Demonstration of a physiologic sphincter at duodeno-jejunal junction

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1. ABSTRACT

Current evidence suggests that there are three sphincters that regulate the flow of chyme from stomach to the duodenum. We investigated the hypothesis whether a fourth 'physiologic sphincter' exists at the duodeno-jejunal junction. The pressure response of the jejunum, duodeno-jejunal junction and duodenum to individual balloon distension of the jejunum and duodenum was recorded in 28 healthy subjected before and after anesthesizing the jejunum, duodeno-jejunal junction and duodenum. The duodeno-jejunal junction length was measured by the station pull-through technique. Duodenal balloon distension with 2 and 4 ml of normal saline did not change the pressures in the duodenum, duodeno-jejunal junction or jejunum ($p>0.05$). Distension with 6 ml saline produced an increase of duodenum pressure ($p<0.01$), a decrease of duodeno-jejunal junction pressure ($p<0.01$), and no change in the pressure of the jejunum ($p>0.05$), the balloon was expelled to the jejunum. Eight, and 10 ml duodenum balloon distension produced pressure changes similar to those of the 6 ml distension ($p>0.05$). Jejunum balloon distension with 2 and 4 ml saline induced no jejunum, duodeno-jejunal junction or duodenum pressure changes ($p>0.05$). Six ml balloon distension effected increase of jejunum ($p<0.01$) and duodeno-jejunal junction ($p<0.05$) pressure, but no duodenum pressure changes ($p>0.05$). Jejunum balloon distension with volumes more than 6 ml produced pressure changes similar to the 6 ml distension. Distension of the anesthetized duodenum, duodeno-jejunal junction or jejunum did not change the duodeno-jejunal junction pressure. A high pressure zone of 1.6 ± 0.04cm length was detected at the duodeno-jejunal junction. Together, the findings show that a high pressure zone exists at the duodeno-jejunal junction suggesting that this region might act as a physiological sphincter.

2. INTRODUCTION

The duodenum extends from the pylorus to the duodeno-jejunal junction and receives the chyme from the stomach. In addition to the chyme, the duodenal content is comprised of duodenal mucosal secretions, pancreatic secretions which include lysolecithin and bicarbonate as well as bile which contains bile acids, pigments and bilirubin (4-6). The flow of chyme into the duodenum is regulated by physiologic antropyloric mechanisms comprised of three sphincters (1-3). The first sphincter is located at the distal end of the duodenal bulb and may be responsible for segmental achalasia and megabulb (7). A second sphincter exists proximal to the ampulla of Vater and a third sphincter so called, 'Ochsner muscle' is located below the ampulla of Vater (8-9). In addition to the gastroduodenal pyloric sphincter, it has been suggested that other sphincters might exist in the duodenum (7-9). The function of these sphincters is to delay the passage of the chyme from duodenum to insure the mixing of chyme with biliary and pancreatic secretions. However, the verification of these sphincters as anatomical structures is still debated (10). According to a second theory, the duodenal delay in chyme transmission might result from presence of a 'physiologic' and not an anatomical sphincter. Similar physiologic sphincters exist in the esophagus (11-17), in the gut, and at the rectosigmoid junction (18,19). In this report, we tested the hypothesis that a physiologic sphincter exists at the duodeno-jejunal junction.

3. MATERIAL and METHODS

3.1. Subjects

28 healthy subjects volunteered for the study after signing an informed written consent. Sixteen subjets were men and 12 women with a mean age of 36.6±6.3 SD years (range 29-44). The volunteers had no previous gastrointestinal complaint in the past or at the time of enrollment. Physical examination including neurologic assessment revealed no abnormality. The results of examination of the blood count, renal and kidney functions and electrocardiography were all unremarkable. The study was approved by the Internal Review Board (IRB) and Ethics Committee of the Cairo University Faculty of Medicine.

3.2. Methods

Each subject fasted for 12 hours. A condom was applied to the distal end of a Ryle stomach tube (8 French, Pharma Plast Inc AS/DK 3540, Lynge, Denmark) accommodating multiple lateral apertures. Each end of the condom was tied so as to fashion a high compliance balloon between the strings. A silver clip was applied to the distal end of the tube for radiologic control. A mechanical puller for automatic tube withdrawal (9021 H, Disa, Copenhagen) was used. The empty condom and tube were swallowed by the volunteers and, under radiologic control, the condom was directed to lie in the jejunum. The tube was connected to a strain gauge pressure transducer (Statham 220 B, Oxnard, CA, USA).

