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Viral Zoonosis: A Comprehensive Review

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Abstract: Zoonoses are human diseases caused by animal pathogens or animal diseases that are transmissible to humans. Zoonotic pathogens identified are mostly viral origin and are emerging and reemerging. Zoonotic viral infections are grouped based on the type of infection they produce in natural host. Some are associated with encephalitis/hemorrhages and others may cause only local lesions like rashes and arthalgia. Transmission of these viruses usually involves arthropod vectors, which sometime act either as mechanical and/or biological vectors. Some zoonotic agents may be transmitted directly through animal bite or close contact with infected animals or fomites. The zoonotic microbes continue to evolve and adapt with tremendous acceleration and expansion of global trade, human movement and population explosion for efficient adaptation in new host and ecosystem results in catastrophic effects. They continue to cause health hazards in most parts of world and are economically important and public health concern. Control of zoonotic diseases and protection of public health are challenging tasks as the world population is increasing proportionately. The prevention of these infections depends on improved diagnosis and highly effective therapeutics/prophylactics. The collective effort of professionals from medical and veterinary and others is necessary to combat these zoonotic infections. In this review most important zoonotic infections along with their specific etiology, transmission (role of wild-life) manifestations and epidemiology and control/preventive measures are described, so as to create awareness to the scientific/public health community.

Key words: Zoonosis, emerging diseases, vectors, epidemiology, control and prevention

INTRODUCTION

Zoonosis (zoo-e-no-sis) is an infectious disease that may be transmitted from animals (wild and domestic) to humans or from humans to animals. The word zoonosis is derived from the Greek, zoon (animal) (pronounced as zoo-on) and *nosos* (disease). Of the 1415 microbial diseases affecting humans, 61% are zoonotic (Taylor *et al*., 2001) and among emerging infectious diseases, 75% are zoonotic with wildlife being one of the major sources of infection (Daszak *et al*., 2001). A new virus has been emerging almost every year since last two decades (Woolhouse and Sequeria, 2005). Of 534 zoonotic viruses (belonging to 8 families) identified 120 cause human illnesses with or without the involvement of intermediate host/vectors. In the past 15 years, many zoonotic viral infections

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are of emerging and re-emerging in nature (Wilke and Hass, 1999) and haemorrhagic fever causing viruses transmitted by insect vectors (arboviruses i.e., yellow fever virus) (Khan *et al*., 1988), rodents i.e., Hanta viruses (Peters and Khan, 2002) and also by direct contact i.e., Filoviruses (Payling, 1996). Thus, they pose a great challenge to both veterinary and public health professionals. It is essential to investigate the complex interactions between pathogens, host, vectors and environment to curtail these infections. This review focuses on description of the important zoonotic viral infections with especially the recently emerging and reemerging diseases and their causes, transmission, clinical manifestations, distribution and preventive measures, to abreast the knowledge on zoonoses.

Transmission

Zoonotic viruses are transmitted to humans either directly or indirectly. Direct transmission involves contact between the infected and susceptible individual (orf), bite (rabies) and handling of the affected animal's tissues or materials (Orf). Indirect transmission involves transmission through the bite of a hematophagous (blood-sucking) arthropod after replicating in the reservoir animal host (Japanese encephalitis, yellow fever). Most viral zoonoses require blood-sucking arthropods for their transmission to humans. Among them, mosquitoes (Equine encephalitis complex) are the most common followed by ticks (Powassan virus), sand flies (Vesicular stomatitis) and midges (bluetongue). The arthropod vector becomes infected when it feeds the blood of a viraemic animal. In most of the cases, virus replicates in the arthropod tissues and reaches their salivary glands. The arthropod then transmits the virus to a new susceptible host when it injects infective salivary fluid while taking a blood meal. The extrinsic incubation period (time between ingestion and transmission of the virus) is usually 8 to 12 days. This period depends on the virus, the environment and the vector species involved (Hubalek and Halouzka, 1999). Arthropod-borne viruses generally remain undetected until humans encroach on the natural enzootic focus or until the virus escapes the primary cycle via a secondary vector or vertebrate host. Wild birds are important to public health as they carry various zoonotic pathogens and they either act as reservoir hosts or help in disseminating the infected arthropod vectors (Reed *et al*., 2003). In addition, bird migration provides a mechanism for the establishment of new endemic foci of disease at great distances from where an infection was acquired (avian influenza). There has been a change in the transmission pattern especially in the occurrence and incidence of diseases due to broadening of host range (Monkey pox and Nipah viruses), high mutation rate (avian influenza, FMD) and anthropogenic environmental changes viz., ecological imbalance and change in agricultural practices (Wilke and Haas, 1999).

