Abdominal pain is a common complaint in pediatric patients, but children are vulnerable to a variety of serious conditions that can present as this seemingly benign complaint. In such cases, emergency physicians must possess a keen diagnostic acumen to prevent major complications and death, as well as a thorough understanding of the appropriate and efficient diagnostic imaging tools to implement, while mitigating the risks of ionizing radiation.

Procedural sedation frequently is used in the emergency department for the management of pain and anxiety—a protocol that enables patients to tolerate uncomfortable or unpleasant procedures. Emergency physicians must possess a thorough understanding of how to administer these medications, monitor patients, and manage any complications that might arise.
Imaging in Pediatric Abdominal Pain

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Objectives

On completion of this lesson, you should be able to:

1. Describe common abdominal pathologies that manifest as pain in different pediatric age groups.
2. Determine the appropriate imaging modalities for children presenting with trauma.
3. List the common abdominal masses seen in the pediatric population.
4. Explain the approach to diagnostic imaging in children with chronic abdominal pain.
5. Discuss the approach to diagnostic imaging in postpubertal females.
6. Discuss the risks involved in ionizing radiation in the pediatric population, and describe ways to minimize radiation exposure.

From the EM Model

1.0 Signs, Symptoms, and Presentations
1.2.5 Abdominal Pain

Cases

Case 1

An 8-year-old boy without a significant medical history was traveling in the rear seat of a vehicle that struck an oncoming truck while traveling approximately 50 mph. The child was restrained with a lap belt. He is transported via ambulance to your Level 1 trauma center, where is found to be alert and oriented with a GCS of 15. His heart rate is 90 beats per minute, respiratory rate 20 breaths per minute, blood pressure 110/65, and oxygen saturation 100% on room air.

On examination, he remains comfortable in a cervical collar, but complains of tenderness at the mid epigastrium. There is a transverse area of ecchymosis across his abdomen with a minor abrasion over the left lower quadrant. He does not show evidence of any further injury; routine trauma laboratory tests, including hemoglobin and liver function tests, do not reveal any abnormalities.

Critical Decision

How does the age of a child affect the differential diagnosis and subsequent imaging choices?

The evaluation of a pediatric patient with abdominal pain is challenging due, in part, to the evolving nature of the underlying etiologies of pain as the child ages. Classic historical features, including location, timing, character, severity, duration, and radiation of abdominal pain should be considered within the context of a patient's age.

It can be helpful for emergency physicians to stratify patients into three broad age groups to provide a framework from which a targeted workup should proceed. Distinct intra-abdominal pathologies seem to present in children less than 2 years of age more often than in school-age children and early adolescents.

Case 2

An 11-year-old girl without a significant medical history presents with progressively worsening abdominal pain that began 48 hours prior to arrival. She says she has had no appetite today and reports several episodes of non-bloody, non-bilious emesis in the last 48 hours. Her mother reports an oral temperature of 101.3, and says the girl complained of pain during the car ride to the hospital. The child is alert and oriented and is most comfortable with both hips flexed.

Her heart rate is 125 beats per minute, respiratory rate 18 breaths per minute, blood pressure 120/75, and oxygen saturation 97% on room air. The patient's eyes are sunken with dry mucous membranes, and there is voluntary guarding on abdominal examination with rebound tenderness at the right lower quadrant. She cries out in pain with a bilateral heel strike. She denies tenderness in the periumbilical, suprapubic, and left portions of her abdomen. Routine laboratory tests reveal a WBC of 21.
Critical Decisions

- How does the age of a child affect the differential diagnosis and subsequent imaging choices?
- How should acute abdominal pain in the setting of trauma be evaluated with imaging in a pediatric patient?
- How should a potential abdominal mass in a child be approached with diagnostic imaging?
- What is the best approach to diagnostic imaging in the child with chronic abdominal pain?
- What imaging considerations should be made when evaluating the postpubertal female patient with abdominal pain?
- When are CT scans justified, and how can the risks of ionizing radiation be avoided?

However, the astute clinician knows that no age-specific cutoff is absolute; a high index of suspicion should remain for potentially life-threatening etiologies, regardless of age. In any patient less than 2 years old presenting with abdominal pain, the emergency physician should remain wary of conditions such as intussusception, volvulus, and – as always – trauma. Other less common causes, including incarcerated hernia and Hirschprung disease, also should be considered in the very young with non-specific abdominal complaints.

School-age children often present with abdominal pain as a sign of acute gastroenteritis; however, appendicitis remains the most common, non-traumatic surgical emergency in children and should be properly investigated. Abdominal trauma also remains a potential etiology for this age group, as do gynecologic problems in peripubertal females (discussed in a separate section).

Intussusception

Intussusception, which occurs most commonly between 3 and 12 months of age, is the leading cause of acute intestinal obstruction in infants. Colicky abdominal pain is the classic clinical manifestation of this medical emergency. Although flat and upright plain films of the abdomen can reveal signs of intestinal obstruction and occasionally a characteristic “target” sign, most medical centers have adopted ultrasound evaluation as the first line for suspected intussusception. Several studies report near 100% sensitivities and specificities of ultrasound in detecting the condition in the pediatric population. Ultrasound also carries the advantage of identifying potential pathologic lead points, as compared with barium or air enema. Once the presence of intussusception is confirmed with ultrasound, a therapeutic air enema under fluoroscopic guidance can be performed.

Ultrasound also offers diagnostic benefits without exposing patients to ionizing radiation. As hospitals become more comfortable with this imaging method, its often-cited operator dependency is diminishing. In fact, emergency physicians appear to have the ability to detect intussusception as well as their radiologist colleagues after only 1 hour of focused training in bedside ultrasound.

Malrotation of the Bowel

Malrotation of the bowel is a congenital condition involving abnormal fixation of the mesentery to the bowel, which predisposes portions of the small and large intestines to volvulize and potentially lose their blood supply. To avoid a medical catastrophe, the emergency physician should maintain a high index of suspicion for this condition in a child with bilious emesis and abdominal pain. The condition usually manifests in utero or during neonatal life, but also can present in older children.

Flat and upright plain radiographs of the abdomen to investigate for dilated loops of bowel with air-fluid levels is not an unreasonable place to start, but the use of plain x-rays in screening children with abdominal pain has begun to fall out of favor due to its limited diagnostic utility. The study of choice in such cases is an upper GI series. If the diagnosis is confirmed, the patient should be prepared for immediate surgery. A high degree of clinical suspicion must be maintained as the sensitivity of upper GI for malrotation is 94% to 96%. For neonates, who are notorious for their inability to localize pain, however, plain radiographs can be a helpful adjunct to a comprehensive history and physical examination to evaluate for intestinal obstruction. X-rays also can detect necrotizing enterocolitis in neonates (most commonly seen in premature births).

Appendicitis

In children older than 2 years, appendicitis and trauma should remain high in the differential diagnosis. Accurate diagnosis and early consultation with a surgeon are important in both scenarios. The child with classic signs and symptoms of appendicitis should be referred to a pediatric surgeon promptly, while avoiding further testing that might delay required surgery. The appropriate path for the investigation of an equivocal case
can be complicated and potentially confusing. Studies investigating the utility of laboratory tests are myriad, and their application depends on the surgeon. The diagnostic imaging approach has been similarly fraught with debate, but recent literature supports an initial sonographic evaluation followed by abdominal CT scan only after ultrasound has failed to make a definitive diagnosis.

The American College of Emergency Physicians, American Academy of Pediatrics, and American College of Radiology all point to ultrasound as the initial imaging modality of choice. Ultrasound has the advantages of being widely available and relatively inexpensive, while avoiding the dangers of exposing the highly sensitive tissues of pediatric patients to ionizing radiation. The reported sensitivity of ultrasound 80% to 92% with a specificity of 86% to 98%. Its use in the evaluation of acute appendicitis, however, has been criticized for the modality’s reliance on operator technique and limited utility in patients with a high body-mass index or retrocecal appendix. The finding of a non-compressible, peristaltic, blind-ending tubular structure arising from the cecum on ultrasound is diagnostic of acute appendicitis.

