Effects of treatment with oxytocin, xylazine butorphanol, guaifenesin, acepromazine, and detomidine on esophageal manometric pressure in conscious horses

Anne A. Wooldridge, DVM, MS; Susan C. Eades, DVM, PhD; Giselle L. Hosgood, BVSc, MS; Rustin M. Moore, DVM, PhD

Objective—To compare effects of oxytocin, acepromazine maleate, xylazine hydrochloride-butorphanol tartrate, guaifenesin, and detomidine hydrochloride on esophageal manometric pressure in horses.

Animals—8 healthy adult horses.

Procedure—A nasogastric tube, modified with 3 polyethylene tubes that exited at the postpharyngeal area, thoracic inlet, and distal portion of the esophagus, was fitted for each horse. Amplitude, duration, and rate of propagation of pressure waveforms induced by swallows were measured at 5, 10, 20, 30, and 40 minutes after administration of oxytocin, detomidine, acepromazine, xylazine-butorphanol, guaifenesin, or saline (0.9% NaCl) solution. Number of spontaneous swallows, spontaneous events (contractions that occurred in the absence of a swallow stimulus), and high-pressure events (sustained increases in baseline pressure of > 10 mm Hg) were compared before and after drug administration.

Results—At 5 minutes after administration, detomidine increased waveform amplitude and decreased waveform duration at the thoracic inlet. At 10 minutes after administration, detomidine increased waveform duration at the thoracic inlet. Acepromazine administration increased the number of spontaneous events at the thoracic inlet and distal portion of the esophagus. Acepromazine and detomidine administration increased the number of high-pressure events at the thoracic inlet. Guaifenesin administration increased the number of spontaneous events at the thoracic inlet. Xylazine-butorphanol, detomidine, acepromazine, and guaifenesin administration decreased the number of spontaneous swallows.

Conclusions and Clinical Relevance— Detomidine, acepromazine, and a combination of xylazine butorphanol had the greatest effect on esophageal motility when evaluated manometrically. Reduction in spontaneous swallowing and changes in normal, coordinated peristaltic activity are the most clinically relevant effects. (*Am J Vet Res* 2002;63:1738–1744)

Luminal esophageal obstruction is the most commonly diagnosed esophageal disorder of horses, and an impaction of feed or bedding is the most common cause.[1] The equine esophagus is composed of skeletal muscle in the proximal two-thirds and smooth muscle in the distal one-third.[1,2] Most obstructions occur in the skeletal portion at the postpharyngeal area or at the area of the thoracic inlet.[1] Sedatives, tranquilizers, and analgesics, such as xylazine hydrochloride, detomidine hydrochloride, acepromazine maleate, and butorphanol tartrate, are commonly used in the treatment of this condition to reduce pain and anxiety, lower the horse's head, and potentially relax the spasm around the obstruction.[1] Additionally, oxytocin administration has recently been advocated to decrease esophageal pressure and resolve obstructions in the proximal portion of the esophagus. However, results of in vitro studies on smooth and skeletal esophageal muscle indicate that oxytocin has no effect on the proximal portion of the esophagus and causes relaxation of the distal portion of the esophagus.[3,4,a]

Effects of some sedatives and tranquilizers on esophageal motility have been studied by use of contrast radiography, but none have been evaluated manometrically in horses.[5-7] However, swallows in clinically normal horses have been characterized manometrically.[8,9] The use of contrast radiology reveals that detomidine administration, but not acepromazine, results in changes in esophageal motility in horses.[6] The effects of xylazine, butorphanol, and guaifenesin on the equine esophagus have not been evaluated. Guaifenesin, a centrally-acting skeletal muscle relaxant, causes relaxation of pharyngeal and laryngeal musculature and is used in anesthetic induction regimens to facilitate endotracheal intubation.[10] There is a possibility that guaifenesin administration would also cause relaxation of the proximal portion of the esophagus. Xylazine, butorphanol, and detomidine decrease

