Aging and Neural Control of the GI Tract
IV. Clinical and physiological aspects of gastrointestinal motility and aging

WILLIAM C. ORR1 AND C. L. CHEN2

1Lynn Health Science Institute, Oklahoma City, Oklahoma 73112; and 2Buddhist Tzu Chi Medical School and Hospital, Hualien, 970, Taiwan

Orr, William C., and C. L. Chen. Aging and Neural Control of the GI Tract. IV. Clinical and physiological aspects of gastrointestinal motility and aging. Am J Physiol Gastrointest Liver Physiol 283: G1226–G1231, 2002; 10.1152/ajpgi.00276.2002.—The gastrointestinal motility changes that occur as a function of age are reviewed herein. Careful attention must be given in any review of aging phenomena to exclude, or at least be cognizant of, the many comorbid conditions that can alter physiological functioning in older adults. The dramatic increase in life expectancy over the past 10–15 years demands that clinicians be aware of the various physiological and clinically relevant changes that occur with age. Gastrointestinal motility changes associated with age are relatively subtle, and in many instances only conflicting data exist. As the older adult population increases, and as the control of disease is improved, much more work needs to be done to understand the true effects of aging on gastrointestinal functioning.

gastroesophageal reflux disease; dysphagia; lower esophageal sphincter; incontinence

LIFE EXPECTANCY HAS INCREASED dramatically over the past 10–15 years, and the population of individuals over 65 yr old is expected to more than double by the year 2050. The projected rise in the number of Americans over the age of 85 yr is expected to increase from 4 to 18 million over a similar interval of time. As life span increases, the probability increases that individuals will acquire chronic and debilitating diseases such as osteoarthritis, Parkinson’s disease, and other neurological conditions, and the risk of stroke and its debilitating sequelae is also increased. These conditions are all associated with gastrointestinal (GI) complications, particularly those related to the esophagus and swallowing. Thus age-related changes in GI functioning can be categorized in terms of those associated with these comorbid conditions of aging or those associated with the aging process itself.

Relatively little work has been done to describe the GI changes associated with aging, largely due to the invasive nature of the procedures required. Thus in many instances there is a dearth of normative data on which to base clinical comparisons. For example, very little work has been done to describe normal colonic functioning, and only a few studies have been published that described normative parameters of esophageal peristalsis and lower esophageal sphincter (LES) functioning. Similar limitations apply to gastric and small bowel functioning. Studies that have been done commonly reveal conflicting results due to differences in the technology used (i.e., manometric vs. radiographic). In addition, the manometric techniques that are used vary considerably, with only the more recent studies using intraluminal solid-state transducers, which allow a much more sophisticated assessment of pressure changes compared with those that were acquired or described using more conventional and commonly applied perfusion pressure technology. These issues preclude definitive statements regarding GI functioning in older adults, and the data presented here should be interpreted with caution, realizing that improvements in technology and medical care will ultimately result in a much better understanding not only of GI changes associated with aging itself but also of changes associated with the various comorbid disorders that affect GI functioning in older adults.

This brief review will focus not only on physiological changes but also on associated symptoms in older adults such as dysphagia, chronic constipation, and fecal incontinence. This is not intended to be an exhaustive review of the literature but rather a starting point from which one can assess the current status of GI motility changes associated with the aging process. The reader is also referred to an excellent similar recent review by Firth and Prather (9).
ESOPHAGEAL MOTILITY

Dysphagia is a common complaint, especially among older adults. Oropharyngeal dysphagia clearly increases in the adult population and has been noted to occur in ~50% of nursing home residents, resulting in a high frequency of aspiration pneumonia (5). Oropharyngeal dysphagia can result directly from subtle changes in upper esophageal sphincter (UES) functioning particularly associated with aging, but more commonly this symptom is associated with alterations in pharyngeal and UES functioning associated with neuromuscular disorders or central nervous system diseases such as stroke, Parkinson’s disease, or multiple sclerosis. Zenker’s diverticulum and cervical osteophytes are conditions that uniquely produce oropharyngeal symptoms in older adults. Perhaps the more common of these is the Zenker’s diverticulum, which is an out-pouching in the posterior pharyngeal wall immediately above the UES. These can become quite large in some individuals and are capable of retaining food, causing patients to experience symptoms of cough, fullness, and gurgling in the neck region and the much more serious complication of pulmonary aspiration. The UES functions as a primary barrier to the aspiration of refluxed gastric contents and is composed primarily of the cricopharyngeus muscle, which is a skeletal muscle, producing a relatively high pressure in this area (60–80 mmHg). Because it is a skeletal muscle, events associated with swallowing are very rapid and difficult to measure with most conventional manometric techniques. As a result, the most accurate means of assessing pharyngeal and UES functioning have been described in older adults. These are unlikely to be clinically significant, and they are nicely described in detail in a review by Shaker and Staff (24).

