REVIEW ARTICLE

Bat Borne Diseases

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ABSTRACT:
A bat-borne disease is any infectious disease whose primary reservoir is any species of bat. It is not a coincidence that some of the deadly viral disease outbreaks in recent years like severe acute respiratory syndrome (SARS), Middle East respiratory disorder (MERS), Ebola, Marburg and the new 2019-nCoV virus are speculated to be originated in bats. Rarely some bacterial and fungal diseases are also related to certain species of bats. Such illnesses are part of Zoonosis, which refers to the human diseases of animal origin. In this review we highlight some of the bat-borne diseases with emphasis on the viral outbreaks as bats world-wide harbor a greater proportion of viruses than several other groups of mammals.

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INTRODUCTION

Bats are found on each mainland with the exception of the coldest and most separated pieces of Earth, including few islands, the Arctic, and the Antarctic. It is assessed that there are more than 1,200 types of bats on the planet.[1] Bats are partitioned into two fundamental sorts: megabats and microbats. Flying foxes are the biggest bats while the smallest are the honey bee bats, as indicated by the University of Michigan, Museum of Zoology.[2] Despite the multiple benefits attributed to these animals, since the ancient times through myths and misapprehensions, bats have gained a bad reputation in the general public. The classical literature is full of examples in which bats are associated with evil and darkness.[3] (Fig:1).

Fig.1: A bat depicted as Satan. Modified from Dante Alighieri's Inferno from the Original by Dante Alighieri and illustrated with the designs of Gustave Doré – 1861. (Source: commons.wikimedia.org.)

Moreover, Bob Kane, an American comic book artist, ideated a character called Batman a positive character that, however, disguises in a bat costume to scare his enemies: '*Criminals are a superstitious cowardly lot. So, my disguise must be able to strike terror into their hearts. I must be a creature of the night, black, terrible..... 'Just then a huge bat flies in the open window'. A bat! That's it! It's an omen. I*

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shall become a bat! In: Detective Comics no 33, 1939.[3]

Transmission of Pathogens from Bats

Bats are significant stores of various pathogenic organisms, and a considerable number of them have caused disease episodes around the world. More than 200 infectious diseases have been related with bats, and practically all are RNA viral infections most likely inferable from their incredible capacity to adjust to changing natural conditions through a higher hereditary changeability. [3] These viruses often don't seem to harm the bats that carry them, which points to a long history of co-evolution, the metabolic activities in their bodies and the immune system they have. 'Spillovers' from bats to human either occur directly, through contact with infected bats or indirectly through intermediate hosts such as domestic or wild animals that have been contaminated by blood, saliva, urine or faeces of bats.[4]

Outbreaks of bat related zoonotic diseases have increased in recent decades as a result of bush meat consumption as well as human encroachment into natural habitats involving deforestation and agricultural intensification. On the other hand, our ability to identify the causes of such disease has also increased.[5] Frugivorous (fruit eating) bats, truth be told, can't ingest wide measures of nourishment as a result of the streamlined features of flight therefore, they extract nutrients by chewing fruits and spitting the residues. This partially digested food dropped on the ground can then be ingested by other animals and is a potential infectious source. A similar modality of viral transmission has also been described for insectivorous bats.[6] Bats have the ability to infect humans directly. This can happen through ingestion of contaminated bat meat, as in certain territories bats are a nourishment source, or through bat's nibble as on account of rabies infection.[5] Joshua Lederberg, a Nobel Laureate quotes *"The single biggest threat to man's continued dominance on the planet is the virus".*

Common Viruses from Bats Coronavirus

Bats are the reservoir of many viruses; corona virus is of them. Corona virus can cause many severe and fatal diseases in humans and in agricultural animals. Common corona viruses can cause severe acute respiratory syndrome (SARS), Middle East respiratory syndrome (MERS), porcine epidemic diarrhea (PED), severe acute diarrhea syndrome (SADS) and COVID-19.[7]

Table-1: Is showing common coronaviruses with their intermediate and effected hosts.[8]

Corona Virus	*Affected Host*	*Reservoir Host*	*Intermediate Host*
PEDV	Pigs	Bat (*Scotophiluskuhlii)*	None identified
SADS- CoV	Pigs	Bat (*Rhinolophus* spp.)	None identified
SARS- CoV	Humans	Bat (*Rhinolophus* spp.)	Himalayan palm civet/raccoon
2019- nCoV/ SARS-CoV-2	Humans	Bat (*Rhinolophus* spp.)	Pangolin
MERS-CoV	Humans	Bat (*Taphozousperforatus*, *Rhinopomahardwickii* and *Pipistrelluskuhlii)*	Dromedary camels