Received Jan 9, 2002.
Accepted June 4, 2002.
From the Equine Health Studies Program, Department of Veterinary Clinical Sciences, School of Veterinary Medicine, Louisiana State University, Baton Rouge, LA 70803. Dr. Wooldridge's present address is the Department of Pharmacology and Cancer Biology, Duke University Medical Center, Durham, NC 27710.
This report represents a portion of the thesis submitted by the first author to the graduate school, Louisiana State University, in partial fulfillment of the requirements for the MS degree.
Data from this study were presented at the ACVIM Forum in Seattle, Washington, May 25, 2000 and at the 7th International Colic Research Symposium, Manchester, England, July 2002.
This study was supported by a grant from the LSU School of Veterinary Medicine Equine Health Studies Program.
The authors thank Catherine Koch, Colleen Price, and Angelica Veitch for technical assistance and Michael Broussard for assistance in manuscript preparation.
Address correspondence to Dr. Wooldridge.

motility in the cecum, colon, and small intestine and may have a similar effect on the smooth muscle of the esophagus.[11-13]

We hypothesized that treatment with oxytocin, xylazine-butorphanol, detomidine, and acepromazine would decrease pressure in the proximal and distal portions of the esophagus, and that treatment with guaifenesin would decrease pressure in the proximal portion of the esophagus. The purpose of the study reported here was to determine and compare the effects of oxytocin, acepromazine, xylazine-butorphanol, guaifenesin, and detomidine on equine esophageal manometric pressure in vivo.

Materials and Methods

Animals—The Louisiana State University Institutional Animal Care and Use Committee approved this study. Eight adult healthy horses that were not sedated were used. Horses included 7 geldings and 1 mare. Breeds included 3 Thoroughbreds and 5 crossbred Quarter Horses. Health status was assessed on the basis of records from the research herd and via a complete physical examination. Two weeks before the beginning of our study, horses were conditioned to stand in stocks.

Instrumentation—Manometric techniques used were similar to those described previously.[9] A vinyl nasogastric tube[b] (outer diameter, 12 mm) modified with 3 flanged, polyethylene tubes[c] (inner diameter, 1.67 mm) was used for manometric recordings. A separate tube specifically fitted for each horse was used. The tube was passed into the esophagus, and the flanged ends were positioned in the postpharyngeal area at the thoracic inlet and immediately orad to the lower esophageal sphincter in the smooth muscle of the distal portion of the esophagus (**Fig 1**). The polyethylene tubes were connected by rigid Y-pieces to infusion pumps[d,e] and pressure transducers.[f] The pressure transducers were interfaced with a multichannel polygraph,[g] and pressure waves were recorded with a multichannel recorder.[h] Pumps were continuously infused with water at a rate of 3 mL/min. Tubing was passed through the opposite nostril into the pharyngeal area and secured; water was infused through the tubing to stimulate swallows if spontaneous swallowing was halted. Proper positioning in the esophagus was determined by comparing the induced waveforms in the 3 areas with known typical waveforms from esophageal pressure profiles of clinically normal horses.[8,9]

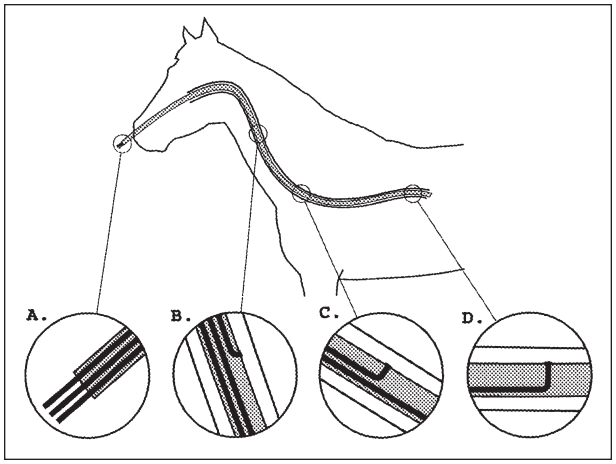

Figure 1—Diagram of the positioning of the nasogastric tube in the esophagus of the standing horse. A—All 3 polyethylene (PE) tubes enter the main tube at the nose. B—The first PE tube exits the main tube in the postpharyngeal area. C—The second PE tube exits the main tube at the thoracic inlet. D—The third PE tube exits the main tube in the distal portion of the esophagus.

