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COLIC TREATMENT AND POST-COLIC NUTRITION

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Treatment of Colic

INTRODUCTION

The main goals for treating horses with colic include relieving pain, correcting physiologic imbalance, and stimulating or maintaining intestinal transit. Primary treatments are aimed at decompressing the gastrointestinal tract, treating dehydration or shock, correcting electrolyte imbalances, stimulating intestinal motility, and decreasing intestinal inflammation. When necessary, surgery is used to relieve strangulation or simple obstruction. However, treatment before and after surgery is often needed to address pain, ileus, or inflammation associated with obstructive disease.

Decompression

A primary method to alleviate abdominal pain is decompression of the distended stomach or intestine. Nasogastric intubation can help relieve gastric tympany or remove gastrointestinal reflux due to a small intestinal obstruction or ileus. The tube can be left in place for chronic decompression after surgery or in horses with proximal enteritis, but should be checked every 2 to 3 hours as stomach pressure may not force the fluid through the tube even with extreme distention (White, 1987). Horses with gastric dilatation can have stomach rupture, even after the recent passage of a stomach tube or with a stomach tube left in place for passive decompression. An attempt to start a siphon should be made in all cases by filling the tube with water and then lowering the end of the tube below the level of the stomach.

The other site at which distention from gas can be relieved is the cecum. Decompression (enterocentesis) can resolve a primary cecal tympany or help relieve gas buildup from a large colon or small colon obstruction. Decompression of the cecum is done in the right paralumbar fossa midway between the last rib and the ventral prominence of the tuber coxae. A 5- or 6-inch, 14-16 gauge needle or catheter over a needle is used. Suction is helpful for rapidly reducing cecal tympany. Concurrent palpation per rectum can help push gas into the cecal base and facilitate removing as much as possible. Once the gas is removed, saline or an antibiotic solution should be infused through the needle as it is pulled out of the cecum to avoid leaving a trail of contaminated material in the peritoneum or body wall.

Systemic Analgesics

Nonsteroidal anti-inflammatory drugs (NSAIDS): Some of the most useful drugs for relief of pain associated with either surgical or nonsurgical disease in horses are the nonsteroidal anti-inflammatory drugs (NSAIDs). They inhibit the enzyme cyclo-oxygenase, thereby decreasing the production of eicosanoids formed during degradation of arachidonic acid from cell membranes. The role of prostaglandins in equine intestinal disease is not fully understood. However, there is a favorable response during colic after administration of NSAIDs, which inhibit their formation. Different drugs produce varying levels of analgesia, possibly due to the different concentrations of the two types of cyclo-oxygenase, COX-1 and COX-2, in tissues (Morrow and Roberts, 2001). COX-1 regulates the production of prostaglandins necessary for normal organ and vascular function. COX-2 becomes active in response to cytokines, serum factors, or growth factors, and causes marked increases in prostaglandin production. COX-2 up-regulation by endotoxin is activated by p38 MAP kinase (Jones et al., 2005). Depending on their relative ability to inhibit COX-1 and COX-2, different NSAIDs provide different effects.

Prostaglandins have several effects on healing of the intestine. The constitutive prostaglandins, formed by COX-1, help regulate normal function such as motility and mucosal healing. PGE2 is needed to maintain the intestinal mucosa and glandular mucosa in the stomach. Excess use of nonselective COX inhibitors predisposes to gastric and intestinal ulceration. This creates a dilemma when treating horses for colic as the common NSAIDs—phenylbutazone, flunixin meglumine[i], ketoprofen[ii], and aspirin—inhibit COX-1 and COX-2, though apparently with different levels of effectiveness (Tomlinson and Blikslager, 2005).

Flunixin meglumine (flunixin) is the most effective of the NSAIDs used to treat acute abdominal disease in the horse. It blocks the production of prostaglandins, specifically thromboxane and prostacyclin, for 8 to 12 hours after a single dose (Semrad et al., 1985). In cases where a strangulated segment of intestine is suspected, the use of flunixin preoperatively can be helpful in diminishing the detrimental response due to the endotoxin release (6 to 8 hours) and return of borborygmi. The inability to eliminate pain with flunixin suggests a disease exists that requires more than simple medical treatment. For this reason, horses given flunixin should be observed carefully after its administration. If signs of colic return, particularly after a short period (1 to 2 hours), the horse should be immediately suspected of having more than a simple medical colic.