Simultaneous measurement of the pressure in the duodenum, duodeno-jejunal junction, and the jejunum was carried out by means of perfused open-ended tubes of 1 mm internal and 1.5 mm external diameter. One tube was introduced into each of the duodenum and duodeno-jejunal junction, and into the jejunum approximately 8 to 10 cm distal to the duodeno-jejunal junction. Each tube was connected to a Statham pressure transducer. The position of the tube was accurately determined by means of the barium meal performed prior to the pressure measurements and by fluoroscopic screening. For the latter, a silver clip had been applied to the distal end of each tube. The pressure recordings were performed 20 minutes after tube positioning to allow gut adaptation to the inserted tube.

Pressures at rest were recorded in the duodenum, duodeno-jejunal junction and jejunum. While still lying in the jejunum, the condom was filled with normal saline in increments of 2 ml and the pressure at the above sites was measured again. The condom was then emptied, pulled up to lie in the duodeno-jejunal junction and again filled with saline in increments of 2 ml and the pressure in the jejunum, duodeno-jejunal junction and duodenum was registered. The test was repeated after pulling the emptied condom to lie in each of the 4 parts of the duodenum.

The duodeno-jejunal junction length was measured by the station pull-through technique. The puller was adjusted to pull the tube into the jejunum at a rate of 10 cm/min. After placing the tube in the jejunum, the resting jejunal pressure was calculated. The tube was withdrawn by means of the automatic puller up to the duodenum, passing through the duodeno-jejunal junction. The pressure was recorded during tube withdrawal.

To ensure reproducibility of the results, each test was repeated at least twice in an individual subject, and the mean value was calculated.

3.3. The effect of DD-, DJJ- and JJ- anesthetization on the DJJ pressure

The effect of distension of the anesthetized duodenum on the duodeno-jejunal junction was determined. The duodenum was anesthetized by filling it with 50 ml of 2 percent of lidocaine, injected through the tube inserted into the duodenum. The duodeno-jejunal junction response to distension of the anesthetized duodenum was determined 20 minutes later and then after 2 hours when the anesthetic effect had waned. The test was repeated using normal saline instead of lidocaine. After 2 days, the duodeno-jejunal junction response to the anesthetized jejunum was recorded. The jejunum segment just distal to the duodeno-jejunal junction was anesthetized by means of an endoscopic injection of 2 ml of 2 percent of lidocaine, circumferentially injected at multiple sites in the jejunum segment where the balloon was distended. The duodeno-jejunal junction response to distension of the anesthetized jejunum was registered 20 minutes and 2 hours after lidocaine injection. The test was repeated using normal saline instead of lidocaine. Two days later, the response of the anesthetized or saline-injected duodeno-jejunal junction to separate duodenum and jejunum distension was tested as above mentioned. The duodeno-jejunal junction was anesthetized by endoscopic injection
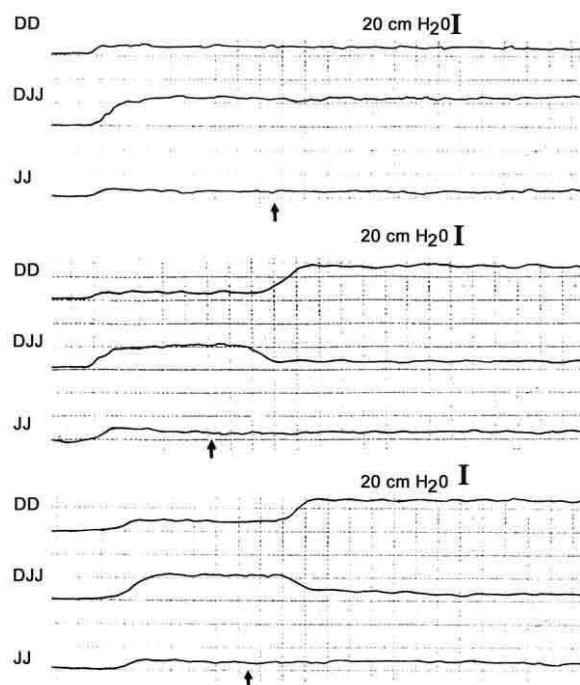
Figure 1. Response of the duodenal (DD), duodeno-jejunal junction (DJJ), and jejunal (JJ) pressures to A. 2 ml, B. 6 ml, and C. 10 ml duodenal balloon distension with saline. a: duodenal pressure, b) duodeno-jejunal junction pressure, c) jejunal pressure. ↑ = duodenal balloon distension
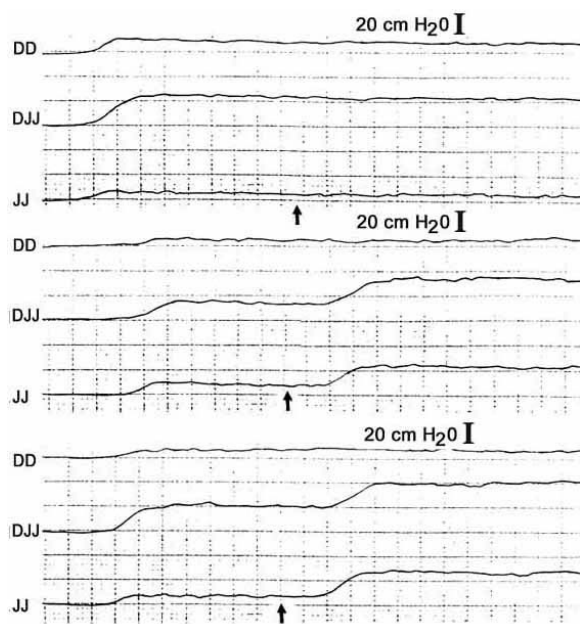

