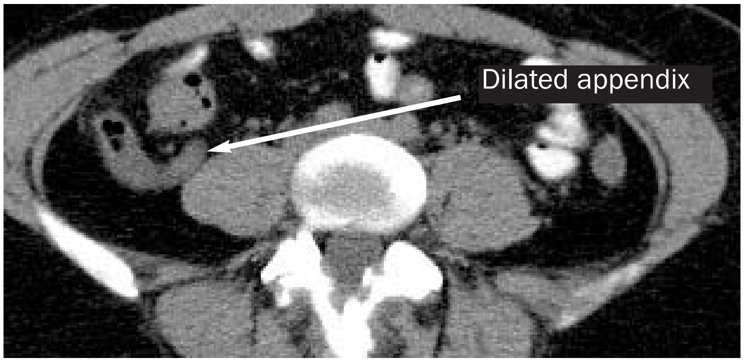
Imaging

When imaging is deemed necessary, the choice of ultrasound, CT, or MRI depends on the patient, institutional preference, and local expertise. Ultrasound and CT are the most commonly available and widely used modalities, although MRI is gaining acceptance for use in pregnant women. Ultrasound is widely available, easy to repeat in a serial manner to follow resolution or progression of disease, and is free of ionizing radiation. However, ultrasound is less sensitive than CT and technically more difficult to perform. MRI is expensive, time consuming, and not as widely available for emergency department patients, but it can make the diagnosis in pregnant patients with a non-diagnostic ultrasound. Each of these modalities will be discussed.

There is great interest in the literature in the accuracy of CT scan to diagnose acute appendicitis, with the goal of preventing unnecessary negative laparotomies. However, the rates of negative laparotomy and perforated appendicitis have not changed during the past decade,[33] despite the introduction of CT. Does CT decrease the negative appendectomy rate? Some say yes, others no.[34-40] Routine CT offers no advantage in patients with classic appendicitis presentation.[41,42] These patients should have surgical consultation without imaging. A more targeted utilization is recommended with imaging only in equivocal cases or patient groups with multiple possible alternate diagnoses, such as women, children, and the elderly. Women of childbearing age may benefit from pre-operative imaging CT or ultrasound, as many conditions simulate appendicitis. The accuracy of clinical evaluation only in this group is 65%, compared to 82% in the rest of the population.[43] (*See Tables 3 and 4.*) (*See Figures 1-6.*)

There are two schools of thought regarding the use of CT scan for the diagnosis of acute appendicitis: one supporting its routine use due to the decreased incidence of negative appendectomies,[44-51] and the other one against its routine use, reserving it for selected cases due to the increased cost, radiation exposure, and delay in surgical management.[52-55] A systematic review of 23 studies (19 of which were prospective) included individual results of 3474 patients

Figures 1 and 2: Moderate Acute Appendicitis



A 38-year-old non-pregnant female presents with 3 days of constant abdominal pain located in the right lower quadrant. The pain is mild and feels like gas. There is no nausea, vomiting, or fever. Examin-ation is notable for tenderness over McBurney's point and the right periumbilical area. No peritoneal signs are present. WBC is 9000/mm^3 without left shift, and urinalysis is normal. The patient drank only half of a cup of oral contrast and refused the remainder. She also refused IV contrast. Partially enhanced CT images are shown above. The appendix was dilated, retrocecal, and lateral in position. There is inflammation of the distal appendix, with periappediceal fat stranding. The patient underwent laparoscopic appendectomy. The pathology report noted moderate acute appendicitis, focally transmural with minimal periappendiceal inflammation.

undergoing CT scanning for suspected appendicitis. CT scan results were correlated with pathologic findings or clinical follow-up. The aggregated specificity and negative predictive value among all modes of CT scanning were similar (specificity range 95-98%, NPV range 94-99%). There was a greater range of values in sensitivity (83-97%) and positive predictive values (86-98%) among modes of CT scanning.[56] CT scan protocols using enteric and IV contrast encompassing the entire abdomen and pelvis in general had the best accuracy. The primary role for CT is for those patients with an equivocal clinical assessment and to identify those patients with complications such as perforation or abscess who may need initial non-operative management.

Much controversy exists as to the best CT technique to diagnose appendicitis, with arguments for and against oral contrast, rectal contrast, IV contrast, triple contrast, and no contrast at all.[57] IV combined with oral contrast is currently the most common technique used for abdominal CT.[58] The abdomen also can be evaluated for other pathology with this technique.

Is oral contrast necessary?

The focus of early CT imaging of the abdomen and pelvis was aimed at mitigating the degradation of image quality that occurred due to respiratory motion, slow data acquisition, and bowel peristalsis. Oral contrast was added to help overcome these limitations and has been in use since the early stages of CT development. It helped delineate soft tissue planes between intraperitoneal structures. The introduction of rapid helical scanning and, more recently, multidetector devices, has made the utility of oral contrast media uncertain.[58] Now, the focus is on development of protocols that may streamline the flow of the patients through the busy ED.

The theoretic advantage of oral contrast is that it opacifies the cecum, allowing for the assessment of appendiceal obstruction. Inflammatory conditions of the bowel often manifest with abnormalities in the fat of the peritoneal cavity and omentum. The stranding and hazy fat changes aid localization of pathology and should be detectable with or without oral contrast. Opacification of the rectum and sigmoid colon also help distinguish pelvic organs, such as ovaries, from adjacent bowel loops. Lack of retroperitoneal and intra-abdominal fat may make identification of the appendicitis and surrounding inflammation difficult without oral or IV contrast.

The drawback of oral contrast is that the patient must drink the contrast or have it given through the NG tube, requiring 45-60 minutes to reach the cecum post-ingestion. This increases scan time by 1-2 hours.[59-61] Additionally, the patient may vomit or have ileus, thus making the contrast ingestion problematic. Rectal contrast may fail to reach the cecum or increase the risk of perforation due to increased hydrostatic pressure. Unenhanced CT has sensitivities reported from 96%, specificities of 99%, and diagnostic accuracy of 97%.[62]

Figure 3: CT Scan Axial View Showing Tubular Shaped Appendicolith

Figure 4: CT Scan Coronal Reconstruction View Showing Appendicolith Within Dilated Appendix Measuring 11 mm in Diameter (arrow)

Mun et al evaluated 173 patients undergoing CT for evaluation of possible appendicitis using their protocol of only IV contrast in patients who had an equivocal examination. CT diagnosis of appendicitis was made in 59 patients, with 56 of these being true positives. The three false positives were in female patients and were diagnosed with salpingitis, terminal ileitis, and normal appendix. All of the 114 patients with negative CT scans were true negatives by alternative diagnosis or one week negative clinical follow-up. The sensitivity of CT with IV contrast only in this study was 100% with a specificity of 97%. The positive predictive value was 95%, and the negative predictive value was 100%.[63]

Is any contrast necessary?

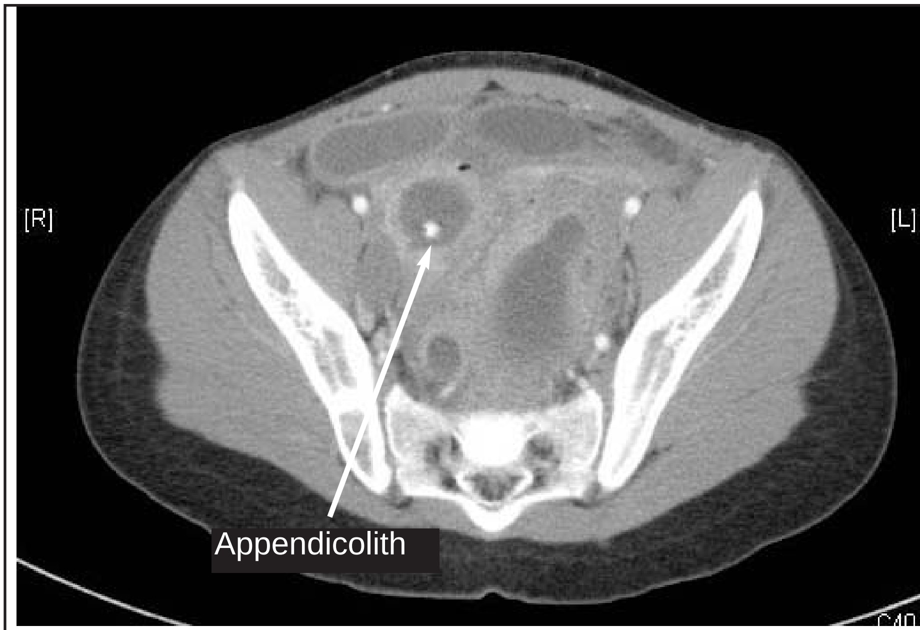
The use of IV contrast facilitates visualization of the bowel wall. In a clinically suspect population, the sensitivity of unenhanced CT is 96%, specificity of 99%, and accuracy of 97%.[57-65] However, alternative diagnoses are achieved in only 35% of patients.[64] In a recent study of patients with normal appendices, the use of IV contrast did not aid in the identification of the appendix over scans without IV contrast.[66] However, the presence of ample intra-abdominal fat was helpful in making the diagnosis when oral contrast was not used. The diagnosis of appendicitis is harder to make via unenhanced CT without ample intra-abdominal fat, so the patient's body habitus should be taken into consideration when choosing which CT modality to employ.

Disadvantages of IV contrast include exacerbation of renal insufficiency, anaphylactic reactions, and the need for a larger caliber IV.

What does it mean when the appendix is not visualized on CT?

