# Controlling Strongyle Parasites of Horses: A Mandate for Change

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Future approaches to equine parasite control must seek greater sustainability by exploiting inherent host resistance and acquired immunity, implementing management procedures that reduce transmission, and using anthelmintic treatments much less frequently and only in selected members of a herd. Author's address: East Tennessee Clinical Research, Inc., 80 Copper Ridge Farm Road, Rockwood, Tennessee 37854; e-mail: crr@easttenncr.com. 

## 1. Introduction

Historically, practical management of equine parasitism has been based on pervasive misconceptions about the basic objectives of parasite control: unrealistic assumptions that eradication was both desirable and feasible, inappropriate emphasis was placed on therapeutic rather than prophylactic approaches, and exclusive use of drugs for implementing programs. The ultimate abandonment of traditional control practices is inevitable,[1] but the prospect of prevalent and expanding resistance of target parasites to multiple classes of equine anthelmintics lends particular urgency. Future approaches to equine parasite control must seek greater sustainability by exploiting inherent host resistance and acquired immunity, implementing management procedures that reduce transmission, and by using chemical treatments much less frequently and only in selected members of a herd.

## 2. Objectives of Strongyle Control

The overall goal of effective parasite control is to optimize the health and performance of our equine patients. Health goals are relatively straightforward, but parameters of performance vary with the use or classification of the horse and can be very difficult to quantify. Examples of improved performance include more live foals for stallions, more weaned foals for broodmares, more blue ribbons for competitive horses, and faster times for racing athletes. For backyard horses, optimal health and performance might be achieved simply by fewer episodes of colic and easy maintenance of body condition. Qualitative outcomes are more common than quantitative measurements, because Western civilization has romanticized the horse to the point that it is rarely viewed as a production animal.

It is a pervasive misconception that the objective of parasite control is to kill adult worms (i.e., the worms that lay the eggs detected by fecal examination). However, all strongyle parasites of horses exert their greatest pathogenicity in the larval stages that are by definition incapable of sexual reproduction. *Strongylus vulgaris* offers an excellent example for clarifying this point. The major pathology inflicted by *S. vulgaris* is verminous arteritis (the so-called "aneurysms") of the cranial mesenteric artery. These arterial lesions are caused by migrating larvae, and therefore, the ma-

**NOTES**

jority of damage is inflicted weeks or months before the time when *S. vulgaris* females return to the gut, mature, and begin to lay eggs. Adult large strongyles attach firmly to the gut wall and purportedly ingest blood and tissue proteins, but this is a minor feature of their overall pathogenicity. Similarly, the greatest damage by cyathostomins occurs when developing larvae emerge from cysts in the mucosa and submucosa of the cecum and ventral colon. This event generally precedes patency by more than a month. Adult cyathostomins attach to the gut weakly, if at all, and feed mostly on organic material within the gut lumen.

The objective of control for nearly all types of parasites is to prevent contamination of the environment with potential infective stages. “Deworming” as a component of a control program is an unfortunate term, because it emphasizes treatment rather than prevention. Anthelmintics would be used more appropriately as pre-emergent herbicides than therapeutic agents. An alternative view is to think of reproductive neutralization as the ultimate goal of parasite control. Accordingly, a product that sterilized female strongyles but failed to kill adult worms would be extremely effective in managing parasites. In the strictest sense, waiting until large or small strongyles begin to reproduce before attempting to disrupt the life cycle is an example of “too little, too late.” Yet, the presence and number of strongyle eggs in feces remain the only available tools for assessing the efficacy of control efforts, so it becomes a practical challenge to achieve balance between excessive treatment and negligence.

