Gastrointestinal Anatomy and Physiology

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… Lori Constantine MSN, RN, C-FNP, original course author.

Purpose & Objectives

The focus of this gastrointestinal anatomy and physiology course is to teach you about the structures and functions of the gastrointestinal system and its accessory organs. The anatomical structures of the gastrointestinal system work together to achieve three major goals. These goals are to digest, transport, and absorb nutrients. Understanding the fundamental structures and functions of the gastrointestinal system and its accessory organs will allow you to provide care for all patients and intervene effectively for those with alterations in gastrointestinal status.

After successful completion of this course, you will be able to:

Identify the functions of various anatomical structures within the gastrointestinal system.

Discuss the process of digestion, transport, and absorption within the gastrointestinal system.

Identify the functions of the accessory organs of the gastrointestinal system; the liver, gallbladder, and the exocrine pancreas.

Introduction

The functions of the gastrointestinal tract and its accessory organs are essential for life.

The process of digestion supplies nutrients to each and every cell in our body. If there is a disruption in any of these mechanisms, the whole body suffers.

This course will provide healthcare professionals with information about the anatomy and physiology of the gastrointestinal system.

Glossary

Bile: A greenish-brown alkaline fluid secreted by the liver and concentrated in the gallbladder, which aids digestion.

Bilirubin: Orange-yellow pigment in the bile formed as a breakdown product of hemoglobin in the red blood cells.

Caudate lobe: A small, well defined segment of an organ.

Chyme: The thick, semifluid contents of the stomach.

Clotting factors: Chemical and cellular constituents of the blood responsible for the conversion of fibrinogen into a mesh of insoluble fibrin causing the blood to coagulate or clot.

Conjugated bilirubin: (Also known as direct bilirubin.) Bilirubin that has been taken up by the liver cells and conjugated to form the water-soluble bilirubin diglucuronide.

Endocrine gland: A gland that secretes substances directly into the circulatory system; and include the pituitary, thyroid, parathyroid, and adrenal glands, the pineal body, and the gonads.

Exocrine gland: A gland that secretes substances through a duct opening on an internal or external surface of the body.

Hemolysis: Breakdown of red blood cells.

Kupffer cells: Specialized cells in the liver that destroy bacteria, foreign proteins, and worn-out blood cells.

Lumen: Hollow part of the gastrointestinal tract.

Macrophages: White blood cells that destroy invading microorganisms.

Partial Parental Nutrition (PPN): A solution, containing essential nutrients, which is injected into a vein to supplement other means of nutrition, usually a partially normal diet of food.

Thrombocytopenia: An abnormal drop in the number of platelets in the body. Platelets are blood cells involved in forming blood clots.

Total Parental Nutrition (TPN): A solution containing all the required nutrients that is injected over several hours, into a vein. TPN provides a complete and balanced source of nutrients for patients who cannot consume a normal diet. All TPN consists of dextrose and amino acids, and may also consist of lipids.

Unconjugated bilirubin: (Also known as indirect bilirubin). Bilirubin that is in a lipid-soluble form, and circulates in loose association with the plasma proteins.

Viscera: Soft, internal organs of the body.

Structure and Functions of the Gastrointestinal Tract

Understanding the anatomy and physiology of the gastrointestinal system is important in accurately assessing patients with gastrointestinal disorders.

The gastrointestinal tract is essentially a tube that extends from the mouth to the anus. It has generally the same structure throughout. There is a hollow portion of the tube known as the lumen, a muscular layer in the middle, and a layer of epithelial cells. These layers are responsible for maintaining the mucosal integrity of the tract.

There are three main functions of the gastrointestinal tract:

- Transportation
- Digestion
- Absorption of food

The mucosal integrity of the gastrointestinal tract and the functioning of its accessory organs are vital in maintaining the health of your patient.

The gastrointestinal tract's accessory organs include the liver, pancreas, and gallbladder (Scanlon, 2011).

