Lower Gastrointestinal tract, Hepatobiliary system, Blood and nerve supplies of the abdominal organs

BMES310 Human Gastrointestinal System and Nutrition

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1. The Lower Gastrointestinal Tract

The gastrointestinal tract is conventionally divided into two major parts; the upper GI tract and the lower GI tract. The accepted boundary demarcates these two parts is the duodeno-jejunal junction of the small intestine. Clinically, bleeding in the GI tract proximal to this junction is defined as upper GI bleeding, and therefore bleeding distal to this junction is lower GI bleeding. Since the structure of upper GI tract had been described in the prior lecture, this section is primarily explain the anatomy of the lower GI tract, including jejunal and ileal parts of the small intestine, the large intestine, rectum and anal canal.

1.1 Jejunum and ileum

Jejunal and ileal parts of the small intestine have overall average length of 6-7 meters, starts from duodeno-jejunal flexure to ileocecal valve. Both parts are hanged with the posterior abdominal wall by a broad, thick membrane of mesentery; therefore both parts are intraperitoneal organs. Topographically, most part of jejunum is located in the left and right upper quadrants of abdomen, while most of ileum situates within the right lower quadrant (figure 1). The mesentery associated with jejunum and ileum contains substantial amount of adipose tissues, and numerous branches of superior mesenteric artery and vein which deliver blood into and from small intestine, respectively. Remarkable feature of superior mesenteric artery is the arterial arcades, which are arches of anastomosing branches of this artery near the wall of jejunum and ileum. From these arcades, small branches called vasa recta arise and hence supply the intestinal tissues. Jejunum is usually has large, few arterial arcades, but has numerous long branches of vasa recta. Ileum, in contrast to jejunum, has many small arcades, but has fewer and shorter vasa recta (figure 2).

Figure 1 Position of jejunum and ilium related with abdominal surface quadrants (Moore, Agur & Dalley, 2010).
Similar to duodenum, circular folds (plicae circulares) is the prominent internal feature of both jejunum and ileum. However, the number and height of folds are decreasing in the ileum, and might be absent in the terminal ileum. Anatomically, there is no distinct boundary between jejunum and ileum, but both parts have many different features that can be compared and differentiated, as summarized in the table below.

<table>
<thead>
<tr>
<th>Features</th>
<th>Jejunum</th>
<th>Ileum</th>
</tr>
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<tbody>
<tr>
<td>Thickness of intestinal wall</td>
<td>Thicker</td>
<td>Thinner</td>
</tr>
<tr>
<td>Blood supply</td>
<td>More</td>
<td>Less</td>
</tr>
<tr>
<td>Arterial arcade</td>
<td>Few but large arcades, and usually has single row of arcades</td>
<td>Many small arcades with more than one row of arcades</td>
</tr>
<tr>
<td>Length of vasa recta</td>
<td>Longer</td>
<td>Shorter</td>
</tr>
<tr>
<td>Plicae circulares</td>
<td>Taller and more frequent</td>
<td>Shorter and more sparse, maybe absent in the terminal part</td>
</tr>
<tr>
<td>Lymphoid nodules (Peyer's patches)</td>
<td>Less</td>
<td>More</td>
</tr>
<tr>
<td>Fat deposit in the mesentery</td>
<td>Less</td>
<td>More</td>
</tr>
</tbody>
</table>

Fast response. This text discusses the internal features of the small intestine, specifically comparing the jejunum and ileum. It highlights that while the jejunum and ileum share some similarities, such as circular folds (plicae circulares), the ileum has fewer and shorter folds, which may be absent in the terminal ileum. Anatomically, there is no clear distinction between jejunum and ileum, but they differ in many features as summarized in Table 1. The table compares the thickness of the intestinal wall, blood supply, arterial arcade, length of vasa recta, plicae circulares, lymphoid nodules, and fat deposit in the mesentery. Figures 2 and 2 demonstrate the anatomical differences between the jejunum and ileum, showing variations in lumen size, numbers of arterial arcades, and vasa recta. The Large intestine section briefly describes the large intestine as the distal part of the gastrointestinal tract, ranging from ileocecal valve to the anal canal, and its prominent external features are the teniae coli.
are three longitudinal bands of smooth muscle that are start from vermiform appendix and end at the rectosigmoid junction by blend with longitudinal muscles of the rectum. Along the bands of teniae coli, small pieces of adipose tissues are attached, which are named **omental (epiploic) appendices**. Furthermore, the bands of teniae coli also pull the wall of large intestine together, forming an appearance of continued sacs called **hastraa** (figure 3). Folds inside internal wall of large intestine also presented, but are called **semilunar folds**.