Experimental design—Baseline values were recorded for 15 minutes. Drugs were administered IV as a bolus to each horse, and pressures were continuously recorded for 45 minutes thereafter. The following drugs (and doses) were used: saline (0.9% NaCl[i]) solution (5 mL), oxytocin[j] (0.22 U/kg), xylazine[k]-butorphanol[l] (0.5 and 0.02 mg/kg, respectively), detomidine[m] (0.04 mg/kg), guaifenesin[n] (25 mg/kg), and acepromazine[o] (0.07 mg/kg). Sedative and tranquilizer doses were chosen on the basis of those commonly used clinically for esophageal lavage in horses with esophageal feed impaction. Butorphanol was administered 3 minutes after the xylazine in all horses. A piece of tubing that reached the pharynx was placed into the nostril opposite the nasogastric tube, and water was infused through this tube to induce swallows. Three swallows were induced 1 minute apart at 5-minute intervals unless horses were frequently swallowing spontaneously. Drugs were administered in random order as determined by a Latin square design. At least 72 hours were allowed to elapse between drug or saline (0.9% NaCl) solution administration.

Measurements—Characteristics of 3 spontaneous or induced swallows were measured per period. Baseline measurements were recorded for 15 minutes, followed by measurements at 5, 10, 20, 30, and 40 minutes after drug or saline

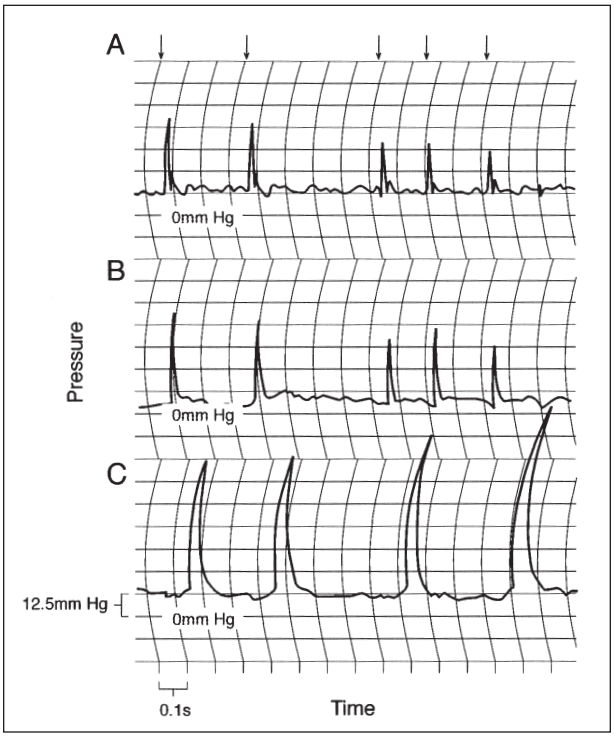

Figure 2—Typical esophageal peristaltic waves of a horse that were recorded by a physiograph after swallow stimuli (arrows). A—Recording from the postpharyngeal area. B—Recording from the thoracic inlet. C—Recording from the distal portion of the esophagus. Notice that the first 3 swallows result in normal appearing peristaltic waves. The fourth swallow results in a peristaltic wave from the postpharyngeal area to the thoracic inlet, but not to the distal portion of the esophagus, probably because the fourth swallow stimulus occurred soon after the third swallow stimulus. The waveform in the distal portion of the esophagus resulting from the fifth swallow stimulus is probably large because the previous waveform was not peristaltic.

(0.9% NaCl) solution administration. Maximum amplitude (mm Hg) and duration (seconds) of the 3 waveforms corresponding to a peristaltic wave induced by a swallow stimulus per period were measured. Rate of propagation in the esophagus (mm/s) from the postpharyngeal area to the thoracic inlet and from the thoracic inlet to the distal portion of the esophagus was measured for 3 sets of waveforms stimulated by a swallow per period (**Fig 2**). If the measured distance from the start of the postpharyngeal waveform to the thoracic inlet waveform or from the thoracic inlet waveform to the distal portion of the esophagus waveform was > 10 mm, they were not considered part of a peristaltic wave and would be categorized as a spontaneous event. Other variables evaluated included the number of spontaneous swallows, number of spontaneous events, and number of high-pressure events per period (**Fig 3**). Spontaneous swallows were defined as swallows that occurred without a water stimulus in the pharynx, and spontaneous events were defined as contractions of any segment of the esophagus not associated with a swallowing stimulus. Sustained increases in the baseline pressure of > 10 mm Hg were considered high-pressure events.