Organ Location

The location of the organs can be divided into four quadrants: the right upper quadrant, the left upper quadrant, the left lower quadrant, and the right lower quadrant.

Right Upper Quadrant

The right upper quadrant contains:

- Liver and gallbladder
- Duodenum
- The head of the pancreas
- The right adrenal gland
- A portion of the right kidney
- The hepatic flexure of the colon
- Portions of the ascending and transverse colon (Jarvis, 2011).

Left Upper Quadrant

The left upper quadrant contains:

- Left lobe of the liver
- Spleen
- Somach
- Body of the pancreas
- Left adrenal gland, a portion of the left kidney
- Splenic flexure of the colon
- Portions of the transverse and descending colon (Jarvis, 2011).

Left Lower Quadrant

The left lower quadrant contains:

- Lower pole of the left kidney
- Sigmoid colon
- A portion of the descending colon
- Left ureter
- Left ovary and fallopian tube or left spermatic cord (Jarvis, 2011).

Right Lower Quadrant

The right lower quadrant contains:

- Lower pole of the right kidney
- Cecum and appendix
- A portion of the ascending colon
- Right ureter
- Right ovary and fallopian tube, or right spermatic cord (Jarvis, 2011).

Mouth

The mucosal layer of the mouth is composed of stratified squamous epithelial cells. These cells slough off during normal food chewing and are easily replaced.

The mouth functions to break down food into smaller parts.

The main structures of the mouth include:

Tongue - a muscle that is covered by taste buds. It also assists with the process of chewing, and helps to maneuver food to a position where it can be swallowed easily.

Salivary glands - these glands produce saliva, which moistens food to assist with swallowing. The salivary glands also begin the process of chemical digestion through the secretion of the enzyme, salivary amylase, which begins the process of breaking down carbohydrates. Lingual lipase in saliva is responsible to begin digestion of fats. Ptyalin and salivary amylase begin the digestion of starch and maltose. Additionally, the saliva is composed of mucous to facilitate swallowing and Immunoglobulin A (IgA) which consists of antibodies that fight bacteria and viruses.

Teeth - teeth mechanically break food down into smaller particles for easier swallowing and ingestion

Pharynx - allows the passage of both food and air (Scanlon, 2011).

Esophagus

The esophagus is the “food tube” that allows the passage of the food bolus from the mouth to the stomach. It plays no part in the digestive process.

The esophagus only produces mucus, which acts to:

- Facilitates the passage of food
- Lubricate and protect the esophagus

At the lower end of the esophagus is the gastroesophageal or cardiac sphincter. This sphincter prevents reflux of gastric contents into the esophagus.

Increased gastrin secretion and certain drugs that increase parasympathetic activity influence the patency of this sphincter.

Cigarettes and alcohol decrease the sphincter’s tone and increase the potential for reflux here as well.

Blood supply to the esophagus comes via the left gastric artery (Scanlon, 2011).

Stomach

The uppermost regions of the stomach are the cardiac region and the fundus, which lead into the body of the stomach. The antrum is the lower segment of the stomach, leading into the most distal part of the stomach, known as the pylorus.

At the base of the pylorus is the pyloric sphincter, which allows the passage of chyme into the small intestine.

The stomach functions to store, churn, and puree food into a substance known as chyme:

- Digestion of fats and starches begin in the mouth with the action of salivary enzymes, and continues in the stomach.
- Protein digestion begins in the stomach.
- There is some digestion of water, alcohol, and glucose in the stomach.

Additionally, gastric acid is produced in the stomach which destroys most bacteria that is ingested with food.

Gastric Juices

Gastric juices are secreted by the cells of the stomach, contributing to chemical digestion. The food ends up in semi-liquid form that is called chyme. The stomach functions to store, churn, and puree food into chyme:

Digestion of fats and starches begin in the mouth with the action of salivary enzymes, and continues in the stomach.

Protein digestion begins in the stomach.

There is some digestion of water, alcohol, and glucose in the stomach.

