New Perspectives in Equine Intestinal Parasitic Disease

Insights in Monitoring Helminth Infections

Kurt Pfister, DVM, Dip EVPC[a,b,*], Deborah van Doorn, DVM, PhD[c]

KEYWORDS

• Equine • Strongyles • *Parascaris* • SAT • TST • Egg counts
• Anthelmintic resistance • Epidemiology

KEY POINTS

- Regular anthelmintic treatment schedules have significantly contributed to the spread of anthelmintic resistance in horse helminths, particularly in small strongyles and *Parascaris*.
- This mass (or strategic) anthelmintic treatment—in most cases without prior diagnosis—was originally developed owing to a lack of larvicidal drugs against *Strongylus vulgaris*.
- This high prevalence of AR and shortening of strongyle egg reappearance period after avermectins/moxidectins requires epidemiologically appropriate and sustainable measures.
- As a consequence, (targeted) selective anthelmintic treatment is a much-needed, rational, and therefore highly valuable deworming approach, especially for adult horses.
- This method has been successfully used in several countries and many horse owners show a high degree of compliance.

INTRODUCTION

Parasites are an integral part of the global fauna, and consequently parasitic infections are ubiquitous in horses. Parasitism represents a significant consideration for any appropriate horse breeding, husbandry, and management program. However, when properly managed, equine parasite infections rarely pose major problems or can be successfully handled and treated. The authors present the most relevant horse helminths with an emphasis on temperate areas, in a priority ranking—according to pathogenic potential and the horse's age—and propose ways of keeping these infections under control by applying evidence-based medicine. Conventional interval treatment

Dedication: In memory of Prof. Gene Lyons, an outstanding equine parasitologist.

[a] Parasite Consulting GmbH, Wendschatzstrasse 8, CH-3006 Berne, Switzerland; [b] Institute of Comp. Tropical Medicine and Parasitology, LMU – University Munich, Munich, Germany; [c] Department of Infectious Diseases and Immunology, Faculty of Vet. Medicine, Utrecht University, Yalelaan 1, 3584CL Utrecht, The Netherlands
* Corresponding author. Institute of Comp. Tropical Medicine and Parasitology, LMU – University Munich, Munich, Germany.
E-mail address: kpfister@duc.ch

Vet Clin Equine 34 (2018) 141–153
https://doi.org/10.1016/j.cveq.2017.11.009 vetequine.theclinics.com

measures that have led to the development of significant drug resistance are contrasted with a more efficacious and highly targeted antiparasitic approach.

PARASITE SPECIES IN ORDER OF PATHOGENICITY

Parascaris spp

Horses ingest the thick-walled *Parascaris* eggs while grazing. The eggs hatch and larvae begin to migrate from the intestine, through the liver to the lungs (about 1–2 weeks after infection). Subsequently, larvae penetrate the alveolar capillaries to enter the airways, and migrate via the bronchi to the trachea, are coughed up and swallowed. Within 3 weeks, larvae are back in the small intestine and develop into adult worms. The prepatent period is approximately 9 to 16 weeks. Elimination of all eggs from the environment (stables, paddocks, pastures) is virtually impossible; larvated eggs can survive for years.

STRONGYLES ("LARGE" AND "SMALL" STRONGYLES)

Large Strongyles (Strongylus spp.)

The 3 species of this genus (*Strongylus vulgaris*, *S edentatus*, and *S equinus*) are robust, dark-red nematodes (10–50 mm) residing in the cecum and colon, and undergoing mandatory, parenteral migration in their larval stages. *Strongylus* spp. infections are pasture-associated parasite infections and on pasture, the excreted eggs develop into infective larvae 3 (L3). Ingested L3 undertake a parenteral migration and subsequent development occurs outside the alimentary tract.

S vulgaris larvae migrate along arteries and congregate at the root of the cranial mesentery artery, where they remain for several months and undergo a molt to L5 before returning to the large intestine via circulation. *S vulgaris* adults begin to lay eggs approximately 6 to 7 months after infection. In many parts of Europe and North America, *S vulgaris* has become rare.