### 3. Historic Approaches to Strongyle Control

Most approaches to strongyle control fail to consider the complex biology of the target organisms. Instead, anthelmintics might be used episodically when signs of perceived or actual clinical parasitism are observed. Other, quasi-prophylactic approaches are linked to regular intervals like management events (e.g., quarterly deworming) or farrier visits, neither of which has anything to do with the biology of the worms. The most widely adopted approach to strongyle control has been the interval treatment program proposed by Drudge and Lyons in 1966.[2] This program can be summarized as anthelmintic treatment of every horse on the premise at bimonthly intervals during the year with rotation of anthelmintic classes between successive treatments. The interval treatment program was based on experimental observations that fecal egg counts of horses remained low for a predictable interval after administration of the benzimidazole anthelmintic, thiabendazole. Approximately 8 wk after treatment, egg counts began to rise again and inevitably would return to pre-treatment levels. The intent of deworming at specific intervals was to maintain low fecal egg counts; this would minimize environmental contamination with potential infective stages and thereby, achieve the primary goal of effective parasite control. It should be noted that in the 1960s, when the interval approach was first conceived and implemented, the major targets of parasite control in mature horses were large strongyles, typified by *S. vulgaris*.

The interval approach was so effective in controlling strongyles that monitoring the continued efficacy of anthelmintic products was considered superfluous. Ultimately, that would prove to be a serious mistake.

### 4. Abandoning Historical Approaches

Although the interval approach was highly successful for many years, the playing field has changed drastically, and interval programs no longer represent an acceptable standard of practice for strongyle control. A consequence is that large strongyles, the original and most important targets of interval programs, have been practically eradicated from most well-managed horse farms.[3] The means by which this was accomplished will be detailed later in this article.

The major change that has rendered interval programs ineffective is the widespread development of anthelmintic resistance by cyathostomin nematodes,[4–7] which have replaced large strongyles as the main target of parasite control in mature horses. Virtually all of the anthelmintics currently marketed for strongyle control belong to only three chemical classes (benzimidazoles, pyrimidines, and macrocyclic lactones). A survey published recently[8] documented that cyathostomin populations in $>95\%$ of large horse herds in the southeastern United States were resistant to the benzimidazole class (i.e., fenbendazole), and nearly 50% were also resistant to pyrimidines (i.e., pyrantel pamoate). Thus, in many herds, anthelmintic rotation is no longer an option, because only one chemical class (macrocyclic lactones like ivermectin and moxidectin) remains consistently effective against cyathostomins. It is now recognized that frequent, perennial treatments are unnecessary and can select strongly for the development of anthelmintic resistance.

Additionally, awareness that individual horses differ markedly in their susceptibility to strongyle infection is growing, and these differences are manifested in the magnitude of fecal egg counts.[9–12] Many horses apparently have an innate or acquired ability to control strongyle infections in the total absence of chemical treatments, and those horses should not be dewormed as frequently as other members of the herd.

Other urgent reasons exist for recommending a dramatic departure from traditional parasite control practices for horses. First, anthelmintic resistance in *Parascaris equorum*, which does not belong to the strongyle family, was recently recognized.[13–17] Second, the three classes of dewormers that are currently marketed represent the entire armamentarium at our disposal and that situation is unlikely to change for the next few years. If a new class of equine anthelmintic were currently in development, it would still require several years before a product could be approved by regulatory agencies for use in the field. Therefore, the existing chemical tools must be used more judiciously to preserve the efficacy that they still provide. Third, it is clear that more sustainable approaches to strongyle control must be implemented. All chemical strategies for parasite control have a finite lifespan,[18] and future approaches must incorporate the unique contributions of environment, management, and host genetics and immunity.

## 5. Applied Biology

The transmission of most equine parasitisms is influenced more by environmental conditions than by host factors. A general failure to understand or appreciate environmental influences has given rise to many pervasive rumors and misconceptions about equine parasite control. The rules of strongyle transmission are reviewed herein.

### Sources of Infection

Strongyles are transmitted almost exclusively on pastures. Stall habitats are not very favorable, regardless of their physical condition. Equine feces desiccate fairly rapidly, and stall habitats with clean, dry bedding do not offer sufficient moisture for strongyle eggs to develop to the infective, third larval stage. In contrast, the bedding in some horse stalls is fairly damp, but the excess moisture often originates as urine. The urea in urine breaks down into ammonia, and ammonia is highly toxic to developing strongyle larvae. Dirt paddocks and non-vegetated turn-out areas lack the thatch layer necessary to provide a humid and aerobic microclimate that is essential for larval development and survival. Thus, by evolution and by default, the vast majority of strongyles are acquired from forage.