Clinical observation suggests phenylbutazone is not as good an analgesic for colic as flunixin. Its use appears to be more helpful for musculoskeletal problems than for visceral pain, perhaps because of differences in tissue concentrations. There is evidence that indicates phenylbutazone is more effective in reducing PGE2, thereby reversing ileus during endotoxemia (King and Gerring, 1989). The dosage response for this is not known, but 0.5 to 2 mg/kg has been used. The author has used a combination of flunixin (1.0 mg/kg IV, BID) and phenylbutazone (0.5-1.0 mg/kg IV, BID) by alternating administration of each drug every 6 hours. Whether this is more beneficial than either drug alone is unknown.

Ketoprofen has been used clinically for treatment of colic. It is effective in alleviating some clinical responses after experimental administration of endotoxin similar to flunixin. Gastric ulceration is also said to be less with this drug though at low doses this is not considered a problem with flunixin. Anecdotal reports suggest ketoprofen is less effective as an analgesic for colic than flunixin meglumine.

Eltenac[iii] has been tested in horses and has some adverse effects at 2 to 3 times the normal dose (Goodrich et al., 1998). Its effects in blocking the deleterious effects of endotoxemia are similar to those of flunixin (MacKay et al., 2000). Eltenac is reported to be less ulcerogenic than the commonly used NSAIDs in horses. This NSAID has not yet been used extensively for colic.

Disadvantages of the NSAIDs, particularly phenylbutazone, include the potential for adverse side effects such as mucosal ulceration of the gastrointestinal tract or renal damage (Collins and Tyler, 1984; Karcher et al., 1990; Meschter et al., 1990). This is particularly true if these drugs are administered orally, for long periods, during periods of dehydration and/or in combination with aminoglycoside antibiotics. Nonselective NSAIDs with COX-1 activity can decrease intestinal healing and, when used chronically, may alter intestinal motility (Blikslager et al., 1997; Van Hoogmoed et al., 2002). The administration of COX-2 inhibitors is limited to experimental use in horses (Morton et al., 2005; Tomlinson and Blikslager, 2005). Carprofen[iv] has been used as an anti-inflammatory after colic surgery (0.7 mg/kg SID or BID) because it is potentially less ulcerogenic, but its efficacy has not been clinically or scientifically proven. Meloxicam, currently available in Europe, is a selective COX-2 inhibitor that can be used for colic and does not inhibit healing of the intestinal mucosa after ischemia (Beretta et al., 2005).

Alpha-2 agonists: Several alpha-2 agonists are potent analgesics and cause muscle relaxation and sedation. This drug group includes xylazine[v], romifidine[vi], and detomidine[vii], which have been used for control of abdominal pain in horses. These drugs appear to act by stimulation of central alpha-2 adrenoreceptors, which modulates the release of norepinephrine and directly inhibits neuronal firing. This causes sedation, analgesia, bradycardia, and in the horse with colic, relief of pain (Muir and Robertson, 1985; Kohn and Muir, 1988; Merritt et al., 1998). The heart rate can be markedly reduced to less than 20 beats per minute by second-degree heart block. This causes a significant reduction in the cardiac output for a short period and thereby may have a detrimental effect on the horse that already has a critical reduction in circulating blood volume. Alpha-2 agonists reduce blood flow of obstructed large intestine and decrease intraluminal pressure (Muir and Robertson, 1985; Kohn and Muir, 1988). Similarly, in experimental small intestinal ischemia, xylazine reduced blood flow and increased oxygen utilization. There is a transient increase in urine production, which may complicate dehydration and circulatory shock (Stick et al., 1987).

Xylazine also has potent effects on intestinal motility. The jejunum and large intestine have less activity for up to 2 hours after a 1.1 mg/kg dose (Lowe et al., 1980; Adams et al., 1984; Roger and Ruckebusch, 1987; Mitchell et al., 2005). This is a profound effect giving relief from both somatic and visceral pain caused by distention or strangulation (Lowe et al., 1980; Muir and Robertson, 1985; Jochle et al., 1989; Dabareiner and White, 1995). Analgesia may last only 10 to 30 minutes or have minimal effect in horses with strangulating lesions such as large colon torsion. In horses with large or small colon impactions, xylazine appears beneficial in relieving the spasm of the intestine around the obstructing mass, thereby allowing passage of gas and rehydration of ingesta. This can often be accomplished with doses of 0.1 to 0.3 mg/kg intravenously and titrated to effect. If a prolonged effect is desired, xylazine can be administered intramuscularly at doses of 0.4 to 2 mg/kg.

