



Grayson-Jockey Club Research Foundation: Review Article

Infection control and biosecurity in equine disease control

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Summary

Infectious diseases are an important cause of morbidity and mortality in horses, along with economic costs and broader impacts associated with the loss of members of a species that generates income, acts as a working animal and is a companion. Endemic diseases continue to challenge, emerging diseases are an ever-present threat and outbreaks can be both destructive and disruptive. While infectious diseases can never be completely prevented, measures can be introduced to restrict the entry of pathogens into a population or limit the implications of the presence of a pathogen. Objective research regarding infection control and biosecurity in horses is limited, yet a variety of practical infection prevention and control measures can be used. Unfortunately, infection control can be challenging, because of the nature of the equine industry (e.g. frequent horse movement) and endemic pathogens, but also because of lack of understanding or motivation to try to improve practices. Recognition of the basic concepts of infection control and biosecurity, and indeed the need for measures to control infectious diseases, is the foundation for successful infection prevention and control.

Keywords: horse; infection control; infectious diseases; biosecurity

Introduction

In 1995, a novel morbillivirus (now termed Hendra virus) was identified in fatal infections of horses and their caretakers in Queensland, Australia [1]. The fact that this virus is endemic in an abundant wildlife reservoir (fruit bats) and continues to cause sporadic infections in horses and human individuals (including equine veterinarians) [2] has caused a massive re-evaluation of standard infection control and horse management practices in the region, and in some cases, consideration by veterinarians of whether they will work with horses. What other new pathogens lurk in wildlife reservoirs?

In 1999, West Nile virus entered North America and subsequently became an endemic disease with a major impact on horses and man [3,4]. What pathogen might be the next to follow this pattern?

In 2004, a large equine teaching hospital was temporarily closed because of an outbreak of salmonellosis that infected 54 horses and cost the facility over US\$4 million [5], just one of many such outbreaks [6–9]. Are outbreaks in equine hospitals an unfortunate but unavoidable risk?

In 2007, a breakdown in quarantine measures led to an outbreak of equine influenza in Australia that ultimately affected over 4500 premises [10], cost billions of dollars and resulted in mass disruption. Was this a 'one-in-a-million' event or a sign of future infectious disease challenges in the highly mobile international equine population?

In 2011, an equine herpesvirus-1 (EHV-1) outbreak from an American cutting horse competition ultimately involved at least 242 premises across 19 US states [11], with further movement into two Canadian provinces. Are large outbreaks of disease caused by this endemic pathogen inevitable?

These represent only a few of the infectious disease challenges that the equine industry has faced and they may seem daunting. There should be no doubt that infectious diseases are an important problem in the equine industry. They have historically been a leading cause of illness and death in horses, continue to pose significant challenges today and undoubtedly will continue to challenge in the future. As veterinary medicine advances, one might expect infectious disease risks to decline, but the high-risk nature of many facets of the equine industry and continual emergence of new issues mean that infectious disease challenges will probably increase in coming years.

Yet, all is not lost. While there is a focus on dramatic events, infection control successes abound. The 2012 Olympic Games in London were accompanied by the challenges of protecting 348 horses from numerous countries and the broader British horse population [12]. This was an overwhelming success, with no significant disease occurrences during the Games [12]. On a small geographic but larger horse scale, identification of 2 horses with EHV-1 infection at a Canadian racetrack housing over 2000 horses was contained, with no further neurological disease, only 3 other horses with fever, and perhaps most importantly, no evidence of any pathogen transmission after the initial cases were identified (unpublished data). Countless animals have been treated by veterinarians on farms and in equine hospitals with no infectious complications, despite highly susceptible individuals and circulating endemic diseases. A promising vaccine has been produced to help control Hendra virus [13]. These are all indicators of advancement of infection control and infection control successes. Thus, while infectious diseases will undeniably continue to pose challenges, there are measures that can and must be implemented to reduce the incidence and impact.