Most horse pastures do not present a uniform risk of infection. Horses with adequate grazing area instinctively divide pastures into two distinct zones, called roughs and lawns. Roughs are areas with tall, overgrown forage and weeds, and inspection of roughs reveals that they are noticeably contaminated with feces. The forage within a rough is not overgrown because of fertilization; it is tall, because the horses will not graze it down. Roughs are areas where horses defecate but do not graze; they are analogous to bathrooms for the pastured horse. In contrast, lawns are areas of relatively short forage where horses graze closely but do not defecate. Lawns are analogous to dining rooms for the pastured horse. Herd and Willardson[19]showed that the numbers of strongylid larvae available in pasture roughs were 15 times greater than in the lawns. Thus, grazing in roughs poses an increased risk for transmission of parasites.

If left to their own devices, grazing horses employ an elegant system for limiting their exposure to parasitism. However, that system is compromised whenever a pasture is harrowed or dragged. This practice merely disseminates high levels of infectivity from roughs into the relatively clean lawns and creates a pasture environment that is uniformly infective to horses residing in it.

Although mowing, dragging, or harrowing pastures can have negative consequences for parasite control, concerns about general pasture management occasionally prevail. So, if a pasture must be dragged or harrowed, it should be done during the hottest months of the year, and the pasture should be left vacant for several weeks immediately thereafter. In cooler regions, harrowing at the end of the grazing season has been shown to reduce overwinter survival of infective stages.[20]

### Seasonal Patterns of Transmission

Strongyles exhibit predictable, seasonal patterns of transmission that are determined by climatic factors. Strongylid eggs pass in the feces, and under appropriate environmental conditions (~43–85°F), the eggs hatch; emerging larvae develop sequentially through first ($L_1$), second ($L_2$), and third larval stages ($L_3$). The $L_3$ is the only stage that is capable of infecting a new host. Transmission is accomplished when grazing horses inadvertently ingest third-stage larvae with forage. Within the cited temperature range, the rate of development is directly proportional to environmental temperature. At temperatures averaging 55°F, it may take weeks or months for an individual egg to progress to the $L_3$ stage. When daily averages are ~77°F, however, that same developmental cycle can be completed within a week or less. No successful larval development occurs at <42°F or >100°F.[21,22]

After strongyle larvae achieve the infective third stage, environmental temperatures have an opposite effect on their survival. Because third-stage larvae are surrounded by a protective sheath that prevents them from ingesting nutrients, they must rely on stored energy reserves. Energy consumption is minimal at low temperatures, but reserves are depleted rapidly in warm or hot weather. Thus, the duration of larval survival is described as inversely proportional to environmental temperature. Larvae die fairly rapidly at temperatures >90°F, but at the other extreme, third-stage larvae tolerate freezing well.[23] The purported pasture cleansing effect of "killing frost" during winter is a myth.

Environmental conditions affecting transmission differ geographically. The major horse-raising areas within continental North America can be divided into two distinct zones, termed the Northern Temperate (NT) and Southern Temperate (ST) regions. In ST regions, winter is a favorable season for transmission, because daytime temperatures are often warm enough to permit hatching of eggs and development of new larvae. Yet, average conditions are cool enough that persistence of infective stages in the environment is excellent. In ST areas, the lar-