Statistical analyses—Percent change from baseline values was calculated for each interval for waveform maximum amplitude, duration, and rate of propagation. Data were found to follow a normal distribution after arcsine transformation, using the Shapiro-Wilk statistic, with failure to reject the null hypothesis of normality at $P < 0.05$. The transformed data were analyzed using a mixed effect general linear model, and accounting for the random variance of horse and repeated measurements on each horse. When significant effects of treatment (drugs) and time (intervals) were identified at $P < 0.05$, predetermined comparisons to baseline and time controls were made using the differences of least squares means and by maintaining an experiment-wise error of $\alpha = 0.05$. A software program[14,p] was used for the analysis. The effect of drug treatment and esophageal segment on the number of spontaneous events, high-pressure events, and spontaneous swallows was explored using a log linear model. A significant effect of drug treatment was determined on the basis of the Wald statistic at $P < 0.05$. The measure of significant drug effects was determined on the basis of the multiplicative estimate, compared with control. The estimate was exponentiated to quantify the effect of the drug on events, compared with the events of control. A software program[q] was used for analysis. All data are reported as mean (± SEM) values.

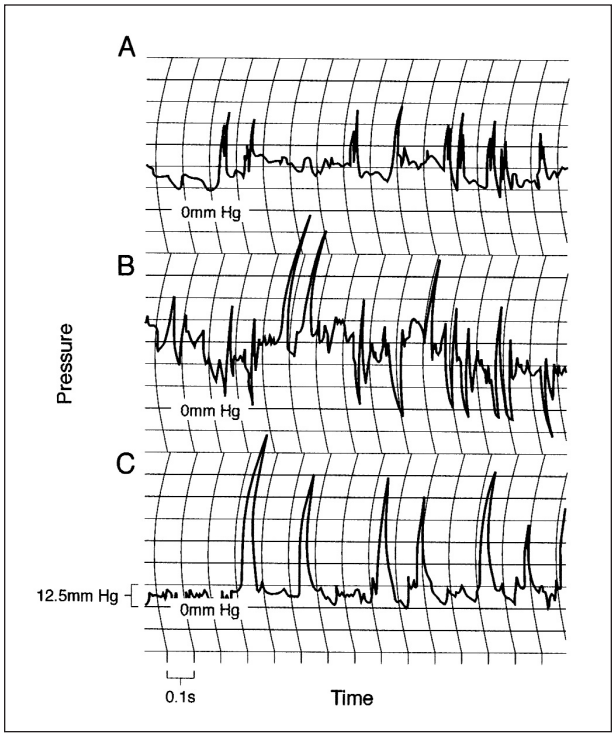

Figure 3—Spontaneous and high-pressure events in the esophagus of a horse that were recorded by a physiograph. No swallow stimuli occurred during this tracing. A—Recording of spontaneous events in the postpharyngeal area. B—Recording of high-pressure events (sustained increase in baseline of > 10 mm Hg) in the thoracic inlet. C—Recording of spontaneous events in the distal portion of the esophagus.

Results

The response rate of the system after side-hole occlusion was 34.2 ± 0.34 mm Hg/s. Before drug administration, all horses responded to swallow stimuli with typical peristaltic waves for the postpharyngeal area, thoracic inlet, and distal portion of the esophagus segments. Two geldings became transiently anxious and began to sweat after oxytocin bolus administration. Guaifenesin caused appreciable ataxia and weakness in 2 horses, but neither became recumbent, and both horses recovered within 15 minutes. In horses sedated with xylazine-butorphanol, detomidine, or acepromazine, fluid refluxed spontaneously from the nasogastric tube.

Baseline waveforms for the postpharyngeal area and for the thoracic inlet were of short duration (1.97 ± 0.74 and 2.5 ± 1.02 seconds, respectively). Mean amplitude of these waveforms was 60.8 ± 0.44 and 53.7 ± 0.29 mm Hg, respectively. Baseline waveforms for the distal portion of the esophagus were of longer duration (4.01 ± 0.81 seconds), and the mean amplitude was 65.5 ± 0.43 mm Hg.

Waveform amplitude—No drug caused a significant decrease in waveform amplitude. At 5 minutes after administration, detomidine caused a significant increase in waveform amplitude at the thoracic inlet, compared with baseline and control values (**Fig 4**).