Biosecurity vs. infection control

The realistic goals of any disease prevention programme must be considered. While some consider 'infection control' and 'biosecurity' to be equivalent terms, there are important differences. There are various definitions of biosecurity, and it can be broadly defined as measures to reduce the risk of pathogen transmission. More often, it is used to refer to measures used to *prevent the entry of pathogens into a population*. In contrast, infection control aims to *limit the impact of the introduction of pathogens into a population*. For example, intensive biosecurity practices are widely used in poultry production, with measures such as all-in/all-out production, tight personnel access controls and prevention of wildlife exposure, all designed to minimise the chance that various pathogens enter the farm. At the other end of the spectrum is infection control in a veterinary hospital, where infectious animals are willingly admitted but measures are in place to limit the risk of transmission. While equine farms cover a wide spectrum, very few can practice true biosecurity because of

the regularity of horse movement, cross-movement of personnel, the endemic nature of many pathogens and the commonness of latent infections (e.g. EHV-1). That does not mean that facilities should not strive to prevent entrance of pathogens. Rather, it means there must be acknowledgement that exposure of the horse population to relevant pathogens is largely inevitable, so measures must be in place to identify and contain any threats, along with measures to reduce the risk of pathogen entry.

Burden of disease

The impact of infectious diseases is difficult to quantify because of a lack of surveillance systems, particularly those directed at endemic diseases, and difficulties quantifying the impact even when the incidence of disease is known. Most available data are from outbreak investigations and geographically focused (and often small) research studies involving single conditions. Broad data, or even estimates, of the burden of disease are therefore lacking, complicating an understanding of the impact of various diseases and precluding objective cost–benefit assessments of potential control measures.

Morbidity

There are no broad estimates of the impact of infectious disease on horse health. Studies evaluating certain pathogens or populations provide some insight into the importance of infectious diseases in horses, but usually involve relatively small numbers of horses and narrow geographic ranges.

Mortality

Deaths attributable to infectious diseases have been reported for specific outbreaks, yet these are relatively limited in number and broader relevance. Most mortality data from other reports are either case reports or mortality data from retrospective studies of specific conditions [11,14–16]. While these data are informative, it can be difficult to extrapolate them in a broader context if the incidence of disease is not known (e.g. knowing that a disease kills 10% of affected horses but not knowing how many horses are affected). Another aspect of mortality is euthanasia of horses because of the presence of infection, not severity of disease, such as for diseases under tight regulatory controls such as equine infectious anaemia and equine piroplasmiasis [17], where euthanasia is the typical response for disease control purposes.

Animal welfare

While closely tied to morbidity, there is increasing concern about the impact of diseases on animal welfare, and a broadening recognition of the ethical role of horse owners and veterinarians in controlling infectious diseases because of the impact on horse welfare. As regulatory bodies in some regions gain more authority (or willingness to intervene), there may be a greater likelihood of investigation of facilities and practices from a welfare standpoint. This is not to suggest that minor deficiencies in infection control practices will prompt a welfare investigation, but rather the potential that individuals or facilities that exhibit wanton disregard for the health of their animals and the broader equine population could come under scrutiny from animal welfare or regulatory agencies.

Economic impacts

Objective data regarding the cost of infectious diseases are limited in number and broader relevance. Indeed, accurate determination of direct and indirect costs of infections is exceedingly difficult. The most compelling data are from investigation of the 2007 Australian equine influenza outbreak, which reported direct and indirect costs that were 'well into the billions of [Australian] dollars' [18]. Clearly, this is an extreme event but not beyond the possibility of occurring again in Australia or elsewhere in response to a new and highly transmissible pathogen (e.g. new equine influenza subtype). The impact of new introduction of a less transmissible agent was demonstrated in a study of the cost of a high incidence of West Nile virus infections in North Dakota, USA in 2002, which identified costs to horse owners of US\$1.5 million, along with state government costs of

US\$1.9 million [19]. These should be taken as an indication of the potentially profound impact of infectious diseases, yet they focus on very rare occurrences; a rather unprecedented equine influenza outbreak and the initial stages after introduction of an arbovirus into a new region. Less is known about the impact of endemic diseases that continue to occur in horses and tend to receive less attention than high-profile outbreaks.

An aspect that is often forgotten in the developed world is the importance of equids as working animals in many countries. A 1994 study estimated that draught animals including, but not exclusively, horses were used in 52% of cultivated areas of the world, and for hauling 25 million carts [20]. For those owners, the impact of a sick or dead animal, or an outbreak, could be profound and beyond that typically considered in other regions.

Societal disruption

Societal impacts of equine diseases are not often considered. These can range from minor inconveniences from a cancelled event, to broader impact in the equine community from international restriction of travel and competition. Additionally, unwillingness to accept disruption (e.g. reluctance to keep a sick horse home from an event) is a significant barrier to infection control and therefore one that needs to be studied.

