required or even effective. Severe odynophagia may be treated with a topical anesthetic agent. Esophageal strictures may be treated with bougienage.

In the critical care unit, prevention of esophageal injury is the best approach to the problem. If possible, patients should have the head of the bed elevated during oral medication administration with sufficient quantities of water given afterward. Certain medicines should be used with caution in patients with cardiomegaly or in those who are elderly or have known or suspected underlying esophageal obstruction. Oral potassium should be avoided in critically ill patients.

## References


## Chapter 158: Gastrointestinal Motility Disorders

### GASTROINTESTINAL MOTILITY DISORDERS

Nicholas Verne • John G. Lieb, II

Motility is fundamental to the function of the gastrointestinal (GI) system such that alterations may lead to many gastrointestinal disorders, such as gastroesophageal reflux disease (GERD), irritable bowel syndrome, chronic constipation/diarrhea, and adynamic ulcers. Although only the rare patient will be admitted to the intensive care unit (ICU) solely on the basis of a GI motility disorder, motility is a significant contributor to several ICU admission diagnoses such as aspiration pneumonia, Ogilvie syndrome, sigmoid volvulus, and so forth. In addition, disorders of gastrointestinal motility can complicate a patient’s ICU course as in oropharyngeal dysfunction, gastroparesis, and enteral nutrition failures, a topic that is covered elsewhere. In this chapter, the major motility disorders that affect ICU management will be discussed starting at the esophagus and ending in the hindgut.

## ESOPHAGUS

For several reasons, the esophagus is the ideal introductory topic to a chapter on GI motility. First, the esophagus is vulnerable to various insults in the ICU. Second, many of the principles of esophageal motility and dysmotility are fundamental to an understanding of other GI organs. Third, these principles are the best studied of any GI organ because of easy access to the esophagus.
The principal role of the esophagus is propulsion of sustenance towards the stomach, i.e., motility. The body of the esophagus, a muscular esophageal sphincter (UES) and the lower esophageal sphincter (LES), is integral. Although the process of propulsion from oropharynx to stomach, i.e., primary peristalsis, appears simple, it requires a remarkably coordinated series of actions; for example, striated and smooth muscle must coordinate. Also, nitric oxide and acetylcholine—seemingly antagonistic neurotransmitters—must act synergistically. That the esophagus can accomplish these roles without the aid of, and even against, gravity, is all the more remarkable.

A brief review of normal esophageal physiology will assist in later discussions of esophageal motility disorders in the ICU. As in the rest of the GI tract, esophageal motility depends on intact function of the muscular layers of the esophageal wall and an intact local and central nervous system. The thickest and strongest contractile element of the esophagus is the muscular wall. In the proximal esophagus, including the UES, this muscle wall is striated, whereas in the distal two thirds of the esophagus, the muscle wall consists of two smooth muscle layers: longitudinal and circular. These smooth muscle layers are mostly under the control of the vagus nerve and the enteric nervous system, a “second brain,” whose neural tissue weighs almost as much as the brain. This second brain consists of a neural plexus throughout the gut wall that regulates wall movement through the activation of local reflexes. These reflexes and some vagus nerve coordinate the formation of the circular smooth muscle layer, i.e., the “peristaltic wave,” which consists of a contractile wave and a relaxation “bubble.”

For example, the power of the contractile wave depends on acetylcholine, a neurotransmitter that causes an intrinsic relaxation bubble form the esophagus just ahead of the contractile wave and helps propel food down the esophagus, achieving pressures as high as 35 mm Hg in the upper, 35 mm Hg in the middle, and 69 mm Hg in the lower third of the esophagus. Equally important, nitric oxide (NO) and vasodepressant intestinal peptide (VIP) relax smooth muscle caused to the bolus, creating a zone of lower pressure, that is a “bubble” of relaxation. This relaxation bubble also travels the length of the esophagus just ahead of the contractile wave and helps propagate the contractile wave toward the stomach. Together, the contractile wave and relaxation bubble form the peristaltic wave. To further propagate the peristaltic wave, the longitudinal smooth muscle layer contracts to shorten the length of the esophagus (1–5). The peristaltic wave of contraction and relaxation propels the food bolus and eventually reaches a point just above the LES (6). This is termed primary peristalsis, whereas secondary peristalsis occurs when a pressure stimulus is applied to the esophagus, such as from residual food left from an unsuccessful primary peristalsis or from refluxed gastric contents (7).

The LES is defined by esophageal manometry as a 2– to 6-cm zone of high resting pressure at the gastroesophageal junction (GEJ). This high resting pressure is formed by an extrinsic component of the surrounding crural diaphragm and an intrinsic smooth muscle component. Motilin and intra-abdominal pressure also cause LES contraction, which is abolished by atropine (8).

Relaxation of the LES is crucial to the pathophysiology of many motility disorders in the ICU and occurs under several circumstances. The first is a result of primary peristalsis from esophageal distention just proximal to the LES. With primary peristalsis and relaxation of the LES, a bolus is propelled into the stomach within 8 to 10 seconds (9). A second type of relaxation is transient LES relaxation, the primary motility disorder in GERD. This occurs in normal fasting and vomiting, and is activated through partly local and brainstem mechanisms. It may be elicited by pharyngeal stimulation, proximal gastric distention, and introduction of fat into the duodenum. Several common pharmacologic agents affect the function of the LES (Table 158.1).

With this background, we can now initiate a discussion of some of the most common esophageal motility disorders encountered in the ICU.

**Oropharyngeal Motility Disorders**

Any disorder of the upper esophagus inevitably involves the entire oropharyngeal system, including the oropharynx, thyroid cartilage, upper esophageal sphincter (UES), and more remnants of the “gill arches” such as the larynx, hyoid bone, and several cranial nerves (V, VII, IX, X, XII). The muscle of the oropharynx is exclusively striated and therefore requires nicotine-acetylcholine and myelinated innervation as opposed to the muscarinic cholinergic smooth muscle of the distal two thirds of the esophagus. The advantage of striated muscle is its speed. However, measuring disorders of this speed necessitates testing inaccessible to most ICU patients: solid-state manometry in the UES and upper esophagus, or a cinemetric esophagram with higher-speed fluoroscopy for example “rehab swallow”—than that used for a routine barium swallow (10). Another disadvantage of striated muscle is that the upper esophagus is subject to the same damage as other striated muscle in the body. For example, rhabdomyolysis, polymyositis, hyperthyroidism, and myopathic drugs such as amiodarone, alcohol, vincristine, steroids, and statins can all disrupt the normal functioning of the oropharyngeal system.

The extensive neurologic innervation and coordination is a second Achilles heel of this system and explains why so many disorders of this system are neurologic in origin. For example, one third of stroke, Parkinson, and Alzheimer patients have oropharyngeal dysphagia (10–13). Oropharyngeal dysfunction affects the outcome of acute stroke, probably through increasing the risk of aspiration pneumonia (14). The risk of aspiration is best assessed by video barium swallow; clinical assessments are less sensitive (15,16).