S edentatus larvae move via portal veins to the liver and migrate through the parenchyma before further migrating beneath the peritoneum of the ventral abdomen and flanks and returning to the intestinal lumen. The prepatent period of *S edentatus* is approximately 11 months.

After first forming nodules in the gut wall, *S equinus* larvae also travel to the liver to migrate through the parenchyma before continuing to the pancreas and returning to the large intestine; the prepatent period is approximately 8 to 9 months.

Small Strongyles (Cyathostomins)

Small strongyles encompass more than 50 species, of which about 10 comprise more than 98% of all small strongyle populations. These nematodes (4–25 mm) reside exclusively in the cecum and colon, and may be present in huge numbers, often exceeding 100,000 per horse. The prevalence of small strongyles in young (<4 years), pastured horses approaches 100%, so cyathostomin infections are virtually ubiquitous in grazing horses. Despite their high prevalence, adult cyathostomins generally do not inflict pathology. Owing to similarities of morphology, biology, and epidemiology, these nematodes are usually considered as a single entity, and therefore are discussed accordingly.

Eggs produced by adult cyathostomins develop into infective L3s on the pasture in the presence of appropriate climatic conditions. After ingestion, L3s invade the gut wall and are enclosed in a fibrous capsule of host origin (encysted stages). After intervals ranging from weeks to perhaps more than 2 years, larvae emerge into the intestinal lumen and molt into young adult worms. The prepatent periods vary from 5 weeks to several months, depending on species and whether larvae undergo arrested development while in the host. Favorable microclimatic conditions on pastures during the grazing season not only facilitate the hatching of eggs and the development to infective stages, but also the survival of L3s for extended periods. These conditions all contribute to accumulation of infective larvae on pastures toward the end of the grazing season, posing an increased risk of infection. In temperate climates, infective L3s can overwinter on the pasture, especially if protected by a snow cover, and be a source of reinfection in the spring.

Anoplocephala and Anoplocephaloides

All cestodes (tapeworms) require an intermediate host; for equine tapeworms, these hosts are oribatids (mites), which are ubiquitous in forage and associated soils. Thus, tapeworm infections are most frequent in pasture-based management systems. Three species of tapeworms are known to equids. *Anoplocephala perfoliata*, 2.5 to 4 cm, is the most common, and is predominantly found in the cecum near the ileocecal junction. *A magna* (up to 50 cm) and *Anoplocephaloides* (1–4 cm) are usually found in the small intestine. Equids are infected while grazing and ingesting oribatid mites with an infective metacestode stage. After a prepatent period of at least 6 weeks, adult worms produce thick-shelled, irregularly round- or trapezoidal-shaped eggs containing an oncosphere surrounded by a pear-shaped apparatus. Mite populations amplify similar environmental conditions also favorable for strongylid larval development, so there seems to be an increased risk for horses during late summer and autumn.

Other intestinal parasitic infections include *Strongyloides westeri*, *Trichostrongylus axei*, *Oxyurids*, *Cryptosporidium* spp. (in foals), *Giardia* spp. (in foals), and *Gasterophilus* spp. Three bot species, *G intestinalis*, *G nasalis*, and *G haemorrhoidalis*, have been introduced into the Americas. All these species should be specifically diagnosed and treated according to available drugs and published recommendations.

CLINICAL SIGNS IN VARIOUS AGE GROUPS

Virtually every horse harbors some intestinal parasites, beginning at a few days of age and continuing throughout its life. The majority of these infections cause no clinical signs, either because the parasite is inherently nonpathogenic, or is not present in sufficient numbers to disrupt homeostasis. Regardless, any abnormal clinical signs of the alimentary tract should trigger some consideration for parasitic disease, even in horses that recently received anthelmintic treatment.

This article's scheme for addressing clinical parasitoses is (i) to rank horses into distinct age groups, (ii) to identify distinct clinical signs, and (iii) to formulate a differential diagnostic list of potential parasitic pathogens.

New-Born Foals up to Weaning

Alimentary clinical signs

Diarrhea at 2 to 3 weeks of age could be associated with the protozoa *Cryptosporidium* spp. or occasionally by *S westeri*. These infections can be accompanied by inappetence, diarrhea, unthriftiness, and emaciation.