2019- nCoV/SARS-CoV-2

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is the infectious strain that causes coronavirus disease 2019 (COVID-19), a severe respiratory disease. It is informally known as the coronavirus, and was recently alluded to by its temporary name 2019 novel coronavirus (2019-nCoV).[9,10] SARS-CoV-2 is a positive-sense single-stranded RNA virus.[11] It is infectious in people, and the World Health Organization (WHO) has assigned the continuous pandemic of COVID-19 as a Public Health Emergency of International Concern.[12] Systematically, SARS-CoV-2 is a strain of Severe acute respiratory syndrome related coronavirus (SARSr-CoV).[7] It is accepted to have zoonotic birthplaces and has close hereditary likeness to bat coronaviruses, proposing it to rose up out of a bat-borne infection.[13] Along with bats , Pangolins are also considered as intermediate host of this virus.[14]

The most common symptoms at the onset of COVID-19 illness are high grade fever, cough, and fatigue, while other symptoms include sputum production, headache, haemoptysis, diarrhoea, dyspnoea, and lymphopenia. Clinical features revealed by chest CT scan in such patients, presented as pneumonia, however, there were abnormal features such as RNAaemia, acute respiratory distress syndrome, acute cardiac injury,

and incidence of ground-glass opacities in lungs that led to death.[15]

MERS-CoV

MERS-CoV has a place with the lineage C betacoronaviruses, which are related with bats.[16] Also, the nearest family members of MERS-CoV have been distinguished in vesper bats from Europe, Asia, and South Africa.[17]MERS-CoV rose in Saudi Arabia in 2012 and kept on causing human illness with a case casualty pace of 35%.[18] Dromedary camels are a characteristic store for MERS-CoV. In the Arabian Peninsula and across Northern Africa, the seroprevalence rate for MERS-CoV in dromedary camels ranges from 70% to almost 100%.[19] Live MERS-CoV has been successfully isolated and cultured from camel specimens.[20]

Middle East respiratory disorder coronavirus (MERS-CoV) causes sickness portrayed dominatingly by gentle to extreme respiratory objections, with most patients expecting admission to medical clinic due to pneumonitis or intense respiratory trouble disorder. Mature age and the nearness of comorbidities or immunosuppression appear to expand the danger of contamination and are related with extreme types of the illness. In any case, a few patients can stay asymptomatic or somewhat symptomatic and atypical introductions, for example, gastroenteritis have also been reported.[21] As of December 2, 2013, 163 laboratory-confirmed cases, including 71 deaths, have been reported to WHO.[22] These cases were legitimately or in a roundabout way connected to the Middle East area, including Saudi Arabia, Qatar, United Arab Emirates, Kuwait, Oman, and Jordan.[16,22]

SARS-CoV

Severe acute respiratory disorder (SARS) first showed-up in November 2002 in Southern China and spread the world over, regularly conveyed via carrier voyagers, and in the long run killed a number of individuals in 37 nations. It was contained by setting patients in isolation. The flare-up finished in 2004 and the malady has never re-emerged.[23]

In any case, researchers have consistently expected that SARS could return. Consequently, the endeavors of Chinese researchers drove by Shi Zheng-Li and Cui Jie of the Wuhan Institute of Virology, China, to follow the wellspring of the flare-up. Researchers at first speculated that civet felines, sold in business sectors in China, were the wellspring of the infection however later directed their concentration toward bats, which they understood were the prime wellspring of the infection. Civets were simply a middle host.[23] Some symptoms of SARS are headache, sore throat, cough, coryza, sputum, myalgia, diarrhea, dizziness, chills/rigors and fever.[24]

Ebola Virus:

Recognizing a characteristic repository for Ebola infection has evaded analysts for a considerable length of time. As of late, Leroy et al. introduced the most convincing proof to date that three species of fruit bats may comprise a long-missing untamed life supply for Ebola infection in Zaire.[25] The initial two Ebolavirus species were at first perceived in 1976 during concurrent flare-ups in Sudan (Sudan Ebolavirus) and Zaïre (new Democratic Republic of the Congo) (Zaire Ebola virus).[5] Since 1976, there have been more than 20 EVD (Ebola virus disease) episodes across Central Africa, with the majority brought about by Ebola infection (species Zaire Ebolavirus), which generally has exhibited the most elevated fatality rate (up to 90%).[25]