Manometric studies must be used to detect pressure, and there are two studies that document that UES pressure is significantly diminished in older adults. A study by Fulp and colleagues (10) shows a correlation of .54 between age and UES pressure in an age range from 24 to 79 years. Shaker et al. (23) did not find any alteration in pharyngeal or UES functioning in older adults. On the other hand, the study by Fulp and colleagues (10) also described a somewhat delayed UES relaxation relative to the pharyngeal peak in older adults. It has also been documented that the efficiency of pharyngeal clearance during swallowing was somewhat impaired, which would increase the exposure time of the glottis to the swallowed bolus. This could result in a higher risk of pulmonary aspiration in older adults, but in the Shaker et al. study (23), pharyngeal peristaltic waves and the UES pressure response to esophageal distention by air were preserved. Thus the clinical significance of these findings remains unclear. In a particularly interesting and significant study, Aviv et al. (3) have shown that, as the aging process continues, sensory discrimination in the oral cavity progressively diminishes, which would be consistent with complaints of dysphagia and aspiration. They have demonstrated progressive diminution in pharyngeal and supraglottic sensitivity in older adults, which they suggest is a contributing factor to the development of dysphagia and aspiration in this population. Results of this study are particularly provocative since it focuses on sensory functioning, as opposed to motor functioning, as a major cause of oropharyngeal symptoms in older adults.

Esophageal dysphagia, as opposed to oral pharyngeal dysphagia, in older adults has been commonly attributed to what is referred to as “presbyesophagus”; that is, disorders that are due to endogenous changes in esophageal function with aging. With the advent of more sophisticated technology to measure the parameters of esophageal peristalsis (i.e., amplitude, duration, and transit time), the mythology associated with the existence of presbyesophagus has largely disappeared. Most recent studies seem to indicate that the frequency of abnormal esophageal motility is no greater in older adult populations, with the possible exception of individuals over 70 yr of age. In this age group, there are data to indicate that there may be a decrease in the amplitude of esophageal contractions and “defective” peristalsis. It appears that cells of the esophageal enteric nervous system diminish with age, and this could explain the diminished strength of peristaltic contractions noted in studies of esophageal motility in older adults. Again, the clinical significance of these findings remains unclear.

Dysphagia is a common complaint in any age group, but it is estimated to occur in up to 10% of individuals over 50 yr of age (24). The complaint of dysphagia does require physiological investigation to determine the cause, and it is not a condition generally treated symptomatically. Due to the numerous comorbid conditions that can cause dysphagia in older adults, this complaint is somewhat more problematic in this patient population. In general, there are no data that would indicate that dysphagia is, in and of itself, a complaint associated with aging alone. Primary esophageal motility disorders associated with clinical complaints of dysphagia would include achalasia, diffuse esophageal spasm, “nutcracker” esophagus, and other nonspecific esophageal motor disorders, which would include primarily ineffective peristalsis (peristaltic amplitudes <40 mmHg). Although achalasia is usually encountered in patients between the ages of 20 and 40 yr, a secondary peak appears to occur in older adults (5). Classic symptoms associated with this condition are dysphagia, regurgitation, weight loss, and, to a lesser extent, chest pain. Manometric patterns that generally accompany, and help to diagnose, this condition are marked increase in the LES pressure, impaired relaxation of the LES with swallows, and a primary motor disorder in the body of the esophagus (usually aperistalsis).

Medication-induced esophageal injury is perhaps the most common cause of esophageal disorders in older adults. The diagnosis of medication-induced esophagi-
geal injury is generally obtained from a history of acute onset of substernal pain, odynophagia, or dysphagia in a patient taking one of the drugs commonly implicated in this disorder. The most common of these are tetracycline, quinidine, alendronate, NSAIDs, and potassium chloride. Diagnosis is generally obtained by barium swallow and/or endoscopy. Barium swallow can identify esophageal lesions and provides information about the possible existence of extrinsic esophageal compression. Subsequent endoscopy can confirm the diagnosis. Lesions may vary from some erythema to an ulcer or definite stricture. These injuries are generally self-limiting but occasionally may produce more serious esophageal injuries such as a stricture (5).

