Literature review of three common equine hoof ailments: Laminitis, Thrush and Navicular disease

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Abstract
The health of the equine hoof is closely tied to the animal's overall condition and well-being. Despite this, hoof pathology remains relatively understudied. Laminitis, thrush, and navicular disease are three common disorders which impact domestic horses and donkeys. Laminitis can present itself in three different forms: acute, mechanical, and endocrine (Ramey, 2011). Acute and endocrine laminitis are related to hormone imbalances in the body, specifically those regulating sugar consumption and insulin production (Morgan, 2015). Mechanical laminitis is most often related to conformation faults at birth, but can also be due to poor trimming or shoeing methods (Ramey, 2011). Thrush is an anaerobic bacterial infection of the hoof by the Fusobacterium necrophorum bacteria in the absence of Dichelobactor neodosus bacteria (Petrov, 2013). This infection typically goes untreated as it appears to cause minimal external damage, but often causes extensive pain if left untreated. Navicular disease is the least understood of these three diseases (Yorke, 2014). It is generally described as pain originating from the navicular bone but there exist conflicting theories regarding what is causing the pain. Through this research, it can be concluded that a more effective protocol for diagnosing and treating these three ailments needs to be further developed, in part by encouraging the collaboration between veterinarians and farriers.

Keywords
Equine Health — Laminitis — Thrush — Navicular disease

1. Introduction

The expression "no hoof, no horse" is common within equine communities, and yet so many diseases which impact the equine hoof are left understudied. Disorders such as laminitis, thrush, and navicular disease are of particular concern for domestic horses. In a news article by the Inquirer, Andrew van Eps describes that in the early 2000s, veterinarians still believed that all cases of laminitis were similar and related to issues of blood flow (Jerardi, 2017). Current research has only just begun to delve into how insulin is a major contributor to problems concerning laminitis.

Thrush is an ailment often left untreated as it does not appear to be a particularly concerning problem for affected horses. However, horses which go years without successful treatment often develop the more severe white line disease. With current practices encouraging the use of ineffective and drastic shoeing practices, many horses never find relief. The most understudied of these maladies is navicular disease. Without a clear understanding as to how to diagnose the disease, many horses are left for years with mystery lameness. Even once the horse has been diagnosed with navicular disease, the causes are understudied and there is minimal action that owners can take to help their horse. This paper intends to explore the diagnosis, causes and treatments for these common hoof ailments, through literature review as well as discussion with hoof lameness specialists.

2. Laminitis

Laminitis can manifest due to a variety of ailments and has a wide range severity and onset. Laminitis is a disease reflected by the inflammation of the connective tissue in the hoof capsule called the laminae (Ramey, 2011). As laminitis progresses and the laminae become weaker, the P3 bone or distal phalanx can begin to rotate downward; an action referred to as foundering (Ramey, 2011).

Laminitis can be divided into three subtypes depending on the cause: acute, mechanical, and endocrine. Acute laminitis can be caused by an excessive one-time intake of sugar or by toxins in the form of bacterial infection or colic. Mechanical laminitis is caused by the physical malformation of the hoof or by poor trimming or shoeing techniques, in combination with impact over time. Endocrine laminitis can be caused by obesity, hormonal imbalances, acute or prolonged periods of stress, or by toxins created by liver or respiratory diseases (Rendle, 2017a). As much as laminitis is a serious disease in its own right, more often than not it is a symptom of a larger

problem. Both acute laminitis and endocrine laminitis are related to the horse's inability to correctly regulate insulin (Rendle, 2017a).

3. Acute laminitis

Within domestic horse populations, acute laminitis most often presents itself in the form of sudden increase in the intake of excess sugars (Ramey, 2011). This can be in the form of excess grains or other concentrated feeds over time or in an acute setting. However, more commonly the excess sugars are found in grasses in the spring and fall. Fructans are the plant's polymers or oligosaccharides of stored fructose . These sugars are present in greater amounts in grasses in the spring and fall following frost events, as well as throughout the winter while the grasses survive under the snow (Ramey, 2011). The sugars in the grass can be problematic during these times because the fructan form of sugar cannot be digested by the horse. The oligosaccharides pass through the horse's small intestine and are deposited into the hind gut undigested. This sugar is then processed and consumed by Streptococcus lutetiensis bacteria (Ramey, 2011).