Although in many hospitals, the CT scan remains the gold standard for diagnosing suspected appendicitis due to its high sensitivity and specificity (>95%) and independence from operator technique, it should be reserved for patients in whom there is a high suspicion for appendicitis and equivocal ultrasound results. Classic CT findings of acute appendicitis include an enlarged appendix, a thickened and enhanced appendiceal wall, and periappendiceal fat stranding.

**CRITICAL DECISION**

How should acute abdominal pain in the setting of trauma be evaluated with imaging in a pediatric patient?

**Blunt Trauma**

More than 90% of pediatric abdominal traumas involve a blunt mechanism. Children are at increased risk for intra-abdominal complications after blunt injury because of their immature musculoskeletal system and elevated abdominal organ-to-body-mass ratio. The initial evaluation of patients suffering from blunt abdominal trauma should focus on the ABCs of the primary survey. The secondary survey and adjuncts to the trauma evaluation should include laboratory and radiologic tests. The utility of a bedside ultrasound FAST scan in adult trauma patients has been well established, with reported sensitivities of 85% to 98%. Although the FAST scan’s effectiveness in the pediatric population has not been widely studied, it has been criticized for its insufficient sensitivity and negative predictive value in hemodynamically stable pediatric trauma patients. Here again, the effectiveness of the imaging modality appears to be largely dependent upon the skill and experience of the physician.

The CT scan is considered the gold standard for the evaluation of intra-abdominal trauma in pediatrics. Its popularity has risen dramatically over the last 15 years due to its sensitivity, availability, and ever-decreasing cost. This escalating reliance on CT scans does not come without risk, however, as less than 15% of pediatric patients suffering from blunt abdominal trauma have a documented intra-abdominal injury, and the majority of these injuries in children are managed nonoperatively. As awareness about the risks of exposure to ionizing radiation has grown, a corresponding interest in limiting the “pan-scan” approach to the evaluation of pediatric trauma has developed.

Several leading studies have shown that clinical prediction tools that focus on examination and laboratory data can be used to effectively identify patients at “high risk” of intra-abdominal injury after blunt trauma. In fact, clinical prediction models designed to drive selective imaging appear to reduce CT scan use by more than 30%. A major multicenter prospective study of a prediction tool for intra-abdominal injury focused specifically on physical examination findings revealed a sensitivity of 97% and negative predictive value of 99.9%.

It is clear that the future of radiologic evaluation in cases of pediatric blunt abdominal trauma likely will show an increased reliance on bedside FAST scans and selective imaging with CT scans for patients identified as being at highest risk for intra-abdominal injury.

**Penetrating Trauma**

Although it accounts for less than 10% of abdominal trauma in children, penetrating trauma can lead to devastating injuries. The colon and small bowel are the organs most commonly affected by penetrating injury, followed by the liver, spleen, and major vessels. The definitive evaluation and treatment for the unstable patient suffering from penetrating abdominal trauma is exploratory laparotomy. In most

As more data emerges about the harmful downstream effects of ionizing radiation on children, clinical practice is compelled to change as a matter of public health.
cases, this procedure should not be delayed to obtain radiologic studies. Local exploration for evidence of peritoneal perforation is imperative in patients who are hemodynamically stable or suffering from superficial anterior or dorsal wounds. In stable patients, an abdominal CT scan with IV contrast can be used to confirm the extent of intra-abdominal injury in conjunction with selective laparoscopic evaluation for wounds that penetrate the peritoneum.

**CRITICAL DECISION**

How should a potential abdominal mass in a child be approached with diagnostic imaging?

The evaluation of a potential abdominal mass in a child is informed by the patient’s age. Intra-abdominal masses in neonates tend to originate from the genitourinary tract, whereas malignant lesions such as neuroblastomas, Wilms tumors, and lymphomas predominate in the older child. Initial stabilization of the ill child and a thorough history and physical examination should precede diagnostic imaging.

A multilayered approach, beginning with a plain film of the abdomen, is a reasonable starting point. X-rays can provide useful information about the location of a mass, evidence of an intestinal obstruction, or presence of calcifications that herald a malignant mass such as a teratoma. Ultrasound can provide further information, including the organ of origin and potentially the type of tissue components present in the mass (solid vs. cystic). A CT or MRI scan can reveal even more specific information about the mass, including a more accurate account of its point of origin, other potential areas of involvement, or metastasis in the case of malignancy.

In neonates, hydronephrosis and multidyplastic kidney are the most common etiologies of a palpable abdominal mass. Ovarian cysts also can present perinatally; in such cases, sonography is an appropriate first-line diagnostic imaging test. Though rare, masses that arise from the gastrointestinal tract in neonates often are caused by gastric duplication cysts. Ultrasound can be used to better characterize these lesions, and a Meckel scan can confirm the presence of ectopic gastric tissue frequently found within these masses.

Neuroblastoma, the most common extracranial solid tumor in childhood, is the most likely cause of an abdominal mass in an infant or older child (approximately 60% to 70% originate from within the abdomen). Wilms tumor is the second most common etiology of an abdominal mass in childhood and the most common primary renal malignancy. The presenting size of the mass might be rather large, given its retroperitoneal origin. Wilms tumors classically present as painless masses, but can become painful with hemorrhage and rupture. Approximately 15% of children with this disease will have metastatic involvement. The lungs, liver, and lymph nodes are the most likely organs of disease spread.

The third most common abdominal mass presenting in childhood is lymphoma. Sixty percent of cases are characterized as non-Hodgkin lymphomas, and a third are intra-abdominal in origin. Intussusception often is the presenting sign due to a lymphomatous lead point. These tumors tend to grow rather quickly, but have been known to respond well to chemotherapy.

In all cases of suspected abdominal mass, ultrasound should be performed first to confirm the lesion; a follow-up CT or MRI scan is warranted to further characterize the organ of origin, determine the extent of involvement, and search for potential areas of metastasis. It is prudent to evaluate the contralateral kidney in the case of a Wilms tumor. Other adjunctive bone, CT, and MRI scans should be tailored to the specific malignancy and individual patient’s treatment protocol.

**CRITICAL DECISION**

What is the best approach to diagnostic imaging in the child with chronic abdominal pain?

Chronic or recurrent abdominal pain (RAP) is a common presenting complaint in the emergency department. The classic definition of RAP is described as “paroxysmal abdominal pain in children between the ages of 4 and 16 years that persists for more than 3 months and affects normal activity.” The Subcommittee on Chronic Abdominal Pain of the North American Society for Pediatric Gastroenterology, Hepatology, and Nutrition offers a more functional definition for RAP: “long-standing, intermittent or constant abdominal pain.” Although the prevalence of RAP is unknown, it has been reported in up to 10% to 15% of patients in that age range, and is a common reason for children to miss school.

Functional abdominal pain is far and away the most common diagnosis in patients with RAP. Most frequently considered a diagnosis of exclusion, it can lead to expensive and time-consuming evaluations that yield few significant findings. Because the emergency department is better suited for the evaluation of acute presentations than chronic symptoms, the very nature of RAP makes it a challenge to manage. The history and physical examination are likely to play a more valuable role in the evaluation of RAP than radiologic tests.

Special attention should be placed on the chronicity of pain, age of onset, associated symptoms, physical examination, and laboratory evaluation. In addition to the management of RAP itself, emergency providers must be attune to the common emergent diagnoses that can occur in patients with chronic pain. They should familiarize themselves with the common “red flags” that can signal an organic etiology of abdominal pain. Pain that wakes a
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Ultrasound is a good screening

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of abdominal pain in the emergency

diagnosis of functional abdominal

pain. Functional abdominal pain

is not generally associated with

significance vomiting or diarrhea;

unwanted weight loss; or systemic

symptoms such as fever, rash, joint

pain, aphthous ulcers, or dysuria.

Laboratory findings of guaiac-

positive stool, anemia, or elevated

inflammatory markers, as well as

a family history for inflammatory

bowel or peptic ulcer disease, should

lead one away from a diagnosis of

functional abdominal pain.17,18

The evaluation of chronic

abdominal pain is not driven by

imaging; therefore, the most effective

way to address the radiologic

screening of RAP is to discuss the

conditions that might lead to the

historical or examination “red flags”

listed above. The most useful test for

the assessment of chronic abdominal

pain with obstructive symptoms or

dyspepsia (pain with eating, nausea,

vomiting, early satiety, and excessive

belching) is an upper GI series

with small bowel follow through.