![Figure 3 Large intestine with its parts and major features (Drake, Wayne & Mitchell, 2006).](image)

The most proximal part of the large intestine is an enlarged pouch called **cecum**, which connected with terminal ileum by the **ileocecal orifice**. Around the border of this orifice are **ileocecal valves**, which prevent reflux of contents from cecum back into terminal ileum (figure 4 left). At the inferior part of cecum is the location of small, elongated blind sac commonly known as **vermiform appendix**. Even though cecum is usually attached to the posterior abdominal wall (therefore is a secondary retroperitoneal structure), but the vermiform appendix is hanged by the small part of mesentery that derived from terminal ileum called **mesoappendix**, hence this structure is an intraperitoneal structure. Vermiform appendix is also subjected to anatomical variations; two-third of population has this structure located posterior to cecum (called retrocecal position), whereas about one-third has its location in the pelvic region (figure 4 right).
Distal to cecum, the large intestine is commonly called **colon**, and can be divided into 4 parts according to their direction within abdomen (figure 3):

- **Ascending colon**, which ascends from cecum and reaches hepatic (right colic) flexure.
- **Transverse colon**, which transverse the abdominal cavity from hepatic flexure to splenic (left colic) flexure. Anteriorly, most part of transverse colon is covered by greater omentum. This part is also the longest part of the large intestine.
- **Descending colon**, which descends from splenic flexure to the level of left iliac fossa.
- **Sigmoid colon**, which curves into S-shape and travels from left iliac fossa to the rectosigmoid junction that related to S3 vertebral level.

Among these 4 parts of colon, the ascending and descending parts are secondary retroperitoneal structures. The transverse colon and sigmoid colon are intraperitoneal structures, which attached to the posterior abdominal wall by the **transverse mesocolon** and **sigmoid mesocolon**, respectively.

### 1.3 Rectum and anal canal

Rectum and anal canal are the pelvic part of the gastrointestinal tract. **Rectum** is a cylindrical muscular tube that situated at the posterior region of the pelvis, just anterior to S3 to S5 levels of sacral vertebrae. Along the length of the rectum, there are three slightly bends called **lateral flexures** (superior, intermediate and inferior), which protrude into lumen of rectum and forming **transverse rectal folds** (figure 5). The inferior part of rectum located on the muscle of pelvic diaphragm (the
levator ani) and enlarged into the **ampulla of the rectum**. This part is where the fecal mass is collected before transferred into the anal canal.

At the level of anorectal junction, the tube is making a major anterior bend (about 80 degrees) before descends in the posteroinferior direction. This bend is called **anorectal flexure**, which is pulled anteriorly by the **puborectalis muscle**, which is a part of levator ani muscle that controls passage of fecal matter into the anal canal (figure 6).

**Figure 5** Coronal view of rectum and anal canal. This figure shows rich plexuses of blood supply surrounding wall of both rectum and anal canal. Transverse rectal folds and anal sphincters are also identified (Moore, Agur & Dalley, 2011).

**Figure 6** Anorectal flexure, which is pulled anteriorly by puborectalis muscle (Moore, Agur & Dalley, 2011).
**Anal canal** is the distalmost part of the gastrointestinal tract, which has only about 2.5-3.5 cm in length. Surrounding the anal canal are two sets of sphincter muscles:

- **Internal anal sphincter** surrounding superior 2/3 part of the anal canal. This is involuntary smooth muscle innervated by sympathetic nerve fibers. When the ampulla of rectum has low pressure, this muscle has tonic contraction to prevent unnecessary transfer of contents in the rectum. During defecation, this muscle is relaxed by parasympathetic outflow.

- **External internal sphincter** surrounding inferior 1/3 part of the anal canal, and can be further subdivided into deep, superficial and subcutaneous parts. This sphincter is the skeletal muscle that innervated by inferior rectal nerve (from S4 spinal nerve). This muscle contracts synchronously with the puborectalis muscle to control defecation voluntarily.

The internal wall of the anal canal has several longitudinal ridges at the superior half, which are called **anal columns**. Inferior part of these columns are fused together and forming **anal valve**, and the line inferior to anal valve is identified as the **pectinate line** that demarcates between superior 2/3 and inferior 1/3 parts of the anal canal. This line also a boundary of different developmental origins and neurovascular supply as summarized in the table 2. Inferior to this pectinate line is a histological boundary between anal canal and skin of anal aperture called **anocutaneous (white) line**. The region between pectinate line and anocutaneous line is called **anal pecten** (figure 7).