As noted previously, methodology has a substantial impact on results of previous studies. For example, radiographic and manometric studies do not always agree, and manometric studies using outdated infusion technology would not produce results that more recent studies would be capable of determining. For example, radiographic studies have shown abnormalities in older adults with regard to esophageal functioning and have identified the retrograde “escape” of barium more commonly in older adults. In a study by Kahrilas and colleagues (13), this escape phenomenon was generally associated with peristaltic amplitudes <40 mmHg, which can only be determined via manometry. In one of the few studies conducted in which a within-group assessment was accomplished, Kruse-Anderson and colleagues (14) studied a group of individuals over a median interval of time of eight years with regard to their esophageal functioning. No differences were noted in the LES pressure or acid-clearing parameters. In a study by Adamek and colleagues (1), distinguished by the fact that it used modern solid-state technology and ambulatory monitoring conditions, no significant differences were noted in esophageal function in younger vs. older adult populations. Of interest here is the fact that the older adult population had an average age of only 62 yr.

It would appear from other studies in which the population was somewhat older (>70 yr) that some minor but statistically significant differences were found. Thus the age of the older adult population also appears to be a significant variable to add to investigative variables that should be considered in the evaluation of studies in older adults. In a particularly interesting study using a much older population (mean age 74 yr), Ren and colleagues (21) showed a distinct deficiency in the older adult population with regard to their ability to generate secondary peristaltic contractions in response to esophageal distention.

In summary, data with regard to the intrinsic changes in esophageal function with aging remain conflicting. At best, it would appear that there are subtle alterations in esophageal function, namely diminished peristaltic amplitude and deficiencies in the ability to generate secondary peristaltic contractions. Some sensory deficits have been noted in oropharyngeal functioning, and decreased UES pressure has also been documented. The clinical significance of these changes is most likely relatively minor. However, the fact that aging is associated with a variety of comorbid conditions that clearly affect esophageal functioning cannot and should not be ignored by the perspicacious clinician.

GASTROESOPHAGEAL REFLUX DISEASE

Although there are data to suggest that heartburn is a more common symptom in older adults, other studies that have investigated heartburn prevalence as a function of age have not noted an increased incidence in older adults. In a population survey by Raiha and colleagues (19), reflux symptoms in general were not noted to be more prevalent with age, but their subjects ranged from 65 to 85 yr of age. There was not a younger control group. Other studies (14) have addressed this issue and have not shown significant differences in reflux or esophageal acid defense mechanisms in the older group. However, it should be noted that these studies were not accomplished in individuals who would, by today’s standards, be regarded as “older adults.” A study that used modern technology in a group that would be considered older was performed by Smout and colleagues (25), in which they addressed the percentage of time the pH was <4 in a group of individuals ranging in age from 45 to 73 yr (mean 61 yr). They clearly noted a strong relationship between advancing age and esophageal acid contact time. In assessing the pathophysiology of this finding, the mechanisms of reflux and esophageal acid clearance need to be examined. These would include a hiatal hernia, LES functioning, salivation, and esophageal peristalsis.

There is a general assumption that the presence of a hiatal hernia does increase with age, but there are not a large number of studies to document this (5). With regard to functioning of the LES, it is now widely accepted that the main dysfunction associated with the LES as it relates to reflux is the occurrence of the transient LES relaxation. No studies document the occurrence of transient LES relaxation responses in older adults, although at least one study did not document any difference in resting LES pressure (14). The documentation of diminished peristaltic amplitudes in aging could be of clinical significance depending on the decrease in pressure. For example, if, as is commonly noted in patients with gastroesophageal reflux disease, peristaltic amplitudes are particularly weak (ineffective peristalsis), this would very likely compromise swallowing and esophageal acid clearance. Add to this a slight decrease in salivary flow and these alterations associated with aging could certainly account for prolonged esophageal acid contact time. These physiological changes could offer an explanation for the observation that older adults do appear to have more severe manifestations of gastroesophageal reflux disease (6).

In summary, then, it would appear that in adults older than 50 yr old, there is an increased incidence in reflux and esophageal acid contact time. This is very likely due to a combination of increased incidence of
hiatal hernia, diminished peristaltic amplitudes, and reduced salivary response to esophageal acid contact.