Depending on the severity of the

patient’s presentation, this evaluation

might be performed more practically

in ambulatory or inpatient settings.

In cases of suspected constipation,

plain abdominal radiographs can be

used to help evaluate the stool load

in the colon, but should not supplant

a complete physical examination,

including a digital rectal examination.

Ultrasound is becoming

increasingly popular in the evaluation

of abdominal pain in the emergency

department, but its role in the

evaluation of chronic or recurrent

abdominal pain is not as clear.

Ultrasound is a good screening

tool for particularly concerning

symptoms (eg, definitively localized

pain), and can help identify acute

causes of pain such as appendicitis,

cholecystitis, and torsion of the ovary.

It also can provide reassurance to

the patient and family at the bedside.

Use of an abdominal CT scan is not

recommended in cases of chronic

or recurrent abdominal pain in the

absence of other symptoms such

as fever or elevated inflammatory

markers.

**CRITICAL DECISION**

What imaging considerations should

be made when evaluating the

postpubertal female patient with

abdominal pain?

The evaluation of a postpubertal

female with abdominal pain can be

challenging due to the extensive list

of potentially dangerous etiologies.

Common diagnoses include

dysmenorrhea, mittelschmerz,

ruptured ovarian cysts, ovarian

torsion, and urinary tract infections.

It is incomplete, however, to rest on

common culprits if a more serious

pathology is possible.

Paramount in the evaluation of

such patients is a thorough history

and physical examination, including

sexual, menstrual, and social

histories. A pelvic examination by an

experienced practitioner also is an

essential element of the workup, and

ultrasound examination is warranted

in cases suggestive of life-threatening

pathology or pregnancy.

**Pregnancy**

Postpubertal females who present

to the emergency department with

abdominal pain should be considered

pregnant until proven otherwise.

Urinalysis or serum pregnancy testing

(beta-human gonadotropin, beta-
hCG) should be considered a default

measure in this patient population.

The diagnosis of pregnancy can

be based on the presence of any of

the following: detection of human

gonadotropin in the blood or

urine, identification of pregnancy

by ultrasound examination, or

identification of fetal cardiac activity

by Doppler ultrasound.

On transvaginal ultrasound

examination, a gestational sac

usually is visible at 4.5 to 5 weeks

gestation. The yolk sac can be

noted at the beginning of the fifth

week of gestation. An embryonic

pole with cardiac activity is first

detected at 5.5 to 6 weeks.19

A transabdominal approach will allow

visualization of these structures at

slightly later dates. More advanced

ultrasonographic techniques,

including biometric measurements,

can be used to estimate gestational

age and delivery date.

In a known pregnant patient

presenting with vaginal bleeding

during the first half of pregnancy,

consider miscarriage (incomplete,

complete, threatened, missed).

Bleeding in this situation might

or might not be accompanied by

abdominal or pelvic pain; thus, any

bleeding or pelvic pain in a pregnant

woman warrants further evaluation.

While a pelvic examination is

essential to assess the volume of

bleeding and confirm that the uterus

is the source, pelvic ultrasound is the

most useful test in this situation.20

Ectopic pregnancy is life

threatening without medical or

surgical intervention. It is the leading

cause of death in the first trimester of

pregnancy and has seen an increased

incidence with the rise in pelvic

inflammatory disease (PID) and

tubal surgery.21 In a postpubertal

female presenting with abdominal

pain associated with amenorrhea, the

combination of a serum quantitative

beta-hCG and transvaginal

ultrasound is the most useful

diagnostic approach and will provide

a definitive diagnosis in almost all

cases.19 In normal pregnancies, the

serum beta-hCG doubles every 2

days. The hCG concentration rises

much more slowly in most, but not

all, ectopic and nonviable intrauterine

pregnancies.22 Transvaginal

ultrasound has a sensitivity of 99% to

100% and a specificity of 80% to 99%

for identifying ectopic pregnancy.23

**Ovarian Torsion**

Ovarian torsion must be a

diagnostic consideration in any

adolescent female presenting with

intermittent and often unilateral

abdominal or flank pain. Torsion
in the premenarchal female also occurs and must be maintained in the differential diagnosis. Torsion occurs when the ovary rotates on its pedicle, leading to the compromise of its own blood supply. This is considered a surgical emergency due to the implications of loss of fertility, infection, sepsis, or death. Again, ultrasound is the diagnostic imaging modality of choice; its sensitivity in the diagnosis of ovarian torsion ranges from 46% to 75%.

MRI and CT typically are not used for the evaluation of ovarian torsion, but can be implemented in cases of equivocal ultrasound findings.

**Pelvic Inflammatory Disease**

Finally, emergency physicians should have a low threshold for the diagnosis of pelvic inflammatory disease (PID) in any adolescent girl presenting with lower abdominal pain and cervical motion tenderness on physical examination. While ultrasound can play a complementary role in the identification of PID or tubo-ovarian abscess, prompt empiric treatment is warranted when clinical suspicion for PID is high.

**CRITICAL DECISION**

When are CT scans justified, and how can the risks of ionizing radiation be avoided?

Recent literature documents the increasing popularity of CT scans in the pediatric patient population. The test can provide invaluable diagnostic information, but comes at the cost of ionizing radiation and uncertain risk. New evidence has determined, beyond theoretical association, that ionizing radiation from CT scans increases the risk of cancer in children. Abdominal CT scans deliver approximately 1,000 times the dose of an anteroposterior chest x-ray in adults. This dosage calculation is only magnified in the highly dividing tissues of a child.

**Risk vs. Reward**

Clinicians should consider the risks and benefits of radiation dosing when deciding on imaging. Helpful tools such as www.xrayrisk.com can help facilitate these discussions with patients. As more data emerges about the harmful downstream effects of ionizing radiation on children, clinical practice is compelled to change as a matter of public health. Many pediatric medical centers already have begun to reduce their use of CT scans. Of note, a number of hospitals have significantly increased their use of abdominal ultrasound in the evaluation of abdominal pain, an uptick that might herald a growing trend.

The future of diagnostic imaging in all patients, including children, will require both the justification and optimization of medical radiation. Justification can be broken down into the “three As”: awareness, appropriateness, and audit. In a 2004 survey of radiologists and emergency physicians, approximately 75% significantly underestimated the radiation dose from a CT scan, and a majority did not believe CT scans increased a patient’s lifetime exposure to cancer. These sentiments undoubtedly have changed in light of new evidence, but this example highlights the lack of awareness that existed just a few years ago. Radiation safety movements (eg, Image Gently) are furthering the cause by advocating for and educating both providers and patients about the long-term harm of radiation exposure.

Appropriate use is the second prong of radiation justification. The recent trend of increasing abdominal ultrasound use in the diagnosis of abdominal pain highlights the importance of seeking alternatives to abdominal CT whenever possible. Some medical centers are finding creative ways to limit and optimize radiation exposure. Quick-brain MRI has become more commonplace in the evaluation of potential brain injury; other hospitals are adopting low-dose CT scans to keep medical radiation as

**Pearls**

- Ultrasound is the initial imaging study of choice in the emergency department evaluation of a patient with potential intussusception.
- Children with a history and physical examination findings suggestive of classic appendicitis (ie, periumbilical pain radiating to the RLQ, anorexia, fever, emesis) do not require radiographic studies to confirm the diagnosis.
- Neuroblastoma is the most common malignancy presenting as abdominal mass in an infant or child.
- Rule out pregnancy in any postpubertal female patient presenting with abdominal pain.

**Pitfalls**

- Failing to obtain a thorough history (eg, sexual, menstrual, and social) and fully evaluate a postpubertal female patient with abdominal pain.
- Relying on bloodwork or imaging tests to diagnose functional abdominal pain. This is a diagnosis of exclusion, and is not associated with radiographic abnormalities or elevated inflammatory markers.
- Unnecessarily exposing pediatric patients to ionizing radiation through CT scans. The risks posed to this vulnerable population, including the latent development of cancer, must be considered.
low as reasonably achievable.