Industry disruption

Many pathogens are restricted to selected regions, by virtue of the range of competent insect vectors (e.g. African horse sickness, piroplasmiasis), differences in presence of the pathogen in reservoir species (e.g. rabies) and effective elimination or control strategies (e.g. equine infectious anaemia, equine influenza). Based on a desire to remain 'disease free', different countries have different strategies for import testing and quarantine, and testing of resident horses. These are far from infallible but play an important role in controlling selected diseases. Some countries also have importation restrictions in place to prevent (or complicate) importation of horses from selected regions, as a way to reduce the risk of introduction of 'foreign' pathogens. Thus, emergence of 'foreign' diseases in a country may not only have a direct impact on the health of horses in that country, it may be accompanied by importation bans that can have a profound impact on some components of the equine industry [21], given the importance and frequency of international movement of some horse populations.

Social and emotional costs

Many horses are companion animals and the impacts of illness and death of companion horses are virtually impossible to quantify but are undoubtedly important. While often considered simply to be inconveniences, some situations can be associated with profound psychological distress, and the potential for secondary health consequences. For example, 34% of survey respondents during the Australian equine influenza outbreak reported 'high psychological stress', with greater rates in the high-risk infection and disease buffer zones compared with people in unaffected zones [22]. People who rely on the equine industry as their principal source of income, not surprisingly, exhibited higher rates of stress [22]. However, many individuals have significant emotional bonds with their horses and the potential impact of infectious diseases on the human–animal bond must not be overlooked.

Public health

Most equine infectious diseases are of limited or no public health concern, but some equine pathogens are zoonotic (e.g. *Salmonella*, methicillin-resistant *Staphylococcus aureus* [MRSA], dermatophytes, *Leptospira*, Hendra virus). The impact may be variable, from common but mild conditions such as ringworm to potentially deadly diseases like Hendra virus infection. The incidence of equine-associated zoonoses is completely unknown but there is undeniably some burden of disease. A related area of concern is the risk posed to 'high-risk' people. This is typically defined as people younger than 5 years and older than 65 years, people with an immunocompromising disorder or medical treatment, and pregnant women. A study focusing on companion animals reported that approximately 50% of households contained one or more high-risk individuals [23]. The percentage of people that have horse contact that fall

into these groups has not been evaluated but is likely to be substantial. There is also particular concern for therapeutic riding (hippotherapy) facilities, which can involve a greater proportion of high-risk individuals [24,25].

Outbreaks

Outbreaks receive much attention and certainly can cause a significant burden. While outbreaks are undeniably important, it is likely that the impact of endemic disease far supersedes that from outbreaks, except in extreme circumstances such as the Australia equine influenza outbreak. Plans to identify and address outbreaks are needed, but infection control measures cannot be restricted to outbreaks. A proactive (infection control) approach is better than a reactive (outbreak containment) approach.

Endemic disease

The impact of endemic diseases is easy to overlook, particularly when disease is considered an inevitable risk of equine management and when control may be very difficult. However, the greatest impact on equine infectious diseases can probably be achieved through focusing on measures to reduce the endemic burden of disease. Doing so requires some consideration of broad types of infections, since an understanding of potential mechanisms of transmission is the basis of any infection control or biosecurity programme.

Equine-origin community-associated infections

Most equine infectious diseases are caused by pathogens that primarily or solely infect equids. This includes pathogens that continuously circulate without long-term hosts (e.g. equine influenza virus), pathogens that may result in long-term subclinical carriage (e.g. *Streptococcus equi*), pathogens that cause latent infections that may recrudescence at any time (e.g. equine herpesvirus) and opportunists that can be present as part of the commensal microbiota (e.g. staphylococci, Enterobacteriaceae). Many pathogens can be shed by clinically normal horses prior to the onset of clinical disease, after resolution of infection or as part of the microbiota of a healthy animal, in addition to shedding during periods when clinical signs are apparent. Therefore, identification of potentially infectious horses is complicated, with some syndromes (e.g. fever, diarrhoea) strongly suggestive of the presence of an infectious agent but with any horse potentially shedding a range of pathogens. Measures can be in place to identify and contain horses at increased risk of shedding infectious agents but all horses will pose some degree of risk, highlighting the need for strong routine infection control practices.

