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ELECTRIC ACTIVITY SPREADS IN THE COLONIC LONGITUDINAL BUT NOT THE CIRCULAR MUSCULATURE. ROLE IN COLONIC MOTILITY

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1. ABSTRACT

The colon has a circular and longitudinal muscle layers and possesses an electric activity. The current study investigated the spread of this electric activity in the colonic musculature. The tests were performed in 16 patients (mean age 40.6 ± 10.8 SD years, 10 men, 6 women) during operative correction of their incisional hernias in the anterior abdominal wall. Three electrodes were applied to the longitudinal muscle of the descending colon, and 3 to the circular muscle. The colonic pressure was monitored by a 10-F tube inserted per anus and connected to a pressure transducer. Electric waves in the form of pacesetter potentials (PPs) and action potentials (APs) were recorded from the longitudinal but not the circular muscle coat. The PPs and APs had the same frequency, amplitude and conduction velocity from the 3 electrodes of the same patient. The APs were associated with a rise of the intracolonic pressure. The results were reproducible in the individual subject. Being of the visceral type, the colonic smooth muscle fibers are controlled by non-nervous stimuli. Colonic motility is suggested to be effected by means of 2 mechanisms: the longitudinal muscle fibers activity through the action of the electric waves and the circular muscle fibers through the stretch reflex.

2. INTRODUCTION

The motor functions of the colon are varied and complex. The colon has 2 types of movements: mixing and propulsive (1). The mixing movement comprises combined contractions of the circular and longitudinal muscle layers. These contractions usually reach peak intensity in about 30 seconds and then disappear during the next 60 seconds (2). This movement provides a minor amount of forward propulsion of the colonic contents. The propulsive or mass movements start as a constrictive ring followed by contraction of a long segment distal to the constrictive ring. They occur 1 – 3 times each day, and effect the major part of forward propulsion.

Previous studies have demonstrated that the colon possesses an electric activity in the form of slow waves or pacesetter potentials (PPs) and fast activity spikes or action potentials (APs) (3-10). The latter are always associated with a rise of the intracolonic pressure. The waves' amplitude, frequency and conduction velocity increase upon increase of colonic distension (9,10). It is suggested that the APs are responsible for colonic motility. The function of the PPs is not exactly known. It is suggested that PPs initiate APs and pace the colonic contractile activity in terms of direction and frequency (9,10).

The colonic musculature consists of 2 layers: inner circular and outer longitudinal. The latter is aggregated into 3 longitudinal strips called the teniae coli. As aforementioned the colon possesses electric activity. The current communication studied the spread of the electric activity in the colonic musculature.

3. MATERIAL AND METHODS

3.1. Subjects

16 subjects were studied (mean age 40.6 ± 10.8 SD years, range 26–53, 10 men, 6 women) after giving an informed consent. We selected patients with a huge incisional hernia which followed cesarean section in 6 women, splenectomy in 3 men, vagotomy and pyloroplasty in 3 men, and cholecystectomy in 4 men. The subjects had no gastrointestinal complaint in the past or at the time of presentation. They had normal complete blood count,

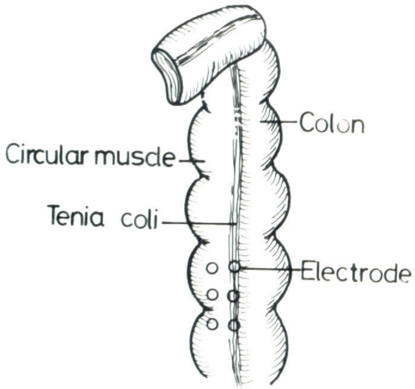

Figure 1. Sites of electrodes applied to the colon.

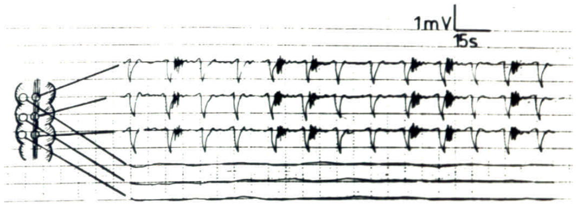

Figure 2. Pacesetter (PPs) and action potentials (APs) recorded from the 3 electrodes applied to the longitudinal muscle layer. No waves were recorded from electrodes applied to the circular muscle layer.