Foals are susceptible to *S westeri* infections until about 6 months of age. *S westeri* mainly reside in the duodenum and jejunum, and may cause local mucosa erosions followed by inflammation and edema. When present in large numbers, the infection can lead to catarrhal enteritis and diarrhea; clinical signs may be associated with high *Strongyloides* egg counts. Diarrhea in young foals may be caused by different circumstances (eg, postfoaling estrus of the mare), the presence of *Strongyloides* eggs in a foal with diarrhea is not proof of cause and effect.

Developing stages of *Cryptosporidium* spp. in the lower part of the small intestinal mucosa are responsible for stunting and swelling of microvilli. Severe infections can be accompanied by watery diarrhea.

Parascaris spp. are the most common pathogenic parasites of foals. Potential clinical signs include diarrhea, obstipation and/or colic, lethargy, rough coat, pot-bellied appearance, and weight loss or poor growth. Adult *Parascaris* reside in the small intestine, and worst case scenarios can involve intestinal obstruction or impaction, with potential intestinal perforation and fatal peritonitis. Ascarid impactions frequently occur within 48 hours after deworming the foal with anthelmintics that have a neuromuscular mode of activity (eg, avermectins, moxidectins, and pyrantel).

Low burdens of adult *Parascaris* generally remain asymptomatic. *Parascaris* disease mainly occurs during the first year of life, because strong protective immunity develops, independent of treatment.

Weaned Foals from 6 to 12 Months of Age

Alimentary clinical signs

Until the onset of protective immunity, *Parascaris* infections can cause diarrhea, impaction colic, and unthriftiness. Large *Parascaris* burdens can contribute to mechanical obstruction of the intestinal lumen.

This age group of foals may exhibit colic caused by either *Parascaris* spp. or migrating *S vulgaris* larvae, resulting in proliferative endarteritis with potential thromboembolic sequelae, obstruction of the mesenteric circulation, and intestinal infarction.

Diarrhea and unthriftiness in foals have been associated with emerging larval stages of cyathostomins.

Anoplocephala infections occasionally are the cause of alimentary signs related to ileal obstruction or cecal intussusceptions. They can be very difficult to diagnose definitively ante mortem.

Juveniles 1 to 4 Years of Age

Alimentary clinical signs

Adult small and large strongyles, even when present in high numbers, generally do not cause alimentary signs, mainly because they reside in the gut lumen and do little damage to the intestinal mucosa. Adult worms are observed occasionally in the feces, but they provide no indication of the size of the worm burden or their pathogenicity.

As part of their obligatory life cycle, larval cyathostomins invade the mucosa and submucosa of the cecum and colon, causing inflammation marked by edema, hemorrhage, and accumulation of eosinophilic and mononuclear cells. The severity of mucosal lesions varies with the number of ingested larvae and the immune status of the host. Burdens of several hundred thousand worms are not uncommon. The most severe syndrome associated with small strongyle infection results from mass emergence of large numbers of encysted cyathostomin larvae. Such emergence usually coincides with the cessation of arrested development, which explains its late winter or early spring seasonality in northern temperate climates. This syndrome, termed larval cyathostominosis, may also be triggered by a recent anthelmintic treatment during seasons when high numbers of hypobiotic larvae have accumulated. Removal of luminal worm populations by deworming may stimulate the emergence of encysted larvae to repopulate the vacated niche.

Clinical signs of larval cyathostominosis include watery diarrhea, dramatic weight loss, and ventral edema. Horses suffering from larval cyathostominosis exhibit hypoalbuminemia, hyper-β-globulinemia, a decreased albumin to globulin ratio, leukocytosis, dehydration, and additional physiologic disruptions. Larval cyathostominosis cannot be reversed by therapeutic deworming, and severe cases have a high mortality rate.

Diarrhea, colic, and unthriftiness may also be associated with *Anoplocephal*a infections, presumably related to ulceration of the cecal mucosa at their attachment sites. This may lead to ileal impaction, cecal intussusception, and spasmodic colic.