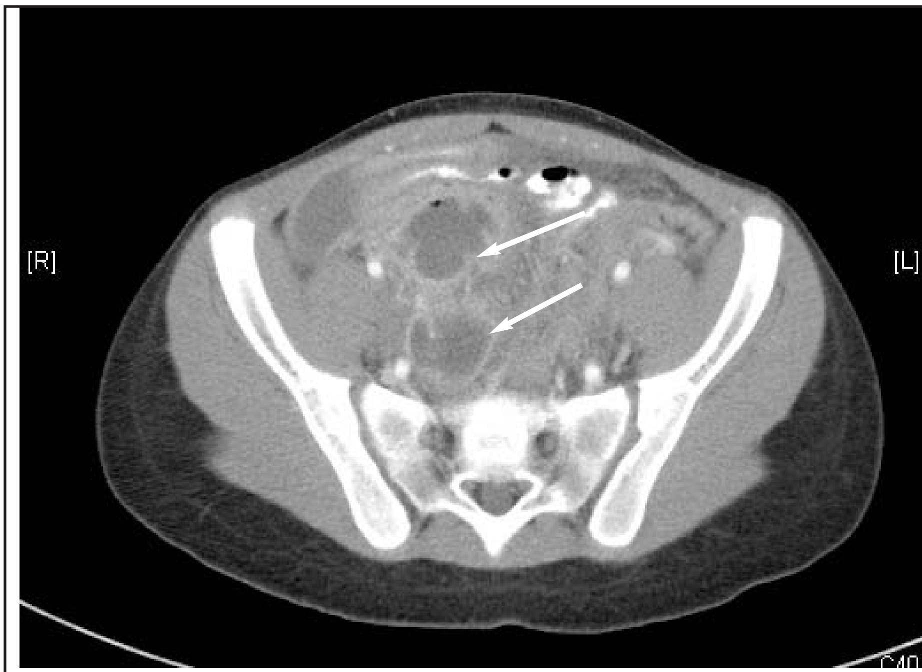
In a considerable number of CT scans obtained for right lower quadrant pain, the appendix is not seen. In two recent studies, this occurred in 13% and 14% of patients.[67,68] Ganguli et al retrospectively reviewed CT scans using oral and IV contrast. Of the 400 exams, the appendix was not visualized in 59 of these. In 49 of the 59 patients, the pain resolved or another diagnosis was found. Nine patients were lost to follow-up. One patient presented 9 weeks later with appendicitis. The authors concluded that the non-visualized appendix was 98% sensitive for the absence of

Figure 5: Perforated Appendicitis with Appendicolith and Multilocular Abscesses



A 12-year-old female presented with 7 days of abdominal pain. She was afebrile, but her WBC was 18,000/mm^3. CT with IV contrast alone demonstrated a perforated appendicitis with an appendicolith (Figure 5 arrow) and multilocular abscesses (Figure 6 arrows).

Figure 6: Perforated Appendicitis with Appendicolith and Multilocular Abscesses



appendicitis (95% CI; 71-100%).[5] Nikolaidis et al recommended that non-visualization of the appendix on CT may be used safely to exclude acute appendicitis.[68]

When does CT miss appendicitis?

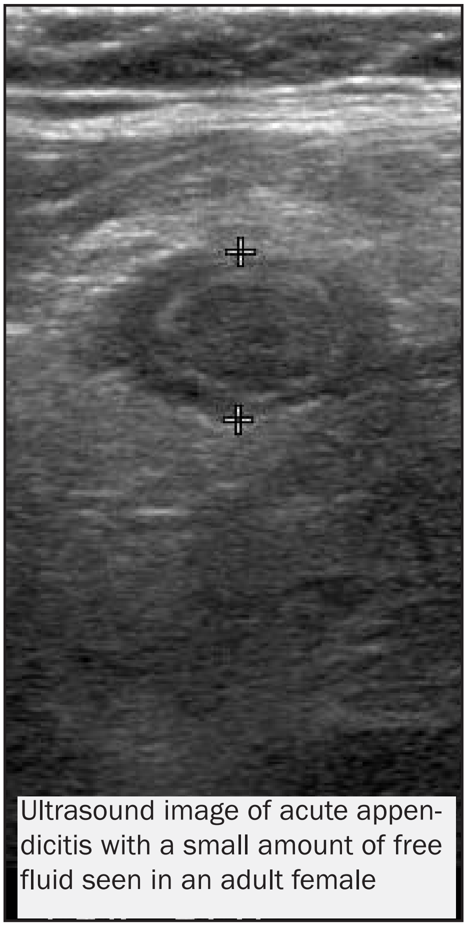
The most common reason for a false-negative diagnosis of appendicitis is related to a paucity of intra-abdominal fat. Intra-abdominal fat (IAF) serves as a natural contrast agent, allowing inflammatory changes to be noted easily, even when subtle.[69] A small pediatric study found a significant difference in appendix visualization rates between patients with low and medium amounts of fat and showed that appendix visualization improved in older patients.[70] This finding was confirmed by others who showed a trend toward more IAF and better appendix visualization in children older than 10 years.[71-73] Conversely, a lack of IAF may contribute to more indeterminate CT interpretations[72,73] and more diagnostic errors.[69] Levine showed that 96% of patients with incorrect CT interpretations had little IAF.[69] The practical problem for the ordering clinician is that a patient's IAF (which is determined during CT interpretation) is unknown at the time the CT is ordered. Thus, how can one decide which CT protocol to use for any given patient? Further study in this area is needed.

Appendicitis with inflammatory changes in the right lower quadrant may cause reactive dilatation of the small bowel. This dilatation may be enough to mimic a small-bowel obstruction, resulting in a missed diagnosis of the underlying problem, which is the inflamed appendix. The dilated small bowel impedes the flow of oral contrast, thus causing suboptimal opacification of the cecum. In Levine's study, 38% of patients with missed appendicitis had small bowel dilatation.[69] Inadequate bowel opacification led to misses as well in this study.

Tsao et al retrospectively studied 1078 children with appendicitis, including subsets of who did or didn't have pre-operative CT. They found the positive predictive value of CT was 91.8%, while the PPV for clinical evaluation without imaging was 90.8%.

For patients who have a clinical picture suggestive of appendicitis, a negative CT scan may be misleading and does not rule out the diagnosis. Often, the question is not when to order a CT scan to diagnose acute appendicitis, but rather when to

Figure 7: Ultrasound Image of Acute Appendicitis



Ultrasound image of acute appendicitis with a small amount of free fluid seen in an adult female

rely on a CT scan to make the diagnosis. The data suggest that CT scan is a very accurate test to rule in acute appendicitis when the study is positive. When the study is inconclusive or negative, however, the diagnosis is not always excluded and, perhaps, when the CT is negative or indeterminate, the ED provider should request attending interpretation, as this is superior to that of a resident.[74]

Ultrasound. (*See Figure 7.*) The lack of ionizing radiation is the primary reason ultrasound is used as a diagnostic modality in the evaluation of acute appendicitis, primarily in pregnant women and children.

With the patient supine, the transducer is used to compress the right lower quadrant during imaging. Gentle pressure is applied with the transducer to displace the air-filled bowel loops. Slow graded compression is started at the point of maximal tenderness. This allows the adjacent bowel to move out of the right lower quadrant.

The inflamed appendix is relatively fixed and can be imaged by this technique in most cases. Transverse images are most useful. Visualize that it is an elongated, blind-ending structure to differentiate it from the adjacent terminal ileum.

The appendix appears as an elongated, blind-ending structure. Unlike normal bowel, the inflamed appendix is fixed, non-mobile, compressible, and appears round on transverse images. The inflamed fat appears brightly echogenic and noncompressible. With perforation, the contour of the appendix is irregular or a periappendiceal fluid collection may be seen. The appendix is more easily visualized when it is inflamed. With an experienced sonologist with modern equipment, non-visualization of the appendix has an NPV of 90%.[75] A perforated appendix is easy to miss as it decompresses when perforation occurs.

A recent systematic review with meta-analysis of six studies that evaluated graded compression US and CT in the same adult and adolescent patient population found that CT increased the diagnostic certainty more than US.[76] The positive likelihood ratios (LR+) were 9.29 for CT versus 4.50 for US, and the negative likelihood ratios (LR-) were 0.10 for CT versus 0.27 for US.[76]

CT is more sensitive and specific than ultrasound in patients suspected of having acute appendicitis with an equivocal presentation. Furthermore, CT has relative advantages in obese patients, a group in which ultrasound had definite limitations.

MRI. Like ultrasound, the greatest benefit of MRI is that it avoids ionizing radiation, which is important mainly in pregnant patients. Its main drawbacks are limited emergent availability, high cost, and long study time. There are no known adverse human effects related to non-contrast MRI. However, gadolinium should be avoided, especially in the first trimester, as it easily crosses into the fetal circulation. The usefulness of MRI will be discussed under the pregnancy section.

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Physician CME Questions

51. Which of the following is the most common location of the appendix?
   A. retrocecal
   B. paracolic
   C. preilial
   D. subcecal
   E. pelvic

52. Regarding the clinical presentation of acute appendicitis, which statement is *false*?
   A. Fever is not common in most cases of uncomplicated appendicitis
   B. Nausea and vomiting are common
   C. The point of maximal tenderness is always at McBurney's point
   D. Digital rectal examination offers little or no diagnostic value in evaluating a patient for appendicitis
   E. The psoas and obturator signs are not reliably present in most cases of appendicitis

53. Which of the following is *not* a component of the Alvarado or MANTRELS clinical scoring system?
   A. nausea/vomiting
   B. right lower quadrant tenderness
   C. rebound pain
   D. leukocytosis
   E. All of the above are components of the Alvarado system.

