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Review Article

African Horse Sickness Resurgence and its Implication for Nigeria: A Review

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Abstract

Infectious viral diseases are typically difficult to control, especially when a unique intermediate host and a vector are both involved in the epidemiology. African Horse Sickness (AHS), the most dreaded equine disease, was again confirmed in Nigeria in December 2022. Isolated cases are still being confirmed by the National Veterinary Research Institute. For a proper integrative and concerted control or management approach for AHS to be instituted, it is necessary to review the epidemiology of the disease and its associated intricacies, i.e., the role of the midge vector, reservoir host, and climatic factors, and then its economic consequences, the prevention and control strategies employed by other countries that have survived a bout with AHS at different times, and those in which the disease is still endemic and how such could be deployed in the Nigerian context. This review revealed the need for instituting a concerted integrative prevention and control (containment) protocol, which at the very least must contain three elements of vaccination, quarantine, and vector control, in addition to other methods that should be supported by active seromonitoring and the implementation of early warning systems.

Keywords: African Horse Sickness; Epidemiology; Economic Importance; Quarantine; Vaccination; Vector Control

Introduction

African Horse Sickness (AHS) is the most significant disease of horses worldwide, which makes it notifiable. This is a vector-borne, non-contagious infectious disease, and the etiological agent is a multicomponent double-stranded RNA (dsRNA) virus with nine distinct serotypes, in which immunity to one strain does not necessarily confer protection from another [1,2].

From a historical perspective, AHS outbreaks have been recorded in Nigeria, unsurprisingly due to its geographical location, in the years 1971, 2006, and 2007 [2,3], and recently in 2022 [4]. All countries south of the Sahara have a consistent history with this disease, notably South Africa [5]. The outbreak of December 2022, and indeed subsequent other cases, were confirmed by the Regional Laboratory for Animal Influenza and Transboundary Animal Diseases, National Veterinary Research Institute, Vom, Plateau State, Nigeria. The serotype for the recent and ongoing outbreak has yet to be characterized, and that is largely due to limitations as regards molecular characterization technology [4].

Nigeria's equine industry, and indeed the country as a whole, is now faced with the challenge of having to manage and survive the consequences and effects of this dreaded equine disease. The drastic socioeconomic consequences accompanying a full-blown AHS outbreak, which will bear directly on the rapidly growing equine industry and indeed the entire country of Nigeria, are what compels a detailed review of how best to handle this resurgence. It is therefore imperative that the country learn from the experience of other countries that have survived a bout with AHS at different times and those in which the disease is endemic by implementing similar or the same containment methods.

Etiology, and epidemiology of African horse sickness

Etiology

African Horse Sickness virus (AHSV) is a non-enveloped multicomponent double stranded RNA (dsRNA) orbivirus belonging to the Reoviridae family of viruses [3]. The remarkable ability of all orbiviruses to proliferate in both mammalian and arthropod cells distinguishes them from other Reoviridae family members [6]. African horse sickness (AHS) was first identified as an equine illness in South Africa in 1891, and the virus that causes it was discovered there in 1900 [7]. The virus can kill up to 95% of completely vulnerable horses and is spread by hematophagous *Culicoides* midges [8]. The AHSV is temperotolerant (relatively heat stable), and can be destroyed at pH ≥ 12 or pH < 6, and inactivated by lipid solvent disinfectants such as ether [4].

The virion is about 70nm in diameter with a triple capsid structure enclosing 10 segmented dsRNA and transcription factors coding for structural and non-structural proteins [1]. The AHSV genome, which encodes seven structural proteins (four main and three minor), is contained inside the innermost layer [8]. The outer capsid layer is made up of two of the key structural proteins, VP5 and VP2, while the AHSV core particle is made up of the three minor structural proteins, VP1, VP4, and VP6, as well as the other two major structural proteins, VP3 and VP7 (Figure 1).

The inner core layer has T = 1 symmetry with each of the 60 units composed of a homodimer of VP3, while the outer core is composed of 260 trimers of VP7 and has T = 13 icosahedral symmetry [1]. The outer capsid layer consists of 120 globular trimers of VP5 and 60 triskelionshaped spikes of VP2 [1,9].

Epidemiology

The occurrence of any illness is often believed to be primarily driven by interactions between a susceptible host, a pathogen, and the environment [10]. The epidemiology of African Horse sickness (AHS) depends on the interaction of an infected host, an expert vector, and susceptible uninfected equidae in a supportive environment [11,12]. The availability and quantity of the competent vector (s) would correspond with periodic outbreaks of the illness after its introduction (often from late summer to late autumn) [13].