Wildlife or vector-associated infections

Insect vectors are responsible for various equine infectious diseases, including equine infectious anaemia, African horse sickness, West Nile virus, Eastern/Western/Venezuelan equine encephalitis and piroplasmosis. Similarly, wildlife may be sources of a range of pathogens, including *Sarcocystis neurona*, rabies virus and *Salmonella* spp. Control of wildlife-associated diseases can be difficult, particularly insect borne diseases, yet there are measures that can be implemented to reduce the risk of exposure.

Foodborne and waterborne infections

Food and water are known or possible sources of diverse pathogens from horses, other domestic animals or wildlife, such as *Salmonella*, *Neorickettsia risticii*, *Sarcocystis neurona*, *Giardia* and *Clostridium botulinum*. Limited information is available about feed and waterborne infections in horses. Whether this is because food and waterborne infections are rare, or rarely identified is unclear.

Hospital-associated infections

In human healthcare, hospital-associated (also known as nosocomial) infections are a leading cause of morbidity and mortality. Hospital-associated infections certainly occur in equine hospitals, with the

main concerns being infectious diarrhoea (e.g. salmonellosis) and surgical site infections. Transmission of a wide range of other pathogens such as equine influenza virus, EHV-1 and various multidrug resistant pathogens is also a concern, as are other hospital-associated infections such as invasive device (e.g. intravenous catheter, urinary catheter) infections and neonatal sepsis. Hospital-associated infections can have an impact beyond the infected horse if pathogens are transferred to the horse's home facility after discharge.

Ambulatory practice-associated infections

Most veterinary-horse contact occurs at equine facilities, not equine hospitals. The impact of ambulatory veterinary care on equine infectious diseases has been poorly evaluated, yet various areas of concern exist, such as iatrogenic septic arthritis from joint injections and surgical site infections [14,26]. Poor needle handling and blood product management (by veterinarians or owners) have been linked to piroplasmosis [17] and equine infectious anaemia outbreaks [27] on farms. Veterinarians, along with their equipment and vehicles, are also potential sources of transmission of pathogens between facilities.

Emerging diseases

If an equine veterinarian is asked in 2014 to list the main infectious disease concerns that they have for their patients, the list would be likely to include some pathogens that were minor concerns or even unheard of by the previous generation (or even a few years earlier). Emerging infectious diseases, both newly identified pathogens and new challenges from previously known pathogens, are an ongoing threat. By their nature, it is impossible to predict emerging infectious disease challenges. Infection control practices that focus on known pathogens (e.g. vaccination, pathogen screening) are important but are ineffective against new threats, highlighting the need for broad infection control approaches that help contain both known and unknown threats. Various types of emerging diseases can be considered.

Known diseases that are new to a region because of gradual range expansion

Infectious diseases may be confined to specific ranges because of range of an insect or wildlife vector or reservoir. While horses carrying the infectious agent might move to a new region, the lack of a competent vector in that new region prevents any subsequent transmission. However, if the vector's range expands, the disease range can be expected to expand in concert. Climate change can modify the ranges of some insect vectors [28,29], and this will be likely to have a corresponding influence on diseases such as equine piroplasmosis, African horse sickness, Lyme disease and arboviral encephalitis.

Known diseases introduced to a completely new region

In addition to the gradual movement of pathogens described above, more remarkable (e.g. intercontinental) shifts can occur. Prior to 1999, West Nile virus had not been found in the western hemisphere, but it somehow entered North America and was able to spread widely enough in reservoir species to become an endemic pathogen. The 2007 Australian equine influenza outbreak was another dramatic demonstration of this [30,31], with the predictable problems associated with entry of equine influenza in an immunologically naïve population.

Emergence of unknown diseases

Countless potential pathogens are likely to be lurking in wildlife reservoirs globally. Severe acute respiratory syndrome coronavirus and Middle East respiratory syndrome coronavirus are recent examples of devastating new human diseases [32], with Hendra virus being the most dramatic example in horses [1,33]. Schmallenberg virus, a midge-borne disease of ruminants, provides another example. This virus entered central Europe, presumably from Africa, through unknown routes and rapidly caused significant morbidity and mortality across most of the continent [34]. It is fortunate for

the horse population that this was a ruminant, not equine, pathogen. The question is not whether another new equine disease will emerge. Rather, the questions are where it will emerge and what it will be?