Nonspecific or general clinical signs

Migrating larvae of *S vulgaris* cause proliferative endarteritis and thrombus formation in juvenile horses, as well as in foals. Pathologic changes within the circulatory system include aneurysm and thromboembolic infarction. The major clinical sign is colic.

Tail rubbing is a common response to pruritus of the perianal region, caused by the egg-laying activity of adult *Oxyuris*. Pinworm infection is not restricted to any age category, although historically younger horses were more prone to infection. Local skin infections and damage to the hair coat are the major consequences of pinworm infection.

Although *Parascaris* eggs can still be detected in juvenile horses, severe clinical signs are no longer expected.

Adult Horses (>4 Years of Age)

Alimentary clinical signs

In general, parasites cause minimal clinical disease in mature horses, so specific diagnostic measures are recommended rather than rote, empirical deworming.

Larval cyathostominosis may occur in adult horses subsequent to massive larval exposure or compromised immunity. *Parascaris* eggs are occasionally detected in the feces of mature horses, but clinical signs are not expected.

Other parasitic causes of unthriftiness or colic in adult horses include *Anoplocephal*a infections and larval *S vulgaris* infections.

DIAGNOSTIC PROCEDURES

Clinical signs, age, and a recent deworming history are undoubtedly insufficient to arrive at a definitive parasitologic diagnosis. Clinical decisions should always be substantiated by laboratory diagnostics. Many procedures can be performed in a veterinary practice setting with appropriately trained and supervised staff and requires minimal specialized equipment.

Merely detecting the presence of reproductive products is sufficient to confirm some tentative diagnoses. For example, demonstration of *Oxyuris* eggs in a perianal scraping is sufficient to confirm a diagnosis of oxyurosis in a tail rubbing horse. In contrast, strongyle eggs are so ubiquitous in the feces of grazing horses that their mere presence does not confirm strongylosis as the cause of the present signs.

CONTROL OF PREVALENT GASTROINTESTINAL PARASITES

This section focuses on Strongyles (large and small strongyles), *Parascaris* and *Anoplocephala* and presents a modern, sustainable program called selective anthelmintic treatment (SAT) in comparison with the conventional interval dose treatment.

CONVENTIONAL INTERVAL TREATMENT

The introduction of the benzimidazoles in the 1960s was soon followed by a novel approach to parasite control, that is , using anthelmintics to disrupt the life cycle of horse nematodes. This treatment approach consisted of repeated deworming at regular intervals, which effectively coincided with the egg reappearance period of common strongylid nematodes. This regimen, termed the interval dose system, was developed by Drudge and Lyons,[1] and its main objective was control, if not eradication, of *S vulgaris*. A rote regimen of bimonthly or 3 to 4 times per year deworming rapidly supplanted targeted treatments based on a specific diagnosis. Regrettably, routine habit displaced monitoring for efficacy, and undoubtedly contributed to the ubiquity of benzimidazole resistance. As other anthelmintic classes became available for commercial use, the same schedules were followed and the inevitable consequence was resistance in other target parasites as well, most notably *Parascaris* spp.[2,3]

The basic element responsible for the success of the interval system was deworming at a frequency coincident with the egg reappearance period of the target parasite(s).[4] The various anthelmintic classes have different egg reappearance periods, (https://aaep.org/guidelines/parasite-control-guidelines) and deworming at intervals equal to or shorter than the egg reappearance period can select very intensively for anthelmintic resistance (AR).

Blind treatments (those administered without specific diagnostic evidence) against *Anoplocephala* traditionally consisted of 1 or 2 anthelmintic treatments against cestodes with either praziquantel or pyrantel during the spring and/or autumn. Based on tapeworm epidemiology, a single-blind treatment in the autumn is acceptable if *Anoplocephala* is known to be endemic on a farm.

Performing diagnostics to know when to treat for *Parascaris* is more difficult, because heavy infections can rarely cause problems during larval migration, and treatments against adult worms can cause intestinal blockage in foals and weanlings.

Blind treatments with any dewormer should not be administered unless the AR status of the herd is known. Use of anthelmintics against resistant populations is clinically ineffective, and contributes to further intensification of the resistance status. Establishing the resistance status of endemic *Parascaris* strains is critical, because macrocyclic lactone resistance is ubiquitous, and pyrantel resistance has been documented in several herds.