Geographical distribution

Primary and secondary endemic areas

For ease of understanding, the terms primary and secondary endemic regions have been improvised. Primary Endemic Regions (PER) are areas where the virus is historically thought to be endemic. These includes tropical and sub-tropical areas of Africa south of the Sahara occupying a broad band stretching from Senegal in the west to Ethiopia and Somalia in the east, and extending as far south as northern South Africa [5]. The virus may also be endemic in one place outside Africa, in Yemen in the Arabian Peninsula. Periodically the virus makes excursions beyond its endemic areas to other regions termed the Secondary Endemic Regions (SER), and these includes India and Pakistan in the east, and Spain and Portugal in the West [5,14].

Naïve or virgin areas

These are areas where AHS have never been recorded. Most of the countries that constitute these areas are developed, and first world countries with adequate biosecurity and animal husbandry practices. These includes the Americas, Eastern Asia and Australasia [15].

Role of the midge vector

African Horse Sickness (AHS) is a non-contagious, vector-borne infectious disease of equids. Indeed, the ability to replicate in both mammalian and arthropod cells distinguishes orbiviruses from other members of the reoviridae family [1]. The virus has been documented to be carried by a variety of vectors, including ticks from the genera *Hyalomma* and *Rhipicephalus* and mosquitoes from the *Aedes*, *Culex*, and *Anopheles* genera [16]. The quantity, regularity, and seasonality of the insect vectors that carry AHSV are key factors in determining how quickly the illness spreads [17,18]. Adult female *Culicoides* midges, the most significant of which is *Culicoides imicola*, which is widespread throughout Africa and South East Asia but wasn't discovered in southern Europe until 1982, are the main vectors of African Horse sickness virus (AHSV) [19,20]. The distribution of AHSV, most importantly, is governed by the prevalence and seasonal incidence of the major vector and until recently, *C. imicola*, the Afro-asiatic species and indeed the most widely distributed, was considered to be the only *Culicoides* species involved in AHS transmission [5,12,21]. The North American vector of Blue Tongue virus *Culicoides sonorensis* is also an efficient laboratory vector of AHSV [5], which makes it a potential field vector for this disease. Venter., *et al*. (2000) [11] also implicated a second African species, *C. bolitinos*, as a potential field vector of this virus. *Culicoides bolitinos* has a vast range in southern Africa, notably in cooler highland locations where *C. imicola* is scarce [5].

Climatic conditions

Climatic conditions dictates prevalence and seasonal incidence of the African Horse sickness virus (AHSV) midge vector. The AHSV has demonstrated the ability to overwinter in southern Spain and Portugal, and in Morocco as a result of more severe outbreaks in Spain between 19881990, in Portugal in 1989 and in Morocco between 1989-1991 [5]. The midge vector's capacity to overwinter has been linked to climate change, and this has led to a major extension of the vector's range northward to cover much of Portugal, Spain, Italy, and Greece as well as southern Switzerland [22,23]. This problem is consistent with the idea that arthropod-transmitted illnesses will be more likely to develop as a result of climate change since it will encourage the expansion of tropical insects and the agents they disseminate [17]. Vector activity is halted by unfavorable weather conditions in the winter. However there will inevitably be seasonal incidence of the disease and prolonged prevalence once the climatic circumstances are moderate and allow the adult midge vector to be active, and this concern regarding the possible influence of climate change on the onset of these diseases have been raised by the recent introduction of multiple *Orbiviruses* throughout most of Europe and portions of North America [5].

The role of reservoir host

The African Horse Sickness Virus (AHSV) is spread based on a number of factors, one of which being the existence or absence of a long-term vertebrate reservoir [24,25]. Horses are probably an unintentional host due to the disease's severity and the disease's high fatality rate [26]. Additionally, the fact that AHSV has not established itself outside of Africa's tropical and subtropical climates, where zebra are mostly found, shows that horses, mules, and donkeys are not typically long-term AHSV reservoirs and are not responsible for the virus's ongoing persistence [5]. Zebras are known as the AHSV reservoir host, and reports have shown that they are essential to both the continued existence of the illness in endemic regions and the spread of the disease to new regions [5]. The removal of the vast free-ranging zebra populations via hunting appears to have corresponded with the drop in the yearly number of AHS outbreaks, especially in the southern regions of South Africa [27]. As a comparison to this observation, large populations of zebra have been restricted to game parks in the northeastern parts of South Africa, where AHSV is still endemic [5,27].

Economic impact of African horse sickness

African horse sickness (AHS) has serious economic repercussions for the afflicted nations and the equestrian sector. Economic impact of AHS ranges from direct death of a large proportion of horses in a country, to trade barn imposition and everything in between.

The early 2020 AHS epidemic in Thailand resulted in over 90% mortality, which directly affects the livelihood of those working in the equestrian sector in addition to other major socioeconomic repercussions including trade restrictions on the export of horses or equine products and loss of OIE free zone designation [28]. Historically, an outbreak in Middle East and South West Asia resulted in the death of about 300,000 horses between 1959-1963 [1]. Over 1137 horses perished in Senegal as a result of the AHSV serotype 2 epidemic, and the disease's overall evaluation cost roughly 1.2 million Euros [2]. One thousand seven hundred (1700) horses perished in the southern Africa epidemic of 1719, and over 70,000 horses perished in the outbreaks of 1854– 1855. At that time, the latter comprised more than 40% of the population of horses [1].