Additionally, hydrochloric (or gastric) acid is produced in the stomach, which destroys most bacteria that is ingested with food. Food usually remains in the stomach for three to four hours for the process of breakdown (Krumhardt & Alcamo, 2010).

Test Yourself

The pyloric sphincter allows the passage of chyme into the:

Esophagus

Large Intestine

Small Intestine – Correct!

Gastric Cells

There are several types of cells in the stomach that serve both protective and digestive functions:

- Goblet cells: Are typically mucus secreting cells. Their role in the stomach is protective in nature.
- Parietal cells: Secrete hydrochloric acid which lowers the pH of the stomach to destroy bacteria, viruses, and other organisms. The hydrochloric acid also changes pepsinogen into pepsin and intrinsic factor. These two substances aid in vitamin B12 absorption.
- Chief cells: Secrete pepsinogen, which helps to change ingested proteins into amino acids.

- G cells: Located in the antrum of the stomach, which is lined by mucosa that does not produce acid. The G cells secrete the hormone, gastrin. Gastrin secretion is stimulated by stomach distention, presence of protein in the stomach, vagal stimulation, elevated blood levels of calcium and epinephrine, and decreased acidity. Gastrin helps the gastric mucosa grow and repair itself. It stimulates the secretion of hydrochloric acid by the parietal cells and pepsin by the chief cells. Many drugs that prevent the formation of gastric ulcers work in this area of the stomach. Gastrin also increases the flow of bile and decreases gastric emptying (Krumhardt & Alcamo, 2010).

Gastric Blood Supply & Innervation

Blood supply to the stomach is via the celiac plexus.

The celiac plexus is composed of:

- The right and left gastric artery
- Gastroduodenal artery
- Splenic artery

Innervation to stomach includes:

- Intrinsic innervation: This occurs via the mesenteric (Auerbach's) plexus and the sub-mucosal (Meissner's) plexus. Intrinsic innervation influences muscle tone, contractions, speed, excitation, and secretions of the stomach.
- Extrinsic innervation: This occurs via the parasympathetic and sympathetic nerves. Parasympathetic innervation occurs via the vagus nerve, which causes:
    - Increased gastrointestinal functions and activity by increasing acetylcholine.
    - Increased glandular section and decreases sphincter tone.

Conversely, sympathetic tracts run alongside the blood supply to the stomach and secrete norepinephrine when stimulated. Sympathetic stimulation inhibits gastrointestinal activity (Krumhardt & Alcamo, 2010).

Small Intestine

The small intestine extends from the pylorus to the ileocecal valve. The small intestine is composed of the duodenum, jejunum, and ileum. The ligament of Treitz divides the duodenum from the jejunum. Upper gastrointestinal bleeding occurs above this ligament and lower gastrointestinal bleeding occurs below this ligament.

The primary function of the small intestine is the absorption of vitamins and nutrients, including electrolytes, iron, carbohydrates, proteins, and fats. Most digestion of nutrients happens here.

The small intestine also absorbs approximately 8,000 milliliters (mL) of water per day (Barron, 2010). Three thousand milliliters of digestive enzymes are secreted in the small intestine daily.

These enzymes include:

Lipase – splits fats into monoglycerides, glycerol, and fatty acids

Amylase – converts starch to maltose

Maltase – converts maltose to glucose

Lactase – converts lactose into galactose and glucose

Sucrase – converts sucrose into fructose and glucose

Dextrinase – converts specific dextrins into glucose

Intestinal Hormones

The mucosa in the intestines also contains hormones. These include (Barron, 2010):

Enterogastrone: Found in the duodenal mucosa. Inhibits gastric acid secretion and gastric motility.

Gastric inhibitory polypeptide (GIP): Found in the duodenal and jejunal mucosa. Inhibits gastric acid secretion, pepsin secretion, and gastric motility.

Secretin: Found in the duodenal mucosa. Stimulates pepsinogen secretion, secretions of pancreatic digestive enzymes, and secretion of bile from the liver. Also decreases gastric acid secretion.