**Figure 7** Medial view of sagittal section of pelvic cavity, showing the location of rectum and anal canal. Regions of anal canal are also identified (Moore, Agur & Dalley, 2011).
Table 2 Embryonic origin, neurovascular supply and lymphatic drainage of parts of anal canal

<table>
<thead>
<tr>
<th>Structures</th>
<th>Superior 2/3 of anal canal</th>
<th>Inferior 1/3 of anal canal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embryonic origin</td>
<td>Hindgut (endodermal origin)</td>
<td>Proctodeum (ectodermal origin)</td>
</tr>
<tr>
<td>Artery</td>
<td>Superior rectal artery (from inferior mesenteric artery)</td>
<td>Middle rectal artery (from internal iliac artery) and Inferior rectal artery (from internal pudendal artery)</td>
</tr>
<tr>
<td>Vein</td>
<td>Superior rectal vein (to inferior mesenteric vein)</td>
<td>Middle &amp; inferior rectal veins (to inferior vena cava)</td>
</tr>
<tr>
<td>Nerve</td>
<td>Inferior hypogastric plexus (autonomic plexus)</td>
<td>Inferior rectal nerve</td>
</tr>
<tr>
<td>Lymphatic drainage</td>
<td>Internal iliac lymph nodes</td>
<td>Superficial inguinal lymph nodes</td>
</tr>
</tbody>
</table>

It should be noted that rectum and anal canal have rich vascular supply especially in the submucosal layer. If these vessels are enlarged, haemorrhoids can develop and frequently causing passing blood during or after defecation. Types of haemorrhoids are identified from their sites related to pectinate line; haemorrhoid above this line is called internal haemorrhoid, while below this line is called external haemorrhoid.
2. The Hepatobiliary System: Liver, Biliary tract and Pancreas

Structures in the hepatobiliary system is sometimes regarded as the accessory organs of the gastrointestinal tract, although their functions are crucial to the body homeostasis. All these organs are embryologically derived from hepatic diverticulum that arised from distal part of foregut, and therefore received blood supply from the foregut origin similar to stomach and duodenum.

2.1 Liver

Liver is the heaviest internal organ in our body, with normal weight of 1.4 to 1.6 kilograms. From abdominal surface, it spans from right hypochondriac region, epigastric region to left hypochondriac region. It is normally protected by rib cage; its superior surface reaches dome of diaphragm around 5th rib, and its lower border is at 10th rib. During full inspiration, lower border of liver descends slightly and allows physician to examine manually. Superior, posterior and anterior surface of liver is closely related to inferior surface of diaphragm, thus are named diaphragmatic surface. The inferior surface of liver is faced toward abdominal structures, therefore is called visceral surface. It should be noted that the peritoneum is covered all surfaces of liver except for some part of its posterosuperior surface, where it directly opposed with inferior surface of diaphragm, and called bare area (figure 8B,C). In the central of bare area is the location of hepatic veins drain into inferior vena cava. Besides, the connection between hepatic veins and inferior vena cava helps hold liver in its normal location.

As mentioned before that anterior and posterior surfaces of liver are covered by peritoneum, thus there are peritoneal recessed formed in between liver and nearby structures. Anteriorly, there is subphrenic recess that lies in between anterosuperior surface of liver and inferior surface of diaphragm. Posterior to the liver is the hepatorenal recess that located between liver and structures in posterior abdominal wall including right kidney and suprarenal gland (figure 8C).

Liver is suspended by ligaments derived from peritoneal folds. It is attached to the anterior abdominal wall by the falciform ligament, which also separates liver into left and right lobes. Inferior border of the falciform ligament is thickened and becomes cord-like structure called round ligament of liver (ligamentum teres hepatis) that is a remnant of embryologic umbilical vein (figure 8A). Superiorly, liver is hanged to diaphragm with left and right triangular ligaments that located at the superior corners of liver. There triangular ligaments are connected with falciform ligament by short coronary ligament that surrounds bare area. Moreover, visceral surface of liver is connected with lesser curvature of stomach and proximal part of duodenum by hepatogastric and hepatoduodenal ligaments, respectively. Reminded that both ligaments are components of the lesser omentum.
Figure 8 Anatomical features of liver and gallbladder. (A) Anterior view. (B) Posteroinferior view, showing visceral surface of liver with abdominal organs relation and location of porta hepatis. (C) Sagittal section displays location of subphrenic recess and hepatorenal recess (Moore, Agur & Dalley, 2011).
Anatomically, liver is divided into four lobes (figure 8A,B). From the anterior surface, **left and right lobes** is separated clearly by the falciform ligament. Considering visceral surface, smaller two lobes can be found:

- **Caudate lobe**, which is located superiorly and related to inferior vena cava at the right side, and fissure for ligamentum venosum to the left.
- **Quadrate lobe**, which is located inferiorly and related to gallbladder and its fossa at the right side, and fissure for round ligament of liver at the left.