Detomidine is an alpha-2 agonist like xylazine and is a potent sedative. It can produce complete cessation of colic for up to three hours, and during experimental cecal distention, it provided mean analgesia of 45 and 105 minutes at 20 μg/kg and 40 μg/kg respectively (Lowe and Hilfiger, 1986; Roger and Ruckebusch, 1987). Horses stand with their heads lowered and are reluctant to move. Second-degree heart blocks are common. Detomidine will reduce intestinal motility similar to xylazine, and it can obscure signs of pain that might help the clinician diagnose the cause of the colic. Because this is such a potent drug, any signs of colic observed within 30 to 60 minutes of administration are an indication that a severe disease is present and the horse may require surgery. The dosage can be titrated in 5-10 μg/kg increments (Dabareiner and White, 1995).

Opioids: The pure opioid agonists such as morphine and oxymorphone are potent analgesics, but they may cause excitation in the horse unless used in combination with drugs such as xylazine. Morphine reduces progressive motility of the small intestine and colon while potentially increasing mixing movements and increasing sphincter tone (Phaneuf et al., 1972; Senior et al., 2004). This can delay transit of ingesta. The disadvantages of morphine and oxymorphone in the horse with abdominal disease are sufficient to discourage their use. Epidural morphine (0.1 mg/kg qs to 30 cc of saline) can provide analgesia for 8 to 16 hours without CNS excitation.

Butorphanol[viii] is a partial agonist and antagonist, which gives the best pain relief with the least adverse effects of the opioids (Gingerich et al.,1985; Muir and Robertson, 1985; Kohn and Muir, 1988). It can be used in combination with xylazine or detomidine. The dosage can vary from 0.05 to 0.1 mg/kg, the high dosage being necessary for the most severe colic. Exceeding 0.2 mg/kg may cause an increase in heart rate, systolic blood pressure, and excitation in horses. Butorphanol can also be administered as a constant rate intravenous infusion at up to 23.7 μg/kg/hour. Butorphanol reduces small intestinal motility yet has minimal effect on pelvic flexure activity (Merritt et al., 1989; Merritt et al., 1998). Repeated use has the risk of delaying intestinal transit and causing impaction as seen with other opiate-like drugs. An overdose can be partially reversed with equal doses of naloxone[ix].

Spasmolytics: Spasmolytic drugs can indirectly provide analgesia by reducing spasms of the intestine. Increased frequency of intestinal contractions or spasms occurs with oral to intraluminal obstruction such as an impaction. Spasmolytic drugs include cholinergic blockers such as atropine. Because of the potential for prolonged intestinal stasis, use of atropine to treat equine acute abdomen is contraindicated.

The combination of hyoscine N-butylbromide and para-aminophenol derivative (dipyrone)[x] is popular in Europe for treatment of horses with colic, specifically spasmodic colic and impactions (Keller and Faulstich, 1985; Roelvink et al., 1991). Hyoscine has shorter-acting muscarinic cholinergic blocking effects compared to atropine and is effective in relaxing the bowel wall to prevent contraction. The drug can be detrimental in horses with ileus where inhibition of motility causes tympany and complicates the abdominal stasis that was already present (Keller, 1986). Hyoscine, by itself, is now available in the United States and is an effective antispasmodic. The drug is effective for treatment of spasmodic colic and impactions. Hyoscine gives excellent relaxation of the rectum facilitating examination per rectum. Lack of response to the drug suggests that there is a more serious problem that may require surgery or more aggressive treatment.

Lidocaine: Lidocaine has become popular as a prokinetic drug for use in the treatment of ileus (Malone and Turner, 1994; Cohen et al., 2004; Malone et al., 2006). Its effects appear to include both stimulation of gut motility and analgesic effects (Robertson et al., 2005). Lidocaine decreases inflammation by preserving microvascular integrity, preventing neutrophil migration and inhibiting cytokine production (Schmid et al., 1996; Takao et al., 1996; Lan et al., 2004a; Lan et al., 2004b). Lidocaine appears to be effective in treating pain for medical problems such as impactions and duodenitis-jejunitis as well as postoperative pain. An initial bolus of 1.3 mg/kg is followed by a constant-rate intravenous infusion at 0.05 mg/kg/min. Toxicity is exhibited as muscle fasciculation, erect hair, and weakness or recumbency (Malone and Turner, 1994). These signs quickly disappear after discontinuing the infusion.