EVD is characterized by the sudden onset of fever and malaise, accompanied by other nonspecific signs and symptoms such as myalgia, headache, vomiting, and diarrhea. Among EVD patients, 30%–50% experience hemorrhagic symptoms. In severe and fatal forms, multiorgan dysfunction, including hepatic damage, renal failure, and central nervous system involvement occur, leading to shock and death.[26]

Rabies Virus:

Every year, rabies infection contamination causes an overabundance of 55,000human passing all inclusive, generally from hound chomps in creating nations. Fruitful immunization projects of tamed creatures have basically killed hound rabies in North America in the course of the last 50 years,

and later inoculation systems for untamed life populaces have controlled rabies infection in other carnivores. Be that as it may, BRV (Bat rabies virus) variations are at present the main wellspring of rabies in people in the United States, and bat inoculation isn't yet reasonable. Along these lines, rabies will probably be kept up in bat population, giving a repository to human contaminations and a hotspot for new variations equipped for developing or reappearing later on.[27]

Other Viruses:

Other viruses of Rhabdoviridae, Filoviridae, Paramyxoviridae, Orthomyxoviridae, Bunyaviridae and Reoviridae families are also associated with zoonotic infections spread from different families of bats as listed in following Table-2.

Table-2: Overview of bat associated viral infections.[28]

Pathogen	*Diseases in Human*	*Bat-to-Human Transmission*
Rhabdoviridae		
Rabies Virus	Acute fatal encephalitis	Yes
European Bat Lyssavirus type 1	Acute fatal encephalitis	Yes
European Bat Lyssavirus type	Acute fatal encephalitis	Yes
Australian Bat Lyssavirus	Acute fatal encephalitis	Yes
Irkut Virus	Acute fatal encephalitis	Yes
Duvenhage Virus	Acute fatal encephalitis	Yes
Filoviridae		Yes
Ebola Virus	Ebola haemorrrhagic fever	Yes
Marburg Virus	Marburg haemorrhagic fever	Yes
Paramyxoviridae		
Nipah Virus	Nipah disease (severe encephalitis)	Yes (pigs)[a]
Hendra Virus	Hendra disease (fatal respiratory disease)	Yes (horses)[a]
Orthomyxoviridae		
Influenza A Virus	Respiratory tract infection	No
Bunyaviridae		
Hantaan Virus	Fatal haemorrhagic fever	No
Reoviridae		
Mammalian orthoreovirus	Enteric and respiratory infections	Unclear

a: intermediate hosts

Common Bacteria from Bats

Bats are responsible for many bacterial infections in humans; here we will discuss few pathogens transferred from bats to humans.

Bartonella Species:

Basic vampire bats (Desmodusrotundus) have high commonness of Bartonella all through their huge geographic range in Latin America. Vampire bats are of specific concern since they subsist on blood, which could make open doors for Bartonella transmission to people and domesticated animals either from nibbles during blood taking care of or through vector sharing encouraged by closeness.[29] Recently, two types of Bartonella – B. *mayotimonensis* and B. *naantaliensis* – were identified from both blood smears of bats and in their ectoparasites, recommending that bats may be a wellspring of the human bacterial pathogens.[30]

Pasteurella Species:

Pasteurella is ordinarily spread among creatures as a feature of the typical microbiota of the oral, nasopharyngeal and upper respiratory tract. This family involves pioneering pathogen species that can cause endemic infection and are related with epizootic outbreaks. Animal nibbles and nasal emissions are the most probable wellsprings of transmission to people. In bats, different Pasteurella species – fundamentally P. *multocida* – have been distinguished as the primary pathogens of a few limited and fundamental infections.[31] The dominating wellspring of diseases gives off an impression of being wounds brought about by the nibble of household predators. Be that as it may, an ongoing report from Wisconsin in USA revealed just because an episode of intense pasteurellosis from P. *multocida* in wild bats without related horrendous harms.[28]

Leptospira Species:

Leptospira has overall dissemination and its transmission to people is principally through introduction to water sullied with the pee of contaminated animals. Bacterium harbors in a few wild and local hosts, colonizes their kidneys and it

is dispensed with in their urine. The nearness of Leptospira in bats has been shown in a few investigations.[28] Leptospirosis happens most ordinarily in individuals who are presented to the bacteria during their work, for instance ranchers, veterinarians and meat laborers. The best method to abstain from getting leptospirosis from bats is to forestall bat urine from coming into contact with broken skin or your eyes, nose or mouth. Hands ought to consistently be washed in the wake of thinking about bats.[32]

Enteropathogenic Bacteria:

Many organisms of Enterobacteriaceae have been isolated from different families of Bats.