ANTHELMINTIC RESISTANCE

AR is the ability of parasites to survive dosages of drugs that were effective against the same species and stage of infection when the product was first introduced.

The universal use of benzimidazoles since the mid-1960s resulted in highly prevalent resistance among cyathostomins by the late 1970s. Resistance against the tetrahydropyrimidines exists in many parts of the world, and at least in North America may be related to the availability of formulations for daily dosing in the United States and Canada.[5] Resistance of cyathostomins to both of these drug classes now occurs worldwide.[2,6]

It was hypothesized that AR to macrocyclic lactones would not develop readily in cyathostomins or *Parascaris*, owing to the presence of large environmental *refugia* (the proportion of the parasite population not under selection pressure of an anthelmintic, here, pasture L3s and embryonated eggs). Resistant *Parascaris* spp. were first reported by Boersema and colleagues,[3] but since in many countries.[7,8]

During recent decades, the macrocyclic lactones have been used mainly or exclusively on many premises, and in many intensively managed facilities the control of cyathostomins was done through blind anthelmintic treatments, without monitoring for AR.

Pursuing alternative strategies to slow the development of macrocyclic lactone resistance in cyathostomins should be a priority, because no classes of anthelmintics with new modes of action are currently under development for horses.

HOW TO DETECT RESISTANCE

Fecal egg count reduction testing (FECRT) is still considered the gold standard for detecting AR in vivo. Nevertheless, it may be difficult to document true AR among cyathostomins, especially if FECRT indicates that the anthelmintic is still highly effective against the adult stages.[9]

Because more than 50 species of cyathostomins have been identified, it seems probable that various species have differing susceptibilities to AR development.[10] Lyons and colleagues[11] found luminal larval stages shortly after ivermectin treatment in necropsied horses and suggested that these larval stages had survived owing to macrocyclic lactone resistance. A shortened egg reappearance period may indicate the development of macrocyclic lactone resistance in larval stages.[12]

Fortunately, many authors have published on the interpretation of equine parasitologic diagnostics, and recent guidelines for interpreting equine FECRTs in a research setting have been adopted in the United States.[5] Owing to reported shortening of the egg reappearance period on some premises,[13] egg counts for FECRT comparisons should not be limited to days 0 and 14, but should also be performed at 42 or 56 days after treatment with ivermectin or moxidectin, respectively.

A critical analysis of various issues associated with conventional interval treatment clearly demonstrates that more appropriate monitoring and alternative control regimens are needed.[5,14,15] Also, it is, in the author’s opinion, unnecessary and ecologically and ethically inappropriate to treat a high percentage of horses that do not show any detectable gastrointestinal parasite infection.

THE NOVEL CONTROL PROGRAM “SELECTIVE ANTHELMINTIC TREATMENT” STRATEGY IN CONTRAST WITH THE “CONVENTIONAL INTERVAL DOSE TREATMENT” OR (“ROTE DEWORMING STRATEGY”)

The SAT deworming strategy focuses on the presence of strongyles as an essential prerequisite for treatment. With the SAT approach, only horses with individual egg counts of 200 eggs per gram of feces (EpG) or higher will be treated with anthelmintics. Alternatively, groups of horses, with a maximum of 10 animals in a pool, would be treated as a group when the average strongyle egg count exceeds 100 EpG. An additional consideration for modifications to SAT would be the documented presence of other, potentially pathogenic parasites. For additional background information for Northern European countries, with mild climatic conditions see the following websites: “Decision Tree Horse” (http://www.parasietenwijzer.nl/eng/horse/GB_DesicionTreeHorse.html) or “Cavallo – Calendar” (http://www.cavallo.de/pferde-medizin/wurmkur-fuers-pferd-selektive-entwurmung-und-weidehygiene.626691.233219.htm#1, or for North America: https://aaep.org/sites/default/files/Guidelines/AAEPParasiteControlGuidelines_0).