54. In which of the following patients would CT of the abdomen and pelvis be most useful in making the diagnosis of acute appendicitis?
   A. 25-year-old female with lower abdominal pain and nausea for 2 days
   B. 7-year-old male with periumbilical pain that is now in his right lower quadrant, accompanied by nausea and leukocytosis
   C. 32-year-old male with right lower quadrant pain that began in the mid-abdomen, accompanied by localized guarding and leukocytosis
   D. 75-year-old female with 3 days of right lower quadrant pain, normal white blood cell count, and tenderness diffusely of her lower abdomen
   E. Both A and D would benefit from a CT.

55. Which of the following findings reliably rules out appendicitis?
   A. normal CT
   B. normal ultrasound
   C. normal appendix on pathology report
   D. lack of tenderness at McBurney's point
   E. normal WBC count

Emergency Medicine Reports

CME Objectives

To help physicians:

- quickly recognize or increase index of suspicion for specific conditions;
- understand the epidemiology, etiology, pathophysiology, and clinical features of the entity discussed;
- apply state-of-the-art diagnostic and therapeutic techniques (including the implications of pharmaceutical therapy discussed) to patients with the particular medical problems discussed;
- understand the differential diagnosis of the entity discussed;
- understand both likely and rare complications that may occur.

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Physicians participate in this continuing medical education program by reading the article, using the provided references for further research, and studying the questions at the end of the article. Participants should select what they believe to be the correct answers, then refer to the list of correct answers to evaluate their knowledge. To clarify confusion surrounding any questions answered incorrectly, please consult the source material. *After completing this activity, you must complete the evaluation form that will be provided at the end of the semester and return it in the reply envelope provided to receive a certificate of completion.* When your evaluation is received, a certificate will be mailed to you.

56. The most common reason for missed appendicitis on CT is:
   A. concurrent small bowel obstruction.
   B. lack of IV contrast.
   C. lack of oral contrast.
   D. paucity of intra-abdominal fat.

57. What is the value of oral contrast when performing CT scans of the abdomen?
   A. reduction in bowel motility when using slower CT scans
   B. distinguishing bowel from adjacent organs
   C. accentuating inflammatory changes in the omentum
   D. Both A and B are correct.

58. Graded compression US is most useful in which patient populations for the diagnosis of acute appendicitis?
   A. elderly patients
   B. pregnant patients
   C. children
   D. A and B
   E. B and C

59. Which of the following statements is true comparing CT with US for the diagnosis of acute appendicitis in adolescents and adults?
   A. CT is more sensitive but less specific than US.
   B. CT is less sensitive but more specific than US.
   C. CT is both more sensitive and specific than US.
   D. CT is both less sensitive and specific than US.

60. Which of the following statements is true regarding the use of MRI for acute appendicitis?
   A. It is especially useful in pregnant patients.
   B. It is especially useful in children.
   C. Scan time is less than CT.
   D. It is especially useful in the elderly.

CME Answer Key

51. A; 52. C; 53. E; 54. E; 55. C; 56. D; 57. D; 58. E; 59. C; 60. A

In Future Issues

Appendicitis Part II

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Burns may range from a minor injury from a brief contact with hot water to a life-threatening, devastating injury. Burns may be obvious or subtle depending on the mechanism and type of force producing the injury. The early recognition and aggressive management of even the smallest burn makes a significant impact on the outcome of each individual patient, especially in terms of function.

Acute care providers need to be able to aggressively resuscitate a major burn victim and at the same time recognize small burns that may benefit, either based on location or type of burn, from management by a specialist at a burn center. Being aware of burn center resources and appropriate utilization of this available expertise facilitates an optimal outcome in an acutely burned patient.

— The Editor

Optimizing Outcome in the Adult and Pediatric Burn Patient

Author: **Sidney Miller, MD, FACS,** Professor of Surgery; Director, The Ohio State University Burn Center, The Ohio State University College of Medicine University Hospitals, Columbus.

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Introduction

Fires and related burn injuries are a major issue in health care. The U.S. Fire Administration data shows that in 2006, 3,245 civilians lost their lives as the result of fire.[1] There were 16,400 civilian injuries that occurred as the result of fire; 81% of all civilian fire deaths occurred in residences, and 106 firefighters were killed while on duty. Direct property loss due to fires was estimated at \$11.3 billion. In 524,000 structural fires, there were 2,705 deaths and 14,350 injuries, resulting in \$9.6 million dollars of direct loss.[2,3] The U.S. Fire Administration/National Fire Data Center report on fatal fires estimated that there were 3,300 fatal fires that claimed 3,380 civilian lives (86% involved single fatalities, 14% involved multiple fatalities).[4] Seventy-four percent of fatal fires occurred in structures; 94% of these were on residential properties. The leading cause of fires that resulted in

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fatalities was arson (27%), followed by smoking (18%). Smoke alarms were either not present or not functional in 63% of residential fires.

The Agency for Healthcare Research and Quality (AHRQ) of the Department of Health and Human Services outcomes data for 2005 for burn injuries in the United States shows 40,687 hospital discharges.[5] The mean length of stay was 7.1 days, mean charges were $41,000, and the in-hospital mortality rate was 2.4%. This represents $1.67 billion in health care cost annually for the management of patients with burns. Of this care, 28.7% was provided under private insurance; however, Medicare and Medicaid paid for 42% of care, and this government expenditure represents $709 million. Additionally, uninsured patients, whose costs are passed on to other insurers, represented 15% for $245 million; however, this figure does not represent the entire uninsured group, as many burn patients in most states qualify for Medicaid because of the magnitude of their burn injuries.

Thermal burns may result from contact with flames, hot liquids, hot surfaces, and other sources of intense heat; chemical burns and electrical burns may also occur. In addition, mass casualties and disasters, explosions, and fires can cause a variety of serious injuries, including burns. Prevention and planning are vital; the public must understand how to behave safely in mass casualty and fire situations and to comprehend basic principles of first aid for burn victims, as immediate care can be lifesaving. The Centers for Disease Control and Prevention (CDC) indicates that only 60% of Americans have an escape plan, and of those, only 25% have practiced it.[6] The CDC estimates that smoke alarms cut the chances of dying in a fire in half.[6]

This article discusses the initial evaluation and management of the burn patient and summarizes the current approach to these patients.

Initial Evaluation and Management of the Burn Patient

The initial evaluation and management of the burn patient frequently establishes the path for hospitalization and ultimate outcome. Decisions made during the first few hours after injury can have long-term effects on both the functional and cosmetic outcomes.

The goals in the initial management of the burn patient are:

1. A thorough evaluation, as with any trauma patient;
2. Evaluation and management of any traumatic associated injuries that might produce life-threatening hemorrhage, such as fractures, intra-abdominal hemorrhage, and chest trauma;
3. Appropriate evaluation of the status of the burn wound;
4. Determination of the appropriate management course for the patient;
5. Differentiation of whether hospital or ambulatory care is most appropriate; and
6. Initiation of appropriate hospital care, if needed, or arrangement for follow-up care.

The first step in the treatment of any burn is to stop the burning process. All clothing should promptly be removed and a complete examination performed, making sure to include the patient's front and back. Attention should be paid to safeguard the safety of the health care provider as well as the victim, especially in the case of chemical injuries.

The mechanism of the injury is important in the evaluation and management of the burn patient. A patient burned in a closed space has a high possibility for an inhalation injury. If the patient was burned in a motor vehicle crash or explosion, associated traumatic injuries must be considered. Scald burns differ depending on the source. Boiling water can quickly run off the patient, tending to burn less deeply than hot grease, which adheres to the skin and retains the heat as it slowly cools.

An initial primary survey should be performed to determine the presence of any life-threatening injuries. The primary patient survey includes the "ABCs" of airway, breathing, and circulation. The airway must be assessed and established as patent. A history of being burned in a closed space, facial burns, or soot in the oropharyngeal area suggests a possible inhalation injury. Chest x-rays and blood gases are of little use during this early time period; however, if there is delay in establishing the airway until the patient has obvious evidence of respiratory distress, such as wheezing, or severe respiratory distress, oral intubation may not be possible and a cricothyrotomy or tracheostomy may need to be performed.

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If signs of an inhalation injury are present and there is a question as to the need for intubation, a bronchoscopy can be performed to assess the status of the airway and, if needed, an endotracheal tube can be inserted. Experience has shown that early placement of an endotracheal tube may avoid a very difficult surgical airway later. The largest tube possible should be placed, at least 7.0 or higher in adults, and in general any patient who requires intubation should be bronchoscoped. Findings on bronchoscopy are prognostic of the extent of the injury and help identify patients who might be extubated early.[7]

Once the airway has been established, attention is turned to the patient's breathing. The lungs must be inflating and the chest fully expanding. Occasionally, a leathery, full-thickness burn encircling the chest will limit excursion of the chest wall, impairing full expansion of the lungs. In such cases, a chest escharotomy may be needed to allow for proper chest wall expansion. In addition, evidence of possible chest trauma, including rib fractures, hemopneumothorax, tension pneumothorax, or flail chest, must be sought and effectively treated.

Any uncontrolled hemorrhage must then be identified and managed. Circulation is supported by the administration of appropriate intravenous (IV) fluids. The amount is based on the burn size estimate and the patient's weight. Two large-bore IVs should be started in the most readily accessible locations; while effort should be made to avoid insertion through any burn area, if patient has extensive burns IVs may need to be started through the burned areas. The patient with a major burn will need to have a Foley catheter inserted so that the adequacy of the fluid resuscitation can be monitored. The "D" in the "ABCDEs" of initial evaluation signifies examining for any disability. The "E" stands for exposing the patient and monitoring the environment, which should be warm to avoid hypothermia in the cold environment of most emergency departments. Initial management should include assessment of any associated injuries, if present. Early deaths in burn patients are usually due to one or more associated injuries. The burn injury itself rarely produces severe hypotension and shock except in extreme circumstances, and other sources of undetected hemorrhage or internal injuries must be sought.