Role of Wildlife in Zoonosis

The significance of wild life as animal reservoir for zoonotic viruses has been traced long back with two important ancient diseases such as rabies and West Nile virus and represent as large spectrum of transmission mode (Marr and Calisher, 2003). Of the total emerging diseases, 75% are considered zoonotic with wild life as a major source of reservoir. Recent emerging viral diseases which moved into new species such as AIDS, SARS and avian influenza have a strong evidence of wild life origin due to human encroachment and changed international trade and travel patterns. Commonly the pattern of moving of viral agents from wild animal species to human occurs either as actual transmission being rare (HIV, Influenza A, Ebola and SARS) but will be maintained and has potential of man to man transmission or direct/indirect manner through animal bite and arthropod vectors (rabies, Nipah, West Nile

virus and hantavirus) (Bengis *et al*., 2004). Many zoonoses with a wildlife origin are spread through insect vectors (Rift Valley fever, equine encephalitis and Japanese encephalitis), whereas, rabies by animal bite and hantaviruses by contact with rodent excreta is common. The outcome in the form of clinical manifestation in humans depends on the transmission pattern of the agent causing the disease. Direct contact and vector bite lead to the formation of rashes and ulcers, whereas, intake of contaminated meat/water lead to digestive tract problems and diseases transmitted by inhalation of infected foci of dust cause pneumonia like illness (Kruse *et al*., 2004). Wild life are basically involved in epidemiology of the disease which is influenced by other factors such as change in agro-climatic conditions, host abundance, movement of pathogens/vector/animal host including migratory birds and anthropogenic factors. For example, increase in transmission and subsequent spread of Sin Nombre Hantavirus causing Hantavirus Pulmonary Syndrome (HPS) to humans is due to increase in heavy rainfall and host abundance in USA. Increase in the emergence of some wild life diseases result in high potential of emergence of human pathogens as in the case of West Nile virus spread in USA. A potential threat to human health, animal welfare and species conservation from domesticated and wild life is presented equally by emergence of human and wild life pathogens.

Manifestations of Viral Zoonoses

Zoonotic infections are broadly grouped in to (1) diseases causing no illness, (2) nonspecific viral syndrome and (3) severe illness. The third category of infections is further classified in to (1) hemorrhagic fever, (2) encephalitis and/or rash arthralgia, (3) emerging and reemerging and (4) rare zoonotic infections.

Encephalitis

The major viral zoonoses, which are associated with encephalitis, are listed in Table 1. They are arthropod borne and belong mostly to five viral families (Rhabdoviridae, Flaviviridae, Togaviridae, Reoviridae and Bunyaviridae). Most of them are transmitted through mosquito or tick bites, except a few which are transmitted through bite of an infected host (rabies). Mosquitoes and ticks are major vectors for this category of infections. They cause symptoms like fever, vomition, encephalitis, headache and neurological disorders. Some of these infections are confined to a particular country (Colorado tick fever), while others are distributed worldwide (rabies). Prophylactic/therapeutic measures are available for some of the infections, while for others vector elimination is the only means of control. Intense research is required towards the development of vaccines including conventional as well as recombinant. Specific diagnosis of this group of infections is done employing serological tests like Hemagglutination-Inhibition (HI), Complement Fixation (CF) and Virus Neutralization (VN).

Hemorrhagic Fevers

Most of the viral zoonoses causing haemorrhagic fevers are reported to be of emerging and reemerging in nature (Murphy, 1998). There are more than 16 zoonotic infections in this category (Table 2) belong mainly to four viral families (Arenaviridae, Bunyaviridae, Flaviviridae, Filoviridae). These infections are often associated with extensive bleeding in human (Lacy and Smego, 1996). Most of them are transmitted upon vector bite. The common vectors are mosquitoes and ticks. Vaccines are not available for majority of the infections and therefore, control relies on supportive treatment. Control of vector is the main means of control. Chemotherapy is available for some of the infections (Crimean-Congo haemorrhagic