SELECTIVE ANTHELMINTIC TREATMENT AND REFUGIA

SAT is a valuable, alternative anthelmintic approach that has been adopted rapidly in several areas of Europe and North America. In Denmark, this system has even been mandated by national regulation. At present, use of the SAT system is restricted to adult horses, although some promising results have been reported for horses less than 3 years of age.[16]

The SAT system is based on the distribution of intestinal worms within a host population. It is well-known that the majority of parasites occur in a limited number of individuals within any host population.[17,18] Accordingly, only some adult horses are wormy, although up to 50% of all herd members shed very few or no worm eggs in the feces.[19] This "low shedding" proportion requires few if any anthelmintic treatments.[20–22]

Some readers will misconstrue selective treatment as an attempt to deworm only those individuals with high worm burdens. However, it should be noted that the magnitude of a horse's worm burden cannot be quantified ante mortem and alternative criteria for treatment selection must be considered. Although egg counts are not correlated with worm numbers, strongyle egg shedding is a good indicator of future infection pressure on contaminated pastures, and high-contaminating horses often shed more eggs than the rest of the herd combined. When low- or zero-shedders are sorted out on a particular farm, fecal monitoring and anthelmintic treatments can be concentrated on the high egg shedders, who are responsible for the majority of contamination. An international consortium of equine parasitologists has set a tentative threshold for a strongyle treatment at 200 EpG (IEIDC meeting Kentucky 2012).

How does one implement a SAT program for a given horse population?

- Three fecal samples should be examined from each herd member during the first year as a baseline and characterization of the horses in a herd. All horses repeatedly shedding 200 EpG or more are characterized as high strongyle egg shedders, and will consequently be treated regularly, in contrast with other members of the herd.
- All horses with an egg count higher than the threshold will be appropriately dewormed with a product known to be effective against the target strongyle population.
- Regardless of their egg counts, individual horses that seem to demonstrate clinical manifestations of a parasitic disease may be specifically dewormed on the recommendation of a veterinarian.
- Because anthelmintic treatment is limited to horses shedding high numbers of worm eggs, contamination of the horse paddocks and pastures will be significantly reduced over time.
- This method will allow for a simultaneous efficacy evaluation of the drugs administered. To monitor AR development, fecal samples for quantitative examination should be collected before treatment, at Day 14 and again 42 days after ivermectin treatment, and 56 days after dosing with moxidectin. For anthelmintics containing benzimidazoles or pyrantel salts, fecal counts should be performed at 14 days after treatment. FECRT is conducted to compare changes in egg counts presumably owing to anthelmintic treatment.
- Detection of AR within the herd will drive decisions regarding anthelmintic selection, and can help to prevent spreading of resistant strains on the pastures and paddocks.
- Low and/or moderate contaminator horses (egg counts below threshold level of 200 EpG) will continue to shed eggs without any selection pressure, and thereby contribute positively to the maintenance of *refugia* on the pastures.
- Continuous egg shedding by low EpG horses may enhance host immunity through constant stimulation of host defense factors.
- The SAT system provides adequate parasite management for horse herds, while promoting and maintaining controllable *refugia*.[23]

The SAT system can be modified for individual horses or for characterized groups of horses for premises with very large populations of equids.

SELECTIVE ANTHELMINTIC TREATMENT PRACTICAL TREATMENT PROCEDURE

General Considerations

Owing to the ubiquity of AR in cyathostomins and ascarids, it is recommended that no antiparasitic treatments should be administered to adult horses without preceding diagnostics. In some countries, such as Denmark, prophylactic anthelmintic treatment is forbidden by law.

A comprehensive diagnostic analysis, at least at the herd level, would include a (pooled) larval culture or a molecular-based analysis to demonstrate the presence or absence of large strongyles on the farm. Because up to 50% of adult horses within a discrete population may shed no or very few nematode eggs, there is no medical indication for the anthelmintic treatment of those individuals, let alone of the entire herd. It is recommended that comprehensive records of fecal examinations be maintained, because historical evidence could support future changes to the parasite management program.

After examining 3 samples from each horse during the introductory year, horses can be classified confidently as low, moderate, or high egg shedders. Egg counts from individual horses are very repeatable,[21,22,24] so future monitoring could be performed at a lower frequency.