The metabolism of fructans by these bacteria can cause harmful problems for the horse in two ways. First, the Streptococcus lutetiensis bacteria produce harmful lactic acid in the horses gut as they consume the sugar. Secondly, the disruption in the horses gut triggers the body to produce an increase of insulin, the increase of which is related to the inflammation of the laminae. Horses which are free to graze most of the time have a stronger ability to adjust to changes in the grass. However, horses who are only pastured part time and are fed supplemental grains and hay will likely have difficulties processing the grass. An event like this may also cause the horse to develop colic, which can create other toxic side effects which may contribute to acute inflammation of the laminae.

4. Mechanical Laminitis

Although equally as serious as acute, mechanical laminitis is far simpler in nature. When the horse's heel is left artificially long in order to "enhance" natural movement, it can impact the internal structures of the hoof including the distal phalanx (Ramey, 2011). When the laminae are forced into a weak position due to improper shoeing or trimming style, the force of impact with the ground can cause the laminae to become inflamed over time, establishing chronic laminitis. The horse may also face conformation faults such as a "club foot" which may also force the laminae into a weak position (Ramey, 2011). Mechanical laminitis can cause serious pain and discomfort for the horse and, in severe cases, mechanical laminitis can develop into foundering, wherein the animal succumbs to laminitis. However, mechanical laminitis is the easiest form of laminitis to treat. Often this laminitis can be treated when the hoof shape is corrected through various trimming methods (Ramey, 2011).

5. Endocrine laminitis

Endocrine laminitis is the most complicated form of laminitis to treat and, according to a study by Morgan (2015), about 90% of laminitic horses have some form of endocrine laminitis, although no study to date has been conducted to determine which forms of endocrine laminitis are more common. Endocrine laminitis can be caused by an array of hormonal imbalances in the horse's body, the two most prevalent being equine metabolic syndrome and pituitary pars intermedia dysfunction (Rendle, 2017a). Although these diseases can have devastating results, evidence from the literature suggests that both can be diagnosed and treated at early enough stages before the disease progresses into laminitis (Morgan, 2015).

5.1 Equine metabolic syndrome

Equine metabolic syndrome develops when both obesity and insulin resistance are present in an equine. Obesity can be observed as a regional increase of fatty tissues in the crest (top of neck) and rump or general weight gain evenly across the body (Morgan, 2015). Insulin resistance can be characterized by excessive insulin production or insulin dysregulation, which can be detected through blood testing (Morgan, 2015). According to the literature studied by Morgan (2015), obesity is prevalent in 19-40% of domestic horses and insulin resistance occurs in 22-29% of domestic horses. The main risks associated with equine metabolic syndrome are due to adipose tissues being higher in obese horses.

Adipose tissue behaves as an endocrine organ and secretes adipokines including leptin and adiponectin. Adipose tissue also secretes cytokines including tumour necrosis factor alpha and interleukin-1 (Morgan, 2015). When adipose tissue is present in excess, the chemicals secreted can cause both local and system-wide problems for the horse. The exact mechanism of insulin resistance in equines is unknown, yet researchers have identified a combination of symptoms which can lead to equine metabolic syndrome and laminitis (Morgan, 2015). When adipose tissue is present to a large extent, there is a combination of local and remote inflammation (caused by the increase of chemical secretions), oxidative damage, lipid overspill, and alterations in the release of adipokines. When these factors are present in the horse's system, it insulin signalling within the fat tissues is impaired (Morgan, 2015). The altered signalling can lead to excessive production and/or dysregulation of insulin within the body.

The high amounts of insulin in the horse's body results in the alteration of the form and function of vascular tissues with the body. Equine metabolic syndrome-based inflammation is associated with rapid and significant disruption of vascular membranes. The lamina (a vascular tissue) becomes inflamed as it is unable to process the insulin in the bloodstream (Mor-

gan, 2015). As previously mentioned, as the lamina become inflamed, the lamellar-hoof wall junction becomes disrupted from its regular form and function (Rendle, 2017a).