Table 1: Zoonotic infections causing encephalitis

Sl #	Zoonotic virus	Taxonomic status	Transmission	Vectors	Symptoms	Distribution	Prophylactics/Therapeutics	Reference
1	Colorado tick fever/ American mountain fever *(multiple genotype exists)	F: *Reoviridae* G:*Coltivirus*	Tick bite and blood transfusion	*D.andersoni* (Rokcy mountain wood tick)	Fever, chills, myalgias, prostration, meningitis and encephalitis and also hemorrhagic fever in children (5%)	USA, Canada	Supportive prevent tick bites	Murphy *et al.* (1999)
2	Equine encephalitis viruscomplex (EEE, WEE and VEE)*	F: *Togaviridae* G: *Alphavirus*	Mosquito bite	Mosquitoes (*C. melanura*) Wild birds (R)	Encephalitis	USA, Caribbean Island	Inactivated vaccines for both human and horses	Murphy *et al.* (1999)
3	Japanese encephalitis	F: *Flaviviridae* G: *Flavivirus*	Mosquito bite	*C. tritaeniorhynchus* Pigs, amplifying hosts	Encephalitis	Asia, Australia	Formalin-inactivated mouse brain vaccine employing Nakayama strain	Anonymous (1993)
4	Califoruia serogruop encephalitis (including La Crosse virus)*	F: *Bunyaviridae*, G: *Bunyavirus*	Mosquito bites maintained in eastern chipmunk, tree squirrels and foxes	*A. triseriatus* small mammals (R)	Headache, fever and seizures	Central, Eastern USA	Prevention of central odema and seizures; avoid mosquito bites; No vaccine	McJunkin *et al.* (2001)
5	Murray valley encephalitis #*	F*: Flaviviridae*, G: *Flavivirus*	Mosquito bites Maintained in water birds and *Culex* mosquitoes	Water birds *Culex* mosquitoes Humans: Dead end hosts	Fever, headache, vomition and myalgias	Australia, New Guinea	Mosquito control	Mackenzie *et al.* (1998)
6	Powassan virus #	F: *Flaviviridae* G: *Flavivirus*	Maintained in rodents	*Ixodes ticks*	Neurological signs and convulsions	Eastern Canada and the Northern USA	Tick bite No vaccine/treatment Tick control	CDC (2001)
7	Rabies virus (Other members of lyssavirus are Duvenhage and EBL2 associated with human rabies)	F:*Rhabdoviridae* G: *Lyssavirus*	Dog bite inhalation Raccoon-reservoir host (USA) Skunk-reservoir- central and western USA Rodents and lagomorphs: rarely affected	Bite of infected animal	Neurological disorders	Worldwide	Human diploid cell rabies vaccine (HDCV), Rabies vaccine absorbed (RVA), Purified chick embryo cell vaccine (PCEC)	Krebs *et al.* (2000) and Anonymous (1999)
8	Tick-borue encephalitis(Eastern and Western) #	F: *Flaviviridae* G: *Flavivirus*	Tick bite drinking raw milk	*Ixodes persulcatus*	Encephalitis	Eastern Europe to China	Inactivated vaccines for both eastern and western TBE	Dumpis *et al.* (1999)
9	West Nile virus	F: *Flaviviridae* G: *Flavivirus*	Mosquito bites wild birds and *Culex* mosquitoes	*Culex* mosquitoes	Encephalitis	Africa, Asia, the Middle East and Europe	Vaccine for horses No vaccine for humans	Petersen and Roehrig (2001)
10	Kunjin virus	F: *Flaviviridae* G: *Flavivirus*	Birds-amplifying hosts	Mosquito bites	Encephalitis in human and lethal in horses	Australia	No vaccine	Petersen and Roehrig (2001) and Murphy *et al.* (1999)

EEE: Eastern equine encephalitis, WEE: Western equine encephalitis; VEE: Venezuelan encephalitis; R: Reservoir host. *Man to man transmission #Potential for bioterrorism