Cholecystokinin (CCK): Found in the jejunal mucosa. Stimulates contraction of the gallbladder and secretion of pancreatic enzymes, and inhibits gastric motility.

Vasoactive intestinal peptide (VIP): Found in intestinal mucosa. Similar effects as secretin, stimulates production of intestinal secretions that decrease chyme acidity, and inhibits gastric secretion.

Somatostatin: Found in the intestines. Inhibits secretion of gastric acid, saliva, pepsin, intrinsic factor, and pancreatic enzymes. Inhibits gastric motility, gallbladder contraction, intestinal motility, and blood flow to the liver and intestine. Also inhibits secretion of insulin and growth hormone.

Serotonin: Found in the intestines. Inhibits gastric acid secretion.

Intestinal Blood Supply & Innervation

Blood supply to the small intestine is derived from:

- The celiac artery
- The superior mesenteric artery

Innervation of the small intestine is the same as for the stomach (Krumhardt & Alcamo, 2010).

Did You Know?

Peristalsis is the process of wave-like muscular contractions that move digested material through the intestine. The process of digestion is completed in the small intestine. At this stage the nutrients that the body needs are absorbed through the walls of the small intestine. Peristalsis occurs via the autonomic nervous system and is coordinated by the myenteric plexi. Peristaltic activity is generally weak, but can be increased by laxatives and certain kinds of illness or toxicity (Barron, 2010).

Large Intestine

The large intestine extends from the terminal ileum at the ileocecal valve to the rectum. At the terminal ileum, the large intestine becomes the ascending colon, the transverse colon, and then the descending colon. Following the descending colon is the sigmoid colon and the rectum (Scanlon, 2011).

The main function of the large intestine is water absorption. Typically, the large intestine absorbs about one and one-half liters of water per day. It can, however, absorb up to six liters.

The large intestine also absorbs potassium, sodium, and chloride. It produces mucous which lubricates the intestinal wall and holds the produced feces together for elimination.

The superior and inferior mesenteric arteries and the hypogastric arteries supply the blood supply to the large intestine. Innervation of the intestine is the same as for the stomach (Scanlon, 2011).

Test Yourself

The large intestine's main function is to complete the absorption of:

Fats

Water – Correct!

Electrolytes

Gallbladder

The gallbladder is a pear-shaped, sac-like organ attached to the liver that serves as a storage facility for bile. It can hold and concentrate approximately 50 mL of bile.

The cystic duct connects the gallbladder to the common bile duct, which terminates at the Sphincter of Oddi in the duodenum of the small intestine.

When a large or fatty meal is consumed, nerve and chemical signals (release of the enzyme CCK) cause the gallbladder to contract. This contraction releases bile into the digestive system.

The gallbladder receives blood from the cystic and hepatic artery and is innervated by the splanchnic nerve and the right branch of the vagus nerve (Scanlon, 2011).

Did You Know?

Gallbladder removal (cholecystectomy) is a common procedure. After an individual no longer has a gallbladder the bile that is produced in the liver has nowhere to be stored. Therefore, instead of bile being released in a bolus with a fatty meal, bile continuously drips from the liver into the small intestine (Nelson & Zeratsky, 2011).

Bile & Bile Pigments

Bile has three major components:

- Water
- Bile salts
- Bile pigments

Bile salts absorb and emulsify fats and fat-soluble vitamins (A, D, E, & K).

Bile pigments are composed primarily of bilirubin, cholesterol, and phospholipids.

Bilirubin is the by-product of hemolysis (Scanlon, 2011).

There are Two Types of Bilirubin

Indirect-Bilirubin - Unconjugated or indirect-bilirubin: This is bilirubin that is in a lipid-soluble form, and circulates in loose association with the plasma proteins. When red blood cells, or erythrocytes, are broken down, the heme is converted to unconjugated bilirubin by the cells in the pancreas. It can then bind to albumin to go to the liver.