**Table 1. Equine Anthelmintics With Labeled Efficacy Against Large Strongyles and Cyathostomins**

| Anthelmintic | Dosage | Comments |
|---|---|---|
| Fenbendazole | 5 mg/kg | Widespread resistance by cyathostomins |
| Fenbendazole | 10 mg/kg, q 24 h, for 5 days | Larvicidal for migrating large strongyle larvae and a portion of encysted cyathostomins |
| Ivermectin | 0.2 mg/kg | Larvicidal for migrating large strongyle larvae; no resistance by cyathostomins |
| Moxidectin | 0.4 mg/kg | Larvicidal for migrating large strongyle larvae and a portion of encysted cyathostomins; no resistance by cyathostomins |
| Oxibendazole | 10 mg/kg | Some cyathostomin populations are resistant |
| Piperazine | 44 mg/kg | Rarely used; inconvenient to administer; no efficacy against large strongyles |
| Pyrantel pamoate | 6.6 mg/kg | Effective against adult stages only; some cyathostomin populations are resistant |
| Pyrantel tartrate | 2.64 mg/kg, q 24 h | Top-dressed on feed daily as preventive against strongylid infection; some cyathostomin populations are resistant |

vae contaminating pastures in autumn are likely to persist through the winter and following spring. Pasture infectivity does not decrease until the weather turns hot in June. Summer conditions in the ST are generally very hot, which disfavors both development and persistence. For ST horses, the major relief from the risk of strongyle infection occurs during summer, even for pastured animals.

The NT transmission season is virtually perennial. Although new larval development occurs only from spring through summer and autumn, winter pastures can still be a source of substantial infection, because larval survival is excellent in cold, even freezing, conditions. The only respite from infection for NT horses occurs when they are stabled for substantial intervals or turned out to non-vegetated dry lots and fed hay. Autumn and spring, with their moderate daytime and nighttime temperatures and generally high levels of precipitation, are favorable seasons for strongyle development and transmission in nearly all areas of the United States.

## 6. Elements of Life Cycles and Pathogenicity

Equine strongylids are traditionally divided into two groups, large strongyles and small strongyles (or cyathostomins). The environmental requirements for larval development and persistence are virtually identical for both groups.

### Large Strongyles

Large strongyles and cyathostomins differ in two key ways: (1) large strongyle larvae migrate extensively within the host through extra-alimentary tissues such as the liver, peritoneum, or regional arteries, and (2) large strongyle females exhibit relatively long pre-patent periods (PPPs) with a minimum of 6 mo between initial infection and the first appearance of eggs in the feces.

Larval large strongyles are highly pathogenic and damage the organs through which they migrate. Clinical signs of large strongyle infection are vague and non-specific but may include weight loss, poor growth, recurrent colic, rough hair coat, and compromised performance. Adult large strongyles attach to the mucosa and purportedly ingest blood and plasma, but this is a negligible feature of their overall pathogenicity.

### Cyathostomins

Shortly after infection, cyathostomin (small strongyle) larvae invade the lining of the cecum and ventral colon where they molt and grow within fibrous cysts in the mucosa or submucosa. Larvae may reside in the cysts for just a few weeks or for as long as 2.5 yr.[24] Cyathostomin larvae invoke minimal inflammatory response by the host as long as they remain encysted. When the cyst wall is ruptured by an emerging larva, however, the accumulated excretory and secretory products are released, creating foci of intense mucosal inflammation. The most significant damage caused by cyathostomins is associated with synchronous emergence of large numbers of encysted larvae, resulting in diffuse inflammation (hemorrhage and edema) of the cecum and ventral colon.[25] Adult cyathostomins live adjacent to the mucosa and primarily feed on organic material within the ingesta. Thus, mature cyathostomins do not play a significant role in the pathophysiology of clinical strongylosis.

## 7. Practical Control of Large Strongyles

Anthelmintics with label efficacy against adult or larval large strongyles are listed in Table 1. Because of the extraordinarily long PPPs of large strongyles, highly effective larvicidal treatments present a unique opportunity for strategic control. After a single larvicidal treatment, an entire PPP

