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Avian viral Diseases: Emerging Zoonoses and Challenge to Global Healthcare System and Economic Infrastructure

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ABSTRACT

Avian infections include many different types of diseases that affect both wild and domestic birds all over the world. It possesses serious global threat due to their effect on both human and poultry health leads to burden on economic infrastructure. Several avian infection viruses, like Highly Pathogenic Avian Influenza (HPAI), Newcastle Disease Virus (NDV), Marek's Disease Virus (MDV), and West Nile Virus (WNV), have caused significant mortality in bird populations and raised concerns about their ability to infect humans. Among these, alone H5N1 and H7N9 strains of avian influenza are responsible for more than 2,500 human infections incidence worldwide, with 30% to 50% mortality rate. This review tries to explores the explore the different type of viral avian pathogens, their patterns of transmission, and the risks they pose at the animal-human interface. It also highlights critical gaps in research, including less study on transmission, limited post-mortem data in birds, and insufficient vaccine coverage and diagnostic facility in many regions of world.

KEYWORDS: Avian influenza, Avian Influenza Viruses, Avian Leukosis Virus, Bursal Disease Virus, Marek's Disease Virus, Newcastle Disease Virus.

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INTRODUCTION

Avian infections composed of a broad array of diseases which affects both wild, and domesticated birds worldwide.[1] It serves as both reservoirs and amplifiers of different infectious agents and facilitates their transmission across the ecological boundaries. Particularly migratory birds, act as natural carriers of these pathogens, responsible for spreading across the continents. In domestic setup, densely populated poultry farms become epicentre's for rapid disease transmission and also their evolution, sometimes resulting in highly virulent strains which are capable to interspecies transmission.[2]

Avian infections encompass a diverse group of diseases caused by viral like Avian Influenza Viruses (AIVs), Newcastle Disease Virus (NDV), Avian Leukosis Virus (ALV), Infectious Bursal Disease Virus (IBDV), Marek's Disease Virus (Herpesvirus), Infectious Bursal Disease Virus (IBDV), West Nile Virus (WNV).[3,4] Bacterial infections like *Chlamydia psittaci* (Psittacosis), *Salmonella species*, *Mycoplasma gallisepticum*, *Pasteurella multocida* (Fowl Cholera).[5] Fungal and parasitic pathogens like Aspergillosis (*Aspergillus fumigatus*), *Histomoniasis* (Blackhead Disease), Coccidiosis (*Eimeria spp.*), *Plasmodium spp.* (Avian Malaria).[6] These infections responsible for significant morbidity and mortality of avian populations, posing serious threats to global poultry industries, food security, and public health.

Avian and human health are closely interconnected, which highlighted the concept of One Health approach, which include the health of human, animal, and their surrounding environmental. Outbreaks of avian-transmitted diseases like H5N1 and H7N9 strains of influenza A, caused sporadic human infections with high mortality rates, prompting concerns about future risk of pandemics. In addition, these infections also contribute to high avian mortality rates, necessitating mass killing of birds and economic losses.[7]

Majority of scientific literature on avian infections focuses heavily on avian influenza like H5N1 and H7N9, due to their zoonotic risk and high fatality rates in humans while other viral infections are remained least reported. So, keeping this point in mind this review tried to explore the other viral diseases beyond influenza, role of different organisation in controlling the avian infection, emerging risk factor and current research gap. This takes wider view to better understand how these infections affect animals, people, and the environment.

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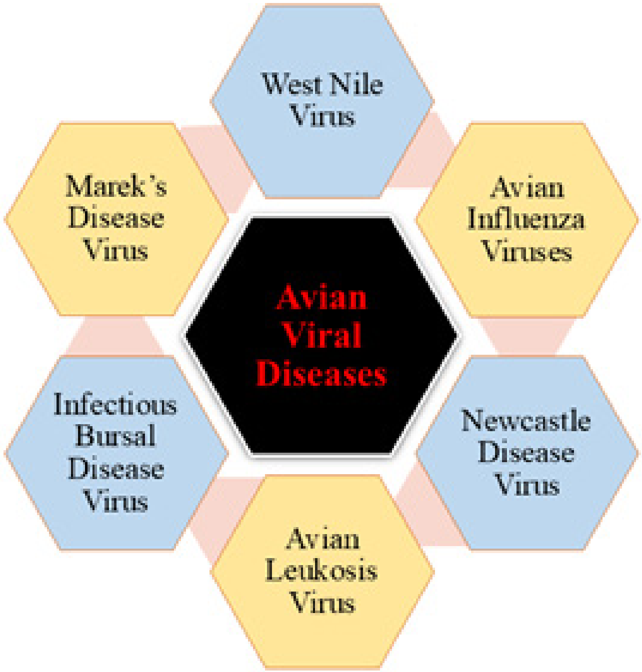

