Physiology of the Small Intestinal Motility and Secretion
(Lecture 5)

The small intestine

- It is divided into duodenum, jejunum and ileum.
- The intestinal mucosa has villi, microvilli and mucosal folds that increase the intestinal surface. Between the bases of the villi are found the intestinal glands (crypts of Lieberkuhn) which secrete intestinal juice (succus entericus). Brunner's glands are found in submucosa and their ducts open at the base of crypts.

The villi

❖ The C.T core of villi contains a central arteriole that breaks up into capillaries that connect to venules, lymph vessel (lacteal), nerve fibers, smooth muscle cells. The epithelial lining the villi includes:

1- Enterocytes which are digestive and absorptive columnar cells.
2- Mucous secreting goblet cells.
3- Few endocrine epithelial cells.

❖ The lining epithelial cells of the crypts include:

* Undifferentiated cells which migrate on to the villus and differentiate into enterocytes.
* Goblet cells.
* Epithelial endocrine cells.

❖ The enterocytes have microvilli which are covered by a layer of glycocalyx (polysaccharide and protein) that adsorbs pancreatic enzymes and place the final products of digestion in a proper position for absorption.

Types of potentials of smooth muscles of the small intestine

1- Basal electrical rhythm

2- Action potential spike

Types of intestinal motility

1- Migrating motor complex (MMC)

- It is bursts of depolarization accompanied by peristaltic contraction that begins in empty stomach during interdigestive period, travels a long whole length of small intestine to reach ileocaecal valve after 1.5-2 h. where it disappears. A new wave of MMC starts.
- The activity of MMC terminates as soon as food is ingested.
- The cycle of MMC consists of three phases:
  - * Phase I is characterized by absence of contraction.
  - * Phase II is characterized by irregular contraction.
  - * Phase III is characterized by a burst of regular large amplitude contraction.
- The function of MMC is to propel any remnants in stomach & small intestine into colon during the interdigestive period.

2- Segmenting (mixing) contraction

* They are ring-like contractions of circular muscle layer appearing at regular intervals along a length of small intestine.

* Soon they disappear and are replaced by another set of ring contractions, arranged such that the parts that were contracted become relaxed.

* They persist after extrinsic denervation, but disappear after destroying the intrinsic nerve plexus in small intestine.

3- Peristalsis

* Peristalsis consists of a travelling wave of contraction above the bolus preceded by relaxation at the bolus site and below. It is controlled by an intramural myenteric reflex.

* It usually travels in an oral-caudal direction
* A peristalsis wave travels at a rate which varies between 2-25 cm/sec.

4- Antiperistalsis

In the opposite direction occurs between stomach and duodenum to allow more time for neutralization of chyme and between ileum and caecum to allow time for absorption.

5- Peristaltic rush

- ♦ Powerful rapid peristalsis due to severe irritation of intestinal mucosa as in infectious diarrhea.
- ♦ It is initiated mainly by extrinsic nervous reflexes to brain stem and back to gut.
- ♦ It sweeps the contents of intestine into the colon and thereby relieving the small intestine of irritative chyme or excessive distension.

6- Movement of the villi

- ◙ The villous movement consists of fast shortening and slow lengthening as well as side to side movements.
- ◙ Villous contractions are initiated by local nervous reflexes in response to chyme in small intestine.
- ◙ They facilitate absorption and lymph flow from central lacteals into lymphatic system.
- ◙ They are stimulated by villikinin hormone released by intestinal mucosa when it comes in contact with digestive products.

Control of intestinal movements

1- Neural factors

* Vagal excitation increases intestinal and villous movements.
* Sympathetic excitation decreases intestinal and villous movements.

Gastroileal reflex is initiated by gastric distension. Impulses are conducted through myenteric plexus to initiate a fast peristaltic wave passing to the ileum. The ileocaecal valve relaxes allowing chyme to pass into caecum. This reflex is mediated by vagus nerve.

2- Hormonal factors

* Gastrin, CCK, insulin and serotonin stimulate intestinal motility. Gastrin and CCK relax ileocaecal sphincter.
* Secretin and glucagons inhibits intestinal motility and contract ileocaecal sphincter.
* Motilin secreted from duodenum stimulates intestinal motility and regulate MMC.
* Villikinin stimulates movement of the villi.

Intestinal secretion

* Brunner'glands in the duodenum between the pylorus and ampulla of vater secrete an alkaline fluid that contains mucus but no enzymes.
* Mucus protects the mucosa.
* Succus entericus

It is secreted from intestinal crypts

Volume: 1800 ml/day.

PH: 7.5-8. It participates in the neutralization of acid chyme delivered from stomach.

Composition: 0.6 % organic, 1 % inorganic substance.

Most of the enzymes are found either in the brush border or in the cytoplasm of the enterocytes. The enzymes that are actually secreted into the lumen are enteropeptidase and amylase

Digestion in the small intestine

1- Protein digestion

Complete protein digestion occurs in the intestine by:-

a. Aminopeptidases which split off terminal AA with free amino group. The resulting is a mixture of AA and oligopeptides.

b. Oligopeptidases which break down oligopeptides into free AA.

c. Intracellular di and tripeptidases which break di and tripeptides into AA.