The most effective way to reduce the use of CT scans, however, is to avoid them altogether. Research indicates that CT scans could be replaced by alternative modalities or not performed at all in up to one-third of cases.

**Case Resolutions**

**Case 1**

After a complete primary survey, including a negative FAST (focused assessment with sonography for trauma) examination, the car accident victim underwent an abdominal CT scan with contrast that revealed a duodenal hematoma. She was admitted to the pediatric surgery service, and total parenteral nutrition and nasogastric decompression were initiated. He remained in the hospital for several weeks for conservative management, and was discharged with resolution of the duodenal hematoma on follow-up abdominal CT scan. This case illustrates the importance of maintaining a high index of suspicion for intra-abdominal injury in scenarios involving severe blunt trauma to the abdomen.

**Case 2**

The pediatric surgery service was consulted promptly, given the 11-year-old girl’s constellation of symptoms, the decision was made to operate the following morning. Intravenous isotonic fluids, analgesia, and antibiotics were initiated and the patient’s airway, breathing, and circulation is paramount. A thorough history and physical examination with an awareness of intra-abdominal pathologies specific to certain age groups will provide important diagnostic information. The remainder of the workup relies on the judicious use of imaging to arrive at a timely diagnosis.

**Summary**

The approach to imaging in the pediatric population is continually evolving as more literature concerning long-term radiation risks is revealed and newer technology is implemented. However, the principles of emergent stabilization of the child with abdominal pain remain the same. A complete assessment of the patient’s airway, breathing, and circulation is paramount. A thorough history and physical examination with an awareness of intra-abdominal pathologies specific to certain age groups will provide important diagnostic information. The remainder of the workup relies on the judicious use of imaging to arrive at a timely diagnosis.

**References**

Wafarin inhibits the synthesis of vitamin K-dependent coagulation factors II, VII, IX, and X. Reversal of warfarin in the setting of life-threatening hemorrhage traditionally is done with vitamin K and fresh frozen plasma (FFP). However, this method can be time consuming and requires substantial fluid administration.

Vitamin K replacement restores the production of intrinsic clotting factors necessary for sustained reversal of anticoagulation. The recommended dose is 5 to 10 mg intravenously; however, it can take up to 4 hours to achieve the desired effects. The rate of anaphylaxis is only 3/10,000.

Fresh frozen plasma requires ABO blood group compatibility testing and 30 to 60 minutes to thaw. The initial recommended minimal dose for warfarin anticoagulation reversal is 15 ml/kg (approximately 4 units for the average 70-kg person); it typically takes 13 to 48 hours to achieve full effect.

Recombinant-activated factor VIIa (rFVIIa) has been used as an off-label treatment for hemorrhage in non-hemophiliac patients. In healthy patients with an international normalized ratio (INR) less than 2, the agent has been proven to reverse the INR in less than 1 hour; however, the clinical impact of this reversal is unknown. rFVIIa carries a risk of thrombotic events (10% to 20%), but should remain a consideration in patients with religious objections to blood products.

Prothrombin complex concentrates (PCCs) are derived from pooled human plasma. Three-factor PCCs contain factors II, IX, and X, proteins C and S, and a small amount of heparin; 4-factor PCCs also contain factor VII. These agents require a small volume of administration (<100 mL) and eliminate the need for ABO-compatibility testing. Reversal of INR can occur in 10 to 30 minutes and lasts for about 6 hours. The use of PCCs in brain hemorrhage has been associated with improved neurologic outcomes and reduced hematoma growth, compared to FFP. Risks include thrombotic events (occurring in 0.9% to 3.8% of patients) and the potential for transmitting infectious agents.

Key Points

- For warfarin reversal of life-threatening bleeding, vitamin K should be administered early through an IV route.
- FFP should be given when other agents are unavailable.
- PCC, preferably 4-factor, is an attractive option for warfarin reversal due to its low volume, faster INR reversal, and growing evidence of clinical superiority.
- When using 3-factor PCC, consider using FFP or rFVIIa, given the lack of factor VII.
The Critical ECG

Case
A 26-year-old man presents with severe weakness and lightheadedness.

Sinus bradycardia (SB), rate 45, frequent premature atrial complexes (PACs) in a pattern of quadrigeminy, peaked T waves suggestive of hyperkalemia. The overall rhythm is regularly irregular. Regular irregularity should suggest one of two possibilities: second-degree atrioventricular (AV) block or regular-occurring PACs. Second-degree AV block is ruled out because all of the P waves are conducted. On the other hand, PACs appear every fourth beat and are followed by a pause in the regular cycle of beats. Peaked T waves are noted in the lateral precordial leads as well, diagnostic of hyperkalemia. Hyperkalemia-associated T waves can be distinguished from other causes of large T waves by their narrow base, symmetric shape, and “sharp” peaked apex. Other causes of large T waves tend to be broad-based and more rounded at the apex. The patient's serum potassium level was 8.3 mEq/L. Although common teaching regarding ECG manifestations of hyperkalemia focuses on peaked T waves, widening of the QRS complex, and ventricular dysrhythmias, hyperkalemia is well known to produce unusual bradycardias, AV blocks, fascicular blocks, and bundle branch blocks as well.

Procedural Sedation and Analgesia

Joy Kay, MD

Objectives

On completion of this lesson, you should be able to:

1. Explain the sedation continuum and define the terms “moderate,” “deep,” and “dissociative” sedation.
2. Describe the indications for procedural sedation.
3. Describe the pharmacology of commonly used agents and their associated adverse events.
4. List the absolute and relative contraindications for ketamine use as a procedural sedation agent.
5. Describe the personnel, equipment, and monitoring protocols needed to perform procedural sedation.

From the EM Model

19.0 Procedures and Skills
   Integral to the Practice of Emergency Medicine
   19.3.3 Procedural sedation and analgesia

Procedural sedation and analgesia (PSA) is defined by the American College of Emergency Physicians (ACEP) as a technique for administering sedatives or dissociative agents with or without analgesics to induce an altered state of consciousness. PSA allows patients to tolerate unpleasant procedures while maintaining cardiorespiratory function. It is often used in the emergency department for painful procedures such as joint reductions, cardioversions, and laceration repairs (Table 1). While the use of PSA is common, the practice varies across institutions.

Case Presentations

Case 1
A 3-year-old boy presents with an actively bleeding laceration on his forehead. His parents report that he was at home playing with an older sibling when he fell, striking his head on the edge of a table. He cried immediately following the accident and never vomited or lost consciousness. The patient is otherwise healthy, and his immunizations are up to date. On physical examination, he is awake and alert and acting appropriately for his age. There is a deep, linear laceration (4 cm long) over the patient’s right eyebrow that continues to bleed. The boy is apprehensive about being approached, and will not allow a proper examination to be done.

Case 2
A 47-year-old man presents with a complaint of palpitations that started suddenly approximately 1 hour ago while he was sitting at his work desk. He denies any chest pain, but states that he feels short of breath and lightheaded. The patient does not have a significant medical history, but regularly consumes alcohol (roughly 2 beers per day). Upon arrival, initial vital signs are pulse 140, blood pressure 90/45, respiratory rate 22, and oxygen saturation 97%. An EKG shows an irregularly irregular rhythm with narrow QRS complexes. Aside from the patient’s irregular heartbeat, the physical examination is normal. A peripheral IV is established and the patient is placed on a cardiac monitor.

Case 3
A 72-year-old man is brought in by EMS after a highway motor vehicle accident in which he was the
Critical Decisions

- What pertinent information must be obtained in the pre-sedation evaluation of a patient?
- What are the biggest advantages and disadvantages of commonly used PSA medications?
- What clinical personnel are required when performing procedural sedation?
- How should patients be monitored during PSA, and what equipment is necessary?
- When is it safe to discharge a patient home following PSA?