Figure 1: Graphical abstract.

MAJOR AVIAN VIRAL DISEASES

Avian Influenza Viruses

Avian influenza viruses (AIVs) belong to the *Orthomyxoviridae* family which further classified on the basis of two surface glycoproteins: hemagglutinin (HA) and neuraminidase (NA). to date 18 subtypes of HA and 11 subtypes of NA has been identified. The most concerning subtypes for avian and human health are H5, H7, and H9 subtypes, particularly H5N1 and H7N9, due to their high pathogenicity and zoonotic potential. AIVs are further classified into low pathogenic avian influenza (LPAI), responsible for mild symptoms in birds, and highly pathogenic avian influenza (HPAI), responsible for high mortality in poultry.[8] Wild aquatic birds are the natural reservoirs of AIVs, which often carry the influenza virus without any observed symptoms. However, when it transmitted to domestic poultry system, HPAI strains mainly H5N1 can cause outbreaks with 100% mortality rates. In human these infections are sporadic, but often found to be severe. Since its emergence in 1997, H5N1 has infected over 986 humans with a 48% mortality rate. Similarly, H7N9, first reported in 2013, led to 1,568 human infections with a 39% fatality rate. H5N6, H9N2, and H10N3 are the other emerging subtypes, with varying degrees of severity and zoonotic risk.[9]

Vaccination is a vital tool in controlling the avian influenza, especially in poultry. Inactivated whole-virus vaccines are widely used in endemic regions to reduce the viral load and bird-to-bird transmission. However, vaccines are subtype-specific, and their efficacy can be compromised by emergence of new viral clades or antigenic drift. For example, clade 2.3.4.4b of H5N1 has shown genetic diversity, which compromised the effect of existing vaccines. Successful mRNA vaccine platforms, in human influenza and COVID-19, are being explored for avian influenza due to their adaptability and rapid production. For humans, currently no universal vaccine is available for avian influenza. However, prototype vaccines against H5 and H7 subtypes have been developed and stored by various government agencies for pandemic preparedness. To minimize the impact of evolving risk, continuous surveillance system, genomic monitoring, and vaccine development are essential to staying ahead of this evolving threat.[10]

Newcastle Disease Virus

Newcastle Disease Virus (NDV), caused by *Avian orthoavulavirus 1*, is a contagious RNA virus that infects mainly domestic and wild birds. It classified into three different categories based on their severity like, lentogenic (mild), mesogenic (moderate), and velogenic (severe) strains, with velogenic types causing mortality rates up to 100% in unvaccinated poultry. It spreads via aerosols, contaminated feed, water, and direct contact with infected birds or surfaces, making it a major concern for global poultry industries due to severe economic loss and trade restrictions.[11]

In birds, NDV primarily target the respiratory, nervous, and digestive systems, leading to symptoms such as respiratory distress, greenish diarrhoea, paralysis, twisted necks (torticollis), and sudden death. Wild birds, especially waterfowl, act as reservoirs, persistence and spread of virus.[12]

NDV is also considered as zoonotic virus, although human infections are rare and usually mild in nature. Their transmission in human occurs mainly through occupational exposure among poultry workers, veterinarians, and laboratory staff. In humans, it causes only mild infection like conjunctivitis, mild flu-like symptoms, or transient fever, with no documented human-to-human transmission or fatalities.[13]