Combating Ileus

Distention, endotoxemia, sympathetic stimulation, and bowel wall inflammation inhibit motility. The classic mechanisms of the sympathetic balanced with parasympathetic or cholinergic versus adrenergic stimulus no longer explains all the mechanisms controlling intestinal motility. The chief clinical problem is postoperative ileus involving the small intestine. Numerous drugs have been evaluated in normal horses. Few clinical trials have examined the efficacy of prokinetic drugs for treatment of equine postoperative ileus and those reporting success are limited to cisapride (Gerring and King, 1989), metoclopramide (Gerring and Hunt, 1986; Hunt and Gerring, 1986; Sojka et al., 1988), erythromycin (Nieto et al., 2000), and lidocaine (Malone and Turner, 1994; Malone et al., 2006). Recent research has supported the lack of usefulness of these compounds in horses with clinical disease (Nieto et al., 2000; Koenig and Cote, 2005). Inflammation from intestinal distention or ischemia potentially prevents the enteric nervous system or agents acting directly on muscle from stimulating progressive motility (Koenig and Cote, 2005). Only lidocaine appears to be of some value for treatment of postoperative ileus in horses with injured intestine, possibly due to its potential anti-inflammatory or analgesic effects rather than from direct stimulation of intestinal motility. New compounds that have yet to have reported for use in clinical cases include tegaserod[xi], a selective serotonin subtype 4 receptor agonist, and methylnaltrexone[xii], an opioid antagonist. Both stimulate pelvic flexure and jejunal motility in vitro (Delco et al., 2005; Van Hoogmoed et al., 2005).

Hydration

Hydration is usually accomplished with administration of balanced electrolyte solutions such as Ringer's, lactated Ringer's, or acetated Ringer's solutions. The greatest need is to replace total body water. Sodium replacement with the appropriate solution is needed to maintain water in the extracellular fluid (ECF) space without sacrificing potassium levels during long-term fluid administration. The level of dehydration is determined by evaluation of capillary refill, skin turgor, packed cell volume (PCV), and total protein (TP). The volume needed is calculated by estimating the water loss as a percent of the body weight or the percent of the blood or ECF change. An estimate can be calculated from the PCV and TP in the following formula:

Calculation for Initial Fluid Replacement

$$\frac{(\text{measured PCV or TP}) - (\text{normal PCV or TP}) \times 100}{(\text{normal PCV or TP})}$$

$$= \text{percent change in the PCV or TP}$$

This percent change represents the change in the blood or the ECF volume from normal. The calculated percentage multiplied times the blood volume (7% of the body weight in kg = liters of blood) is the estimated amount of fluid which needs to be replaced immediately to provide an adequate circulatory volume. This estimate is critical for the horse requiring surgery. The same estimate calculated on the ECF volume (30% of the body weight in kg = liters of ECF) calculates the total replacement required for rehydration of the ECF space. Because the PCV can vary widely in horses during colic, calculations using total protein may give a better estimate.

Horses with slight intestinal distention and ileus with accompanying pain often respond immediately to fluid replacement. Intravenous fluid administration has also been helpful in increasing the available fluid for intestinal secretion. The constant secretion of the intestinal tract provides the needed water to soften an impacted food mass. This "overhydration" technique can be used as a primary treatment for pelvic flexure and cecal impactions. The fluid can be administered intravenously over a 24-hour period or as a bolus. By regulating intravenous fluid administration to maintain the plasma protein at 5.0 to 5.5 g/dl (normal 6.0-6.5 g/dl), a state of overhydration will be maintained with adequate fluid available to help intestinal secretion. This normally requires a fluid administration rate of 2 to 4 liters per hour, double or triple maintenance requirements. When a bolus of fluids is administered, 20 liters in 1 to 2 hours is usually sufficient to decrease the plasma protein concentration.

In horses with severe dehydration including horses with endotoxic shock, administration of hypertonic saline can be used as an emergency measure to restore circulating volume (Bertone et al., 1990). A 7.5% saline solution is administered at 4 to 5 ml/kg as rapidly as possible. This rapidly draws water from the extracellular and intracellular space into the vascular space. This will improve perfusion and lower heart rate, but it must be followed with adequate replacement fluids to help restore hydration. Hypertonic saline is very useful in resuscitating horses in severe shock, and its use should be reserved for those horses. Hypertonic saline (4 ml/kg) can also be combined with hetastarch[xiii] or pentastarch[xiv] (6-10 ml/kg) to provide colloid support in horses with decreased protein concentrations (Corley, 2006).

Electrolyte imbalances are not common in horses with acute simple colic. However, decreased serum calcium concentrations occur more frequently in horses with large colon displacements or small or large colon strangulations (Dart et al., 1992). Calcium gluconate or calcium borogluconate are commonly used to replace calcium at 0.2-1.0 ml/kg of a 20% solution (Corley, 2006). Hypomagnesemia is less commonly associated with colic and is most common in horses that are off feed without electrolyte supplementation. Depression, anorexia, and cardiac dysrhythmias are signs associated with hypomagnesemia. Intravenous administration of magnesium sulfate or magnesium chloride at 2 mg/kg/min should not exceed 50 mg at one time (Corley, 2006). Oral supplementation with magnesium oxide at 20-30 mg/kg/day may also be considered.