Cross-species transmission

Many pathogens can infect multiple different animal species, with various antimicrobial resistant pathogens being examples. While study of interspecies transmission of pathogens tends to focus on animal–human transmission, it is clear that both directions of transmission can occur. As an example, MRSA has emerged as an important opportunistic pathogen in horses [9,35,36], with the main MRSA clones in horses in some regions being human epidemic clones [37]. More recently, there has been an emergence of the livestock-associated sequence type 398 (ST398) MRSA in European horses [38–40]. As other antimicrobial resistant pathogens such as extended spectrum β -lactamase producing Enterobacteriaceae increase in the general population, exposure of horses is inevitable. This will not always be accompanied by any risk of disease in horses, but many of the multidrug resistant pathogens found in man can probably also infect horses, and further introduction of new resistant pathogens from human caretakers remains a concern.

Major modification of endemic pathogens

The impact of endemic pathogens can be minimised by population protection conferred through natural immunity or vaccination. While not completely preventing pathogen circulation and disease, this reduces the magnitude of the susceptible population (the concept of herd immunity) and the degree of susceptibility of individual animals, thereby limiting the amount of transmission and severity of disease. The protective effects of natural immunity and the immune system can be compromised by genetic shifts in pathogens. This is most often discussed in the context of ‘antigenic shift’ of influenza viruses, whereby a recombination event produces a novel virus to which the host has little or no immunity. Fortunately, equine influenza virus has been rather stable in the equine population, with only the A/H3N8 subtype identified over the past 30 years [41]. While antigenic drift, gradual and typically minor genetic variation, has occurred, the impacts of this have been limited because of cross-protection afforded by H3N8 vaccination and natural infection. Even though equine influenza H3N8 has been more stable than human influenza viruses, the potential for a recombination event (antigenic shift) should not be discounted. Emergence of a new equine influenza subtype could prove devastating, with the combination of a highly transmissible virus, widespread international horse movement, variable (and often weak) infection control practices and no pre-existing vaccine or natural immunity. This could result in an event analogous to the 2007 Australian equine influenza outbreak, but on an international scale.

A clash of culture

As discussed above, the ‘accepted’ nature of infectious diseases in horses poses a challenge if there is unwillingness to challenge dogma and reconsider traditional practices that might pose an unnecessary risk. During investigation of an EHV-1 outbreak associated with a Standardbred yearling sale in Ontario, Canada, purchasers were asked to indicate what percentage of yearlings they expect to develop an infectious disease after a sale. Most indicated ‘80–100%’, demonstrating a high ‘accepted’ rate of disease (unpublished data). Yet, is this an ‘acceptable’ rate, and can it not be lowered through implementation of practical measures? Further, the fact that many individuals brought those newly purchased horses, horses that they assumed were or would become ill, directly into their racing stable (with subsequent disease in racing horses) shows an illogical approach that may be rooted in standard practices that are not re-evaluated.

Certainly, many factors that drive infectious disease risk in horses cannot be modified (e.g. movement of competing horses). However, many practices that increase the risk of pathogen transmission (e.g. allowing direct horse–horse contact at events, cross-contaminating or sharing items at events, failure to quarantine new arrivals, unnecessary mixing of horses of different disease risk status) can be modified with practical

TABLE 1: Properties that facilitate eradication of an equine pathogen

Readily identifiable clinical disease
No chronic disease state with active infection
No long-term carrier state
Only infects horses, with no wildlife reservoir
Highly sensitive diagnostic tests available
Highly effective vaccines available

approaches. Some areas create debate between economic, traditional and infectious disease concerns. For example, artificial insemination can presumably reduce the risk of movement of pathogens between farms (because fewer horses are transported for breeding) and the risk of venereal disease transmission from natural breeding. While artificial insemination has been embraced by some sectors of the equine industry, others prohibit it. Infection control should not be the *only* factor considered when evaluating practices such as this, but it should be a prominent factor.