In between caudate and quadrate lobes is a transverse fissure that contains vessels and bile ducts from inside liver. These structures are collectively identified as the **porta hepatis**, which normally consists of hepatic artery proper, hepatic portal vein and bile ducts. These three structures are topographically related as portal vein located posteriorly to hepatic artery proper and bile ducts, and bile ducts are situated on the left to the artery (figure 9). The relationship between structures of porta hepatis is of clinical importance, since they must be identified correctly during surgical interventions of liver and biliary tract.

Functionally, liver is further divided into **functional segments** according to branches of vessels and biliary system. Eight functional segments are identified and related to anatomical lobes of liver. For example, left lobe is divided into segment II and III, while caudate lobe is designate as segment I. Detailed on boundaries of each segments will not be explained here, but functional segmentation of liver is useful for hepatic lobectomy and segmentectomy, such as in liver cancer patient.

### 2.2 Gallbladder and biliary tract

Gallbladder is a pear-shaped sac located on the lower right part of visceral surface of liver between right lobe and quadrate lobe. This organ serves as reservoir and concentrating place of bile secreted from liver tissue. It can be divided into 3 parts (figure 10):
• **Fundus**, which is the inferiormost part that slightly protrudes inferior to lower border of liver.

• **Body**, which is a middle part and related anteriorly to transverse colon and first part of duodenum.

• **Neck**, which is a superior part that narrows before continued to **cystic duct**. Inside this part the spiral duct can be found, which acts as a valve controlling bile flow from gallbladder.

![Figure 10 Gallbladder and related biliary tract (Drake, Wayne, Mitchell, Tibbits & Robertson, 2007)](image)

The biliary tract starts from **bile canaliculi**, which is microscopic ducts adjacent to hepatocytes that receives bile directly. These canaliculi drain bile into larger **left and right hepatic ducts**, and subsequently join together to form **common hepatic duct**. At this part, cystic duct from gallbladder joins common hepatic duct and forms **common bile duct** (figure 10). The common bile duct descends posterior to first part of duodenum and head of pancreas, and joins with main pancreatic duct at **hepatopancreatic ampulla** (of Vater) before finally emptied into lumen of second part of duodenum via **major duodenal papilla** (figure 12). Surrounding hepatopancreatic ampulla is a sphincter of smooth muscle called the **sphincter of Oddi**, which controls flow of bile and pancreatic secretion into duodenum.

### 2.3 Pancreas

Pancreas is a thin, elongated organ located posterior to stomach and entirely attached to posterior abdominal wall, hence classified as secondary retroperitoneal structure. Anatomically, pancreas is divided into 5 parts (figure 11):
- **Head**, which is on the right side and directly adjacent to curvature of duodenum, and anterior to common bile duct. Inside this part the hepatopancreatic ampulla can be found.
- **Uncinate process** is the inferior, hook-shaped continuation of head of pancreas. Anterior to this part is the superior mesenteric vessels.
- **Neck**, which is on the left side of head of pancreas, and anterior to superior mesenteric vessels.
- **Body**, which is elongated to the left side of abdomen. Splenic artery is located on the superior border of this part of pancreas.
- **Tail**, which points toward hilum of spleen.

![Figure 11 Parts of pancreas and anatomical relationship with adjacent organs (Drake, Wayne & Mitchell, 2006).](image)

Inside the central core of pancreatic tissue is the **main pancreatic duct**, which can be found from tail to head of pancreas, and joins common bile duct at the hepatopancreatic ampulla. Frequently, a smaller duct arised from uncinate process and some parts of head of pancreas called **accessory pancreatic duct** can be identified, and this duct is directly emptied into duodenum through **minor duodenal papilla**.