Salmonella Species:

Salmonella and other bacteria (Listed in Table-3) that because gastroenteritis may be found in animal faeces. Most cases of salmonella infection are caused by eating undercooked or raw food contaminated with salmonella bacteria. The infection may also be acquired from close physical contact with animals such as dogs, poultry and cattle. It is assumed that some flying foxes (mega bats) may also carry the bacteria. Hands should always be washed after handling bats or their faeces or urine.[32] Many different serotypes of Salmonella has been identified and observed in phenotypically healthy bats. All these serotypes have wide spectrum with respect to their host.

Salmonella typhi is the causative bacteria of typhoid fever and solely connected with disease in people. Strangely, this serotype was isolated from heart blood, interior organs and bile of Pteropusrufus bat from Madagascar, which again give some proof to foundational bacterial disease conceivably stress-initiated by catch and treatment of bats in clearly contaminated with Salmonella typhi.[33]

Shigella Species:

Shigellosis is an exceptionally infectious foodborne illness ofhumans that is brought about by four unique types of Shigella. Shigellastrains ofserogroups B to D have been confined from mega and microbats of assorted feeding environments.[33]

Other Bacteria:

Few gram-positive organisms like *Clostridium species*and *Listeria Monocytogenes* are also identified in bats. Table 3 shows many bacterial pathogens which have been isolated from normal and diseased bats.

Table- 3: Common bacterial species isolated from different families of bats[33]

Bacteria	Family of Bat
Campylobacter jejuni *Clostridium perfringens* *Clostridium sordellii* *Listeria spp.* *Salmonella spp.* *Salmonella group d* *Salmonella enteritidis* *Salmonella typhimurium* *Shigella flexneri* *Vibrio spp.* *Yersinia enterocolitica*	Vespertilionidae
Yersinia spp. *Yersinia enterocolitica* *Y. Pseudotuberculosis* *Clostridium Spp.* *Listeria Monocytogenes* *Salmonella Caracas* *Salmonella Group I* *Salmonella Anatum,* *Salmonella Enteritidis* *Salmonella O48*	Molossidae

Common Disease-Causing Fungi from Bats:

Histoplasma *Capsulatum*:

Histoplasma*capsulatum* is a dimorphic pathogenic fungus of warm-blooded creatures, which causes pneumonic and systemic contaminations in people and it is obtained through inward breath of the contagious spores. This microorganism is normally found in soil related with extraordinary measures of feathered creatures' droppings mostly pigeons or bats guano. Albeit bats are viewed as the fundamental repository and dispersers of this fungus on the earth, their job in spreading H. capsulatum stays muddled.[28] Not very many individuals who are presented to Histoplasma capsulatum experience any manifestations. Truth be told it is believed that under 5% of those tainted become unwell. Manifestations of the contamination show-up inside 3 to 17 days after introduction, most regularly 12 – 14 days.[28]

The seriousness of the ailment is identified with what number of spores the individual was

presented to, and the capacity of their invulnerable framework to decimate Histoplasma fungal elements in the body. It can cause acute and chronic respiratory and invasive infections in its severe form.[33] It can be diagnose by blood, sputum and biopsies samples of infected and ulcerated tissues.[32]

Pseudogymnoascus *destructans*:

White-nose syndrome (WNS) is a recently emerged wildlife disease in North America, which in 4 years has resulted in unprecedented deaths of hibernating bats in the northeastern United States, and is a widespread epizootic disease among bats. Very less studies are present about WNS. Major cause of this syndrome is *P. destructans.*[34]There is no significant risk from this fungus to humans to date.[34]

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LIMITATIONS OF STUDY

This is a short review article on Bat borne diseases. The article encompasses the common diseases transferred to humans through bats. The article focuses on the bats and the zoonotic pathogens they harbor.

CONFLICT OF INTEREST

None to declare

FINANCIAL DISCLOSURE

None to disclose

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Author's Contribution

MI: Conception of idea, acquisition of data, manuscript drafting and final approval of the manuscript.

MTH, WA, AM: Drafting of manuscript, Intellectual input.