Typical symptoms and signs include choking and gagging during meals; repeated (often unsuccessful) attempts at swallowing, nasal regurgitation of food and drink, and immediate regurgitation of the swallowed bolus—or in the case of a Zenker diverticulum, regurgitation of old undigested food. Other bulbar signs and symptoms such as vertigo, hiccup, tinnitus, ataxia, diplopia, horizontal ophthalmoplegia, and drop attacks may indicate brainstem and cranial nerve dysfunction such as from verteobasilar insufficiency, stroke, the Miller-Fisher variant of Guillain-Barré syndrome, or paraplastic cerebellar degeneration. Muscle fatigability and nasal voice would point to myasthenia gravis. Generalized weakness would point to a rhabdomyolysis, myostio, a steroid or drug-induced myopathy, or a motor neuron degenerative process such as amyotrophic lateral sclerosis (ALS). Symptoms of dry mouth should point to anticholinergic side effects of ICU.
TABLE 158.1

<table>
<thead>
<tr>
<th>Agents That Affect the Lower Esophageal Sphincter (LES)</th>
<th>Elevated LES pressure</th>
<th>Decreased LES pressure</th>
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<tr>
<td>Drugs</td>
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<tr>
<td>α-agonists</td>
<td>α-agonists</td>
<td>β-agonists</td>
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<td>β-antagonists (especially β2)</td>
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<td>Cholinergics (bethanecol)</td>
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<td>Sucratoximethonium (142)</td>
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<td>Domperidone</td>
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<td>Esopremazol (not pancuronium)</td>
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<td>Anticholinergics</td>
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<td>Theophylline</td>
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<td>Diazepam</td>
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<td>Nitrates</td>
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<td>Dopamine</td>
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<td>ETOH</td>
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<td>Caffeine</td>
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<td>Endogenous modifiers</td>
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<td>Gastrin</td>
<td>Cholecystokinin</td>
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<td>Motilin</td>
<td>Secretin</td>
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<td>Substance P</td>
<td>Glucagon</td>
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<td>Prostaglandin F2-an</td>
<td>Progestrone</td>
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<td>Food</td>
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<td></td>
<td>Peppermint</td>
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</table>

ETOH, ethanol; VIP, vasoactive intestinal peptide.

Drugs or the sicca syndrome of rheumatoid arthritis or Sjögren syndrome (17).

Some other disorders that may impair oropharyngeal function, and hence render the patient vulnerable to aspiration, include radiation-induced neuronal and myopathic damage, postcricoid webs, and cervical osteophytes. Some of the most common devices in the ICU, e.g., nasogastric or nasoduodenal tubes, can further disturb oropharyngeal and upper esophageal motility, and lead to aspiration (18).

The treatment of oropharyngeal disorders is guided by three principles: (a) a multidisciplinary approach is vital, (b) treatment must be tailored to the cause of the disorder, and (c) treatment is chronic and progress can be slow. In particular, involvement of the speech and swallow therapists is essential. They teach swallowing exercises, dietary modifications, and techniques tailored to the disorder to help the patient improve swallowing function. Also, rheumatologists can assist in the treatment of connective tissue disease with anti-inflammatory therapies. Additionally, neurologists can assist in the diagnosis and medical management of myasthenia gravis with acetylcholinesterase inhibitors and Parkinson disease with dopadopaminergic drugs. They can also rule out immediate concerns such as vertebrobasilar stroke and drug effects. Finally, radiologists and gastroenterologists can assist with ruling out other diagnoses and offer means of long-term feeding access.

**Diffuse Esophageal Spasm**

In contrast to disorders of the oropharynx, which are often multisystem in origin and treatment, the first disorder of the intrinsic esophagus is mostly a primary esophageal disorder. In the ICU, diffuse esophageal spasm may manifest as chest pain with workup negative for acute myocardial infarction, pulmonary embolus, or aortic dissection. The hallmark of diffuse esophageal spasm (DES) is uncoordinated esophageal contraction, often unprovoked by swallowing. In DES, peristalsis is haphazard, with multiple—sometimes spontaneous—and nearly simultaneous high-amplitude contractions.

Nitric oxide sequestration and donation have been shown to induce and inhibit, respectively, the contractions seen in DES (19,20), pointing to disorganized, nitric oxide–dependent esophageal body relaxation in this disorder. This disordered contraction is either primary or may be secondary to GERD, as evidenced by the disproportionate prevalence of GERD in patients with DES. In addition, some patients are hyperresponsive to the contractile effects of cholinergic stimuli during edrophonium testing (21).

**Clinical Presentation**

Chest pain is the cardinal feature of DES. This can be difficult to distinguish from angina pectoris, especially since the majority of patients are older than age 50 years. Pain may be provoked by swallowing, emotional distress, cholinergic stimuli, or rarely, exercise, and lasts seconds to minutes, and sometimes hours. Some patients may also present with dysphagia.

**Diagnosis**

Spasm may be present on barium radiographs showing multiple, unprovoked nonlumen-occluding contractions that may propel the barium both caudally and cephalad. However, manometry is considered the gold standard for diagnosis.
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Although much debate surrounds the definition of DES, most authorities believe a few of the following manometric criteria—especially numbers 1, 2, and 3—would rule in the diagnosis:

1. Nonpropulsive contractions on at least 10% of test swallows
2. High-amplitude contractions greater than 30 mm Hg
3. Triple-peaked contractions
4. Hypertensive LES

**Treatment**

Because many patients have DES secondary to GERD, most physicians advocate that the first treatment should be an empiric course of antireflux therapy. Trials using twice-daily proton pump inhibitors (PPIs) for patients with chest pain may demonstrate close to 90% efficacy with comparable diagnostic accuracy to ambulatory pH monitoring. Antispasmodics such as sublingual nitroglycerine (22), nifedipine, and anticholinergics may be used but are inconsistent at relieving pain (23,24), probably because they also relax the LES and perpetuate reflux. Therefore, anticholinergics should be used only for PPI failure. Some patients respond to attempts at decreasing visceral pain sensation with antidepressants such as trazodone, 100 to 150 mg, or low-dose tricyclic antidepressants (25).

**Nutcracker Esophagus**

A variant of esophageal spasm that presents with chest pain, almost always during swallowing, and high-amplitude but coordinated contractions is called nutcracker esophagus. Manometrically, nutcracker esophagus is defined as greater than 80% of contractions effective and peristaltic, with an amplitude greater than 180 mm Hg. In theory, this pressure may be enough to decrease blood supply to the esophagus, and may be the cause of pain in this disorder. However mucosal integrity is almost universally intact due to the redundant blood supply to the esophagus (26). Treatment focuses on GERD and is similar to that of diffuse spasm.

**Achalasia**

Classic or idiopathic achalasia, as its Greek root for “lack of relaxation” implies, is defined by two key abnormalities: poor relaxation of the LES, and aperistalsis of the esophageal body (27,28). It is a rare disorder, occurring in 1 in 10,000 (29)—common enough for most gastroenterologists to have seen a few cases, but uncommon enough to make its diagnosis and treatment challenging. For example, years may pass between the development of symptoms and the diagnosis of achalasia. Therefore, it is not uncommon of for achalasia to be diagnosed in the ICU in a patient with an unexplained wide mediastinum (Fig. 158.1) or aspiration.

The cause of idiopathic achalasia is unknown, but several hypotheses have been suggested, including viral (30), neurodegenerative (31), genetic (32), autoimmune (33), or, more likely, a combination of the above. Regardless, the end pathophysiologic event is destruction of nitric oxide and VIP neurons in the myenteric plexus, preventing effective LES relaxation and causing esophageal body aperistalsis.

The symptoms of achalasia include dysphagia to solids and liquids (like most motility disorders as opposed to structural disorders), weight loss, and regurgitation of phlegm (especially...
in the morning) and undigested food, often several days old. Some patients may present with pneumonia or food impaction (described later). A few case reports in the literature have described acute postprandial airway obstruction in patients with classic achalasia (34) combined with "upper achalasia," i.e., inability of the upper esophageal sphincter to relax. In those cases, swallowed air cannot be released and the resultant dilatation of the esophagus compresses the airway. Emergent nasogastric tube (NGT) decompression of the esophagus is the immediate treatment of choice (35). For chronic therapy of upper achalasia, a ciprophyragylary myotomy or Botox to the UES by endoscopy may be effective.

Some diagnostic features of classical achalasia include the bird's eye—a long and narrow LES on barium swallow—and characteristic manometric findings. Other possible presenting features include a retrocardiac mass or mediastinal air fluid level on plain chest radiographs and an epiphrenic esophageal diverticulum, which can be perforated by Dobbhoff or NGT placement.