![Figure 12 The position of main pancreatic duct, hepato-pancreatic ampulla and major duodenal papilla (Drake, Wayne & Mitchell, 2006).](image)
3. Arterial Supply of the Gastrointestinal System

The arterial system that supplies all abdominal organs derived from the abdominal aorta, which continues from its thoracic part by passing through aortic hiatus of diaphragm at the level of T12 vertebral body (figure 13A). This abdominal aorta descends in the posterior abdominal wall and bifurcates into left and right common iliac arteries at the level between L4 and L5 vertebral bodies. Along its route in abdomen, it give rises to three unpaired major branches that supply organs of the digestive system: the celiac trunk, the superior mesenteric artery, and the inferior mesenteric artery.

3.1 Celiac trunk

Just below to the aortic hiatus, the celiac trunk branched from the abdominal aorta and give rises to branches that supply organs derived from foregut. Three major branches that come from celiac trunk are left gastric artery, splenic artery and common hepatic artery (figure 13B).

Figure 13 (A) Abdominal aorta with locations of major branches. (B) Celiac trunk and its braches supplying stomach, duodenum, liver, gallbladder, spleen and pancreas (Morton, Peterson & Albertine, 2006).

- **Left gastric artery** is the smallest branch among three arteries from celiac trunk. This artery courses along the upper part of lesser curvature of stomach and therefore supplies superior part of stomach. It also give rises to small esophageal branch that supplies gastroesophageal junction.
- **Splenic artery** that is the largest branch of celiac trunk. This artery courses toward left side of abdomen by locates onto superior border of pancreas before enters spleen through its hilum. Along its tortuous course, it give rises to these arteries:
  - **Pancreatic branches** including dorsal and great pancreatic arteries, which supply body and tail of pancreas
  - **Left gastro-omental artery**, which branched near tail of pancreas and associated with greater curvature of stomach to supply body of stomach and greater omentum
  - **Short gastric arteries**, which are small branches that supply fundus of stomach.

- **Common hepatic artery** is another large branch that courses toward the porta hepatis of liver, and supplies parts of stomach, duodenum and liver. Along its course, many branches can be identified as following:
  - **Gastro-duodenal artery** that descends posterior to the first part of duodenum and give rises to **right gastro-omental artery** that associates with greater curvature of stomach and anastomoses with left gastro-omental artery. Another branch from gastro-duodenal artery is the **superior pancreatico-duodenal artery**, which descends further to supply duodenum and head of pancreas.
  - **Right gastric artery** courses along lesser curvature of stomach and anastomoses with left gastric artery.
  - **Hepatic artery proper**, which courses toward right side and enters liver via porta hepatis, where it usually bifurcates into **left and right hepatic arteries** before penetrate into lobes of liver. It should be noted that right hepatic artery has small branch called **cystic artery** that supplies gallbladder.

### 3.2 Superior mesenteric artery

The superior mesenteric artery (SMA) give rises to branches that supply parts of GI tract derived from midgut; from third part of duodenum to proximal 2/3 of transverse colon. This artery branched from the abdominal aorta at the level of L1 vertebral body, then descends posterior to neck of pancreas before emerges anterior to uncinated process of pancreas and locates within mesentery. Along its path, this artery branches into following arteries (figure 14):

- **Inferior pancreatico-duodenal artery**, which is the first branch of SMA that recurrent superiorly to supply head and uncinated process of pancreas and distal part of duodenum. This branch anastomoses with branches from superior pancreatico-duodenal artery, thus provides connection between celiac trunk and superior mesenteric artery.
• **Jejunal and ileal arteries**, which are numerous branches that supply jejunal and ileal parts of small intestine.

• **Middle colic artery**, which pass toward right side before ascends to transverse colon and therefore supplies this structure.

• **Right colic artery**, which supplies ascending colon. Its branch also anastomoses with branches from middle colic artery at the hepatic flexure.

• **Ileocolic artery**, which is considered as terminal branch of SMA that supplies terminal ileum, colon and vermiform appendix through its ileal branch, cecal branch, appendicular branch and colic branch.

![Superior mesenteric artery and its branches supplying jejunum, ileum, cecum, ascending colon and part of transverse colon (Morton, Peterson & Albertine, 2006).](image)

### 3.3 Inferior mesenteric artery

The inferior mesenteric artery (IMA) is responsible for blood supply to the GI tract derived from hindgut, which ranged from distal 1/3 of transverse colon to superior part of rectum. This artery is branched from the abdominal aorta at the level of L3 vertebral body, then descends to the lower abdomen and give rises to these arteries (figure 15):
• **Left colic artery**, which is the first branch of IMA that supplies descending colon. It also anastomoses with branches from middle colic artery at the splenic flexure, which is clinically identified as marginal artery of Drummond. This anastomosing branches are especially important in surgery since they provide collateral circulation to transverse colon and descending colon.