GASTRIC AND SMALL BOWEL MOTILITY

The major physiological functions of the stomach are to receive ingested food and to mix and triturate gastric contents into nutrients and suspensions suitable for emptying into the duodenum and small intestine. Increasing prevalence of coexisting diseases and medication with age make studies on healthy individuals beyond the seventh decade of life difficult. It has been reported that gastric emptying of liquids or a mixed meal is delayed in elderly patients (7). Some have suggested that this may be limited to the liquid phase only. Fich et al. (8) have observed that age did not alter fasting and postprandial antral motility, which is believed to play an important role in the emptying of solid food. Conversely, fundic activity may be affected by age, which may account for a disturbance in liquid emptying (7).

Small intestinal motility is necessary for appropriate digestion and absorption of nutrients and also for the clearance of cell debris, secretions, and undigested materials during fasting. During fasting, there is a sequence of motor events referred to as the migrating motor complex (MMC). This is composed of three sequences termed **phases I–III**. **Phase I** is a period of silence and inactivity of the small bowel; this is followed by the irregular patterns of **phase II**, and subsequently there is an aborally migrating sequence of phasic contractions. This MMC serves as a “housekeeper” for the gut. Meals induce irregular contractions for a considerable period of time postprandially, and the quiescent phase (**phase I**) begins after the meal activity has subsided. Age-related changes have been documented, but not until the eighth or ninth decade of life (4). Patterns of small bowel motility in older adults have been documented via ambulatory manometry monitoring by Husebye and Engedahl (11). MMC was present in all subjects, with **phase III** activity occurring at normal intervals. Velocity of the MMCs appeared to be prolonged compared with those in healthy young adults. This confirms the presence and persistence of the MMC in the very late stages of life. The authors note that the changes in the older adults are well within the range of normality and certainly not of clinical relevance. Thus intestinal abnormalities such as malabsorption and bacterial overgrowth cannot be attributed to age-related motility changes in the small bowel.

The control of the propagation of **phase III** motor activity is mainly attributed to intrinsic neural pathways. Animal studies on aging of the enteric nervous system have shown substantial decrease in the number of neurons in the myenteric plexus, a decreased responsiveness of cholinergic receptors in the isolated ileum, and a dramatic reduction in nonadrenergic innervation of the myenteric plexus in the proximal jejunum. Therefore, a reduced propagation velocity may reflect the combined effect of age-related alteration in neurons, receptors, and cell messengers of the enteric nervous system.

Effects of aging on the motor function of the gut are most apparent in the interface regions of the gut, especially those possessing both smooth and skeletal muscle. Overall, these observations suggest that the motor function of gut smooth muscle remains largely unimpaired, probably reflecting remarkable plasticity in the control of motility. The plasticity and reserved capacity of the enteric nervous system may compensate for degenerative processes due to aging. A decrease in the number of myenteric plexus nerve cells and any motility dysfunction would appear only after exhaustion of this reservoir of neuronal functioning.

COLONIC MOTILITY AND CONSTIPATION

It has been commonly assumed that complaints of chronic constipation, as well as alterations in colonic motor functioning, are a natural consequence of aging (26). For example, in a study by Stewart and colleagues (26) of over 3,000 individuals, 26% of women and 16% of men reported recurrent constipation. They reported increasing constipation with age beyond 65 yr, and the most important variables associated with constipation were age, female sex, total number of drugs taken, abdominal pain, and hemorrhoids. Respondents with hemorrhoids or diverticulosis were more than twice as likely to report constipation. However, research to date is not convincing with regard to the veracity of these findings. There are two persistent problems plaguing research in these areas, to wit: the definition of constipation and the unreliability of recall reports of bowel function. Although the actual percentage of older adults complaining of constipation may be somewhat elevated, the percentage of individuals who actually have infrequent defecation is relatively low. In a survey of 497 individuals from 72 to 90 yr of age, Milne and Williamson (17) found that only 2% of men and 7% of women reported defecation less frequently than every third day, which is a common definition of constipation. In another study by Whitehead and colleagues (27), they noted that <3% of men and <2% of women reported fewer than three bowel movements per week. The primary symptom used to define constipation in this population was straining to defecate. The number of psychological symptoms are also correlated positively with self reports of constipation in both men and women. Similarly, in a study conducted in our laboratory, a subsample of individuals from a group indicating that they had fewer than three bowel movements per week was asked to keep a bowel log for 2 wk. In this subset of individuals, the average number of bowel movements per week was over seven (18).

The actual documentation of abnormalities in colonic function in older adults is difficult to obtain. Numerous studies have assessed sigmoid functioning and colonic transit, and there is very little evidence of any alteration in these measures in older adults. Perhaps the most consistent physiological findings pertain to decreased rectal compliance and an increase in the sen-
sory threshold for an urge to defecate. A large, relatively noncompliant rectum would certainly be consistent with an infrequent urge to defecate, and the presence of stool in the rectum for lengthy periods of time (due to a poor sensation of an urge to defecate) would also be consistent with a presence of straining at stool and hard pellet-like stools.