Secondary causes of achalasia should be ruled out, including gastroesophageal, lung, or breast cancer; lymphoma; amyloidosis; sarcoidosis; paraneoplastic syndrome; and Chagas disease caused by a trypanosome protozoan prevalent in South America and resulting in megaesophagus and megacolon (see below) due to inflammation in the myenteric plexus. Treatment aims to relax the LES, including esophageal Botox injection or balloon dilation (36), and Heller myotomy. Botrox works by poisoning acetylcholine (ACh)-containing neurons, thus restoring a balance in the LES between ACh and nitric oxide—between contraction and relaxation. Various medications have been tried, such as oral nitrates (37) and sildenafl (38), as well as calcium channel blockers, especially the dihydropyridine calcium channel blockers; the nondihydropyridines, such as diltiazem and verapamil, may be somewhat less effective (39). Unfortunately, tachyphylaxis limits the clinical utility of these oral antispasmodics in the treatment of achalasia.

**Hypotonic Lower Esophageal Sphincter**

A hypotonic LES, defined by a manometric pressure less than 10 mm Hg, may also be suggested radiographically by a patent aortic arch on chest radiograph or by increased LES pressure drops from a baseline of 20 cm H$_2$O (40). Several techniques may limit the impact of hypotonic LES, including esophageal Botox injection or balloon dilation (36), and Heller myotomy. For the ICU, the hypotonic LES may assume great importance during cardiac arrest. Many studies over decades have typically associated these findings with GERD, often with a sliding hiatal hernia.

For the ICU, the hypotonic LES may assume great importance during heart arrest. In animal models, the LES pressure drops from a baseline of 20 cm H$_2$O to 5 cm H$_2$O (3.8 mm Hg) (40). In simulations of cardiac arrest during ventilation with bag-valve-mask device, this low pressure leads to stomach ventilation (41), diaphragm elevation, reduced respiratory system compliance (42), aspiration, and poor outcomes (43). Several investigators have shown acute drops in LES pressure during carotid artery occlusion (44). Several techniques may limit the impact of hypotonic LES during cardiac arrest. We propose that first responders minimize peak airway pressure to less than 5 cm H$_2$O lower tidal volumes to 300 to 500 mL with a higher FiO$_2$ (45), and decrease peak inspiratory flow (46). Pressure can be applied over the cricoid to seal off the esophagus (47). Arguably, several of these techniques could be extrapolated to patients on noninvasive ventilation.

**Impaired Esophageal Motility**

Weak esophageal body motility has more recently been termed ineffective esophageal motility (IEM). Manometrically, IEM has more than two swallows out of ten associated with esophageal body contraction amplitudes less than 30 mm Hg, which is the minimum required to propel a barium bolus. Some patients with IEM may complain of dysphagia secondary to slow transit through the esophagus. Much controversy surrounds whether GERD and acid exposure are the cause, or the result, of IEM. Patients may develop secondary overgrowth with Candida, or may develop one of the most common causes of GI bleeding in the ICU: esophagitis. Dobbhoff and NG tubes, which lower LES pressure, can be especially dangerous in these patients, facilitating acid-induced esophageal damage. If ICU clinicians require gastroduodenal access, ruling out epiphrenic diverticula is advised before nasogastric or nasoduodenal tube placement in IEM, as in the case of achalasia.

Conditions that predispose to IEM, other than GERD, include many of the connective tissue diseases such as scleroderma, CREST, hypothyroidism, mixed connective tissue disease, rheumatoid arthritis, Raynaud's phenomenon, systemic lupus erythematosus, chronic intestinal pseudoobstruction, amyloidosis, diabetes mellitus, and multiple sclerosis. Scleroderma, CREST (calcinosis, Raynaud phenomenon, esophageal motility disorders, sclerodactyly, and telangiectasia), and mixed connective tissue disease often have additional factors that predispose to GERD and esophageal damage including decreased LES pressure, gastroparesis, and colonic inertia. Mechanisms are controversial but likely include spasm and vasculitis of the vasa nervorum (capillaries around nerve bodies), periaxonal collagen deposition, and even antimyentric plexus antibodies. All of these mechanisms may eventually progress to atrophy and fibrosis of smooth muscle in the esophagus. Fundoplication may improve esophageal motility in some patients with IEM but can be risky in connective tissue disease patients due to the high incidence of postoperative dysphagia (48). Therefore, the principal management is twice-daily proton pump inhibitors and antireflux measures, such as avoiding drugs that relax the LES, and elevation of the head of the bed. Some investigators have tried promotility drugs effective elsewhere in the GI tract such as metoclopramide and more recently, tegaserod in the management of IEM. Unfortunately, no one has shown a clear-cut clinical benefit from these agents as of yet (49). However, anecdotal experience at our institution suggests that erythromycin, tegaserod, and an older procholinergic prokinetic, formerly used in surgical patients with postoperative gastroparesis and bladder atony, bepasnecol, may be useful. In diabetic or connective tissue disease patients, treatment other than twice-a-day proton pump inhibitor and avoidance of Dobhoff and NG tubes is aimed at the systemic disease.

**Food Impaction in the Esophagus**

Abnormal motility may contribute to an important esophageal emergency: food impaction. The three typical areas of impaction, in order of increasing frequency, include the upper...
esophageal sphincter, the level of the aortic arch, and the distal esophagus. Predisposition varies depending on the location. In the upper esophagus, neurologic disease or Zenker diverticula can be factors, whereas in the middle esophagus, extrinsic compression by aortic aneurysm and malignant lymph nodes predominate. In the most common location, the distal esophagus, many disorders may predispose to impaction, such as Schatzki ring, achalasia, esophagitis, and cancer. In some series, approximately 50% of patients with food impaction have underlying motility disturbance such as eosinophilic esophagitis (50). Patients may present with choking or foreign body sensation, neck pain, and sudden onset of the inability to swallow food or saliva. Inability to speak, or hoarseness, may imply supralaryngeal impaction or compression of the larynx by a distended esophagus, and may necessitate an otolaryngologic consult to rule out impaction that could endanger the airway before an endoscopy is performed. Most patients with food impaction are not critically ill, but occasionally they may be dehydrated or may have aspirated. Immediate management aims to relieve the obstruction and prevent potential complications such as aspiration, bleeding, or esophageal perforation. Most authors recommend immediate endoscopic removal of the impacted bolus or foreign body to prevent edema and fibrosis, and to restore patency of the lumen.

**STOMACH AND SMALL INTESTINE**

Motility disorders of the stomach and small bowel are common in the ICU. To understand these disorders, we must review normal physiology.

The physiology of the stomach and small bowel is intimately linked. Specifically, the stomach functions as three suborgans: (a) a body/fundus for storage, (b) an antrum for grinding, and (c) a pacemaker for the entire gastrointestinal tract, usually along the greater curve. The pacemaker governs the migrating motor complex (MMC), an essential gastrointestinal motility pattern that links stomach and small bowel. Disorders in any of the suborgans can have profound symptomatology, such as distention and intolerance to tube feeds, increased aspiration risk, decreased absorption of drugs, increased risk for stress ulceration, and so forth.

The suborgans of the stomach monitor food content and regulate the speed of gastric emptying. For example, the second suborgan, the antrum, is the area primarily responsible for grinding of solid food particles in the fed state. This grinding better prepares the food for absorption in the small intestine (31). However, the drawback of this grinding is a delay of gastric emptying of solids, which is significantly slower than that of liquids. Furthermore, under normal circumstances, only particles less than 1 mm pass the pylorus, so that particles larger than that may have delayed emptying. For example, on average, the stomach clears 1-cm pieces of calf liver after 5 hours, whereas most 2- to 3-mm pieces are emptied within 2 hours, and homogenized liver empties within 30 minutes (52). However, erythromycin, a propulsive agent, can stimulate the passage of particles larger than 1 mm through the pylorus.