• **Sigmoid arteries**, which consists of 2-4 branches supplying sigmoid colon.

• **Superior rectal artery**, which descends further to the pelvic cavity and crosses left common iliac artery during its course. This artery supplies superior part of rectum and anastomoses with middle rectal artery (from internal iliac artery) and inferior rectal artery (from internal pudendal artery). Thus, these rectal arteries supply both rectum and anal canal.

4. Venous and Lymphatic Drainages of the Gastrointestinal System

4.1 Hepatic portal vein and major tributaries

Virtually all blood that returns from the gastrointestinal tract is drained back to liver via the hepatic portal vein (figure 16). This vein has two major tributaries: splenic vein and superior mesenteric vein.

• **Splenic vein** receives blood drainage from spleen, pancreas and stomach. It also receives tributary from the **inferior mesenteric vein** that drains blood from distal part of transverse colon, descending colon, sigmoid colon and rectum. Splenic vein is located at the superior border of pancreas parallel with splenic artery.

• **Superior mesenteric vein** receives blood from small intestine, cecum, ascending colon and proximal part of transverse colon. This vein and its tributaries are parallel with branches of superior mesenteric artery, and finally located just right to trunk of superior mesenteric artery before joins splenic vein.
The hepatic portal vein itself also receives small tributaries from left gastric vein and cystic vein. Blood in portal vein is distributed through liver parenchyma, and subsequently drained into hepatic veins, which then drained into inferior vena cava.

**Figure 16** Venous drainage of gastrointestinal system showing hepatic portal vein and its tributaries (Morton, Peterson & Albertine, 2006).

### 4.2 Portocaval venous anastomosis

In case of cirrhosis, the pressure inside hepatic portal system will be increased, and leads to portal hypertension. Consequence of this pathology is that blood flow from gastrointestinal tract has tendency to be congested due to high pressure in portal vein. In order to maintain venous return to inferior vena cava and heart, blood from gastrointestinal tract must be diverted to small veins that anastomose with tributaries of systemic venous system. This special routes is called the portocaval anastomosis, and major sites of anastomoses are (figure 17):

- **Esophageal veins** at the distal end of esophagus, which blood from gastric veins can be drained via these veins and finally delivered into azygos vein.
- **Paraumbilical veins** which drains blood from portal vein into epigastric veins at the anterior abdominal wall, and subsequently into common and external iliac veins.
- **Retroperitoneal veins** which drains blood from colic veins back to tributaries in the posterior abdominal wall and then into inferior vena cava.
- **Middle and inferior rectal veins** which connects with superior rectal vein, and drain blood into internal iliac vein and common iliac vein, respectively.
Figure 17 Major sites of portocaval venous anastomosis including A: esophageal vein B: rectal veins C: paraumbilical veins and D: retroperitoneal veins (Moore, Agur & Dalley, 2011).

However, these venous anastomoses are composed of small veins that cannot tolerate large volume of blood. Thus, in case of severe portal hypertension, these anastomoses start to show signs of varicose veins and bleeding. For instance:

- **Esophageal varices** and **hematemesis** (vomiting of blood) due to bleeding from esophageal veins.
- **Caput medusa sign** surrounding umbilicus due to varices of paraumbilical veins.
- **Hemorrhoid** in rectum and anal canal due to varices and bleeding from middle and inferior rectal veins.

Since portal hypertension might be difficult to measure, these signs is useful for diagnosis and assessment of severity in patients with liver diseases. In very severe case, surgeon might consider creating **portosystemic shunt** by directly connects portal vein to inferior vena cava.
4.3 Lymphatic drainage of the gastrointestinal system

Abdominal organs have extensive network of lymphatic vessels and nodes. Most of major lymph nodes are located near the branching point of main arteries supplying GI tract from abdominal aorta, and thus collectively called **preaortic lymph nodes**. Lymphatic drainage into these nodes is similar to arterial supply to the abdominal organs.

- **Celiac lymph nodes** are adjacent to celiac trunk. These group receive lymph from minor lymph nodes that located close to organs derived from foregut (figure 18):
  - **Gastric and gastro-omental lymph nodes** receive lymph from most parts of stomach
  - **Pancreatico-splenic lymph nodes** associate with splenic artery and receive lymph from spleen and pancreas
  - **Pyloric lymph nodes** receive lymph from pyloric part of stomach
  - **Pancreatic-duodenal lymph nodes** locate along curvature of duodenum and head of pancreas, and receive lymph from these two structures.
  - **Hepatic and cystic lymph nodes** receive lymph from liver and gallbladder, respectively.