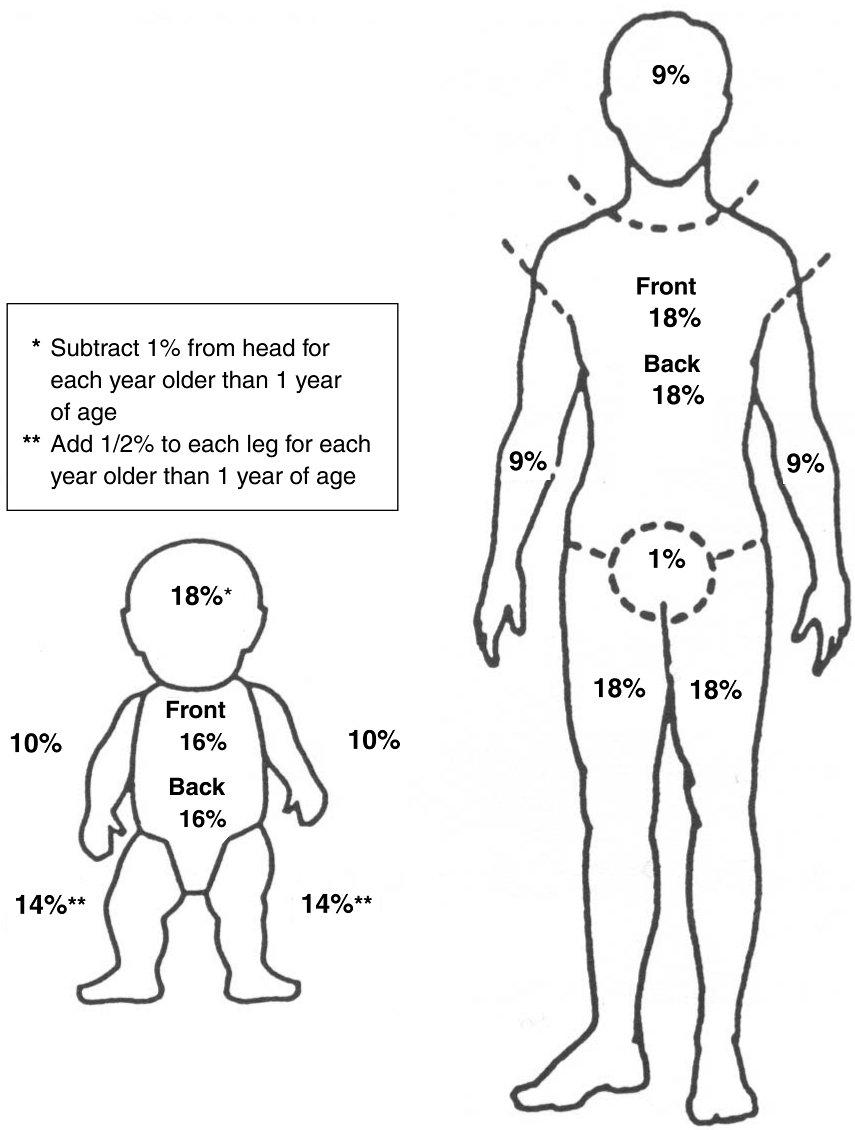
Once the airway is established, the patient is breathing adequately, and access to and support of the circulation is established, the secondary survey is performed. The secondary survey encompasses a complete head-to-toe evaluation of the patient. Only after all of the immediate life-threatening problems have been managed during the primary survey can a complete history and physical examination can be performed.

After the primary and secondary trauma surveys have been completed, attention can be turned to the burn wound. The extent of the burn wound must be determined, as well as any associated medical conditions that might adversely affect the patient's outcome. Generally, patients with major burns, which the American Burn Association (ABA) defines as greater than 20% of the body surface area (or greater than 10% in the young and elderly), will require treatment for the effects of burn-wound shock.[8]

The depth of the burn wound is dependent on the temperature and duration of contact of the burning agent. The burn injury rarely is uniform in depth and frequently will have a central area of maximal damage with skin necrosis (zone of necrosis) that is surrounded by a zone of sluggish blood flow referred to as the zone of stasis. More peripherally is the zone of hyperemia, with increased blood flow secondary to the systemic response to the burn injury. In the central zone of necrosis, cellular damage is irreversible and a variety of toxic substances and electrolytes are released into the general circulation. Because of capillary dilation and the local inflammatory response to these released cytokines, fluid and serum proteins are lost from the intravascular space into extravascular space (the "third-space effect"), leading to hypovolemia, hypoalbuminemia, and hypotension. In the zone of stasis, the relatively sluggish blood flow produces cellular hypoxia and acidosis that leads to further hypotension and platelet clumping and, ultimately, to cellular necrosis. This is magnified with prolonged hypotension and shock. The zone of hyperemia is characterized by increased blood flow, with a diversion of blood from the central circulation that further decreases blood flow to vital organs. If circulation remains poor for any reason, or if tissue ischemia and necrosis develop in the area of stasis, additional tissue death will occur and the central zone of necrosis will expand. Therefore, the goals of burn resuscitation are to treat overall hypovolemia, maintain the local capillary circulation to the remaining viable tissues, and reestablish blood flow to vital end organs.

The severity of the burn is a combination of the extent and depth of the burn, the mechanism of the injury, pre-existing medical conditions that might complicate or delay wound healing, and associated injuries. The initial assessment of the extent of the burn is best determined by using a body diagram or chart to estimate burn size. Commonly, the Rule of 9s is used because it is easy to remember.[9] *(See Figure 1.)* The body surface of an adult is divided into 11 segments of 9% each, or multiples of 9%, with 1% reserved for the perineum. There are two segments for each leg, two each for the anterior and posterior thorax, one for each arm, and one for the head. When using the Rule of 9s in children, 9% is taken from the legs and added to the head for a child up to age 1 year. Each subsequent year, 1% is returned to the legs until, at approximately age 9, the child's head is in proportion to that of an adult's. For smaller or scattered areas, the palm of the patient's hand, which represents approximately 1% of the patient's body surface, is used to estimate burn size. The more detailed Lund and Browder chart can be used to estimate burn size as, particularly in children, it may be more accurate. The use of these two methods is just about evenly divided among burn units. This suggests that there is not a standard for use of either the Rule of 9s or the Lund and

Figure 1. Rule of 9s



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lacking, and much research is being performed in this area.

Equally important in the evaluation of the magnitude of the burn injury is estimating the depth of the burn. Burns are described as partial thickness or full thickness. This classification more truly represents the pathophysiologic status of the injury rather than the older first-, second-, and third-degree classification. *(See Figure 2.)* A partial-thickness burn involves only a portion of the dermis, and those dermal elements such as sweat glands and hair follicles necessary for re-epithelization of the burn wound remain intact. These skin appendages are necessary for healing of the partial-thickness burn and must have their capillary blood supply maintained by adequate resuscitation. If this blood supply is lost, the surviving appendages will die. In addition to inadequate resuscitation, infection can lead to loss of skin appendages and conversion of a partial-thickness to a full-thickness burn. With the partial-thickness burn, the nerve fibers to the dermis also are preserved. Therefore, the partial thickness burn wound is wet, painful, and blanches with pressure. With the full-thickness burn, all dermal elements have been destroyed, and except for those that involve only a very small area, will require skin grafting. The full-thickness burn is dry, leathery, and insensate.

Browder chart, except by facility preference.[9]

It should be noted that these calculations are only estimates, and that superficial burns that are just pink or red, such as sunburn, are not used in the calculation. Only partial-thickness and full-thickness areas of burn are used in estimating the extent of burn.

Since many decisions regarding care, both during and after hospitalization, are based on these "estimates," they should be recorded as accurately as possible and performed by skilled staff. Frequently, hospital staffing and reimbursement are based on these estimates. Unfortunately, objective and accurate methods of estimating burn size and depth are

Following stabilization, a detailed past medical history is essential. Since the major burn injury is still one of the few tetanus-prone injuries, it is important to determine the date of the patient's most recent tetanus immunization. The American College of Surgeons' guidelines should be followed.[10] Tetanus guidelines suggest that if the patient's immunization status is unknown or if the patient has not had the recommended three doses of immunization, both tetanus toxoid and tetanus immunoglobulin should be given. If the patient has had a full three-dose immunization series, tetanus toxoid should be given if it has been longer than five years since the last booster.

Figure 2. Degrees of Burn Thickness

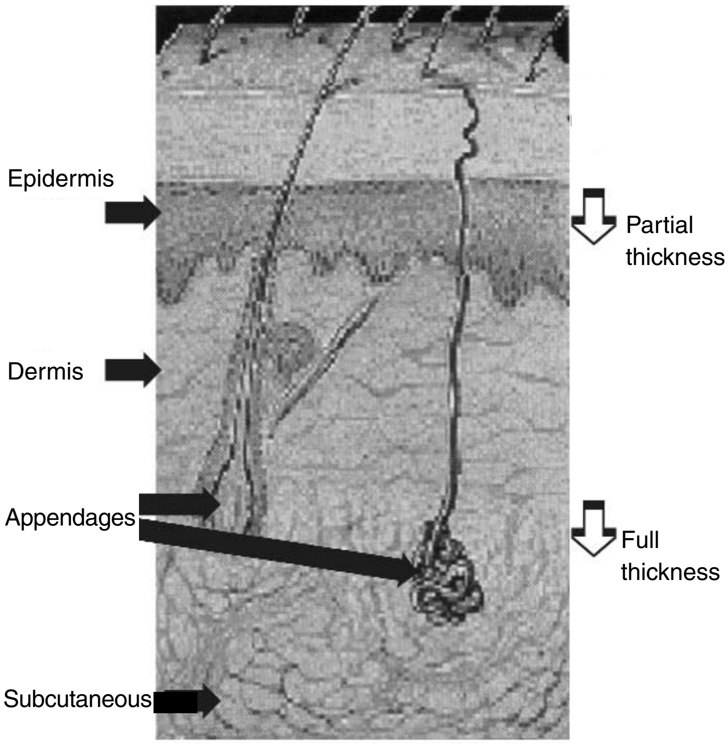


Table 1. Parkland Formula for Fluid Resuscitation in Burn Patients

1ST 24 HOURS AFTER BURN OCCURS:

- Crystalloid / lactated Ringer's solution
- 4 mL × kg body weight × % total body surface area burned
- 1/2 volume given in first 8 hours; second half given over next 16 hours
- Monitor urine output

Debate continues regarding the use of nasogastric decompression. Generally, if there will be a delay in transfer of the major burn patient or if the patient will need to be transferred over a long distance, the stomach should be decompressed with a nasogastric tube to avoid the possibility of vomiting and aspiration while en route. Gastric ileus, however, can usually be completely avoided by instituting tube feedings or an oral diet within four to six hours of the burn injury, when possible.