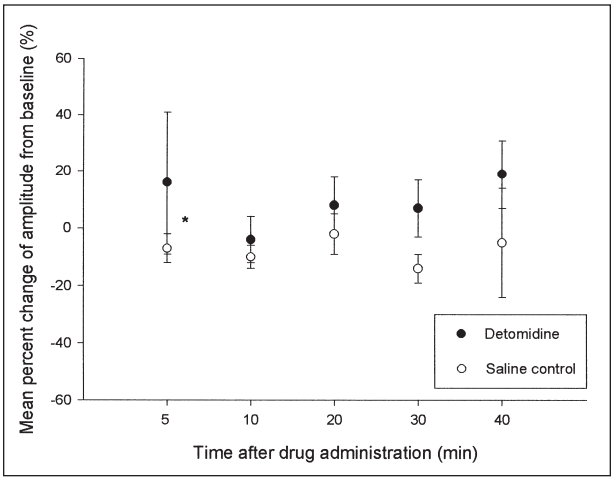

Figure 4—Mean (± SEM) percent change of esophageal manometric waveform amplitude from baseline pressure at the thoracic inlet versus time following detomidine hydrochloride and saline (0.9% NaCl) solution administration in horses. *Significant ($P < 0.05$) difference in detomidine values, compared with baseline and control (saline solution) values.

Waveform duration—At 5 minutes after administration, detomidine caused a significant decrease in waveform duration at the thoracic inlet, compared with baseline and control values (**Fig 5**). At 10 minutes after administration, detomidine caused a significant increase in waveform duration at the thoracic inlet, compared with baseline and control values.

Rate of propagation—No drugs had any significant effect on the rate of propagation from the postpharyngeal area to the thoracic inlet or from the thoracic inlet to the distal portion of the esophagus.

Spontaneous events—A significant overall stimulation effect of drug was identified (e^x = 0.46; 95% confidence limits, –0.8358 and 0.7024; $P < 0.001$), indicating 54% more spontaneous events after drug administration. Significantly more spontaneous events were identified at the thoracic inlet (e^x = 1.73; 95% confidence limits, 0.6309 and 0.4714; $P < 0.001$) than at the postpharyngeal area or the distal portion of the esophagus. Acepromazine, detomidine, and guaifenesin administration all resulted in an increase in spontaneous events at the thoracic inlet, and acepromazine also resulted in an increase in spontaneous events at the distal portion of the esophagus (**Table 1**).

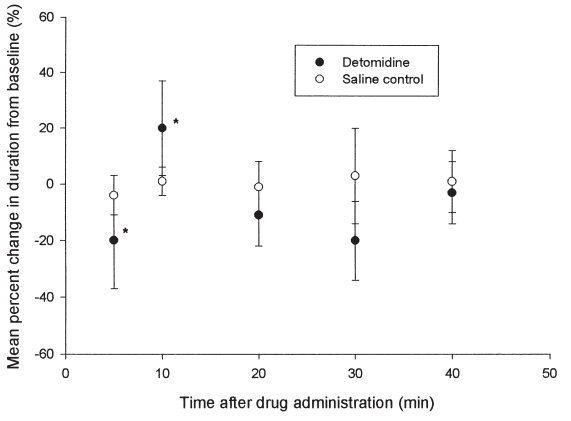

Figure 5—Mean (± SEM) percentage change of esophageal manometric waveform duration from baseline pressure at the thoracic inlet versus time following detomidine hydrochloride and saline (0.9% NaCl) solution administration in horses. *Significant ($P < 0.05$) difference in detomidine values, compared with baseline and control (saline solution) values.

Table 1—Estimates of the effect of acepromazine maleate, detomidine hydrochloride, and guaifenesin on the number of spontaneous events (contractions that occurred in the absence of a swallow stimulus) by location in the esophagus of conscious horses

			Estimate values		
Treatment	Location	e^x	Upper 95% confidence limit	Lower 95% confidence limit	*P* value
Overall	TI	1.73	0.6309	0.4714	< 0.001*
Overall	DPE	1.01	0.1041	–0.0749	0.7492
Acepromazine	TI	3.71	1.5437	1.0807	< 0.001†
Detomidine	TI	3.46	1.4750	1.0085	< 0.001†
Guaifenesin	TI	1.52	0.7026	0.1399	0.003†
Acepromazine	DPE	1.84	0.8461	0.3730	< 0.001†

The estimate was exponentiated (e^x).
*Significantly ($P < 0.05$) more spontaneous events were identified at the thoracic inlet than at other areas of the esophagus. †Significant ($P < 0.05$) increase in the number of spontaneous events compared with saline (0.9% NaCl) solution administration.
TI = Thoracic inlet. DPE = Distal portion of the esophagus.