- **Superior mesenteric lymph nodes**, which locate at the branching point of SMA from abdominal aorta (figure 18, 19). This group receive lymph drained from numerous **mesenteric and colic lymph nodes** that are located near to wall of small and large intestines.

- **Inferior mesenteric nodes**, which can be found near the branching point of IMA from abdominal aorta (figure 19). This group drains lymph from mesenteric and colic lymph nodes that locate near descending colon, sigmoid colon and superior part of rectum. It should be noted that lymph from the inferior part of rectum to superior 2/3 of anal canal are drained into internal iliac nodes, and the inferior 1/3 part of anal canal are drained into superficial inguinal nodes.

Lymph from these preaortic lymph nodes are drained toward upper body via **intestinal lymph trunks**, and finally drained into **cisterna chyli**, which is an enlarged sac of lymphatic vessel that can be identified just right to abdominal aorta at the level between L1/L2 vertebral bodies. From cisterna chyli, lymph are drained into thoracic duct in the posterior mediastinum.
Figure 18 Directions of lymphatic drainages from the upper GI tract and small intestine and locations of associated lymph nodes (Moore, Agur & Dalley, 2010).

Figure 19 Lymphatic drainages from colon and locations of mesenteric and colic lymph nodes (Moore, Agur & Dalley, 2010).
5. Innervation of the Gastrointestinal System

The motor system that controls activity of the abdominal viscerae is primarily the fibers from autonomic nervous system (ANS), which consists of sympathetic and parasympathetic divisions and fused together as autonomic plexuses. Sensory fibers from abdominal organs, mainly transmit pain and stretching sensations, are convey with sympathetic system and of particular importance in clinical symptomatology.

![Diagrammatic representation of autonomic and visceral afferent fibers innervating upper GI tract](Drake, Wayne & Mitchell, 2006).

Figure 20 Diagrammatic representation of autonomic and visceral afferent fibers innervating upper GI tract (Drake, Wayne & Mitchell, 2006).

5.1 Sympathetic division

The sympathetic fibers that innervate abdominal organs originated from preganglionic neurons in the spinal cord from level T7 to L2 or L3. From there, the preganglionic fibers are carried by spinal nerves and reach sympathetic ganglia, but without synapse with postganglionic neurons in these sympathetic ganglia. Instead, these fibers continue to synapse with postganglionic neurons in
prevertebral sympathetic ganglia via a group of splanchnic nerves. Finally, the postganglionic fibers fuse with other nerve fibers as a part of autonomic plexuses and then reach wall of GI tract and organs. In summary, the major components of sympathetic system in abdomen are the splanchnic nerves and the prevertebral sympathetic ganglia (figure 21, left).

The table 3 below summarizes the abdominal group of splanchnic nerves and their levels of origin, associated prevertebral sympathetic ganglia, and target organs.

<table>
<thead>
<tr>
<th>Splanchnic nerves</th>
<th>Level of sympathetic trunk originated</th>
<th>Prevertebral sympathetic ganglia</th>
<th>Target organs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greater splanchnic nerves</td>
<td>T5 – T9</td>
<td>Celiac ganglia</td>
<td>Foregut derivatives; stomach, duodenum, liver, gallbladder &amp; pancreas</td>
</tr>
<tr>
<td>Lesser splanchnic nerves</td>
<td>T10 – T11</td>
<td>Superior mesenteric &amp; aorticorenal ganglia</td>
<td>Midgut derivatives; jejunum to large intestine (to proximal 2/3 part of transverse colon)</td>
</tr>
<tr>
<td>Least splanchnic nerve</td>
<td>T12</td>
<td>Renal ganglia</td>
<td>Kidney</td>
</tr>
<tr>
<td>Lumbar splanchnic nerves</td>
<td>L1 – L3</td>
<td>Inferior mesenteric ganglia</td>
<td>Hindgut derivatives; distal 1/3 part of transverse colon to superior half of rectum</td>
</tr>
<tr>
<td>Sacral splanchnic nerves</td>
<td>S1 – S4</td>
<td>Ganglia in inferior hypogastric plexus (in pelvic cavity)</td>
<td>Inferior part of rectum and anal canal</td>
</tr>
</tbody>
</table>

5.2 Parasympathetic division

The parasympathetic fibers innervating abdominal organs are convey via two sources: the vagus nerve (CN. X), and the pelvic splanchnic nerve (figure 21, right).
- **Vagus nerve** is associated with esophagus as anterior and posterior vagal trunks, which both of them blend into autonomic plexuses surrounding abdominal aorta and supply the part of GI system derived from foregut and midgut.