A challenge with equine metabolic syndrome is to treat the disease before it manifests as laminitis. The most effective way to diagnose equine metabolic syndrome is through visual body condition scoring in combination with blood tests if further concern is piqued. In many domestic settings, equine obesity is not treated as a serious condition, which makes early diagnosis rare (Morgan, 2015). If equine metabolic syndrome is diagnosed early enough, the primary means of treatment are diet, exercise, and controlled pharmaceuticals.

It is important the horse's new diet does not contain concentrated feeds or grains, or succulent treats such as carrots or apples. Foraging that is low to medium in non-structural carbohydrates (no more than 10%) is of importance(Morgan, 2015). Non-structural carbohydrates in their most concentrated form are found in plant seeds, followed by the leaf and stalk; thus the type of grasses in the hay and the cut of the hay will impact the percentage of non-structural carbohydrates (Morgan, 2015). Horses trying to lose weight should consume approximately 1.25% of their body weight in hay; a healthy horse might consume between 2 and 2.5%. If more drastic measures need to be taken in order to promote weight loss rapidly, soaking the hay in water is an effective strategy. Soaking hay in cold water for about one hour reduces the sugar content in the hay by about 30%, while soaking it for 12-16 hours can reduce the sugar content by about 50% (Morgan, 2015). It is critical that horses being fed soaked hay are provided with adequate supplements, as many of the water soluble macronutrients found in the hay will be leached out in the process (Morgan, 2015).

The horse should take on a new and healthy exercise routine to help with weight loss. This should include regular turnout on a dirt paddock (or a grass paddock with a grazing muzzle). If the horse is starting at zero fitness, the exercise regime should start with short trot sets that increase in number of sets and length of sets over time (ie 10 minutes of walking followed by trotting for 3 minutes repeated two times; after six weeks this might shift to 10 minutes of walking followed by 5 minutes of trotting repeated three times). Studies have shown that exercise, independent of weight loss, can help improve the body's sensitivity to insulin and reduce symptoms of equine metabolic syndrome (Morgan, 2015). Pharmaceutical intervention is generally seen as a last resort if diet and exercise are not helping to relieve the horse's symptoms. The primary drug to treat equine metabolic syndrome is an anti-hyperglycemic drug which improves blood glucose homeostasis [name of drug?] (Rendle, 2017a).

5.2 Pituitary Pars intermedia dysfunction

Pituitary pars intermedia dysfunction (PPID) is also known as equine Cushing's disease. This disease is relatively common, as approximately 30% of domestic horses are at risk (Rendle, 2017b). Pituitary pars intermedia dysfunction is characterized by an over-active intermediate lobe of the pituitary gland causing an excessive release of metabolically active proteins and hormones (Rendle, 2017b). The primary proteins and hormones that are released are adrenocorticotropic hormone, endorphins, and melanocortins. These chemicals, when released in excess, have the capability to damage the nerve supply to the pituitary gland (Rendle, 2017b).

PPID progresses slowly, and is found primarily in older domestic horses. The symptoms include hirsutism, abnormal fat deposits, laminitis, muscle wasting, polydipsia, and polyuria (Rendle, 2017b). Hirsutism is the excess growth of hair and lack of hair loss during the summer. This is the most common symptom which can be used to identify PPID, as it is the only equine disease that will cause the increased hair growth and retention (Rendle, 2017b). Abnormal fat deposits primarily occur in the animal's crest. The dangers of abnormal fat deposits in the crest area of the horse's body are identical to those discussed earlier in the paper in reference to equine metabolic syndrome. Laminitis is the most severe symptom of PPID. Muscle wasting is a symptom of particular importance as the deconditioning of the horse may impact their energy habits (Rendle, 2017b). Polydipsia and polyuria are when the horse increases water consumption and urination production, respectively. Horses who are suffering from PPID may experience a one-third increase in water consumption. It is unknown why horses experience polydipsia and polyuria - however, it is not the only disease that can present these symptoms (Rendle, 2017b).