Although initial monitoring makes parasite control more demanding than rote treatment programs, these measures are justifiable from a veterinary medical and ethical point of view. Moreover, selective treatment uses fewer doses of drugs, with evident economic and ecologic advantages.

On premises that still have endemic *S vulgaris* populations, it is recommended to administer a moxidectin treatment to all horses during late autumn (mid-November to mid-December). The objective of such a treatment is to reduce the number of migrating large strongyle larvae, plus a portion of encysted cyathostomin larvae, with the added benefit of concurrently removing *Gasterophilus* spp instars over wintering within the horse.

For any specific anthelmintic treatment, it is essential to know the resistance status for that drug class in the resident parasite population. Also, the egg reappearance period after the use of that drug on the farm should be compared with the published egg reappearance period at the time of initial introduction. A shortened egg reappearance period may be a sign of developing resistance. SAT can only be successful if AR testing is an integral feature of the program.

ADULT HORSES

Single Horses and Small Groups

The SAT system can be adopted for single horses or very small herds. After characterizing the contamination potential of the horse(s) with 3 samples during the first grazing season, treatment decisions are implemented as for larger groups. Thereafter, a treatment schedule may be followed as outlined in the “Cavallo-Calendar” or the “Decision tree” or the American Association of Equine Practitioners guidelines. A horse that never exceeds the threshold level of 200 EpG will not require any treatment, but should be monitored in the future with at least 1 fecal analysis per year. Horses with strongyle EpG of 200 or greater, or with diagnostic evidence of *Parascaris* or cestode infections should be treated and/or monitored according to the “Cavallo – Calendar” (http://www.cavallo.de/pferde-medizin/wurmkur-fuers-pferd-selektive-entwurmung-und-weidehygiene.626691.233219.htm#1), or “Decision Tree”(http://www.parasietenwijzer.nl/eng/horse/GB_DesicionTreeHorse.html), or the American Association of Equine Practitioners guidelines (https://aaep.org/sites/default/files/Guidelines/AAEPParasiteControlGuidelines_0).

If products other than macrocyclic lactones remain efficacious against strongyles, they should be used preferentially, and macrocyclic lactones be kept in reserve. If *S vulgaris* is detected, either through larval cultures or by polymerase chain reaction, it is recommended that the entire group be treated with a macrocyclic lactone.

If *Parascaris* is present, however, the horse should not be treated with macrocyclic lactones unless the AR status on the farm has been determined. For *Anoplocephala*, the drugs of choice are either praziquantel or a double dose (13.2 mg/kg) of pyrantel. Nematocides and cestocides can be combined if there is a simultaneous need for treatment of small strongyles. In general, however, combination products should not be used unless there is specific evidence of concurrent nematode and cestode infections.

Horses in Large Populations

SAT can be implemented for large herds of horses as previously. However, modifications may be considered if age-clustered groups of horses are regularly kept together on the same pasture. In such cases, fecal samples from subgroups of horses (eg, n = 10) can be pooled, and the threshold for treating such a group is 100 EpG for strongyles.[25] Detection of *Parascaris* eggs, however, will require that—out of a positive pooled sample—individual fecal samples be examined to identify the affected horse(s). Thereafter, the same schedules can be followed as for individual horses. Thus, treat individual horse if eggs of *Parascaris* are detected, and treat the whole herd if eggs from *Anoplocephala* are detectable.

For optimal epidemiologic benefit, all horses on a single premise should participate in a SAT system, particularly any that share a common grazing venue.

Geriatric Horses

Opinions vary whether geriatric horses are more susceptible to parasitic disease. However, fecal analyses are highly recommended for geriatric horses with compromised health, followed by anthelmintic treatment if appropriate.

HORSES AT BREEDING FARMS

Mares and stallions at breeding facilities may be managed the same way as other adult horses with the SAT system. However, owing to the high economic value of breeding animals, owners and managers may be much more reluctant to “trust” selective treatment, and may prefer to maintain an interval treatment program, or even to administer pyrantel tartrate on a daily basis.