Table 2. Historical Versus Current Status of Justifications for Interval Deworming

| Justification | 1966 | 2009 |
|---|---|---|
| Large strongyles (L. S.) are the major targets | L.S. were the most important cause of colic | L.S. practically eradicated from most well-managed herds |
| Rotation of drug class with each treatment | All anthelmintic classes were effective against strongyles | Only one class remains consistently effective |
| Treat perennially at bimonthly intervals | Interval treatment suppressed environmental contamination | Perennial treatment is unnecessary; frequent treatment selects for resistance |
| All horses in the herd treated identically | Contamination by the entire herd was suppressed | Members of a herd should be dewormed as individuals |

must expire before a treated horse could cause further contamination in its environment with large strongyle eggs. The minimum PPP for the large strongyles is 6 mo for *S. vulgaris*, and therefore, repetition of larvicidal treatments at intervals that do not exceed 6 mo would eliminate the host as a source of infection. If the entire herd were treated, the only other source of large strongyles infection on the farm is pasture, and infective strongylid larvae can persist in the environment for a maximum of only 1 yr (in all but extreme northern locales). Thus, larvicidal treatments administered at 6-mo intervals over a period of 18 mo will practically eradicate large strongyle infections from a premise.[26] Thereafter, maintaining a closed herd or treating new arrivals with a larvicide and quarantining them in a stall for 96 h should be sufficient to maintain the eradicated status.

## 8. Evidence-Based Control of Cyathostomins

The four main justifications for implementing interval treatment, as first proposed in 1966, have all been rendered moot in recent years (Table 2). Based on traditional attitudes and approaches, the prospects for achieving effective cyathostomin control may seem insurmountable. Rotation is no longer an option in many herds, frequent deworming selects strongly for anthelmintic resistance, and perennial, whole-herd treatments are excessive and unnecessary. So what, if any, recommendations can practitioners make for controlling small strongyles in the face of all these limitations?

The answer lies in what could be termed "evidence-based parasite control." The information that practitioners need to support effective control recommendations can be generated by answering three basic questions: (1) which anthelmintics are still effective in the herd, (2) which individual horses within the herd require minimal, moderate, or intensive control measures, and (3) what intervals or timing of anthelmintic use are appropriate for controlling specific parasites in the respectively classified individuals? All of these questions can be answered with simple technology and modest expense.

### Showing Anthelmintic Efficacy

With the exception of placebos in a clinical trial, no responsible veterinarian would knowingly use a product that was ineffective. And yet, millions of suboptimal anthelmintic doses are administered every year despite wide dissemination of information about increasing parasite resistance problems. Evidence-based parasite control demands that we use the best knowledge available. At a minimum, anthelmintic susceptibility profiles must be determined for the cyathostomin populations on every farm to identify the best tools for implementing a control program. Anthelmintic efficacy or resistance can be shown by fecal egg count reduction testing (FECRT), which employs quantitative, rather than qualitative, fecal examination techniques.[27] Several quantitative egg counting procedures have been described in the literature, but the McMaster technique is a rapid and inexpensive method that can be adopted easily by most veterinary practices.[28]

FECRT should be performed with horses ≥3 yr of age and only after a sufficient interval has elapsed since their last anthelmintic treatment; 6–8 wk should be a sufficient interval after dewormers of the benzimidazole or pyrimidine classes, but a 10–12 wk interval should be used after using ivermectin or moxidectin. Every eligible member of a small herd should be evaluated with FECRT, but in larger groups, a representative sample might be tested by enrolling 6–10 individuals per farm. Pretreatment fecal egg counts of all candidate horses are performed, but only those animals with egg counts ≥200 eggs per gram (EPG) should be included in formal calculations. After a pre-treatment egg count, every candidate horse to be screened is treated with an appropriate dose of the anthelmintic or drug class. Only three chemical classes are in common use, and therefore, in larger herds, it might be feasible to screen all drug classes during a single deworming episode. The product to be tested should be used strictly according to label directions, (i.e., dose the horse on the basis of a recent body weight measured with a livestock scale or girth tape, ensure that the product is not expired and has been stored properly before use, and administer the product meticulously so that spillage does not compromise efficacy testing). Rinsing feed or hay out of the oral cavity with tap water before paste or gel administration facilitates product retention and optimal dosing.