Treatment of Impactions

Impaction colic is the most frequent type of simple obstruction causing colic (Tinker et al., 1997; White and Dabareiner, 1997). Factors associated with impactions include poor dentition, lack of access to water, coarse feeds, acute cessation of routine exercise with confinement, and treatment for musculoskeletal diseases (Dabareiner and White, 1995; White and Lopes, 2003). Damage or dysfunction of the enteric nervous system may also cause alterations in motility leading to impaction. Intestinal adhesions, which are suspected to alter motility patterns at the pelvic flexure, are also known to cause colon impactions (Schusser and White, 1997).

The basic premise for treating colon impaction is relieving pain, softening the consistency of the impacted ingesta, and stimulating motility to increase fecal transit. Xylazine, detomidine, hyoscine/dipyrone, and flunixin meglumine are efficacious, at least in part, by reducing intestinal spasm at the obstruction (Dabareiner and White, 1995; White and Dabareiner, 1997; White and Lopes, 2003). In the author's experience, titration with xylazine or detomidine appears sufficient to relieve the pain and initiate transit without excessive decreases in motility seen with the alpha agonists. The combination of alpha agonists with flunixin also appears effective for managing impactions, which can take several days to soften and move from the colon (White and Lopes, 2003). If these drugs do not control pain, most likely the impaction is severe enough to require surgery or another surgical disease is present.

Though administration of mineral oil via nasogastric tube is widely recommended for treatment of impaction colic, there is evidence that administration of oral or intravenous fluids may be preferable when an impaction is resistant to routine analgesic and laxative therapy. Administration of intravenous fluids has been used to help "overhydrate" the circulatory system, thereby stimulating secretion into the dehydrated ingesta in the colon (White and Lopes, 2003). Beyond systemic hydration afforded by fluid administration, dilution of plasma protein in the vascular system reduces plasma osmotic pressure, allowing water diffusion into tissues and specifically in regions of distended bowel. However, fluid treatment administered at 10 ml/kg per hour for 12 hours did not significantly alter colon hydration in normal fistulated horses (Lopes et al., 2004)(Figure 1).

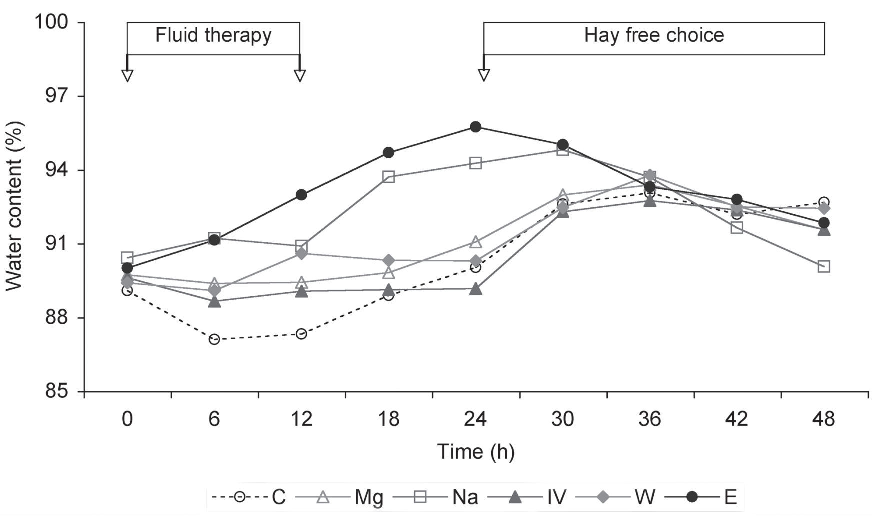

Figure 1. Water content of ingesta in the right dorsal colon increased significantly after enteral treatment with Na_2SO_4 (1.0 g/kg) and with 5 liters every hour for 12 hours of a balanced electrolyte solution. Enteral water, $MgSO_4$ (1.0 g/kg), and intravenous lactated Ringer's solution at 5 liters per hour for 12 hours did not affect water content in the colon in normal horses (Lopes et al., 2004).