Treatments for pituitary pars intermedia dysfunction are subdivided into pharmaceutical allopathic medicine and natural long term treatments. Pergolide is a drug that stimulates the dopamine receptors in the equine brain, replacing the function of the nerves damaged by PPID. This results in a reduction of the hormones released, lowering them to their previous normal levels (Rendle, 2017b). Cyproheptadine is another common drug for PPID treatment. This antihistamine can have a range of impacts on the body's hormones; though on its own it is not considered effective in treating the disease, it is used in conjunction with pergolide (Rendle, 2017b).

Natural remedies are commonly discounted through a scientific lens, but it is important not to entirely disregard these powerful forms of medicine. There are a variety of herbal remedies that can aid recovery, including extract from chasteberry (Vitex agnus-castus) and other marketed products such as "CUSH-AID". Marketed products often have vitamin B complex, iron, folic acid, garlic oil, and fenugreek (Animal health company, 2017). Another important natural remedy is correctly trimmed barefoot management of horses. Although there is very little scientific evidence supporting the barefoot trim as treatment, I have witnessed success with a variety of horses through Kate Romenanko's trimming school and apprenticeship hours. Furthermore, there are many ways to

naturally aid a horse's natural digestion that will help with their metabolism of sugars; for example adding probiotics and prebiotics to "reseed" the gut and adding apple cider vinegar to their water [to do what?] (Rendle, 2017b).

When both equine metabolic syndrome and pituitary pars intermedia dysfunction are caught in their early stages and effectively treated, whether through natural treatments such as diet and exercise or through pharmaceutical options, laminitis can be prevented.

5.3 Next Steps

The causes of acute, mechanical, and endocrine laminitis are relatively well-understood. However, during an acute attack, mechanical failure, or the onset of endocrine laminitis, treatments which can fight the swelling of the laminae and displacement of the P3 bone are relatively understudied. Throughout research conducted in this reading course, many theories for improving the care for horses experiencing laminitis were suggested. Yet, confusion and tension remain at the heart of how to treat this painful condition. Veterinarians continue to publish contradicting studies with a wide range of efficacy. Although the success of treatment is dependent on a broad range of factors, further research needs to be conducted to help establish a basis for effective treatment protocol.

6. Thrush

Thrush is a bacterial infection that can occur on the bottom of the hoof capsule, occuring on the sole or the horn. Thrush can be easily identified on the hoof as black, foul-smelling necrotic material in its later stages or as a slight whitening of tissues during its early stages, usually only visible during a trim (Petrov, 2013). The anaerobic bacteria that cause thrush tend to thrive in the collateral groves and central sulcus of the hoof (the deep grooves between the frog and the bars and the groove in the center of the frog, respectively) (Petrov, 2013).

There is very minimal research regarding the frequency of thrush; however, a study by Abidin (2013) surveyed five Malaysian stables and thrush was found to be present at all 5, but horses in stables with poor property management were about 12% more likely to contract the disease. Of the 53 horses observed, 40% of them suffered from thrush to some degree (Abidin, 2013).

Thrush in horses is slightly different then foot rots in other common domestic animals. In animals such as cows, sheep, pigs, and goats, foot rot is caused by two bacteria: Fusobacterium necrophorum and Dichelobactor nodosus. In contrast, equine thrush is caused by Fusobacterium necrophorum in the absence of Dichelobactor nodosus (Petrov, 2013).

This bacteria can manifest on the hoof capsule when poor trimming or shoeing methods have been used; when the hoof does not work correctly, it is unable to "pop" dirt and other particulates out of the sole area of the foot and anaerobic bacteria can begin to thrive (Petrov, 2013). Another cause of thrush is a lack of exercise; many domestic horses are kept in stalls for a significant portion of the day, preventing movement leading to dirt and debris remaining longer in the sole area of the foot.

Thrush can also travel up into the hoof capsule underneath the wall. When this occurs, the Fusobacterium necrophorum causes white line disease. White line disease can occur on any part of the hoof capsule, causing the it to manifest as a range from very mild to quite severe (Petrov, 2013). Depending on the location of the bacteria on the foot, ground force may not be severe (quarter areas) or may cause separation of the hoof wall and the lamina (toe area) (Petrov, 2013). Thrush can develop into white line disease as the bacteria make their way up through the foot, or due to direct trauma which can introduce the bacteria to a location higher up in the hoof capsule (Petrov, 2013).