The horse sports business is extremely vulnerable to this illness. Significant economic value is attached to horse racing. A total of over 160,000 thoroughbred races costing several hundred billion dollars were staged in 47 countries in 2009 alone [12].

Working horses' morbidity and death from AHS may limit the draught power they can supply in low-income nations, which would have an impact on food security and the fight against poverty [12]. In summary, some of the main pecuniary effects includes losses in the equine industry, trade restrictions, costs of control and eradication, tourism impact, impact on agriculture and loss of valuable equine genetic diversity [12,29].

The World Organization for Animal Health (OIE) regionalization policy

General vaccination of equids in a country experiencing an African Horse sickness (AHS) epizootic comes at the risk of losing OIE AHS free zone certification. The concept of regionalization based on location of an outbreak and proximity to such has been outlined in the OIE terrestrial code, and this has been translated into different pieces of legislature in the EU, the UK and South Africa [28]. A schematic illustration of regionalization is seen in Table 2.

Vaccine platforms and diagnostic techniques

African Horse Sickness virus has a large number of serotypes reflecting a high genetic and phenotypic variation which can complicate diagnostic and immunization efforts for their identification and prevention [30,31].

Vaccines

Polyvalent Live attenuated AHS vaccine

Despite the primary related problems, vaccination with the polyvalent live attenuated vaccine (pLAV) continues to be a reliable preventive measure for African horse sickness. In addition to the confirmed reports of reversion to virulence and lack of ability to distinguish vaccinated from infected animals (DIVA capability) when tested by any of the current diagnostic procedures, the p-LAV is for one not authorized for usage beyond the African subcontinent [1]. Reassortment of genetic segments between several AHSV serotypes in the vaccine has been shown to cause reversion to virulence. Serotype 5 was removed from the p-LAV in 1990 because of such reassortment, which has been proven to occur between serotypes 5 and 4 [32]. Other problems with the p-LAV include the requirement for up to 8 vaccinations over the course of 6 years before adequate immunity against all 9 serotypes is achieved. Since serotypes 5 and 9, which are not parts of the p-LAV, have produced outbreaks in South Africa within the population of vaccinated horses in 2006, it is still questionable if this purported protection against all serotypes exists [1].

Inactivated vaccine

Although it was effective at the time and was commercially produced and utilized during the 1987–1991 AHS epidemic in Spain, Portugal, and Morocco, a formalin-inactivated AHSV vaccine is no longer readily accessible [5]. Inactivated vaccines' primary negatives are their high cost of production, which necessitates the extensive separation of infectious viruses and increases the danger of bio-containment; second, to guarantee long-lasting protective immunity, multiple vaccinations may be necessary [1]. Excessive vaccine administration can lead to hypersensitivity or immunological unresponsiveness [33]. The vaccination platforms approved for use in endemic areas are largely to blame for the inability of the available diagnostic tests to distinguish infected from vaccinated horses; as a result, research into the development of alternative vaccine types that might enable this differentiation has continued over time.

Prospective vaccine candidates

In order to meet the OIE policy requirements for recovering a free-zone designation after an outbreak, the vaccine administered during an epidemic of African Horse Sickness should be able to distinguish between diseased and vaccinated horses (DIVA capability). A continuing, recurring, or convalescent case of African horse sickness results in the same antibody responses that the whole virus live attenuated vaccine and the inactivated vaccination for the disease induce [28]. It is currently exceedingly difficult to distinguish between an antibody response and the presence of AHS virus particles in terms of their origin, whether it is from vaccination or a continuing or remitted infection, and failing to do so runs the danger of losing the free zone OIE accreditation [32,34]. Intense research has been conducted on potential vaccination platforms with DIVA capacity, such as protein sub-unit vaccines, vectored AHS vaccines, etc., as a result of the daring necessity to discriminate antibody response and the presence of AHS virus particles as to their origin [1]. Appropriately combining these with diagnostics methods aimed at the components of the aforementioned vaccines, and or viral components that does not constitute the vaccines used in say a case of an outbreak could help in differentiating an actual infection from vaccination, be it for the antibody response or presence of whole virus or viral structural components. Features, prospect and associated issues of these other vaccine types in development, together with those of live attenuated, and inactivated vaccines are succinctly summarized in Table 1.

Diagnostic techniques

The direction and execution of control methods during an outbreak are laborious and time consuming, and they are dependent on a confirmation diagnosis. This emphasizes the necessity of a prompt, precise diagnosis. Fast, specific, able to distinguish between virus serotypes, and able to determine the DIVA capability of vaccinations should all be requirements for gold standards for diagnosis during an African Horse sickness (AHS) outbreak.