Figure 2. Response of the duodenal (DD), duodeno-jejunal junction (DJJ), and jejunal (JJ) pressure to A. 2 ml, B. 6 ml, and C. 10 ml, jejunal balloon distension with saline. a: duodenal pressure, b. duodeno-jejunal junction pressure, c. jejunal pressure. ↑ = duodenal balloon distension

of 2 ml of 2 percent of lidocaine circumferentially injected into the duodeno-jejunal junction.

To ensure reproducibility of the results, the recordings were repeated at least twice in the individual subject, and the mean value was calculated.

3.4. Statistical analysis

The results of the study were analyzed statistically using the Students t - test. Differences assumed significance at $p < 0.05$, and values were given as the mean ± standard deviation (SD).

4. RESULTS

No adverse side effects were encountered during or after performing the tests, and all the individuals were evaluated. The mean resting pressure in the duodenum was 8.3 ± 1.2 cmH$_2$O (range 7-11), in the duodeno-jejunal junction 19.6 ± 3.2 cmH$_2$O (range 16-23) and the jejunum 7.9 ± 1.2 cmH$_2$O (range 6-10) (Figure 1). The length of the duodeno-jejunal junction as measured by the pull through technique ranged from 1.4 -1.8 cm (mean 1.6 ± 0.04 SD).

4.1. Response of the DD, DJJ, and JJ pressures to DD distension

Duodenum balloon distension with 2 and 4 ml of saline did not effect significant changes in duodenum, duodeno-jejunal junction or jejunum pressures ($p > 0.05$, respectively, Figure 1, A), recording a mean of 7.8 ± 1.2, 19.2 ± 3.2, and 8.1 ± 1.2 cmH$_2$O, respectively. Meanwhile, 6 ml duodenum balloon distension produced a significant increase in duodenum pressure to a mean of 28.6 ± 6.3 cmH$_2$O (range 21-36, $p < 0.01$), a decrease of duodeno-jejunal junction pressure to a mean of 7.7 ± 1.2 cmH$_2$O (range 5-9, $p < 0.01$), and no significant change in the jejunum pressure ($p > 0.05$; Figure 1, B), and the balloon was dispelled to the jejunum. Duodenum balloon distension with 8 and 10 ml of saline produced pressure changes in the duodenum, duodeno-jejunal junction, and jejunum similar to those of the 6 ml distension ($p > 0.05$; Figure 1, C). We did not distend the jejunum with more than 10 ml for fear of duodenal injury. These results were obtained when the balloon was distended in the 1st, 2nd, 3rd, or 4th duodenal segment with no significant difference ($p > 0.05$).

