Gut Motility, Sphincters and Reflex Control

Adrian Thomas

The gastrointestinal tract is made up of layers of serosa, longitudinal muscle, circular muscle, submucosa and mucosa. The muscle layers are composed of bundles of smooth muscle fibres joined together at multiple points so that action potentials can travel along the length of the gastrointestinal tract. The two basic types of electrical activity are slow waves and spike potentials (spikes). Slow waves are minor depolarizations (5–15 millivolts) occurring 3–12 times/minute. They mainly modify the spikes and cause contractions only in the stomach. Spikes occur when the resting membrane potential becomes more positive than about −40 millivolts. The frequency varies from 1 to 10 spikes/minute and is regulated by the slow waves. The higher the slow wave potential rises above −40 millivolts the greater the spike frequency. Many factors influence the resting membrane potential. Gastrointestinal hormones, acetylcholine, parasympathetic stimulation and stretching of the muscle make it more positive and more excitable whereas noradrenaline, adrenaline and sympathetic stimulation make it more negative and less excitable. Muscle contraction is initiated by calcium entering the muscle fibres.

Gastrointestinal movements and secretions are controlled by the enteric nervous system. This comprises two plexuses:

- the myenteric (or Auerbach’s) plexus between the longitudinal and circular muscle layers
- the submucosal (or Meissner’s) plexus in the submucosa.

The plexuses are influenced by the sympathetic and parasympathetic innervation of the gastrointestinal tract.

The two types of movement in the gastrointestinal tract are propulsive or peristaltic and mixing movements or local constrictive movements). Peristalsis is a ring of contraction moving from the proximal gastrointestinal tract distally; the usual stimulus is distension of the lumen.

Chewing and swallowing

Chewing (mastication) breaks food up into small particles, increasing the surface area for digestion and absorption. Swallowing is a complex action requiring the coordinated activity of 26 muscles of the mouth, pharynx and oesophagus, six cranial nerves, the brainstem and cerebral cortex. It consists of two voluntary phases (oral preparatory, oral) and two involuntary phases (pharyngeal).

Motor function

The stomach

The stomach has three main motor functions.

Storage: food entering the stomach induces relaxation of the muscular wall via a vasovagal reflex. This allows the stomach to expand to accommodate food up to a volume of about 1.5 litres.

Mixing: food is mixed with gastric secretions by means of mixing or constrictor waves. These are weak peristaltic waves originating from slow waves occurring in the stomach wall. They are each 15–20 seconds long and spread towards the antrum. Some of these peristaltic waves become more intense (constrictor rings) and force the antral contents towards the pylorus. The pylorus contracts to slow gastric emptying and results in further mixing of gastric contents.

Emptying: the more intense peristaltic waves promote antral emptying. As the stomach empties, these constrictor rings begin further up in the body of the stomach promoting further gastric emptying. The pylorus allows fluid, but not usually solid, gastric contents to enter the duodenum. The rate of gastric emptying is regulated by gastric (weak influence) and duodenal (strong influence) factors.

Gastric factors include the gastric food volume and gastrin, which is released in response to gastric stretching, and the presence of certain foods. Carbohydrates remain in the stomach for the shortest time, proteins are intermediate and fats remain for the longest time.

Duodenal factors include enterogastric neural reflexes. These are stimulated by the acidity and osmolality of duodenal juice, the presence of digested proteins, duodenal distension and irritation. Cholecystokinin and other hormones (released particularly in response to duodenal fats) also have a role.
Small intestine
Mixing (segmentation) contractions: distension with chyme elicits regularly spaced contractions each 20–30 seconds. When relaxation occurs in these areas, contractions occur in intervening areas. These alternating contractions mix the chyme with small intestinal secretions and help to propel it distally.

Propulsive movements: peristalsis spreads chyme throughout the absorptive surface of the small intestine and propels it towards the ileocaecal valve. This slows the flow of chyme, often for several hours, until the next meal is eaten and the gastroenteric (gastroileal) reflex increases ileal peristalsis. Peristalsis slows from the proximal to the distal small intestine. Most peristaltic waves last for 3–10 cm and small intestinal transit time is 3–5 hours. Peristaltic activity is promoted by the entry of chyme into the duodenum, by the gastroenteric reflex secondary to gastric distension and by various gastrointestinal hormones including gastrin and cholecystokinin. Secretin and glucagon inhibit small intestinal motility. During fasting a ‘migrating motor complex’ or peristaltic wave passes down the upper gastrointestinal tract every 90 minutes to prevent any accumulation of secretions. Severe intestinal inflammation can result in intense and rapid peristalsis (peristaltic rush).

Ileocaecal valve
The ileocaecal valve slows the flow from the ileum to the caecum and prevents backflow from the caecum into the ileum. Distension or irritation of the caecum results in a reflex increase of tone in the ileocaecal valve and inhibition of ileal peristalsis, thereby delaying ileal emptying.

Colon
Proximal colonic movements are slow, which promotes reabsorption of fluid and electrolytes. Simultaneous contractions of the circular muscle and longitudinal muscle strips (taeniae coli) result in outward bulging of the bowel wall in between (haustations). As in the small intestine, alternating areas of contraction and relaxation result in mixing of the colonic contents. Slow forward propulsion also occurs. In the distal colon, modified peristaltic waves or ‘mass movements’ 1–3 times/day move the faeces towards the rectum. These movements are initiated by colonic inflammation and by gastrocolic and duodenocolic reflexes resulting from gastric and duodenal distension following meals.

Defecation
The internal anal sphincter consists of circular involuntary smooth muscle whereas the external anal sphincter consists of striated voluntary muscle, which is continually contracted unless consciously inhibited. Faeces entering the rectum, initiate an intrinsic defecation reflex mediated by the myenteric plexus. This results in peristalsis in the descending colon/rectum and relaxation of the internal anal sphincter. The intrinsic defecation reflex is weak and usually requires reinforcement by a parasympathetic defecation reflex, mediated via the sacral segments of the spinal cord and the pelvic nerves. This amplifies the peristaltic waves and relaxes the internal anal sphincter. Deep inhalation, closure of the glottis and contraction of the abdominal muscles are also initiated via the spinal cord. Defecation can be inhibited by conscious control over the external anal sphincter.

Gastrointestinal hormones
Several hormones influence gastrointestinal motility and secretions. The two main ‘families’ of gastrointestinal hormones are gastrin and secretin. The gastrin family includes gastrin and cholecystokinin (CCK), which are polypeptides with the same terminal five amino acids. The secretin family includes secretin, glucagon, glicentin, vasoactive intestinal peptide (VIP) and gastric inhibitory peptide (GIP), which all have similar structures. The functions of the most important gastrointestinal hormones are summarized in Figure 1.