Vaccination is still the primary control strategy for NDV. Live attenuated vaccines, including LaSota and Hitchner B1 strains, are widely used because of easy administration via eye drops, drinking water, or sprays. Inactivated oil-adjuvant vaccines are also used for developing long-lasting immunity, particularly in breeding flocks. In endemic areas, combined vaccination strategies (live prime followed by inactivated booster) are effective. Research on recombinant vector vaccines with DIVA capability is ongoing. While NDV possess the minimal risk to humans, its significant impact on poultry health and trade emphasizes the need for integrated control through biosecurity, vaccination, and surveillance.[14]

Avian Leukosis Virus

Avian Leukosis Virus (ALV) member of retrovirus, belong to *Alpharetrovirus* genus that affects chickens, leading to tumor formation, immunosuppression, and decrease in production.[15] It is divided into numerous subgroups (A–J), with subgroups A, B, and J are the most pathogenic in nature.[16]

ALV spreads in two ways, one from parent birds to their chicks via the egg known as vertical transmission and second is the between birds through contact or comes in infected environment known as horizontal transmission. The virus presents in breeding flocks for a period of long time because it can pass through the eggs.[17] It is responsible for lymphoid leukosis, erythroblastosis, and myeloid tumors, which can decrease the flock productivity due to poor weight gain, decreased production of eggs, and increased mortality. Through successful eradication programs, ALV almost remove from the commercial poultry farm in the Western world. However, the virus still found in the backyard, hobby, and local chickens' population, have chance to spread in commercial flocks. To avoid this type of threat, there is continuous needs of surveillance and biosecurity, especially in areas where mixed poultry types are found.[18]

Currently, no effective vaccine for ALV, especially for subgroup J are available. To control this virus, farmers depend on testing and removal of infected birds, and using chicken breeds that are naturally more resistant. Lab tests like ELISA and PCR help to find the virus at early stage and make it easier to manage. To date, ALV is not known to infect humans, but it remains a major pathogen found in poultry system may cause threat to global biosecurity and commercial production.[19]

Infectious Bursal Disease Virus

Infectious Bursal Disease Virus (IBDV), also known as Gumboro disease, is a viral infection that spreads quickly and widely. It belongs to the family of Birnaviridae, which affects only the bursa of Fabricius, responsible for bird's immune system. It mostly affects young chickens. Chickens with 3 to 6 weeks are particularly susceptible, and infection within this period of time can result in considerable immunosuppression.[20]

It spreads mainly through the fecal-oral routes. Contaminated feed, water, litter, or equipment are major sources of infection. The virus spreads quickly once it enters in flock population. Common symptoms are depression, ruffled feathers, watery diarrhoea, and not wanting to move. The mortality rates vary based on the strain, like the most highly virulent (vvIBDV) variants potentially resulting in losses of 60–70% in unprotected flocks.[21]

However, it is not transmitted into the humans, its impact on poultry health and the industry is substantial.Infected birds often fail to respond properly to other vaccines due to compromised immune system, leading to chance of secondary infections. Economic losses arise in form of both mortality and poor productivity. There is no exact treatment are available for IBDV. Thus, vaccination is the major way to control the disease before it starts is very important. Both live and inactivated vaccines are used for treatment of IBDV. These are often given through drinking water or as eye drops. Chicks also get some protection from their mothers if they are vaccinated. Given the virus's ability to survive in the environment for long periods, enhanced biosecurity, regular sanitation, and flock monitoring are key to long-term control. Regular monitoring and vaccinations are needed, especially in those regions, where immune-evasive strains have emerged.[22]

Marek's Disease Virus (Herpesvirus)

Marek's Disease is a fast-spreading virus in chickens caused by a type of herpesvirus called the Marek's Disease Virus (MDV). It belongs to the group of Alphaherpesvirinae, mostly affects the young birds. It is responsible for tumor formation and weakening their immune system. This makes it a serious problem for poultry industry and commercial chicken production. It generally targets the lymphoid tissues and nerves, leading to a wide range of clinical signs. Affected birds may show paralysis of legs or wings, loss of weight, pale combs, and irregular pupils due to ocular lymphomatosis. It appears in different forms, including classical neural form, acute visceral lymphomas, and cutaneous Marek's form. In unvaccinated flocks, mortality can reach 10% to 50%, based on the virulence of the strain.[23]