Associated illnesses have a significant impact in the physiologically compromised burn patient. The patient with preexisting cardiac or renal disease may have additional difficulties with the large fluid requirements of a major burn. The diabetic patient or the patient on corticosteroids is more prone to infections. Additionally, the diabetic patient frequently has peripheral microvascular disease leading to poor wound healing.

Resuscitation of Patients with Major Burns

The primary objectives of fluid resuscitation are to maintain capillary circulation to the potentially viable skin and to support the circulation to vital organs. The estimate of the burn size is used to determine a starting point for resuscitation. Resuscitation is started with crystalloid, usually lactated Ringer's solution, which most closely resembles intravascular serum lost into the extracellular space. The most commonly used formula to determine initial fluid replacement is the Parkland formula, which estimates the IV fluid needs during the first 24 hours after the burn injury as [4 mL crystalloid × the percentage body surface area burned × weight in kg]. *(See Table 1.)* Generally, half of this estimated amount is given over the first eight hours after the injury and half during the next 16 hours, but the rate of fluid administration needs to be adjusted to maintain a urine output of 30–50 mL per hour in adults (1–1.5 mL/kg in children). Fluid overload is associated with increased cardiac strain, and cerebral and pulmonary edema is as harmful as hypovolemia. The balance between adequate fluid resuscitation and minimizing overload is critical — and challenging to achieve.

Ongoing monitoring is very important. Patients with normal mental status should remain alert and oriented and have an appropriate glomular filtration rate as reflected by an adequate urine output.

Ventilated patients frequently require monitoring of arterial blood gases, typically through an arterial line. Initial resuscitation is started with two large-bore peripheral lines that are usually replaced with a central line at the burn center. Routine use of Swan-Ganz catheter is not recommended, however, as the mechanical trauma across the tricuspid valve can lead to nearly always fatal acute bacterial endocarditis.[7]

The hematocrit, serum osmolality, and serum sodium are routinely monitored. These three tests are additional indicators of the adequacy of fluid resuscitation. Ideally, the hematocrit should be less than 55%, the osmolality less than 350 mOsm, and the serum sodium less than 155 mEq/liter. By maintaining the appropriate electrolyte levels and urine output, adequate fluid resuscitation for the burn patient is assured, and fluid overload can be avoided.

Burns of Special Concern

The overwhelming majority of burns seen are thermal in nature. Electrical and chemical burns, however, are unique and provide very special challenges to the health care provider.

Electrical Injuries. Electrical injuries may be deceptively subtle injuries; there can be tissue damage from the passage of the electric current as well as burn from the ignition of clothing or other materials. Internal injury is a major concern with electrical injury, since the electrical current will pass

Table 2. American Burn Association Criteria for Referral to Burn Center

- Partial-thickness burns of greater than 10% of the total body surface area
- Burns that involve the face, hands, feet, genitalia, perineum, or major joints
- Third-degree burns in any age group
- Electrical burns, including lightning injury
- Chemical burns
- Inhalation injury
- Burn injury in patients with preexisting medical disorders that could complicate management, prolong recovery, or affect mortality
- Any patients with burns and concomitant trauma (such as fractures) in which the burn injury poses the greatest risk of morbidity or mortality.
  - ➔ If the trauma poses the greater immediate risk, the patient's condition may be stabilized initially in a trauma center before transfer to a burn center.
- Burned children in hospitals without qualified personnel or equipment for the care of children
- Burn injury in patients who will require special social, emotional, or rehabilitative intervention

Source: American Burn Association, Chicago, IL.

Table 3. American Burn Association Criteria for Hospitalization of Burn Patient

- 20% or greater total body burn
- 10% or greater burn of child or older adult
- 5% or greater full-thickness injury
- Burns to the hands, feet, face, or perineum
- Burns of the eyes or ears
- Suspected inhalation injury
- Electrical and chemical burns
- Patients with pre-existing illness
- Patients with associated injuries

through the entire body and can produce difficult-to-detect internal injuries. This passage of electrical current has multiple effects. Electric current can cause contraction and fibrillation of both skeletal and cardiac muscle, destruction of cell membranes, thrombosis of blood vessels, and coagulation necrosis of tissues. The violent contraction of the muscles caused by the passage of the current can produce fractures that may go undetected in the early resuscitation period.

Injured muscles discharge electrolytes and myoglobin into the bloodstream, which have the potential to produce further damage, and released potassium can produce cardiac arrhythmias; cardiac monitoring is mandatory. Myoglobin released from the damaged muscle mechanically plugs the renal tubules and can lead to renal failure. In patients who have myoglobinuria, a higher-than-usual urine output is desired to flush the myoglobin from the renal tubules. These patients have a port-wine-colored urine in the emergency department, and IV fluids must be administered at a rate to produce a urine output of 100–150 mL/hour until the urine grossly clears of myoglobin. Occasionally, an osmotic diuretic may be given to increase urine output and further flush out the myoglobin.

The passage of the electrical current also produces heat, which is produced by the resistance of the various tissues to the passage of the electrical current. Bone has the highest resistance to the passage of the electrical currents; therefore, a large amount of heat is produced in the bone and the surrounding muscle with no apparent injury to the overlying skin. Necrotic muscle needs to be fully debrided, as it is an excellent medium for bacterial colonization and infection. Amputation is a frequent sequela of extensive electrical injuries.

Chemical Injuries. Chemical burns, like thermal burns, usually involve just the skin. The initial management is dilution by continuous showering for a prolonged period after the injury. Attempts to neutralize the chemical can have an adverse effect and produce further tissue injury. The mixture of a strong acid and a strong base produces an exothermic reaction with further heat production and tissue damage. Knowing the actual chemical producing the injury is important, as many chemicals, particularly industrial chemicals, will require specific treatments or have significant systemic effects when absorbed through the skin. Hydrogen fluoride, a commonly used agent in glass and metal etching, bonds to the subcutaneous tissues and continues to produce damage until neutralized with calcium gluconate. If the injury occurs at work, it is important that any involved chemicals are identified, and that the container of the chemical is brought with the patient to the emergency department for proper identification.

Indications for Hospitalization of the Burn Patient

The American Burn Association has established guidelines for referral of burn patients to tertiary care facilities.[8] *(See Tables 2 and 3.)* Usually, any patient with a burn involving greater than 20% of the total body surface should be hospitalized. In the young and old, who are less tolerant of burn injuries, a total body burn of 10% warrants hospitalization, and any patient with more than a 5% full-thickness burn should be referred and managed with primary excision, usually within five days of the injury. This is euphemistically referred to as the "5/10/20 rule" of burn care.

Other indications for hospitalization include complicating medical conditions such as diabetes, heart disease, and associated injuries. These affect or delay recovery or place the patient at a higher risk. Because of the special needs of patients with significant or circumferential burns involving the perineum, hands, feet, and face, they should be considered for hospitalization even though the burn size might be relatively small. Due to their functional importance, burns of the hands and feet are critical and their management should take place in a burn center, where personnel have experience in caring for these injuries.

Nonsurgical Care of the Burn Patient

The majority of burn patients can be managed with nonoperative care. Generally, smaller burns of less then 10% of the body surface area that do not involve critical areas such as the face, hands, feet, or perineum can be managed on an outpatient basis. The three issues that should be addressed in the management of these patients are wound management, pain control, and follow-up care. Wound management is probably the easiest of the three to deal with. Since the early 1970s, effective topical antibiotics for the management of the burn wound have been readily available. Silver sulfadiazine (SSD) cream is most commonly used, as it is painless on application, easy to remove, covers a broad range of skin surface organisms, and is relatively inexpensive. SSD, however, has been shown to delay wound healing and must be changed at least once or twice daily until the wound is healed.[11] The wound should be covered with an absorbent dressing that is held in place with roller gauze and/or an ace bandage. Over the past several years, a number of newer silver-containing wound care products have come on the market. Most of these are designed to be applied and left in place for up to a week while the wound heals underneath. Once they have stuck to the wound, the wound usually can be left open to the air. Because the twice-daily dressing changes with SSD are eliminated, pain can usually be controlled with acetaminophen, aspirin, or other NSAID. Elevation of the extremities will aid with both swelling and pain control, and the majority of these outpatients do not need narcotic pain medication.