The third suborgan of the stomach, the pacemaker for the MMC, plays a crucial role in the emptying of solids. This pacemaker is located in 80% of patients on the greater curve of the stomach and the remainder in the duodenum (53). Several times daily in the normal fasting state, massive motor waves, dubbed the activity front of the MMC (Fig. 158.2), stimulate emptying of large particles through the pylorus and into the small intestine. Disruption of the pacemaker of the MMC may in part explain the high rate of gastrointestinal symptoms after partial gastrectomy/bariatric surgery. For example, without a pacemaker and MMC to clear particles greater than 1 mm, bezoars may form; in theory, bezoars may predispose to aspiration. In addition, these activity fronts of phase III of the MMC are essential in the function and coordination of the stomach and entire small bowel. The activity front of phase III is the ‘gastrointestinal housekeeper’ and propagates all the way to the ileum. In addition to assuring gastric emptying of large particles, this pacemaker is responsible for clearing large food particles from the stomach, e.g., bezoars, and large food particles from the duodenum and jejunum, e.g., bezoars.

![Figure 158.2](image-url) Activity front of the MMC seen by antroduodenal manometry. The y-axis is the distance from the pylorus at multiple leads, and the x-axis is time. Phase III is the Activity Front (AF) of the MMC. MMC, migrating motor complex. (From Braz J Med Biol Res 1998;31(7):889-900, with permission.)
particles, these waves clear bacteria from the proximal small bowel to prevent the syndrome of bacterial overgrowth. These waves also clear the entire GI tract of shed epithelial cells. Interestingly, caloric intake of as little as 200 kcal inhibits these important waves. This is the principle why an astute public speaker will eat a candy bar to prevent stomach “growling” on the lecture circuit. Theoretically in the ICU, patients receiving continuous enteral feedings may have less frequent or diminished activity fronts of the MMC. This lack of a GI housekeeper could predispose to tube-feed diarrhea, bloating, abdominal pain, bacterial overgrowth and translocation, poor stomach emptying, and aspiration.

The best studied method of measuring the activity fronts of the MMC is by antroduodenal (small bowel) manometry. Manometry requires insertion of a pressure-sensitive catheter in a cooperative patient, under fluoroscopy, into the proximal small bowel. Three leads are antral and three are duodenal. In only extraordinary cases, manometry can be accomplished in the ICU. However, in outpatients, the antroduodenal manometry catheter monitors fed and fasting states and responses to various prokinetic agents. Generally, low-dose octreotide—50 μg at bedtime—is the best stimulant of MMC activity fronts in ambulatory patients. However, in gastroparetic, our anecdotal experience with small bowel manometry favors erythromycin liquid, 400 mg each morning (which has virtually no risk of prolonging QT), or erythromycin liquid, 200 mg every 6 hours, 30 min before meals if the Q-Tc is less than 440 msec. The risk of sudden death with erythromycin is highly controversial (see below, Gastroparesis).

The first-mentioned suborgan of the stomach, the fundus, regulates for differences between liquid and solid emptying. Relaxation and enlargement of the fundus are crucial to the digestion of large liquid meals or solid meals that contain liquid. The vagal nerve mediates this relaxation of the fundus (54). Diabetics may have a vagal neuropathy and, together with surgical vagotomy patients, often lack this ability of the stomach to accommodate, leading to rapid liquid emptying, postprandial pain, and diarrhea. The effect of metoclopramide in the symptom relief of gastroparesis may be due to procholinergic stimulation of fundic relaxation and compliance. The nutritional content of gastric contents also regulates how the stomach processes food. For example, isotonic materials empty quickest, whereas hypertonic ones empty slowest, with hypertonic materials emptying at intermediate speed. Proteins and carbohydrates empty equally well and much better than fats, which stimulate cholecystokinin, thought to perturb gastric emptying in such disorders as chronic pancreatitis (55). Delays in the gastric clearance of fat may have profound importance; common diabetic drinks and enteral formulations are usually low in carbohydrates, but their high fat content in theory may decrease gastric emptying. High-glucose concentrations, at a threshold of 8%, may also empty slower than 1% glucose solutions, which empty quickly, at about the same rate as 0.9% NaCl (56).

The stomach and small bowel are also in close communication via the gastroilcal reflex. When high-nutrient contents reach the ileum, normal patients have a feedback reflex that delays release of stomach contents into the duodenum and decreases gastric emptying. In animals, this can be induced by instillation of fat into the ileum. The gastroileal reflex, in theory, may partly explain the paradox of the typical ICU patient: intolerant of tube feeds, with simultaneous diarrhea—due to poor absorption and high nutrient contents reaching the bacteria of the large bowel—and bloating/distention due to gastroparesis.

In the following text, we will investigate disorders of gastric and small intestinal motility.

Gastroparesis

Definitions of gastroparesis vary but, in general, the hallmark of gastroparesis is a delay in the emptying of solids. Patients complain of nausea (93%), abdominal pain (90%), early satiety (86%), and vomiting (68%) (57). Another common complaint is bloating, either perceived or frankly visible; patients may describe changing belt or pant size after meals.

Gastroparesis may contribute to aspiration pneumonia by two mechanisms. The first is by increasing gastroesophageal reflux. For example, up to 15% of ambulatory patients with refractory GERD have gastroparesis (58); leading one to speculate that gastroparesis may predispose to aspiration pneumonia in the ICU (59). In addition to promoting more frequent reflux in the ICU, gastroparesis stimulates colonization of the stomach with Gram-negative enteric and nosocomial flora, putting patients in the ICU with gastroparesis at increased risk for Gram-negative pneumonia (60).

The diagnosis of gastroparesis can be problematic. Barium studies lack caloric content and are liquid based. Therefore, they are a poor reflection of gastric or, for that matter, small bowel motility. Evidence suggests noncaloric liquids empty based only on the pressure they apply to the luminal wall (61). However, gastric scintigraphy with a technitium-99 labeled egg sandwich more accurately measures gastric emptying, especially of solids. Unfortunately, nearly every large medical center in this country seems to have its own protocol, controls, and standards for this test. In addition, a single patient’s gastric emptying can vary from day to day due to nicotine intake or to recent narcotic or prokinetic ingestion. Male and female populations have different standards for gastric emptying, but generally a half-time of emptying of greater than 90 minutes implies gastroparesis. More specificity can be gained by extending the amount of time the patient remains in the scanner. For example, the gastric residual at 2 hours is the most common measurement in community hospitals, and although sensitivity may be 100%, specificity is only 20%. The 4-hour measurement is more accurate with 100% sensitivity and 70% specificity (62). However, even the 2-hour measurement is impractical for the ICU setting, and gold standards to compare against scintigraphy are lacking. In addition, clinicians often encounter the quandary of a patient with borderline emptying at 100 minutes. One way to handle such a case is to recollect that, in our hands, most patients with symptoms of gastroparesis have emptying half-times greater than 120 minutes. However, many patients with normal half-times clinically benefit from prokinetics. Therefore, in borderline cases, we move to antroduodenal manometry or treat empirically.

Causes for gastroparesis are similar to almost all motility disorders and are quite diverse, including metabolic disorders: diabetes, hypothyroidism, uremia; drug-induced em-
or hypoaalbuminemia; nonetheless, many remain idiopathic. Diabetics presenting with gastroparesis often have evidence of neuropathy. Indeed, a peripheral neuropathy is believed to be the fundamental problem in diabetic gastroparesis. Due to the rising incidence of type 2 diabetes, the number of gastroparesis patients with type 2 diabetes now equals that with type 1 diabetes. Idiopathic patients are more often female of childbearing age. The hormone progesterone may be responsible for hyperemesis gravidarum and idiopathic gastroparesis.