Enteral administration of fluids is effective in increasing intestinal water (Lopes et al., 2004). Treatment of colon impactions with water administered via nasogastric tube

(10 liters every 30 to 60 minutes) until the impaction is resolved is effective; however, alterations in serum electrolytes can result from prolonged treatment (Lopes et al., 2002). Administration of $MgSO_4$ (1 g/kg in 1-2 liters of water via stomach tube) does not increase colon ingesta hydration but hydration of the feces did occur. Sodium sulfate (1 g/kg in 1-2 liters of water via stomach tube) significantly increases colon content hydration and created hypernatremia. Saline, originally prescribed for sand colic, increased colon water content but resulted in hypernatremia and hyperchloremia. Administration of a balanced electrolyte solution containing 5.37 g NaCl, .37 g KCl, and 3.78 g $NaHCO_3$ per liter is as effective as any laxative in hydrating colon contents without altering serum electrolyte values (Table 1). The balanced electrolyte solution is administered via a feeding tube at 5 to 10 liters per hour. This hydrates colon contents as well as restoring systemic hydration.

Table 1. Formula in grams with estimates using measuring teaspoons to make a balanced electrolyte solution for use as an enteral fluid to treat colon impactions. Administered at 5-10 liters per hour, this solution will soften impactions and provide systemic hydration.

Specific Ingredient	*Grams/liter*	*Grams/5 liters*
NaCl	5.37	26.85
KCl	0.37	1.85
$NaHCO_3$	3.78	18.9
Ingredient	*Amount/5 liters*	*Total dose/5 liters*
Salt	3 teaspoons	Equals 21 g NaCl
Litesalt®	1 teaspoon	Equals 3.5 g NaCl and 2 g KCl
Baking Soda	4 teaspoons	Equals 20 g $NaHCO_3$

Research suggests that colon hydration is increased when fasted horses are fed hay. Though feeding may increase motility and oral water intake, feeding horses with impactions should be delayed until there is evidence that the impaction is moving or is resolved (Dabareiner and White, 1995; White and Lopes, 2003). When initiating feeding after the impaction has moved out of the colon, a laxative diet without grain, such as grass or alfalfa hay, is preferred. Use of bran as a laxative is controversial. Though pure bran is high in fiber, most milled bran contains large amounts of carbohydrate, which reduces total fiber content and potentially decreases water content in the colon.

Equine Nutrition after Colic

INTRODUCTION

There is little research on how to feed horses after an episode of colic or after abdominal surgery. Veterinarians have adopted feeding protocols that have worked for the most common types of colic. This is likely because up to 80% of all colic episodes are considered simple colic with no specific diagnosis or known cause (Tinker et al., 1997). Spasmodic or gas colics make up about 8% of colic cases and rarely have a specific cause identified or specific dietary needs. Most of these simple types of colic episodes are easily treated and often there is no interruption in feed intake. Approximately 8-10% of colic episodes in the normal population result from impactions of the colon (Tinker et al., 1997). Though most are successfully treated with analgesics and a laxative, continued feeding is not recommended until transit of ingesta suggests that newly ingested feed will not add to the impaction (White and Dabareiner, 1997). Diseases that create ileus or complete obstruction are the most serious type of colic episodes and require a special feed type and timing of ingestion. Many of these serious diseases require surgery and treatment for shock or infection which complicate the nutritional needs of these horses. Currently, recommendations for nutrition have not been scientifically tested nor have specific types of diet been correlated with success in treating or preventing colic or specific type of obstruction of the horse's intestine.

Enteral Nutrition

The energy needs of horses after colic or abdominal surgery are not known. Because of the wide variation in the severity of colic, clinicians have assumed that there is no need for an increase in nutritional requirement after simple colic. In most cases horses are only off feed for a short period of time (12 to 48 hours), if at all, and there is no apparent clinical effect in these horses. Sixteen Mcal (32 kcal/kg), the energy requirement for maintenance for an adult horse on pasture, may not be needed for many horses that are stall-confined and considered to have basal metabolism. During the immediate postoperative period, less energy should be expended for digestion, possibly as much as a 15-20% decrease (Geor, 2007). The basal requirement for stall-confined horses postoperatively is likely sufficient unless they are challenged by a systemic inflammatory response syndrome due to peritonitis or endotoxemia. If the basal requirement is 70% of maintenance, the requirement for the stall-rested horse would be approximately 21 kcal/kg per day. Estimates for the increased energy requirement for horses due to abdominal surgery or shock are based on human information, which suggests an increase of 30-100% above maintenance, but this has not been substantiated in the horse. The protein requirement for maintenance is estimated at 1.25 g/kg per day providing 0.9 g/kg per day of available protein (Geor, 2007). Basal requirements for protein may also be decreased to 0.6-0.8 g/kg per day. Adequate energy from carbohydrates or fat is needed to prevent utilization of protein for energy during nutritional therapy. Though not currently recognized as the standard of care, horses that are not ingesting at least 50% of their maintenance requirement (15-18 kcal/kg per day) for 48 to 72 hours should have nutritional support (Dunkel and McKenzie, 2003; Magdesian, 2003).