Pathogen eradication

Global elimination of smallpox was a hallmark event in public health, yet it remains the only human disease to have been eradicated. More recently, rinderpest, a disease of ruminants, was eradicated [42]. Obviously, eradication of pathogens would be the ideal approach to disease control. However, many factors make eradication of equine pathogens impractical and unlikely. For there to be a realistic chance of global eradication of a pathogen, it must possess various properties (Table 1). Further, the disease must be considered of enough importance internationally to dedicate significant resources and time to an eradication programme, and this must be done in every region where the pathogen is present, otherwise the effort will ultimately be futile. There are few equine pathogens that are viable candidates for eradication, based on disease characteristics or practicality (particularly economic factors). The potential for eradication of strangles has been discussed [43,44]; however, the feasibility of this has been questioned [45,46]. While the ultimate goal of eradication of certain pathogens should be kept in mind, it is questionable whether any equine diseases will be eradicated in the near (or even distant) future. Accordingly, the focus must remain on *control* of pathogens and *prevention* of disease.

Implementing infection prevention and control measures

Detailed review of infection control and biosecurity practices is beyond the scope of this article. Various general resources are available (Table 2) to help guide development and implementation of infection control and biosecurity programmes. There is unfortunately little objective evidence of the efficacy of almost all such programmes and recommendations; however, they are based on basic principles of infectious diseases, common sense, expert opinion and extrapolation from other species. Proper study of the efficacy and cost–benefit of specific practices or bundles of measures would be preferred, but in its absence, such logical but unproven measures must form the basis of an infection control programme.

Few discussions of infection prevention and control fail to discuss vaccination. Certainly, vaccination is an important component for prevention of many infectious diseases. The availability of safe and effective vaccines has had a profound impact on equine health, at both individual animal and population levels. Vaccine efficacy is variable, population-based research to guide the most effective vaccination approaches is limited and compliance is sporadic, yet vaccination remains a key component for the control of infectious disease. However, while important, vaccination should not be the cornerstone of an infection control programme. Rather, vaccination should be used to reduce the risk of disease when measures to reduce the risk of exposure are ineffective or impractical. The response to the question ‘What is your infection control programme?’ should never be ‘I vaccinate against. . .’.

TABLE 2: Examples of important infection control questions that remain unanswered

Can quarantine reduce the risk of infectious diseases?
What are optimal quarantine periods (overall and pathogen-specific)?
What are optimal cleaning and disinfection practices for farms?
Does hand hygiene have an impact on equine infections?
What is the role of veterinarians, farriers and other personnel in transmission of pathogens, within and between farms?
Is/when is screening for pathogens useful for prevention of disease?
What should be done in response to identification of a single case of strangles, EHV-1 abortion, EHV-1 myelocephalopathy and other diseases on a farm?
What are optimal perioperative antimicrobial prophylaxis approaches?
What measures can reduce transmission of pathogens at events?
What measures (e.g. checking body temperature and excluding horses with fevers) can reduce pathogen transmission at sales?
What is the role of the environment in various infectious diseases?
What can reduce the incidence of transportation-associated respiratory infections?
Is prophylactic antimicrobial treatment of neonatal foals justifiable?

Objective data, where do we stand?

There has always been some understanding of the need for infection control and basic principles of infection control, and this has increased in recent years, in part because of incidents such as those described above. Yet, there are limited objective data regarding the usefulness of most infection control measures in horses, including longstanding and widely used practices. Important and basic questions remain unanswered, only a few of which are presented in Table 2. Indeed, it is difficult to cite proper studies that have evaluated the efficacy of nonpharmaceutical approaches to reduce infectious diseases in horses. Many reasons account for this. One is the limited number of individuals with an interest in equine infection control research. Limited funding opportunities for evaluation of infection control interventions may also play a role. Practical aspects of study design and implementation also complicate the field. Ultimately, it will probably be impossible to assess some common approaches in controlled studies because of resistance of caretakers to be part of a controlled study and the ethical aspects of using a placebo group to test a practice that is widely considered to be effective (e.g. not cohorting horses in the event of an outbreak). This does not mean that research efforts are futile. There must be some degree of willingness to put in the step beyond current beliefs and challenge current practices, particularly those not supported by studies in other species or with a clear biological basis.

In the absence of equine data, information from other species can be considered. Data are available regarding the efficacy of a wide range of infection control practices in different species, particularly man and food-producing animals, and it is reasonable to consider them when developing practices in horses. Yet, care must be taken because there may be significant limitations to data from other species. In some ways, horses are similar to livestock. In others, they are most similar to man or household pets (e.g. travel, potential for encountering numerous outside individuals, potential use of expensive treatment and preventive measures) and in some respects there may be no reasonable comparison with other species. Data from other species should therefore not be ignored but should be used as general guidance or for hypothesis generation, and not typically direct extrapolation. Further, there are profound differences in management of different types of horses and in practices in different regions, complicating interpretation of any studies that are performed in horses.