The assessment of colorectal functioning and the attendant symptoms associated with colonic dysfunction, constipation, and straining remain problematic and await further, more sophisticated investigations into the difficult arena of colonic physiology. Present data do not clearly implicate abnormalities in colonic motility in older adults, but chronic constipation does appear to be associated more frequently with abnormalities of rectal dysfunction and perhaps afferent sensory mechanisms. Whether these abnormalities are due to inherent physiological changes associated with aging or are secondary to chronic bowel habits such as straining at stool await further elucidation.

**ANORECTAL FUNCTIONING AND FECAL INCONTINENCE**

Relatively few studies in the literature address issues of anorectal functioning in healthy older adults. As is the case with the evaluation of GI motility in this population, the results are conflicting due to differences in methodology as well as the number and composition of elderly subjects. The bulk of evidence would support the presence of a decrease in both resting and squeeze pressures in the anal canal. In a study by McHugh and Diamant (16), 157 healthy volunteers ranging in age from 20 to 89 yr were evaluated, with 74 subjects over the age of 50 yr. This is perhaps the most comprehensive study that has been accomplished, and it shows a clear decline in both resting and anal canal squeeze pressures with age. The rate of decline in rectal filling pressure was more obvious in females, but it was surprisingly not related to parity. Similar results have been reported by Akervall and colleagues (2). There are conflicting data with regard to whether or not there is a loss of rectal sensation with aging. In a study by Loening-Baucke and Anuras (15) and in another study by Read and colleagues (20) using rectal infusion of saline until the first sensation and the first leak occur, no differences were found in older adults with regard to sensory functioning (15, 20). However, it has been noted that the threshold sensation for rectal filling does increase with age (2). Again, age-dependent changes appear to be largely influenced by the variables measured and the methodologies used. For example, the sensation of rectal distention is influenced by the rate of volume distention and whether air or water is used as the distending vehicle. This issue remains controversial, but certainly diminished sensation in older adults would predispose to problems such as fecal incontinence and chronic constipation.

It appears that older women do have a significantly greater degree of perineal descent both at resting and on straining, and this in combination with a weak sphincter may lead to anterior rectal mucosal prolapse. This does not appear to particularly impair defecation, but it may predispose to greater straining and result in damage to the innervation of the pelvic floor. McHugh and Diamant (16) have also pointed out the difficulty of establishing “normal” values of anorectal functioning, especially in older adults, due to the substantial variation in pressures and the difficulty in correlating these with clinical phenomena such as constipation and/or incontinence. For example, they point out that in their study 43% of a group of incontinent patients had normal values for both resting and squeeze pressures. Furthermore, 28% of the individuals with a resting anal canal pressure in the normal range had resting pressures that would be considered “at risk” for incontinence.

Anorectal dysfunction is commonly noted in patients with fecal incontinence, and this is a very common problem in older adults. Estimates of the prevalence of incontinence in the older adult population vary widely, but clearly this is substantially more common in older adults (12). It is a common cause of institutionalization and is a particularly bothersome and costly symptom in nursing homes. The prevalence of fecal incontinence in institutionalized older adults has been estimated between 30 and 60% (22). It is likely that the aforementioned alterations in anal functioning and the reported deficits in the ability of these patients to detect rectal filling would contribute substantially to the development of anorectal incontinence in older adults.

**SUMMARY AND CONCLUSIONS**

Identifying GI motility changes that occur exclusively as a function of aging, independent of comorbid conditions, has proven to be a difficult task. The common occurrence of comorbid conditions renders the available population small, and the invasive character of most studies evaluating GI motility also creates limitations in recruiting volunteers to particulate in such studies. Add to this the issues of different methodologies and techniques used to assess GI motility, and the numerous studies with conflicting results are not surprising. It would seem reasonable to conclude that there are major sphincteric changes in aging related to decreases in the UES and sphincteric protective reflexes, alteration in LES functioning, and anal canal pressures. In addition, sensory functioning and visceral perception remains an important, but often overlooked, component of GI functioning that appears to be significantly diminished with age.

**REFERENCES**

3. Aviv JE, Martin JH, Jones ME, Woo TA, Diamond B, Keen MS, and Blitzer A. Age-related changes in pharyngeal and...