Definitions

Procedural sedation exists in a continuum of altered level of consciousness ranging from minimal to general anesthesia, with dissociative sedation falling outside of the continuum. **Minimal sedation** (anxiolysis) is defined as a drug-induced state during which patients respond normally to verbal commands, while their ventilatory and cardiovascular functions remain unaffected. **Moderate sedation** is defined as a drug-induced depression of consciousness during which patients respond purposefully to verbal commands or light stimulation, while spontaneous ventilation and cardiovascular function are maintained. **Deep sedation** is defined as a drug-induced depression of consciousness during which patients cannot be easily aroused but respond purposefully to repeated or painful stimuli. Deep sedation causes possible impairment in ventilation, although cardiovascular function is maintained. **General anesthesia** is defined as a drug-induced loss of consciousness during which patients are not arousalable and may have an impaired cardiorespiratory function that requires support. **Dissociative sedation** is defined as a trance-like cataleptic state induced by ketamine. It is characterized by profound analgesia and amnesia with maintenance of airway reflexes, spontaneous respirations, and cardiopulmonary stability.²,³

CRITICAL DECISION

What pertinent information must be obtained in the pre-sedation evaluation of a patient?

Prior to starting procedural sedation in any patient, a focused history and physical examination must be performed. A careful history should include diseases involving major organs, current medications, allergies, past experience with sedation agents, and most recent oral intake. A focused physical examination should include a thorough airway assessment, as well as heart and lung examinations.⁵

Consider using the Mallampati classification or LEMON mnemonic (look, evaluate, Mallampati class, obstruction, neck) to predict difficult intubation during airway assessment. Routine laboratory testing is not required and should be guided by the patient’s underlying medical conditions. As with all procedures done in the emergency department, the risks, benefits and potential complications must be discussed with the patient, and consent must be obtained.³,⁴

Recent food intake alone is not a contraindication to PSA, but aspiration risk should be determined according to each individual patient’s risk factors, timing of last meal, and urgency of the procedure.⁵ Risk factors for aspiration include older age, underlying medical conditions, airway difficulties, and conditions predisposing patients to gastroesophageal reflux such as hiatal hernia, bowel obstruction, ileus, and peptic ulcer disease.⁵

The American Society of Anesthesiologists recommends at least 2 hours of fasting for clear liquids; 4 hours for breast milk; and 6 hours for solids, cow’s milk, or infant formula (Table 2). These guidelines are based on healthy patients undergoing elective operative procedures, and are

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**Table 2.**

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<tr>
<th>Type of Food</th>
<th>Fasting Period</th>
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<tr>
<td>Clear liquids</td>
<td>2 hours</td>
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<tr>
<td>Breast milk</td>
<td>4 hours</td>
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<tr>
<td>Infant formula</td>
<td>6 hours</td>
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<tr>
<td>Milk</td>
<td>6 hours</td>
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<tr>
<td>Light meal/solids</td>
<td>6 hours</td>
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not necessarily applicable to patients undergoing procedural sedation in the emergency department. In fact, multiple studies of emergency department procedural sedation show no evidence that fasting has any impact on aspiration risk.\(^6\) There also is no evidence to support the idea that prophylaxis with antacids, histamine-2 blockers, or anticholinergics lowers aspiration risk or improves outcomes.

**CRITICAL DECISION**

**What are the biggest advantages and disadvantages of commonly used PSA medications?**

There are many medications in different drug classes that can be used alone or in combination for procedural sedation and analgesia. No one drug is appropriate for use in every situation. It is up to the emergency physician to select the best agent after considering its risks and benefits, and the type and length of procedure to be performed. Among the most commonly used medications for PSA in the emergency department are ketamine, propofol, ketamine/propofol, versed/fentanyl, etomidate, and dexmedetomidine.

**Ketamine**

Ketamine is a phencyclidine derivative with dissociative, sedative, analgesic, and amnestic properties;\(^7\) it preserves airway reflexes and allows spontaneous respirations.\(^8\) Ketamine non-competitively blocks the N-methyl-D-aspartate receptor, decreasing the excitatory neurotransmission and causing a functional dissociation between the cortical and limbic systems of the brain.\(^9,7\) It also is a weak bronchodilator that possesses some opioid and sympathomimetic properties. As a result, ketamine has analgesic effects and can cause an elevation in heart rate, blood pressure, and myocardial demand.\(^10\)

Unlike other agents used in PSA, ketamine’s effect on sedation is not dose dependent. Ketamine dissociation appears at approximately 1-1.5 mg/kg intravenously (IV) and 3-4 mg/kg intramuscularly (IM). Once the dissociation is reached, administration of additional ketamine does not deepen the sedation.\(^9\) The current recommended regimen by IV route is an initial dose of 1.5-2 mg/kg in children or 1 mg/kg in adults, with incremental doses of 0.5-1 mg/kg every 5-10 minutes. The recommended IM regimen is 4-5 mg/kg followed by incremental doses of 2-4 mg/kg.

Both IM and IV routes display similar rates of respiratory and adverse agitation effects.\(^9\) While the IM route is useful when IV access cannot be achieved, its disadvantages include longer recovery times and higher rates of emesis. Current ACEP guidelines do not recommend the IM route for adult patients.

Ketamine has been used safely in the pediatric population since its discovery in the 1960s. However, its use in adults remains more limited due to an increased risk of emergent reactions, which occur more frequently in adults than in children. Other notable side effects of ketamine include laryngospasm, hypersalivation, respiratory depression, apnea (mostly transient), and emesis (most common in early adolescence and with an IM route).\(^9\)

Emergent reactions (reported in 7.6% of pediatric and 10% to 20% of adult patients\(^9\)) are well documented and include increased agitation, restlessness, dysphoria, hallucinations, and nightmares.\(^10,11\) There is some research to suggest a significant reduction in recovery agitation when midazolam prophylaxis is given with ketamine.\(^3\) Other studies, however, conclude that this approach fails to reduce the occurrence of emergent reactions, but does decrease the incidence of emesis.\(^2\) Because the co-administration of midazolam increases the risk of respiratory complications, the current recommendation in both children and adults is to use it only when needed.

Laryngospasm is a rare but potentially life-threatening complication that occurs in roughly 0.4% of patients.\(^10\) Laryngospasm is caused by the closure of true vocal cords, leading to partial or complete airway obstruction. This complication is more common in children than in adults; it occurs shortly after drug administration and usually is transient.\(^7\) Despite the potential for disastrous airway problems, most cases of laryngospasm resolve with simple airway maneuvers or with bag-valve mask ventilation; endotracheal intubation is rarely necessary.

Hypersalivation is another known side effect of ketamine, prompting some to prophylactically use anticholinergic agents such as atropine or glycopyrrolate to decrease the risk of aspiration and respiratory complications. Because anticholinergic agents are associated with a higher incidence of airway complications, ACEP guidelines do not support their routine use with ketamine.

Absolute contraindications to

> **Proper equipment and supplies must be in place to manage the potential complications of PSA, including allergic reactions, cardiac arrest, and respiratory arrest.**
ketamine use are an age less than 3 months (due to an increased rate of airway complications) and a history of/suspected psychosis (due to potential exacerbation of the condition). Relative contraindications include procedures involving stimulation of the posterior oropharynx, underlying cardiovascular disease, and underlying thyroid disorders. Conditions leading to increased intracranial pressure (eg, intracranial mass, hydrocephalus) and increased intraocular pressure (eg, acute globe injury, glaucoma) are regarded as relative contraindications. More studies have recently emerged, however, that appear to refute this finding (Table 3).

**Propofol**

Propofol is a highly lipid-soluble, sedative-hypnotic drug that has no analgesic effects. It appears to operate by potentiating the gamma-aminobutyric acid receptor system. The drug possesses many properties that are desirable for procedural sedation, including a rapid onset and extremely short half-life, which results in few residual effects once it wears off. Because it is lipid soluble, propofol is rapidly and extensively distributed in the body; it crosses the blood-brain barrier, resulting in a quick onset time of 30-45 seconds. Propofol's short duration effect of 6 minutes is due to the rapid redistribution from the central nervous system to other tissues; however, it is dose dependent, and repeated dosing can lead to drug accumulation that prolongs sedation.