In North America, pyrantel tartrate is approved for daily administration (2.64 mg/kg/d) and the aim is to prevent the establishment of immature strongyles or ascarids after the ingestion of infective stages. Daily pyrantel tartrate has label claims against large strongyle adults (*S vulgaris*, *S edentatus*, and *Triodontophorus* spp.), cyathostomin adults, and fourth stage larvae, *Oxyuris equi* adults and fourth stage larvae, and *Parascaris equorum* adults and fourth stage larvae. Daily pyrantel tartrate can, under certain circumstances, be a very useful management tool. One example would be individual treatment of high-shedding horses that graze with a herd. By reducing the fecal egg count of a selected number of horses, the potential exposure for the entire group is reduced. But, application to entire groups of horses is rarely necessary because low and moderate shedders may not cause sufficient contamination to justify the expense, and this tenet applies to all individual anthelmintic treatments of low to moderate shedding horses.

There is a reasonable concern that daily exposure of a parasite population to an anthelmintic compound would help to select for resistance. However, pyrantel tartrate has no activity against encysted mucosal or migrating larval stages, so a considerable proportion of the worm burden of horses on daily treatment is technically *in refugia* (a worm population that is not subjected to a pharmaceutical drug, eg, parasite stages on the pasture, etc). Horses maintained on daily pyrantel tartrate still produce strongyle eggs, albeit in fewer numbers than if they were not on this prophylactic program.[26]

TREATMENT AND PREVENTION OF *GASTEROPHILUS* INFESTATIONS

In areas with endemic *Gasterophilosis*, a treatment for larval stages is indicated even though these parasites are generally of low pathogenicity. In the Northern hemisphere, it is recommended that all horses on farms at risk be treated during late autumn, after pasture grazing has terminated and adult flies are no longer active. Owing to the broad spectrum of the macrocyclic lactones, the only efficacious drug class, a specific treatment for *Gasterophilus* spp. effectively serves as a so-called late fall treatment against large strongyles and/or larval cyathostomins.

TREATMENT OF *ANOPLOCEPHALA* INFECTIONS

Anoplocephala infections should be targeted with a single active ingredient, unless there is diagnostic evidence of concurrent nematode and cestode infections. Unfortunately, praziquantel is not available as a single treatment option in every country. Because *Anoplocephala* is endemic in most herds, and these infections are very difficult to detect, all horses in a given herd should be treated whenever positive diagnoses are made in individual horses. Because *Anoplocephala* populations accumulate over the grazing period, it is recommended to administer a single treatment near the end of summer to reduce worm burdens through the winter.[27]

INFECTION POTENTIAL IN STABLES

The biological development of strongyles from eggs to the infective L3 stage is strongly associated with vegetation on pastures, that is, grazing, climate, humidity, and so on. Although some limited larval development may also occur in stables or even on bare ground or paddocks, the contribution of these larvae to the total uptake for horses is quantitatively irrelevant.

Foals can also acquire infective roundworm eggs or *S westeri* larvae in a stable. Therefore, hygienic measures should be implemented.

Last, horses of all ages can acquire *Oxyuris* infections when stabled.

PASTURE INFECTIONS AND PASTURE MANAGEMENT

Because pastures are the major, immediate source of strongyle and tapeworm infections, pasture management plans should consider the potential impact of any measures on transmission of these parasites. As shown by Herd,[28] frequent removal of feces from horse pastures (2–3 times weekly, depending on the climate) affords significant reduction of pasture infectivity, thereby reducing the potential of reinfection for grazing horses.

However, such labor-intensive measures are rarely implemented, owing to lack of staff or equipment. Certain alternative strategies have been considered.

1. It has been shown repeatedly that “cross-grazing” of horses with sheep or cattle can significantly reduce pasture larval transmission.[29]

2. Rotational grazing can be very effective, but proper implementation requires a thorough understanding of parasite epidemiology in the local area. Strongyle larvae can survive for long intervals on pasture under the right environmental conditions, and tend to accumulate over a grazing season. Contaminated pastures often remain infective even in the absence of horses.

ACKNOWLEDGMENTS

The authors sincerely thank Dr Craig R. Reinemeyer, Rockwood, Tennessee, for his greatly appreciated editorial help, his constructive and critical comments, and his frankness toward our ideas.

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