Direct-Bilirubin - Conjugated or direct bilirubin: This is bilirubin that has been taken up by the liver cells and conjugated to form the water-soluble bilirubin diglucuronide. Most conjugated bilirubin ends up in bile.

Total bilirubin is the indirect plus the direct bilirubin. When total bilirubin is elevated and the cause is unknown, direct and indirect bilirubin should be measured (Krumhardt & Alcamo, 2010).

Liver

The liver is a very large organ located in the upper right abdomen. There are right, left, and caudate lobes of the liver. Each of these lobes is further sub-divided into eight segments. These segments can be resected during surgery if diseased or traumatized.

The functional unit of the liver is the lobule or the acinus.

Blood supply to the liver arises from both the portal vein and hepatic artery. Nearly one-quarter of our cardiac output is delivered through the liver per minute, most of which travels through the portal vein.

The blood is filtered through the Kupffer cells of the liver, which destroy debris and unwanted organisms (Scanlon, 2011).

Functions of the Liver

Although there are literally hundreds of functions of the liver, the main functions can be categorized into five groups:

1. Conjugation of bilirubin
    - Bilirubin is typically formed from the destruction of red blood cells. Conjugation or conversion to the water-soluble form of bilirubin occurs in the liver. The kidneys can excrete this form of bilirubin.
    - Patients with liver dysfunction are often jaundiced due to the accumulation of bilirubin in the body.
2. Synthesis and deactivation of clotting factors
    - Produces all Vitamin K dependant clotting factors including II, VI, VII, IX, and X.
    - Removes activated clotting factors and produces heparin which prevents too much clot formation in the body.
    - Patients with nutritional problems have abnormal clotting mechanisms and may develop thrombocytopenia.
3. Detoxification of hormones, ammonia, and drugs
    - Converts many fat-soluble drugs and substances into a water-soluble form that can be excreted from the body in the urine.
    - Patients with liver dysfunction may manifest inability to excrete certain drugs, ammonia, and hormones.
4. Phagocytosis

- Seventy percent of the body's total macrophages are in the liver in the form of Kupffer Cells.
- Patients with liver dysfunction have a poor immune response.

5. Carbohydrate, protein, and fat metabolism

- Maintains normal serum glucose levels by carbohydrate synthesis, metabolism, and transport.
- The liver allows the body to use essential nutrients effectively, even if the nutrients are artificially supplied through partial parental nutrition (PPN) or total parental nutrition (TPN). So, giving a patient with liver failure TPN or PPN may not correct their nutritional deficits.
- Patients with liver dysfunction have extreme nutritional deficits.

(Scanlon, 2011)

Pancreas

The pancreas is both an endocrine and exocrine gland.

The endocrine functions include the production of:

- Insulin
- Glucagon
- Somatostatin (see also the RN.com course on Endocrine Anatomy and Physiology)

The exocrine function of the pancreas is mainly digestive in nature, and involves the secretion of pancreatic enzymes and bicarbonate.

The major digestive enzymes secreted by the pancreas are:

- Trypsin
- Lipase
- Amylase

These enzymes help digest carbohydrates, proteins, and fats. They are normally secreted into the duodenum in their inactive form. Once in the duodenum they are converted to their active form and begin the digestive process.

Bicarbonate is necessary to neutralize these and other enzymes located in the duodenum. Bicarbonate is secreted by the exocrine pancreas to prevent duodenal ulceration and irritation (Scanlon, 2011).

Test Yourself

The exocrine function of the pancreas involves the secretion of pancreatic enzymes and:

Sodium

Potassium

Bicarbonate – Correct!

Blood Supply & Innervation of the Pancreas

Blood supply to the pancreas occurs via the hepatic and cystic artery.

The pancreas is innervated by the splanchnic nerve and right branch of the vagus nerve.