Thrush can be treated through a variety of store-bought remedies such as "Thrush Buster", or one can use more natural treatments such as apple cider vinegar mixed with tea tree oil. Thrush can also be prevented through correct and routine hoof care (Petrov, 2013). Although this bacteria is relatively easy to treat, too often it goes untreated or unnoticed until it develops into the more severe white line disease. Often shoeing methods are used to "hold the foot together" as a method of treatment. Shoeing the horse, while performed with good intentions, can unintentionally seal the bacteria into the foot causing the progression, and not the regression, of the bacterial infection (Petrov, 2013).

6.1 Next steps

Research needs to be conducted on the effectiveness of treatment methods for thrush. Questions such as how a farrier can effectively treat thrush or white line disease without inadvertently aiding in the progression of the disease need to be answered. Research also needs to be conducted regarding the effectiveness of natural treatments such as the application of apple cider vinegar as compared to store-bought formulas.

7. Navicular Disease

Navicular disease or navicular syndrome is a less common, but very serious condition related to the health of the equine hoof capsule. This disease is characterized through pain or lameness originating from the digital sesamoid bone, also known as the navicular bone (Parks, 2015). The first indication of a problem with the navicular bone is that the horse will stand forward at the knee and will not fully straighten at the knee standing or in motion. A second indication of navicular disease is that the pain significantly decreases after a nerve block of the palmar digital nerve (Smith, 2015). A standard diagnosis has yet to be established.

7.1 Causes

Some researchers advocate that the exact cause of navicular disease is unknown, due to the fact that the complex disease is seriously under researched (Yorke, 2014). Although the detection for navicular disease has become significantly more sophisticated, it is critical to remember that often navicular disease has a snowball effect on the horse's body, meaning that it is often not a single disorder occurring with the navicular bone and rather a sum of problems (Dyson, 2011).

One common theory behind the pain associated with navicular disease is related to the common finding of ossified fragments adjacent to smooth concave areas of the navicular bone. This identification of ossified bone fragments began in 1937 with the use of radiographic imaging on horses who suffered from navicular disease (Yorke, 2014). However, it was later discovered that there is no statistical difference between horses who experience lameness and those who do not in correlation to distal border bone fragments, though this common theory persists (Yorke, 2014). In recent years, magnetic resonance imaging (MRI) has been used to image the hoof capsule when navicular disease is suspected as it can allow for a more definitive diagnosis. The MRI can identify a variety of potential causes for pain including pathology of the navicular bone and the associated ligaments (Park, 2015). The MRI can detect increased uptake of radiopharmaceuticals which can provide indication of injured areas of both bone and soft tissues which would not otherwise be visible on radiographic images (Dyson, 2011).

One suggested cause of navicular disease is the chronic overloading of the forelimbs (Frevel, 2014). The excess force on the forelimbs will induce dorsiflexion of the hoof capsule and change the amount of force on the navicular apparatus (Frevel, 2014). This pulls the impar and suspensory ligaments to a taut and almost overextended stance. As this extension occurs over time, the junction between the ligament and the associated bones is put under stress. This tension then contributes to increasing force on the navicular bone, potentially being a source for pain (Frevel, 2014). In more extreme cases, the navicular bone can be subject to avulsion fractures, meaning that the bone is fractured from the force of the impar ligament (Yorke, 2014).

Another suggested cause of navicular disease is vascular disturbances (Zaag, 2016). The navicular bone has two large arteries which pass through the bone and into the hoof capsule (Belknap, 2017). When functioning correctly, the spindle-shaped navicular bone should pivot with every step the horse takes. This pivoting action is important in order to control blood flow into and out of the hoof, acting both as a pump and a limit to the amount of blood in the hoof capsule (Belknap, 2017). A defect can occur during a horse's fetal stage which can impact the function of the navicular bone - if a defect of this nature occurs, the navicular bone can be prevented from pivoting, causing the arteries to be permanently left "on" or "off". Consequently, this either causes erosion of the bone leading to pain or, more seriously, preventing blood flow to the hoof capsule (Zaag, 2016).