Table 2: Viral zoonotic infections causing haemorrhagic fevers

Sl #	Zoonotic virus	Taxonomic status	Transmission	Vectors	Symptoms	Distribution	Prophylactics/Therapeutics	Reference
1	Lymphocytic choriomeningitis (LCM), Lassa fever*, Argentine (Junin virus), Bolivian *(Machupo virus), and Venezuelan, Brazilian (Sabiavirus) hemorrhagic fevers.	F: *Arenaviridae* G: *Arenavirus*	Direct contact with infected rodents, wild rats and mice (R)	Not reported	Aseptic meningitis and influenza like illness and rarely severe hemorrhagic manifestations	World wide (Europe, Asia, Africa and Americas) and Tacaribe virus found in Trinidad	No safe vaccine available for arena viruses. Live attenuated vaccine has been developed for Junin virus in Argentina	Maiztegui *et al.* (1998)
2	Crimean-Congo hemorrhagic fever #	F: *Bunyaviridae* G: *Nairovirus*	Tick bite	Ticks	Fever, haemorrhages	Sub-Saharan Africa, E. Europe, Russia, the Middle East, W. China	No vaccine is available; Treatment is supportive; Ribavirin-limited success	Hoch *et al.* (1995)
3	Dengue fever/ hemorrhagic fever (DEN-1, DEN-2, DEN-3 and DEN-4 serotypes)	F: *Flaviviridae* G: *Flavivirus*	Mosquito bite	*Aedes aegypti*	Fever, haemorrhages in children	World wide (Asia, Africa, America and Pacific)	No vaccine, however, significantly achieved in the development of conventional and recombinant vaccines Mosquito control and personal hygiene	Gubler (1998) Perez *et al.* (2001) Kiuney and Huang (2001)
4	Ebola and Marburg*# Ebola: Zaire, Sudan, Ivory Coast subtypes in non-human primates in human and Reston Marburg only one subtype	F: *Filoviridae* G: *Ebolavirus* *Marburgvirus*	Direct contact with infected patients	Not reported	Fever, haemorrhages in children	Ebola in humid rain forests in Central and western Africa whereas Marburg in central and eastern Africa	Supportive treatment; No vaccine isolation, identification and barrier nursing	Feldmann and Klenk (1996), Georges *et al.* (1998), Peters and Duc (1999), Miranda *et al.* (1999) and Fabiansen *et al.* (2008)
5	Kyasanur forest disease	F: *Flaviviridae*	Tick bite wild birds and small mammals: reservoirs; monkeys: amplifier hosts	*Haemophysalis spinigera*	Fever, headache, myalgias, prostration, haemorrghic	Shimoga Distt of Karnataka (India)	No treatment and vaccine; Avoid tick bite and contact with sick monkeys	Murphy *et al.* (1999) and Pattnaik (2006)
6	Rift valley fever	F: *Bunyaviridae* G: *Phlebovirus*	Mosquito bite Aerosol: sick sheep and goats	Mosquitoes	Fever, headache, myalgias, prostration, haemorrghic	Kenya, sub-Saharan Africa, Egypt, and Saudi Arabia	No vaccine; Avoid tick bite and contact with sick ungulates	Lacy and Smego (1996)
7	Yellow fever	F: *Flaviviridae* G: *Flavivirus*	Mosquito bite Monkeys and Humnas	*A. aegypti*	In-apparent infection to a deadly hemorrhages	Tropical America and Africa	Live attenuated 17D vaccine	Martin *et al.* (2001) Chan *et al.* (2001)

*Potential for man to man and nosocomial transmission. #Potential for bioterrorism; R: Reservoir host

fever) with a limited success. Though some of these infections have local importance (Kyasanur forest disease), others have global impact (Dengue, Yellow fever). Specific laboratory diagnosis of hemorrhagic fevers usually requires special serological or virological tests like enzyme-linked immunosorbent assays (ELISAs) to detect virus-specific immunoglobulin. Other tests like Haemagglutination Inhibition (HI), Complement Fixation Test (CFT) and Virus Neutralization (VNT) have to be carried out on paired serum samples collected on two occasions i.e., acute and convalescent phases of illness.

Rashes and Arthralgia

A very few viruses are associated with local rashes and arthralgia and almost all belong to *Togaviridae* family (Table 3). Most of them are transmitted to humans through infected mosquito bites. These vectors are mainly from *Aedes* and *Culex* families. No specific treatment is available and control depends on the elimination of vectors. EU countries appear to be free, while other continents are endemic for these infections.

Emerging and Reemerging Zoonoses

The complex interaction between environment/ecology, social, health care, human demographics and behavior influences the emergence and re-emergence of zoonotic viral diseases. Periodic discovery of new zoonoses suggest that the known viruses are only a fraction of the total number that exist in nature. The RNA viruses are capable of adapting to changing environmental conditions rapidly and are among the most prominent emerging pathogens (Ludwig *et al*., 2003). Mutations are more common in RNA viruses (Influenza) than DNA viruses (Pox). The common mutations are point (insertion/deletion), drift (minor) and shift (major). In addition to these, movement of population, birds, vectors, pathogens and trade contribute to the global spread of emerging infectious diseases (influenza, severe acute respiratory syndrome). Other factors viz., human migration, change in land use pattern, mining (disturbance of ecosystem), coastal land degradation, wetland modification, construction of buildings, habitat fragmentation, deforestation, expansion of agents host range, human intervention in wild life resources like hiking, camping and hunting also influence on acquiring zoonotic infections from wildlife (Daszak *et al*., 2001; Bengis *et al*., 2004; Patz *et al*., 2004). Cessation of vaccination against smallpox since 1980s, emergence of some genetically related orthopoxviruses has been reported throughout the world i.e., monkey pox (Nalca *et al*., 2005), buffalo pox (Singh *et al*., 2007) and Bovine Vaccinia (BV) infections (Fernandes *et al*., 2009).