2- Nucleotidases

Which split nucleotides into purine and pyrimidine bases, phosphoric acid and pentose sugar.

3- Lipid digestion

By lipase which splits TG into MG + FA.

4- CHO digestion

a. Maltase splits maltose into 2 glucose

b. Sucrase splits sucrose into glucose + fructose.

c. Lactase splits lactose into glucose and galactose.

5- Dietary fibers

Include cellulose are not digested by pancreatic or intestinal enzymes, they are metabolized by intestinal bacteria to short chain fatty acids and gases. This stimulates intestinal motility.

Control of intestinal secretion

1- Brunner's gland secretion is stimulated by secretin, tactile and vagal stimulation.

2- Intestinal juice secretion is stimulated by:

a. Distension, tactile and irritating stimuli.

b. Hormones as gastrin, secretin, CCK, glucagon, enterocrinin.

c. Sympathetic stimulation exerts an inhibitory effect.

Intestinal absorption

- The small intestine is the main site of absorption of nutrients.
- For a substance to be absorbed, it must traverse an unstirred water layer, a glycocalyx layer, the brush border, cytoplasm and the basal borders of the enterocytes and enters either a capillary into portal circulation or a lacteal into lymph, thoracic duct into systemic circulation.

1- Absorption of CHO

It mainly occurs in the upper intestine

A- Glucose and galactose

They are absorbed by 2ry active transport i.e. 2ry to the action of Na^+-K^+ ATPase. There is a membrane carrier protein in the brush border for cotransport of glucose (or galactose) and Na^+ to inside of cell where they are released. Glucose is further transported by facilitated diffusion across the basolateral membrane by another carrier.

B- Fructose

Transported by facilitated diffusion.

C- Pentose

Transported by passive diffusion and had slowest rate of absorption.

2- Absorption of proteins

It occurs in the upper intestine.

* D- AA are transported by passive diffusion.

* L- AA are transported by 2ry active transport.

* Di and tripeptides cross the brush border by active transport protein carrier. They are hydrolyzed by brush border and cytoplasmic oligopeptidases.

* AA leaves the cell at the basolateral membrane by facilitated transport.

3- Absorption of fats

It occurs mostly in the upper small intestine.

* Bile salts form micelles in which molecules are aggregated in such a way that water soluble hydrophilic polar groups are facing the outer side of the micelle, while fat soluble hydrophobic chains are facing the interior of the micelle.

Long chain FA, monoglycerides, cholesterol and fat soluble vitamins are incorporated into the interior of the micelle. In this way water insoluble compounds are made water soluble.

* The mixed micelle enters the unstirred water layer and makes contact with the brush border of enterocytes.

* Long chain FA, MG and cholesterol enter the enterocytes by passive diffusion.

* FA and MG are taken by the smooth endoplasmic reticulum and recombined to form new TG. They aggregate into globules along with the absorbed cholesterol and phospholipids.

* The phospholipids arrange themselves in these globules with the fatty portion toward the center and the polar portion located on the surface. This makes the globule soluble within the fluids of the cell.

* Small amount of B-lipoprotein coat part of the surface of each globule to form chylomicrons. It diffuses to side of the cell and is excreted by exocytosis into the central lacteal of villi, to lymph, then to thoracic duct.

* Short chain FA are absorbed directly into capillary blood of the villi to portal blood as they are more water soluble.

4- Absorption of vitamins

A- Absorption of fat soluble vitamins (A, D, E, K) is tied to that of fat. If fat absorption is deficient, absorption of fat soluble vitamins will be also defective.

B- Absorption of vitamin B_{12} (water soluble vitamin) requires the presence of intrinsic factor that stimulates endocytosis of vitamin B_{12}.

5- ***Absorption of water***

- Secretion from GIT add 7 L/day. Ingested water is 2 L/day. The net daily absorption in the small intestine is 8 L/day, and in the colon 1 l/day. The remainder (200 ml) is excreted in the stool.
- About 98 % of water entering the lumen of GIT each day is absorbed. Water moves freely in and out of the lumen of small intestine depending on the osmotic pressure of its contents.

6- ***Na^+ absorption***

Na+ in the lumen moves passively in either direction across intestinal epithelium following water movement depending on osmotic gradient.

The other part moves across the luminal border of the small intestine and colon along a concentration gradient created by Na^+ - K^+ ATPase at the basolateral membrane. Such actively absorbed Na^+ facilitates absorption of glucose, AA and short chain FA.

7- ***K^+ absorption***

K^+ moves across the intestinal epithelium by diffusion with a net movement occurs into the lumen (as it is electronegative). Small amount of K^+ is actively secreted into lumen as part of mucus.

8- ***Cl^- absorption***

Cl^- is actively absorbed in exchange for HCO^{-3} which tends to make lower intestinal contents alkaline.