Lastly, between 10 and 14 days after treatment, collect fecal samples from the same individual horses for which you have pre-treatment results, and repeat fecal egg counts with the post-treatment samples. Fecal egg count reduction (FECR) is a measure of anthelmintic efficacy that is expressed in percentages. FECR is calculated by the formula:

$$\text{FECR} = (\text{mean}_{\text{control}} - \text{mean}_{\text{treated}}) / \text{mean}_{\text{control}} \times 100$$

Interpretation of the magnitude of egg count reduction that comprises acceptable efficacy varies with the class of compound. For benzimidazoles and pyrimidines, FECR >90% is considered satisfactory, but for ivermectin and moxidectin, 95% FECR is the minimum acceptable level.

Successful FECRT will identify the anthelmintic classes to which the resident cyathostomins are resistant or susceptible. If worms are resistant to a particular drug class, products from that chemical group should never again be used singly on the premises for cyathostomin control. Anthelmintic resistance seems to be a permanent genetic feature of a parasite population, and reversion to susceptibility may never occur.[29] Bear in mind, though, that drugs to which cyathostomins are resistant may retain substantial efficacy against other important equine parasites (e.g., *Parascaris equorum*), and they may have some utility for general strongyle control if administered simultaneously with an anthelmintic from another drug class.

After initial screening, the continuing efficacy of any drug classes that are still effective should be evaluated by annual FECRT.

#### Determining the Needs of Individual Horses

It is generally recognized that parasites tend to be over-dispersed within populations, so >80% of all the parasites within a herd might be harbored by only 20% of the hosts.[9] Such non-normal distributions are not determined by the parasites but by the host. Variations in host susceptibility are genetically controlled and are manifested in horses by differences in the magnitude of cyathostomin fecal egg counts. Approximately 50% of the horses in most herds consistently exhibit low fecal egg counts (<200 EPG) even in the absence of anthelmintic treatment. This has been shown to be a very consistent trait in individual horses over time.[30,31] Such animals contribute little to the egg contamination of communal pastures and probably benefit minimally from anthelmintic treatment. Reduction of egg passage by anthelmintic treatment of these individuals has comparatively little impact on strongyle transmission within the herd. Conversely, a small proportion of the herd (~20%) may be responsible for the majority of pasture contamination with strongyle eggs, and controlling parasites in these animals will have the greatest impact on the risk of infection for the entire herd.[9]

An individual horse's relative ranking by egg count within the herd can be determined by using the McMaster technique or other quantitative procedures. Again, a sufficient amount of time after the most recent deworming should be allowed to elapse. All mature horses in a herd should be tested, rather than a representative sample, because this is an assessment of individual characteristics. Definitive criteria for classifying a horse's strongyle contaminative potential are currently in development, but a preliminary estimation of herd rank can be based on general egg count ranges. Thus, horses with fecal egg counts <200 EPG are classified as low contaminators. Those with egg counts of 200–500 EPGs are considered moderate contaminators, and high contaminators are those with fecal egg counts >500 EPG. Because the strongyle contaminative potential of individual animals is genetically determined, it may be adequate to measure it only one time during an animal's lifetime.[32]

#### Program Recommendations for Individual Horses

The first two steps of an evidence-based control program will reveal the anthelmintics that are effective and will classify mature herd members by their respective strongyle contaminative potentials. The final step, implementation of selective control recommendations, is based on two additional factors: the seasonal patterns of transmission for the farm in question, and evidence-based timing of treatment applications. Seasonal transmission patterns were discussed previously in this article.

## 9. Egg Reappearance Periods

As Drudge and Lyons[2] reported over four decades ago, strongyle egg counts of horses decrease to very low numbers within a few days after effective anthelmintic treatment. Eventually, egg shedding resumes and egg counts return to pre-treatment levels. The interval between the treatment and resumption of fecal egg counts that would constitute <80% FECR is known as the egg reappearance period (ERP). The duration of ERPs is a very predictable parameter in mature horses, but it differs markedly with the anthelmintic used.[33–35] Typical ERPs for the most common equine anthelmintics are presented in Table 3.