Despite successful eradication of some viral diseases (small pox and almost polio in humans and rinderpest in cattle) due to intensive research and dedicated coordinated efforts, modern medicine has failed to control many infectious diseases resulting from emerging and reemerging viruses (Table 4). Some infectious agents already known to be pathogenic have gained increasing importance in recent decades due to change in disease patterns. Several previously unknown infectious agents with a high pathogenic potential have also been identified (Manojkumar and Mrudula, 2006). Several infectious viral agents (DNA and RNA viral families) have been emerged as zoonotic agents (Table 4). They are associated with flu-like signs (Alkhumra virus infection, influenza A) to respiratory (SARS), pox lesions mostly localized distributed over hairless parts of body namely udder, teats, ears and tail (in buffaloes) and fingers and hands (in humans) due to buffalopox (Fig. 1a) and Orf virus infections in affected goats (Fig. 1b), hepatitis (hepatitis E virus), haemorrhagic fevers (Ebola, Marburg and hanta virus infections) and encephalitis (Henipa virus complex). Treatment/prophylaxis is not available to many of these infections. But some of antiviral

Table 3: Viral zoonotic infections causing rashes and arthralgia

Sl #	Zoonotic virus	Taxonomic status	Transmission	Vectors	Symptoms	Distribution	Prophylactics/Therapeutics	Reference
1	Barmah forest virus	F: *Togaviridae* G: *Alphavirus*	Mosquito bite	Mosquitoes	Florid rash and less common arthritis	Australia	No vaccine; Hygienic practice	Mackenzie *et al.* (1998)
2	Chikungunya	F: *Togavirida* G: *Alphavirus*	Mosquito bite	*A. aegypti*	Arthralgias, Hemorrhages	Africa and Asia	No vaccine; Avoid mosquito bite	Carey (1971) Schuffenecker *et al.* (2006)
3	Mayaro virus	F: *Togaviridae* G: *Alphavirus*	Mosquito bite	*Haemagogus* sp.	Fever, headache, backache, myalgia, epigastric pain, chills, nausea, photophobia, arthralgia and maculo-papular rash	Caribbean and South America	No vaccine; Avoid mosquito bite	Tesh *et al.* (1999)
4	O'nyong-nyong	F: *Togaviridae* G: *Alphavirus*	Mosquito bite	*Anopheles* and other mosquitoes	Less pronounced fever; lymphadenopathy	East Africa (Uganda)	No vaccine; Avoid mosquito bite	Kiwanuka *et al.* (1999)
6	Ross valley fever	F: *Togaviridae*. G: *Alphavirus*	Mosquito bite	*Aedes* and *Culex* sp.	Myalgia, polyarthritis, headache, anorexia, nausea, tenosynovitis, less fever	Australia, Southwestern Pacific Islands and Fiji	No vaccine; avoid mosquito bite	Gubler (1981)
7	Getah virus	F: *Togaviridae* G: *Alphavirus*	Mosquito bite	Mosquitoes	Mild fever	South East Asia	No vaccine; avoid mosquito bite	Murphy *et al.* (1999)