Spontaneous swallows—A significant overall effect of drug was identified (e^x = 1.29; 95% confidence limits, 0.1148 and 0.4084), indicating 29% more spontaneous swallows before drug administration. Acepromazine, guaifenesin, xylazine-butorphanol, and detomidine administration all caused a significant decrease in the number of spontaneous swallows, and xylazine-butorphanol and detomidine administration caused the greatest change. There were 89% fewer spontaneous swallows after xylazine-butorphanol administration and 81% fewer spontaneous swallows after detomidine administration, compared with saline (0.9% NaCl) administration (**Table 2**).

High-pressure events—A significant overall stimulant effect of drug was identified (e^x = 0.70; 95% confidence limits, –0.1271 and –0.5924), indicating 30% more high-pressure events after drug administration. Significantly more high-pressure events were observed at the thoracic inlet (e^x = 2.27; 95% confidence limits, 1.0752 and 0.5649; $P < 0.001$) than at the postpharyngeal area or distal portion of the esophagus. Acepromazine and detomidine administration resulted in an increase in the number of high-pressure events at the thoracic inlet (**Table 3**).

Table 2—Estimates of the effect of xylazine hydrochloride-butorphanol tartrate, detomidine, acepromazine, and guaifenesin on the number of spontaneous swallows in conscious horses

		Estimate values		
Treatment	e^x	Upper 95% confidence limit	Lower 95% confidence limit	*P* value
Xylazine-butorphanol	0.11	–1.5207	–2.8288	< 0.001*
Detomidine	0.19	–1.1249	–2.1634	< 0.001*
Acepromazine	0.63	–0.1331	–0.8069	0.006*
Guaifenesin	0.20	–1.0423	–2.2071	< 0.001*

*Significant ($P < 0.05$) decrease in the number of spontaneous swallows compared with saline (0.9% NaCl) solution administration.
See Table 1 for remainder of legend.

Table 3—Estimates of the effect of acepromazine and detomidine on the number of high-pressure events in the esophagus at the thoracic inlet in conscious horses

			Estimate values		
Treatment	Location	e^x	Upper 95% confidence limit	Lower 95% confidence limit	*P* value
Overall	TI	2.27	1.0752	0.5649	< 0.001*
Acepromazine	TI	6.33	2.5488	1.1428	< 0.001†
Detomidine	TI	2.33	1.6282	0.0664	0.033†

*Significantly ($P < 0.05$) more high-pressure events were identified at the thoracic inlet than at other areas of the esophagus. †Significant ($P < 0.05$) increase in the number of high-pressure events compared with saline (0.9% NaCl) solution administration.
See Table 1 for remainder of legend.

Discussion

The most important findings of our study were the effects of the sedatives and tranquilizers, acepromazine, xylazine-butorphanol, and detomidine on esophageal manometric pressure. These drugs had the most significant effects on esophageal pressure, contraction events in the esophagus, and the number of spontaneous swallows, all of which could influence the movement of feed boluses and passage or treatment of a luminal obstruction. We hypothesized that oxytocin, acepromazine, detomidine, and xylazine-butorphanol administration would relax the proximal and distal portions of the esophagus. Acepromazine was the only drug to directly influence the distal portion of the esophagus in our study. Acepromazine administration resulted in an increase in high-pressure events in the distal portion of the esophagus, which may indicate lack of normal peristalsis from esophageal distention. Detomidine administration had effects on the proximal portion of the esophagus that were likely the result of distention and lack of normal peristaltic activity. Xylazine-butorphanol administration caused a large decrease in the number of spontaneous swallows that could certainly affect normal peristaltic activity. Oxytocin administration had no effect on the proximal or distal portion of this esophagus in our study. We hypothesized that guaifenesin would cause relaxation of the proximal portion of the esophagus. Guaifenesin administration did increase spontaneous events at the thoracic inlet, but did not affect the postpharyngeal area. Guaifenesin administration also significantly decreased spontaneous swallowing.