Knowledge of ERPs is very useful for designing strongyle control programs. Theoretically, if one administered an effective anthelmintic at precise intervals that coincided with the ERP of the product used most recently, egg contamination could be suppressed for as long as the products remained effective. This strategy achieves the main objective of parasite control (i.e., suppression of environmental contamination) and was the original premise of the interval treatment recommendations in 1966.[2]

## 10. Example of Evidence-Based Application

The principles discussed may become more evident by examining a sample program that shows the

**Table 3. Duration of Cyathostomin Egg Reappearance Periods After Treatment With Various Anthelmintics**

| Anthelmintic Class | Drug | ERP in Mature Horses*† |
|---|---|---|
| Benzimidazoles | Fenbendazole | 4 wk |
| | Oxibendazole | 4 wk |
| Pyrimidines | Pyrantel pamoate | 4 wk |
| | Pyrantel tartrate | Administered daily, so egg reappearance periods do not apply; counts >100 EPG during a regimen suggest inefficacy |
| Macrocyclic Lactones | Ivermectin | 6–8 wk |
| | Moxidectin | 12 wk |

*Assumes a cyathostomin population that is susceptible to the respective drug.
†Egg reappearance periods in juvenile horses are 25–40% shorter.

principles of (1) basing treatments on the needs of individual horses, (2) concentrating treatments during the major season of local transmission, and (3) administering anthelmintics at optimal intervals. A sample program, organized by strongyle contaminative potential and monthly intervals, is presented in Table 4. Note that the column headers in the table do not correspond to numbering conventions for calendar months (2 is not February). Rather, month 0 represents the start of the annual strongyle transmission season in a given locale. In the ST region, month 0 would occur during autumn, whereas month 0 represents spring in a NT locale.

Program recommendations for the various levels of strongyle contaminative potential can be thought of as a pyramid. Horses that are low contaminators will receive a minimal maintenance program. The same measures will also be provided for moderate and high contaminators; however, moderate contaminator horses will receive one more intervention than the low contaminator group, and the high contaminator animals will be treated at least one time more than the moderate contaminator horses.

Because most well-managed herds have essentially eradicated large strongyles, it seems a laudable goal to maintain this eradication as the bare minimum standard for parasite control in all horses. Thus, every animal on the premise should be treated with a large strongyle larvicide at intervals ≤6 mo. Table 4 presents the options of ivermectin or moxidectin, but the larvicidal regimen of fenbendazole (10 mg/kg daily for 5 consecutive days) could be substituted. Although little is known about strategic control of equine tapeworms, the addition of praziquantel (or pyrantel pamoate at 13.2 mg/kg) to the biannual larvicidal treatment should limit transmission of *Anoplocephala* in most circumstances. Biannual administration of ivermectin or moxidectin also disrupts transmission of cyathostomins for at least 2 mo after treatment, so these measures are proposed as the sole control efforts for horses that are low contaminators.

The entire herd would benefit if moderate and high contaminators received one or more additional anthelmintic treatments to reduce cyathostomin egg excretion during the main season of local transmission. Because most chemical control programs will rely heavily on the macrocyclic lactone class of products, it would be preferable to use something other than ivermectin or moxidectin for intermediate treatments if an effective alternative exists. Benzimidazoles or pyrimidines could be used, if known to be effective, or the two could be used in combination if either still retains efficacy.

**Table 4. Example of a Selective Treatment Program for Controlling Strongyle Infections in North American Horses**

| Strongyle Contaminative Potential | Months (Main Transmission Season) | | | | | | Months (Minor Transmission Season) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12/0 |
| | Iv-P | | | | | | Mx-P | | | | | | Iv-P |
| Low | Mx-P | | | | | | Iv-P | | | | | | Mx-P |
| | Iv-P | | BZD/PYR† | | | | Mx-P | | | | | | Iv-P |
| Moderate | Mx-P | | | BYZ/PYR | | | Iv-P | | | | | | Mx-P |
| | Iv-P | | BZD/PYR | Iv/Mx | | | Mx-P | | | | | | Iv-P |
| High | Mx-P | | | BZD/PYR | Iv | | Iv-P | | | | | | Mx-P |
| | | | Bots–ST | | | | | | Bots–NT | | | | |

*Month 0 is ~March/April in northern regions and ~September/October in southern regions.
†A benzimidazole or pyrimidine product may be used if known to be effective; both classes may be given in combination if one or the other is known to be effective.
Iv, ivermectin; Iv-P, ivermectin + praziquantel; Mx, moxidectin; Mx-P, moxidectin + praziquantel; BZD, benzimidazole; PYR, pyrimidine; NT, northern temperate region; ST, southern temperate region.