Traditional classical virology techniques, such as virus isolation and serotyping using virus neutralization assays, have a number of drawbacks, including a lengthy turnaround time for diagnosis results, a lack of serotype specificity due to the reliance on the availability of suitable reference strains and antisera, and the inability or difficulty of diagnosing early AHS infections because infected animals will typically pass away before a detectable humoral response is elicited [1].

Parameters	Live attenuated vaccine	Inactivated vaccine	DNA vaccine	Sub-unit vaccine	Poxvirus-vectored vaccine	Reverse genetics vaccine	Viral particle vaccine
Vaccine Component	Whole attenuated AHS virus	Whole inactivated AHS virus	AHSV VP2 DNA	A specific viral protein	Gene encoding an antigen target	Cloned cDNA copy of AHSV gene lacking one functional gene segment.	AHSV structural proteins
Strategy/ Principle of Vaccine platform and design	Attenuation by serial passages in heterologous host or cell culture	Inactivation by physicochemical means	DNA encoding viral proteins is injected as vaccine	Recombinant DNA technology is used to produce a purified specific viral protein	Complex method involving cloning of an antigen target gene into a pox virus vector	These vaccine are created in mammalian cell lines using a twofold transfection technique and rely on the availability of cloned cDNA copies of the viral genes.	Structural proteins are expressed from recombinant bacterial strains in diverse expression systems.
DIVA Complaint	No	No	Yes	Yes	Yes	Yes	Yes
Immune Response Induced	Humoral and cellular responses	Majorly humoral, but cellular mediated immunity contributes.	VP2-specific humoral and cellular immune response		Both humoral and cellular		Induces both innate and adaptive humoral and cellular immune responses
Immuno genicity	Immunogenic; mimics subclinical infection	Immunogenic	Immunogenic	Weak immunogens	Immunogenic. Vaccine is delivered directly to the cells where the viral protein is expressed and presented to the host immune system.	Despite the technology's potential, further study is required to establish the minimal dosage requirement and the duration of the immune response.	Immunogenic. Antigens are created when structural proteins selfassemble into particles that resemble viruses.
Risk of Genetic Reassortment	Yes	No	No	None	Unlikely	Low risk of genetic reassortment	No risk
Reversion to virulence	Yes	No	Safe and stable, thus highly unlikely to revert.	No	No	No	No
Duration of Immunity	Immunity is long-lived	Transient	Low humoral responseimmunity will be shortlived			More research needed to determine longevity of immunity	Strong immune response
Cost of production	Cost effective	Expensive	Cost effective once gene is clone	Expensive	Expensive	Expensive	Depending on the expressions used. Costly if expression systems from insects and mammals are employed. Plant expression systems are inexpensive
Application and scalability	In use vaccine in endemic areas.	unavailable for usage any longer. utilized during the AHS outbreak in Morocco, Portugal, and Spain.	The likelihood of creating a viable AHSV DNA vaccine appears to be low.	Given the high manufacturing costs connected with it, its potential for use as an animal vaccine appears to be limited.	Prospective vaccine candidate. Experimental application, no on field use recorded at the moment	These prospective vaccine candidates may not be successfully commercialized because of the price and scale constraints.	Particularly attractive vaccine candidates

Table 1: Features of prospective vaccine types in development, and live attenuated and inactivated vaccines.

The enzyme linked immunosorbent assay (ELISA) for the group conserved VP7 antigen, although specific, cannot serotype the implicated AHSV and it has no DIVA capacity [35].

The use of a real-time RT-PCR, and a triplex AHSV type specific reverse transcription – polymerase chain reaction (RT-PCR) for the detection of three serotypes is also prevalent [1]. This is unique to the conserved VP7 antigen and with these techniques, diagnosis within hours can be achieved, and this will go a long way to contribute in instituting timely control measures in the face of an outbreak. The same issue remains; it also has no DIVA capacity [36,37]. Additionally, the component of currently employed vaccines, viral RNA, and complete virus particles are both detectable by RT-PCR, and full virus particles may be detected up to 100 postvaccination [28].

Prevention and control of African horse sickness

Below are some of the preventive and control strategies that can be implemented in a concerted effort before- and during- an outbreak. These have proven effective in combating the entry of this dreaded disease into free areas and in containment of outbreaks in endemic areas.