The most dramatic effect was the decrease in the number of spontaneous swallows following detomidine and xylazine-butorphanol administration. Acepromazine and guaifenesin administration also significantly decreased spontaneous swallowing, but to a lesser extent. The likely mechanism is CNS depression, which reduces the response of central nuclei to mechano- and chemoreceptor-mediated afferent impulses.[15-18] The decrease in spontaneous swallowing could lead to pooling of saliva. The accumulation of saliva may cause secondary peristalsis, which provides an explanation for the increases in spontaneous and high-pressure events. The fact that water was used to stimulate swallowing could augment this effect as a result of an increase in the amount of fluid that was pooled. However, water was used to stimulate swallowing in horses treated with saline (0.9% NaCl) solution or drugs, and a significant increase in the number of spontaneous and high-pressure events in horses treated with acepromazine and detomidine was still observed (although horses treated with saline solution had more spontaneous swallowing). An obstruction model would be necessary to determine whether decreases in swallowing, and therefore decreases in normal peristaltic activity, are beneficial or detrimental in the treatment of clinical obstruction. One theory would be that decreases in spontaneous swallowing could prevent the horse from pushing against an existing obstruction and perhaps allow the esophagus more time to lubricate and pass the obstruction. The doses of acepromazine, detomidine, and xylazine-butorphanol used in our study were typical of those used for sedation in horses.[10] Butorphanol is often given after an α_2-adrenergic agonist such as xylazine to avoid the transient stimulant effect of opiates given concurrently or prior to α_2-adrenergic agonist administration.[19] For this reason, butorphanol was given 3 minutes after the xylazine in our study. This is unlikely to change the synergistic effect of these 2 drugs on the gastrointestinal tract because results of a previous study documented this effect for up to 30 minutes.[13]

The next significant findings were the effects of detomidine at the thoracic inlet. The thoracic inlet is a common area for esophageal obstruction although not as common as the postpharyngeal area. Five minutes after administration, detomidine increased mean swallow-induced waveform amplitude. Detomidine administration decreased waveform duration at 5 minutes and increased waveform duration at 10 minutes. The changes in waveform amplitude and duration occurred soon after drug administration, suggesting that high concentrations of the drug were required to cause an effect. The responses of equine small intestine visceral smooth muscle to detomidine is similarly biphasic and dose-related.[13] Esophageal spasm in humans is indicated by an increase in waveform amplitude or duration by use of esophageal manometry.[20] Distention of the esophagus in humans can result in failure of propulsive peristaltic contractions or in a decrease in amplitude or duration of waveforms as determined by manometry.[20] The increase in waveform amplitude caused by detomidine administration in our study could be viewed as detrimental in treatment of an obstruction that is located at the thoracic inlet, but a decrease in waveform duration occurs simultaneously, which is more indicative of distention. Because high-pressure events were also significantly increased at the thoracic inlet in response to detomidine administration, all of these changes are likely a result of esophageal distention at the thoracic inlet and loss of normal coordinated peristaltic activity. Results of previous studies that used contrast radiography to examine esophageal function indicate that detomidine administration increases transit time.[6,7] Because detomidine administration did not affect the rate of propagation of peristaltic waves in our study, it is likely that the prolonged transit of barium in other studies[6,7] resulted from lack of spontaneous swallowing, esophageal distention, and lack of normal peristaltic activity.

Oxytocin administration had no effect on the proximal portion of the esophagus in our study. The dose of oxytocin used in our study was reported to be effective for reduction of esophageal pressure in a previous study.[16] Our findings corroborate results of an in vitro study in which oxytocin had no effect on the skeletal muscle.[a] These results contradict that of a previous study in which esophageal pressure was increased to 50 mm Hg by use of a water-filled balloon, and oxytocin administration (0.11 and 0.22 U/kg) resulted in a decrease in esophageal pressure at the postpharyngeal area and the thoracic inlet, usually immediately after ocytocin administration.[3] In that study, the greatest change in esophageal pressure was approximately 6 mm Hg at the postpharyngeal area.[3]