TABLE 3: Examples of online equine infection control and biosecurity resources

Resource	Location
California Department of Food and Agriculture Biosecurity Toolkit for Equine Events	http://www.cdffa.ca.gov/ahfss/Animal_Health/Equine_Biosecurity.html
Equine biosecurity principles and best practices	http://www.abvma.ca/Biosecurity/documents/EquineBiosecurityPrinciplesandBestPracticesguide.pdf
Biosecurity for Horse Owners	http://www.equineguelph.ca/pdf/facts/bio_security_info_FINAL.pdf
Equine biosecurity risk calculator	http://www.equineguelph.ca/Tools/biosecurity_2011.php
American Association of Equine Practitioners: Infectious Disease Control	http://www.aaep.org/info/infectious-disease-control
HBLB Codes of practice for Equine Breeders	http://codes.hblb.org.uk/

HBLB = Horserace Betting Levy Board.

Infection control evidence; a call to arms

The limitations in available data and in generating equine- and equine sector-appropriate data must not be taken as excuses for not implementing reasonable infection control practices and for performing appropriate research. The human infection control field faced similar challenges and evolved from a marginal and overlooked area to a highly specialised field with abundant and high-quality research over the past 4 decades.

The equine industry has many infection control challenges and implementation of practical infection control practices could have profound impacts on horse health and welfare, economic loss and impacts on the human-animal bond. Infection control must move from a reactionary field to one that is proactive, seeking out evidence, implementing changes based on evidence of varying strengths, studying the impact of changes, and overall, developing a culture of infection control across all parts of the equine sector.

Conclusions

Veterinary medicine has made tremendous advances, so why do infectious diseases continue to pose such challenges? Many factors contribute to this ongoing risk, some inevitable (e.g. latent pathogens, emerging diseases, the need for frequent horse movement) and some preventable (e.g. poor infection control measures). The concept of the 'preventable fraction' is widely used in hospital infection control to indicate the percentage of infections that could have been prevented with the use of practical infection control measures (e.g. isolation, hand hygiene, good surgical technique). The preventable fraction for equine infectious diseases is completely unclear but, certainly, a reasonable percentage of equine infections could be prevented through application of basic infection control measures.

The importance of equine infectious diseases, while poorly defined, is undeniable. Similarly, while the state of infection control in the equine industry is poorly defined, there is clearly room for improvement, on farms, at events, at sales, by ambulatory veterinarians and in equine hospitals. There is also probably increasing legal liability in the event that 'reasonable' measures are not undertaken, and it has been stated that

there is a standard of expected veterinary care in terms of infection control [47]. Similar expectations are presumably increasing for other components of the equine industry.

There is a need for a 'culture-change' to challenge dogma, and recognise the importance and potential impact of infection control practices. How to achieve change is unclear, and equal parts education and motivation are required. Education is needed to provide the skills and tools to improve, and while evidence-based guidelines are lacking, various good resources are readily available (Table 3). However, for improvements to be made, there must be recognition of the need and motivation to make changes. Equine veterinarians should be a driving force behind both education and motivation, and take a leading role in improving the state of equine infection control and biosecurity.

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SPECIFIC RESULTS AND PROGRESS GROWING FROM GRAYSON-FUNDED PROJECTS INCLUDE:



- Establishing that up to 90% of horses suffering major injury had pre-existing conditions
- Established parameters for safe use of shock wave therapy
- New tests for common diseases such as EHV, influenza, botulism, and EPM
- Establishing dosage protocols of Xylazine to tranquilize injured horses
- Study how and why cryotherapy works to control laminitis
- Developing an Equine Viral Arteritis Vaccine
- Definition of Colitis X
- Airway contamination controls
- Understanding risk factors of high toe grabs in front
- Maintaining pregnancies
- Increasing survival rate of foal pneumonia patients
- The “physiological trim” to enhance healthy hooves
- Herpesvirus research to help control outbreaks
- Virus Abortion vaccine process
- Understanding Placentitis and uterine clearance of infection
- Understanding effects of exercise on cartilage and bone development of young horses
- Welfare & Safety of the Racehorse Summits to share and distribute information and recommendations
- EPM workshop
- Supporting sequencing of the *Rhodococcus equi* genome



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