MDV spreads through the inhalation of virus-laden dust and feather dander. Once shed, MDV remains environmentally stable, making eradication difficult. There is no vertical mode of transmission are available, only horizontal transmission is the primary route of their transmission. The major concerns with this disease are the ability to evade host immunity and evolve rapidly. Despite of widespread vaccination, outbreaks still happen from more virulent strains, such as very virulent (vvMDV) and very virulent plus (vv+MDV). These strains have emerged partly because of long term use of vaccine.[24]

Vaccination is the major strategy to prevent the Marek's Disease. It usually involves weakened herpesvirus-based vaccines, like HVT (Herpesvirus of Turkeys), or combinations of two or three vaccine types. However, while vaccines protect birds from getting sick, but they are unable to make the virus from infecting them or being spread. Due to this ability MDV can still circulate in flocks even after vaccination

Although, MDV is not zoonotic and have no direct threat to human health, its impact on poultry health, welfare, and production is substantial. Effective control measure requires early vaccination, strict biosecurity, and continuous monitoring for emerging virulent strains.[25]

West Nile Virus

West Nile Virus (WNV) is a type of flavivirus, spread by mosquitoes that can infect many types of birds and mammals, including people. It was first found in Uganda in 1937, and has since spread to many regions of the world, including Africa, Europe, the Middle East, Asia, and the Americas. Birds are the major natural carriers of the virus, and it usually spreads through bites from infected Culex mosquitoes.[26]

In avian species, it is responsible for encephalitis, neurological disorders, and high mortality, especially among corvids (like crows and jays) and raptors. In poultry industry especially geese and turkeys, outbreaks can result in prominent losses. However, chickens are more resistant to WNV. Migratory birds contribute significantly to long-distance virus dispersal.[27]

In humans, WNV infection is usually asymptomatic or mild, but in some cases, particularly in elderly or immunocompromised individuals, it is responsible for neuroinvasive disease, including meningitis, encephalitis, or acute flaccid paralysis. The neuroinvasive form has mortality rate ranging from 4% to 14%, depending on region and age group.[28] There is no specific treatment are available for WNV. Human management remains supportive, focusing on symptom relief and complications. In animals, particularly birds, treatment is also limited, and outbreak control depends mainly on vector management and surveillance system.

While there are no currently approved human vaccines for WNV available, licensed veterinary vaccines are exist for horses. In poultry and wild birds, no routine vaccination is implemented, although experimental vaccines have been tested. Prevention hinges on mosquito control, public health awareness, and minimizing bird–mosquito–human transmission cycles.

Though not traditionally classified as a primary avian infection, WNV's impact on bird populations and zoonotic potential positions it as an important virus within the One Health framework, linking animal and human health through shared ecological risks. Preventing WNV is mostly depends on controlling mosquitoes, raising public awareness, and reducing the chances of the virus spreading between birds, mosquitoes, and people. While WNV is not usually seen as a major bird disease, its effect on bird populations and its ability to infect humans make it important to watch.[29]

ROLE OF WHO, FAO AND OIE IN SURVEILLANCE AND CONTROL OF AVIAN INFECTIONS

To control the avian infection worldwide, we need coordinated surveillance and response system. This strategy is crucial for those viruses which have zoonotic potential like avian influenza and West Nile Virus. The international organization like World Health Organization (WHO), Food and Agriculture Organization (FAO), and the World Organisation for Animal Health (WOAH, formerly OIE) play the important roles in monitoring and mitigating these threats under the umbrella of One Health framework.