A hallmark of gastroparesis treatment is medical management. Erythromycin, a motilin agonist, is one of the strongest pharmacologic stimulants of gastric emptying (63,64). Unfortunately, it is short acting, limited by tachyphylaxis, and must be given in intravenous (IV) form immediately before eating, or in PO (oral) form about 30 minutes before each meal. Given the fast-paced environment in today’s intensive care units, it may be impractical to dose this medicine at the exact time it is needed. Because gastric emptying to solids is slower than that of liquids, we prefer the suspension over the tablet form, 100 to 200 mg three times daily and before meals. However, IV administration may be more effective, and we have some experience with outpatients who require a PICC (peripherally inserted central catheter) line with chronic four-times-daily IV erythromycin. Another use of erythromycin in the ICU was found in one study to increase the tolerance of enteral nutrition in critically ill patients (66).

Much controversy surrounds the dangers of QTc prolongation in patients taking erythromycin. One methodologically problematic study found several deaths due to dysrhythmias in patients taking chronic erythromycin (67). Although these risks may be overstated, to be cautious, we recommend avoiding IV agents in patients taking erythromycin. Fortunately, another option is azithromycin which does not prolong the QTc interval (65). During antrodouodenal manometry, we have pronounced antral contractions from azithromycin at a dose of 400 mg liquid orally 30 min before breakfast (unpublished data). However, like all macrolides, azithromycin can cause significant diarrhea. This side effect can be used in the patient with acyclovir ileus, chronic colonic inertia, or constipation-predominant irritable bowel syndrome, but can be problematic in ICU patients with antibiotic or tube-fed-associated diarrhea. Another drawback of the macrolides is some patients will develop abdominal pain and nausea. Part of this phenomenon can be explained by experiments showing that overdrive pacing the stomach faster than its baseline contraction rate of three waves per minute can sometimes delay gastric emptying (68). Therefore, it is not unreasonable to start low, at 100 mg liquid orally three times daily 30 minutes before meals.

Another agent in the treatment of gastroparesis is metoclopramide, a mixed dopamine antagonist and procholinergic. This drug has fallen out of favor in recent years for several reasons. First, 20% of patients develop Parkinsonism early or sometimes very late into treatment. Usually, this is reversible. However, 3% of patients taking metoclopramide will develop irreversible tardive dyskinesia (69). In addition, many patients experience restlessness and agitation. Metoclopramide is not as potent a stimulant of gastric emptying as the macrolides, and some patients will develop abdominal pain and nausea. Part of this phenomenon can be explained by experiments showing that overdrive pacing the stomach faster than its baseline contraction rate of three waves per minute can sometimes delay gastric emptying (68). Therefore, it is not unreasonable to start low, at 100 mg liquid orally three times daily 30 minutes before meals.
or gastric resections (83,84). Inadvertent damage to the vagal nerve as in esophageal surgery or from neuropathy can also cause dumping syndrome. Therefore, ICU clinicians may encounter this disorder. In the dumping syndrome, abnormally rapid emptying of gastric contents leads to early delivery of osmotically rich food into the small intestine, resulting in volume shifts and the excessive release of vasoactive peptides and insulin. Symptoms include adrenergic discharge with symptoms such as tachycardia, diaphoresis, agitation or confusion, diarrhea, abdominal cramps, and even hypotension. Measurable hypoglycemia was once thought to be common in dumping syndrome, but further studies have not concurred; perhaps the autonomic nervous system provides sufficient counterregulation to insulin surge in most patients to prevent frank hypoglycemia. A key historical point in the diagnosis of dumping syndrome is that patients are free of these symptoms under fasting conditions. The symptoms are classified as early dumping, within the first 30 to 60 minutes after meal ingestion, and less commonly, late dumping, within 90 to 240 minutes after meals. Liquids and foods rich in carboydrates are generally not well tolerated, and patients may lose weight due to fear of eating meals (84).

Dietary adjustments are fundamental to the management of the dumping syndrome (85). Patients should divide their caloric intake over at least six meals per day and minimize intake of fluids with solids. Meals rich in carbohydrates, such as Boost or Ensure, commonly induce dumping symptoms. Therefore, dumping patients should eat meals high in protein and fat and low in carbohydrates. Because lactose is absorbed in the jejunum, many patients experience milk intolerance after gastrointestinal symptoms, although these supplements are not universally well tolerated. Dietary fiber may be effective in dumping syndrome (86,87). Acarbose, which delays carbohydrate absorption, may prevent late dumping (88,89). However, diarrhea due to fermentation of unabsorbed carbohydrates limits long-term use.

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Most of the patients received IV propofol, which has a high fat content and can delay gastric emptying. However, a second study of critically ill patients also found delayed absorption of acetaminophen, a marker of gastric emptying (94). In the acetaminophen study, significantly higher volumes of gastric contents were aspirated while on dopamine. Dopamine may also prevent the normal fundic relaxation that is essential to prevent aspiration during ingestion of large volumes (95). Perhaps metoclopramide, a dopamine antagonist, which primarily stimulates fundic relaxation and accommodation, could reverse this effect of dopamine (see gastroparesis section for pitfalls of metoclopramide use). Vasopressin may also delay gastric emptying (96). Overall, mechanical ventilation and pressor use may decrease antral motility and reduce fundic relaxation, perhaps accounting for the bloating and high gastric tube outputs sometimes seen in enterally fed ICU patients.

**Intestinal Ileus (Acute Intestinal Pseudo-obstruction)**

Although many ICU patients have the aberrant, feed-state stimulation of MMCs demonstrated above, a more common scenario is inhibition of small intestinal motility in the ICU, leading to the condition of the small intestinal ileus, or paralytic ileus, an acute delay in caudad passage of intestinal contents in the absence of obstruction.

Patients with ileus present with distention, poorly localized abdominal pain, nausea, vomiting, obstipation, and decreased bowel sounds. Differential diagnosis of mechanical obstruction can be challenging, and an obstruction series abdominal film can be suggestive. However, passage of computed tomography (CT) contrast into the colon within 4 hours virtually excludes mechanical obstruction (97).

Recent surgery or bowel manipulation can decrease bowel motility, leading to ileus. Frequently, small intestinal motility returns within 24 hours after surgery, whereas gastric motility returns after 48 hours and that of the colon after 3 to 5 days. Various surgical factors are thought to account for differences in length of postoperative ileus, such as vagotomy, degree of intestinal manipulation, and presence of enterotomy, but these have not been proven (98,99). Several investigators have shown that activity of the left colon is key to recovery from postoperative ileus (100,101).

Causes of ileus are often multifactorial. Laparotomy decreases the amplitude of MMCs; activation of the sympathetic nervous system is likely a major factor. Similarly, inflammation plays an important role and may account for decreases in postoperative ileus in laparoscopic, as compared to open, surgeries (102). Epidural anesthesia may decrease the incidence of ileus compared to conventional narcotic analogs (103). Sepsis, mesenteric ischemia, myocardial infarction, lower lobe pneumonia, lower rib fractures, chronic mesenteric ischemia, phenothiazines, calcium channel blockers (especially the non-dihydropyridines), hypokalemia, hypomagnesemia and hypermagnesemia, hyponatremia, hypercalcemia—please note that because many ICU patients are hyperalbuminemic, an ionized calcium value is crucial here—and thyroid disorders have all been associated with intestinal ileus (104). Hypocalbuminemia may lead to bowel edema, which may account for part of the decreased motility seen in portal hypertension (105).
Most patients can be managed conservatively by identifying and treating/removing contributors to ileus. In patients with marked intestinal obstruction, NG suction should be initiated. In our practice, we recommend physical therapy and turning or sitting patients upright every shift. Some have advocated serial rectal exams, a brief trial of a rectal tube, or gentle tap water or 1 to 2 Fleet enemas (although, because these contain sodium phosphate, they should not be used in hypernatremic, hyperphosphatemic patients) to stimulate motility. Oral and stimulant laxatives should be avoided, especially lactulose, which releases hydrogen gas that can add to the problem, especially if mechanical obstruction has not definitively been ruled out. Unfortunately, prokinetic agents have so far been disappointing in the treatment of intestinal ileus. Metoclopramide is more potent in the foregut than hindgut. Erythromycin, a more potent foregut agent, is also active in the hindgut, but has not been shown to be effective in postoperative patients (106). The latter agent and tegaserod may have roles in the medical patient with ileus. Many agents are being tested in this exciting area of motility research.