Table 4: Emerging and re-emerging zoonotic infections

Sl #	Zoonotic virus	Taxonomic status	Transmission	Vectors	Symptoms	Distribution	Prophylactics/Therapeutics	Reference
1	Alkhumra virus infection	F: *Flaviviridae* G: *Flavivirus*	Mosquito bite Direct contact with affected sheep and goats	Mosquitoes	Flu-like illness with hepatitis, hemorrhagic manifestations and encephalitis	Saudi Arabia	No vaccine; avoidance of tick bite and contact with infected animals	Madani (2005) and Charrel *et al.* (2006)
2	Avian influenza (H5N1)*	F: *Orthomyxoviridae* G: *Orthomyxovirus* (type A)	Direct contact with affected birds; Migratory birds	Not reported	Flu-like illness	Worldwide	Oseltamivir; Combination of Amantadine and Oseltamivir; H5 vaccine (safe and potent)	Swayne and King (2003), Areechokchai *et al.*(2006) and Hayden *et al.* (2009)
3	Buffalo pox	F: *Poxviridae* G: *Orthopoxvirus*	Direct contact common in human infection Mechanical transmission in animals but not in humans	Not reported	Pox like lesions on udder, perineum, hairless parts of the body	India, Pakistan, Bangladesh	Live vaccine (Vij 1996) at IVRI, Mukteswar	Kolhapure *et al.*(1997), and Singh *et al.* (2006, 2007)
4	Hemorrhagic fevers with renal syndrome (HFRS) two types; Korean HFRS and HFRS	F: *Bunyaviridae* G: *Hantavirus*	Direct contact with infected rodents	Not reported	Hemorrhagic fever, renal and pulmonary syndrome	Korean type in south east Asia and HFRS in Europe, Asia	No vaccine; ribaviririn treatment in earlier cased useful; avoid contact with rodents	McCaughey and Hart (2000)

Table 4: Continued

Sl #	Zoonotic virus	Taxonomic status	Transmission	Vectors	Symptoms	Distribution	Prophylactics/Therapeutics	Reference
6	Hantavirus pulmonary syndrome (Sin Nombre virus)	F: *Bunyaviridae* G: *Hantavirus*	Direct contact with infected deer mice	Not reported	Acute fulminant illness; case fatality rate 36%	North and South America	No vaccine; avoid contact with rodents but recent report on inactivated vaccine being tried. out in China	McCaughey and Hart (2000), Hooper and Li, (2001) and Peters and Khan (2002)
7	Hendra and Nipah (Henipa)	F: *Paramyxoviridae* S.F:*Paramyxovirinae* G: *Henipavirus*	Hendra: Contact with infected horses Nipah: Contact with infected pigs	Not reported	Fever, pneumonia, encephalitis	Australia, Singapore, Malaysia	No vaccine; Supportive treatment	Barclay and Paton (2000) Chua (2003)
8	Hepatitits E virus infection (Swine and deer strains transmission to human under investigation)	F: *Hepeviridae* G: *Hepevirus*	Consumption of contaminated pork	Not reported	Hepatitis, jaundice	World wide	No vaccine; Supportive treatment	Fauquet (2005) and Goens and Perdue (2004)
9	Marburg and Ebola* #	F: *Filoviridae* G: *Ebolavirus Marburgvirus*	Direct contact with infected person African green monkey (source)	Natural reservoir and vector unknown so far	Hemorrhagic fevers	Ebola in humid rain forests in Central and Western Africa whereas Marburg in Central and Eastern Africa	No vaccine and treatment	Peters and Duc (1999) and Miranda *et al.* (1999)
10	Severe Acute Respiratory Syndrome (SARS)*	F: *Coronaviridae* G: *Coronavirus*	Direct contact with infected person	Himalayan civet cat: source	Respiratory and enteric symptoms	Guangdong Province, China., southern China, Hanoi, Hong Kong, Singapore and Canada	No vaccine; Control: stringent quarantine and avoid contact with infected person	Tai (2006) and Peiris and Poon (2008)
11	Monkey pox* #	F: *Poxviridae* G: *Orthopoxvirus*	Direct contact with infected monkeys and wild rodents	Wild rodent and non-human primates as reservoir. Emerged in USA due to imported wild rodents	Flu like illness, fever, malaise, back pain and rashes similar to smallpox	Basically endemic in Central and Western Africa but emerged in USA recently	No licenced therapy but smallpox partially protects. Recently LC16 m8 vaccinia virus lacking B5R protein useful in monkeys	Giulio and Eckburg, (2004), Nalca*et al*, (2005), Saijo *et al.* (2006) and Parker *et al.* (2007)
12	New variant Creutzfeldt-Jakob disease (vCJD)	Unclassified agents as Prions	Consumption of infected /contaminated food by BSE	Not reported	Nervous signs	United Kingdom	No vaccine and treatment	Murphy *et al.* (1999) and Will (2003)