Strict control on equid importation

Importation of infected Equids have a proven role in African Horse sickness (AHS) outbreaks in many countries [28,2,5]. The importation of equids should only be from Countries with free zone certification by the OIE. This is critical, as differentiating an infected horse from a vaccinated horse is not possible with current diagnostics [28]. One key factor that has contributed to maintenance of the OIE free zone status by naïve or virgin regions like the Americas is strict guidelines on the importation of horses. According to a qualitative risk assessment, the risk of African Horse sickness virus (AHSV) introduction through importation is "very low" in these countries because of the strict regulations on the importation of horses and horse products, and the risk of AHSV introduction through wind dispersal of infected vectors is currently "negligible" because AHSV has not been discovered in any of Ireland's neighboring countries [3]. Nigeria is already an endemic area as regards AHS and as such the explicit importance of strict control of equid importation may not be apparent. However it could go a long way in preventing the entry of new and more virulent serotypes of the virus from other neighboring endemic African countries.

Modelling the distribution of the midge vector

The presence of populations and conducive habitat for the major vector of African Horse Sickness virus (AHSV) confers significant risk of the disease. Across the years, the abundance and distribution of *C. imicola* has been modelled with significant accuracy using methods based on satellite-based proxy climatic variables as revealed by the work of Baylis., *et* al. (1998) [38]. The most important of these as reported by Mellor., *et al*. (2004) [5] are the normalized vegetation index (NDVI). This correlates photosynthetic activity measure with soil moisture and land surface temperature (LST). The significance of this becomes apparent when the required breeding conditions (damp and wet soil) of *C. imicola* is considered [5]. Evidently a high NDVI correlates with the presence of breeding sites as shown in Morocco and Iberia [38]. The more recent modelling methods was developed for the Blue tongue virus [39,40], another Orbivirus vectored by *C. imicola*, and as such the usefulness of such a method could be extrapolated to apply to AHSV. This method incorporated and accounted for a number of variables including altitude, NDVI, middle infra-red reflectance, LST and air temperature and such was predictive of breeding sites of the vector with 95% accuracy [41]. One reason for the continued confirmation of African Horse Sickness virus in samples sent to the Regional Laboratory for Animal Influenza and Transboundary Animal Diseases – National Veterinary Research Institute Vom from across Nigeria is the abundance of infective *Culicoides* vector of this disease and the presence of yet to be modelled breeding sites. These predictive models discussed above could be applied in the Nigerian context to identify the possible breeding sites of vectors of AHS and habitat alteration methods applied to reduce the burden of the infective vectors.

Active serosurveillance and implementation of early warning system

This is an effective preventive and control strategy. Sero-surveillance of horses in the surveillance zone will help identify new infections, and also will help assess the level of protection in vaccinated horses. This is critical and will go a long way in containment of the outbreak to specific areas where the disease has been confirmed. Regular seromonitoring of known unvaccinated Equids scattered throughout the surveillance, and free zone has been done by countries like South Africa, Senegal Spain and Portugal in accordance to the OIE regionalization policy in order to ensure confinement of the AHS virus to the infected, and protected zones alone if possible [1,2]. Coupled together with routine surveillance is the implementation of early warning system which have been shown to be effective in various outbreaks, including that of Thailand in 2020 [42]. An effective early warning system will go a long way in reducing the impact of an AHS outbreak as it sets in motion other preventive measures. Status report of infected horses in specific region was put in place to quickly contain infection in Senegal [2]. The effectiveness of response to an AHS outbreak depends on how quickly the outbreak is reported to the respective authorities, and how recommended preventive measures such as movement control, vaccination, slaughter and proper burial of infected horses, and vector-directed methods are instituted.

Vector control

This approach is one that may be used both before and during an outbreak. It's important to remember that populations of the vector Culicoides are practically hard to eradicate entirely.

Evidently, there are many factors involved in pest management as a preventative technique. The persistence of adult *C. imicola* all year in portions of Spain, Portugal, and Morocco is the primary reason that African Horse sickness virus was able to overwinter in the region four times before being eradicated by a coordinated control program [19]. Free countries or zones with short winter and milder climatic conditions are at risk of AHS introduction due to global warming and climate change driving northward migration of the biting midge vector [28].

First, strategies aimed at the specific vector should be implemented by both endemic zones, and zones free of the disease. Critical to vector control before an outbreak is the accurate modelling of the abundance and breeding sites of the *Culicoides* vector and instituting vector-directed approaches in other to minimize the burden or load of infective vectors with reduction of infecting bites as the objective [5]. These vector-directed methods could be towards the environment of the vector, the adult *Culicoides*, and the immature potentially infective vectors. Others could include indirect methods that aims to protect the Equine hosts from the *Culicoides* vector. These vector control strategy could generally include; accurately modelling habitat distribution of *Culicoides*, habitat alteration, routine sampling of vectors for virus monitoring, application of regionalization policy to areas modelled to have high/ or infected vector burden, and other direct methods like the use of insecticides and repellants [43,44]. Secondly, country specific policies directed at minimizing global warming will help in restricting this reported northward movement of the midge vector. Recommended precautionary measures can be put in place by horse owners in Nigeria as suggested by the Terrestrial animal health code of the OIE (2014) to prevent equines from *culicodes* attack. In addition to the vector-directed strategies discussed above, these precautionary measures could include destruction of vector habitats around farms or facilities , vector control around horse stables using insecticides or covering of stable opening with mesh impregnated appropriately with approved insecticide e.g. alphacypermethrin [45].