Vagal (parasympathetic) stimulation results in the secretion of pancreatic enzymes. These secretions travel through the main pancreatic exocrine duct, the Duct of Wirsung. This duct terminates next to the common bile duct at the Sphincter of Oddi (Scanlon, 2011).

Biliary Ducts

While not organs themselves, the ducts of the biliary tract are very important in the proper functioning of the gastrointestinal system and body as a whole.

In the liver, bile is collected in the bile calculi, which eventually become the left and right hepatic ducts, which exit the liver as the common hepatic duct.

The cystic duct allows stored bile to be released from the gallbladder. The cystic duct and the common hepatic duct meet to form the common bile duct, which eventually terminates in the duodenum, next to the Duct of Wirsung (from the pancreas) at the Sphincter of Oddi (Krumhardt & Alcamo, 2010).

Obstruction or damage to any of these ducts may result in the improper drainage of bile and pancreatic enzymes.

Complications can include hepatitis, liver failure, pancreatitis, cholangitis, cholecystitis, and others (Scanlon, 2011).

Effects of the Nervous System on the Gastrointestinal Tract

The autonomic nervous system (ANS) is responsible for regulation of internal organs and glands, which occurs unconsciously.

This system is comprised of two main parts:

- The sympathetic nervous system (SNS)
- The parasympathetic nervous system (PNS)

The PNS is responsible for stimulation of "rest-and-digest" activities that occur when the body is at rest, including salivation, digestion, and defecation.

The SNS is responsible for stimulating activities that occur when the body is in the “fight-or-flight” mode.

These systems function in opposition to each other, which is complementary rather than antagonistic (Scanlon, 2011).

Sympathetic Versus Parasympathetic Nervous Systems

Arousal of the SNS causes a "fight or flight" response in the gastrointestinal tract, corresponding with energy release and inhibition of digestion.

Arousal of the PNS promotes a "rest and digest" response, promoting digestion.

Stimulation of SNS	Stimulation of PNS
Vasoconstriction of blood vessels supplying internal viscera	Vasodilation of blood vessels supplying internal viscera
Inhibition of gastrointestinal motility and peristalsis	Stimulation of gastrointestinal motility and peristalsis
Inhibition of gastrointestinal secretions	Stimulation of gastrointestinal secretions
Stimulation of glycogen breakdown in the liver to release glycogen stores	Inhibition of glycogen breakdown in the liver to preserve glycogen stores
Decreased pancreatic enzyme production	Increased pancreatic enzyme production
Decreased insulin release	Increased insulin release

Conclusion

Understanding the anatomy and physiology of the gastrointestinal system is key in accurately assessing your patients with gastrointestinal disorders.

Understanding the structure and functions of the gastrointestinal system, will assist in the recognition and interpretation of assessment findings related to the patient's history and physical exam.

References

Barron, J. (2010). Small intestine functions: Physiology of the Small Intestine. Retrieved September, 2014 from: http://www.jonbarron.org/enzymes/digestive-health-physiology-small-intestine-1

Krumhardt, B., & Alcamo, I. (2010). E-z anatomy and physiology. New York, NY: Barron's Educational Series.

Jarvis, C. (2011). Physical examination and health assessment, (6th ed). St. Louis: W.B. Saunders.

Mosby Company. (2012). Mosby's medical dictionary (9th ed.). New York: Elsevier.

Nelson, J., & Zeratsky, K. (2011). What's OK to eat after gallbladder removal? Retrieved September, 2014 from http://www.mayoclinic.org/healthy-living/nutrition-and-healthy-eating/expert-blog/gallbladder-removal-diet/bgp-20056135

Nettina, S. (ed.). (2010). Lippincott manual of nursing practice (9th ed.). Philadelphia: Lippincott Williams & Wilkins.

Scanlon, V. (2011). Essentials of anatomy and physiology (6th ed.). Philadelphia: F.A. Davis Co.

Venes, D. (ed.) (2013). Tabers® cyclopedic medical dictionary (22nd ed.). Philadelphia: F.A. Davis Co.