**Chronic Intestinal Pseudo-obstruction**

Although it would be quite rare to diagnose chronic intestinal pseudo-obstruction in the ICU, for completeness, we will review the presentation, pathophysiology, causes, and treatments of this family of disorders. These rare motility disorders are characterized by symptoms and signs of chronic nonmechanical intestinal obstruction. Many of these disorders can affect the GI tract in several areas, causing megacolon, megaeosophagus, megaduodenum, and so forth. The presence of small bowel dilations should prompt a search for one of these disorders. Patients can present with strangury from small bowel overgrowth, alternating constipation and diarrhea depending on recent antibiotic use, feculent vomiting and halitosis, gastrointestinal pseudo-obstruction, pseudoachalasia, or even GI hemorrhage. Generally these disorders are characterized as either myopathic or neuropathic, and can be congenital or acquired.

The visceral myopathies involve degeneration and fibrosis of the muscularis propria, which can involve the smooth muscle of the bowel (enlarged esophagus, megaduodenum, redundant colon); irs (mydriasis); face (ptosis, ophthalmoplegia); bladder (macycystitis); and uterus (uterine inertia). They can present at any age, genetically or sporadically (107). Histology may show absence of actin, degenerating myofibrils, and mitochondrial abnormalities (108). Systemic disorders can cause visceral myopathy such as scleroderma and amyloidosis. Barium enema may show lack of haustrations, unlike the neuropathic disorders reviewed below. Antroduodenal manometry may show low-amplitude or absent MMCs (109).

In contrast, the visceral neuropathies are degenerative disorders of the myenteric plexus but can also be familial or sporadic. Histologically, these disorders display degeneration and/or inflammation of axons, dendrites, and absence of silver staining, occasionally with viral inclusions of cytomegalovirus (CMV) (110) or Epstein-Barr virus (EBV) (111). Other systemic contributors to visceral neuropathy include myxedema, Parkinson, narcotic bowel syndrome, late-stage Chagas disease, tumor or stroke of the medulla, acute encephalitis, and paraneoplastic neuronal degeneration, often from occult small cell carcinoma. This association is important to recognize because the time from diagnosis of extraintestinal primary small cell tumor to death is less than 1 year, in contrast to the myopathic disorders, the neuropathic disorders show uncoordinated bursts of activity, and abnormal propagation and configuration of MMCs (113). As in the myopathic disorders, suction biopsy can sometimes be diagnostic, but often a full thickness biopsy is required (113).

Treatment of visceral myopathy and neuropathy can be medical with erythromycin (115) or low-dose octreotide, 50 µg at bedtime, especially in scleroderma (114,115), nutritional with addition of B2 and fat-soluble vitamins with or without TPN, or surgical with resection of involved segments (116).

**LARGE INTESTINE**

Diarrhea

Diarrhea is a common ICU problem. Although a comprehensive approach to acute and chronic diarrhea is too expansive for this chapter, several important ICU diagnoses need to be ruled out, including *Clostridium difficile* toxemia, medication-induced diarrhea, acute mesenteric ischemia, pseudo-obstruction, and malabsorption.

The diagnosis of *C. difficile* infection is covered in depth elsewhere in this text, but is important to mention because of several common pitfalls. First, *C. difficile* can rarely be toxin negative, even when the standard three samples are sent for analysis, with *colonoscopy* and *stool* culture serving as the gold standard (117). Therefore, if clinical suspicion for *C. difficile* colitis or enteritis is high, antibiotic therapy and isolation should be initiated before toxin results can come back, and should be continued until at least three samples are toxin negative—potentially longer if GI consultation recommends. Second, care must be taken in interpreting a single positive toxin, especially in the patient at risk for antibiotic-associated non-*C. difficile* diarrhea. For example, 20% of patients have a false-positive *C. difficile* toxin. These patients actually have medication-related, antibiotic-associated diarrhea or simple colonization, without signs of serious illness such as fever, abdominal pain, leukocytosis, and acute hyperalimentation (118). Removing the offending agent, often a macrolide, is the definitive management of antibiotic-associated diarrhea and is also important in *C. difficile* diarrhea. Recall that the diarrhea of *C. difficile* is often hemocult positive. For patients who must remain on antibiotics, much controversy surrounds the use of probiotic agents such as lactobacillus and *Saccharomyces boulardii* in the prevention and treatment of antibiotic-associated diarrhea. These agents are generally safe but are not FDA-regulated, and there have been several case reports of *S. cerevisiae* fungemia and lactobacillus bacteremia in immunocompromised patients due to handling of central catheters after placing the medication in feeding tubes (119).

Other bacterial infectious enteritides are quite rare in the patient who develops diarrhea. However, in the ICU patient with diarrhea admitted from the emergency department (ED) for other reasons, it is reasonable to test for the most common causes of acute infectious bacterial enteritis, such as *Campylobacter*, salmonellosis, shigellosis, and *Escherichia coli* 0157:H7. Recall that these patients can appear toxic, and any of these...
enteroinvasive bacteria can present with hemolytic-uremic syndrome or toxic megacolon. *Campylobacter jejuni*, as its name implies, can present with severely thickening on CT resembling mesenteric ischemia. Recall that a classic finding of salmonellosis is fever without tachycardia, one of the rare infections other than mycoplasma that give that presentation.

The diarrhea of acute mesenteric ischemia is important to recognize. It is often heme positive and can appear maroon or melanic. Slighting of mucosa may be seen and, in addition to sudden distention, may portend infarction. In the patient with pain out of proportion to physical exam early in the course, many signs are absent, and a high clinical suspicion must be maintained. A rancid odor may be appreciated but can be stifled by a rectal tube with balloon, only to be noticed when the bag is changed. Patients may not appear toxic until late in the course when bowel infarction, peritonitis, and lactic acidosis occur. In our experience, patients at highest risk are vascular surgery patients, those undergoing cardiorespiratory bypass, patients with embolic risk whose anticoagulants are held for surgery patients, those undergoing cardiopulmonary bypass, and critically ill patients on broad-spectrum antibiotics, the presence of unaltered tube feeds in the stool may be the only sign. The diagnosis of a colonic perforation during PEG requires a CT scan with PEG-instilled contrast, as a kidney, ureters, and bladder (KUB) will show some free air even in normal post-PEG patients. In the patient with new tube feeds and diarrhea, the ICU clinician may need to rule out jejunal ischemia, as there have been several case reports (123). If, in fact, tube feed diarrhea is idiopathic, a possible treatment is adding soluble partly hydrolyzed guar as a source of fiber. In one randomized controlled trial in mechanically ventilated and septic patients, guar significantly reduced—from 32% to 9%—the percentage of tube feed-induced diarrhea (124). The only enteral formula with fiber is Jevity, but even this may not be sufficient. Elemental or semi elemental formulas such as Peptimen may be easier to absorb, especially in ICU patients, but are expensive.