Quarantine and movement control

African Horse Sickness (AHS) outbreaks are controlled by quarantining equines travelling from endemic and epidemic AHS regions to virus-free areas [12]. Restrictions on the movement of equids should be implemented, and this should be respected by horse owners as it might be an effective way to reduce the impact of the disease. Introducing animal movement restrictions helps to prevent infected animals from initiating new foci of infection [5]. This strategy has proven effectiveness in Thailand, South Africa, Senegal, Portugal and Spain when they experienced outbreaks of AHS [2,5,28]. In Senegal, even leisure activities with horses in such defined risk zones was forbidden [2].

Implement a regionalization policy

This was implemented during the serotype 2 outbreak of 2007 in Senegal where horses were not allowed to leave a defined risk zone [2]. Such was also implemented in Thailand [28]. Areas with reported outbreaks should be considered as "infected'' zones, and all other areas surrounding it be geographically named as outline in OIE regionalization policy. This will help specific control measures targeted at each zone in order to mitigate the possibility of a countrywide outbreak. There should be strict movement control of equids implemented together with other control measures like accurate and timely diagnosis, and testing of individual equid, wide spread vaccination, insect control, and rigorous sero-surveillance. Regular seromonitoring of known unvaccinated Equids scattered throughout the surveillance, and free zone is done in order to ensure confinement of the AHS virus to the infected, and protected zones alone if possible. In countries like South Africa, vaccination of horses in the free, and surveillance zones requires special permission. Once a horse is confirmed positive for AHS in the surveillance zone, horses exports to the EU is suspended for 2 years [1].

Vaccination

Vaccination with live attenuated strains of AHSV is the primary means of controlling AHS in both endemic and epidemic scenarios [12]. Mass vaccination should involve not just infected zone, but in some cases even sub-regional countries. Countries like Ethiopia, South Africa, Spain, Portugal, Senegal, and Thailand have all made use of mass or ring vaccination during various outbreaks with recorded success [2,5,12,46]. One key factor that boosted the effectiveness of the control measure instituted in Senegal during the 2007 outbreak is Ring vaccination. Ring vaccination initiated in the environment of initial cases was also used to contain the serotype 1 outbreak in South Africa as reported by Grewer., *et al*. (2013) [47]. In Senegal, it was reported that 5,938 horses (85.9%) out of an estimated 6,910 horses were vaccinated in 2007 in Dakar region of Senegal. In outbreaks outside of Dakar, over 230,000 doses of AHS vaccine was used under the Emergency Vaccination Program [2]. In these regions outside of Dakar, a total of 175,300 horses (33.8%) out of a possible 518,212 were vaccinated with the polyvalent vaccine within 4 months starting in August 2007 and countries like Egypt contributed to the supply of such vaccines as aids [2]. Implementing such urgent vaccination program requires concerted effort involving every stakeholder in the Equine industry, Nigerian Agricultural Quarantine Services (NAQS), Federal Ministry of Agriculture and Rural Development (FMARD), National Veterinary Research Institute Vom (NVRI), Veterinarians, and neighboring countries. Mass vaccination, along with other control measures, helped put an end to the deadly Middle East pandemic that expanded to India and Pakistan in 1961 [19]. In the case of Thailand during the outbreak of the serotype-1 AHSV in 2020, vaccination of susceptible animals with live attenuated vaccines was also done and it helped in stopping the spread of the disease [48].

Slaughter and compensation policy

The 1966 AHSV-9 outbreak in Cadiz Province, Spain, was eliminated within three weeks, following the application of slaughter policy in addition to other control measures [5]. The effectiveness of this policy in an integrated prevention and control strategy for AHS depends on consent from both the government and equine owners. Such is really difficult to achieve in Nigeria, most especially the compensation aspect.

Habitat alteration and husbandry modifications

This action is intended to limit or restrict vulnerable animals access to vectors. The majority of *Culicoides* vector species, including *C. imicola*, are exophilic [49]. The risk of infection will thus be greatly reduced by stalling vulnerable equids during the crepuscular hours and at night, when vector activity is at its peak. Additionally, sand-fly netting or other fine-mesh or coarse-mesh materials coated with insecticides (such as a synthetic pyrethroid) can be used to screen conspicuous portals of entrance to such housing, such as windows and doors, to further lower bite rates [50].