The World Health Organization (WHO) are major health organization worldwide, responsible for addressing the public health issues caused by avian infections, mainly those with zoonotic potential such as H5N1 and H7N9. It actively collaborates across worldwide to detect early human cases, assess their risks, and strengthen preparedness strategies. In addition, WHO also issues time to time alerts to the global community, guides the selection of vaccine strains, and helps to build local capacities in research laboratories and outbreak management through training programme and technical support.[30]

The FAO plays crucial role in for the animal's health, especially when it comes to detect bird diseases on early stage. It works hand-in-hand with local veterinary teams to strengthen disease tracking, improve farm hygiene practices, and guide smart vaccination plans for poultry. The FAO is also involved in providing the research facility and coordination that helps to understand the mechanism of transmission from animals to human. The WOAH, formerly known as OIE makes international standards for how to report the animal diseases, run respected labs and established the veterinary infrastructure. It runs the World Animal Health Information System (WAHIS), responsible for collecting and shares real-time information related to bird disease outbreaks around the worldwide. WOAH's recognition of reference laboratories and expert centres helps to diagnose the diseases around the world.

All these organizations work together to make sure the mutual share of data and keep an eye on both human and animal health. These steps are crucial for controlling the pandemics and lowering the threats of global avian infections.[30]

ZOONOTIC POTENTIAL AND EMERGING RISKS

Bird-related infections is one of the serious threats to human health, especially when certain viruses are adapted to infect people who are in close contact with poultry industry or near contaminated environments. Avian influenza is one of the well-known examples is related to this type of infection. There subtypes like H5N1, H7N9, and H5N6 have shown ability to jump from birds to humans. Since 2003, more than 860 human cases of H5N1 have been reported worldwide, with nearly 53% mortality rate published by the World Health Organization (WHO, 2023). H7N9, which first infected humans in 2013, has led to infect over 1,500 people, with a mortality rate between 30% and 40%, making it a major concern for global public health.

Zoonotic transmission mainly spreads, when people come into direct or indirect contact with infected birds, for example- in live bird markets or when they are farming in their backyards. The risk is multiplied in those places where there are a lot of birds, poor sanitary measures, and a lot of contact between people and animals. Genetic mutation in viruses makes it more likely to spread between people or cause pandemics.[31] While most of avian viruses are host-specific, their continued exposure and ecological changes, including urban expansion, wildlife trade, climate shifts, and intensive poultry farming, create favorable environments for spillover. Notably, WNV and NDV have also shown occasional zoonotic characteristics, but their risk in humans are rare less severe compared to influenza viruses.

CURRENT GAPS IN RESEARCH

Despite decades of monitoring and vaccine development efforts, we are still unable to fully control the avian infections, especially those with zoonotic potential. These limitations not only decrease the poultry health and productivity but also for global readiness in the face of emerging infectious diseases. One of the biggest problems is that peoples are unaware to avian infections and their transmission to human. A lot of countries also don't have strong systems for keeping an eye on zoonotic diseases, mainly in rural areas where people come in contact of poultry system frequently. People with mild are neglected or may be misdiagnosed. It is hard to figure out how dangerous new avian viruses are for the pandemic if there is not clear information are available about their mode of transmission.[32] One of the most ignored areas is the lack of post-mortem studies in avian species, especially those belonging to non-commercial taxa or wild species. A lot of research is performed on outbreaks of sick birds, but their natural reservoirs are still not well explored. This makes unable to understand the viral persistence their host range, and spreads within the body.[33]

Another problem is the lack of sufficient vaccine. Vaccines are available for only few bird diseases, like Marek's disease and infectious bursal disease. Still a lot of small-scale businesses or backyard operations is far away from good immunization programs. Similarly, diagnostic tools might not be easily available If we are unable to early diagnose, it is harder to stop them from spreading. This might lead to severe pandemics.[34] Addressing these research gaps is crucial to break the chain of viral transmission, able to early detection, and ultimately protect both animal and human populations from the evolving threat of avian infections.

CONCLUSION

Avian infections continue to pose a dual threat which affect the poultry health and production while also risk of transmission in human populations. Among the most notable and high-mortality viral diseases are HPAI, NDV, MDV, and WNV. These infections not only responsible for commercial loss but also disrupt global trade and food security system. In some infection cases like H5N1 and H7N9, human mortality rate exceeded 30–50%, emphasizing the urgent need for better preparedness and collaborative action.

The future, research and policy must focus on creating cost effective diagnostic tools, strain-specific vaccines, and genomic surveillance system that work in real time. Investing in training of local health workers, improving data sharing, and inspiring people to report unusual bird deaths or illness are also very important.

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