Propofol typically is given in the emergency department as an initial bolus of 1 mg/kg followed by 0.5 mg/kg every 3 minutes until the desired level of sedation is achieved. General recommendations indicate a lower dose in patients older than 65 as they can achieve sedation more rapidly than younger patients.

Common adverse effects include undersedation, oversedation, hypoxemia, hypotension, and respiratory depression. Notably absent from its list of adverse effects are nausea, confusion, and agitation. The concurrent administration of opioids and propofol should be avoided due to a significant risk of respiratory depression. Propofol appears to be as safe and effective as midazolam, with the added benefit of a significantly shorter length of stay in the emergency department. When compared to ketamine, one study shows propofol has a decreased rate of respiratory depression and a shorter time to recovery, with no difference in the number of clinical interventions used for respiratory depression.

**Ketofol**

Ketofol is low-dose ketamine with propofol, a combination designed to maximize the benefits and minimize the side effects of each drug. The two agents possess entirely different mechanisms of action and clinical features that may allow one drug to offset the other drug’s limitations. For example, propofol’s most feared side effects are cardiovascular and respiratory depression, which might be mitigated by ketamine’s sympathomimetic properties and the ability to preserve airway reflexes. Ketamine also can provide analgesic effects that propofol lacks. Emesis and emergent reactions are ketamine’s principal adverse effects, which can be diminished by propofol’s antiemetic qualities.

New evidence reinforces the efficacy and safety of ketofol over other agents. It is associated with less oxygen desaturation, less vomiting, and greater patient/provider satisfaction than the versed/fentanyl combination. Ketofol also appears to be similar in efficacy and respiratory depression to propofol alone, but results in more consistent sedation while using less propofol during the procedure. It is unclear if ketofol has fewer adverse effects than ketamine or propofol alone. The typical dose of ketofol for PSA is 1 mg/kg of ketamine combined with 1 mg/kg of propofol.

**Fentanyl/Midazolam**

A combination of fentanyl and midazolam traditionally has been used for procedural sedation and analgesia. Midazolam is a...
benzodiazepine that provides anxiolysis and amnesia without analgesic effects. Its lipophilic properties and ability to cross the blood-brain barrier result in quick onset times; however, repeated dosing can cause drug accumulation in the adipose tissue, leading to prolonged sedation. The typical dose for midazolam is 1-2 mg in adults and 0.05-0.1 mg/kg in children every 3-5 minutes.

Fentanyl, a synthetic opioid that is 75 to 125 times more potent than morphine, possesses analgesic properties without any amnestic effects. Fentanyl has an onset time of 2-3 minutes and a duration of 30 minutes. The typical regimen used in PSA is 0.05-0.1 mg/kg of midazolam with 0.5-1 mcg/kg of fentanyl. Although midazolam alone has not been shown to cause respiratory depression, the combined effects of midazolam and fentanyl can result in significant respiratory depression. To mitigate this complication, midazolam should be given first, followed by titrated fentanyl.

Etomidate

Etomidate is a short-acting hypnotic that acts on gamma-aminobutyric acid (GABA) receptors. It possesses sedative and amnestic properties without any analgesic effects and has many advantages, including quick onset (<1 minute), short duration of action (5-15 minutes), and minimal effects on respiratory and cardiovascular function.

The dose of etomidate for PSA is 0.15-0.2 mg/kg; it is usually given with an opioid such as fentanyl for analgesia. Research indicates that etomidate is safe and effective for procedural sedation and causes no major respiratory complications. Its potential side effects in PSA include myoclonus, adrenal insufficiency, and respiratory depression. Of these, myoclonus is the most common (reported in approximately 20% to 40% of patients); this complication is thought to be dose related and can hinder procedure success rates. Adrenal insufficiency typically occurs with the continuous infusion of etomidate. Although decreased cortisol levels have been reported with a single dose of the drug, the clinical significance of such findings remains unclear. Respiratory depression occurs in approximately 10% of patients, with most cases resolving without major intervention or consequences.

Dexmedetomidine

Dexmedetomidine is a relatively new selective alpha-2 adrenoceptor agonist similar to clonidine. The medication provides sedation without respiratory depression, and decreases sympathetic tone while preserving psychomotor function. It typically is used in ICU settings as a short-term sedative in mechanically-ventilated patients or in cases of alcohol withdrawal, where it has been shown to reduce the required amounts of anesthetics and opioids.

Pearls

- Know the agents commonly used for PSA well, and be familiar with their side effects and complications.
- The key to successful PSA is preparation; make sure all necessary materials are in place prior to starting any procedure.
- Titrate the medications to achieve the desired level of sedation, and allow an appropriate time gap before redosing.
- Anticipate and be prepared for complications should they arise.

Pitfalls

- Failing to adequately assess the patient’s airway prior to sedation.
- Failing to have proper equipment and supplies readily available at the bedside, including reversal agents.
- Routinely using prophylactic benzodiazepine or anticholinergic with ketamine.
- Not anticipating or preparing for complications of sedation, including allergic reactions and respiratory or cardiac arrest.
- Failing to adequately monitor the patient after the procedure.

Procedural sedation exists in a continuum of altered level of consciousness ranging from minimal to general anesthesia, with dissociative sedation falling outside of the continuum.
The medication's most common side effects are hypotension, bradycardia, and dry mouth. The recommended dose for PSA is a 0.5-1 mcg/kg loading dose over 10 minutes, followed by 0.2-1 mcg/kg continuous infusion. There is limited data on the use of dexmedetomidine for PSA in the emergency department. Due to hepatic metabolism and renal clearance of the drug, dose reduction should be considered in elderly patients (>65 years) or in cases of hepatic or renal impairment.

**CRITICAL DECISION**
What clinical personnel are required when performing procedural sedation?
All personnel performing PSA must have a thorough understanding of the medications, the ability to properly monitor the patient, and training in the management of potential complications. Guidelines vary by institution, but procedural sedation and analgesia typically requires two trained practitioners – one to monitor the patient (e.g., a nurse), and one to perform the procedure (a physician).

In some instances, the emergency physician might be able to do both tasks. This can be possible, for instance, if the physician is able to maintain visual or verbal communication with the patient while performing the procedure. Some institutions, however, require at least two emergency physicians to be present for PSA, one of whom must be a board-certified faculty member.

**CRITICAL DECISION**
How should patients be monitored during PSA, and what equipment is necessary?
Proper monitoring of the patient during PSA is critical and should involve both clinical assessments and objective parameters. Clinical assessments usually are performed using the Ramsay sedation or observer’s assessment of alertness/sedation scales. Objective measures include vital signs (blood pressure, heart rate, and respiratory rate), which should be obtained at regular intervals before, during, and after the procedure.

Pulse oximetry and cardiac rhythm should be monitored continuously. The limitation of pulse oximetry is its inability to identify

<table>
<thead>
<tr>
<th>Drug</th>
<th>Route</th>
<th>Dose</th>
<th>Repeat Dose</th>
<th>Onset of Action</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dexmedetomidine</strong></td>
<td>IV</td>
<td>0.5-1 mcg/kg over 10 min, continuous infusion of 0.2-1 mcg/kg/hr</td>
<td>0.05 mg/kg q3-5 min</td>
<td>10 min</td>
<td>1-2 hrs</td>
</tr>
<tr>
<td><strong>Etomidate</strong></td>
<td>IV</td>
<td>0.2-0.3 mg/kg</td>
<td>0.05 mg/kg q3-5 min</td>
<td>&lt;1 min</td>
<td>5-15 min</td>
</tr>
<tr>
<td><strong>Ketamine</strong></td>
<td>IV</td>
<td>1-2 mg/kg</td>
<td>0.25-0.5 mg/kg q5-10 min</td>
<td>&lt;1 min</td>
<td>10-20 min</td>
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<tr>
<td></td>
<td>IM</td>
<td>4-5 mg/kg</td>
<td>2-4 mg/kg q10-15 min</td>
<td>2-5 min</td>
<td>15-30 min</td>
</tr>
<tr>
<td><strong>Propofol</strong></td>
<td>IV</td>
<td>1 mg/kg</td>
<td>0.5 mg/kg q3-5 min</td>
<td>30-45 sec</td>
<td>Dose dependent 6 min</td>
</tr>
<tr>
<td><strong>Ketofol</strong></td>
<td>IV</td>
<td>1 mg/kg ketamine: 1 mg/kg propofol</td>
<td>1 mg/kg ketamine: 1 mg/kg propofol</td>
<td>3-5 min</td>
<td>1-2 min</td>
</tr>
<tr>
<td><strong>Fentanyl</strong></td>
<td>IV</td>
<td>0.5-1 mcg/kg slow IV push</td>
<td>0.5 mcg/kg q2 min</td>
<td>2-3 min</td>
<td>30 min</td>
</tr>
<tr>
<td><strong>Midazolam</strong></td>
<td>IV</td>
<td>1-2 mg (adults) 0.05-0.1 mg/kg (children)</td>
<td>q3-5 min</td>
<td>1-2 min</td>
<td>30 min</td>
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early problems with ventilation and detect hypercarbia, especially if supplemental oxygen is used during PSA. Capnography provides a way of monitoring the adequacy of ventilation and identifying potential respiratory compromise before oxygen desaturation takes place.28