Smaller burns, generally less then 10% of body surface area, usually can be treated on an outpatient basis. Blisters should be left intact. Those blisters that have opened should be debrided. The wounds should be cleansed with mild soap and water twice daily. Usually, facial burns can be left exposed and covered with a thick layer of triple-antibiotic ointment. The usual topical creams are very drying for the face, head, and neck areas, but can be used on other areas of the body. A well-applied absorbent dressing should be positioned and usually can most easily be held in place with elastic bandages. Limb elevation not only helps to control edema, but also is an important aspect of pain management. Outpatient care can be coordinated with the regional burn center for addressing any questions or concerns. Appropriate follow-up is important to the management of these outpatient burns and frequently is encountered as an area of concern. Many general practitioners neither have the expertise nor the time necessary for dressing changes in the office for other than the smallest-size burns. Many hospitals, however, have wound care centers that can comfortably manage these outpatients, even those with larger-surface-area burns. The regional burn center will almost always have an outpatient component and frequently is the best site for the management for these patients.

Pain Management

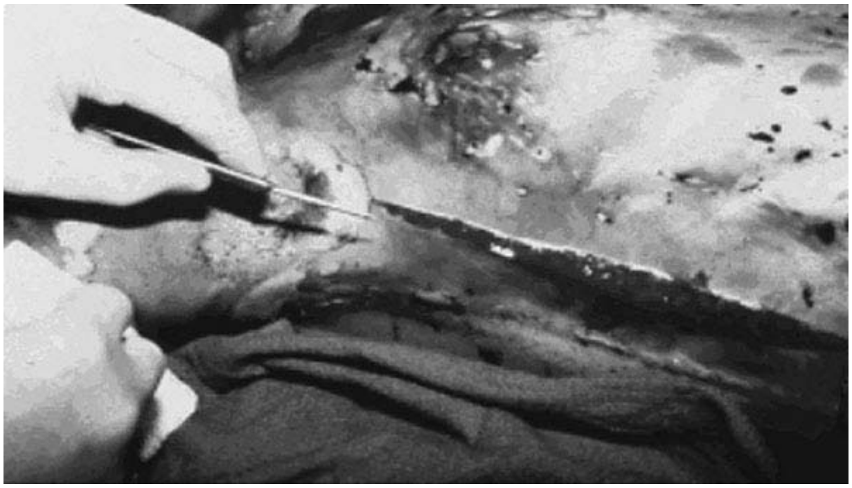
Pain management is a major issue with the burned patient. During the early resuscitative phase of patient management, blood flow to the skin is disrupted for a number of reasons that alter the absorption of intramuscular or subcutaneously delivered pain medication. The neuron–hormonal response to the loss of intravascular fluid volume during the shock phase redirects blood flow to the central core to support blood flow to vital organs. Additionally, subsequent edema development as fluids leak from the intravascular space to the extravascular space during this shock phase (third-space effect) hinders the absorption of intramuscularly administered medication. Judicious use of IV pain medication is indicated during this period.[12] Pain medications may be titrated to control pain and avoid adverse reactions. Pain scores and response to medication should be recorded and monitored.

After the initial burn shock period, the magnitude of the individual patient's pain response may differ. In the very young and very old, pain management can be challenging, as the response of patients in these two groups can be quite variable. With the major burn patient who is admitted to the hospital, pain management takes two forms. The first is management of background pain; this type of pain is generally constant pain that is present until wound closure has occurred, which might be several weeks to months. Once the patient is able to tolerate oral pain management, a long-acting narcotic such as methadone is started and titrated to manage this background pain. Shorter-acting narcotic and NSAIDs also are used to supplement the effects of the long-acting agents.

Episodic pain occurs with specific activities such as dressing changes and wound or extremity manipulation during the necessary physical and occupational therapy required during recovery. Control of this episodic pain is quite variable and dependent on many factors, including how stoic the patient is, past experiences with pain management or drug use, or pre-existing, chronic, painful conditions that might compound the management episodic pain during this particular period of time. A variety of pain management methodologies are employed, including small doses of IV medication, oral pain medications, and the liberal use of anxiolytic agents. The goal is to use the smallest amount of pharmacologic agents as possible to control this episodic pain. Alternative pain management, including music therapy, imagery, and virtual reality, has also been of value.[10-12]

The hallmark of pain management in the outpatient setting is a well-applied wound dressing and limb elevation to

Figure 3. Chest Escharotomy



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decrease dependent edema during the early phase after the burn injury. NSAID agents or acetaminophen are the mainstay of outpatient management. Again, the needs of any particular patient will be influenced by his or her past experience with pain and drug usage, although oral narcotics may be needed for breakthrough pain.

Surgical Care of the Burn Patient

Escharotomy. During the early post-burn period, the patient's extremities may appear pale, feel cool, and exhibit poor capillary refill due to shunting of blood from the periphery to the central core. Once proper resuscitation is initiated and the peripheral circulation is re-established, there is release of a variety of inflammatory mediators. These mediators lead to transudation of intravascular fluids into the extravascular space with the loss of fluids and proteins, producing local swelling. As this swelling occurs in the area of the full-thickness burn, with its rigid and unyielding overlying eschar, compartment syndrome can develop and the adequacy of the peripheral circulation must constantly be monitored. In patients with circumferential burns of the extremities, this is especially concerning and the practitioner should be vigilant for signs of developing compartment syndrome. While usually a late sign, any loss of pulses would certainly suggest vascular compromise.

An escharotomy performed with a scalpel or by electrocautery through the full-thickness burn to the subcutaneous fat allows this rigid tissue to expand and releases the constricting pressure on the underlying vessels. While this should be a painless procedure, as it is usually through an area of full-thickness burn, there is frequently brisk venous bleeding that can be managed with a bulky dressing and elevation of the extremity. **Figure 3** shows a chest escharotomy performed to improve ventilation in patients with circumferential chest burns. **Figure 4** is a chart of escharotomy sites for extremities and the chest. With extremity escharotomies, peripheral pulses should be re-established, and with chest escharotomies, airway pressures should decrease. Local or regional anesthesia usually is not necessary.

Wound Coverage. The classical management of burns for centuries involved waiting for the eschar to separate naturally from the underlying subcutaneous tissue, with subsequent skin grafting, one of the oldest surgical procedures. This eschar separation was due to subeschar infection and liquefaction of the nonviable tissue by bacterial proteolytic enzymes. Sepsis was common, as the bacteria trapped beneath the eschar frequently gained access to the systemic circulation. Since the 1960s, effective topical antibiotics that actively penetrate the eschar have been available. Their use, however, delays eschar separation. Delayed eschar separation results in lengthened patient hospitalization and recovery.

In 1970, Janzekovic published on a series of patients treated with early excision and grafting.[13] The rationale was that the earlier the dead skin was removed, the faster the wound would heal. Excision done within the first 3–4 days resulted in an excellent take of skin grafts, lower sepsis rates, and shorter hospitalizations. If the patient enters the burn unit late or with burn wounds already heavily colonized, skin grafting may result in loss of the skin graft and should be postponed until the bacteria count is acceptable.

Primary excision has become the standard in the management of burn patients, with removal of all nonviable burned skin either by using a dermatome, scalpel, or electrocautery. Excision can be tangential, sequential, or full-thickness. Once the eschar is removed, the next important stage of surgical management of a burn patient is wound coverage.

There are several alternatives to achieve wound closure, the most efficient being to excise the burn wound and suture the skin closed. This is an acceptable method for some small burns and frequently is overlooked. Small burns managed in this fashion usually heal with minimal scarring, and the procedure can be performed on an outpatient basis.

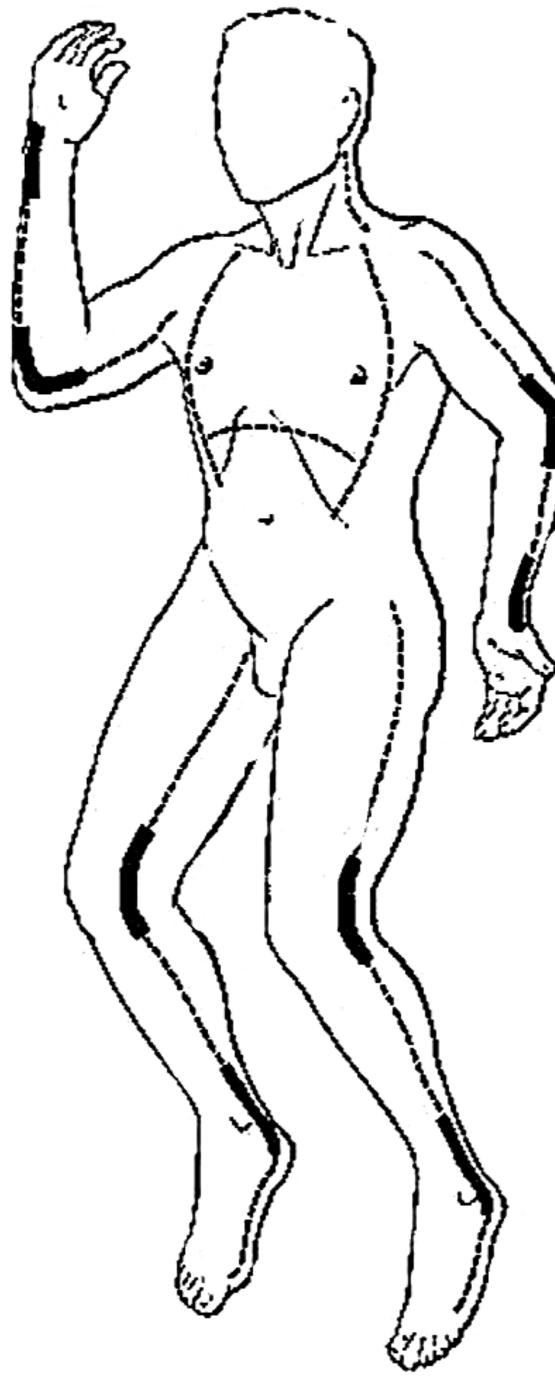
With burns of less than 20% of the body surface area, there is usually an adequate supply of donor sites for skin grafting and wound coverage. Small full-thickness burns might be allowed to heal on their own, as the base frequently is too small to support a skin graft. Larger full-thickness burns and deep partial-thickness burns that are estimated to take longer than three weeks to heal require skin grafting. Burns requiring skin grafting usually are managed by early total excision, although wound coverage sometimes can become an issue because of the lack of available donor sites. With smaller-area burns requiring skin grafting, cosmetic and functional areas such as hands and faces are addressed first. With larger-area burns, patient survival is the first priority, and skin grafting follows certain other priorities. The wound should be closed as quickly as possible to decrease the risk of colonization of the necrotic skin and the chance of systemic sepsis. Wound closure is accomplished most easily in large, flat surfaces such as the chest, abdomen, and anterior upper and lower extremities. With early excision and good skin graft adherence, the total burn size is decreased gradually to a smaller, nonlethal size. Coverage of the burn wound with autografts depends on the extent and location of the wound and the amount of donor skin available. Grafts may be applied as "sheet" grafts, whereby a strip of skin is removed from a donor site and transferred without alteration. Sheet grafts are more durable and produce better cosmesis than meshed grafts, which is particularly beneficial for coverage of areas exposed to shearing forces or the environment such as hands, neck, arms, and face.

