Modulation of Esophageal Peristalsis by Alterations of Body Position
Effect of Bolus Viscosity

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Previous studies have demonstrated that nonviscous liquids traverse the esophagus more rapidly with the subject in the upright rather than the supine position. Conversely, similar studies have shown that viscous liquids traverse the esophagus at similar rates for both upright and supine positions. Our purpose was to define the motor correlates of these differing responses. Six normal volunteers were studied with an infused catheter system incorporating a Dent sleeve for monitoring lower esophageal sphincter pressure. The subjects were given a series of swallows of a water and a viscous (52 centipoise) bolus in both the supine and upright positions. In the upright position, the water bolus caused an increased velocity of propagation in the proximal esophageal segment that was associated with a shortening of lower esophageal sphincter relaxation time and reductions in amplitude and duration of contraction. No significant changes in the peristaltic wave were noted with the viscous bolus during alterations of body position. We conclude that the more rapid transit of a nonviscous water bolus through the esophagus in the upright position is reflected in specific alterations of esophageal peristaltic parameters. The possible mechanisms for these differing responses are discussed.

KEY WORDS: body position; bolus viscosity; propagation velocity; smooth muscle mechanics.

The characteristic feature of esophageal motor activity is a peristaltic contraction that passes in an orderly sequence from the upper esophageal sphincter (UES) at one end to the lower esophageal sphincter (LES) at the other. This chain of events is presumed to lead to the transport of ingested food and saliva to the stomach. The quantitative features of this motor event are not constant, however, being influenced significantly by a number of extraneous variables. Thus, the interval between swallows (1-3) and the level of intraabdominal pressure (4) may grossly alter the peristaltic wave. In addition, certain bolus attributes, such as volume (2, 5) and temperature (6, 7), also may modulate esophageal motor activity.

Bolus viscosity has been shown in a number of radiologic studies to influence the transit of liquid boluses through the esophagus. Boluses of high viscosity traverse the esophagus at a much slower rate than nonviscous boluses (8-10). We have recently correlated these early reports of esophageal transit of viscous liquids with specific alterations in esophageal peristaltic parameters (11), demonstrating a reduction in peristaltic wave velocity and increases in the durations of peristaltic contractions and LES relaxation.

Additionally, the previous studies (8-10) have assessed the effect of alterations in body position on
esophageal transit of different liquid boluses. Non-viscous boluses traverse the esophagus more rapidly when the subject under study is in the upright position as compared to the supine. Conversely, viscous boluses show no alteration of transit time with changes of body position. It is our purpose, in this study, to determine if these alterations in esophageal transit, induced by differing body positions, are reflected in specific changes of esophageal peristaltic parameters.

**MATERIALS AND METHODS**

**Subjects.** Six normal male volunteers without any evidence of gastrointestinal and esophageal disease were included in this study. Their ages ranged from 30 to 51 years (mean 38 years) and all subjects gave fully informed consent under a protocol approved by this institution's research committee. These subjects had taken part in a previous study that documented the effects of bolus viscosity in esophageal motor function (11). The current study was performed independently of the first.

**Esophageal Manometry.** Esophageal manometry was performed with a six-lumen manometric assembly that had four esophageal body recording sites radially oriented, a 6-cm sleeve (Dent) device for continuous recording of lower esophageal sphincter pressure, and a gastric side-hole recording site at the distal end of the sleeve sensor. The distal esophageal side hole was located at the proximal border of the sleeve device, and the next esophageal sensor was located 3 cm proximally. The two remaining esophageal body recording sites were each located at 6-cm intervals proximally. The catheters were continuously perfused with gas-free water by a low-compliance pneumohydraulic infusion pump (Arndorfer Medical Specialties Inc., Greendale, Wisconsin) at a rate of 0.5 ml/min. Resistance to infusion within the system was detected by a series of external Statham P23DB transducers (Statham Inc., Oxnard, California) positioned at the intersection of the costal margin and mid-axillary line of the subject. Sudden occlusion of each orifice resulted in a pressure rise in excess of 300 mm Hg/sec. Pressure profiles were displayed on a multichannel polygraph recorder (Beckman R611, Beckman Instruments Inc. Fullerton, California). The recording assembly was passed orally and positioned with all recording orifices in the stomach. Baseline pressures were set at intragastric pressure. A station pull-through was performed to locate accurately the lower esophageal sphincter. The assembly was then taped in position with the sleeve device straddling the sphincter. The resulting position located the distal esophageal sensor 3 cm above the midpoint of the sphincter (12). This process was repeated with each change in body position (see below) in order to maintain recording accuracy. An adjustment of approximately 1–3 cm was required with each such maneuver.

**Study Design.** All subjects were studied after a minimum 6-hr fast. Once the manometric assembly was positioned correctly, the subject was given 10 swallows (5 ml each) of either water or a viscous liquid. The order of each set of swallows was randomized and all boluses were given at room temperature (23–26°C). The subjects underwent the study in both the supine and upright positions (seated), and the order of these positions was also randomized. All swallows were separated by at least 30 sec, and an event marker was used to denote each swallow event. Where a second swallow was incidentally initiated within 20 sec of the primary event, both swallows were excluded from the subsequent analysis.

The viscous bolus consisted of a 75% dilution of a commercial strawberry syrup (Knott's Berry Farm, Buena Park, California). This liquid had been shown in previous studies to have a significant effect on peristaltic parameters (11). The syrup solution was made up on the day of study and a sample was saved for later determination of the viscosity level. Levels of viscosity were measured with a digital viscometer (model RVTD CP 200; Stoughton, Massachusetts) at 25°C. The viscosity of water was 0.89 centipoise (cp) and the mean viscosity of the syrup solution was 52 cp.

**Analysis of Data.** Individual tracings were coded and analyzed in a blinded fashion for peristaltic wave amplitude and duration, propagation velocity of peristaltic contractions, and duration of LES relaxation. Amplitude of contraction was determined as the peak height of the pressure wave relative to resting esophageal pressure. The onset and offset of each peristaltic wave were determined by drawing a line through the maximum upstroke slope and downstroke slope of the peristaltic wave and then determining the intersection of these lines with the resting esophageal pressure. The interval between these points was recorded as the wave duration (12). The time interval between pressure peaks of the peristaltic waves at each pair of recording sites was measured. The distance traversed divided by the time of wave travel yielded the propagation velocity (5). Duration of LES relaxation was determined by measuring the interval from onset of relaxation to return of LES pressure to its preswallow baseline.

For each subject, peristaltic parameters for each set of swallows were averaged to give individual means. The data for both liquids in the supine position were compared to those observed in the upright position by means of the Student’s t test for paired values with P < 0.05 being considered significant. In addition, the results noted with viscous and nonviscous boluses in each body position were compared in a similar fashion. Mean values for the group of subjects thus represent the mean of the individual means (5).

**RESULTS**

Alteration of body position from supine to upright had significant effects on esophageal peristaltic parameters elicited by the nonviscous bolus. Wave velocity was significantly increased in the proximal esophageal segment when the subject was upright (Figure 1). Wave velocity in the two distal segments was unaffected by alterations in body position. This

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