The American Society of Anesthesiologists recommends the use of continuous capnography for moderate and deep sedation in non-operative settings.3 Although its use allows early detection of hypoventilation, there is no evidence that this feature has any impact on clinical outcomes.1 Current ACEP guidelines do not require the use of capnography for PSA; in many institutions, its use is left to the discretion of the emergency physician.2

Equipment and Supplies

Proper equipment and supplies must be in place to manage the potential complications of procedural sedation and analgesia, including allergic reactions, cardiac arrest, and respiratory arrest.1 Oxygen, suction, bag-valve masks, intubation equipment, and advanced cardiac life-support medications should be readily available during the procedure.3,4 If opioids or benzodiazepines are used, reversal agents, naloxone, and flumazenil, should be easily accessible.3

CRITICAL DECISION
When is it safe to discharge a patient home following PSA?

Patients should be observed and monitored until they are no longer at risk of respiratory depression. They should be alert, oriented, and back to their baseline level of consciousness prior to discharge.3 If any reversal agents are used, monitor the patient for up to 2 hours after the medication is given. There is no evidence that supports the pre-discharge requirement of a patient being able to tolerate oral intake and ambulate without assistance.

Clear discharge instructions should be given and explained to the patient and the caregiver. A friend or caregiver should be available to monitor the patient for several hours following discharge. Although serious adverse events such as hypoxia rarely occur after PSA, patients can experience mild symptoms such as nausea, fatigue, and lightheadedness for up to 24 hours.

Case Resolution

Case 1

The clinical team concluded that establishing IV access would be difficult and distressful for the child with a forehead laceration, so he was given 5 mg/kg of IM ketamine. The laceration, which revealed a tear in the galea, was thoroughly irrigated and repaired without complications. The boy had one episode of emesis after the procedure. He was observed for another 20 minutes and discharged under the care of his parents.

Case 2

The patient with atrial fibrillation required emergent cardioversion; he was placed on a cardiac monitor, and supplemental oxygen and IV fluids were started. Due to its hemodynamic stability and minimal cardiovascular effects, etomidate was chosen as a sedative agent with fentanyl for analgesia. The patient underwent successful cardioversion to sinus rhythm. His blood pressure improved and the symptoms of lightheadedness and shortness of breath resolved. He was admitted to medical services for further evaluation of his new-onset atrial fibrillation, and remained in sinus rhythm upon transfer to the floor.

Case 3

Radiographs were obtained of the elderly car accident victim’s chest, head, pelvis, and hips. The hip x-ray showed a posterior dislocation without fracture; head and cervical spine radiographs did not show any abnormalities. The patient was placed on a cardiac monitor, supplemental oxygen was given, and an IV was established. He underwent PSA using low-dose propofol as a sedative agent and fentanyl for analgesia. Several attempts at hip reduction were made without success; the patient needed repeated doses of propofol to achieve sedation. His blood pressure dropped to 104/60 during the procedure, and he subsequently was taken to the operating room for open reduction by an orthopedic surgeon.

Summary of Lesson

Procedural sedation and analgesia is becoming a common practice in the emergency department for a number of procedures. Emergency physicians must select the sedative agent or combination of agents appropriate for the type of procedure and level of sedation required. Providers must be knowledgeable about the agents commonly used in PSA, and skilled in identifying and managing any complications that might arise. Emergency physicians also must be familiar with the institutional and published guidelines regarding personnel, monitoring, and discharge criteria after PSA.

References


The Critical Image

Case

A 52-year-old woman presents with acute respiratory distress while at rest and when smoking cigarettes. She denies chest pain, but admits to using crack cocaine several hours earlier. Her medical history includes heart failure with an ejection fraction of 30%, ST-segment elevation myocardial infarction, COPD, hypertension, chronic descending aortic dissection, and stroke.

Upon arrival at the patient’s home, EMS noted the patient to be hypertensive and hypoxic to 70% on room air. On arrival to the emergency department, her vital signs are blood pressure 234/128, heart rate 115, respiratory rate 36, and oxygen saturation 100% on 100% non-rebreather mask. The physical examination reveals tachypnea, jugular venous distension, and bilateral wheezing without leg edema. The cardiac examination is regular, but the patient is tachycardic without accessory heart sounds. An ECG shows sinus tachycardia without ST elevation or depression.

The patient is placed on an intravenous nitroglycerin infusion, and noninvasive positive-pressure ventilation is initiated. Given her mixed examination features, which suggest both heart failure and possible COPD exacerbation, albuterol and corticosteroids also are administered. A portable chest radiograph is performed.

A. Portable AP chest radiograph on emergency department presentation, which shows classic signs of pulmonary edema, including cephalization, fluid in the minor fissure, and dependent interstitial edema.
B. Baseline PA chest radiograph of the same patient following a hospitalization for flash pulmonary edema. At the time of this x-ray, she had a normal blood pressure and no pulmonary symptoms, and had undergone diuresis in the hospital. The chest radiograph shows less interstitial prominence compared with the radiograph obtained during the acute presentation. The minor fissure contains less fluid and is only faintly visible.

Key Points

- Normally, gravity causes dependent pulmonary blood vessels to fill and appear most prominently, while vessels in the upper lung zones are relatively empty and radiographically inconspicuous. In cases of abnormally high pulmonary vascular pressures and volume, vessels in the upper lung zones also appear full, a finding termed “cephalization.” As pulmonary edema progresses, dependent areas develop increased interstitial density and fluid can accumulate in the fissures and dependent pleural spaces. If pulmonary edema is severe, fluid can accumulate in alveoli, resulting in air bronchograms, the silhouetting of air-filled bronchi by adjacent fluid-filled alveoli (not seen in this case). Alveolar fluid sometimes obscures landmarks such as the right and left heart borders and diaphragm, resulting in loss of the normal “silhouette sign.” The normal silhouette sign occurs when tissues of different density (eg lung and heart) abut each other, creating a distinct radiographic border or silhouette. When two tissues of similar density (eg fluid-laden lung and heart) are contiguous, no border can be seen between them.¹

- Comparison of current images with prior images can be essential to understanding a patient’s acute presentation. Note that a patient might be suffering from the same type of acute medical emergency they were experiencing when the previous x-rays were taken. Correlating the prior image with the prior clinical presentation is crucial to avoid mistaking “unchanged” for “chronic” or “normal.” In the patient described above, a comparison of images A and C reveals little change because both x-rays were acquired during episodes of acute pulmonary edema.
C. Portable AP chest radiograph from a previous emergency department presentation for hypertension and acute pulmonary edema. Note the similarities to A.

Case Resolution
Enalaprilat was administered intravenously, and the patient rapidly improved. The nitroglycerin infusion and BiPap were discontinued within 1 hour, and she was admitted for further care.

Feature Editor: Joshua S. Broder, MD, FACEP. See also Diagnostic Imaging for the Emergency Physician by Dr. Broder, available from the ACEP Bookstore, www.acep.org/bookstore.