**Table 5. Comparison of the Number of Annual Treatments With Selective Therapy Versus Bimonthly Interval Programs in a Theoretical 10-Horse Herd With 50% Low, 30% Moderate, and 20% High Contaminators**

| Classification | Number of Horses | Number of Annual Doses | Subtotal | Grand Total |
|---|---|---|---|---|
| Low | 5 | 2 | 10 | |
| Moderate | 3 | 3 | 9 | |
| High | 2 | 4 | 8 | 27 |
| Interval | 10 | 6 | 60 | 60 |

Inspection of Table 4 reveals that treatments with benzimidazoles or pyrimidines are scheduled in month 2 after the use of ivermectin but after moxidectin in month 3. This difference is intentional, because these products have differing ERPs (~8 wk for ivermectin and ~12 wk for moxidectin). Exploiting the full duration of a product's ERP reduces treatment frequency and theoretically, selects less intensively for the development of anthelmintic resistance.

High contaminators will receive yet one more treatment during the main transmission season. Table 4 schedules this treatment at 1 mo after treatment with benzimidazoles or pyrimidines, because the ERPs of those products are only 4 wk. If ivermectin is used for the intermediate treatment, the high contaminator group should be treated ~8 wk thereafter.

Deworming horses is unnecessary in all geographic regions during the ~6-mo period that comprises the unfavorable season for strongyle transmission. During this interval, environmental conditions largely prevent new parasites from developing. Even if horses have high egg counts during that period, relatively few of those eggs can develop into future parasites. Therefore, the objectives of parasite control are being accomplished by the climate, and chemical treatment is not required.

Although they are of minimal pathogenicity, bots will probably remain a desired target of equine parasite control; they are readily detectable, and annual boticides are a sacred tradition. To preserve the antinematodal efficacy of macrocyclic lactone products, it is desirable to minimize the number of treatments with this class during an annual cycle. Accordingly, it is regrettable that the only boticides currently marketed are moxidectin and ivermectin. Most bot treatments are administered in late autumn or early winter, so horses in the NT zone would receive one macrocyclic lactone treatment during the off season. For horses in the ST area, an annual boticidal treatment could be synchronized with the remainder of the program.

## 11. Comparisons

Table 4 is not intended to represent an off-the-shelf deworming program that can be implemented by practitioners from Minnesota to south Florida. Rather, it is presented strictly as a teaching tool to illustrate key concepts. Selective treatment should reduce anthelmintic and labor costs, because fewer treatments are administered during an annual cycle (Table 5). Fecal egg counting constitutes an additional cost; however, resistance needs to be proven only one time for each failed drug class and then annually thereafter for any products that are still effective. Similarly, egg counts to characterize a horse's strongyle contaminative potential may only need to be performed once in a horse's lifetime. Even so, the direct financial savings are minor compared with the long-term benefits of retaining drug efficacy and decreasing selection pressure for resistance. Admittedly, long-term studies of the efficacy of selective programs have not been reported, but wider adoption in the future will contribute more to our knowledge for making evidence-based recommendations.

## 12. Conclusion

It is obvious that traditional approaches to equine strongyle control are not sustainable. For decades, horse owners and equine practitioners have relied on rote deworming with drugs that may no longer be effective and have mistakenly assumed that frequent, whole-herd treatment was essential for maintaining the health of their charges. The excesses of the past have resulted in significant, present threats and future challenges. The tenets of evidence-based medicine demand, at the least, that the spectrum of effective products be elucidated for each equine premise. Further gains in sustainable strongyle control can be made if programs are based on knowledge of local, seasonal transmission patterns and customized for individual horses on the basis of their contaminative status within the herd.

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