Pseudodiarhea is important to rule out. Spinal cord patients, diabetic patients, patients with neuropathies/strokes/anticonvulsant therapy, partial pancreatectomy, prostate surgery, and sedated patients may have baseline low anal sphincter pressure. They may be unable to sense the urge to defecate. If the stool is loose because of tube feed, antimotility therapy, the critical care team may start an exhaustive and expensive search for all the causes of diarrhea when a simple rectal exam may be suggestive (125). Treatment is outpatient biofeedback and pelvic floor muscle strengthening.

**Hirschsprung Disease**

A prototypic, but rare, disorder of constipation is congenital aganglionicous of the colon, also known as congenital megacolon. Although it would be rare to diagnose a patient in the ICU, save for the pediatric ICU (PICU), the physiology of Hirschsprung disease is worthy of a brief discussion and illustrates several broadly applicable motility principles.

Hirschsprung disease results from failure of the neural crest cells to migrate into and from the myenteric plexus in a contiguous region of the left colon. Patients present with severe constipation without palpable stool in the rectal vault, without fecal soiling, but with a narrowed, diseased colon segment and a more proximally dilated, normal, colonic segment.

Patients suspected of having Hirschsprung disease should undergo anorectal manometry in the gastrointestinal laboratory, an impossibility in most ICU patients. Lack of compensatory rectal relaxation to distention of the rectal balloon is suggestive. These patients should undergo colonic suction biopsy, which can sometimes reach the muscularis propria and rule out visceral neuropathy, myopathy, and amyloidosis. However, lack of myenteric plexus neurons on endoscopic suction biopsy was

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does not entirely prove Hirschsprung disease, and often a laparoscopic full thickness biopsy is required (126).

The lack of nitric oxide-containing neurons, which prevent rectal relaxation, may be the principal mechanism of disease. Chagas disease can even result in a Hirschsprung-like presentation in adults even in the United States (127). Some have found that 70% of adults with acute megacolon may have some histologic features of congenital neurologic disease (128).

Colonic Inertia

Probably the most common cause of refractory constipation in adults is colonic inertia due to generalized decreased colonic motility. A subset of patients may present with obstruction, evidence of colonic dilation, and even respiratory compromise from diaphragmatic impingement. In patients without a prior radiograph, it may be difficult to rule out acute processes such as megacolon. Patients may have a long history of chronic stimulant laxative use. However, much controversy exists over whether this is in fact the cause or the result of colonic inertia.

Less controversial causes include opiates, dehydration/diuretics, calcium channel blockers, clonidine, hypothyroidism, electrolyte imbalance (see ileus section), and immobility. For diagnosis, ambulatory patients can swallow a capsule filled with radio-opaque beads (also known as Sitz markers) and be followed with daily radiographs of the abdomen (KUBs) (129). Markers that are evenly distributed throughout the colon—more than 5 out of 20 at 4 days—are diagnostic of colonic inertia, whereas those that “pile up” can indicate obstruction or pelvic floor dysynergia.

Ruling out C. difficile in the patient presenting with constipation, bloating, and colonic distention, sometimes with hemoglobin-positive rectal exams as well, is essential. In immunocompromised patients, CMV can present similarly. Although colonic amebiasis would be a rare cause of this presentation (130), the southeastern United States has a higher prevalence than the rest of the nation, especially among individuals at high risk such as travelers to endemic areas and homosexual men. Other causes of infectious colitis can rarely cause toxic megacolon but are in the differential diagnosis.

Treatment is aimed at removing offending agents and gently stimulating bowel movements with tap water or Fleet’s enemas (see section on ileus). Most acute presentations can be treated with manual disimpaction. Rarely would a patient benefit from emergency colonoscopy, unless manual disimpaction and enemas have failed, and colonic dilation proximal to the impaction exceeds 10 cm in the cecum. Prokinetics and oral or stimulant laxatives should not be used until the impaction has been removed. After relief, patients should be maintained on a chronic, safe bowel regimen to prevent impaction, such as once-daily Miralax, or, in patients with normal renal function, with milk of magnesia or magnesium citrate, 1 to 2 teaspoons daily.

Ogilvie Syndrome

One of the most important motility associated diseases is acute colonic pseudo-obstruction. When this condition coincides with recent orthopedic, trauma, gynecologic, or other surgery, it is classically known as Ogilvie syndrome. This is important to distinguish from simple small bowel ileus or from acute colonic obstruction from stool impaction, and so forth, which require different management.

Typical Ogilvie patients present on initiation of diet several days after surgery with acute or subacute colonic dilation, distention, often with lack of gas passage, sometimes with nausea, vomiting, or respiratory compromise due to diaphragmatic compression. Generally, not much stool and no transition point is seen (Fig. 158.3). Massive dilation can occur and may lead to perforation, especially when cecal diameter approaches 11 to 12 cm. The cecum is most susceptible to baro-induced ischemia and perforation, as it is the thinnest walled area of the colon. Laplace’s law states that transmural pressure is highest across the thinnest portion of a wall. Once pressure inside the cecum exceeds that of the superior mesenteric vein, ischemia can occur (131). Predisposing factors to Ogilvie syndrome include colonic inertia, age, immobility, electrolyte imbalance, or neurologic conditions, such as strokes or parkinsonism with dysautonomia.

If the colon is dangerously dilated, the patient should undergo nasogastric tube suctioning, conversion to nothing-by-mouth status, perhaps with total parenteral nutrition, and gentle stimulation with serial rectal exams and enemas. In some patients, a carefully placed rectal tube can release some of the gas buildup if the dilation extends to the rectum. As in the case of fecal impaction, lactulose, which produces more gas, and other oral laxatives should be avoided. The gold standard in management for many years was an emergency water-soluble contrast enema in the radiology suite. The hyperosmolality of the enema often induces evacuation and at the same time rules out obstruction. The waning of expertise in this technique, as well as the widespread and emergency availability of colonoscopy, has resulted in a shift in this paradigm. Careful colonoscopy without oral bowel lavage and with minimal insufflation can decompress a severely dilated colon, but is associated with a 1% or higher risk of perforation in this setting. Placement of a decompression tube has a debatable effect on
recurrence (132). Therefore, since 1999, some proponents have advocated pharmacologic management with erythromycin (133), cisapride (134)—a mixed procholinergic and 5HT4 agonist no longer available in the United States, and neostigmine, a potent acetylcholinesterase blocker that has many of the side effects, albeit much more temporary, of acute nerve gas poisoning. Therefore, patients receiving neostigmine in our institution must be at the intermediate care unit (IMC) or higher level of care, with atropine instantly available. We do not use neostigmine in actively wheezing patients, those on oxygen for chronic obstructive pulmonary disease (COPD), patients with coronary artery disease, or those at higher-than-average risk of bradycardia and asystole, such as those on several atrioventricular (AV) nodal-blocking agents such as amiodarone or a calcium channel blocker with a beta-blocker. We typically notify cardiology or the critical care team of impending neostigmine use and ask patients to sign a consent form. The standard dose is 2.5 mg IV slow infusion over 1 to 3 minutes. An effect is generally seen within 2 to 20 minutes. The response can be dramatic, with massive evacuation of stool and gas and instant relief. The dose may be repeated 2 to 3 times very carefully. A prospective trial showed a 91% response rate compared to 0% with placebo (135). Nevertheless, many patients may have improved on more aggressive nonneostigmine medical therapy (136).

In the presence of peritonitis, leukocytosis, fever, or aecal diameter of greater than 12 cm, surgery may be necessary, which, if ischemia is present, usually includes right hemicolectomy, ileostomy, and mucous fistula formation.