*Potential of man to man transmission. #Potential tool for bioterrorism

Table 5: Rare zoonotic infections

Sl#	Zoonotic virus	Taxonomic status	Transmission	Vectors	Symptoms	Distribution	Prophylactics/Therapeutics	Reference
1	Bluetongue	F: *Reoviridae* G: *Orbivirus*	Culicoides sp.	Culicoides sp in animal infection but not reported in human illness	Conjunctivitis and flu like illness and reported in laboratory workers	Asia, Europe RSA and USA	Inactivated and live attenuated vaccines (USA, EU and RSA) for veterinary use	Gould and Higgs (2009)
2	Borna disease	F: *Bornaviridae* G: *Bornavirus*	Direct contact with persistently infected animals	Not reported	Mental illness and symptoms of neuropsychiatry disorders	Central Europe and eastern Austria	No vaccine	Rott *et al*. (1985), Richt *et al*. (1997), and Chalmers *et al*. (2005)
3	Foot and Mouth disease (FMDV 'O' 'C' and 'A' serotypes)	F*: Picornaviridae* G*: Aphthovirus*	Close contact with infected animals	Not reported VN and CF antibody titres	Fever, vesicular lesions on hands, and increased	Worldwide	Formalin/ BEI inactivated vaccines for veterinary use	Bauer (1997) and Berrios (2007)
4	Monkey B virus infection	F: *Herpesviridae* SF: *Alphaherpesvirinae* G: *B virus*	Macaque/monkey bites/scratches Direct contact and indirectly with infected saliva	Not reported	Persistent latent infection	USA	Acyclovir or gancyclovir	Ostrowski *et al*. (1998) and Murphy *et al*. (1999)
5	Newcastle disease	F:*Paramyxoviridae* G: *Avulavirus*	Direct inoculation	Not reported	Flu-like infection with conjunctivitis and self-limited	Worldwide	Inactivated and attenuated vaccines for poultry use	Capner and Bryden (1998) and Fauquet (2005)
6	Pox viralzoonosis Cowpox, Buffalopox, Camelpox, Monkey pox,Tanapox,Orf, Yatapox, Psuedocowpox, Bovine papular stomatitis, Ausdyk and seal parapox	F: *Poxviridae* G: *Orthopoxvirus* G: *Parapoxvirus*	Direct contact with infected animals	Mechanical transmission by sand flies and midges in animal diseases. Not reported in humans abdomen, face, penis	Pox like lesions on hairless parts of the body especially on hands, legs, back, etc depending on the virus	Worldwide	Inactivated and attenuated vaccines for veterinary use	Baxby *et al*. (1979), Maki *et al*. (1988), CDC (1997), Winter *et al*. (1999), Fields *et al*.(1995) and Murphy *et al*. (1999)
7	Semliki forest virus	F: *Togaviridae* `G: *Alphavirus*	Mosquito bite	Mosquitoes	Mild fever	RSA (central)	No vaccine and treatment	Willems *et al*. (1979) and Winkler and Blenden (1995)
8	Simian immunodeficiency virus and Simian T cell leukaemia	F: *Retroviridae* G: *Lentivirus*	Sexual contact	Not reported	AIDS symptoms with secondary bacterial and fungal complications	RSA	No effective vaccine andtreatment so far developed	Murphy *et al*, (1999) and Marx *et al*. (2004)
9	Vesicular stomatitis infection	F*: Rhabdoviridae* G: *Vesiculovirus*	Direct contact with contaminated materials	Phlebotomine sand flies in animal infection but not reported in human part	Acute influenza like illness with Fever, vesicular exanthemas, headache and myalgias	South America and North America and Northern Hemisphere	No vaccine; controlthrough restricted animal movement	Fields and Hawkins, (1967) and Mumford *et al*. (1998)
10	Simian foamy virus (Human form of SFV) SFV(Human) variant of animal strain	F: Retroviridae G: Foamy virus contaminated meat and blood	Direct contact with non human primates through animal bite, Myasthenia gravis	Not reported African green monkeys, chimpanzees, cats, cattle and rhesus macaques (R)	Caused plethora of diseases namely multiple sclerosis, graves disease and	Central Africa	No vaccine; control through avoiding contact with infected animals	Switzer *et al*. (2004) and Wolfe *et al*. (2004)

Fig. 1: (a) Buffalo pox infection in human particularly milkers showing characteristic localized ulcerative and vesicular skin lesions on hand and fingers and (b) Orf virus infection in goats showing characteristic proliferative skin lesions on mouth, lips and nose

compounds, which are under trial, are found to be effective. For example Ebola and Marburg viruses are inhibited *in vitro* by Carbocyclic-3-deazaadenosine, a first compound to cure these virus infections (Huggins *et al*., 1999).