Conclusion

Viral diseases are associated with significant morbidity and mortality in both humans and animals. Control of viral infectious diseases is usually hard, especially those whose epidemiology involves both a distinct reservoir host and a vector. Preventive and control measures are targeted not just at the etiological agent but also at the vector, the intermediate host, and every factor governing the epidemiological dynamics involved in the spread of all three over space and time. As such, there is an urgent need to institute a concerted integrative containment protocol following the prevention and control strategies outlined in this review article. Vaccination, vector control, and quarantine must be included, in addition to other methods, in this concerted control and management strategy. Implementation of such will require collaboration between the Nigerian Agricultural Quarantine Services (NAQS), the Federal Ministry of Agriculture and Rural Development (FMARD), the National Veterinary Research Institute Vom (NVRI), veterinarians, and stakeholders in the equine industry in order to prevent the accompanying devastating effects of a full-blown African horse sickness outbreak in Nigeria.

Declarations

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Bibliography

1. Dennis SJ., *et al.* "African Horse Sickness: A Review of Current Understanding and Vaccine Development". *Viruses* 11 (2019): 844.
2. Diouf ND., *et al.* "Outbreaks of african horse sickness in senegal, and methods of control of the 2007 epidemic". *Veterinary Record* 172.6 (2013): 152.
3. Thompson G M., *et al.* "A review of african horse sickness and its implications for Ireland. Irish Veterinary Journal 65.1 (2012): 1-8.
4. Adesola R O., *et al.* "Addressing the recent outbreak of African horse sickness in Lagos, Nigeria". *Frontiers in Veterinary Science* 10 (2023): 1160856.
5. Mellor PS and Hamblin C. "African horse sickness". *Veterinary Research* 35.4 (2004): 445-466.
6. Roy P. "Genetically engineered structure-based vaccine for bluetongue disease". *Veterinaria Italiana* 40.4 (2004): 594-600.

7. Verwoerd D W. "History of Orbivirus research in South Africa". *Journal of the South African Veterinary Association* 83.1 (2012): 6-11.

8. Potgieter A C., *et al.* "Consensus Sequence of 27 African Horse Sickness Virus Genomes from Viruses Collected over a 76-Year Period (1933 to 2009)". *Genome Announcements* 3.5 (2015).

9. Manole V., *et al.* "Structural Insight into African Horsesickness Virus Infection". *Journal of Virology* 86.15 (2012): 7858-7866.

10. Demissie G H. "Seroepidemiological study of African horse sickness in southern Ethiopia". *Open Science Repository Veterinary Medicine* (2013): e70081919.

11. Venter G., *et al.* "African horse sickness epidemiology: vector competence of South African Culicoides species for virus serotypes 3, 5 and 8". *Medical and Veterinary Entomology* 14.3 (2000): 245-250.

12. Carpenter S., *et al.* "African Horse Sickness Virus: History, Transmission, and Current Status". *Annual Review of Entomology* 62 (2017): 343-358.

13. Chevalier V., *et al.* "Epidemiological processes involved in the emergence of vector-borne diseases: West Nile fever, Rift Valley fever, Japanese encephalitis and Crimean-Congo haemorrhagic fever". *Revue Scientifique et Technique-Office International des Epizooties,* 23.2 (2004): 535-556.

14. Asia E and West S. African Horse Sickness : A Review of Current Understanding and Vaccine Development in the (2019): 1-24.

15. Clemmons E A., *et al.* "Transboundary Animal Diseases, an Overview of 17 Diseases with Potential for Global Spread and Serious Consequences". *Animals* 11 (2021): 2039.

16. Mellor P. "African horse sickness: transmission and epidemiology". *Veterinary Research* 24.2 (1993): 199-212.

17. Achlan N J M A C L and Uthrie A JG. "Review article Re-emergence of bluetongue, African horse sickness, and other Orbivirus diseases". (2010).

18. Wittmann E J and Baylis M. "Climate Change: Effects on Culicoides-Transmitted Viruses and Implications for the UK". *Veterinary Journal* 160.2 (2000): 107-117.

19. Wilson A., *et al.* "Adaptive strategies of African horse sickness virus to facilitate vector transmission". *Veterinary Research* 40.2 (2009): 16.

20. Du Toit R. "The transmission of blue-tongue and African horse-sickness by Culicoides" (1994).

21. Meiswinkel R and Paweska J T. "Evidence for a new field Culicoides vector of African horse sickness in South Africa". *Preventive Veterinary Medicine* 60.3 (2003): 243-253.

22. Möhlmann TW R., *et al.* "Biting midge dynamics and bluetongue transmission: a multiscale model linking catch data with climate and disease outbreaks". *Scientific Reports* 11.1 (2021): 1-16.

23. Niedbalski W and Fitzner A. "Recent changes in the global distribution of arboviral Infections in ruminants". *Medycyna Weterynaryjna* 76.2 (2020): 71-76.

24. Morales-briceño A. "African horse sickness : A practice update" (2020).

25. Riddin M A., *et al.* "Culicoides species as potential vectors of African horse sickness virus in the southern regions of South Africa". *Medical and Veterinary Entomology* 33.4 (2020): 498-511.