However, a decrease in wall pressure by 6 mm Hg may not be sufficient to aid in impaction resolution. In that study,[3] chloral hydrate was also administered 10 minutes before and 25 minutes after oxytocin administration as a sedative for the manometric evaluation. Chloral hydrate is not thought to affect gastrointestinal motility, but chloral hydrate administration adds another factor and interaction, which could lead to the different results between that study and our study. If oxytocin is truly beneficial for treatment of obstructions in the proximal portion of the esophagus, it may be exerting different effects on esophageal pressure when there is tension in the wall from an obstruction. Oxytocin does act as a neurotransmitter and neuromodulator in the CNS, so perhaps tension in the esophageal wall stimulates different CNS actions of oxytocin that modulate contraction and relaxation of the proximal portion of the esophagus.[21] Oxytocin could modulate skeletal muscle contraction by affecting acetylcholine release, binding, or metabolism at the neuromuscular junction, or could be modulating CNS signals to the proximal portion of the esophagus. We proposed that oxytocin would cause relaxation of the distal portion of the esophagus in vivo because of the observed effects on smooth muscle in vitro.[a] Relaxation of the distal portion of the esophagus could also be a mechanism through which oxytocin acts to relieve esophageal obstructions by opening the passageway for the obstruction. Oxytocin administration did not, however, affect the distal portion of the esophagus in our study.

Guaifenesin administration did not affect waveform amplitude, duration, or rate of propagation in any esophageal segment. Guaifenesin administration did, as previously mentioned, reduce spontaneous swallowing and increase spontaneous events at the thoracic inlet. The dose of guaifenesin was approximately half the amount used to induce extreme skeletal muscle relaxation prior to induction of anesthesia.[10] Most horses tolerated this well, but 2 did become quite unstable. Care should be used if this dose of guaifenesin is used to treat a standing horse with an esophageal obstruction, especially if guaifenesin is combined with sedatives such as detomidine or xylazine that can also cause some ataxia. Guaifenesin causes relaxation of skeletal muscles in the pharyngeal and laryngeal regions and facilitates endotracheal intubation.[10] Guaifenesin may not have had any effect on esophageal skeletal muscle (particularly in the postpharyngeal area) other than its effects on spontaneous swallowing and spontaneous events, because contractions of the esophagus are involuntary. Alternatively, a higher dose of guaifenesin may be required to relax the esophagus. Higher doses may not be practical in a clinical setting unless used in combination with general anesthesia regimens.

Values for waveform amplitude and duration before drug administration were similar to those found in previous manometric studies.[8,9] In control and baseline measurements, contractions progressed from 1 segment of the esophagus to the next rather than occurring simultaneously, which indicated peristaltic activity. The performance characteristics of the system (rate of pressure increase = 34.2 ± 0.34 mm Hg/s after complete occlusion of the flanged opening of the inner polyethylene tubes) we used should not have precluded accurate measurement of drug effects because this rate was similar to a previous manometric study.[9]

[a]Wooldridge AA. *The effects of oxytocin, acepromazine, xylazine, butorphanol, detomidine, guaifenesin, isoproterenol, terbutaline, and dantrolene on equine esophageal manometry and in vitro contractions.* MS Thesis, Department of Veterinary Clinical Scieces, Louisiana State University, Baton Rouge, La, 2001.
[b]Jorgenson Labs, Loveland, Colo.
[c]Intramedic polyethylene tubing, Becton Dickson, Sparks, Md.
[d]Harvard Apparatus Compact Infusion Pump, South Natick, Mass.
[e]Infusion Pump, Medfusion Systems Inc, Norcross, Ga.
[f]DTX plus DT-6012, Becton Dickinson Infusion Therapy Systems Inc, Sandy, Utah.
[g]Model 7D polygraph, Grass Instruments Co, Quincy, Mass.
[h]Chart recorder model 25-60, Grass Instruments Co, Quincy, Mass.
[i]0.9% sodium chloride, Abbott Laboratories, North Chicago, Ill.
[j]Oxytocin injection, The Butler Co, Columbus, Ohio.
[k]Xylazine, Miles Inc, Shawnee Mission, Kan.
[l]Butorphanol tartrate, Fort Dodge Laboratories, Fort Dodge, Iowa.
[m]Detomidine hydrochloride, Pfizer Animal Health, West Chester, Pa.
[n]Guaifenesin 0190-8, Puger Chemical Co, Inc, Irvington, NJ.
[o]Acepromazine maleate, Fort Dodge Laboratories, Fort Dodge, Iowa.
[p]PROC MIXED, SAS V.8.0, SAS Institute Inc, Cary, NC.
[q]PROC GENMOD, SAS V.8.0, SAS Institute Inc, Cary, NC.

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