With large wounds, however, the available donor sites frequently are insufficient to cover the excised area. An early attempt to expand the amount of available skin was made by using "pinch" grafts, in which many small, fingertip-size grafts were used to cover the burn wound. In 1964, Tanner described a meshing devise that cuts small holes in the graft and allows for expansion of the harvested skin graft to allow for coverage of large wounds.[14] The expansion ranges from 2:1 up to 9:1, and experimental expansions of up to 100:1 have been studied in the laboratory.[15,16] The 9:1 expansion is very difficult to work with and infrequently used; 2:1 to 4:1 are used most commonly. The pattern of the meshed skin graft will remain when the graft heals; therefore, every effort is made to avoid the use of meshed grafts on the face, neck, and hands. Donor sites generally heal in 10–14 days and can be re-harvested three or four times. Because donor sites resemble partial-thickness burns, they are usually painful, but with the newer donor-site dressings this pain usually subsides in 3–4 days.

As the application of primary excision has expanded, additional methods of expanded mesh grafting have been developed. One of these is a cultured skin substitute called cultured epithelial autograft (CEA).[17] CEA is used when large, total body surface area burns (generally greater the 50%) require coverage and patients do not have enough donor skin available. A small piece of unburned skin is excised and keratinocytes are grown in a laboratory. These grafts take several weeks to grow, during which time patients are at risk for infection. Although cultured keratinocytes provide more material to cover the patient's wounds, they are less durable than autografts, as they contain no dermal elements. Several additional models are being developed in the laboratory that either grow epithelial grafts earlier on a fibroblast matrix to increase durability, or in which liquid keratinocyte cultures are applied in a spray fashion in the early post-burn period. The keratinocytes spray is under clinical evaluation.

Aggressive, early excision has stimulated a market for a

Figure 4. Escharotomy Sites



The dashed lines indicate the preferred sites for escharotomy incisions. The solid segments of the lines emphasize the importance of extending the incisions across involved joints.

Source: Emergency War Surgery, Second United States Revision of The Emergency War Surgery NATO Handbook. *Operational Medicine.* United States Department of Defense;2001:Fig. 16.
Available at www.brooksidepress.org/Products/OperationalMedicine/DATA/operationalmed/Manuals/NATOEWS/figures/Fig16.html.
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variety of biological and biosynthetic products. These products include allogeneic cadaver skin, human allogeneic dermis, and the "artificial" skin Integra™ (Integra Lifesciences Corp., Plainsboro, NJ), which is a biosynthetic two-part construct of shark cartilage and bovine collagen with an outer silicone sheet.[18] With proper care, once Integra™ "takes," at about 3–4 weeks the outer silicone sheet is removed and a skin graft is applied. It is unclear whether the Integra™ survives long term or merely serves as a strut for the in-growth of the patients' own fibroblasts. Motion and infection are the primary causes of Integra loss, and the vacuum-assisted closure devise has proved beneficial in improving Integra™ assimilation.

The biologic dressings also include porcine or other species xenografts. Amnion is an excellent biologic dressing, but its use has been limited in recent years due to the potential risks of hepatitis and HIV transmission.[19]

A variety of biosynthetic dressings have been developed to temporarily cover the excised full-thickness burn or the partial-thickness wound and promote wound healing. Temporary wound coverings provide a protective barrier either while donor sites heal for future harvesting, until Integra™ is ready for grafting, or for primary coverage of partial-thickness burns. One major advantage of these temporary dressings is that many can be left in place over the partial-thickness wound until it heals, eliminating painful, twice-daily dressing changes. Many of the new synthetic wound coverings have characteristics of biologic coverings, and most are some form of synthetic matrix such as silicone with biologic components such as bovine collagen. Many also have some form of silver ions applied to them, which have antibacterial effects.

The ultimate goal of surgical management is to achieve a functional, durable, and cosmetically acceptable skin surface. Early surgery in the burn patient involves removal of the full-thickness burn and its replacement either with the patient's own skin (autografts) or one of a number of temporary biological or biosynthetic dressings. Patients with large burns will require multiple operations to cover their wounds and may require multiple reconstructive procedures to achieve maximal cosmetic and functional outcomes.

Recently, some patients undergoing elective cosmetic surgery after effective weight-reduction surgery have offered to donate "extra" skin to burn centers, either from good Samaritan desires or for imagined financial gains. These donations are very problematic, and most burn and tissue centers have refused such offers.

Summary

The management of the acute burn injury provides the framework for patient survival and sets the entire course of their hospitalization. Assessments made during this period will have a far-reaching effect on the resultant disability or function that the patient might experience.

The burn patient always must be approached with a complete assessment, just like any other trauma patient. This includes the ABCs of airway, breathing, and circulation, and the recognition of associated life-threatening injuries. A past medical history of any illnesses that might complicate the healing of the burn wound should be obtained. The burn wound needs to be properly assessed for depth and extent to determine the course of treatment. IV fluid replacement needs are calculated from the size estimate.

Hospitalization and the need for referral to a regional burn center should be determined using American Burn Association guidelines. *(See Tables 2 and 3.)* The surgical management of these patients has become quite complicated, with early excision being effectively applied to improve patient survival, shorten hospital stays, and improve patient outcomes.

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18 Heimbach DM, Warden GD, Luterman A, et al. Multicenter postapproval clinical trial of Integra dermal regeneration template for burn treatment. *J Burn Care Rehabil* 2003;24:42-48.
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CME Questions

1. The Centers for Disease Control and Prevention estimates that all of the following are true *except*:
   a. Only 60% of Americans have an fire escape plan.
   b. Only 25% of those who have a fire escape plan have practiced it.
   c. Smoke alarms cut occupants' chances of dying in a fire in half.
   d. Malfunctioning smoke alarms are the major cause of home fire deaths.

2. Burn patient management includes all of the following *except*:
   a. Thorough head to toe evaluation
   b. Evaluation and management of any associated injuries
   c. Full-body CT scan to exclude other injuries
   d. Determination of the appropriate management course
   e. Initiation of appropriate hospital care, if needed, or arrangement for follow-up care

3. The three zones of burn injury are:
   a. Zones of stasis, necrosis, and hypoperfusion
   b. Zones of stasis, hyperemia, and necrosis
   c. Zones of necrosis, hyperperfusion, and stasis
   d. Zones of necrosis, stasis, and hypoperfusion
   e. Zones of necrosis, stasis, and hypoperfusion

4. Early bronchoscopy and intubation are suggested for which of the following?
   a. All major burn patients
   b. Patients burned in a closed space with facial burns or soot in the oropharynx
   c. Patients with abnormal chest x-rays
   d. Patients with abnormal blood gases
   e. Only for patients in acute respiratory distress

5. The "ABCDEs" of burn management include all of the following *except:*
   a. A is for airway
   b. B is for breathing
   c. C is for circulation
   d. D is for disability
   e. E is for escharotomy

6. "Rule of 9s" refers to:
   a. Determining burn sizes of nine body areas
   b. Using 9 mL IV Ringers for each percent body burn
   c. Dividing the body into 11 areas of 9% body surface area each
   d. Dividing the burn size by 9 to determine fluid needs

7. Partial-thickness burns (as opposed to full-thickness burns) are all of the following *except*:
   a. Red
   b. Wet
   c. Painful
   d. Leathery

8. The Parkland formula for fluid resuscitation is:
   a. Crystalloid usually given as LR 7 mL/kg/% body surface area burn
   b. Crystalloid usually given as LR 4 mL/kg/% body surface area burn
   c. Crystalloid usually given as LR 2 mL/kg/% body surface area burn
   d. Crystalloid usually given as D5NS 4 mL/kg/% body surface area burn

9. The usual cause of early renal failure in electrical injury is:
   a. Shock
   b. Sepsis
   c. Myoglobinuria
   d. Multi-system organ failure (MSOF)

CNE/CME Instructions

Physicians and nurses participate in this continuing medical education/continuing education program by reading the article, using the provided references for further research, and studying the questions at the end of the article. Participants should select what they believe to be the correct answers, then refer to the list of correct answers to test their knowledge. To clarify confusion surrounding any questions answered incorrectly, please consult the source material. **After completing this activity, you must complete the evaluation form provided and return it in the reply envelope provided in order to receive a letter of credit.** When your evaluation is received, a letter of credit will be mailed to you.

CNE/CME Objectives

Upon completing this program, the participants will be able to:
a.) discuss conditions that should increase suspicion for traumatic injuries;
b.) describe the various modalities used to identify different traumatic conditions;
c.) cite methods of quickly stabilizing and managing patients; and
d.) identify possible complications that may occur with traumatic injuries.