Most hay or grass is not evaluated for nutrient content, so the daily energy and protein intake frequently is not known for horses during medical care. The use of pellet-formed feeds such as Equine Senior®[xv] allows calculation of energy and protein intake. Other total horse feeds supplied as pellets are usually made partially from grains, thereby increasing soluble carbohydrate concentrations. This may be appropriate for some horses after surgery, but this is dependent on concern for altering the flora in the cecum and colon. In some instances, this readily available source of carbohydrates may be an advantage. Nevertheless, feedstuffs such as bran are not recommended due to the high amount of carbohydrate often present after milling.

Horses suffering from simple colic rarely need alterations in their diet. Food and water should be withheld during the colic episode. Most horses can return to their normal diet after the pain is resolved and there is evidence of fecal transit. Since the cause of simple colic is rarely identified, clinical signs are used to determine whether normal feeding can be continued. In some cases, grain is withheld for several feedings to prevent excess gas production. However, there is no strict guideline as there is great variation in the severity of the colic and feeding practices in specific locales.

Impaction of the colon causes obstruction of the colon either at the pelvic flexure or the right dorsal colon (White and Dabareiner, 1997). The ingesta becomes dehydrated and forms a firm, large mass, which is resistant to moving aborally due to its size and contractions of colon around the mass. Continued feeding appears to prolong the process of clearing the mass from the intestine. In most cases impactions are successfully treated by administration of analgesics and a laxative such as mineral oil (White and Dabareiner, 1997). Impactions resistant to laxative treatment will most always resolve with hydration of the impacted mass using an intravenous or enteral balanced electrolyte administration (Lopes et al., 2002). During this treatment food is withheld until there is evidence of fecal transit and the impaction can no longer be identified by rectal examination. Resumption of feeding is best initiated with hay or pasture without grain until normal transit is established.

The best type of feed or feeding time for a horse after severe distention or abdominal surgery for obstruction or strangulation has not been scientifically determined. In most cases a forage diet of hay or fresh grass is chosen and fed as soon as medical judgment suggests ingested food can be tolerated. Alternatives include pellet-type feeds consisting of alfalfa or total diet feeds[xv]. Grains and sweet feed are avoided to decrease the risk of excess fermentation causing gas production and concern for abrupt changes in intestinal flora by providing too much soluble carbohydrate, thereby increasing the risk of diarrhea or laminitis.

After surgery for large colon disease, water can usually be offered immediately unless there is evidence of shock or lack of intestinal motility. After surgery for a large colon obstruction, grass hay, alfalfa hay, or fresh grass is routinely fed from 6 to 12 hours after surgery. Alfalfa hay is favored by many clinicians for its palatability, high energy and protein content, and laxative effect. Initially feeding 1 pound of hay every 3 hours allows monitoring of intake and response of intestinal motility. Ad lib feeding can usually be started 24 hours after the initial offering.

Water is not offered immediately after surgery for small intestinal disease until gastric reflux has ceased, there is evidence of intestinal motility, and absorption of fluid from the intestine can be documented by stabilization of vascular volume (PCV and TP) and overall hydration. Prior to feeding, the author recommends offering one liter every hour until the horse is no longer thirsty. Hay or a pellet feed is then offered at a rate of 0.5 to 1 pound every 3 hours increasing over 24 to 48 hours when ad lib hay or a specific amount of feed pellets equal to the basal energy requirements can be offered. Freeman and coworkers suggest feeding horses with small intestinal obstruction or strangulation including those with intestinal resection and anastomosis as soon as possible to stimulate normal motility (2000). Though feeding can be a stimulus for intestinal motility and is successful in many horses, early feeding can result in return of colic and accumulation of fluid in the stomach and small intestine. No methods have been established to predict which horses will not tolerate early feeding.

An increased risk of postoperative ileus is associated with an increased PCV and heart rate, prolonged surgery and anesthesia, and signs of endotoxemia prior to surgery (Blikslager et al., 1994; Roussel et al., 2001; Cohen et al., 2004). Other than intraluminal pressure measured at surgery, there is no measure of bowel inflammation or function that helps to predict when enteral feeding will be tolerated. The decision to feed a horse after small intestinal surgery remains a medical judgment without specific criteria to guide the clinician. Experience suggests that small amounts fed at frequently timed intervals prevents overload of the intestine and allows for early detection of problems such as ileus or obstruction.