26. Riyesh T., *et al.* "Global status of african horse sickness: A perspective on emergency preparedness". *Indian Journal of Comparative Microbiology, Immunology and Infectious Diseases* 41.2 (2020): 55-65.

27. Barnard B. "Epidemiology of African horse sickness and the role of the zebra in South Africa". *African Horse Sickness* (1998): 13-19.

28. Castillo-Olivares J. "African horse sickness in Thailand: Challenges of controlling an outbreak by vaccination". *Equine Veterinary Journal* 53.1 (2021): 9-14.

29. Redmond E F., *et al.* "Economic assessment of African horse sickness vaccine impact". *Equine Veterinary Journal* 54.2 (2022): 368-378.

30. Ngoveni H G. "Characterizing the effect of mutation recombination and reassortment on the genetic diversity of African horse sickness virus genomes" (2019).

31. Yadav M P., *et al.* "Emerging and Transboundary Animal Viral Diseases: Perspectives and Preparedness" (2020): 1-25.

32. Rodríguez M., *et al.* "Immune response of horses to inactivated African horse sickness vaccines". *BMC Veterinary* Research 16.1 (2020): 1-13.

33. Gordon S J G., *et al.* "The sero-prevalence and sero-incidence of African horse sickness and equine encephalosis in selected horse and donkey populations in Zimbabwe". *Onderstepoort Journal of Veterinary Research* 84.1 (2017).

34. Wang Y., *et al.* "Development of Differentiating Infected from Vaccinated Animals (DIVA) Real-Time PCR for African Horse Sickness Virus Serotype 1". *Emerging Infectious Diseases* 28.12 (2022): 2446.

35. Maree S and Paweska JT. "Preparation of recombinant African horse sickness virus VP7 antigen via a simple method and validation of a VP7-based indirect ELISA for the detection of group-specific IgG antibodies in horse sera". *Journal of Virological Methods* 125.1 (2005): 55-65.

36. Agüero M., *et al.* "Real-time fluorogenic reverse transcription polymerase chain reaction assay for detection of African horse sickness virus". *Journal of Veterinary Diagnostic Investigation* 20.3 (2008): 325-328.

37. Guthrie A J., *et al.* "Diagnostic accuracy of a duplex real-time reverse transcription quantitative PCR assay for detection of African horse sickness virus". *Journal of Virological Methods* 189.1 (2013): 30-35.

38. Baylis M., *et al.* "Studies of the mortality rate of Culicoides imicola in Morocco". In African horse sickness (1998): 127-136.

39. Ciss M., *et al.* "Ecological niche modelling to estimate the distribution of Culicoides, potential vectors of bluetongue virus in Senegal". *BMC Ecology* 19.1 (2019): 1-12.

40. Navarro Mamani D A., *et al.* "Would Climate Change Influence the Potential Distribution and Ecological Niche of Bluetongue Virus and Its Main Vector in Peru?" *Viruses* 15.4 (2023): 892.

41. Tatem A., *et al.* "Prediction of bluetongue vector distribution in Europe and north Africa using satellite imagery". *Veterinary Microbiology* 97.1-2 (2003): 13-29.

42. King S., *et al.* "Outbreak of African horse sickness in Thailand, 2020". *Transboundary and Emerging Diseases* 67.5 (2020): 1764-1767.

43. Backer JA and Nodelijk G. "Transmission and Control of African Horse Sickness in The Netherlands: A Model Analysis". *PLOS ONE* 6.8 (2011): e23066.

44. Lord CC., *et al.* "Vectorborne diseases and the basic reproduction number: a case study of African horse sickness". *Medical and Veterinary Entomology* 10.1 (1996): 19-28.

45. Zientara S., *et al.* "African horse sickness". R*evue Scientifique et Technique (International Office of Epizootics)* 34.2 (2015): 315-327.

46. Aklilu N., *et al.* "African Horse Sickness Outbreaks Caused by Multiple Virus Types in Ethiopia". *Transboundary and Emerging Diseases* 61.2 (2014): 185-192.

47. Grewar J D., *et al.* "The 2011 outbreak of African horse sickness in theAfrican horse sickness controlled area in South Africa". *Journal of the South African Veterinary Association* 84.1 (2013): 1-7.

48. Lu G., *et al.* "African horse sickness: Its emergence in Thailand and potential threat to other Asian countries". *Transboundary and Emerging Diseases* (2020).

49. Meiswinkel R., *et al.* "Stabling and the protection of horses from Culicoides bolitinos (Diptera: Ceratopogonidae a recently identified vector of African horse sickness". *Bulletin of Entomological Research* 90.6 (2000): 509-515.

50. Awad F., *et al.* "The incidence of African horse sickness antibodies in animals of various species in Egypt. Bulletin of animal health and production in Africa". *Bulletin des sante et production animales en Afrique* 29.3 (1981): 285287.