**Sigmoid Volvulus**

Similar principals can be applied to the management of sigmoid volvulus, the “medical” volvulus; many patients are elderly with a history of chronic constipation and other comorbid diseases (137). In one series, up to 13% were in chronic institutions. Most present with distension and obstipation, but about 30% report pain. Significant tenderness on exam may portend ischemia and peritonitis. Radiographically, a sigmoid volvulus may appear as a markedly dilated, ahastral, sigmoid colon, with paucity of gas in the rectum. The dilated sigmoid loop may extend into the right upper quadrant, to look for an underlying strictureing lesion. However, because of poor preparation, emergency sigmoidoscopy cannot rule out small areas of ischemic mucosa and may delay definitive surgery in some patients. Careful placement of a rectal tube may decrease recurrence, which is quite high, on the order of 50%. Therefore, after emergent sigmoidoscopy, our practice is to continue to cleanse the bowel with enemas and, if tolerated, with gentle oral lavage to permit more accurate exam of the colon at the time of recurrence. Overall mortality of sigmoid volvulus is 8% (140), mostly due to the 20% of patients with ischemia who have a mortality rate of 80% in an older study (138), but a more recently reported rate is 25% (137).

**SUMMARY**

The ICU is home to many motility disorders. Some universal principles of diagnosis include ruling out emergencies such as impending colonic perforation, intestinal ischemia, food impaction, and so forth. In managing these disorders, some basic principles apply: (a) in the “slow disorders” such as gastroparesis, ileus, constipation, Ogilvie’s etc., correct electrolytes, rule out occult thyroid disease, keep glucose less than 150 mg/dL, minimize tubes and drains—especially in the upper GI tract, and remove offending agents (Table 158.2) such as calcium channel blockers, central alpha 2 antagonists, and pure mu-opiotes; (b) in the “fast disorders,” such as diarrhea, avoid magnesium-containing medications, SSRI, PPIs, and unnecessary antibiotics. In patients that fail TEN, consider motility as a cause. Consider guafor diarrhea and changing fat and sugar content for distention. Rule out hyperalimentation and lactic acidosis. In colonic distention, distinguish among fecal impaction (perhaps from chronic inertia) versus Ogilvie versus sigmoid volvulus. Basic management is the same: (i) use clinical assessment to rule out impending infarction; (ii) rule out ce cal diameter greater than 10 cm; (iii) apply gentle enemas and rectal tube if the patient is nontoxic; (iv) consider pro-motility agents only in Ogilvie (the only case in which neostigmine is used) or decompressed volvulus or disimpacted colonic inertia.
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TABLE 158.2

<table>
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<tr>
<th>FACTORS AFFECTING MOTILITY</th>
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<td>Fat</td>
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<td>High level of simple sugars</td>
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<td>Fat (in colon)</td>
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<td>Hyperosmolar</td>
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<td>High level of simple sugar (in colon)</td>
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<td>Hypo-osmolar</td>
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<td>Alpha-2 blockers</td>
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<td>Motility drugs (see text)</td>
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<td>Anticholinergics</td>
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<td>Low-dose octreotide (small bowel only, 50 µg SQ at hour of sleep)</td>
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<td>High-dose octreotide (50–200 µg SQ tid&lt;sup&gt;a&lt;/sup&gt;)</td>
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<td>Metabolic Factors</td>
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<td>Hypoaalbuminemia</td>
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<sup>a</sup>Unless malabsorption is induced via inhibition of bile salt release into lumen.

PEARLS

Motility Disorders of the Esophagus

- Oropharyngeal disorders predispose to aspiration and may be due to stroke, medications, and neurodegenerative or striated muscle disorders. Obtain rehab barium swallow and speech pathology consults early.
- Do not insert a Dobbhoff or NGT into a patient with a distal esophageal hypomotility disorder until epiphrenic diverticula have been ruled out by barium swallow.
- A wide mediastinum may be GI in origin.
- The mucosa of the esophagus is almost never affected by ischemia.
- Be aware of the disorders and drugs that affect LES pressure, as these may contribute to aspiration.
- NGT and Dobbhoff tubes lower LES and predispose to aspiration and esophagitis.
- During cardiac arrest, remember the importance of the LES and maneuvers to decrease gastric ventilation.
- Patients with connective tissue disease, especially those with esophageal dysmotility, are more vulnerable than the average patient to esophageal damage and aspiration.
- A food impaction must be removed immediately by endoscopy. Many are due to motility disturbances.

Motility Disorders of the Stomach

- Remember the stomach is the origin of the MMC in 80% of patients.
- Gastroparesis can predispose to aspiration of nosocomial Gram-negative bacteria and TEN intolerance.
- Secondary causes of gastroparesis, as in most motility disorders, include hyperglycemia, hypothyroidism, hypokalemia, hypercalcemia, uremia, high progesterone states, portal hypertension, connective tissue disease, right-sided CHF, and hypoalbuminemia.
- Treat by keeping blood glucose level less than 150 mg/dL, correcting electrolytes, avoiding precipitants such as opiates, calcium channel blockers, and clonidine.
- If possible, use propoxyphene and/or tramadol for pain control in gastroparetics and other patients with slow motility disorders.
- Erythromycin is the mainstay: start low at 100 mg liquid 30 minutes before meals or IV 10 minutes before meals, titrating to 200 four times daily if QTc is acceptable. Watch for P450 inhibitors and long QTc interactions.
- Some patients may benefit from azithromycin, which does not prolong the QTc, instead of erythromycin.
- Any drug that stimulates gastric emptying can cause diarrhea.
- Gastroparesis is worsened by high salt, sugar, fat, and fiber content. Thus, in outpatients, where aspiration is not a risk, tube feeds can be diluted 50% with water.
- In contrast, patients with dumping benefit from low-carbohydrate, high-fat, high-fiber diets.

Motility Disorders of the Small Bowel

- Recognize why some patients on pressors fail enteral nutrition.
In the management of ileus:

- Correct electrolytes.
- In TEN diarrhea, consider changing or diluting formula if aspiration is not likely. Also rule out jejunal ischemia and misplaced PEG, and consider adding gear-based fiber.
- Be able to distinguish false-positive C. difficile toxin in antibiotic-associated diarrhea from patients with C. difficile disease and false-negative toxins.
- Distinguish Ogilvie syndrome from sigmoid volvulus and fecal impaction with megacolon.
- The initial approach to nontoxic Ogilvie and sigmoid volvulus is nonoperative.
- Ogilvie patients can also be started on erythromycin if QTc is normal.
- Use gentle enemas but not oral-stimulant laxatives or loperamide.
- Correct electrolytes.

**Motility Disorders of the Large Intestine**

Common causes of diarrhea include magnesium salts, SSRIs, PPIs, antibiotics, TEN.

- Common causes of diarrhea include magnesium salts, SSRIs, and antibiotics.
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**References**

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Mesenteric ischemia is a generic term that implies inadequate blood flow to the intestines. It is relevant from a clinical standpoint as two separate disease processes: acute mesenteric ischemia (AMI) and chronic mesenteric ischemia (CMI). Although the underlying process is similar (i.e., inadequate intestinal blood flow), the clinical presentation, diagnostic concerns, and treatment algorithms are different. CMI is almost exclusively related to visceral artery occlusive disease from atherosclerosis and is relevant to intensive care physicians primarily because of the multiple organ dysfunction that occurs after revascularization. AMI results from a broad spectrum of underlying conditions including arterial emboli, in situ thrombosis in the setting of visceral arterial occlusive disease, mesenteric venous thrombosis, nonocclusive mesenteric ischemia (NOMI), and acute aortic dissections. AMI is relevant to intensivists not only because of the early postoperative concerns, but also because it can occur in critically ill patients with other active problems (e.g., post coronary artery bypass, acute pancreatitis). A thorough understanding of both clinical entities is essential for all intensive care physicians. The underlying pathophysiology and treatment of CMI will be discussed first to provide a foundation for addressing AMI. Although not traditionally considered AML, isolated colon ischemia will also be discussed for completeness.

**CHRONIC MESENTERIC ISCHEMIA**

Pathophysiology

The underlying pathophysiology of CMI is the inability to achieve postprandial hyperemic intestinal blood flow. Intestinal...