Oral liquid diets made for humans have been used in horses but contain no fiber and increase the risk of colitis and laminitis (Buechner-Maxwell et al., 2003). Other diets consisting of alfalfa pellets, dextrose, vegetable oils, and amino acids maintained body condition of horses but also increased the risk of diarrhea and laminitis (Naylor et al., 1984). Development of an enteral energy/protein source, which is readily absorbed with minimal risk of disturbing motility or gut flora, is necessary for horses needing enteral nutrition during the initial postoperative period. Supplementation of glutamine has been suggested to help maintain or restore the intestinal epithelium, reduce the inflammatory response of the epithelium, and prevent bacterial translocation (Zhang et al., 1995; Blikslager et al., 1999; Liboni et al., 2005).

Parenteral Nutrition

Feeding horses intravenously, though shown to be possible, has not been proven to be necessary to improve horse survival after abdominal surgery (Lopes and White, 2002). In human medicine, there is no evidence that parenteral nutrition alters mortality of surgical or critical care patients, but there is evidence that complications are decreased particularly in patients that are malnourished (Heyland et al., 1998). A comparison of horses evaluated after abdominal surgery with or without supportive parenteral nutrition did not show a difference in outcome. Nevertheless, there was evidence of significantly decreased triglycerides, total bilirubin, albumin, and urea with significantly higher serum glucose and insulin in horses treated with parenteral nutrition after small intestinal resection and anatomosis (Durham et al., 2004). The treatment did not change time until enteral feeding, or time or cost of hospitalization.

Parenteral nutrition should be considered immediately if ileus, shock, or peritonitis is predicted to prevent oral ingestion of feed for more than a few days. Subjectively, it appears to the author that parenteral nutrition has been responsible for reducing convalescence time and cost for horses in shock and unable to tolerate enteral nutrition immediately after surgery.

Since total energy requirements may be decreased after surgery, partial parenteral nutrition may be sufficient for short-term nutrient supplementation. Use of glucose and amino acids without lipids appears to provide adequate calories. When endotoxemia and shock are present, the addition of lipids as a source of energy may be necessary as insulin resistance may be present in horses during endotoxemia (Lopes and White, 2002).

Addition of single or multiple trace elements as antioxidants (specifically selenium) during parenteral nutrition in human studies was associated with a significant decrease in mortality (Heyland et al., 2005). Since horses are not normally supported with parenteral nutrition for long periods, the benefit of vitamin and mineral supplementation is unknown.

Complications of parenteral nutrition include thrombophlebitis, hyperglycemia, hyperlipidemia, and electrolyte imbalance. Monitoring serum glucose is important during parenteral nutrition, particularly when initiating parenteral feeding. Glucose intolerance detected during the initial 24 to 48 hours requires reduction in the rate of administration or treatment with insulin. Normally the hyperglycemia is transient, but persistent hyperglycemia or hyperglycemia occurring after the initial period of accommodation may be an indicator of disease severity (Lopes and White, 2002).

Although enteral nutrition is always preferred, parenteral nutrition can provide long-term nutritional support. Horses have been kept on total parenteral nutrition for several weeks to one month and been able to maintain or gain weight.

Footnotes

[i] Banamine, Schering Plough Animal Health, Union, NJ 07083
[ii] Ketofen, Fort Dodge Animal Health, Overland Park, KS 66225
[iii] Eltenac, Schering Plough Animal Health, Union, NJ 07083
[iv] Rimadyl, Pfizer Animal Health, Exton, PA 19341
[v] Xylazine, Vedco, Inc., St. Joseph, MO 64507
[vi] Sedivet, Boerhinger Ingleheim, Vetmedica, Inc., St. Joseph, MO 64506
[vii] Dormosedan, Pfizer Animal Health, Exton PA 19341
[viii] Torbugesic, Fort Dodge Animal Health, Overland Park, KS 66225
[ix] Narcan, Endo Pharmaceuticals, Chadds Ford, PA 19317
[x] Buscopan, Boerhinger Ingleheim, Vetmedica , Inc., St. Joseph, MO 64506
[xi] Zelnorm, Novartis Pharmaceuticals, East Hanover, NJ 07936

xii Methylnaltrexone, Progenics Pharmaceuticals, Tarrytown, NY 10591
xiii Hetastarch, Baxter, Deerfield, IL 60015
xiv Pentastarch, Dupont Pharma, Wilmington, DE 19880
xv Equine Senior®, Land 'O Lakes-Purina Feed, St. Louis, MO 63141

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