This same vascular problem can occur over time. With a combination of poor trimming or shoeing and/or poor environmental conditions, a horse's heels can become contracted (Zaag, 2016). As the heels contract, the internal structure of the hoof changes and the bars of the hoof will be pushed closer together and higher up in the hoof capsule. When this shift occurs, the bars will then begin to impact the function of the navicular bone (Zaag, 2016). This slow shifting of horn and bone will likely cause the navicular bone's arteries to be turned on for more time than it can shut off. As the bone erodes from the excess blood flowing through the arteries, the horse will experience pain.

It is also possible that navicular-related pain can be caused by the degeneration of the fibrocartilage (Dyson, 2011). This most often occurs on the palmar aspect of the navicular bone. As degeneration of fibrocartilage occurs and lesions become more significant in the impacted area, the adjacent bone can become damaged (Dyson, 2011). Not only can these lesions impact the surrounding bone, but the lesions may lead to other health problems in the hoof capsule. For example, when the lesions reach a certain size they can have a significantly negative impact on the deep digital flexor tendon and therefore the whole function of the leg (Dyson, 2011).

7.2 Treatments

Again, due to the under-researched nature of this disease, the potential treatments for this disease are relatively unknown. Both in literature and in the general public, treatment for navicular disease is often not an option, the focus being more on pain management (Ruff, 2016). For most horses, pain management means that they are subject to life on a variety of supplements and pain killers. However, one suggested management tool for navicular disease is the use of clodrovic acid (Frevel, 2014). This acid is a bisphosphate which can inhibit bone resorption, the process by which osteoclasts in the body break down bone tissues, releasing minerals that were previously stored in the bone tissue. This deterioration is problematic on two fronts; firstly, the bone deterioration causes mechanical weakness and potential pain in the navicular bone, and secondly, the minerals that are released can travel through the bloodstream and become deposited in other parts of the body (Frevel, 2014). Clodrovic acid inhibits the formation of hydroxyapatite crystals; it is these crystals that allow the osteoclasts to deteriorate bone tissues (Frevel, 2014).

In order to determine the effectiveness of this treatment, 146 horses at different locations in the United States and in Germany underwent observed treatment for 180 days (Frevel, 2014). At 8 weeks of treatment, horses given clodrovic acid experienced statistically significant improvements over those who were not receiving treatment. After 180 days of

treatment, it was observed that the effectiveness of the initial treatment was sustained in 60% of horses who experienced success at the 8-week mark (Frevel, 2014). Although this experiment indicated some success, further research needs to be conducted in order to better help horses who suffer from the disease.

7.3 Next steps

Through the next steps of understanding and addressing navicular disease, a substantial amount of research needs to be conducted. Firstly researchers need to establish which factors or detectable changes to the navicular bone do and do not cause pain for the horse. The confusion surrounding whether or not fragments cause pain needs to be addresses. The relationship between the various causes and how they relate to each other needs to be better understood, as well as how the palmar digital nerve relates to navicular pain. Furthermore, a strategy for early diagnosis needs to be established. Many horse owners do not know what to look for until the symptoms have become severe and the horse is in a great deal of chronic pain. Once the detection of the disease and the cause of the disease are better understood, only then can effective treatments begin to be formed.

8. Conclusion

After investigating these hoof ailments, it is clear that a large amount of research has been conducted in order to better understand the disorders which cause our equine partners pain. The recent revelation that laminitis can come in many different shapes and forms continues to encourage me to question common theories and research which does not align with my personal views or experiences.

As a barefoot trimmer, I come across chronic cases of thrush and white line disease which have persisted for years under the care of farriers who choose shoeing as a solution to the problem; then after two to three barefoot trims the bacteria no longer impacts the hoof. I can only hope that, like laminitis, the common understanding of how the ailment thrives and how to care for the hoof can shift to a healthier, preventative scenario allowing all horses to have bacteria-free feet. The understanding of navicular disease continues to improve through research, and it is critical that veterinarians and researchers are able to use literature to guide them, without getting caught up in simply perpetuating myths regarding the disease. Most importantly, researchers need to continue to ask the difficult questions and to delve deeper into how to help domestic horses overcome hoof-related health concerns.

9. Work Cited

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