10. American Burn Association indications for hospitalization of burn patients include:
    a. Great than 20% total body burn
    b. Greater than 5% full-thickness burn
    c. Any suspected inhalation injury
    d. All electrical and chemical burns
    e. All of the above

Answers: 1. a; 2. c; 3. b; 4. b; 5, e; 6. c; 7. d; 8. b; 9. c; 10. e

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In Future Issues:

ATLS Guidelines Update

Trauma Reports
Evidence-Based Medicine for the ED

TR030109TM

CNE/CME Evaluation — Optimizing Outcome in the Adult and Pediatric Burn Patient

Please take a moment to answer the following questions to let us know your thoughts on the CNE/CME program. Fill in the appropriate space and return this page in the envelope provided. **You must return this evaluation to receive your letter of credit. ACEP members — Please see reverse side for option to mail in answers.** Thank you.

CORRECT ⬬ INCORRECT

1. In which program do you participate? ◯ CNE ◯ CME
2. If you are claiming physician credits, please indicate the appropriate credential: ◯ MD ◯ DO ◯ Other ______________
3. If you are claiming nursing contact hours, please indicate your highest credential: ◯ RN ◯ NP ◯ Other ______________

After participating in this program, I am able to:	Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree
4. Discuss conditions that should increase suspicion for traumatic injuries.	◯	◯	◯	◯	◯	◯
5. Describe the various modalities used to identify different traumatic conditions.	◯	◯	◯	◯	◯	◯
6. Cite methods of quickly stabilizing and managing patients.	◯	◯	◯	◯	◯	◯
7. Identify possible complications that may occur with traumatic injuries.	◯	◯	◯	◯	◯	◯
8. The test questions were clear and appropriate.	◯	◯	◯	◯	◯	◯
9. I am satisfied with customer service for the CNE/CME program.	◯	◯	◯	◯	◯	◯
10. I detected no commercial bias in this activity.	◯	◯	◯	◯	◯	◯
11. This activity reaffirmed my clinical practice.	◯	◯	◯	◯	◯	◯
12. This activity has changed my clinical practice.	◯	◯	◯	◯	◯	◯

If so, how?____

13. How many minutes do you estimate it took you to complete this activity? Please include time for reading, reviewing, answering the questions, and comparing your answers with the correct ones listed. _______ minutes.
14. Do you have any general comments about the effectiveness of this CNE/CME program?

____

I have completed the requirements for this activity.

Name (printed) ______________________ **Signature**______________________

Nursing license number *(required for nurses licensed by the state of California)*______________________

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PLEASE NOTE: If your correct name and address do not appear below, please complete the section at left.

Optional for ACEP members: In accordance with ACEP requirements, below we provide the option for ACEP members to submit their answers for this CME activity. If you wish to submit answers for this activity, please refer to this issue (Vol. 10, No. 2) and circle the correct responses.

1. A
   B
   C
   D

2. A
   B
   C
   D

3. A
   B
   C
   D
   E

4. A
   B
   C
   D
   E

5. A
   B
   C
   D
   E

6. A
   B
   C
   D

7. A
   B
   C
   D

8. A
   B
   C
   D

9. A
   B
   C
   D

10. A
    B
    C
    D
    E

Emergency Medicine Reports
The Practical Journal for Emergency Physicians

Acute Appendicitis Part I

Alvarado/MANTRELS

Variables	Score
Migration of pain to RLQ	1
Anorexia	1
Nausea/vomiting	1
Tenderness in RLQ	2
Rebound pain	1
Elevation of temp (> 37.3°C)	1
Leukocytosis (WBC> 10,000)	2
Shift of WBC to left (> 75% polys)	1
	10

Pediatric Appendicitis Score

Variable	Score
Migration of pain to RLQ	1
Anorexia	1
Nausea/vomiting	1
Temperature > 38°C	1
Cough/percussion tenderness	2
RLQ tenderness	2
WBC > 10,000	1
Polys > 7500 cells/mm^3	1
	10

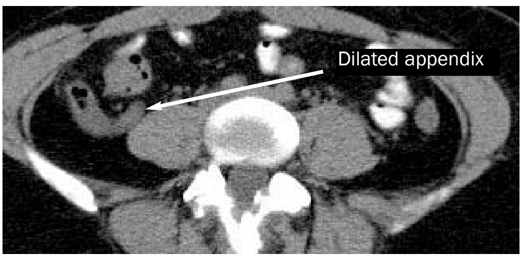
CT Findings in Acute Appendicitis

- Distended with fluid with or without inflammation
- 8 mm diameter or > 6 mm diameter with periappendiceal inflammation
- Thickened wall with increased enhancement with IV contrast
- Appendicolith (secondary sign)
- Periappendiceal inflammation (secondary sign)

CT Signs of Perforation

- Phlegmon
- Abscess
- Extraluminal gas
- Extraluminal appendicolith
- Focal defect in enhancement in appendiceal wall

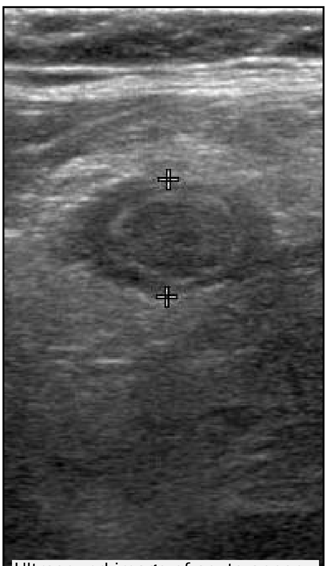
Moderate Acute Appendicitis



A 38-year-old non-pregnant female presents with 3 days of constant abdominal pain located in the right lower quadrant. The pain is mild and feels like gas. There is no nausea, vomiting, or fever. Examin-ation is notable for tenderness over McBurney's point and the right periumbilical area. No peritoneal signs are present. WBC is 9000/mm^3 without left shift, and urinalysis is normal. The patient drank only half of a cup of oral contrast and refused the remainder. She also refused IV contrast. Partially enhanced CT images are shown above. The appendix was dilated, retrocecal, and lateral in position. There is inflammation of the distal appendix, with periappediceal fat stranding. The patient underwent laparoscopic appendectomy. The pathology report noted moderate acute appendicitis, focally transmural with minimal periappendiceal inflammation.

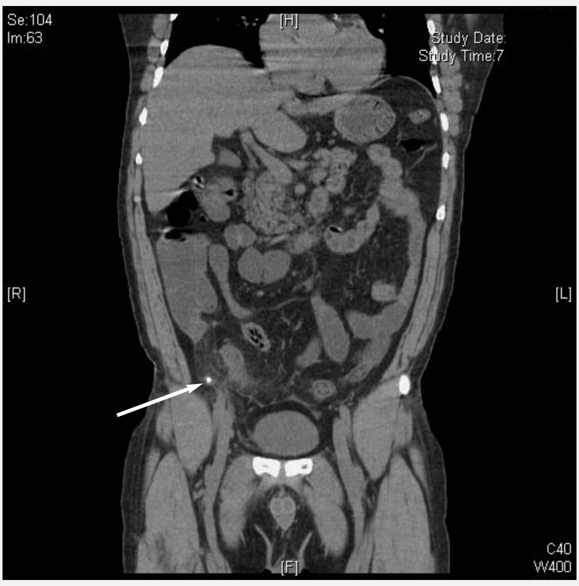
CT Scan Axial View Showing Tubular Shaped Appendicolith

Ultrasound Image of Acute Appendicitis



Ultrasound image of acute appendicitis with a small amount of free fluid seen in an adult female

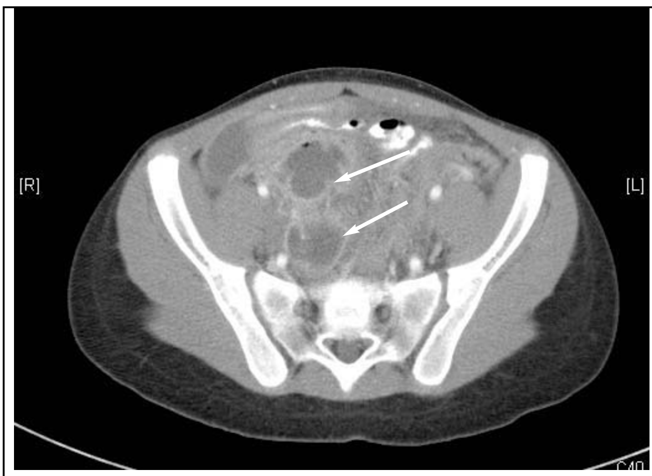
CT Scan Coronal Reconstruction View Showing Appendicolith Within Dilated Appendix Measuring 11 mm in Diameter (Arrow)



Perforated Appendicitis with Appendicolith and Multilocular Abscesses

A 12-year-old female presented with 7 days of abdominal pain. She was afebrile, but her WBC was 18,000/mm^3. CT with IV contrast alone demonstrated a perforated appendicitis with an appendicolith (arrow in image above) and multilocular abscesses (arrows in image below).

Perforated Appendicitis with Appendicolith and Multilocular Abscesses



Supplement to *Emergency Medicine Reports*, March 2, 2009: "Acute Appendicitis Diagnosis and Treatment in 2009: Part I." *Authors:* **Lisa Freeman Grossheim, MD, FACEP**, Assistant Professor of Emergency Medicine, University of Texas Medical School at Houston; **Katrin Takenaka, MD, FACEP**, Assistant Professor of Emergency Medicine, University of Texas Medical School at Houston; and **Amy Noland, MD**, Resident, Department of Emergency Medicine, University of Texas Medical School at Houston.