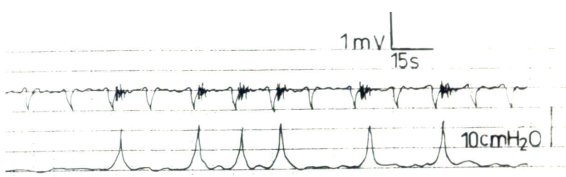

Figure 3. Electric activity (PPs and APs, upper tracing) and colonic pressure (lower tracing) showing pressure rise with action potentials and not with pacesetter potentials.

hepatic and renal function tests and barium enema studies. Our Faculty Review Board and Ethics Committee approved the study.

3.2. Methods

The tests were performed during operative repair of the incisional hernia. The anesthesia was general for all of the patients. The colon was exposed as a part of the operation. The electric activity of the descending colon was recorded by means of monopolar silver-silver chloride electrodes (Smith Kline Beckman, Los Angeles, CA). Each electrode had a diameter of 0.8 mm and was covered by an insulating vinyl sheath sparing its tip. The electrodes were serially fixed by electrode gel to the serosa of the descending colon at approximately its middle third. Three were applied over the tenia coli and another 3 over the circular muscle coat between 2 tenia coli (Figure 1). The distance between one electrode and the next was 3–4 cm. The electrodes were attached to a metal cannula containing a 6–pin socket. The insulated wire leads were attached to the pins in the cannula and connected to a Brush Mark 200 rectilinear pen recorder. The electric activity including the frequency, amplitude and velocity of conduction of the waves was recorded from the 6 electrodes.

The mechanical activity of the colon was simultaneously recorded together with the electric activity. The colonic pressure was measured by means of a 10-F tube with multiple side ports and a distal closed end. The tube was introduced through the anal orifice to lie in the descending colon at the site of electrodes' application to the descending colon. Its position in the colon was guided manually. The tube was connected to a pneumohydraulic capillary infusion system (Arndorfer Medical Specialties, Greendale, WI, USA). The pump delivered saline continually via the capillary tube at a rate of 0.6 ml / min. The transducer outputs were recorded on a rectilinear recorder (RS–3400, Gould Inc, Cincinnati, OH, USA). Occlusion of the recording orifice produced a rising pressure rate greater than 250 cm H_2O/s.

To ensure reproducibility, the measurements were repeated at least twice in the individual subject and the mean value was calculated. The results were analyzed statistically using the Student's t-test. Significance was ascribed to $p<0.05$ and values were given as mean ± standard deviation (SD).

4. RESULTS and DISCUSSION

The tests were completed in all the patients with no adverse effects.

4.1. Colonic pressure and electric activity.

The resting colonic pressure varied from 5–9 cm H_2O (mean 6.4 ±1.2). Electric waves were recorded from the 3 electrodes applied to the tenia coli while no waves were registered from those fixed to the circular muscle layer. The waves consisted of PPs and APs. The PPs had a triphasic configuration with a small positive, a large negative and another small positive deflection (Figure 2). Bursts of fast activity spikes or APs were recorded as negative deflections (Figure 2). They superimposed or followed the PPs randomly and had the same pattern from the 3 electrodes of the individual subject. The APs were associated with a rise of the intracolonic pressure, which recorded a mean value of 19.8±4.2 cm H_2O (range 16–22, Figure 3).

The PPs and APs had the same frequency, amplitude and conduction velocity from the 3 electrodes of the same individual (Figure 2). The mean frequency was 5.2±1.2 cycle/minute (cpm, range 4.5–6.8), amplitude 0.52±0.07 mV (range 0.42–0.76) and conduction velocity 5.1±1.1 cm/s (range 4.3–7.2). The PPs were not associated with increase of the colonic pressure.

During the operative time which ranged from 2–4 hours (mean 3.2±1.1), we could not record waves from electrodes applied to the colon overlying the circular muscle coat.

The aforementioned results were reproducible with no significant difference when the recordings and measurements were repeated in the individual subject.