Case Contributor: Hirsh Sandesara, MD
Cases for “The Critical Image” are contributed by the residents and faculty of the Duke University Hospital Emergency Medicine Residency.

References
CME Questions

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1. Which of the following makes it challenging to diagnose the cause of abdominal pathology in children?
   A. Abdominal pain in an uncommon complaint in pediatric patients
   B. Children often are not as cooperative with the physical examination and history taking as adult patients
   C. Intra-abdominal pathology is very common in cases of chronic abdominal pain
   D. Pediatric patients almost always need to be sedated for CT scans

2. Which imaging study should be the first line in the emergency department evaluation of a patient with potential intussusception?
   A. Abdominal radiograph
   B. Air-contrast enema
   C. CT scan of the abdomen
   D. Ultrasound

3. Which of the following describes why a CT scan can be more valuable than ultrasound in the evaluation of a patient with suspected appendicitis?
   A. CT scans provide a faster diagnostic speed
   B. Surgeons prefer CT scan imaging
   C. Ultrasound is hampered by low sensitivity/specificity
   D. Ultrasound often yields inadequate or non-diagnostic results

4. Which of the following is true regarding abdominal CT scans in cases of blunt abdominal trauma?
   A. CT scans are the only way to avoid missed injuries in pediatric patients who can’t talk or have had an unreliable examination
   B. CT scans have become less popular with the emergence of new technologies
   C. CT scans should be obtained in all patients with abdominal trauma
   D. CT scans should be reserved for patients deemed at highest risk for intra-abdominal injury

5. What is the most appropriate radiologic study in a pediatric patient with examination findings suggestive of classic appendicitis?
   A. Abdominal CT scan
   B. Abdominal radiograph
   C. Abdominal ultrasound
   D. No imaging is required

6. Which is true of the use of bedside ultrasound for FAST examinations in pediatric trauma patients?
   A. Its efficacy has been validated in children, just as in adult trauma patients
   B. It is as sensitive as a CT scan for picking up intra-abdominal injury
   C. Its use and popularity are increasing
   D. The success of the FAST examination is operator independent

7. Which of the following is the most common malignancy that presents as an abdominal mass in infants or children?
   A. Germ cell tumor
   B. Lymphoma
   C. Neuroblastoma
   D. Wilms tumor

8. How can a CT scan be justified and used in the case of a suspected abdominal mass?
   A. A CT scan is never indicated in the setting of an abdominal mass
   B. To characterize the origin of the mass, extent of the disease, and identify sites of metastasis
   C. To determine bony involvement, if present
   D. To determine the specific components (cystic vs. solid) of the mass

9. Which of the following imaging studies should be the first line in the initial evaluation of chronic abdominal pain with obstructive symptoms or dyspepsia?
   A. Abdominal radiograph
   B. Air-contrast enema
   C. CT scan of the abdomen
   D. Upper GI with small bowel follow through
10. Which of the following tests will yield a definitive diagnosis of ectopic pregnancy in almost all cases?
A. Serum quantitative beta-hCG and pelvic examination
B. Serum quantitative beta-hCG and transvaginal ultrasound
C. Transvaginal ultrasound
D. Urine beta-hCG

11. Which of the following accurately describes moderate sedation?
A. A state of depressed consciousness during which patients cannot be easily aroused, but respond purposefully to repeated or painful stimuli; possible impairment in ventilation
B. A state of depressed consciousness during which patients respond normally to verbal commands and light stimulation; ventilatory and cardiovascular functions remain unaffected
C. Drug-induced depression of consciousness during which patients respond purposefully to verbal commands or light stimulation, while spontaneous ventilation and cardiovascular function are maintained
D. Trance-like cataleptic state of profound analgesia and amnesia with maintenance of airway reflexes, spontaneous respirations, and cardiopulmonary stability

12. Which of the following is an absolute contraindication to ketamine use?
A. Acute globe injury
B. Age less than 3 months
C. Coronary artery disease
D. Head trauma

13. Which of the following side effects is not associated with ketamine?
A. Bradycardia
B. Bronchodilation
C. Emergent reaction
D. Hypersalivation

14. Which of the following is associated with the IM route of administration for ketamine?
A. Higher rate of emergent reactions
B. Higher rate of emesis
C. Higher rate of hypersalivation
D. Higher rate of respiratory complications

15. Which of the following is not included in ACEP’s guidelines for standard monitoring of PSA patients?
A. Blood pressure measurement
B. Capnography
C. Cardiac monitor
D. Pulse oximetry

16. In which patient should PSA be performed without consideration of the recommended fasting time?
A. A child with an abscess on the thigh who ate a meal 1 hour prior to arrival
B. An alcoholic man with a complex lip laceration who ate a meal 1 hour prior to arrival
C. An elderly woman with a displaced forearm fracture with neurovascular compromise who ate a meal 1 hour prior to arrival
D. An obese man with an elbow dislocation who ate a meal 1 hour prior to arrival

17. Which of the following reflects the recommended fasting time for breast milk, according to ASA fasting guidelines?
A. 1 hour
B. 2 hours
C. 4 hours
D. 6 hours

18. Which scenario is inappropriate for the dose reduction of dexmedetomidine?
A. Cardiac disease
B. Liver disease
C. Old age
D. Renal insufficiency

19. Which is not a side effect of etomidate?
A. Adrenal insufficiency
B. Hypotension
C. Myoclonus
D. Respiratory depression

20. Which protocol describes a method for mitigating the respiratory effects of opioid/benzodiazepine?
A. Give benzodiazepine prior to opioid
B. Give opioid prior to benzodiazepine
C. Give both opioid and benzodiazepine every 30 seconds
D. Give both opioid and benzodiazepine together
The Drug Box

Methotrexate

By Elizabeth Ulrich, DO, Akron General Medical Center, Akron, Ohio

Methotrexate is an antifolate metabolite that inhibits DNA synthesis, cellular replication, and repair. The medication has multiple applications, but primarily is used for the treatment of autoimmune disorders and as a chemotherapeutic agent. It is classified as an antineoplastic, antimitabolite, immunosuppressive, and disease-modifying anti-rheumatic drug (DMARD). Early, aggressive treatment of rheumatoid arthritis improves pain and swelling, while further reducing joint damage. Routine monitoring of CBC, creatinine, and LFTs are recommended every 2 months.

### Mechanism of Action

Methotrexate irreversibly binds dihydrofolate reductase, ultimately inhibiting purine and thymidylate acid synthesis. This leads to impared DNA synthesis and repair, which inhibits cellular replication. Actively proliferative tissues are most susceptible to methotrexate.

### Indications

Treatment of several types of cancer (e.g., lymphoma, leukemia, breast, skin, head, neck, and lung), rheumatoid arthritis, psoriasis, juvenile idiopathic arthritis

**Off-label:** Crohn disease, dermatomyositis, graft vs. host, ectopic pregnancy

### Dosing

#### (ADULTS)

- 7.5 mg once weekly OR 2.5 mg every 12 hours for 3 doses/week
- Cancer dosing varies based on type of treatment. Ranges include 30–40 mg/m²/week to 100–12,000 mg/m² with leucovorin rescue.

**Note:** Pediatric dosing varies depending on type of cancer or autoimmune disease.

#### Administration:

- PO, IM, SQ, IV, intrathecal

#### Renal insufficiency:

- Clcr 10–50 ml/min — reduced dose to 50%;
- Clcr <10 ml/min — avoid use

### Side Effects

**Multiple US boxed warnings:** Associated with transaminitis, fibrosis, cirrhosis, hepatotoxicity, renal damage, pneumonitis, malignant lymphoma, diabetes, ulcerative stomatitis, TENS, SJS, and bone-marrow suppression, including aplastic anemia. Use caution with NSAIDS. Medication is teratogenic; caution for opportunistic infections. There are many other side effects, ranging from skin photosensitivity to pulmonary fibrosis.

### Precautions

- **Contraindications:** Hypersensitivity to methotrexate, alcoholism, liver disease, immunodeficiency, and blood dyscrasias
- **Pregnancy category:** X
- **Lactation:** Contraindicated

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