- **Pelvic splanchnic nerves** is preganglionic fibers originated from neurons in S2 to S4 levels of spinal cord. After branching from pelvic spinal nerves, these parasympathetic fibers fuse into superior and inferior hypogastric plexuses, and innervate a part of GI tract derived from hindgut and other pelvic organs.

The preganglionic fibers, both from vagus nerve or pelvic splanchnic nerve, enter muscular layers of GI tract and synapse with postganglionic neurons inside these muscular layers.

![Diagram of autonomic nervous system innervating abdominal organs](image)

**Figure 21** Diagrams of autonomic nervous system innervating abdominal organs. Left panel is sympathetic division, and right panel is parasympathetic division (Schuenke, Schulte & Schumacher, 2006).

### 5.3 Abdominal autonomic plexuses

Autonomic plexuses of abdomen are networks of autonomic fibers surrounding abdominal aorta, thus sometimes called periarterial autonomic plexuses (figure 22). Inside these plexuses, prevertebral sympathetic ganglia can be found near the root of major arteries. The autonomic plexuses that contribute to innervation of GI system are:
- **Celiac plexus** around the root of the celiac trunk, and celiac ganglia can also be found in this area. This plexus receives sympathetic fibers from greater and lesser splanchnic nerves, and parasympathetic fibers from vagal trunks.
- **Superior mesenteric plexus** surrounds the root of SMA. This plexus receives sympathetic fibers from lesser, least and upper lumbar splanchnic nerves, and parasympathetic fibers from vagal trunks.
- **Inferior mesenteric plexus** surrounds the root of IMA. This plexus receives sympathetic fibers from lumbar splanchnic nerves, and parasympathetic fibers from pelvic splanchnic nerves. Usually this plexus is interconnected with superior mesenteric plexus by intermesenteric plexus.
- **Inferior hypogastric (pelvic) plexus** is places lateral to pelvic organs. This plexus receives sympathetic fibers from sacral splanchnic nerves, and parasympathetic fibers from pelvic splanchnic nerves.

![Figure 22 Locations of autonomic plexuses surrounding abdominal aorta (Drake, Wayne & Mitchell, 2006).](image)

### 5.4 Abdominal visceral sensory fibers and referred pain

The visceral sensory fibers from abdominal organs mainly convey pain and stretching sensations (such as bloating or tissue damage), and transmitted to central nervous system through autonomic fibers particularly sympathetic nerves. The characteristics of abdominal pain are dull and poorly localized, since sensory fibers can enter many spinal levels. However, the brain interprets visceral pain as it comes from dermatomes, thus patients can feel the visceral pain as it radiates through their dermatomes that related to levels of sensory fibers entering spinal cord. This phenomena is called **referred pain**, and very important in diagnosing abdominal conditions. The table 4 summarizes areas of referred pain from abdominal organs and related level of spinal cord.
### Table 4 Location of referred pain from abdominal organs and related spinal levels

<table>
<thead>
<tr>
<th>Origin</th>
<th>Referred pain site</th>
<th>Spinal cord level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stomach</td>
<td>Epigastric, left hypochondriac regions</td>
<td>T6-T9/T10</td>
</tr>
<tr>
<td>Duodenum</td>
<td>Epigastric region</td>
<td>T5-T9/T10</td>
</tr>
<tr>
<td>Head of pancreas</td>
<td>Inferior part of epigastric region</td>
<td>T8-T9</td>
</tr>
<tr>
<td>Jejunum and ileum</td>
<td>Paraumbilical region</td>
<td>T5-T9</td>
</tr>
<tr>
<td>Colon</td>
<td>Hypogastric region to left lower quadrant</td>
<td>T10-T12 (proximal)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L1-L3 (distal)</td>
</tr>
<tr>
<td>Appendix</td>
<td>Paraumbilical region to right lower quadrant</td>
<td>T10</td>
</tr>
<tr>
<td>Liver and gallbladder</td>
<td>Epigastric and right hypochondriac regions; may radiates to shoulder region due to diaphragmatic irritation</td>
<td>T6-T9</td>
</tr>
</tbody>
</table>

![Figure 23](image)  

Figure 23 Areas of referred pain from major abdominal organs that have clinical relevance (Moore, Agur & Dalley, 2011).
Reference