Colonic motility is under neural, myogenic and hormonal control (11). It is modulated by a number of reflex pathways via the spinal cord and prevertebral ganglia (12-15). Intestinal contents are also responsible for inducing motility variations (16,17). The 2 muscle coats of the colon: circular and longitudinal are responsible for its contractile activity. This activity aims at propelling the colonic contents caudad and is presumably achieved by the combined contraction of the 2 layers of the colon.

The current study demonstrated the presence of electric activity in the longitudinal muscle layer and no activity in the circular one. The electric activity was associated with increase of intracolonic pressure. This is in accord with the results of other investigators (4,5,9,10). It was also demonstrated that these electric waves are myogenic, yet placed under neurogenic control (18,19).

4.2. Mechanism of colonic contraction

The mixing and propulsive colonic movements result from colonic muscle contraction (1,2). These contractions were evoked by the presence of colonic contents and this explains the role of intestinal contents in colonic motility (16,17). It appears that colonic distension by residual food bolus induces colonic contraction by 2 mechanisms: a) Increase of the electric activity induced by the longitudinal muscle, and b) stretch of the circular muscle fibers. The role of these 2 mechanisms in colonic contraction needs to be discussed.

Previous studies have demonstrated that colonic distension effects an increase of the colonic electric activity and pressure (4,5,9,10). The PPs and APs showed increased frequency, amplitude and conduction velocity. These variables increase with augmentation of the colonic distending volume (4,5,9,10). The rise of the colonic pressure associated with the colonic electric activity assumingly indicates contraction of the longitudinal musculature of the colon. Meanwhile, colonic distension by the residual food bolus stretches the circular muscle fibers and evokes the stretch reflex of Bayliss and Starling (20) with a resulting circular muscle contraction. Accordingly, colonic muscle contraction is suggested to occur by means of 2 different mechanisms: the longitudinal muscle fibers acting through the electric activity and the circular muscle fibers through the stretch reflex. These 2 actions share in the forward propulsion of the colonic contents.

The source of the colonic electric activity is not known. We speculate that the electric waves originate from a colonic pacemaker like the case in the stomach (21-23) and rectum (24-26).

4.3. Nervous control of colonic musculature

There are 2 types of smooth muscles: multi-unit and single-unit (27). The former is composed of discrete smooth muscle fibers. Each fiber operates entirely independently of the others and is often innervated by a single nerve ending as occurs for skeletal muscle fibers (27). Therefore their control is exerted mainly by a nerve signal. An example of this type are the smooth muscles of the eye. This is in contrast to the visceral smooth muscle, which is controlled by non-nervous stimuli.

The single-unit or visceral muscle consists of a whole mass of hundreds to millions of muscle fibers that contract together as a single unit (27). The fibers are aggregated into sheets or bundles and their cell membranes are adherent to each other at multiple points so that force generated in one muscle fiber can be transmitted to the next. Furthermore, the cell membranes are joined by many gap junctions so that ions can flow freely from one cell to the next. This syncytial smooth muscle is found in the viscera including the rectum.

It thus appears that the colonic muscle fibers are controlled by non-nervous stimuli. They seem to be stimulated by the electric waves evoked by a pacemaker and stretch by the intracolonic contents. We suggest that colonic distension by intracolonic contents evokes the stretch reflex in the circular muscle fibers and meanwhile augments the electric activity initiated in the longitudinal muscle fibers. The colonic motility could thus be considered as an auto-mechanism. What then could be the role of the enteric nervous plexus in colonic motility?

We do not know the exact role of the enteric nervous plexus in the colonic motility. This plexus seems to modulate the colonic motility in response to other stimuli. It appears that it transmits impulses to the colonic musculature from other organs such as the esophagus or stomach. It is involved in the reflex actions such as the esophago-rectal (28) or recto-anal inhibitory reflex (29,30).

In conclusion, the colonic motility is suggested to be effected by means of the electric activity of the longitudinal muscle fibers which is initiated by a possible colonic pacemaker and by means of stretch of the circular muscle fibers as mediated through the stretch reflex. The colonic musculature, being of the visceral type of smooth fibers, is controlled by non-nervous stimuli. The enteric nervous plexus is believed to effect colonic motility through reflex actions.

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