Rare Viral Zoonoses

Several viral infections cause nonspecific febrile illness in humans and occur rarely (Table 5). Many of them are animal pathogens, but often they produce nonspecific febrile illnesses in humans, though, humans are not the primary hosts. However, there is an increasing trend of occurrence of such infections in recent times (Table 5). Transmission of these infections have been reported upon direct contact of human objects with infected animal (FMD particularly serotypes O followed by C and rarely A, buffalo pox, Orf), handling of such organisms in the laboratory (bluetongue, Newcastle disease), sexual contact (simian immuno deficiency (SID) virus), bite/ scratch (monkey B virus), vectors (semliki forest virus, African horse sickness and louping ill) and food and water (calici viruses such as swine vesicular exanthema, feline calicivirus and rabbit haemorrhagic disease virus (Thiel and Konig, 1999) causing vomition and diarrohoea. Recently, animal rotaviruses and Eyach virus related to Colorado tick fever virus and Oropouche fever virus, an arbovirus (Nunes *et al*., 2005) similar to dengue fever in Trinidad are reported to cause mild infections in humans. Treatment is not available for most of the human infections, while some of them can be treated with nucleoside analogues like acyclovir or gancyclovir.

Other Zoonosis

Prion diseases are caused by scrapie associated prion protien (PrP^{sc}), which are proteinacious infectious agents common in animals and humans. Some of the animal prion diseases are scrapie of sheep, Bovine Spongiform Encephalopathy (BSE) and goats and mink spongiform encephalopathy. Human prion diseases are Creutzfeldt-Jakob Disease (CJD), Kuru, Gertsmann Straussler Schienker Syndrome (GSS) and fatal familial insomnia. The human disease variant (vCJD) is believed to be a zoonotic disease caused by BSE agent and recently an emerging disease as well (Murphy, 1998). The route of transmission of vCJD is not yet fully proven but it is generally transmitted through exposure to food contaminated by the bovine BSE agent (Will, 2003). Human prion diseases can be classified as sporadic, hereditary or acquired. Acquired form i.e., vCJD is caused by the transmission of infection from human to human or, as a zoonosis, from cattle to human. Transmission of infectious agents between species through xenotransplantation called xenosis (Takeuchi and Weiss, 2000) is another way of introducing viruses from animal to human (porcine endogenous retroviruses). No specific treatment and vaccine is available. Prevention is by avoiding consumption of BSE contaminated or half cooked meat.

Prevention, Control Measures and Perspectives

Effective prevention and control measures can be achieved through proper diagnostics and prophylactic aids to curtail further spread in most of zoonotic viral diseases. Improved sanitary conditions such as proper treatment and disposal of human waste, higher standards for public water supplies, improved personal hygiene procedures and sanitary food preparation are vital to strengthen the control measures. A clear understanding of epidemiology of the diseases with wild life as reservoir namely the virulence and transmissibility of many diseases (human monkey pox, Tana pox and Yaba pox) could help in understanding the severity and thereby to take appropriate measures in eradication of such dreadful diseases. Research should focus on molecular biology of these viruses so as to develop diagnostics and prophylactics in a modern way to combat these infections in short time. To safeguard the public health from pathogens of zoonotic infections, application of skills, knowledge and resources of veterinary public health is essential. It is time to combat viral zoonoses with a combined effort of veterinary and public health specialists. A better understanding of avian migration patterns and their infectious diseases would be useful to forecast disease outbreaks due to emerging zoonotic infections like avian influenza. Further, the control measures for emerging and re-emerging viral pathogens are demanding, as there is population explosion. Novel, highly sensitive and specific techniques comprising genomics and proteomics along with conventional methods would be useful in the identification of emerging and re-emerging viruses, thereby; therapeutic/prophylactic/preventive measures would be applied on time. The first line of measure to control any disease is the surveillance. Control and prevention strategies should be designed based on transmission pattern and characteristics of virus, involvement of vectors, environment and epidemiology of the disease. The European Union (EU) has established a net work termed as Med-Vet-Net to develop a network of excellence for the integration of medical, veterinary and food scientists in order to develop food safety measures and to improve research on the prevention and control of zoonoses, including food-borne diseases. The network will also consider the concerns of consumers and other stakeholders throughout the food chain. Another system the Hazard Analysis and Critical Control Point (HACCP), which is regulated under FDA and it aims at analyzing hazards associated with food and identify preventive and control measures to

check spread of food-borne diseases including viral pathogens. Similarly, sanitary and phyto-sanitary measures (SPS) measures, which are set out with WTO are to be strictly followed to have safe food in order to conserve the health of animal, human and plants due to zoonotic agents.

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