4.2. Response of the JJ, DJJ and DD pressures to JJ distension

Two and 4 ml jejunum balloon distension with saline effected no significant change in the jejunum, duodeno-jejunal junction, or duodenum pressures ($p > 0.05$, respectively, Figure 2, A). Six ml jejunum balloon distension produced a significant increase in jejunum and duodeno-jejunal junction pressures, recording a mean of 22.7 ± 4.2 cmH$_2$O (range 18-27, $p < 0.01$), and 36.4 ± 7.6 cmH$_2$O (range 28-48, $p < 0.05$, respectively; Figure 2, B). The duodenum pressure exhibited no significant change ($p > 0.05$). Jejunum balloon distension with 8 and 10 ml of saline produced pressure changes in the duodenum, duodeno-jejunal junction and jejunum similar to those produced by the 6 ml balloon distension ($p > 0.05$; Figure 2, C).

4.3. Response of the DJJ pressure to distension of the anesthetized DD and JJ

Twenty minutes after either of the duodenum or jejunum had been anesthetized, balloon distension of each with up to 10 ml of normal saline resulted in no significant pressure changes in the duodeno-jejunal junction (p>0.05). Two hours later when the anesthetic effect had waned, duodenum or jejunum balloon distension effected duodeno-jejunal junction pressure responses similar to those prior to anesthetization (p>0.05). Similarly, duodenum or jejunum balloon distension during duodeno-jejunal junction anesthetization produced no significant duodeno-jejunal junction pressure changes (p>0.05) after 20 minutes of anesthesia, but changes similar to those before anesthesia were obtained after 2 hours (p>0.05). Distension of the saline-injected duodenum or jejunum induced a duodeno-jejunal junction pressure response similar to that induced without using saline (p>0.05). Furthermore, duodenum or jejunum balloon distension while the duodeno-jejunal junction was saline-injected produced the same responses as those without saline-injection (p>0.05).

When the aforementioned tests were repeated at least twice in the same subject, reproducible results were obtained with no significant difference (p>0.05).

5. DISCUSSION

The current study demonstrates the presence of a high pressure zone at the duodeno-jejunal junction. This zone, which has a mean length of 1.6 cm, is located between two lower pressure zones: the duodenum proximally and the jejunum distally. This segment of the gut appears to act as a 'physiologic sphincter' and delays the passage of chyme from the duodenum to the jejunum. Such an action is consistent with the delay in chyme flow as reported by other investigators (7-9). However, the slowing of the flow of the chyme might also be attributed to the C-shape of the duodenum and the acute angle created at the duodeno-jejunal junction.

The content of the stomach is delivered to the duodenum in jets due to the intermittent pyloric opening (20). This content is accumulated in the duodenum until a certain volume is reached. Distention of the duodenum ultimately leads to its contraction allowing the its content to flow into the jejunum. The small volume of the duodenal balloon used in this study does not cause the distension or leads to elevation of the duodenal pressure. It seems that when chyme, as represented by the distended balloon, collects into the duodenum and attains an appreciable volume, the duodenum contracts as evidenced by increase of the duodenal pressure. Such an increase in pressure then causes the chyme to be expelled to the jejunum.

The presumed physiologic sphincter at the duodeno-jejunal junction regulates the flow of chyme from the duodenum to the jejunum and retards passage of the duodenal contents from duodenum. Such a delay might be necessary for mixing of the chyme with the duodenal, biliary, and pancreatic secretions. The study has demonstrated that, when a certain volume is attained, the duodeno-jejunal junction pressure drops allowing the duodenal content to flow to the jejunum. At the same time, the duodeno-jejunal junction pressure is increased upon jejunal distension. Such an action might be necessary to prevent reflux into duodenum. The duodenojejunal junction pressure response to duodenum or jejunum pressure rise suggests that a physiologic sphincter exists at the duodeno-jejunal junction. The opening of the duodeno-jejunal junction might be mediated by a 'duodeno-jejunal junction inhibitory reflex', and its closure might be mediated by a second 'duodeno-jejunal junction excitatory reflex'. Further investigations are needed to validate presence of such reflexes and demonstrate their functional significance.

6. ACKNOWLEDGMENT

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